NASA-CR-197707

The Mars Observer Mission

(NASA-CR-197707) RETURN TO THE RED PLANET: THE MARS OBSERVER MISSION (JPL) 66 p

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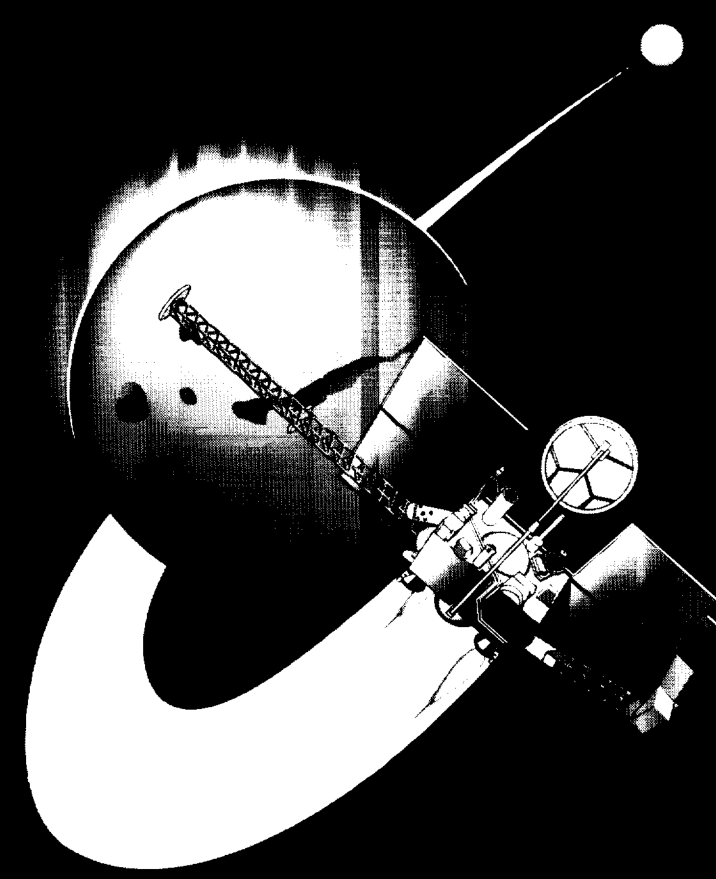
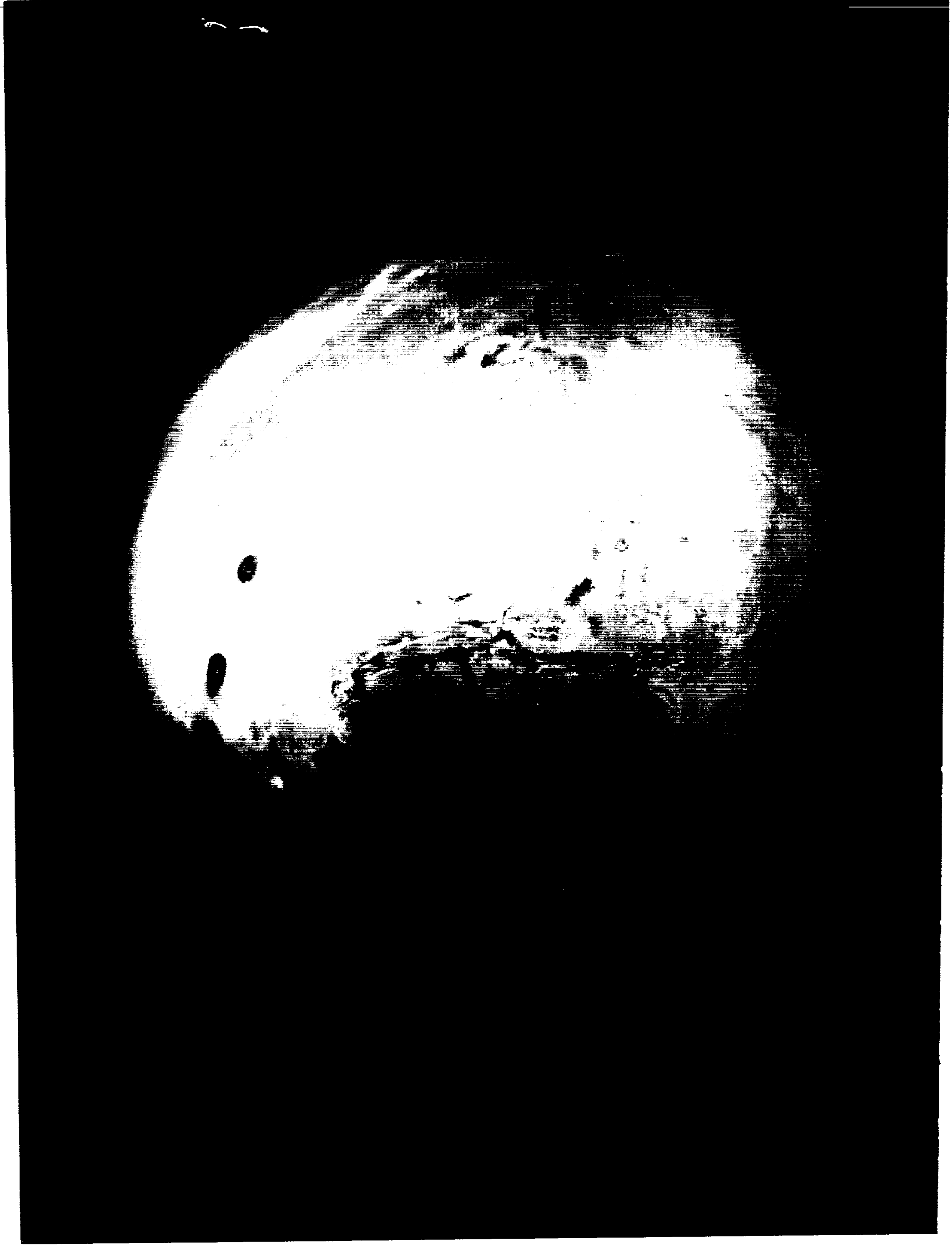




F O R E W O R D

After 17 years, a U.S. spacecraft will again visit Mars. With this journey by Mars Observer, the National Aeronautics and Space Administration (NASA) and the Jet Propulsion Laboratory (JPL) of the California Institute of Technology continue the global explorations of the Red Planet begun in 1971 with the Mariner mission to Mars and carried on in the mid-1970s by the Viking mission.

For the first time, a spacecraft with capabilities similar to the best weather and remote-sensing satellites used for Earth reconnaissance is traveling to a planet millions of kilometers away to carry out a long-term study. The goal is to create a global portrait of Mars by surveying its topography, magnetism, chemical and mineral composition, and atmosphere. The entire Martian globe will be photographed.

The Mars Observer mission will make an enormous contribution to the Martian data archive, giving scientists new perspectives in addressing the many questions about Mars and about the evolution of the planets of the inner solar system. Mars Observer will also help prepare the way for future explorations — missions of the 21st century that will carry automated rovers and, eventually, astronauts to the Red Planet.

◀ *Created from 104 separate images, this Viking mosaic shows Mars' grand canyon Valles Marineris and three prominent volcanoes. (P-38614A)*

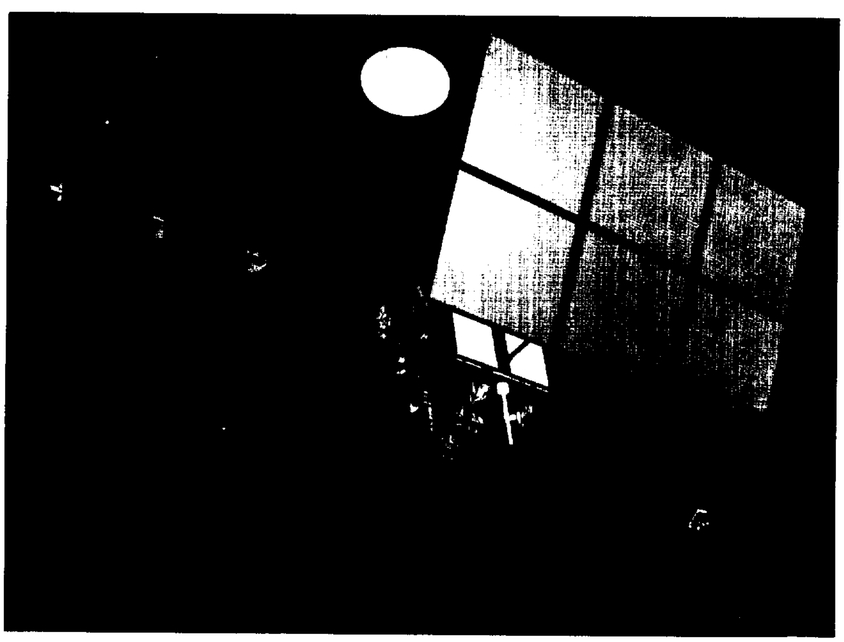
C O N T E N T S

The lance and shield held by Mars, the mythical warrior god, are echoed in the astronomical symbol (♂) for the planet named after him. Ancient astrologers considered the Red Planet's influence malevolent; those born under its sign were thought to be fiery and impetuous.

A Closer Look

In August 1993, a spacecraft, approaching Mars after an 11-month voyage from Earth, will fire its rocket thrusters, slowing its journey and allowing itself to be captured by Mars' gravity. The small craft will then swing into an elliptical, near-polar orbit around the Red Planet. In the months that follow, more rocket firings, orchestrated by mission controllers 340 million kilometers away, will gradually reshape the spacecraft's orbit into a nearly circular path, 378 kilometers above the surface. Mars Observer is ready to go to work.

Once in mapping orbit, Mars Observer will complete one trip around Mars in about two hours. At the same time, as the planet rotates beneath, each new orbit will bring the spacecraft over a new part of



Mars Observer completes one trip around the planet in about two hours. From its near-polar orbit, the spacecraft will collect information for one Martian year (687 Earth days) to form a global portrait of Mars. (P-35177)

FOR GOD AND PLANET

Mars, the planet, owes its name to the ancient Roman god of war. The appellation is hardly arbitrary: It follows instead an historical human association of the planet with battle — mostly due to its bloody red coloring and its puzzling, erratic transit across the sky. Mars, the god, began his history rather insignificantly — as a minor Greek deity named Ares whose main accomplishment was being the husband of Aphrodite, the goddess of love. (The planet's two satellites, incidentally, are named for Ares' attendants, Phobos and Deimos: "fear" and "rout," respectively.) Once the Romans adopted Ares, however, he became increasingly popular — in light of their ever-expanding martial activities — and eventually eclipsed even Jupiter in importance among the Roman pantheon. By the time of Augustus, Mars had become guardian of Roman military affairs as well as the personal avenger of the emperor. In the end, the legend of Mars — both god and planet — has attained rather mythical proportions.

Mars. As the weeks pass, the spacecraft will create a global portrait of Mars — the ancient cratered plains of the southern hemisphere; Valles Marineris, the huge canyon near the equator; the massive volcanoes in the Tharsis region; the gigantic channels carved by ancient floods; and the white, frozen polar caps and the strange layered terrain that surrounds them. During its mission, Mars Observer will pass over the terrain where the two long-silent U.S. Viking landers — separated by over 6,400 kilometers — have rested for 17 years.

As Mars rotates beneath the spacecraft, a battery of instruments will record information in careful detail. Sensitive detectors will measure radiation — gamma rays and visible and infrared rays — from the surface to determine the chemicals and minerals that make up Mars. Another instrument will record infrared radiation from the thin Martian atmosphere, gathering data about its changing pressure, composition, water content, and dust clouds. By firing pulses of light at the surface and measuring the time the reflections take to return, a laser altimeter will map out the heights of Mars' mountains and the depths of its valleys. The Mars Observer camera system will use wide- and narrow-angle components to record landforms and atmospheric cloud patterns. Another sensor will look for a Martian magnetic field. As the telecommunications subsystem beams information back to Earth, engineers will use the signal of the orbiting spacecraft to derive data about the atmosphere and the planet's gravitational field.

Week by week, orbit by orbit, the mapping will continue for one full Martian year (687 Earth days). Extensions of human senses, the instruments will observe the shifting seasons, watching the growth and disappearance of the seasonal polar frost caps as summer turns to winter and then to summer again. They will note the locations of sand dunes and trace swirling dust storms through the atmosphere. They will track the movement of water vapor and carbon dioxide as these gases cycle from the polar caps to the atmosphere, into the soil, and back again.

By February 1996, when a Martian year has passed, Mars Observer will have obtained a unique archive of data — an extensive record of the nature and behavior of another world, its surface, atmosphere, and interior. It will, in fact, have acquired a first "Operating Manual for Planet Mars." We can then begin to understand Mars on a global basis, as a single-world system. We can also begin to plan more specialized explorations that might involve robots, scientific stations deployed to the Martian surface, sample returns, perhaps even human landings. Equally important, we will have critical data on the global operation of another world to help us understand, through comparative planetology, our own planet Earth.

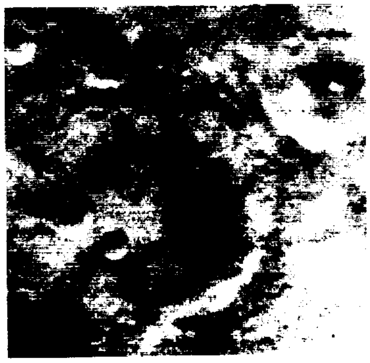
CHAPTER 2

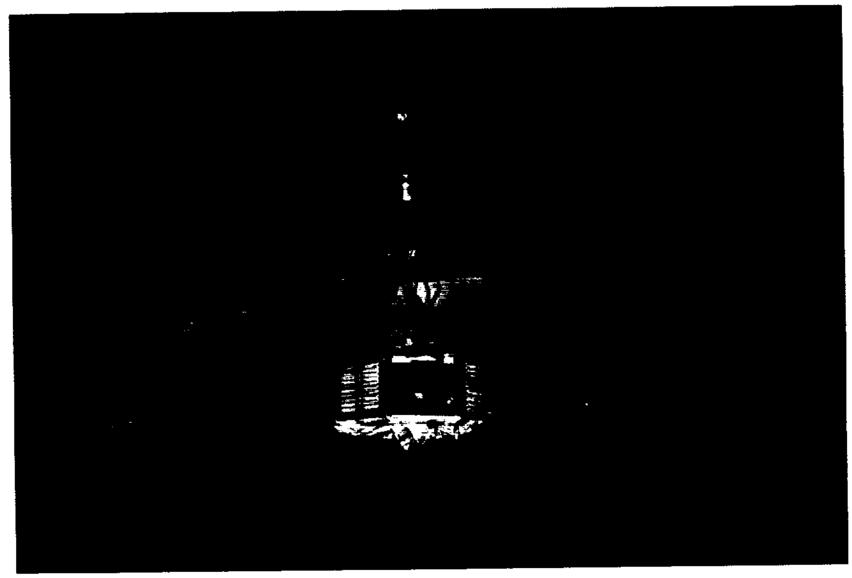
The Call of Mars

Except for the planet on which we live, no world has occupied more of history, thought, and fiction than Mars. Observed from the earliest days of astronomy as a wandering light in the sky, it has long been a part of the human record. Mars was a god to many civilizations, its menacing red color associated with blood and war.

Mars was accepted as a natural, mysterious feature of the cosmos — ancient astronomers knew it as one of several worlds that, they thought, circled the Earth. The Earth-centered system devised by Ptolemy in the second century A.D. was built upon earlier Greek models and dominated European thought for about 1,500 years. Even the Copernican heliocentric solar system model of the 16th century couldn't quite explain Mars, which seems to trace an odd, looping path across the sky. Johannes Kepler finally perceived in the early 17th century that the effect was an illusion caused by a faster moving Earth overtaking Mars, making it appear that Mars slows down, stops, then moves in reverse. Kepler was only able to complete the mathematics for his laws of planetary motion when he realized that Mars moves in an elliptical orbit rather than a Copernican circular orbit.

With the development of telescopes, Mars took on character, and hauntingly Earthlike features appeared. In Italy in 1610, Galileo Galilei made observations with his new "spyglass" and noted that Mars had phases like Earth's Moon and seemed to be irregularly shaped. In 1666, the Italian astronomer Giovanni Domenico Cassini reported that Mars had polar caps that diminished and expanded periodically, and he measured the planet's rotation period as 24 hours, 40 minutes — very near the modern figure of 24 hours, 37 minutes, 22.7 seconds. Eventually, 19th-century optics revealed two tiny moons, an atmosphere, clouds





In 1965, Mariner 4 (right) flew by Mars, taking 22 pictures. Picture number 11 (above) showed mountains, valleys, and craters much like those on Earth's Moon. (P-4732, P-7875A)

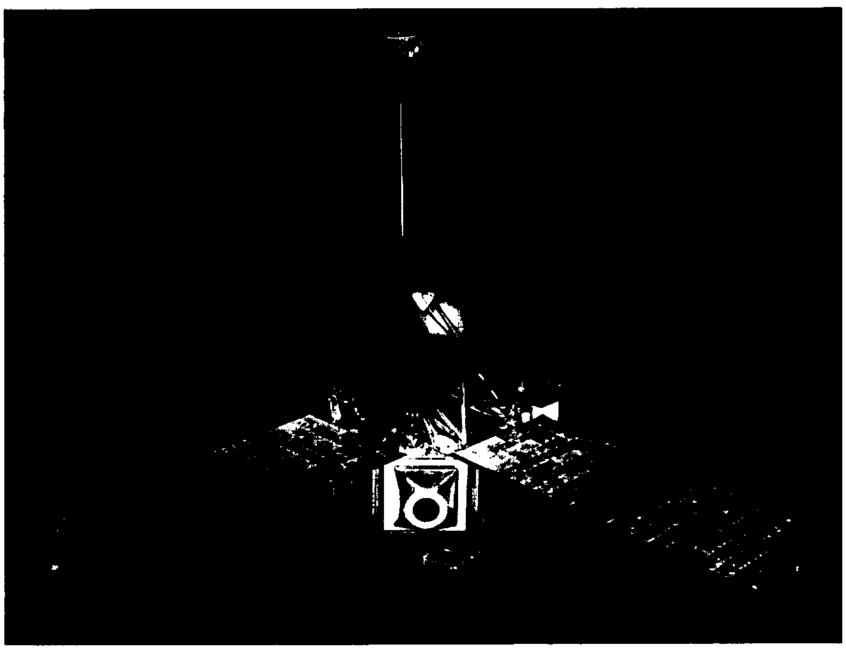
and dust storms, and what seemed to be (but was not) a wave of seasonally blooming vegetation that spread across the planet.

