NASA Facts

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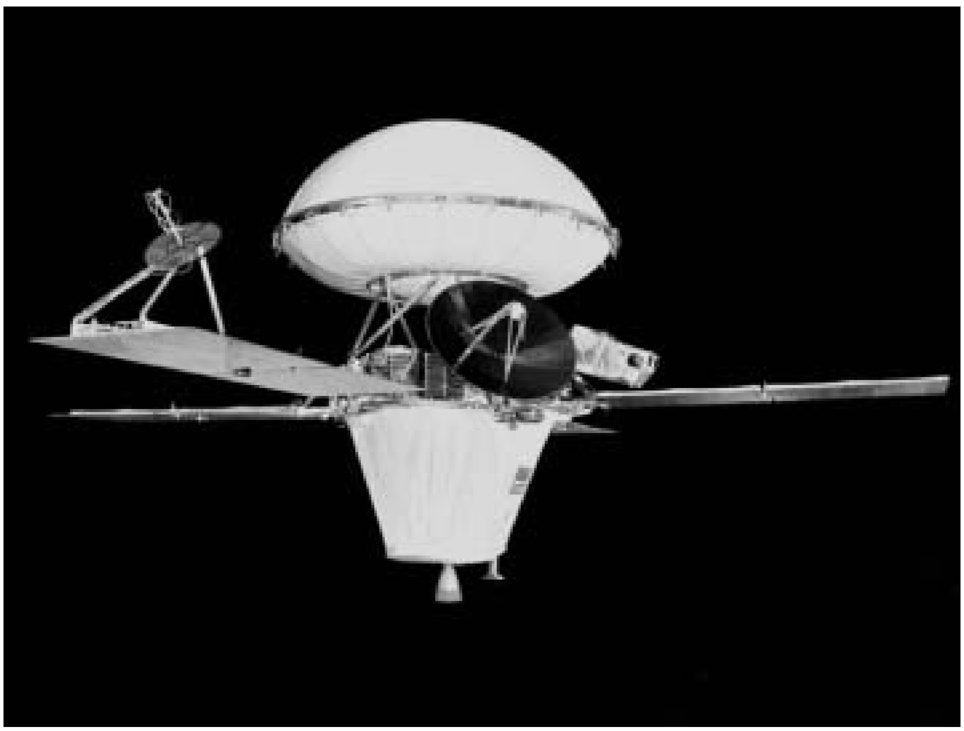
Viking Mission to Mars

NASA's Viking Project was the culmination of a series of missions to explore Mars that had begun in 1964 with Mariner 4, and continued with the Mariner 6 and 7 flybys in 1969, and the Mariner 9 orbital mission in 1971 and 1972. Viking found a place in history when it became the first American mission to land a spacecraft safely on the surface of Mars.



Two identical spacecraft, each consisting of a lander and an orbiter, were built. Each orbiter-lander pair flew together and entered Mars orbit; the landers then separated and descended to the planet's surface.

Mission Design

Both spacecraft were launched from Cape Canaveral, Florida -- Viking 1 on August 20, 1975, and Viking 2 on September 9, 1975. The landers were sterilized before launch to prevent contamination of Mars with organisms from Earth. The spacecraft spent nearly a year cruising to Mars. Viking 1 reached Mars orbit June 19, 1976; Viking 2 began orbiting Mars August 7, 1976.

After studying orbiter photos, the Viking site certification team considered the original landing site proposed for Viking 1 unsafe. The team examined nearby sites, and Viking 1 landed on Mars July 20, 1976, on the western slope of Chryse Planitia (the Plains of Gold) at 22.3 degrees north latitude, 48.0 degrees longitude.

The site certification team also decided the planned landing site for Viking 2 was unsafe after it examined high-resolution photos. Certification of a new landing site took place in time for a Mars landing September 3, 1976, at Utopia Planitia, at 47.7 degrees north latitude and 48.0 degrees longitude.

The Viking mission was planned to continue for 90 days after landing. Each orbiter and lander operated far beyond its design lifetime. Viking Orbiter 1 exceeded four years of active flight operations in Mars orbit.

The Viking project's primary mission ended

November 15, 1976, 11 days before Mars' superior conjunction (its passage behind the Sun). After conjunction, in mid-December 1976, controllers reestablished telemetry and command operations, and began extended-mission operations.

The first spacecraft to cease functioning was Viking Orbiter 2, on July 25, 1978; the spacecraft had used all the gas in its attitude-control system, which kept the craft's solar panels pointed at the Sun to power the orbiter. When the spacecraft drifted off the Sun line, the controllers at JPL sent commands to shut off power to Viking Orbiter 2's transmitter.

