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# VIKING ENCOUNTER PRESS KIT

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# VIKINGS CONVERGE ON MARS

The Vikings are converging on Mars.

After almost a year-long chase through interplanetary space to overtake the planet, the first of two Viking spacecraft is closing fast on Mars, aiming for orbit insertion on June 19.

If all goes well, the first Viking's Lander will touch down on Mars on July 4, the 200th anniversary of the United States.

Seven weeks later Viking 2 will reach Mars. It will begin orbiting the planet Aug. 7, and its Lander will touch down about Sept. 4.

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The instrument-packed spacecraft, two Orbiters and two Landers, will photograph Mars from orbit and on the surface, and conduct a detailed scientific examination of the planet, including a search for life.

Each Orbiter carries three investigations, each Lander contains eight more, and one investigation uses equipment aboard both spacecraft.

The Orbiter's investigations will begin several days before Viking 1 enters Mars orbit. Two high-resolution television cameras will take photographs of the whole disc of Mars, one of its moons and of star fields near the planet. At the same time, two infrared science instruments will begin scanning the planet to map its surface temperatures and look for water vapor concentrations in its atmosphere.

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During the two weeks between orbit insertion and separation of the Lander from the Orbiter, the Orbiter's instruments will carefully study the planned landing sites.

Selected several years ago, these sites will be further verified as safe places for the Lander. Huge radar antennas on Earth will supplement data gathered by the Orbiter. Located at Goldstone, Calif., and Arecibo, Puerto Rico, the antennas will bounce radar echoes from the prime and backup landing sites from May 11 to June 15.

Prime target for Lander 1 is in the Chryse "Land of Gold" region, at the northeast end of a huge canyon first discovered by the Mars-orbiting spacecraft, Mariner 9. The site is 19.5 degrees north and 34 degrees west. Lander 1's backup site is Tritonis Lacus, at 20.5 degrees north and 252 degrees west.

Viking 2's lander also has primary and backup sites. The primary site is Cydonia, in the Mare Acidalium region, at the edge of the southernmost reaches of the north polar hood. Cydonia is 44.3 degrees north and 10 degrees west. The backup site is called Alba, lying 44.2 degrees north and 110 degrees west.

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Another pair of sites has been selected by Viking scientists in the event that Viking 2 primary and backup sites are deemed unsuitable for landing.

No landing site is known to be completely free from hazards. The task of the Viking site certification team is to compare all possible data and try to minimize hazards to the Landers.

Once the Viking 1 landing site has been certified, the Orbiter and Lander will be ready for separation, scheduled for about three hours before landing.

The Lander must survive the searing heat of entry through the planet's atmosphere, land gently on the surface and conduct an intricate series of scientific investigations.

As the Lander enters the Martian atmosphere, several instruments and sensors will measure the atmosphere's structure and chemical composition. A mass spectrometer, a retarding potential analyzer and several sensors will measure atmospheric composition, temperature, pressure and density in the upper atmosphere. Continued measurements will be made in the lower atmosphere by other sensors on the Lander.

One important aspect of the entry investigations is learning as much as possible about the presence of argon in the atmosphere. One Soviet Mars mission reported the presence of as much as 30 per cent argon in the Mars atmosphere. Argon, an inert gas, could have considerable effect on some Viking experiments, especially the gas chromatograph mass spectrometer (GCMS).

Minutes after the Lander touches down on Mars, the taking of the first two surface photographs will begin. These will be telemetered to Earth through the Orbiter and should reach monitors at the mission control center by about midnight (EDT) on the July 4 landing date.

Several other Lander science instruments will also begin operation as soon as the craft touches down and, in the following days, other instruments will study the planet's biology, molecular structure, inorganic chemistry and physical and magnetic properties.

The Lander's surface sampler, attached to a furlable boom, will dig up soil samples for incubation and analysis inside the biology instrument's three metabolism and growth experiment chambers, in the GCMS instrument and in an X-ray fluorescence spectrometer (XRFS).

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These three investigations are particularly important for understanding the biological makeup of Mars, and they will provide knowledge to other scientists on the chemistry and planetology of Mars.

The meteorology instrument, located on a folding boom attached to the Lander, will periodically measure temperature, pressure, wind speed and direction during the mission.

A three-axis seismometer will measure any seismic activity that takes place during the mission, which should establish whether or not Mars is a very active planet.

The physical and magnetic properties of Mars will be studied with several small instruments and pieces of equipment located on the Lander.

Radio science investigations will make use of Orbiter and Lander communications equipment to measure Mars' gravitational field, determine its axis of rotation, measure surface properties, conduct certain relativity experiments and pinpoint the locations of both Landers on Mars. A special radio link, the X-band, will be used to study charged ion and electron particles.

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Viking mission controllers will use a new term to signify time on Mars: Sol, which is the Viking Project word for a Mars day. The special designation is necessary to keep track of the difference between Earth and Mars days. Because of its rotation period, a Mars day is 24.6 Earth hours long (24 hours, 36 minutes).