Naturally, the similarities between Mars and Earth gave rise to speculation about the existence of life (perhaps intelligent life) on Mars. The reported discovery of "channels" on Mars by the Italian astronomer Giovanni Schiaparelli in 1877 started serious consideration of this possibility. During the early years of this century, the observations and well-written arguments of the American astronomer Percival Lowell fanned this speculation into a visible and sometimes acrimonious controversy. Lowell became fascinated with the idea that intelligent beings had built a complex system of canals (a misinterpretation of Schiaparelli's word, *canali*) to manage the water-starved planet's resources. The debate gradually subsided with the death of Lowell and a growing consensus that the "canals" were optical illusions at our end of the telescope. Astronomers realized that ground-based telescopes, no matter how large, couldn't resolve Mars well enough to settle the question of life on the Red Planet.

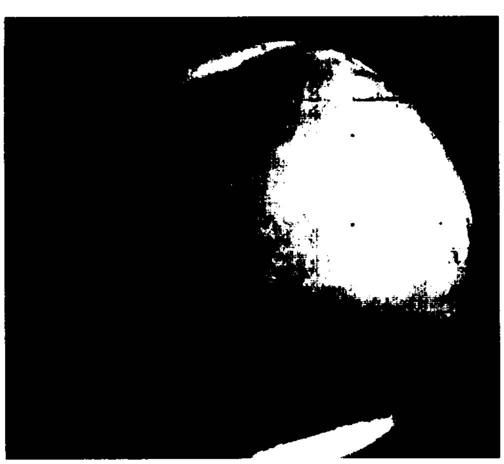
With the arrival of the Space Age, Mars could be studied at close range. Beginning with the 1962 launch of the Soviet Union's Mars-1 spacecraft, 16 U.S. and Soviet missions have flown by, orbited, or landed on Mars. Most of what we now know about the planet came from the U.S. Mariner 9, which began a one-year orbital survey of Mars in 1971, and the U.S. Viking 1 and Viking 2, launched in 1975 and consisting of an orbiter and a lander each.

These spacecraft have shown us that Mars is not uniform — its north and south regions are quite different. Early U.S. flyby missions, such as Mariner 4 in 1965 and the twin Mariners 6 and 7 in 1969, photographed the ancient, heavily cratered highlands in the southern hemisphere, leading to the conclusion that Mars was like Earth's Moon. Only with the orbital photographs from Mariner 9, six years later, did Earthlike geological features appear: huge volcanoes, a great rifted canyon — named Valles Marineris, in honor of the mission — and numerous channels that looked as though they had been cut by running water. (Too small to be seen from Earth, these channels were not the hotly debated "canals," which indeed were optical illusions.) These features made Mars seem even more intriguing. There were many puzzles to solve, but the most compelling question was: Is there life on Mars?

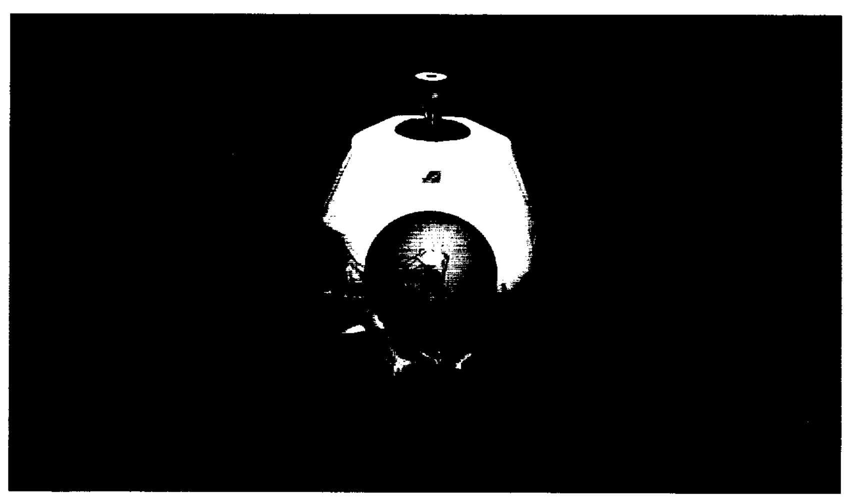
The two Viking landers carried out the first direct search for life on the Red Planet. They dug up samples of the Martian soil, treated some

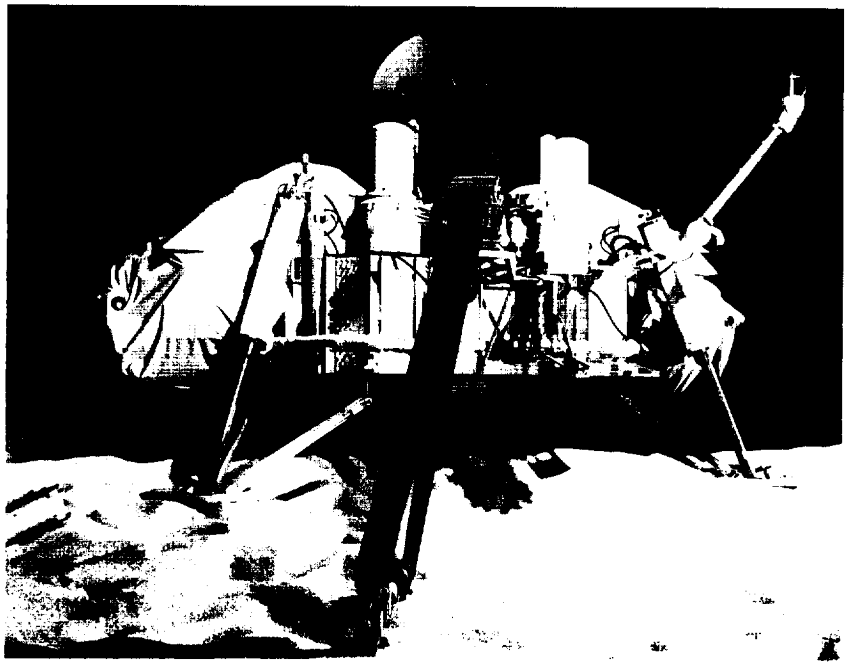


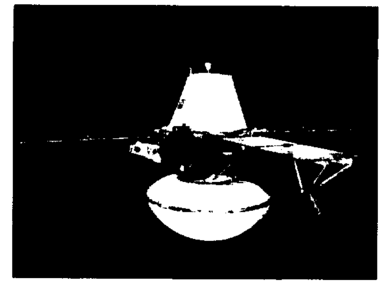
The twin Mariners 6 and 7 (left) flew by Mars in 1969 and photographed about 10 percent of the surface. Both spacecraft detected frozen carbon dioxide (dry ice) and a small amount of water ice in the south polar cap, visible in this photograph (below) taken as the spacecraft approached the planet. (241-212B, P-30105)



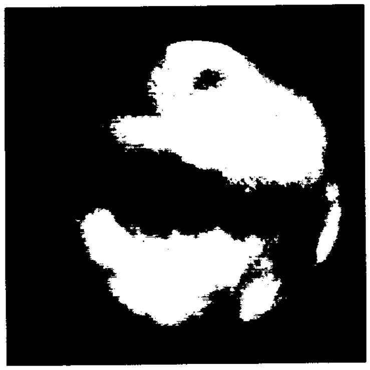
The huge Martian volcano Olympus Mons (right) is the largest shield volcano in the solar system: about 26 kilometers in height and approximately 600 kilometers in diameter. The photograph was taken by Mariner 9 (below) — the first spacecraft to orbit another planet — during its survey of Mars in the early 1970s. (P-13074, P-12035)







The Viking mission to Mars consisted of two orbiters, each carrying a lander. Each spacecraft (above) took photographs from orbit while each lander (left) carried out experiments on the surface. Viking Lander 1 photographed its own footpad (below) on the rocky Martian soil after landing on July 20, 1976. (293-9157, P-17053, P-16124A)



A SHARPER IMAGE

The same evolutionary process seems to affect every human endeavor: Make an observation, proceed to an assumption, develop a theory, infer a hypothesis, discover a fact, reach a conclusion — and then immediately challenge the results and start all over again. Our studies of the planet Mars have not been immune to this "scientific method." Through the centuries, the various mysteries of Mars — coloring, motion, possible vegetation, existence of water, sustenance of life, geology, astrological significance — have been examined, debated, and occasionally even resolved. Each technological advance and analytical improvement creates an increasingly accurate picture of the real Red Planet: Mars' "backward" motion is explained by its elliptical path around the Sun; neither water nor life exist on the planet; and the Martian "canals" are just optical illusions. What remains for us to discover about the Red Planet? Will Mars forever remain the "fuzzy blob" we saw in 1956 (above) — or will we someday see the true picture? This is Mars Observer's mission — to acquire that sharper image.

of them with nutrients, and then tried to detect evidence of microscopic life forms. While analyses of the Viking data found no indications of biological processes, there is still a possibility that life exists somewhere else on the planet, and there may be organic matter or fossils that await detection. This first direct experiment, however, provided no encouragement for the view that there is life on Mars.

Even if barren of life, Mars remains a fascinating world. Among the four terrestrial (rocky) planets of the inner solar system, Mars is unique: partly dead and cratered like the Moon, but with active, Earthlike characteristics because of its atmosphere. The old, cratered parts of Mars may preserve the early history of planetary formation — records that have been erased on ever-changing Earth and Venus. Mars shows us that Earthlike features, such as volcanoes, an atmosphere, polar ice caps, and weather, can form and develop on another world. By comparing Earth and Mars — similar at birth but quite different now — we can better understand our own planet.

Mars may have a unique role in our future. Despite its distance from Earth and its harsh environment, it is the only other world within our solar system where we can reasonably think that humans might someday walk, explore, or even live. If we ever go beyond the Moon, we will go to Mars. Mars Observer, and the automated missions that follow it, have a dual task: to learn as much as possible about the fascinating Red Planet and to collect the data that we must have if we are ever to journey to Mars and explore it firsthand.

The Nature of Mars

Mars is a relatively small planet. It is about 6,800 kilometers in diameter, about half the diameter and with about one-eighth the volume of Earth. Compared to the other planets of the inner solar system, Mars is larger than Mercury, but much smaller than Venus and Earth. The force of gravity at the surface of Mars is only 38 percent that of Earth — a 330-kilogram person on Earth would weigh 125 kilograms on Mars. Mars takes 687 Earth days to travel once around the Sun, making a Martian year almost two Earth years long.

Despite its smaller size, Mars does share certain characteristics with Earth. It turns on its axis in 24 hours and 37 minutes, making a Martian day (called a "sol") only slightly longer than an Earth day. Mars' axis of rotation, like that of Earth, is tilted to the plane of its orbit (at an angle of 25 degrees for Mars compared with 23.5 degrees for Earth). Because of its tilted axis, Mars has Earthlike seasonal changes, making "summer" and "winter" realistic terms — although a warm spring day at many sites on Mars might feel to us like a balmy day in Antarctica.

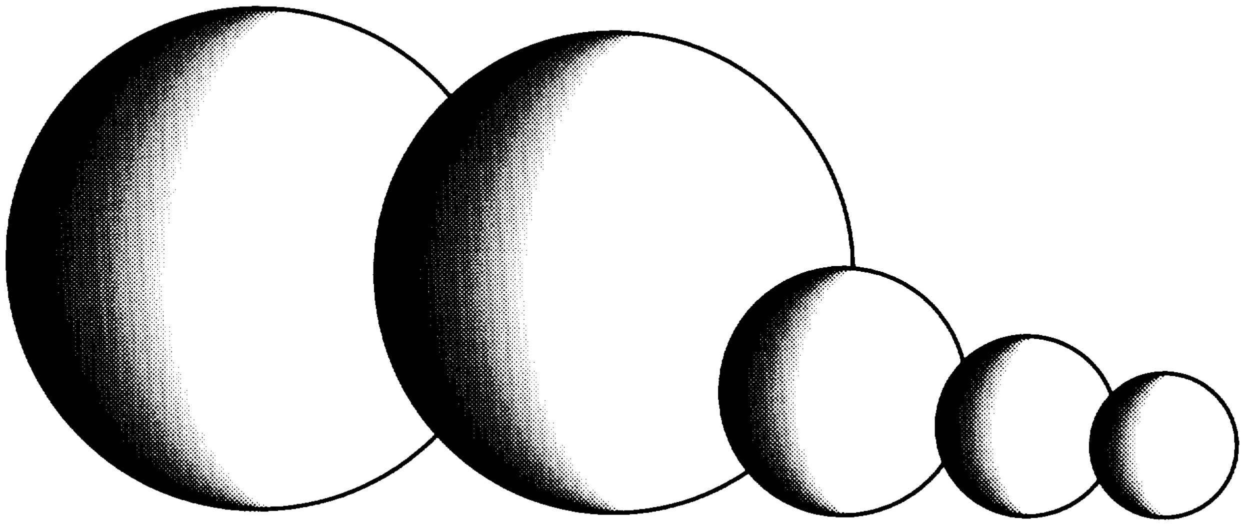
Mars is accompanied by two tiny, dark moons. They are so small that, while their existence had been surmised since the early 17th century, they were not found until the American astronomer Asaph Hall finally discovered and named them in 1887. Phobos, the innermost moon, orbits only 6,000 kilometers above the Martian surface, moving so fast that it rises and sets twice in a single Martian day. Deimos, the outermost moon, moves more sedately at a distance of 20,120 kilometers. Unlike Earth's large, spherical Moon, both of Mars' moons are tiny and irregular. Phobos is about 28 by 20 kilometers in size; Deimos is about 16 by 12 kilometers. (The moons are so oddly shaped that "diameter" loses its meaning as a descriptive term; the longest and shortest

A Viking photomosaic (above) shows Phobos, the innermost moon of Mars, with its many grooves and lunar-like craters. Deimos (below), the outermost moon, has craters that are more subdued and filled in. Both may be captured asteroids. (P-20776, P-17873)

dimensions are given instead.) Observations by the Viking orbiters showed that the moons are heavily cratered, indicating that they are very old; probably they escaped from the asteroid belt between Mars and Jupiter and were captured by Mars' gravity.

Before the age of planetary exploration, both literary and scientific writers proposed that Mars was a cold, dry planet with a very thin atmosphere. This is correct, but they underestimated the case. Temperatures on Mars range from a low of about –133 degrees Celsius to a pleasant high of around 27 degrees Celsius. The atmospheric pressure at the surface is only about 1/125 that of Earth — about equal to atmospheric pressure on Earth at four times the height of Mount Everest. The Martian atmosphere is 95 percent carbon dioxide, with only trace amounts of the nitrogen and oxygen that dominate our own atmosphere, and the amount of water in Mars' atmosphere is less than 1/1,000 of the water in Earth's atmosphere. Conditions on Mars are distinctly hostile to human beings.

Surprisingly, the thin, alien Martian atmosphere produces a wide variety of weather phenomena, a few of which are familiar to Earth-dwellers: winds and clouds as high as 25 kilometers above the surface, low-level fogs, and surface frost. Even before spacecraft visited Mars, astronomers had observed huge dust storms that often start in the southern regions and sometimes spread across the whole planet. (In 1971, the Mariner 9 spacecraft entered Mars orbit at the height of a planet-



wide storm and had to wait for months until the dust settled, revealing the complex geology of the surface.)