Viking Orbiter 1 began to run short of attitude-control gas in 1978, but through careful planning to conserve the remaining supply, engineers found it possible to continue acquiring science data at a reduced level for another two years. The gas supply was finally exhausted and Viking Orbiter 1's electrical power was commanded off on August 7, 1980, after 1,489 orbits of Mars.

The last data from Viking Lander 2 arrived at Earth on April 11, 1980. Lander 1 made its final transmission to Earth Nov. 11, 1982. Controllers at JPL tried unsuccessfully for another six and one-half months to regain contact with Viking Lander 1. The overall mission came to an end May 21, 1983.

Viking Orbiters

The Viking spacecraft consisted of two large orbiters, each weighing 2,325 kilograms (5,125 pounds) with fuel. Each orbiter carried a lander, weighing 576 kilograms (1,270 pounds), and their design was greatly influenced by the size of these landers.

The orbiters were a follow-on design to the Mariner class of planetary spacecraft with specific design changes for the 1976 surface mission. Operational lifetime requirements for the orbiters were 120 days in orbit and 90 days after landing.

The combined weight of the orbiter and lander was one factor that contributed to an 11-month transit time to Mars, instead of the five months for Mariner missions. The longer flight time then dictated an increased design life for the spacecraft, larger solar panels to allow for longer degradation from solar radiation and additional attitude control gas.

The basic structure of the orbiter was an octagon approximately 2.4 meters (8 feet) across. The eight sides of the ring-like structure were 45.7 centimeters (18 inches) high and were alternately 1.4 by 0.6 meters (55 by 22 inches).

Electronic bays were mounted to the faces of the structure and the propulsion module was attached at four points. There were 16 bays, or compartments, three on each of the long sides and one on each short side.

The orbiter was 3.3 meters (10.8 feet) high and 9.7 meters (32 feet) across the extended solar panels. With fuel, the orbiters weighed in excess of 2,300 kilograms (5,000 pounds).

Combined area of the four panels was 15 square meters (161 square feet), and they provided both regulated and unregulated direct current power; unregulated power was provided to the radio transmitter and the lander.

Two 30-amp-hour, nickel-cadmium, rechargeable batteries provided power when the spacecraft was not facing the Sun during launch, correction maneuvers and Mars occultation.

The orbiter was stabilized in flight by locking onto the Sun for pitch and yaw references and onto the star Canopus for roll reference. The attitude control subsystem kept this attitude with nitrogen gas jets located at the solar panel tips. The jets would fire to correct any drift. A cruise Sun sensor and the Canopus sensor provided error signals. Before Sun acquisition four acquisition Sun sensors were used and then turned off.

The attitude control subsystem also operated in an all-inertial mode or in roll-inertial with pitch and yaw control, still using the Sun sensors. During correction maneuvers, the attitude control subsystem aligned the vehicle to a specified attitude in response to commands from the on-board computer. Attitude control during engine burns was provided in roll by the attitude control subsystem and in pitch and yaw by an autopilot that commanded engine gimballing.

If Sun lock was lost the attitude control subsystem automatically realigned the spacecraft. In loss of Canopus lock, the subsystem switched to roll-inertial and waited for commands from the spacecraft computer. The nitrogen gas supply for the subsystem could be augmented by diverting excess helium gas from the propulsion module, if necessary.

Two on-board general purpose computers in the computer command subsystem decoded commands and either ordered the desired function at once or stored the commands in a 4,096-word plated-wire memory. All orbiter events were controlled by the computer command subsystem, including correction maneuvers, engine burns, science sequences and high-gain antenna pointing.

The main orbiter communications system was a two-way, S-band, high-rate radio link providing Earth command, radio tracking and science and engineering data return. This link used either a steerable 1.5-meter (59-inch) dish high-gain antenna or an omni-directional low-gain antenna, both of them on the orbiter. The low-gain antenna was used to send and receive near Earth, and the high-gain antenna was used as the orbiter journeyed farther from Earth.

S-band transmission rates varied from 8.3 or 33.3 bits per second for engineering data to 2,000 to 16,000 bits per second for lander and orbiter science data.

Relay from the lander was achieved through an antenna mounted on the outer edge of a solar panel. It was activated before separation and received from the lander through separation, entry, landing and surface operations. The bit rate during entry and landing was 4,000 bits per second; landed rate was 16,000 bits per second.