The difference between Earth and Mars days also causes periodic changes to the prime shift of mission controllers. In order to be on duty at about the same time each Mars day (Sol), controllers must move their work hours.

From an 8 a.m. to 4:30 p.m. schedule at the beginning of the planetary mission, controllers will shift, July 11, to a 4 p.m. to midnight shift. On July 24 the prime shift changes to midnight to 8 a.m., and Aug. 6 sees a return to the regular day shift. This cycle will periodically repeat throughout the mission.

Another time problem is caused by the extremely long transmission time required for telemetry of commands from Earth and data from Mars. One-way transmission, at the speed of light, takes from 18 to 21 minutes while the Vikings are operating on Mars.

Mission controllers who send a command to the Lander, for example, won't know whether the command was received and executed for at least 36 minutes during the first days of the planetary mission.

And confusion can occur if a particular event time isn't clearly designated. Viking 1's landing, for example, is scheduled for 9:41 p.m. EDT, but mission controllers won't have confirmation of landing until at least 9:59 p.m., which is designated as Earth-Received Time (ERT).

Viking is under the overall management of the Office of Space Science, NASA Headquarters, Washington, D.C. The Viking Project is managed by NASA's Langley Research Center, Hampton, Va. The Landers were built by Martin Marietta Aerospace of Denver, Colo., which also has integration responsibility for Viking. The Orbiters were built by NASA's Jet Propulsion Laboratory (JPL) in Pasadena, Calif.

Nerve center of Viking operations is the Viking Mission Control and Computing Center (VMCCC), located at JPL. A 750-person flight team of engineers, scientists and technicians maintain constant control of the four Viking spacecraft throughout the planetary phase of the mission.

(END OF GENERAL RELEASE. BACKGROUND INFORMATION FOLLOWS.)

## THE SCIENTIFIC GOALS OF THE VIKING MISSION

Mars has excited man's imagination more than any other celestial body except the Sun and the Moon. Its unusual reddish color, which the ancients associated with fire and blood, gave rise to its being named for the Roman God of War.

The invention of the astronomical telescope by Galileo in 1608 opened a new era in the observation of the planet. Instead of appearing merely as a tiny disc, Mars' surface features could be resolved.

Christian Huygens made the first sketch in 1659 of the dark region, Syrtis Major ("giant quicksands"). Able to observe a distinguishable feature, Huygens could show that Mars rotated on a north-south axis like Earth, producing a day that was about half an hour longer than Earth's.

In 1666, the Italian astronomer Giovanni D. Cassini observed and sketched the Martian polar caps. Observers in the early 1700's noted changes in the surface appearance in a matter of hours, probably caused by dust storms, now known to rage periodically. In 1783, William Herschel observed that Mars' axis of rotation is inclined to its orbital plane at about the same extent as Earth's, revealing that long-term changes were often associated with seasons that would result from such inclination.

In the 17th and 18th centuries, it was commonly accepted that Mars and the other planets were inhabited, but the real excitement was created by Giovanni Schiaparelli and Percival Lowell between 1877 and 1920. As a result of extensive observations, beginning with the favorable apparition of 1877, Schiaparelli constructed detailed maps with many features, including a number of dark, almost straight lines, some of them hundreds of kilometers long. He referred to them as "canali" or channels. Through mistranslation, they became "canals" and the idea of civilized societies was propagated.

Lowell's firm opinion that the canals were not natural features but the work of "intelligent creatures, alike to us in spirit but not in form" contributed to the colorful literature. To pursue his interest in the canals and Mars, he founded the Lowell Observatory near Flagstaff, Ariz., in 1894 and his writings about the canals and possible life on Mars created great public excitement near the turn of the 20th Century.

Speculation about intelligent life on Mars continued through the first part of the century, with no possibility of an unequivocal resolution, but a gradual tendency developed among scientists to be very skeptical of the likelihood.

The skepticism was reinforced by the results of Mariner flyby missions, one in 1965 and two in 1969. The limited coverage of only about 10 per cent of the Martian surface by flyby photography indicated that Mars was a lunar-like planet with a uniformly cratered surface.

In 1971-72 the Mariner 9 orbiter revealed a completely new and different face of Mars. Whereas the flyby coverage had seen only a single geologic regime in the cratered highlands of the southern hemisphere, Mariner 9 revealed gigantic volcanoes, a valley that extends a fifth of the way around the planet's circumference, and possible evidence of flowing liquid water sometime in the past. Also revealed were layered terrain in the polar regions and the effects of dust moved by winds of several hundred kilometers an hour.

In short, Mariner 9's 7,000 detailed pictures revealed a dynamic, evolving Mars completely different from the lunar-like planet suggested by the flyby evidence. That successful Orbiter mission showed a fascinating subject for scientific study and also provided the maps from which the Viking sites have been selected.

The scientific goal of the Viking missions is to "increase our knowledge of the planet Mars with special emphasis on the search for evidence of extra-terrestrial life." The scientific questions deal with the atmosphere, the surface, the planetary body and the question of bio-organic evolution. This goal ultimately means understanding the history of the planet.