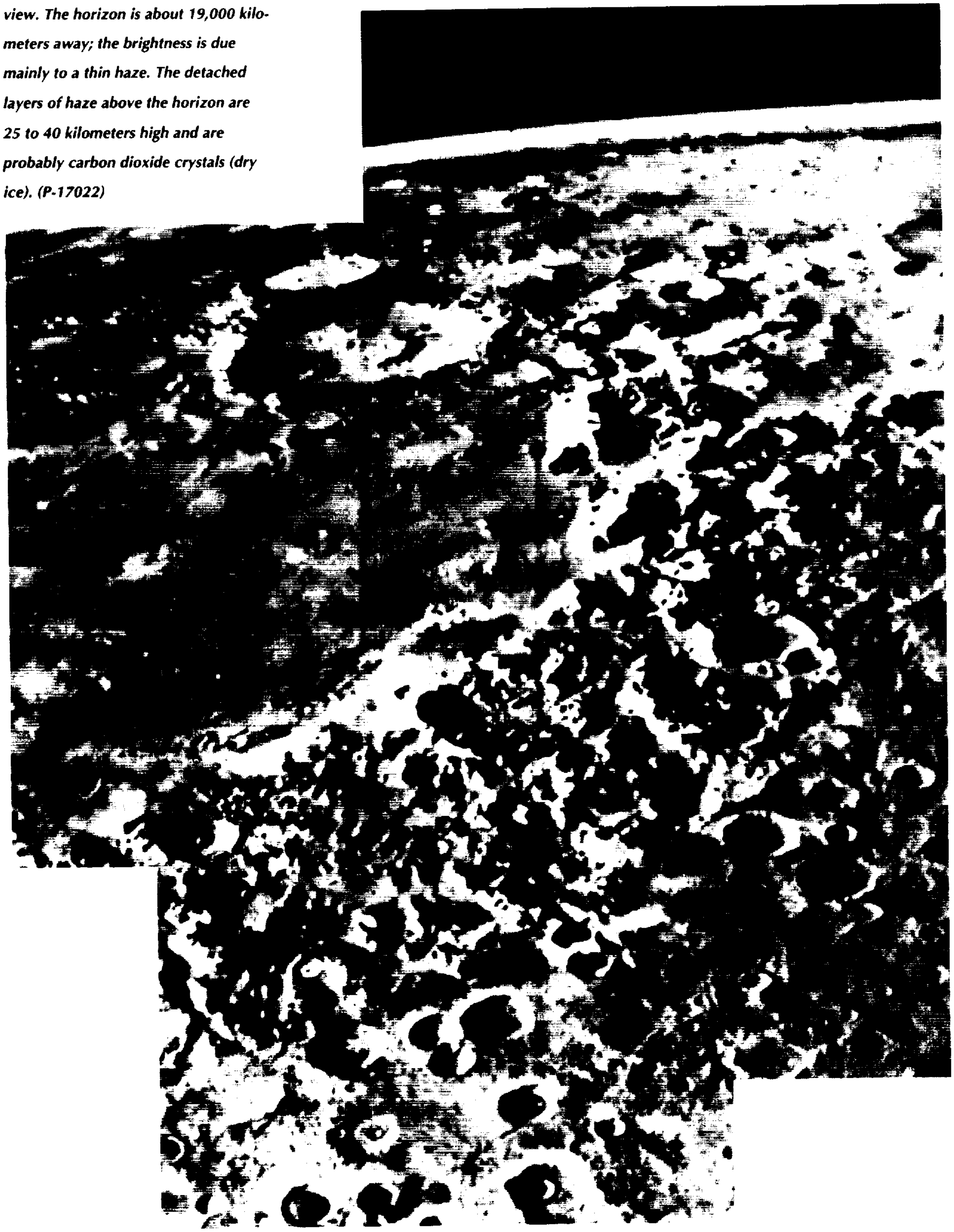
The cameras of the two Viking landers photographed a magnificent desert, with stark panoramas of rocks and soil extending to the horizon, varied by drifts and networks of surface cracks. The rocks and boulders appear volcanic in origin, though none have been chemically analyzed — the landers were equipped with soil scoops but these instruments were unable to scratch or chip the rocks. Chemical analyses made by the Viking landers of the fine, reddish soil showed that speculations were indeed correct: The color is due to oxidized iron, or rust, in the soil and rocks. Interestingly, the red color of Mars extends upwards; fine particles of red dust, borne aloft by the winds, produce a pink-tinted sky.

Mars is divided, very roughly by the planet's equator, into two distinctly different regions. The southern hemisphere is an ancient, Moonlike, heavily cratered terrain that probably preserves records of a violent period from about 4.6 billion years ago to about 4 billion years ago, when all the newly formed planets were bombarded with chunks of unconsolidated debris.

The younger, more Earthlike northern hemisphere retains some evidence of geological activity. There are huge volcanoes in the north, one of which is more than 25 kilometers high and large enough to cover the west coast of the United States. The immense canyon Valles Marineris is just below the Martian equator; more than 5,000 kilometers long, it would stretch across most of the continental United States. Many sinuous channels appear in the northern hemisphere; they were appar-

Although the four terrestrial (rocky) planets of the inner solar system have certain similarities, they exhibit striking differences — the result of divergent paths of evolution. Earth's Moon is shown for comparison; it is not much smaller than Mercury. Earth and Venus have about the same diameter, and Mars is roughly half their size.

It was an unusually clear day on Mars when Viking Orbiter 1 captured this view. The horizon is about 19,000 kilometers away; the brightness is due mainly to a thin haze. The detached layers of haze above the horizon are 25 to 40 kilometers high and are probably carbon dioxide crystals (dry ice). (P-17022)

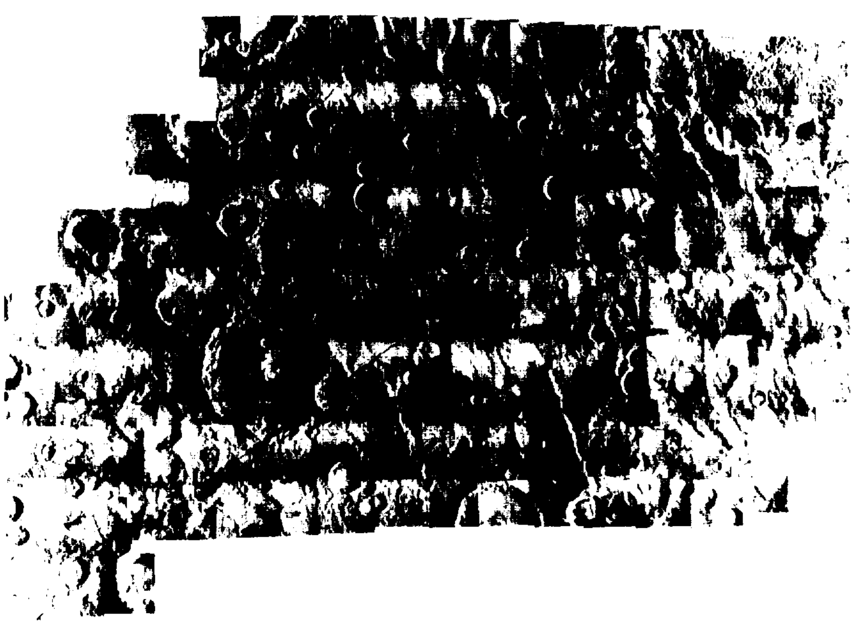


ently cut by running water that may have flooded across Mars hundreds of millions of years ago.

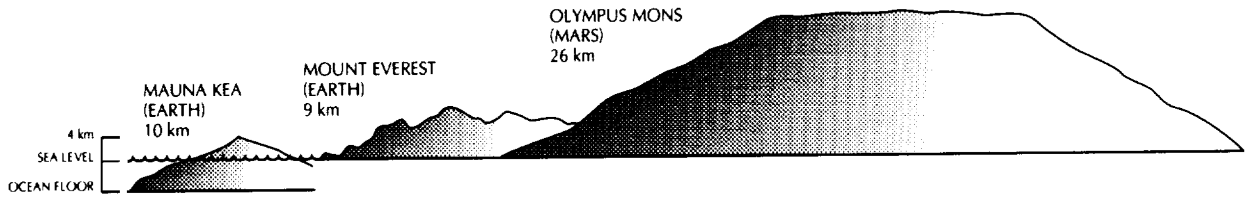
Mars is not only varied in terrain, it is a dynamic planet that changes on several different time scales. During the change of Martian seasons — long observed from Earth — the polar ice caps expand and then retreat, and global dust storms sometimes sweep across the planet. The Mariner 9 and Viking spacecraft documented changes over months and even days: variations in the surface winds, shifting of light and dark regions, slow movements of clouds through the thin atmosphere, formation of fogs at dawn in Martian valleys, and the appearance of thin layers of frost around the Viking landers on especially cold winter mornings.

Both Mars and Earth have polar ice caps, but Earth's polar caps are extensive, massive, and — at least on a seasonal scale — permanent. In contrast, the Martian polar caps are small, thin, and experience seasonal change. The northern perennial cap is the larger and is composed of water ice; the southern perennial cap is made of frozen carbon dioxide (dry ice). Both polar caps have an additional seasonal "frost cap" of carbon dioxide. These seasonal caps expand toward the equator in winter, then sublime (change from ice to vapor) in late spring.

A rock-filled Martian landscape was viewed by Viking Lander 1 from its landing site in Chryse Planitia (Plains of Gold). The large boulder at left, nicknamed "Big Joe," measures 1 by 3 meters and is 8 meters from the lander. The vertical white object is part of the lander's meteorological boom. (P-17430)



This mosaic of images shows part of Mars' heavily cratered southern hemisphere. The surface resembles that of Earth's Moon and reveals that, for reasons unknown, the craters that dot the southern highlands were unmodified by later geological activity. (P-24667)



Mars' Olympus Mons (right) is the largest known shield volcano in the solar system. The dormant Hawaiian volcano, Mauna Kea, which is 10 kilometers in height (measured from the ocean floor), is about a third as high. Even mighty Mount Everest, Earth's highest peak, is overshadowed by Olympus Mons. (P-20942)

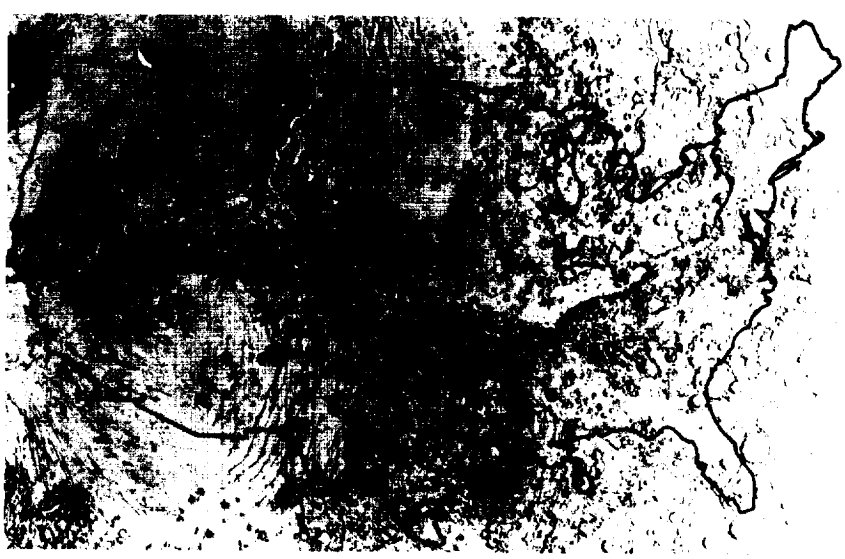
One of the most striking discoveries documented in the years-long record of the Viking landers is the close connection between the seasonal polar caps and the Martian atmosphere. As either the southern or northern cap expands, it removes carbon dioxide from the atmosphere, causing the atmospheric pressure to drop by about 25 percent. (On Earth, such large pressure drops, even inside major hurricanes and typhoons, never occur.) It is possible to estimate the growth of the seasonal polar caps by measuring the atmospheric pressure at any point on Mars, or vice versa.

The question of whether water ever flowed on Mars is a major theme in debates about the planet. Today, Mars is almost totally dry. Liquid water cannot exist at the low pressures at the surface; it turns into water vapor or ice. Yet spacecraft have photographed numerous large and fine channels scoured across the surface of Mars, and the shapes and structures of these channels indicate, almost beyond a doubt, that they were cut by running water.

Where has this water gone? Only a tiny fraction is now seen in the northern polar cap and in the atmosphere. Some of it may have escaped to space, but most of it should have remained on Mars. Is it hidden in permafrost (permanent thick layers of an ice-rock mixture) beneath the surface, just as some water is trapped in the polar regions of Earth? The question of whether water exists on Mars is a critical one. Water is fundamental to the understanding of geological processes and climate change; and it is, of course, essential for human life support. How easily water can be found and extracted will be significant for human exploration and settlement of Mars.

Viking images of the Martian polar regions show wide, smooth zones of layered terrain surrounding the ice caps. These layers are geologically young; they overlie the older surfaces of Mars and possibly were deposited as recently as a few tens of millions of years ago. Scientists think that the layers are a mixture of deposited windblown dust with ices — water and carbon dioxide — that have frozen out of the atmosphere. Formation of a single layer, therefore, depends strongly on dust deposition and thus on past climatic processes. Examining the layers in more detail will help us to reconstruct the climatic history of Mars and to compare it with the record of climate change on Earth.

The atmosphere and surface of Mars conceal more mysteries about the origin and development of the planet. Previous spacecraft missions have not been able to provide much data to help answer the fundamental questions about how Mars evolved.



The enormous canyon system Valles Marineris extends about 5,000 kilometers and roughly parallels the Martian equator. Shown superimposed on an outline of the United States, Valles Marineris stretches from coast to coast. The giant rift is named after the U.S. Mariner 9 spacecraft, which first photographed it. (P-40781B)

Dark rocks contrast with light patches of water frost on Utopia Planitia (above). The photograph was taken during the Martian winter by Viking Lander 2, which recorded the lowest surface temperature during the mission: –120 degrees Celsius. (P-21873)

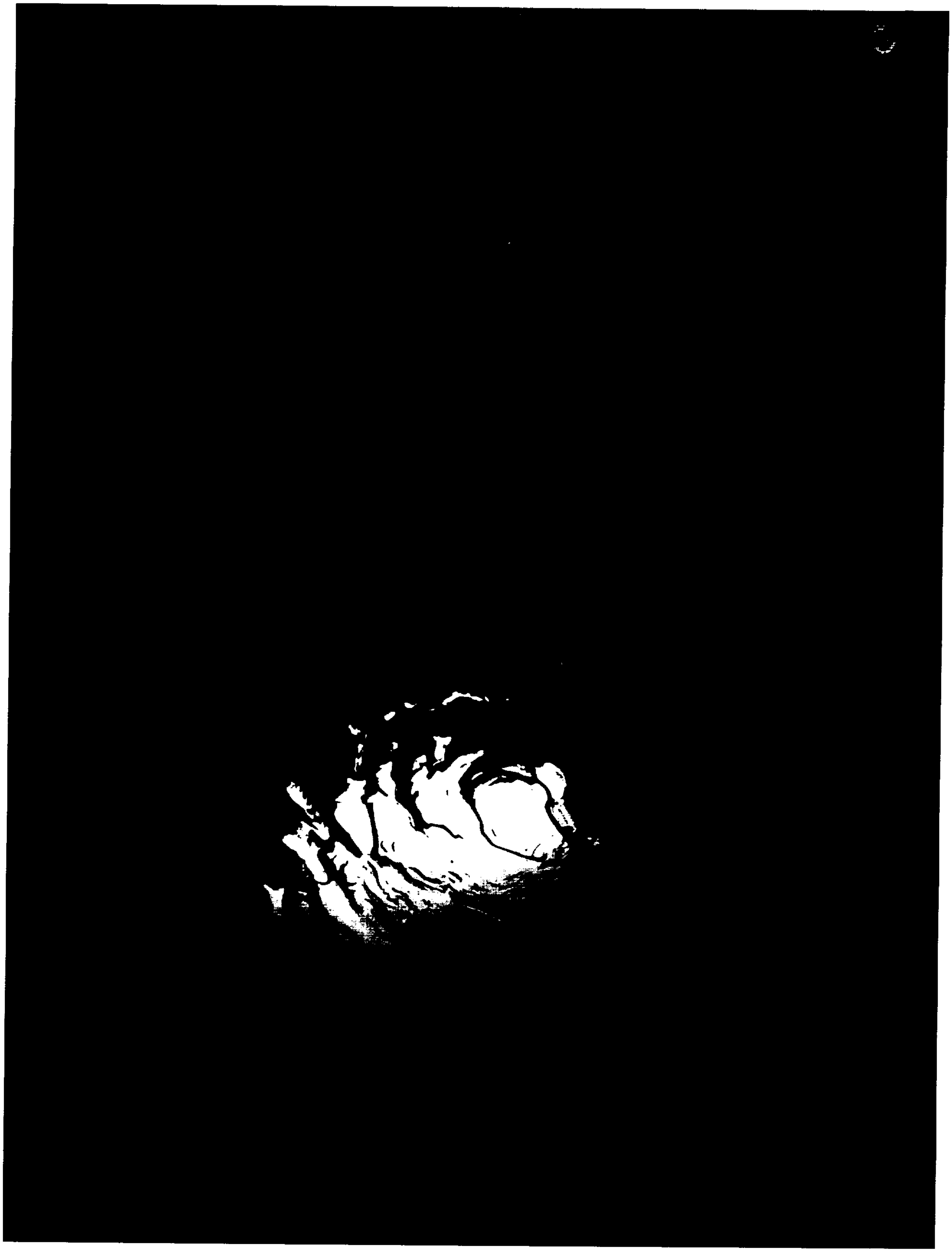
Opposite page: The Martian north and south polar ice caps have additional seasonal "frost caps" of carbon dioxide. The seasonal caps expand toward the equator in winter, then sublime (change from ice to vapor) in late spring. This photograph shows the south polar frost cap in its final stage of sublimation. (P-40390)

We assume that Mars originated in the same way as the other terrestrial planets — through the accretion of smaller bodies, beginning about 4.6 billion years ago. The intense bombardment by debris of the newly formed planets is preserved in the heavily cratered faces of the Moon and Mercury. The battered southern hemisphere of Mars, which is dotted with craters, may also have formed during this time of violent bombardment, and this part of Mars may be closest to the lunar highlands in history and age. Other regions of Mars may be widespread plains of volcanic lava, which erupted from within the planet over a long period of time. Similar eruptions spread across the Moon to form the dark areas known as lunar maria or "seas."

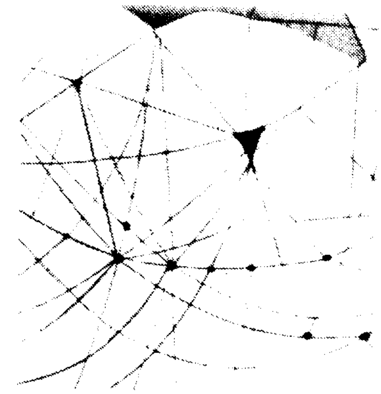
While Mars possesses some similarities to our Moon, much of the planet's early history is still uncertain. We do not know when, or even if, the planet formed an iron core like the large, molten metal core that exists within Earth and produces our planet's magnetic field. We do not know the original bulk composition of Mars, or how rocks of different composition may have been produced from the original mixture. In fact, so little is known about the interior of Mars that it is difficult even to ask the right questions.

The geological history of Mars following the turbulent period of planet formation is unique and very un-Moonlike. During the last 2 or 3 billion years, Mars developed features that resemble those of Earth more than the Moon. Huge, isolated volcanoes — most notably Olympus Mons and the other volcanoes along the Tharsis uplift — formed as the interior of Mars melted and lava rose to the surface. Unlike lava eruptions on the Moon and on the older Martian plains, which spread out as thin sheets over vast distances, the later Martian eruptions built up massive volcanic structures in a few locations.