Data were stored aboard the orbiter on two eight-track digital tape recorders. Seven tracks were used for picture data and the eighth track for infrared data or relayed lander data. Each recorder could store 640 million bits.

Data collected by the orbiter, including lander data, were converted into digital form by the flight data subsystem and routed to the communications subsystem for transmission or to the tape recorders for storage. This subsystem also provided timing signals for the three orbiter science experiments.

Viking Lander

The lander spacecraft was composed of five basic systems: the lander body, the bioshield cap and base, the aeroshell, the base cover and parachute system and lander subsystems.

The completely outfitted lander measured approximately 3 meters (10 feet) across and was about 2 meters (7 feet) tall. It weighed about 576 kilograms (1, 270 pounds) without fuel.

The lander and all exterior assemblies were painted light gray to reflect solar heat and to protect equipment from abrasion. The paint was made of rubber-based silicone.

The body was a basic platform for science instruments and operational subsystems. It was a hexagon-shaped box with three 109-centimeter (43-inch) sidebeams and three 56-centimeter (22-inch) short sides. It looks like a triangle with blunted corners.

The box was built of aluminum and titanium alloys, and was insulated with spun fiberglass and dacron cloth to protect equipment and to lessen heat loss. The hollow container was 1.5 meters (59 inches) wide and 46 centimeters (18 inches) deep, with cover plates on the top and bottom.

The lander body was supported by three landing legs, 1.3 meters (51 inches) long, attached to the short-side bottom corners of the body. The legs gave the lander a ground clearance of 22 centimeters (8.7 inches).

Each leg had a main strut assembly and an A-frame assembly, to which was attached a circular footpad 30.5 centimeters (12 inches) in diameter. The main struts contained bonded, crushed aluminum honeycomb to reduce the shock of landing.

The two-piece bioshield was a pressurized cocoon that completely sealed the lander from any possibility of biological contamination until Viking left Earth's atmosphere.

The two bioshield halves generally resembled an egg, and the shield's white thermal paint heightened the resemblance. It measured 3.7 meters (12 feet) in diameter and was 1.9 meters (6.4 feet) deep. It was made of coated, woven fiberglass, 0.13 millimeters (0.005 inches) thin, bonded to an aluminum support structure.

The bioshield was vented to prevent over-pressurization and possible rupture of its sterile seal.

The aeroshell was an aerodynamic heat shield made of aluminum alloy in a 140-degree, flat cone shape and stiffened with concentric rings. It fit between the lander and the bioshield base. It was 3.5 meters (11.5 feet) in diameter and its aluminum skin was 0.86 millimeters (0.034 inches) thin.

Bonded to its exterior was a lightweight, cork-like ablative material that burned away to protect the lander from aerodynamic heating at entry temperatures which may have reached 1,500 degrees C.

The interior of the aeroshell contained twelve small reaction control engines, in four clusters of three around the aeroshell's edge, and two spherical titanium tanks that contained 85 kilograms (188 pounds) of hydrazine mono-propellant.

The engines controlled the pitch and yaw to align the lander for entry, help slow the craft during early entry and maintain roll control.

During the long cruise phase, an umbilical connection through the aeroshell provided power from the orbiter to the lander; housekeeping data also flowed through this connection.

The aeroshell also contained two science instruments -- the upper atmosphere mass spectrometer and the retarding potential analyzer -- plus pressure and temperature sensors.

The base cover fit between the bioshield cap and the lander. It was made of aluminum and fiberglass; the fiberglass allowed transmission of telemetry data to the orbiter during entry. It covered the parachute and its ejection mortar, and protected the lander's top during part of the entry phase.

The parachute was made of lightweight dacron polyester 16 meters (53 feet) in diameter. It weighed 50 kilograms (110 pounds).

The parachute was packed inside a mortar 38 centimeters (15 inches) in diameter and mounted into the base cover. The mortar was fired to eject the parachute at about 139 kilometers per hour (75 miles per hour). The chute had an extra-long suspension line that trailed the capsule by about 30 meters (100 feet).

The lander subsystems were divided into six major categories: descent engines, communications equipment, power sources, landing radars, data storage and guidance and control.

Three terminal descent engines provided attitude control and reduced the lander's velocity after parachute separation. The 2,600-newton (600-pound) throttleable engines were located 120 degrees apart on the lander's sidebeams. They burned hydrazine mono-propellant.