The physical and chemical composition of the atmosphere and its dynamics are of considerable interest, not only because they will extend our understanding of planetary atmospheric sciences, but because of the intense focus of interest in contemporary terrestrial atmospheric problems.

Scientists want to understand how to model our own atmosphere more accurately and they want to know how the solar wind interacts with the upper atmosphere; to do this more must be known about atmospheric chemistry, the composition of neutral gases and charged particles.

Researchers want to reconstruct the physics of the atmosphere and determine its density profile. They want to measure the atmosphere down to the surface and follow its changes, daily and seasonally. From these data may come clues to the atmospheric processes that have been taking place and determining the planet's character.

Of special interest is the question of water on Mars. Scientific literature is sparse in data and rich in speculation. It is known that there is water in the Mars atmosphere, but the total pressure of the atmosphere (about 1 per cent of Earth's) will not sustain any large bodies of liquid water. Nevertheless, the presence of braided channels suggests to many geologists that they are the result of previous periods of flowing water. This idea of episodic water suggests a very dynamic planet.

The geology of Mars has attracted great interest among planetologists because of the wide variety of features seen in the Mariner photos.

Volcanologists are intrigued by the high concentration of volcanoes near the Tharsis ridge. Scientists who study erosion are fascinated with the great valley (Valles Marineris) that is 100 kilometers (62 miles) wide, 3,000 km (1,800 mi.) long and 6 km (4 mi.) deep. Some geologists have focused on the polar region, which appears to be stratified terrain. The pole resembles a rosette; it has been suggested that this is evidence of precession (wobbling) of the poles. One important question that Viking is not likely to answer, due to payload limitation, is the age of the planet.

One mystery that Viking may solve is the fate of nitrogen. So far there has been no report of nitrogen on Mars. Has it been lost by outgassing? Is it locked up in the surface as nitrates or in some organic form? Chemists and biologists both look upon nitrogen, among the most cosmically abundant of the elements, as vitally important because of the clues it provides to the evolution of the atmosphere and of the planet itself.

There is the final question of life on Mars. This may be one of the most important scientific questions of our time. It is also one of the most difficult to answer.

A negative answer does not prove there is no life on Mars. The landing site may have been in the wrong place, during the wrong season, or we may have conducted the wrong experiments. Many scientists still think there is a low probability of life on Mars.

How can this extensive effort to perform the search be justified? First, it must be aknowledged that there is no evidence at present, pro or con, of the existence of life on Mars. And what experimenters seek is evidence.

Dr. N. H. Horowitz, Professor of Biology, California Institute of Technology, stated: "The discovery of life on another planet would be one of the momentous events of human history."

Finally, a knowledge of the organic character of the planet is regarded as of utmost importance. Whether life has begun or not, it is critical to our concept of chemical evolution to determine the path of carbon chemistry. Mars offers the first opportunity to gain another perspective in the cosmic history of planetary chemistry.

The scientific investigations of Viking were intentionally selected to complement one another. The Orbiter science instruments are used to help select landing sites for the Lander investigations. The Lander cameras help select soil samples for the chemical and biological analyses. The meteorology data are used to determine periods of quiet for the seismology experiment. The atmospheric data are used in determining the chemistry, which in turn is used in understanding the biological result.

But Viking's greatest asset is its flexibility. The scientist-engineer teams will be interacting, hour by hour, during the months that Viking will be returning data. Every day will bring new discoveries and fresh ideas for improving the mission to extract the maximum benefit from this effort.

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## VIKING SCIENCE INVESTIGATIONS

Three science investigations use instruments located on the Orbiter: orbiter imaging, atmospheric water vapor mapping and thermal mapping. One investigation, Entry Science, located on the Lander, is conducted while the Lander is descending to the surface of Mars.

Eight other investigations are conducted from the Lander: lander imaging, biology, molecular analysis, inorganic chemical analysis, meteorology, seismology, physical properties and magnetic properties. One investigation, radio science, has no specific instrument, but uses the Viking telecommunications system to obtain data and do certain experiments.

### Orbiter Imaging

The orbiter imaging investigation has four objectives:

- Add to the geologic knowledge of Mars by providing high-resolution photographic coverage of scientifically interesting areas of the Martian surface.

- Add to the knowledge of dynamic processes on Mars by observing the planet during seasons never before seen.