During the same period, the outer layer or crust of Mars apparently was not entirely stable. This characteristic places Mars, in a geological sense, between the Moon and Mercury, which are similar, and the Earth and Venus. The Moon's crust is thick, cold, and rigid; while Earth's crust is thin, hot, and active. Earth's complex crust is fragmented into more than two dozen plates that float on a hot, viscous layer in the mantle, and most of Earth's geological activity — volcanic eruptions, earthquakes, and mountain-building — occurs at the boundaries of these moving plates. Mars appears to have experienced some Earthlike crustal activity: The huge Valles Marineris canyon system may have formed when two sections of the Martian crust slowly pulled apart about 2 billion years ago. Except for that one event, however, there is no evidence that the Martian crust was active elsewhere or that it is active today. It appears that, at present, Mars has just one crustal plate.



The shapes and structures of many large channels scoured across the surface of Mars indicate, almost beyond a doubt, that they were cut by running water. Viking images showed physical features resembling shorelines, gorges, and riverbeds that suggest global flooding in Mars' distant past. (P-25808)



LOWELL'S CANALS

For years, the question of whether or not intelligent life existed on Mars was a subject of some discussion among astronomers. The controversy heightened after linear markings crisscrossing the planet — first called *canali* or "channels," and then translated as "canals" — were observed in 1877 by Italian Giovanni Schiaparelli. From studies at the observatory he founded in Flagstaff, Arizona, in 1894, Percival Lowell insisted that these canals were actually the work of intelligent beings. Lowell drew detailed maps of Mars, showing the canals as clear networks of geometrical lines — and then inferred that these networks represented a planetwide water-distribution system. (Lowell even went as far as naming many of his waterways.) Needless to say, Lowell's assertions, which were strongly contested by the majority of his contemporaries, were quickly disproved. While increasingly improved views of Mars have shown us what appear to be channels cut by running water, modern-day astronomers do not believe that water flows freely anywhere on the Red Planet.

A generation ago, our study of Mars was limited to distant, blurred views in Earth-based telescopes. Visiting spacecraft have answered many of the questions that scientists have pondered for generations. For example, we know that the "canals" were an optical illusion and that the planet's red color is due to oxidized iron. We have examined the atmosphere and know its density and composition. Viking images revealed to us that the sky we thought might be blue like Earth's has a reddish tint instead, and we know now the source of the color. We know the composition of the polar ice caps. Stunning photographs have shown us large-scale features that are reminiscent of places on Earth. But, as is often the case with scientific endeavors, while many questions have been answered, the answers have in turn led to more questions — many unimaginable before the new discoveries.

What are the details of Mars' geological history? What are the compositions and ages of its bedrock? What is the internal structure of the planet, and how does it differ from the internal structure of the Earth? Are there Marsquakes? Is there an iron core and an internally generated magnetic field? Why are there such huge volcanoes and so few of them? Does the Valles Marineris rift represent the start of crustal plate movement and, if so, why didn't the process continue, as it has on Earth?

These and many other unanswered questions are complex, tantalizing, and challenging. The investigations carried out by the Mars Observer mission undoubtedly will disclose many answers and reveal new mysteries that will lead to new questions, as our explorations of the Red Planet bring us to new levels of understanding.

Both Martian polar ice caps are surrounded by wide, smooth zones of layered terrain. Dust deposited by Martian winds is layered with ice, suggesting a repetitive history of climatic changes. This is the north polar cap; the mottled area in the lower left is the seasonal frost cap in sublimation.

CHAPTER 4

The Mars Observer Mission

The exploration of Mars has been carried out in stages: reconnaissance, exploration, and intensive study. Reconnaissance was provided by the first flyby missions — Mariners 4, 6, and 7 — which took quick looks at small areas of Mars. Later exploratory missions of longer duration with the more complex Mariner 9 and Viking orbiters provided our first global information about the planet. Finally, the two Viking landers focused on a special intensive study: the search for life on Mars.

Although these missions made spectacular discoveries, we still do not know Mars well. This is not surprising, since all planetary missions necessarily have limitations. These first explorers were not able to observe the planet long enough; they did not make enough different kinds of observations; and they did not examine enough different places in sufficient detail to gather all the knowledge needed to resolve the deepest questions.

Thus, the Mars database is extensive but still incomplete. We have photographs of the entire Martian surface, but the coverage is not uniform and the images are of moderate resolution. (Resolution is a measure of the smallest object that can be clearly seen in an image; the higher the resolution, the smaller the objects that can be seen.) We have some measurements of atmospheric pressure and temperature, but many are single measurements made over short periods of time (for example, during atmospheric entry and descent of the Viking landers).

Opposite page: Orbiting in Mars' upper atmosphere, the spacecraft will rotate once per orbit to keep the instruments pointed at Mars. This will allow all the instruments to view the planet uniformly during the entire Martian year. The instruments will collect data simultaneously and continuously on both the day and night sides of the planet. (P-40613)

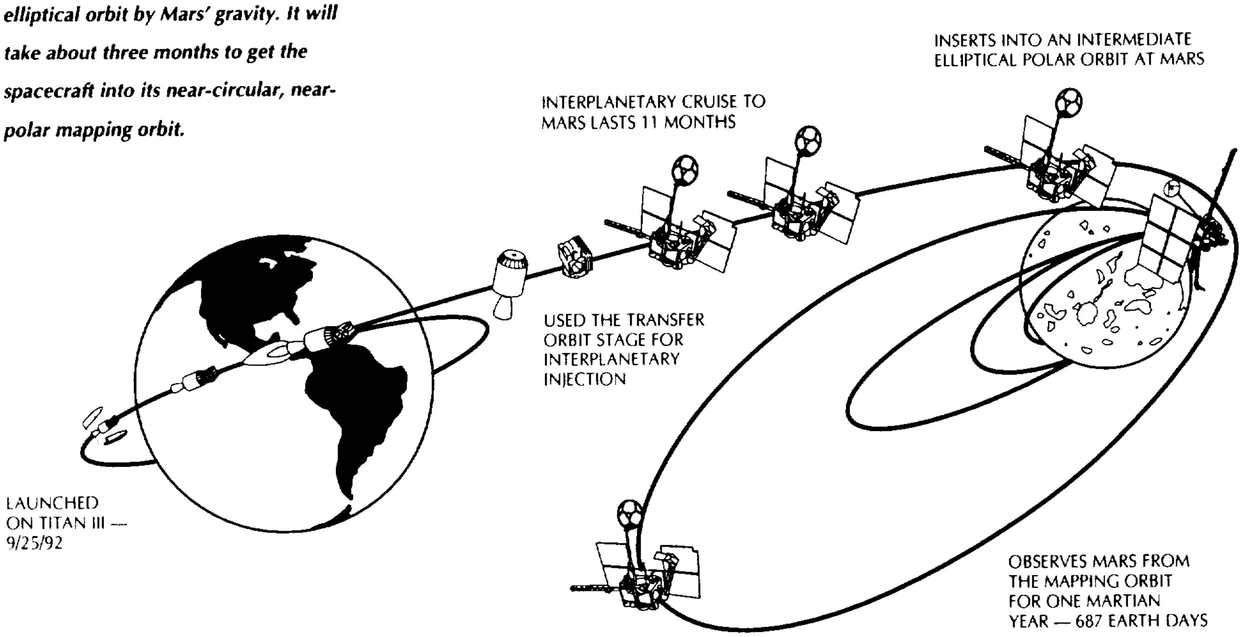
Cameras on the Viking landers provided detailed ground-level pictures of just two small geographical areas, and the lander instruments performed chemical analyses of soil samples only from the immediate area.

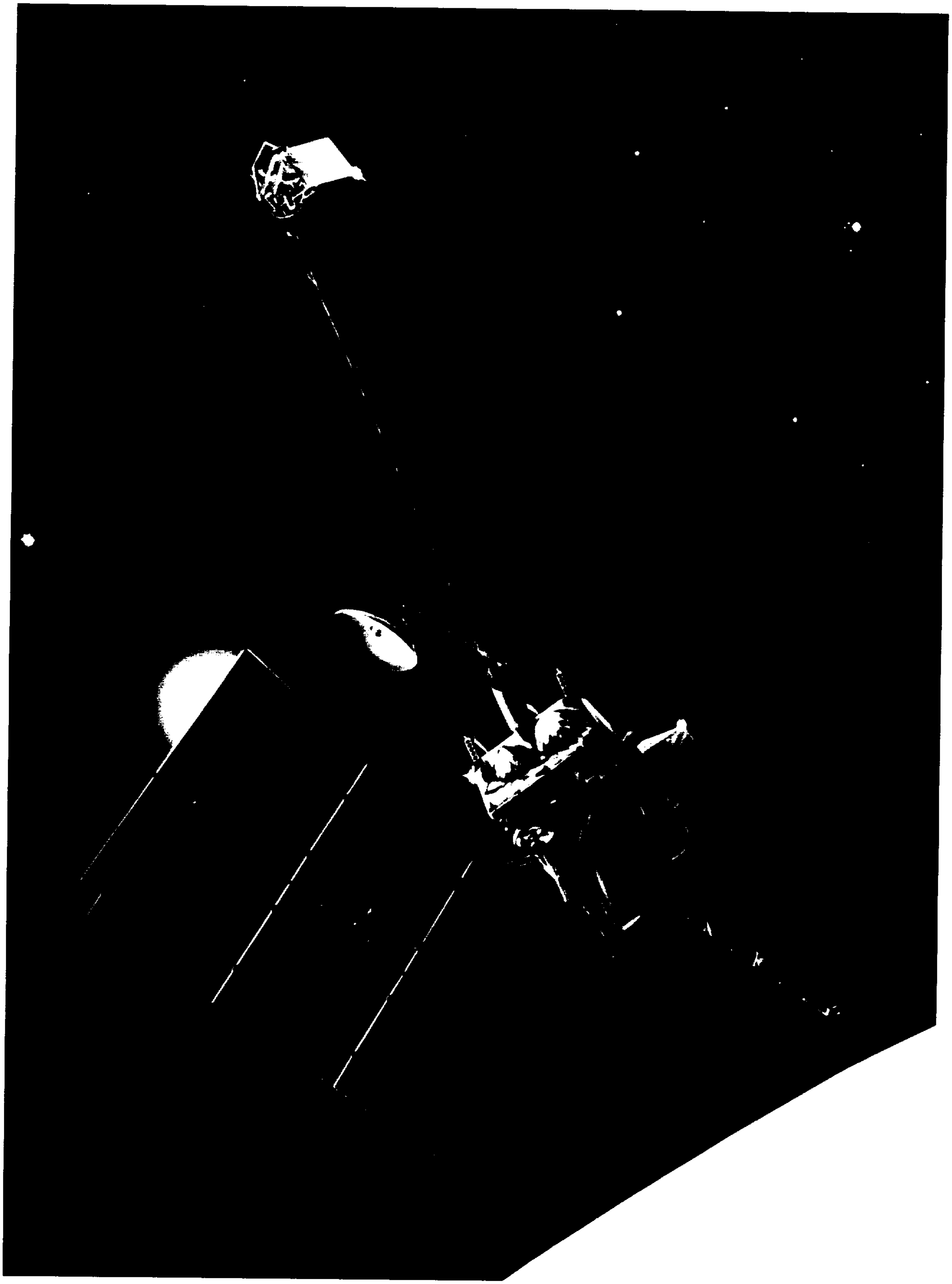
Additionally, a great deal of data consists of "snapshots," limited in time or space. We have only a few measurements (surface atmospheric pressure, for instance) that extend over at least a full Martian year, and we have virtually no global information about the composition of Martian surface material. In short, we have enough data to generate many important questions, but not enough data to find the answers.

By the early 1980s, it was clear that the next mission to explore Mars would have to be more comprehensive and more ambitious than anything done before. To decide on a course of action, NASA and its scientific advisory committees weighed the available data about Mars against unanswered questions. After considerable debate, it was agreed that long-term, global coverage of Mars was the essential next step.

The next Mars mission, then, should make a variety of observations over at least one complete Martian year, studying the surface, atmosphere, and interior. This could be done economically by a single spacecraft that would circle Mars in a nearly polar orbit, carrying a

The major phases of the mission: Following an 11-month cruise after launch from Earth, Mars Observer will allow itself to be captured into an elliptical orbit by Mars' gravity. It will take about three months to get the spacecraft into its near-circular, near-polar mapping orbit.





battery of instruments that would continuously examine the entire planetary environment.

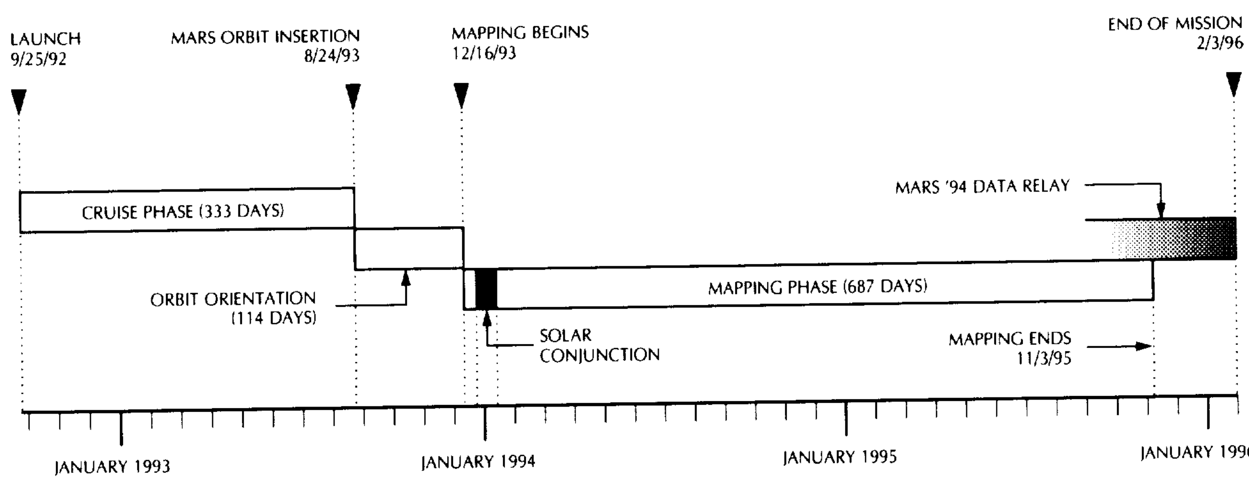
The Mars Observer mission is managed for NASA by JPL, an operating division of the California Institute of Technology. Originally called the Mars Geoscience/Climatology Orbiter, the spacecraft later was renamed Mars Observer, but its global science objectives remained the same. The mission's scientific goals are to:

- Determine the chemical and mineral composition of the surface rocks and soil over the whole planet.
- Measure the gravity field, search for and characterize a planetary magnetic field, and define the topography of the planet.
- Record — over a full Martian year — the composition, pressure, and dynamics of the atmosphere.
- Determine the seasonal cycles of water, carbon dioxide, and dust as they migrate back and forth among the atmosphere, polar caps, and Martian soil.

This systematic, intense global analysis makes Mars Observer one of the most exciting and ambitious efforts undertaken in planetary exploration. The science instruments are diverse and use 1980s technology, making them superior to those used on any previous mission. Designed to be highly productive, Mars Observer will relay to Earth more than 600 billion bits of scientific data during the one-Martian-year long investigation — more than that gathered by all previous missions to Mars.

Near the end of the mapping phase, Mars Observer will participate in the Russian–French Mars '94 mission, planned for launch in late 1994. The U.S. spacecraft will relay data to Earth from instrument packages deployed to the Martian surface by a Russian orbiter.

The mission timeline shows major events and dates. During solar conjunction — which begins December 27, 1993, and lasts for about two weeks — the Sun will be between Earth and Mars and communications will be temporarily disrupted.



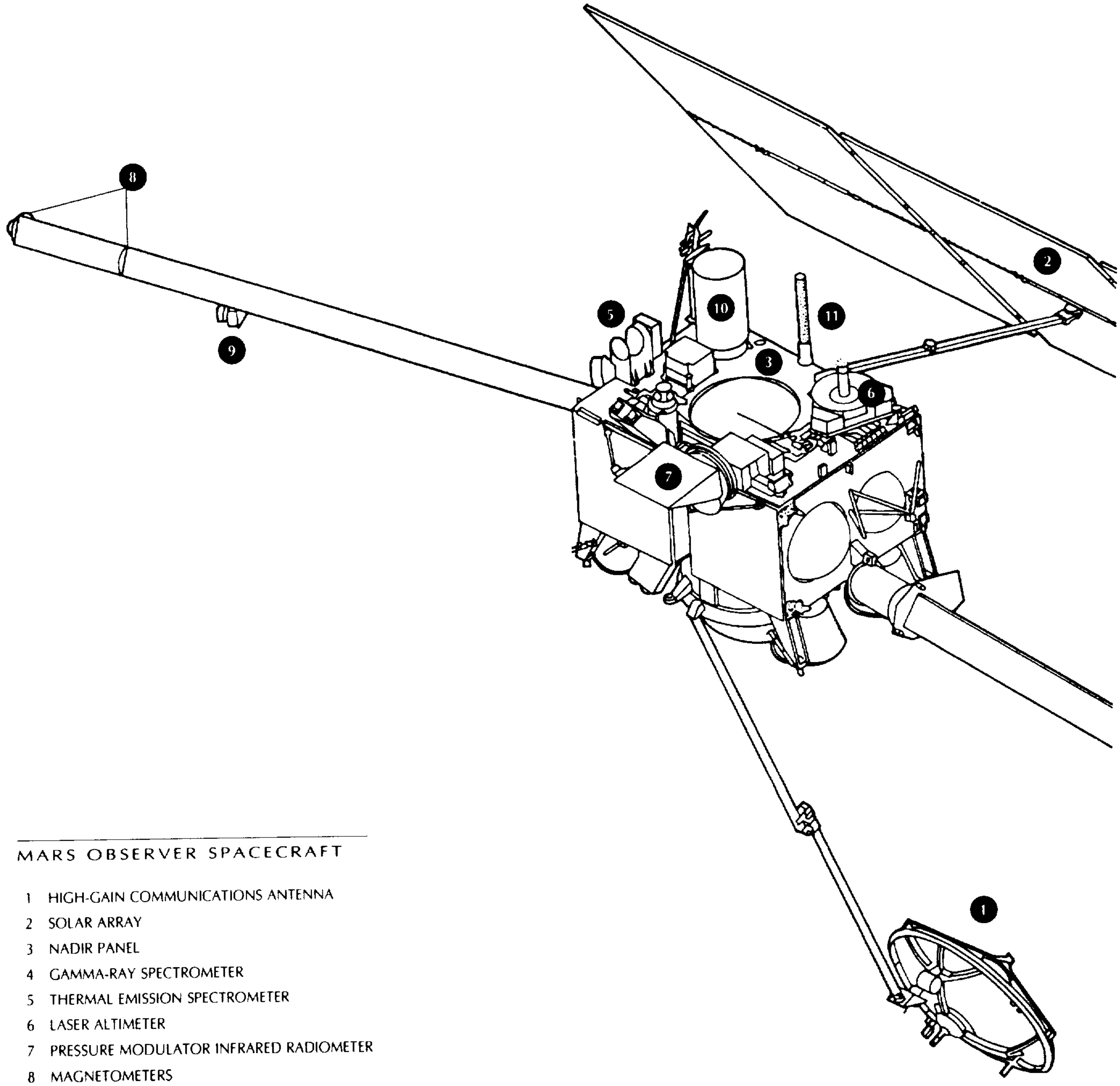
C H A P T E R 5

The Mars Observer Spacecraft

Designed as an orbiting spacecraft, Mars Observer is similar to Earth-orbiting weather and communications satellites and is basically a platform for the science instruments.