The engines used an advanced exhaust design that wouldn't alter the landing site environment. An unusual grouping of 18 small nozzles on each engine would spread engine exhaust over a wide angle that wouldn't alter the surface or unduly disturb the chemical and biological experiments.

Two spherical titanium tanks, attached to opposite sides of the lander body beneath the RTG wind covers, fed the descent engines from an 85-kilogram (188 pound) hydrazine propellant supply.

Four small reaction control engines used hydrazine mono-propellant thrusters to control lander roll attitude during terminal descent. The engines were mounted in pairs on the terminal descent engines' propellant tanks and were identical to those used on the aeroshell.

The lander was equipped to transmit information directly to Earth with an S-band communications system, or through the orbiter with an ultra-high frequency (UHF) relay system. The lander also received Earth commands through the S-band system.

Two S-band receivers provided total redundancy in both command receiving and data transmission. One receiver used the high-gain antenna, a 76-centimeter (30-inch) diameter parabolic reflector dish that could be pointed to Earth by computer control. The second receiver used a fixed low-gain antenna to receive Earth commands.

The UHF relay system transmitted data to the orbiter with a radio transmitter that used a fixed antenna. The UHF system operated during entry and during the first three days of landed operations. After that it was operated only during specific periods.

The radar altimeter measured the lander's altitude during the early entry phase, alerting the lander computer to execute the proper entry commands. The radar was a solid-state pulse radar with two specially designed antennas: one was mounted beneath the lander and one was mounted through the aeroshell. Altitude data were received from 1,370 kilometers down to 30.5 meters (740 miles to 100 feet).

The aeroshell antenna provided high-altitude data for entry science, vehicle control and parachute deployment. The lander antenna was switched into operation at aeroshell separation and provided altitude data for guidance and control, and for terminal descent engine ignition.

The terminal descent landing radar measured the horizontal velocity of the lander during the final landing phase. It was located directly beneath the lander and was turned on at about 12 kilometers (4,000 feet) above the surface. It consisted of four continuous-wave Doppler radar beams that could measure velocity to an accuracy of plus or minus one meter per second.

Both radars were essential for mission success, so the terminal descent landing radar could work with any three of its four beams, and identical sets of radar altimeter electronics could be switched to either of the radar antennas.

The "brain" of the lander was its guidance control and sequencing computer. That computer commanded everything the lander did through software (computer programs) stored in advance or relayed by Earth controllers.

The computer was one of the greatest technical challenges of Viking. It consisted of two general-purpose computer channels with plated-wire memories, each with an 18,000-word storage capacity. One channel would be operational while the other was in reserve.

Among other programs, the computer had instructions stored in its memory that could control the lander's first 22 days on Mars without any contact from Earth. These instructions would be updated and modified by Earth commands once communications had been established.

Basic power for the lander was provided by two SNAP 19-style, 35-watt radioisotope thermoelectric generators (RTGs) developed by the then U.S. Energy Research and Development Administration. They were located atop the lander and were connected in series to double their voltage and reduce power loss.

The SNAP 19 Viking generator was 147 centimeters (23 inches) across the housing fin tips, 96 centimeters (15 inches) in length and weighed 15.3 kilograms (34 pounds).

The first isotopic space generator was put into service in June 1961, on a Navy navigational satellite. Advances in SNAP systems were made with the development and flight of SNAP 19 aboard Nimbus III, launched in April 1969. This use of SNAP 19 represented a major milestone in the development of long-lived, highly reliable isotope power systems for space use by NASA. The SNAP 27 generator was developed to power five science stations left on the Moon by the Apollo 12, 14, 15, 16 and 17 astronauts. The continuing operation of these generators provided new dimensions of data about the Moon and the universe. Four SNAP 19 nuclear generators later provided the electrical power for each of two NASA pioneering Jupiter flyby spacecraft known as Pioneers 10 and 11.

The generators provided a long-lived source of electricity and heat on Mars, where sunlight is half as strong as on Earth, and is non-existent during the Martian night, when temperatures can drop as low as -120 C (-184 F).

The generators used thermoelectric elements to convert heat from decaying plutonium-236 into 70 watts of electrical power.

Waste or unconverted heat was conveyed by thermal switches to the lander's interior instrument compartment, when required. Covers over the RTGs prevented excess heat dissipation into the environment.

Four nickel-cadmium, rechargeable batteries helped supply lander power requirements in peak activity periods. The batteries, mounted in pairs inside the lander, were charged by the RTGs with power available when other lander power requirements were less than RTG output.

This equipment collected and controlled the flow of lander scientific and engineering data. It consisted of a data acquisition and processing unit, a data storage memory and a tape recorder.