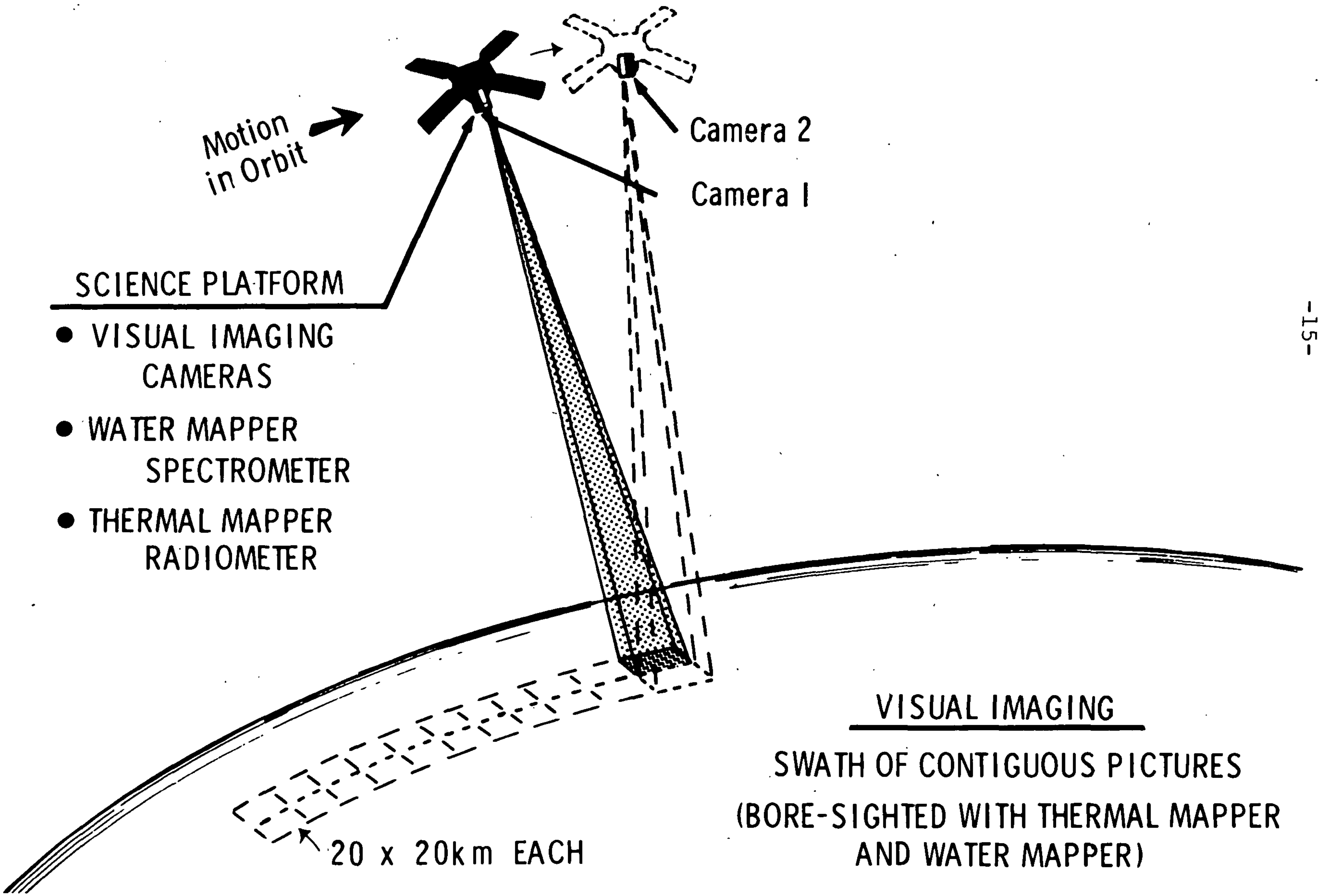
- Provide high-resolution imaging data of the Viking landing sites before landing so site safety and scientific desirability can be assessed.

- Monitor the region around each landing site after landing so the dynamic environment in which Lander experiments are done is better understood.

The Visual Imaging Subsystem (VIS) consists of two identical cameras, mounted side by side on the Orbiter's scan platform.

The cameras will be used in different ways as the mission progresses. As Viking 1 approaches Mars, the planet will be photographed in three colors. The planet's atmosphere is expected to be clear, in contrast to the 1971 Mariner 9's approach to Mars, allowing the first useful approach pictures since 1969.

# ORBITER IMAGERY COVERAGE



Between Mars orbit insertion and landing the cameras will be used almost exclusively for examining the landing site. The intent is to characterize in detail terrain at the site and make estimates of slopes at the Lander scale; examine the region of the site for both long and short-term changes that might indicate wind action; and monitor any atmospheric activity.

For most of the period after landing, the Orbiter will be a communications relay link for the Lander and its orbit will remain synchronized with the Lander; i.e., it will pass over the Lander at the same time each day. Areas visible from the synchronous orbit will be systematically photographed during this time. Areas covered will include the large channel system upstream from the primary landing site, chaotic terrain from which many of the channels seem to originate, and areas of greatest canyon development.