The bus — the rectangular body of the spacecraft — houses computers, the radio system, tape recorders, fuel tanks, and other equipment. Attached to the outside of the bus are 20 rocket thrusters, fired to adjust the spacecraft's path during the cruise to Mars and slow the spacecraft for Mars orbit insertion.

The spacecraft orbits the planet so that one side of the bus, called the nadir panel, always faces the Martian surface. Of the seven science instruments, four — the Mars Observer Camera (MOC), the Mars Observer Laser Altimeter (MOLA), the Pressure Modulator Infrared Radiometer (PMIRR), and the Thermal Emission Spectrometer (TES) — are attached to the nadir panel. Two instruments, the Magnetometer/Electron Reflectometer (MAG/ER) and the Gamma-Ray Spectrometer (GRS), are mounted on separate 6-meter booms attached to the bus. These two instruments are situated away from the bus to avoid interference from the small magnetic field and the gamma rays generated by the bus itself. Also attached to the nadir panel is the data-relay antenna for the Russian–French Mars '94 mission.

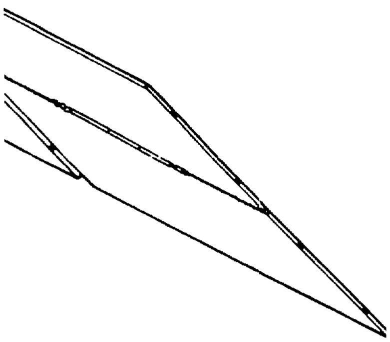


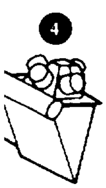
MARS OBSERVER SPACECRAFT

1 HIGH-GAIN COMMUNICATIONS ANTENNA
2 SOLAR ARRAY
3 NADIR PANEL
4 GAMMA-RAY SPECTROMETER
5 THERMAL EMISSION SPECTROMETER
6 LASER ALTIMETER
7 PRESSURE MODULATOR INFRARED RADIOMETER
8 MAGNETOMETERS
9 ELECTRON REFLECTOMETER
10 CAMERA
11 MARS '94 DATA-RELAY ANTENNA

SPACECRAFT STATISTICS

Weight at launch	
Dry (with payload)	1,125 kilograms
Fuel	1,440 kilograms
Total	2,565 kilograms
Bus dimensions	1.0 × 2.1 × 1.5 meters
Solar array dimensions	3.7 × 7 meters
Solar array output power	1,130 watts maximum
Communications antenna	
Diameter	1.5 meters
Boom length	5.3 meters
Basic design	Three-axis control (highly stabilized)
Science instrument boom length	6 meters (GRS and MAG/ER)
Bipropellants	Monomethyl hydrazine and nitrogen tetroxide
Monopropellant	Hydrazine
Thrusters (20)	(4) 490 Newton (4) 22 Newton (8) 4.5 Newton (orbit adjustments) (4) 0.9 Newton (momentum unloading and steering)
Pointing accuracy	Control: 10 milliradians Knowledge: 3 milliradians
Pointing stability	1 milliradian (for 0.5 second) 3 milliradians (for 12 seconds)
Command rate	12.5 commands/second maximum
Uplink data rate	500 bits/second maximum
Downlink data rate	85.3 kilobits/second maximum
Downlink radio frequency power	44 watts
Tape recorders (3)	1.38 × 10^9-bit capacity





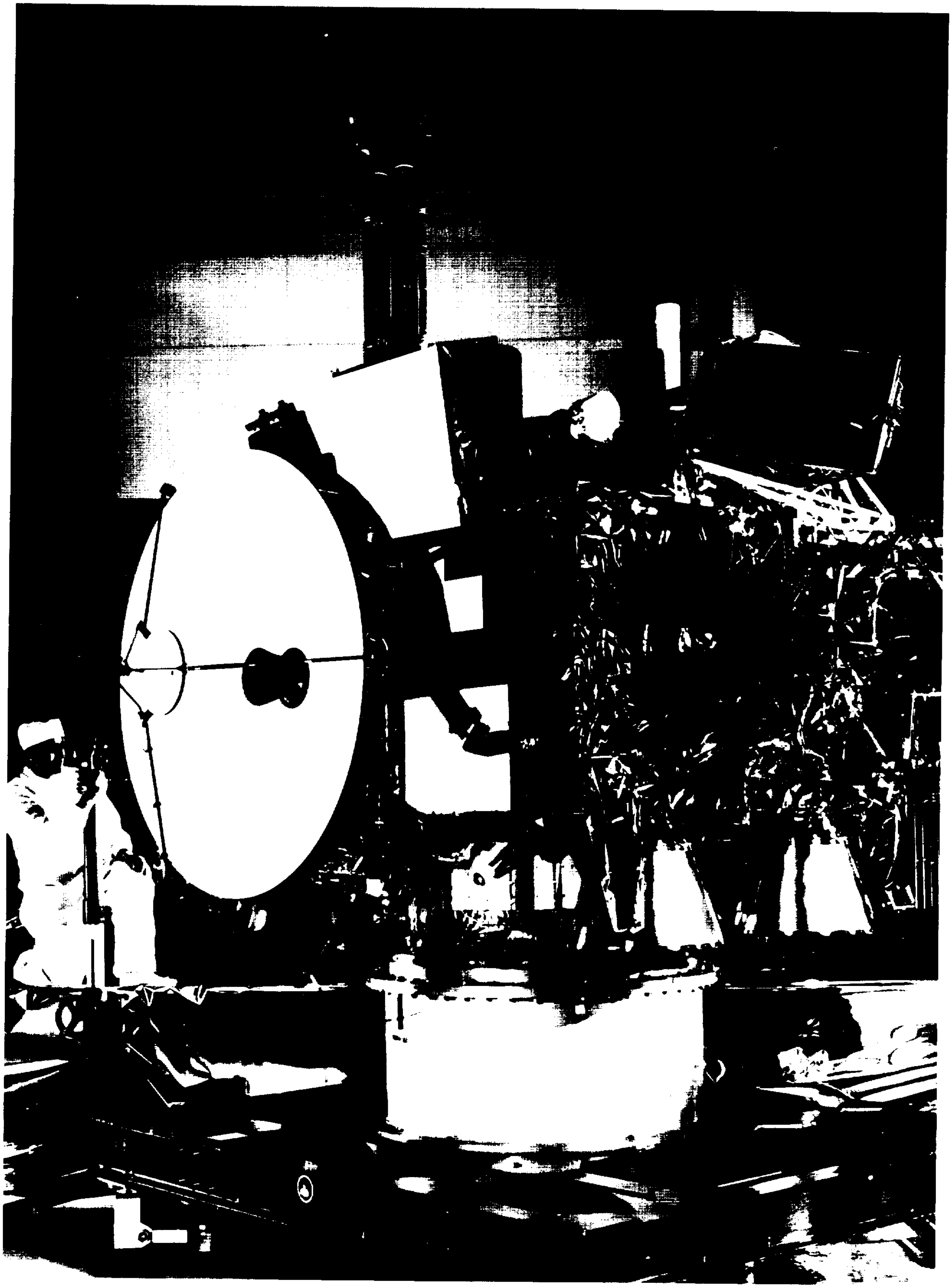
The bus has two additional boom-mounted appendages: a solar array and a high-gain communications antenna. The six-panel solar array provides 1,130 watts of electricity for operating the spacecraft's electronic equipment and for charging two 42-ampere-hour nickel–cadmium batteries. The batteries will provide electricity when the spacecraft is mapping the dark (nighttime) side of the planet. The dish-shaped communications antenna is mounted to the end of a 5.3-meter boom so that its view of Earth is not blocked by the solar array. The steerable antenna is 1.5 meters in diameter and will be pointed toward Earth even though the spacecraft continuously adjusts its position

Opposite page: The Mars Observer spacecraft is based on existing Earth-orbiting satellite designs. Most of the exposed parts of the spacecraft, including the science instruments, are wrapped in thermal blankets to maintain operating temperatures. (P-40614)

SPACECRAFT SUBSYSTEMS

The 10 subsystems of the Mars Observer spacecraft provide a stable, controlled platform for the science instruments.

Structure	The main, rectangular body of the spacecraft to which all other components and appendages are attached, including the solar array, the boom that supports the high-gain antenna, the two science instrument booms, and the adapter that connected the spacecraft and the Transfer Orbit Stage booster rocket during launch.
Attitude and articulation	The Sun and Mars horizon sensors, star mapper, gyroscopes, and accelerometers that determine the spacecraft's orientation in space, including reaction wheels and thrusters that control the orientation.
Mechanisms	The hardware that deploys the solar array panels, the high-gain antenna, and the two 6-meter science instrument booms.
Thermal control	The blankets, paint, tape, heaters, and radiators that keep spacecraft components within their allowable temperature ranges.
Telecommunications	The X-band radio system and onboard antennas that communicate with NASA's deep space tracking stations to provide two-way communication with the spacecraft.
Flight software	Computer programs that conduct the onboard computing functions.
Propulsion	The thrusters and propellants that are ignited to accomplish trajectory corrections, Mars orbit insertion, orbit adjustments, and unloading of the reaction wheels.
Harness	The wiring that interconnects the spacecraft's electrical assemblies.
Electrical power	The solar array and two 42-ampere-hour batteries that provide electricity to operate the spacecraft and the science instruments.
Command and data handling	Two redundant, programmable computers that autonomously operate the spacecraft.



during mapping to keep the nadir panel pointed toward Mars. The spacecraft's radio system, including the high-gain antenna, also functions as the seventh science instrument — researchers will use it for the radio science investigation.

For launch, the two science instrument booms, the solar array, and the communications antenna were folded against the bus. All were partially deployed during the cruise period, and will be fully extended when the spacecraft is in mapping orbit. Most of the outer exposed parts of the spacecraft, including the science instruments, are wrapped in thermal blankets to maintain appropriate operating temperatures.

The prime contractor for the Mars Observer spacecraft is Martin Marietta (formerly General Electric) Astro-Space Division in Princeton, New Jersey.

CATCHING A GRAVITY WAVE

Mars Observer, along with NASA's Jupiter-bound Galileo spacecraft, and Ulysses, a NASA–European Space Agency spacecraft on its way to study the Sun, may help verify a prediction of Albert Einstein's theory of general relativity. Between March 21 and April 9, 1993, the three spacecraft participated in a NASA experiment to detect gravity waves.

Gravity waves are ripples in space-time (the three dimensions of space plus the fourth dimension of time). Einstein perceived that matter, possessing gravity, causes a warp in space-time, somewhat analogous to a billiard ball on a rubber sheet. Asymmetric motion of any object possessing mass produces a ripple of gravity — a traveling distortion of space and time. Other masses are set in motion as the ripple, moving at the speed of light, passes by. But while these space-time ripples cause objects to move, the effect is incredibly small. Gravity is very weak compared to the other forces that affect matter, dominating other forces only on a large scale. Because gravity waves are so subtle, no direct detection of the faint waves has been confirmed.

Large-scale, violent cosmic events produce low-frequency, long-duration gravity waves. The three-spacecraft experiment is sensitive to gravity waves having periods between about 10 and 100 seconds caused by massive black hole formation or a pair of massive black holes in close orbit around one another, out to about the distance of the Andromeda Galaxy.

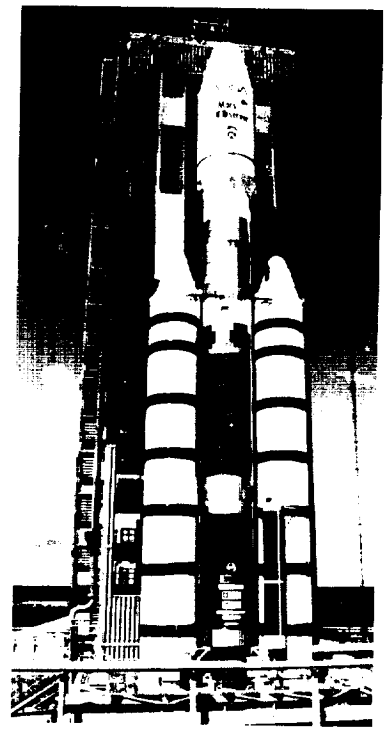
For the experiment, NASA's Deep Space Network continuously beamed radio signals of a precisely known frequency to Mars Observer, Galileo, and Ulysses, and each spacecraft replied with signals at a precisely related frequency. With all else being equal, the return signals should have arrived at Earth showing no effect but a Doppler shift due to the motion of the spacecraft. If a gravity wave were zipping through the solar system, however, Earth and the three spacecraft would have bobbled slightly, causing a small difference in the frequencies of the radio transmissions and receptions. If all three spacecraft registered the difference, the evidence for detection would be stronger.

The low-budget experiment benefited from certain conditions: the three spacecraft were in cruise mode so they were free from perturbations by nearby planets, and all were in the night sky, where radio interference from the solar wind is minimal. Six months to a year of analysis is necessary before experimenters will be able to determine if they have captured a gravity wave.

Destination: Mars

Mars Observer and its Transfer Orbit Stage (TOS) were carried into a temporary orbit around Earth by a Titan III rocket that lifted off from Cape Canaveral, Florida, on September 25, 1992. After the Titan separated from the spacecraft and fell away, the TOS ignited and burned for about 2.5 minutes, freeing Mars Observer from Earth's gravity and placing the spacecraft on a course for Mars. Finally, the TOS separated and maneuvered away to avoid colliding with or contaminating the spacecraft. Within an hour, NASA's Deep Space Network tracking station in Australia picked up Mars Observer's radio signal, confirming that all was well — Mars Observer was indeed heading for the Red Planet. As that announcement broke the tension back on Earth, thousands of people involved in the mission applauded and cheered. After years of work and the extraordinary effort required to coordinate a spacecraft launch, they had endured a nine-day delay past the original launch date.

After an 11-month cruise, the spacecraft will arrive at Mars on August 24, 1993 and prepare for orbit insertion. The orbit insertion maneuver is a critical one and cannot be halted and reattempted later; abort criteria are disabled and the spacecraft is provided with the autonomous capabilities to complete the maneuver. Mars Observer will slow itself down by firing two of its large rocket thrusters and allow itself to be captured by Mars' gravity. The spacecraft will first enter an elliptical (highly elongated) orbit around the planet. Additional burns of the thrusters over the next several months will change the orbit into a nearly circular one that almost crosses the Martian poles.