The data acquisition and processing unit collected the science and engineering information and routed it to one of three places: to Earth through the S-band high-gain antenna, to the data storage memory or to the tape recorder.

Information was stored in the data storage memory for short periods. Several times a day the memory would transfer data to the tape recorder or back to the data acquisition and processing unit for further transmission. The memory had a storage capacity of 8,200 words.

Data were stored on the tape recorder for long periods. The recorder could transmit at high speed back through the data acquisition and processing unit, and the UHF link to an orbiter passing overhead. The recorder could store as many as 40 million bits of information and it could record at two speeds and play back at five.

Science Experiments

With a single exception -- the seismic instruments -- the science instruments acquired more data than expected. The seismometer on Viking Lander 1 would not work after landing, and the seismometer on Viking Lander 2 detected only one event that may have been seismic. Nevertheless, it provided data on wind velocity at the landing site to supplement information from the meteorology experiment, and showed that Mars has very low seismic background.

The three biology experiments discovered unexpected and enigmatic chemical activity in the Martian soil, but provided no clear evidence for the presence of living microorganisms in soil near the landing sites. According to mission biologists, Mars is self-sterilizing. They believe the combination of solar ultraviolet radiation that saturates the surface, the extreme dryness of the soil and the oxidizing nature of the soil chemistry prevent the formation of living organisms in the Martian soil. The question of life on Mars at some time in the distant past remains open.

The landers' gas chromatograph/mass spectrometer instruments found no sign of organic chemistry at either landing site, but they did provide a precise and definitive analysis of the composition of the Martian atmosphere and found previously undetected trace elements. The X-ray fluorescence spectrometers measured elemental composition of the Martian soil.

Viking measured physical and magnetic properties of the soil. As the landers descended toward the surface they also measured composition and physical properties of the Martian upper atmosphere.

The two landers continuously monitored weather at the landing sites. Weather in the Martian midsummer was repetitious, but in other seasons it became variable and more interesting. Cyclic variations appeared in weather patterns (probably the passage of alternating cyclones and anticyclones). Atmospheric temperatures at the southern landing site (Viking Lander 1) were as high as -14 C (7 F) at midday, and the predawn summer temperature was -77 C (-107 F). In contrast, the diurnal temperatures at the northern landing site (Viking Lander 2) during midwinter dust storms varied as little as 4 degrees C (7 degrees F) on some days. The lowest predawn temperature was -120 C (-184 F), about the frost point of carbon dioxide. A thin layer of water frost covered the ground around Viking Lander 2 each winter.

Barometric pressure varies at each landing site on a semiannual basis, because carbon dioxide, the major constituent of the atmosphere, freezes out to form an immense polar cap, alternately at each pole. The carbon dioxide forms a great cover of snow and then evaporates again with the coming of spring in each hemisphere. When the southern cap was largest, the mean daily pressure observed by Viking Lander 1 was as low as 6.8 millibars; at other times of the year it was as high as 9.0 millibars. The pressures at the Viking Lander 2 site were 7.3 and 10.8 millibars. (For comparison, the surface pressure on Earth at sea level is about 1,000 millibars.)

Martian winds generally blow more slowly than expected. Scientists had expected them to reach speeds of several hundred miles an hour from observing global dust storms, but neither lander recorded gusts over 120 kilometers (74 miles) an hour, and average velocities were considerably lower. Nevertheless, the orbiters observed more than a dozen small dust storms. During the first southern summer, two global dust storms occurred, about four Earth months apart. Both storms obscured the Sun at the landing sites for a time and hid most of the planet's surface from the orbiters' cameras. The strong winds that caused the storms blew in the southern hemisphere.

Photographs from the landers and orbiters surpassed expectations in quality and quantity. The total exceeded 4,500 from the landers and 52,000 from the orbiters. The landers provided the first close-up look at the surface, monitored variations in atmospheric opacity over several Martian years, and determined the mean size of the atmospheric aerosols. The orbiter cameras observed new and often puzzling terrain and provided clearer detail on known features, including some color and stereo observations. Viking's orbiters mapped 97 percent of the Martian surface.

The infrared thermal mappers and the atmospheric water detectors on the orbiters acquired data almost daily, observing the planet at low and high resolution. The massive quantity of data from the two instruments will require considerable time for analysis and understanding of the global meteorology of Mars. Viking also definitively determined that the residual north polar ice cap (that survives the northern summer) is water ice, rather than frozen carbon dioxide (dry ice) as once believed.