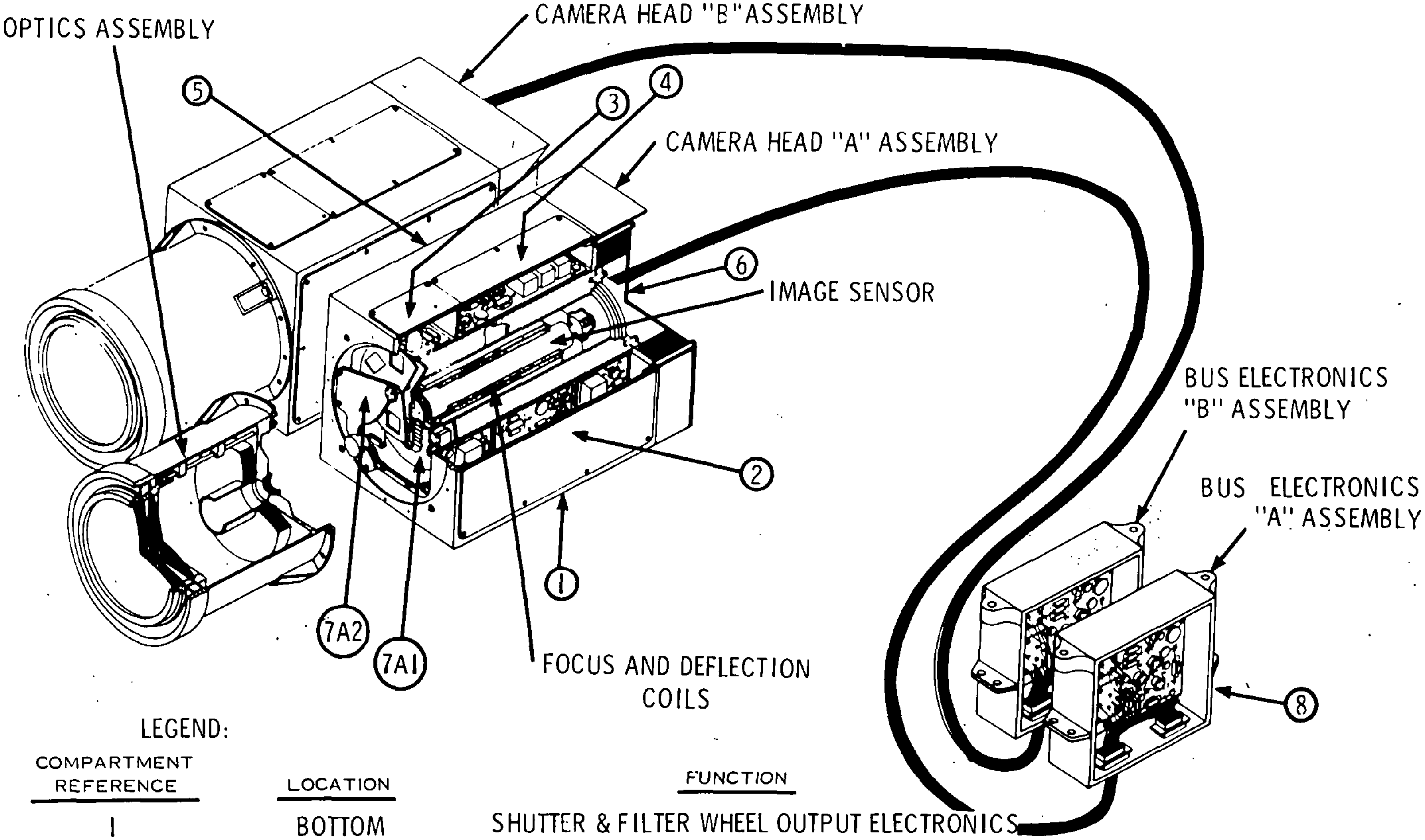
The detailed observations are expected to lead to a better understanding of the origin of these features, and aid in interpreting Lander data. At the same time, activity will be monitored over all the planet that is visible from apoapsis. Any areas of unusual activity will also be examined in detail. The orbital period will be changed for short periods of time to allow the rest of the planet to be seen. During these periods, observations will be made of large volcanoes, channels and other features.

Viking 2 will follow a similar plan, except for one major difference: shortly after Lander 2 lands, the orbital inclination of Orbiter 2 will be increased to perform polar observations. After the inclination change, a period of systematic mapping of the north polar region is anticipated, similar to that undertaken in the canyon lands by Orbiter 1.

The succession of deposits in the polar regions, their thicknesses and relative ages, will be determined with these observations. This portion of the mission is particularly important because of its potential for unraveling past climatic changes and assessing the volatile inventory (primarily carbon dioxide and water) of the planet.

Each visual imaging subsystem consists of a telescope, a camera head and supporting electronics. The telescope focuses an image of the scene being viewed on the faceplate of a vidicon within the camera head. When a shutter between telescope and vidicon is activated, an imprint of the scene is left on the vidicon faceplate as a variable electrostatic charge. The faceplate is then scanned with an electronic beam and variations in charge are read in parallel onto a seven-track tape recorder.

# ORBITER VISUAL IMAGING SYSTEM (VIS) DIAGRAM



LEGEND:

| COMPARTMENT REFERENCE | LOCATION | FUNCTION |
|---|---|---|
| 1 | BOTTOM | SHUTTER & FILTER WHEEL OUTPUT ELECTRONICS |
| 2 | LEFT SIDE | DIGITAL SEQUENCING LOGIC |
| 3 | TOP FRONT | VIDEO AMPLIFIER CHAIN |
| 4 | TOP REAR | ANALOG TO DIGITAL CONVERTER |
| 5 | RIGHT SIDE | VIDICON ANALOG CONTROLS |
|  | REAR | VIDICON POWER SUPPLY |
| 6 | FRONT (A1) | SHUTTER ASSEMBLY |
| 7 | FRONT (A2) | FILTER WHEEL ASSEMBLY |
| 8 | BUS ELECTRONICS | LOW VOLTAGE POWER SUPPLY |

Data are later relayed to Earth one track at a time. A picture is assembled on Earth as an array of pixels (picture elements), each pixel representing the charge at a point on the faceplate (i.e., the brightness at a point in the image). As data are read back, the pixel array is slowly assembled, complete only when all seven tracks have been read. The image is then displayed on a video screen and film copies are made.