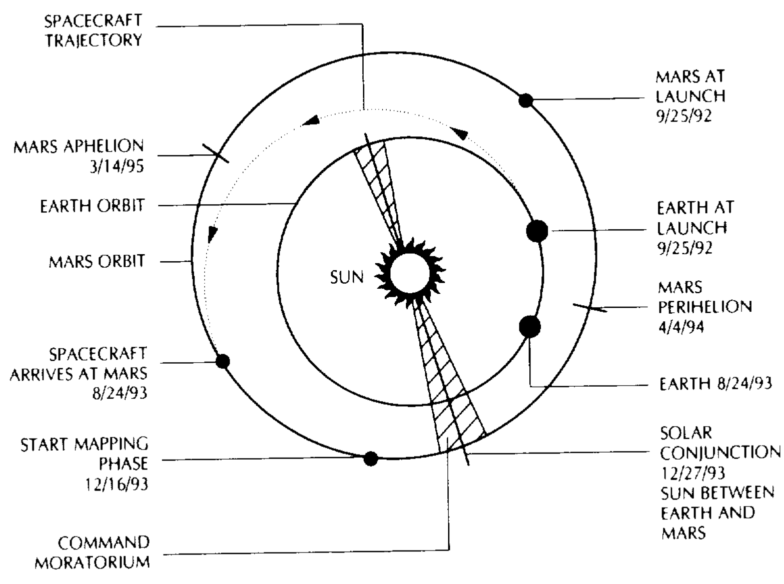
The Mars Observer spacecraft and the Transfer Orbit Stage (TOS) booster sit atop the Titan III launch vehicle. The Titan and the TOS were provided by Martin Marietta Corporation and Orbital Sciences Corporation, respectively. (P-41035B)

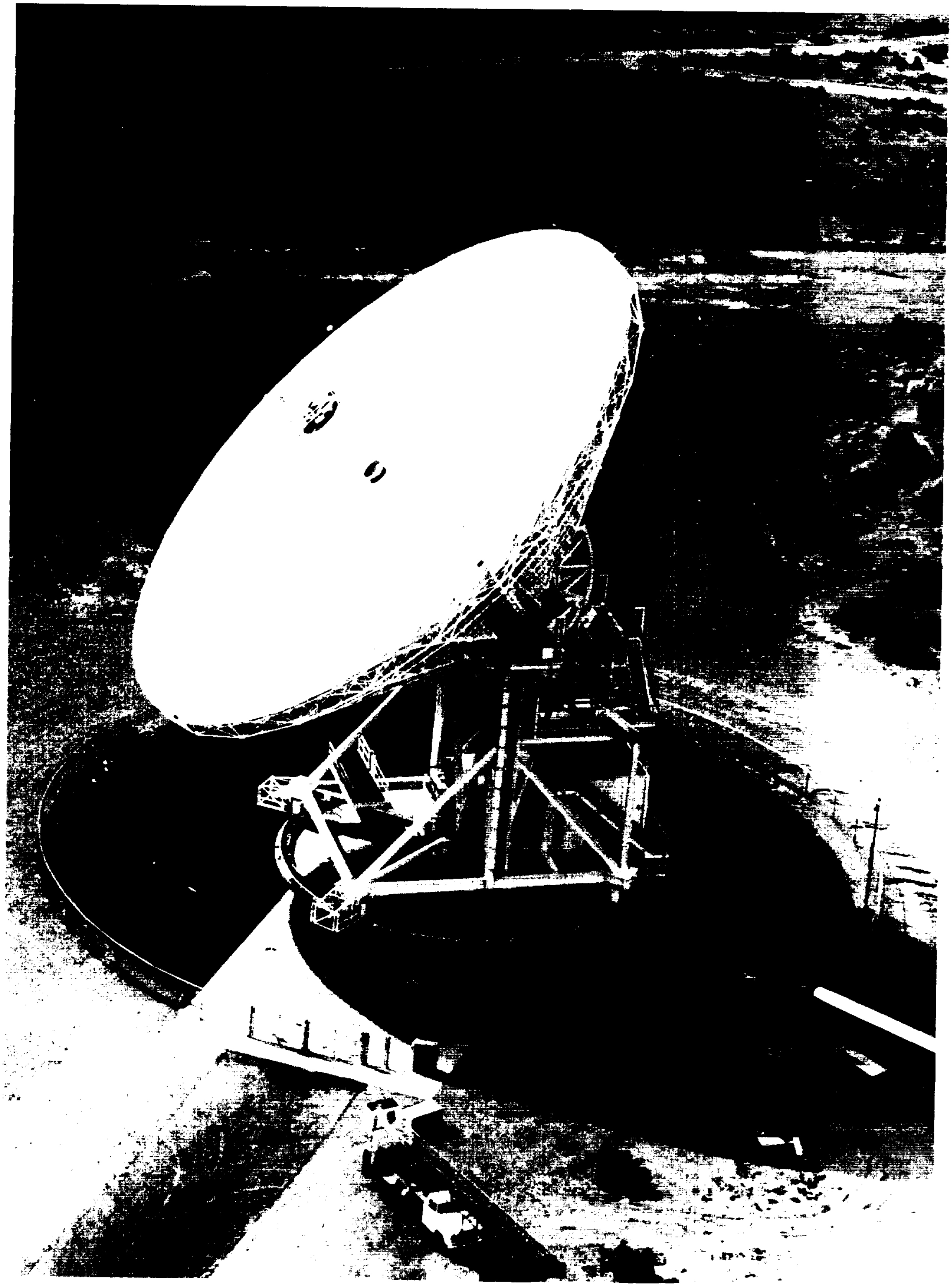
Opposite page: The 34-meter, high-efficiency antennas of NASA's Deep Space Network provide two-way communications with Mars Observer. (355-4127B)

The mapping orbit has been carefully selected. It is low enough (378 kilometers above the surface) so that the instruments can observe the planet at close range, but not so low that the thin Martian atmosphere could drag the spacecraft down. The orbit is nearly polar, so that the spacecraft can progressively observe all of Mars as the planet rotates below it. The orbit is also Sun-synchronous; that is, the spacecraft passes over a given part of Mars at the same time of day. Around 2 p.m. (local Mars time) every orbit, the spacecraft will cross the equator on the daytime side, and around 2 a.m. it will cross the equator on the nighttime side. This timing is essential for atmospheric and surface measurements because it allows separation of the effects of local daily variations from the longer term seasonal and annual trends.

The science instruments will continue to observe Mars until February 1996. When mapping has finally been completed, the spacecraft's rockets may be fired to raise the orbit to an altitude of 405 kilometers above the surface, where the drag of the Martian atmosphere on the spacecraft will be greatly reduced. In accordance with international agreements on planetary protection, efforts are made to minimize, for as long as possible, the chances that a visiting spacecraft might contaminate Mars — considered a "biologically interesting" planet — with terrestrial organisms. The Viking landers went through extensive

Mars Observer will travel 724 million kilometers to keep its August 24, 1993, rendezvous with the Red Planet. Soon after mapping begins, solar conjunction will disrupt communications between Earth and the spacecraft for about two weeks.





FROM EARTH TO MARS

Launch date	September 25, 1992
Cruise period to Mars	11 months
Average speed during cruise (with respect to Earth*)	17.8 kilometers/second
Average speed during cruise (with respect to the Sun*)	25.0 kilometers/second
Arrival at Mars	August 24, 1993 1:42 p.m. (Pacific Daylight Time)
Speed before Mars orbit insertion (with respect to Mars)	5.28 kilometers/second
Speed after Mars orbit insertion (with respect to Mars)	4.56 kilometers/second
Speed in mapping orbit (with respect to Mars)	3.35 kilometers/second
Distance traveled between Earth and Mars	724 million kilometers
Distance from Earth at Mars arrival	340 million kilometers
Distance from Earth during mapping phase	Minimum: 100 million kilometers Maximum: 367 million kilometers
Time for command from Earth to reach spacecraft during mapping phase	Minimum: 5.5 minutes Maximum: 20.4 minutes

*The speed of the spacecraft with respect to Earth is slower than the speed with respect to the Sun because Earth is chasing the spacecraft as each follows its path around the Sun.

sterilization procedures before launch. Procedures for orbiters are simpler; Mars Observer will be placed into a high orbit, where it has at least a 95-percent chance of remaining until at least the year 2039 before it finally succumbs to the steady drag of the atmosphere and crashes onto the Martian surface. This strategy will provide a 40-year, contamination-free period in which to conduct missions to determine the true biological nature of the Martian surface before significant contamination occurs from robot spacecraft — or from visiting human beings.

Instruments, Science, and Scientists

More than 100 scientists — members of the science investigation teams — await the stream of data from Mars Observer. Each team is associated with one of the instruments on board the spacecraft and is headed by a Principal Investigator or a Team Leader. The science investigation teams are composed of researchers from institutions throughout the United States and Europe.

In addition to the researchers associated with the Mars Observer instruments, six Interdisciplinary Scientists, working in broad areas of study, will use data from several instruments to investigate specific questions about Mars.

Shortly after launch, 33 Participating Scientists joined the instrument teams and the Interdisciplinary Scientists. Additionally, 10 Participating Scientists from Russia joined the project as part of the scientific cooperation between the United States and Russia.

Each Principal Investigator, Team Leader, and Interdisciplinary Scientist is a member of an executive subset of the project science team called the Project Science Group (PSG). Chaired by the Project Scientist, the PSG also includes the Deputy Project Scientist and the Program Scientist (from NASA Headquarters). The PSG convenes several times a year to discuss science plans, hear status reports, and discuss specific issues with the project.

Mars Observer carries a complement of seven scientific instruments. The spacecraft telecommunications system, which includes the high-gain antenna, is considered an instrument because radio science experimenters will monitor the radio beams, using their measurements to probe the Martian gravity field and atmosphere. Collectively, the in-

Opposite page: The GRS will detect gamma rays emitted from the Martian surface to identify chemical elements.

A DIFFERENT ENCOUNTER

Previous spacecraft missions were typically characterized by quiet interplanetary cruises punctuated with short, intense planetary encounters — Voyager, for example, had long cruises in between encounters with the four planets in the outer solar system. Mission scientists traveled from their home institutions to JPL for the encounters, settling into offices and receiving initial science data for the few days or weeks involved. Long-lasting orbital missions, however, require a different approach. Neither the operations budget nor the physical space at JPL can support the presence of large numbers of scientists for the months or even years involved in an orbital mission. Mars Observer is the first mission to use a new method of communications and operations.

Throughout the 687 Earth days of the Mars Observer mapping mission, Principal Investigators, Team Leaders, and Interdisciplinary Scientists will have Science Operations Planning Computers at their home institutions. All will be electronically connected to the Project Data Base at JPL, enabling direct involvement in mission operations.

Their computers will be equipped with software that allows the science teams to remotely initiate most of the commands required by their instruments to conduct desired experiments; instrument teams will be able to access raw science data within 24 hours of its receipt on Earth. This automated operation will expedite generation of "quick-look" science data, and investigators can readily monitor instrument health and performance.

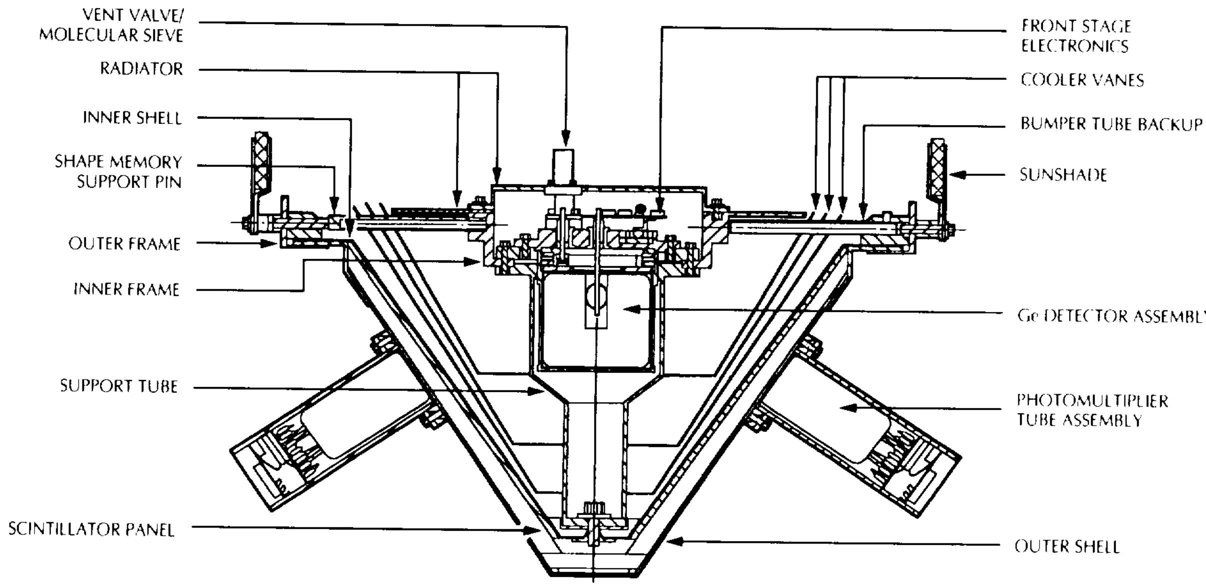
After an initial proprietary period of about six months, reduced (processed) data, as well as some special data products, will be transmitted from investigators' home institutions to the Project Data Base at JPL. All the science data, both raw and processed, along with supplementary processing information and documentation, will be transferred to NASA's Planetary Data System archive for access and use by the broader planetary science community.

struments cover much of the electromagnetic spectrum and will produce data sets that contribute to a variety of scientific investigations. The synergistic organization of the Mars Observer science investigations and scientists reflects the comprehensive nature of the mission. The data returned by the array of instruments will enable scientists to create, for the first time, a complete portrait of Mars.

SURFACE COMPOSITION AND TOPOGRAPHY

Gamma-Ray Spectrometer

The *Gamma-Ray Spectrometer (GRS)* will detect and analyze gamma rays emitted from the Martian surface. By measuring the energy and intensity of the radiation, researchers can identify the chemical elements that produced the emission. The GRS can determine the abundances of such elements as potassium, uranium, thorium, calcium, magnesium, aluminum, and iron in the surface materials.



GRS INVESTIGATORS

Team Leader	Institution	Country
William V. Boynton	University of Arizona	United States
Team Members		
James R. Arnold	University of California, San Diego	United States
Peter Englert	California State University, San Jose	United States
William C. Feldman	Los Alamos National Laboratory	United States
Albert E. Metzger	Jet Propulsion Laboratory	United States
Robert C. Reedy	Los Alamos National Laboratory	United States
Steven W. Squyres	Cornell University	United States
Jacob L. Trombka	NASA Goddard Space Flight Center	United States
Heinrich Wanke	Max-Planck-Institut für Chemie	Germany
Participating Scientists		
Johannes Bruckner	Max-Planck-Institut für Chemie	Germany
Darrell M. Drake	Los Alamos National Laboratory	United States
Larry G. Evans	Computer Sciences Corporation	United States
John G. Laros	Los Alamos National Laboratory	United States
Richard D. Starr	Catholic University	United States
Yuri A. Surkov	Vernadsky Institute	Russia

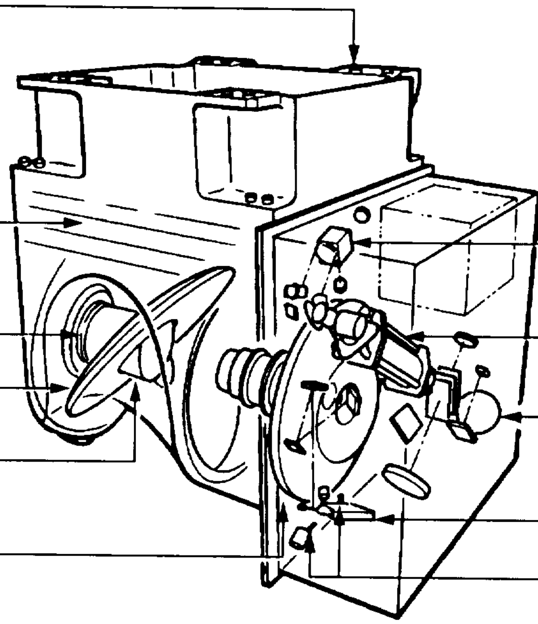
From the GRS data, scientists can determine the amounts of heat-producing radioactive elements and infer the planet's thermal history. Data on other elements will enable geologists to identify different rock types in the Martian crust. In addition, the GRS can detect neutrons arising from hydrogen, oxygen, and carbon, so that scientists can deduce the amounts of carbon dioxide and water near the surface.

Thermal Emission Spectrometer

The *Thermal Emission Spectrometer (TES)* will analyze infrared radiation from the surface. (Everything on the surface of a planet emits a certain amount of heat, even on a planet as cold as Mars.) From the TES measurements and spectra, scientists can determine several important properties of the rocks and soils that make up the Martian surface: how hot and cold they get during the cycles of night and day, how well they transmit heat, the amount of open space in them, and the amount of the surface covered by large rocks and boulders.

Data from the TES can also be used to identify the minerals that make up the wide range of different materials — from solid rocks to sand dunes — present on the Martian surface. This information will be important in understanding how Martian bedrock has weathered on the surface over millions of years and how it may be weathering today. The TES is particularly sensitive to carbonates and sulfate minerals, which (the Viking analyses suggest) are present in the altered surface materials of Mars. These minerals have most likely formed by weathering of the bedrock, possibly as the result of reactions between the original minerals in the volcanic lavas (which probably contained sulfur) and the carbon dioxide and water vapor in the surface environment of Mars. The TES can also provide data about the Martian atmosphere, especially the locations and nature of short-lived clouds and dust.

The TES will analyze infrared radiation from the surface to identify minerals and properties of the rocks and soil.



TES INVESTIGATORS

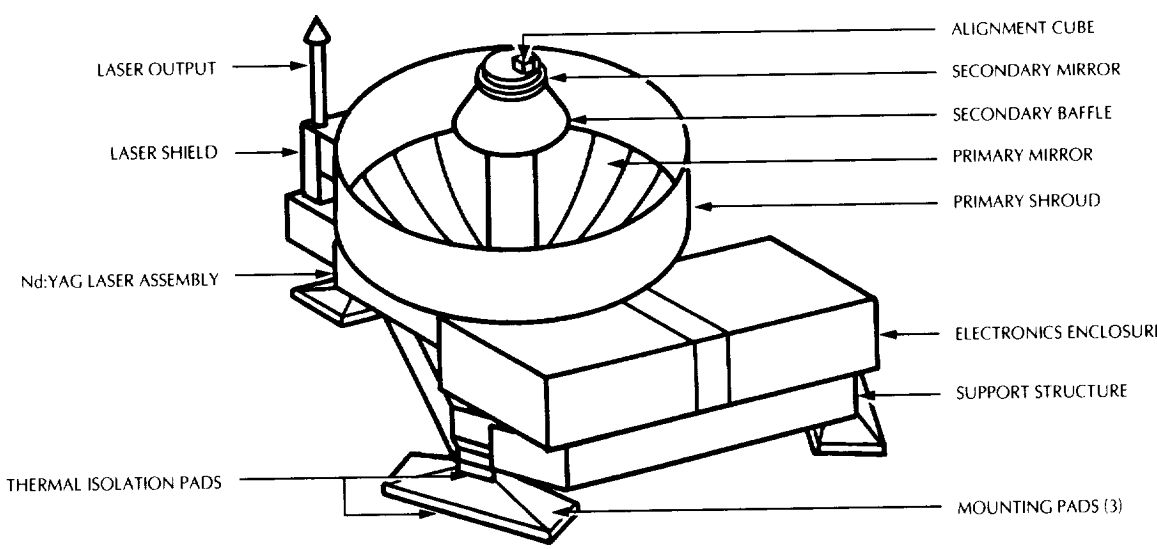
Principal Investigator	Institution	Country
Philip R. Christensen	Arizona State University	United States
Co-Investigators		
Donald A. Anderson	Arizona State University	United States
Stillman C. Chase	Consultant	United States
Roger N. Clark	United States Geological Survey	United States
Hugh H. Kieffer	United States Geological Survey	United States
Michael C. Malin	Malin Space Science Systems, Inc.	United States
John C. Pearl	NASA Goddard Space Flight Center	United States
Participating Scientists		
Todd R. Clancy	University of Colorado	United States
Barney J. Conrath	NASA Goddard Space Flight Center	United States
Ruslan O. Kuzmin	Vernadsky Institute	Russia
Ted L. Roush	San Francisco State University	United States
Arnold S. Selivanov	Institute for Space Devices Engineering	Russia

Mars Observer Laser Altimeter

The *Mars Observer Laser Altimeter (MOLA)* will measure the height of Martian surface features. A laser will fire pulses of infrared light 10 times each second, striking a 160-meter area on the surface. By measuring the length of time it takes for the light to return, scientists can determine the distance to the surface; calculation of the distance of the spacecraft from the center of the planet gives the Martian surface elevation with a precision of a few meters.