Analysis of radio signals from the landers and the orbiters -- including Doppler, ranging and occultation data, and the signal strength of the lander-to-orbiter relay link -- provided a variety of valuable information.

Other Significant Discoveries

Other significant discoveries of the Viking mission included:

❑ The Martian surface is a type of iron-rich clay that contains a highly oxidizing substance that releases oxygen when it is wetted.

❑ The surface contains no organic molecules that were detectable at the parts-per-billion level -- less, in fact, than soil samples returned from the Moon by Apollo astronauts.

❑ Nitrogen, never before detected, is a significant component of the Martian atmosphere, and enrichment of the heavier isotopes of nitrogen and argon relative to the lighter isotopes implies that atmospheric density was much greater than in the distant past.

❑ Changes in the Martian surface occur extremely slowly, at least at the Viking landing sites. Only a few small changes took place during the mission lifetime.

❑ The greatest concentration of water vapor in the atmosphere is near the edge of the north polar cap in midsummer. From summer to fall, peak concentration moves toward the equator, with a 30 percent decrease in peak abundance. In southern summer, the planet is dry, probably also an effect of the dust storms.

❑ The density of both of Mars' satellites is low -- about two grams per cubic centimeter -- implying that they originated as asteroids captured by Mars' gravity. The surface of Phobos is marked with two families of parallel striations, probably fractures caused by a large impact that may nearly have broken Phobos apart.

❑ Measurements of the round-trip time for radio signals between Earth and the Viking spacecraft, made while Mars was beyond the Sun (near the solar conjunctions), have determined delay of the signals caused by the Sun's gravitational field. The result confirms Albert Einstein's prediction to an estimated accuracy of 0.1 percent -- 20 times greater than any other test.

❑ Atmospheric pressure varies by 30 percent during the Martian year because carbon dioxide condenses and sublimes at the polar caps.

❑ The permanent north cap is water ice; the southern cap probably retains some carbon dioxide ice through the summer.

❑ Water vapor is relatively abundant only in the far north during the summer, but subsurface water (permafrost) covers much if not all of the planet.

❑ Northern and southern hemispheres are drastically different climatically, because of the global dust storms that originate in the south in summer.

The Viking Team

NASA's Langley Research Center in Hampton, VA, had management responsibility for the Viking project from its inception in 1968 until April 1, 1978, when the Jet Propulsion Laboratory, Pasadena, CA, assumed the task. Langley and JPL managed the mission for NASA's Office of Space Science, Washington, DC. JPL designed and built the Viking orbiters, managed tracking and data acquisition through the Deep Space Network and managed Viking's mission control and computing center. The former Martin Marietta Aerospace in Denver, CO, designed and built the Viking landers. NASA's Lewis Research Center in Cleveland, OH, had responsibility for the Titan-Centaur launch vehicles.

At NASA Langley, James S. Martin Jr. was

Viking project manager; Dr. Gerald A. Soffen was Viking project scientist. At NASA Headquarters, Walter Jakobowski was Viking program manager; Dr. Loyal G. Goff was Viking program scientist.

Leaders of the scinece teams included Dr. Michael H. Carr of the U.S. Geological Survey, Menlo Park, CA, team leader of the orbiter imaging investigation; Dr. Crofton B. "Barney" Farmer of JPL, team leader of the water vapor mapping investigation; Dr. Hugh H. Kieffer of the University of California, Los Angeles, team leader of the thermal mapping investigation; Dr. Alfred O.C. Nier of the University of Minnesota, Minneapolis, who led the entry science investigation; and Dr. Thomas A. "Tim" Mutch of Brown University, Providence, RI, team leader of the lander imaging investigation.

Investigators on the Viking biology experiments were Dr. Harold P. Klein of NASA Ames Research Center, Mountain View, CA, who led the Viking biology investigation; Dr. Klaus Biemann of the Massachusetts Institute of Technology, who led the molecular analysis investigation; and Dr. Priestley Toulmin III, team leader of the inorganic chemistry investigation.

The meteorology investigation was led by Dr. Seymour L. Hess of Florida State University; the seismology investigation was led by Dr. Don L. Anderson of the California Institute of Technology, Pasadena, CA; Dr. Richard W. Shorthill of the University of Utah led the physical properties investigation; and Dr. Robert B. Hargraves of Princeton University was principal investigator on the magnetic properties team. Radio science investigations were led by Dr. William H. Michael Jr. of NASA's Langley Research Center, Hampton, VA.

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