The telescope has an all-spherical, catadioptric cassegrain lens with a 475-millimeter (18.7-inch) focal length. The sensor is a 38 mm (1.5-in.) selenium vidicon. A mechanical focal plane tape allows exposure times from 0.003 to 2.7 seconds. Between the vidicon and telescope is a filter wheel that provides color images. Each frame has 8.7 million bits (binary digits).

The cameras are mounted on the Orbiter with a slight offset and the timing of each shutter is offset by one-half-frame time so the cameras view slightly different fields and shutter alternately. The combined effect is to produce a swath of adjacent pictures as the motion of the spacecraft moves the fields of view across the surface of Mars. The resolution at the lowest part in the orbit (1,500 km or 810 mi.) is 37.5 m (124 ft.) per pixel. This would allow an object the size of a football field to be resolved.

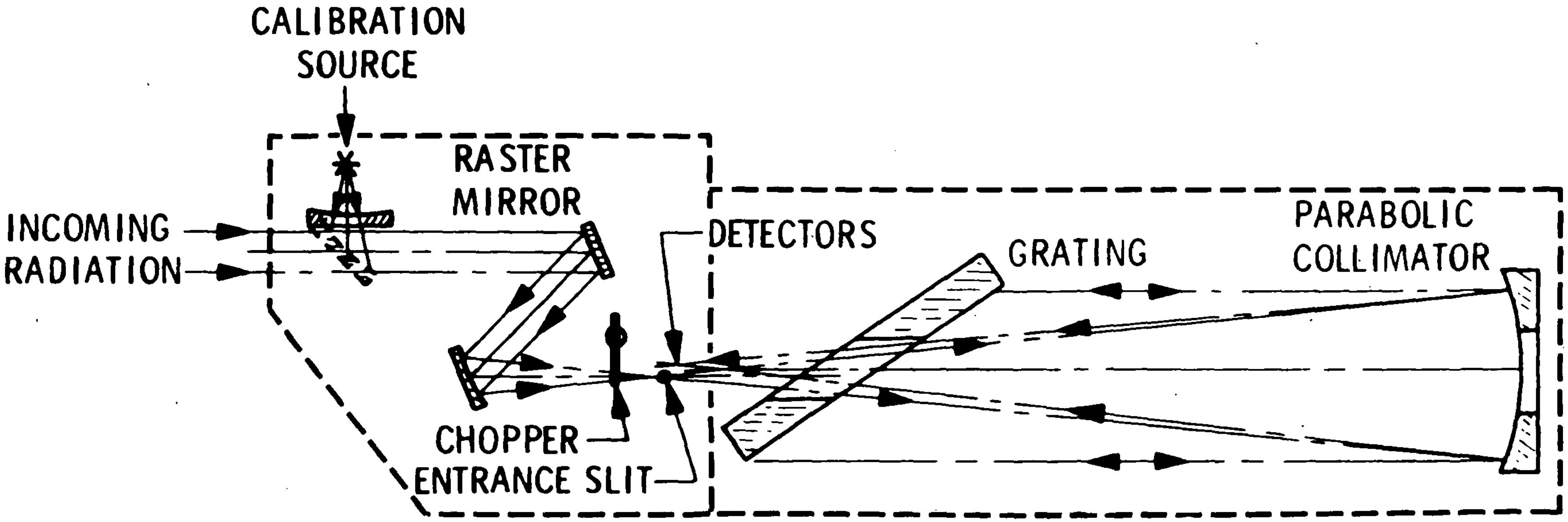
The Orbiter Imaging investigation team leader is Dr. Michael H. Carr of the U.S. Geological Survey, Menlo Park, Calif.

## Water Vapor Mapping

Water vapor is a minor constituent of the Martian atmosphere. Its presence was discovered about 10 years ago from Earth-based telescopic observations. They indicated that the vapor varies seasonally, appearing and disappearing with the recession and growth of the polar cap in each hemisphere, and diurnally (daily), with its maximum close to local (Mars) noon (Mars time). Some evidence was found that water vapor is contained in the lowest layers of the atmosphere, perhaps within the first 1,000 m (3,300 ft.) above the surface.

The abundance of atmospheric water vapor is usually given in units of "precipitable microns," a measure of the thickness of the ice layer or liquid that would be formed if all the vapor in the atmospheric column above the surface were condensed out.