The MOLA will measure the height of surface features to create topographic maps.

Data from the MOLA will be used to construct a detailed topographic map of Mars. The fine details of plains, valleys, craters, and mountains will provide essential information about the height of Martian surface features.



MOLA INVESTIGATORS

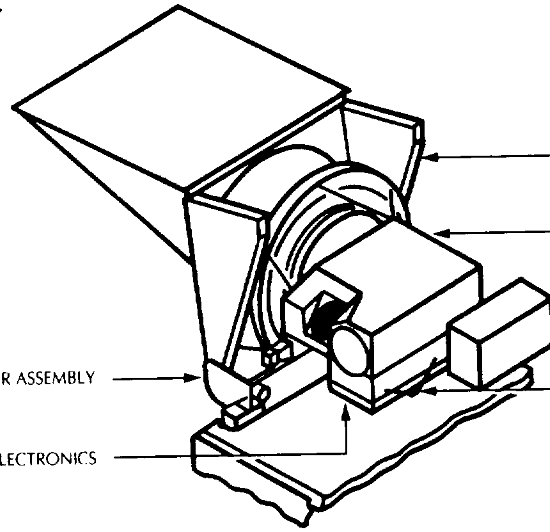
Principal Investigator	Institution	Country
David E. Smith	NASA Goddard Space Flight Center	United States
Co-Investigators		
Herbert V. Frey	NASA Goddard Space Flight Center	United States
James B. Garvin	NASA Goddard Space Flight Center	United States
James W. Head	Brown University	United States
Duane Muhleman	California Institute of Technology	United States
Gordon H. Pettengill	Massachusetts Institute of Technology	United States
Roger J. Phillips	Washington University	United States
Sean C. Solomon	Carnegie Institute	United States
Maria T. Zuber	NASA Goddard Space Flight Center; Johns Hopkins University	United States
H. Jay Zwally	NASA Goddard Space Flight Center	United States
Participating Scientists		
W. Bruce Banerdt	Jet Propulsion Laboratory	United States
Thomas C. Duxbury	Jet Propulsion Laboratory	United States

THE ATMOSPHERE

Pressure Modulator Infrared Radiometer

The *Pressure Modulator Infrared Radiometer (PMIRR)* will measure the temperature, water content, and pressure of the thin Martian atmosphere. Like the TES, the PMIRR measures infrared radiation, but its focus is on atmospheric composition, structure, and dynamics. The PMIRR will determine, from near the surface to as high as 80 kilometers, the vertical profiles of temperature, water vapor, and dust. The best data will come from scans made across the limb of Mars. Scientists can use the PMIRR data to construct models of the atmosphere and to monitor the seasonal behavior of the atmosphere and polar caps.

The PMIRR will measure infrared radiation in the atmosphere to create models and monitor seasonal activity.



PMIRR INVESTIGATORS

Principal Investigator	Institution	Country
Daniel J. McCleese	Jet Propulsion Laboratory	United States
Co-Investigators		
Robert D. Haskins	Jet Propulsion Laboratory	United States
Conway B. Leovy	University of Washington	United States
David A. Paige	University of California, Los Angeles	United States
John T. Schofield	Jet Propulsion Laboratory	United States
Fredric Taylor	Oxford University	England
Richard W. Zurek	Jet Propulsion Laboratory	United States
Participating Scientists		
Michael D. Allison	NASA Goddard Space Flight Center	United States
Jeffrey R. Barnes	Oregon State University	United States
Terry Z. Martin	Jet Propulsion Laboratory	United States
Peter L. Read	Oxford University	England

THE INTERIOR

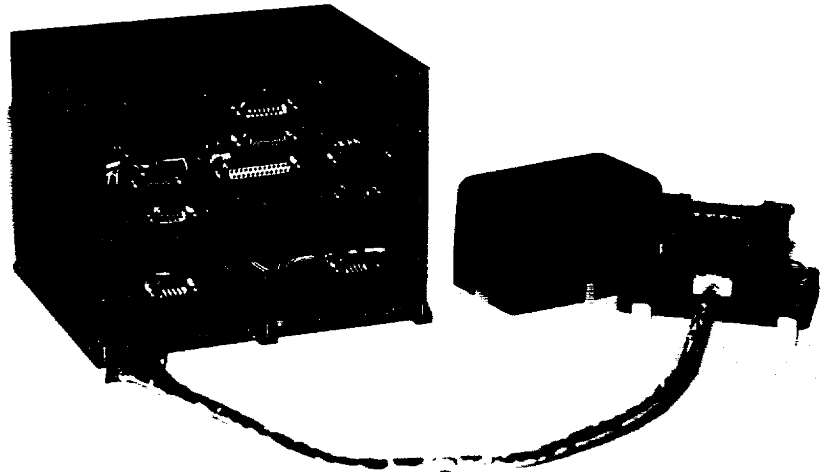
Magnetometer/Electron Reflectometer

Mars is the only planet in the solar system, aside from Pluto, whose magnetic field has not yet been characterized. The *Magnetometer/Electron Reflectometer (MAG/ER)* will search for evidence of a planetary magnetic field and measure the strength of the field, if it exists. These measurements will provide critical tests for current speculations about the early history and evolution of the planet. The MAG/ER will also scan the surface to detect remnants of an ancient magnetic field, providing clues to the Martian past when the magnetic field may have been stronger because the planet had a higher internal temperature.

MAG/ER INVESTIGATORS

Principal Investigator	Institution	Country
Mario H. Acuna	NASA Goddard Space Flight Center	United States
Co-Investigators:		
Kinsey S. Anderson	University of California, Berkeley	United States
Sigfried Bauer	University of Graz	Austria
Charles W. Carlson	University of California, Berkeley	United States
Paul Cloutier	Rice University	United States
John E.P. Connerney	NASA Goddard Space Flight Center	United States
David W. Curtis	University of California, Berkeley	United States
Claude d'Uston	University Paul Sabatier	France
Robert P. Lin	University of California, Berkeley	United States
Michael Mayhew	National Science Foundation	United States
Christian Mazelle	University Paul Sabatier	France
James McFadden	University of California, Berkeley	United States
Norman F. Ness	University of Delaware	United States
Henri Reme	University Paul Sabatier	France
Jean-Andre Sauvaud	University Paul Sabatier	France
Peter J. Wasilewski	NASA Goddard Space Flight Center	United States
Participating Scientists:		
Michel Menvielle	University of Paris	France
Diedrich Mohlmann	DLR Institut für Raumsimulation	Germany
James A. Slavin	NASA Goddard Space Flight Center	United States
Alexander V. Zakharov	Space Research Institute	Russia

The magnetometer will try to find an intrinsic planetary magnetic field and scan the surface for remnants of ancient magnetism.

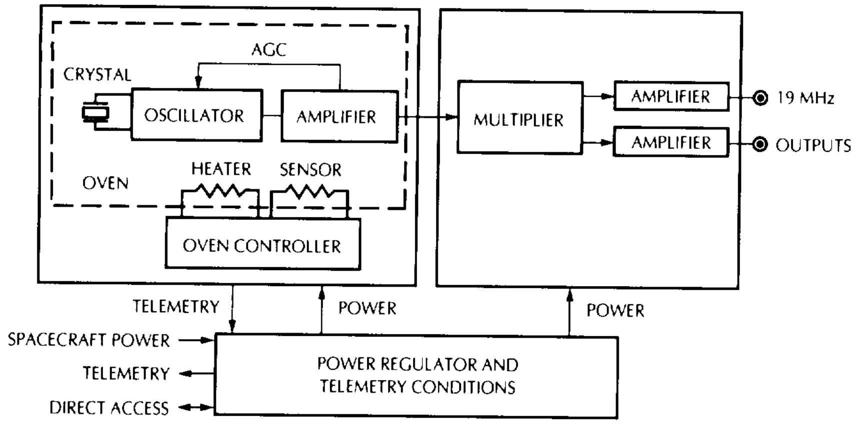


Radio Science

Scientists involved in the *Radio Science (RS)* investigation will use the tracking data provided by the spacecraft's communication system to map out variations in the gravity field of Mars by noting where the spacecraft speeds up or slows down in its passage around Mars. Changes in velocity would reflect changes in the strength of the gravity field felt by the spacecraft.

From these observations, a precise map of the gravity field of Mars can be constructed and related to the structure of the planet. Combined with topographic measurements, the gravity data can be used to determine the strength and vertical density of the Martian crust. They may also detect near-surface concentrations of mass ("mascons") similar to those detected by spacecraft orbiting the Moon.

The RS data can also help scientists map the vertical structure of the Martian atmosphere. Each time the spacecraft goes behind the planet or emerges from behind it, the radio beams must pass through the Martian atmosphere on their way to Earth. The temperature and pressure of the atmosphere can be determined from the way in which the waves are distorted.



The spacecraft's ultrastable oscillator is part of the RS experiment to map Mars' gravity field.

RS INVESTIGATORS

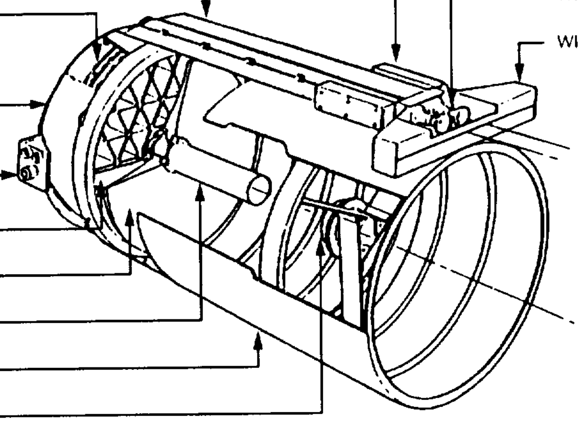
Team Leader	Institution	Country
G. Leonard Tyler	Stanford University	United States
Team Members		
Georges Balmino	Centre National d'Études Spatiales	France
David Hinson	Stanford University	United States
William L. Sjogren	Jet Propulsion Laboratory	United States
David E. Smith	NASA Goddard Space Flight Center	United States
Richard Woo	Jet Propulsion Laboratory	United States
Participating Scientists		
Efraim L. Akim	Keldysh Institute of Applied Mathematics	Russia
John W. Armstrong	Jet Propulsion Laboratory	United States
Michael F. Flasar	NASA Goddard Space Flight Center	United States
Richard A. Simpson	Stanford University	United States

IMAGES

Mars Observer Camera

The *Mars Observer Camera (MOC)* uses a "push-broom" technique that builds pictures one line at a time as the spacecraft moves around the planet, using the camera's orbital motion to sweep out the desired field of view. The MOC will provide complete low-resolution global coverage of the planet every day, together with medium- and high-resolution photographs of selected areas. The wide-angle lens is ideal for accumulating a "weather map" of Mars each day, showing surface features and clouds at a resolution of about 7.5 kilometers. These global views will be similar to the types of views obtained by terrestrial weather satellites. The narrow-angle lens will image small areas of the surface at a resolution of 2 to 3 meters. These pictures will be sharp enough to show small geologic features such as boulders and sand dunes — perhaps even the now-silent Viking landers — and may also be used to select landing sites for future spacecraft missions. Because of the extremely high data volume of the high-resolution images, controllers cannot use the narrow-angle mode continuously, so areas will be sampled in this mode rather than mapped.

The Mars Observer camera has three resolution modes; the narrow-angle lens will be able to resolve features as small as 2 to 3 meters across.



MOC INVESTIGATORS

Principal Investigator	Institutions	Country
Michael C. Malin	Malin Space Science Systems, Inc.	United States
Co-Investigators		
G. Edward Danielson, Jr.	California Institute of Technology	United States
Andrew P. Ingersoll	California Institute of Technology	United States
Laurence A. Soderblom	United States Geological Survey	United States
Joseph Veverka	Cornell University	United States
Participating Scientists		
Genry A. Avenesov	Space Research Institute	Russia
Merton E. Davies	RAND Corporation	United States
William K. Hartmann	Planetary Science Institute	United States
Philip B. James	University of Toledo	United States
Alfred S. McEwen	United States Geological Survey	United States
Peter C. Thomas	Cornell University	United States

INTERDISCIPLINARY STUDIES

Using data from several instruments, Mars Observer's Interdisciplinary Scientists will work in broadly defined areas of global interest.

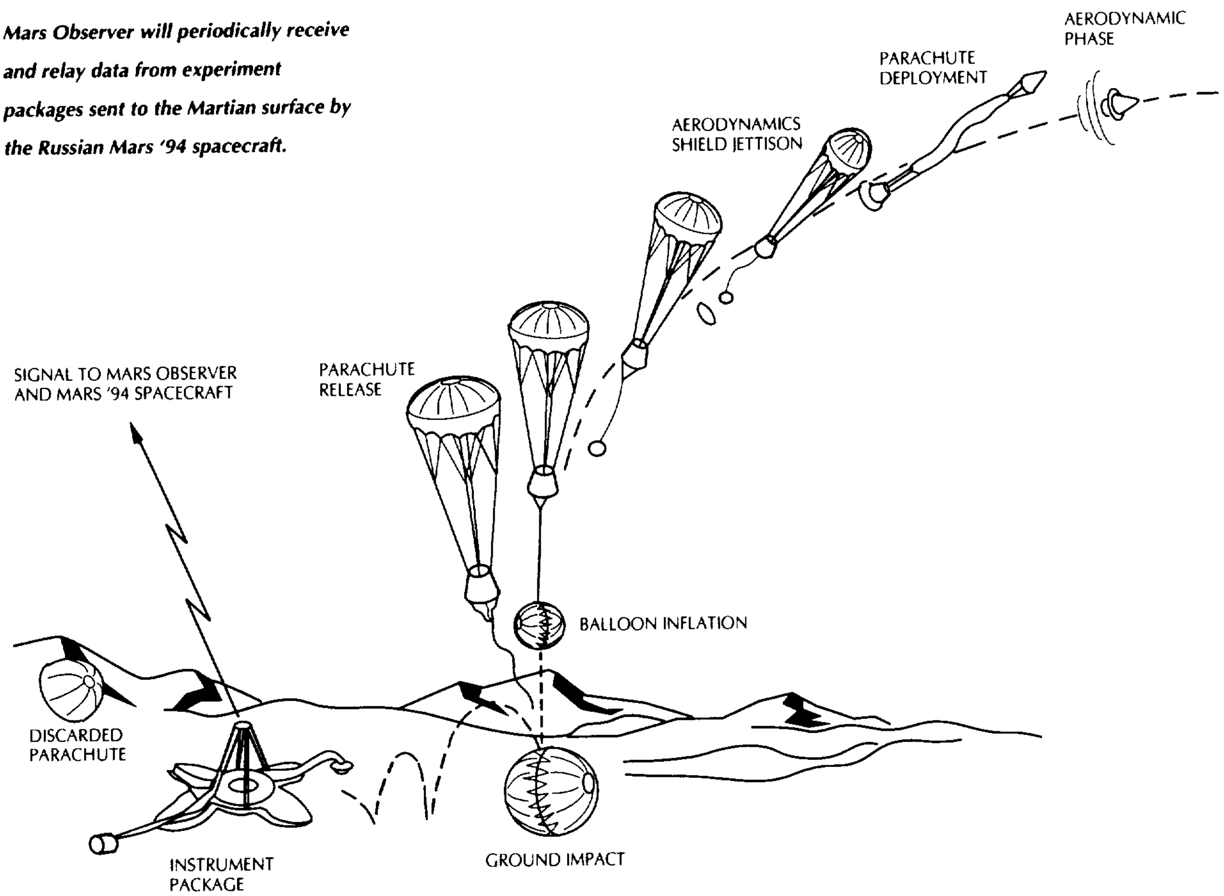
INTERDISCIPLINARY SCIENTISTS

Area of Study	Interdisciplinary Scientist	Participating Scientist
Weathering; data management and archiving	Raymond E. Arvidson, Washington University, U.S.A.	Bruce Fegley, Jr., Washington University, U.S.A.
Geosciences	Michael H. Carr, U.S. Geological Survey, U.S.A.	Alexander T. Basilevsky, Vernadsky Institute, Russia Matthew Golombek, Jet Propulsion Laboratory, U.S.A. Harry Y. McSween, Jr., University of Tennessee, U.S.A.
Polar atmospheric science	Andrew P. Ingersoll, California Institute of Technology, U.S.A.	Howard Houben, Space Physics Research Institute, U.S.A.
Surface–atmospheric science	Bruce M. Jakosky, University of Colorado, U.S.A.	Leonid V. Ksanfomality, Space Research Institute, Russia Aaron P. Zent, SETI Institute, U.S.A.
Climatology	James B. Pollack, NASA Ames Research Center, U.S.A.	Robert M. Haberle, NASA Ames Research Center, U.S.A. Vasily I. Moroz, Space Research Institute, Russia
Surface processes and geomorphology	Laurence A. Soderblom, U.S. Geological Survey, U.S.A.	Ken Herkenhoff, Jet Propulsion Laboratory, U.S.A. Bruce C. Murray, California Institute of Technology, U.S.A.

Russian–French Robotic Mission

Near the end of its prime mission in February 1996, Mars Observer will participate in the joint Russian–French Mars '94 mission. Mars Observer carries a radio receiver/transmitter supplied by the French space agency (Centre National d'Études Spatiales), which will periodically receive and relay data from instrument packages deployed to the Martian surface by the Russian Mars '94 orbiter. The relayed data will be stored in the large solid-state memory of the Mars Observer camera where it will be processed for return to Earth. The Russian orbiter also will acquire and transmit data from the landed packages. Mars Observer's orbit is well suited for this activity, and the cooperative effort will allow maximum data collection. This type of effort also provides an exercise in the multinational exploration of Mars — an experience that will be useful in planning future missions involving international cooperation.

Mars Observer will periodically receive and relay data from experiment packages sent to the Martian surface by the Russian Mars '94 spacecraft.



C H A P T E R 8

The Mars Observer Flight Team

A salute is extended here to the Mars Observer Flight Team — made up of the many individuals who directly contribute to the mission. Most of them work at JPL, except for the majority of the science investigators. Several members of the Spacecraft Team, which is responsible for the safe operation of the spacecraft, are employees of Martin Marietta (formerly General Electric) Astro-Space Division in Princeton, New Jersey, but are resident at JPL for the duration of the mission.

The Mars Observer Flight Team is part of an even larger group of people who also support the mission. That group includes other personnel at the California Institute of Technology and at JPL, at NASA Headquarters and other NASA centers, and at the three Deep Space Communications Complexes of NASA's Deep Space Network. Because all spaceflight projects necessarily span several years, from the early conceptual stage through project end, many who contributed their energies and talents have completed their tasks and gone on to other assignments, or have retired.

Thus, this acknowledgment properly includes current flight team members as well as others in the larger group who have worked to bring Mars Observer to the eve of arrival at its destination and who have contributed their best efforts to a continuing realization of mission objectives.

MARS OBSERVER ORGANIZATION

NASA HEADQUARTERS

Daniel Goldin
Administrator

John Dailey
Acting Deputy Administrator

Solar System Exploration Division

William Piotrowski
Acting Director

Mary Kicza
Deputy Director

Mars Observer Program

William Panter
Program Manager

Marius Weinreb
Program Engineer

Bevan French
Program Scientist

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY

Edward Stone
Director

Larry Dumas
Deputy Director

Office of Flight Projects

John Casani
Assistant Laboratory Director

David Evans
Deputy Assistant Laboratory Director

Deep Space Network

Goldstone, California

Canberra, Australia

Madrid, Spain

Mars Observer Project Office

Glenn Cunningham
Project Manager

Ann Marquez
Secretary

Shirley Maalouf
Clerk

Project Science

Arden Albee
Project Scientist

Frank Palluconi
Deputy Project Scientist

Finance/Resources

Gail Robinson
Manager

Ming Kwong
Assistant

Public Information

Carolynn Young
Administrator

Procurement Negotiators

Bob Kinkade

Terry Nealy

Pat Thompson

Mission Operations

MARS OBSERVER MISSION OPERATIONS ORGANIZATION

Mission Operations

Sam Dallas
Mission Manager

Sandi Hyland
Secretary

John Beck
Clerk

Technical Support

Steve Barba

Alma Beaudoin

Ruth Fragoso

Shelli Henson

Greg Kazz

Sherry Kazz

Irwin Plitt

Howard Solomon

Tracking and Data Systems*

Provides spacecraft tracking and data acquisition capability via the antennas of NASA's worldwide Deep Space Network.

Marv Traxler
Manager

Multimission Operations Systems Office*

Provides computer hardware and software, facilities, and personnel to send commands to the spacecraft and to receive, process, and store data from the spacecraft for access by engineers and scientists at JPL and various remote locations.

Peter Poon
Manager for Mars Observer

Ground Data System Development Office

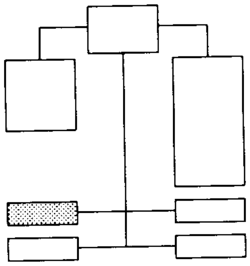
Operations Office

Engineering Office

Science Office

* Not project funded.

MARS OBSERVER GROUND DATA SYSTEM DEVELOPMENT OFFICE ORGANIZATION



Ground Data System Development Office

Fred Hammer
Manager

David Kelly
Deputy

Benjamin Huang
Hardware/Network System Engineer

Ben Jai
Software System Engineer

Testing

Validates the readiness of all project hardware and software systems that support flight operations for the launch, cruise, encounter, and mapping phases of the mission.

Roy Vitti
Lead

Bruce Beaudry

Science Planning and Analysis

Oversees the implementation and operation of the science planning and analysis software installed at science investigator sites.

Tom Thorpe
Lead

Engineering Analysis

Provides hardware and software to the Spacecraft Team for operating the spacecraft and analyzing its performance.

John McLeod
Lead

Data Acquisition and Command

Manages the implementation and maintenance of the Deep Space Network and spacecraft operations computer systems that transfer and monitor data sent to and received from the spacecraft.

Lee Mellinger
Lead

Mick Connally

Gloria Connor

Richard Jackson

Annabel Rivera

Planning and Sequence

Provides software to the Planning and Sequence, Spacecraft, and Science teams for developing commands to be sent to the spacecraft.

Rudy Valdez
Lead

Min-Kun Chung

Martin Lo

Tom Loesch

David Mittman

Robert Von Buelow

Science Support

Provides mission scientists with the hardware, software, and training that enable them to communicate with the Project Data Base at JPL, to command their instruments, and to perform data analysis.

Michelle McCullar
Lead

Wendy Termini

Navigation Analysis

Provides hardware and software to the Navigation Team for orbit determination and trajectory and maneuver analyses.

John Ekelund
Lead

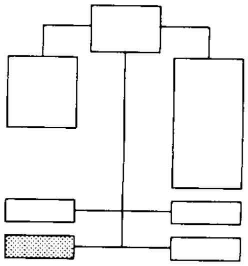
Data Storage and Retrieval

Implements and tests the Mars Observer Project Data Base software used to store and retrieve data; provides support to data base users.

Young Lee
Lead

Al Cherino

Mars Observer Engineering Office Organization



Engineering Office

Joe Beerer
Manager

Dennis Potts
Deputy Manager

Phil Varghese
Uplink Manager

Planning and Sequence Team

Processes all commands destined for the spacecraft.

Bobby Brooks
Chief

Annie Parkhurst
Secretary

Pete Carberry
Brian Chafin
Mark Molander
Judy Morris
Vicky Myers
Patrick O'Bryan
Becky Phillips
Susan Volk
Bruce Waggoner

Mission Planning Team

Develops implementation plans for executing trajectory corrections, Mars orbit insertion, transition to the mapping orbit, science data collection, and orbit adjustments.

Suzanne Dodd
Chief

Sandi Hyland
Secretary

Tammy Miyoshi
Mark Rokey

Navigation Team

Determines the flight path to Mars and keeps the spacecraft on course by developing a plan for firing onboard thrusters; maintains the proper orbit during the mapping phase.

Pat Esposito
Chief

Sandi Hyland
Secretary

Gene Bollman
Al Cangahuala
Stuart Demcak
Cheick Diarra
Jon Giorgini
Eric Graat
Allen Halsell
Dan Johnston
Glenn Kronschnabl
Robert Mase
Duane Roth

Verification Test Laboratory

Tests new and/or modified software and certain commands and sequences to verify their correctness before they are used on the spacecraft; re-creates irregular spacecraft behavior to help determine its cause.

Keyur Patel
Chief

Annie Parkhurst
Secretary

Bob Denise
Harold Felton
George Hansen
Alice Jerahian
Paolo Maiorana
Bob Marak
Victor Mora
Robert Murdock
David Skulsky
Neil Thomas

Spacecraft Team

Responsible for the safe operation of the spacecraft.

Dave Durham
Chief

Scott Davis
Deputy, Analysis

Leigh Torgerson
Deputy, Operations

Pat Sahagian
Secretary

Staff

Maggie Colenzo
Anh Kuhn de Chizelle
John Louie
John McLeod
Jitu Mehta

Systems

Rick Murphy
Lead

Mark Boyles
Ron Cohen
Sandy Krasner
Kevin MacMillan
Nick Medici
Maurine Miller
Bob Oberto
Wayne Sidney
Michael Stracko
Charles Whetsel

Thermal

Bob Miyake
Lead

Bob Hughes
Oliver Liu
Paul McElroy
Naval Raghuwanshi

Propulsion

Ken Walmsley
Lead

Richard Cowley

Attitude and Articulation Control

George Chen
Lead

Leo Barendse
Tyler Brown
Steve Collins
Ed Kan
Raj Rajaram

Information

Carl Steiner,
Lead

Charles Akers
Paul Chen
Joe DeLuca
Martin Gilbert
Paula Pingree
Boris Shenker

Power

Peter Gluck
Lead

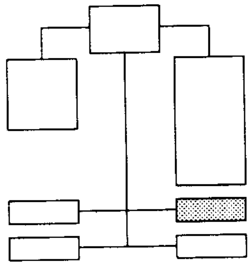
Robert Mueller
Jim Rascon

Telecommunications

Julie Webster
Lead

Wade Mayo
Laura Sakamoto

Mars Observer Operations Office Organization



Operations Office

Mac Grant, *Manager*
Bill Hyland, *Deputy*

Staff

Robyn Gibson
Kathy Ross
Chester Joe
Gerry Stillwell

Mission Control Team*

Coordinates the transmission of commands to the spacecraft and the receipt of telemetry at JPL. Monitors spacecraft health; initiates emergency procedures when spacecraft problems are detected.

Ben Toyoshima, *Chief*
Dan Hurley, *Deputy*

Cindy Alarcon-Rivera
Tommy Chambers
Michael Dean
Bill Heventhal
Carole Hurzeler
Ed Kelly
Cindy Murphy
Cozette Parker
Robert Springfield
Sal Trujillo
Delores Walker

DSN Operations Team*

Prepares and documents the operations plan for Deep Space Network support of the Mars Observer Mission.

Thorl Howe, *Chief*
Mike Kennedy, *Deputy*

Data Administration Team

Administers the Mars Observer Project Data Base, which contains all science and engineering data received from the spacecraft, as well as supplementary information files. Creates files to assist users; prepares data for archiving.

Don Hanks, *Chief*

Operations

Dan Casson
Dana Flora-Adams
Jesse Luna
Paul Lynn
Gary Smith

Archive

Martha DeMore
Ron Green
Jason Hyon
Kristy Marski
Ted Sesplaukis

Operations and Planning Control Team*

Provides the hardware and personnel required to process and store all Mars Observer data.

Dick Hull, *Chief*

Data System Operations

Lloyd Jennings, *Supervisor*
Tom Boreham
Jim Kesterson
Russ Kirkpatrick

Real-Time Operations Control

Curt Eaton, *Manager*

Operations Control

Lawrence Hoadley
Joel Mirelez
Andy Slingo
Andy Stansel

Data Control Operations

Bill Connor
Esker Davis
George Dyke
John Grant
Jim Kipfstuhl
Dorian McClenahan
Ray Williams
Linda Wofford

Data Base Operations

Laura Bridges
Dave Davies
Mike Distaso
Don Hogan
Jim Huynh
Larry Perrine
Sherrie Tuck

Operations Engineer

Carl Pregozen

Simulation Operations

Hugh Brownlee
Jim Kipfstuhl

System Administration

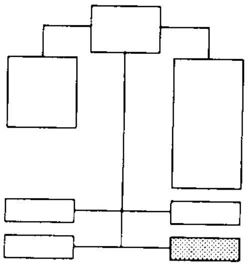
Katherine Alvarez
Robert Birgel
Mike Montgomery
Mike Scharf
Scott Taylor

Tape Library Operations

Edelmira Robles
Diane von Schmausen
John Whisler

* Not project funded.

MARS OBSERVER SCIENCE OFFICE ORGANIZATION



Science Office

Tom Thorpe
Manager

Science Investigation Teams

Interdisciplinary Scientists (IDS)

Radio Science Support Team

Provides operations interface between the Radio Science Investigation Team and the project, the Deep Space Network, and other JPL elements; monitors and maintains the health of the radio science instrument.

Mick Connally
Lead

Sami Asmar

Gina Gonzalez

Patricia Priest

Science Operations Support Team

Acts as liaison to all science teams regarding mission design and operations, instrument commanding and sequence development, and data flow and archiving; communicates project constraints, opportunities, and policies to the science teams.

Thomas E. Thorpe
Chief

Bruce Banerdt (MOLA)

John Callas (GRS)

Mick Connally (RS)

Peter Kahn (IDS)

Adriana Ocampo (TES)

David Rider (PMIRR)

Bill Smythe (Mars '94)

Richard Springer (MOC)

Daniel Winterhalter (MAG/ER)

Science Data Validation Team

Provides system engineering and monitoring of data archive processes and procedures to ensure the quality and continuity of science data delivered to NASA's Planetary Data System.

Peter Kahn
Chief

Paul Andres

James Grimes

Further Explorations

Mars Observer is one of the most ambitious undertakings ever attempted in planetary exploration. It will produce a huge inventory of global data about Mars — the largest archive of planetary information ever obtained.

Mars Observer will give us global maps that will show the composition of the Martian surface material. It will give us thousands of global "weather maps," together with detailed records of atmospheric change, the rise and fall of dust storms, the changing patterns of clouds, and the advance and retreat of the polar ice caps. We will have acquired important clues about the nature of the interior of the planet.

Mars Observer will supply essential information for the further exploration of Mars, preparing the way for many exciting efforts as we anticipate even more complex and challenging endeavors. It will give us a better model of the planet's gravity field. It will delineate the structure of the atmosphere, through which any landing spacecraft must pass, and it will produce high-resolution pictures and accurate surface-elevation maps that can be used to select possible landing sites. Planning is already under way for the next U.S. mission to Mars — NASA's Mars Environmental Survey (MESUR) Pathfinder — which may place a small scientific station on the Martian surface as early as 1997 to obtain data

Opposite page: Exploring Mars' interior and surface evolution, Mars Observer will provide a global portrait of the Red Planet — extending the comparison of Mars with Earth and other planetary neighbors. (P-31317)

about surface weather, soil chemistry, and small-scale landforms. Following MESUR, rovers designed for specific tasks could be sent to collect soil and rock for return samples to Earth, and survey rovers could be used to cover long distances across the planet, collecting and analyzing as they go.

Everything we learn about the geology, atmosphere, weather, polar caps, origin, evolution, and recent history of Mars also contributes to the effort to understand Earth. By comparing Earth and Mars, scientists hope to understand why these planetary neighbors evolved so differently. Comparative planetology gives us a new perspective and may

The Mars Environmental Survey (MESUR) Pathfinder mission will demonstrate a low-cost method of delivering science payloads to the surface of Mars. A later MESUR mission will place a network of scientific stations on Mars. (P-41609)

prove useful in studies of the "greenhouse" warming trend and other factors that profoundly affect life on Earth. Moreover, Mars Observer's objective — to compile a global inventory — has not been done before for any planet. A NASA Mission to Planet Earth is now being developed that would provide a global understanding of our own planet. This program is intended to continue over many years and will involve much that is familiar from Mars Observer — orbital platforms, remote-sensing instruments, long-term operations, and the management of large amounts of data. The technical problems associated with a global inventory of Earth are larger and more complex, but not different in principle, from those of the Mars Observer mission. The experience that we gain with Mars Observer will contribute to the efficient development of a similar mission for Earth.

There is another element in the link between Mars and Earth: literally, a human element. The idea of traveling to another planet is by now a familiar theme. Such an extraterrestrial journey is often seen as a natural outcome of the impulse to explore, with Mars the most likely candidate for a visit. Technologically, we are rapidly approaching the first footfall of human beings on that planet. The scientific findings from the Mars Observer mission will be a substantial part of the legacy available to future mission planners who will make that human presence a reality.

BRAVE NEW WORLD

"At most, terrestrial men fancied there might be other men upon Mars, perhaps inferior to themselves and ready to welcome a missionary enterprise. Yet across the gulf of space, minds that are to our minds as ours are to those of the beasts that perish, intellects vast and cool and unsympathetic, regarded this Earth with envious eyes, and slowly and surely drew their plans against us." With these chilling words, H. G. Wells in his 1897 masterpiece, *The War of the Worlds*, voiced the question that had begun to so occupy the minds of humans in the late 19th and early 20th centuries: Is there intelligent life on Mars? Since those heady days, of course, much of the speculation has been put to rest and we now recognize Mars for what it is — a dry, barren, cold planet that resembles Earth hardly at all. Certainly we entertain few notions of life — intelligent or otherwise — existing anywhere on the Red Planet. Still, not all our flights of fancy are foregone. Mars is a viable destination for humans, and — despite its great distance and harsh environment — may yet be the only world beyond our Moon and in our solar system where we may one day land, walk, and even live.

ACKNOWLEDGMENTS

The manuscript for *Return to the Red Planet: The Mars Observer Mission* was written by Bevan M. French, Mars Observer Program Scientist, NASA Headquarters, and edited by Carolynn Young, Public Information Administrator, Mars Observer Project, JPL. The cover illustration is the work of John Beck of the Mars Observer Flight Team.

Many people associated with the Mars Observer project reviewed and/or verified the text. We thank them for the quality of their contributions and for allowing us to impose our deadlines into their busy schedules.

For their review of the entire manuscript, the following individuals deserve special recognition: Arden Albee, Glenn Cunningham, Sam Dallas, Suzanne Dodd, Frank Palluconi, Gail Robinson, and Tom Thorpe.

For designing and producing *Return to the Red Planet,* we thank the Design Services Group of the Documentation Section at JPL: Marilyn Morgan, Scott Bowdan, David Carlson, Peter Hanegraaf, Adriane Jach, Elsa King, Sanjoy Moorthy, and Audrey Riethle.

Visible on the horizon in this photograph taken by the Viking orbiter are the high-altitude clouds of Mars' thin, carbon dioxide atmosphere. (P-23692) ▶

☆ U.S. GOVERNMENT PRINTING OFFICE: 1993-780-848

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402
S/N 033-000-01129-6