# OPTICAL CONFIGURATION DIAGRAM
# (MAWD)



Compared with Earth, Mars' atmosphere contains very little water. The atmosphere on Earth typically holds the equivalent of one or two centimeters (0.4 to 0.8 inches) of water, but the most water observed on Mars is only a fraction of one per cent of Earth's or 50 precipitable microns (0.002 inches).

The Mars atmosphere is a hundred times thinner than Earth's, however, and its mean or average temperature is considerably lower. The relative water concentrations, therefore, are not very different (about one part per thousand) and the relative humidity on Mars can be significant at times. It is misleading to refer to Mars as a "dry" planet.

Yet in terms of total planetary abundance, evidence suggests that there is very little water on or above the planet's surface in the form of atmospheric vapor or surface ice. Since water is cosmically one of the more abundant molecules, the question arises: Has Mars lost most of its water during its evolution, or is water present beneath the surface, a subsurface shell of ice or permafrost, or perhaps held deeper in the interior to be released by thermal and seismic activity at some future time?

Mariner spacecraft observations of Mars in 1969 and 1971 showed that while the polar hoods are predominantly frozen carbon dioxide, the visible caps left after the carbon dioxide vaporizes are water crystals.

Mariner results revealed other intriguing facts related to the history of water on Mars: The atmosphere loses hydrogen and oxygen atoms to space at a slow but steady rate, and in the relative proportions with which they make up the water molecule. Surface features exist that appear to have been formed by flowing liquid . The latter are quite different from the river-like features caused by lava flows. They appear to be wide braided channels formed from an earlier period of flooding by a more mobile liquid than volcanic lava.

Again a question: Are we now seeing the last disappearing remnants of water that was once much more plentiful on the planet, or is Mars locked in an ice age that has frozen out most of its water in the polar caps or beneath a layer of surface dust?

Martian water clearly holds many clues to the planet's history. By studying the daily and seasonal appearance and disappearance of water vapor in more detail than is possible from Earth by mapping its global distribution, and by determining the locations and mechanisms of its release into the atmosphere, scientists should understand more clearly the present water regime, and perhaps unravel some of the mystery surrounding past conditions on the planet.

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In the context of Martian biology, such clarification may have great significance in establishing the existence, now or in the past, of an environment favorable to the survival and proliferation of living organisms. This presumes that Martian life is dependent on the availability of water as is life on Earth.

The Viking water vapor mapping observations will be made with an infrared grating spectrometer mounted on the Orbiter scan platform, boresighted with the television cameras and the Infrared Thermal Mapper (IRTM). The spectrometer, called the Mars Atmospheric Water Detector (MAWD), measures solar infrared radiation reflected from the surface of the planet after it has passed through the atmosphere.

The instrument selects narrow spectral intervals coincident with characteristic water vapor absorptions in the 1.4-micron wavelength region of the spectrum. Variations in the intensity of radiation received by the detectors provide a direct measure of the amount of water vapor in the atmospheric path traversed by the solar rays.

The sensitivity of the instrument enables amounts of water from a minimum of a precipitable micron to a maximum of 1,000 microns to be measured. The precise wavelengths of radiation to which the detectors respond are also selected so instrument data can be used to derive atmospheric pressure at the level where the bulk of the water vapor resides, providing an indication of its height above the surface.

At the lowest point in the orbit, the field of view of the detector is a rectangle 3 by 20 km (1.9 by 12.4 mi.) on the planet's surface. This field is swept back and forth, perpendicular to the ground track of the Orbiter, by an auxiliary mirror at the entrance aperture of the instrument. In this way the water vapor over selected areas of the planet can be mapped.

A small ground-based computer, dedicated to the use of the two orbiting infrared isntruments, directly reduce data to contour plots of the water vapor abundance and pressure.

During the initial orbits, and particularly through the landing site certification phase of the missions before Lander separation, MAWD observations will concentrate on an area within a few hundred kilometers around the landing sites, to help in site certification and to complement landed science measurements.

In later phases of the mission, observations will be extended to obtain global coverage of water vapor distribution and its variation with time-of-day and seasonal progression. The search for regions of unusually high water content will be emphasized during these later stages, and areas of special interest will be studied, including volcanic ridges, the edge of the polar cap and selected topographic features.

The Water Vapor Mapping investigation team leader is Dr. Crofton B. (Barney) Farmer of the Jet Propulsion Laboratory.

## Thermal Mapping

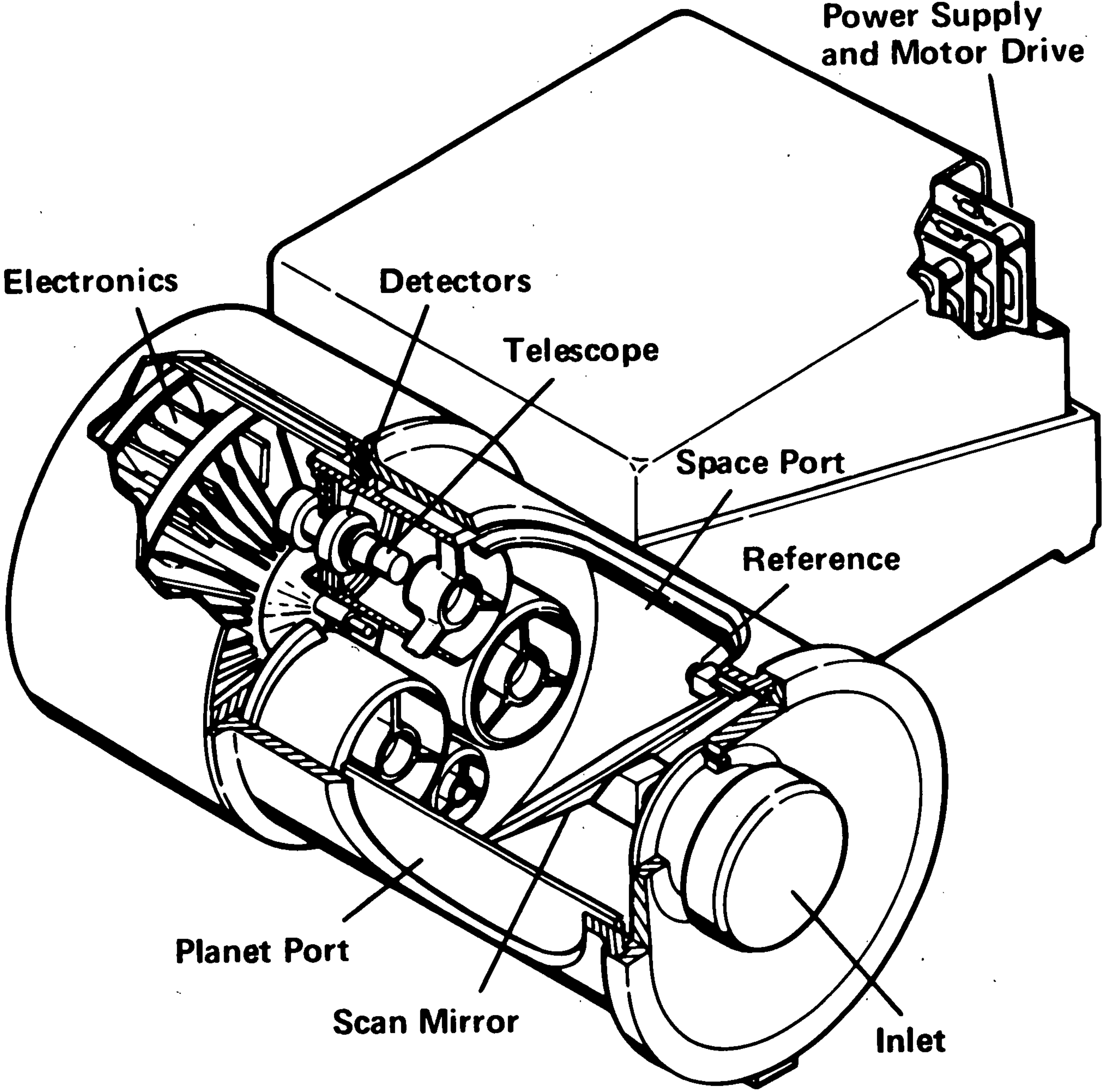
The Thermal Mapping investigation is designed to obtain temperature measurements of areas on the surface of Mars. It obtains the temperature radiometrically with an Infrared Thermal Mapper (IRTM) instrument.

Information obtained by the thermal mapper will contribute to the study of the surface and atmosphere of Mars, which is similar to and in some ways simpler to study than Earth. Mars appears to be geologically younger, and clearly is undergoing major changes. Studies of Martian geology and meteorology can have implications in tectonics (the study of crustal forces), volcanology and understanding weathering and mineral deposition.

Just as fine beach sand cools rapidly in the evening while large rocks remain warm, daily temperature variation of the Martian surface indicates the size of individual surface particles, although the thermal mapper necessarily obtains an average value over many square kilometers. Measurements obtained just before sunrise are especially valuable (the detectors can sense the weak heat radiation from the dark part of the planet), since at that time the greatest temperature differences occur between solid and fine-grained material.

One detector is used to measure the upper atmospheric temperature. That information may be combined with surface temperatures to permit construction of meteorological models. An understanding of the important Martian wind circulation depends on such models.

Data received from the thermal mapper are intended to help establish and evaluate the site for the Viking Lander. Martian organisms would probably be affected by local water distribution and temperatures of the soil and air; these factors are either measured by the radiometer or are dependent on the soil particle characteristics determined by the thermal mapper.



*Infrared Thermal Mapper*

The Infrared Thermal Mapper is a multi-channel radiometer mounted on the Orbiter's scan platform. It accurately measures the temperatures of the Martian surface and upper atmosphere, and also the amount of sunlight reflected by the planet. Four small telescopes, each with seven sensitive infrared detectors, are aimed parallel to the Visual Imaging optical axis. Differences of one degree Celsius (about 1.8 degrees Fahrenheit) can be measured throughout the expected temperature range of minus 130 degrees C to plus 57 degrees C (minus 202 to 135 degrees F.). The instrument is 20 by 30 cm (8x10x12 in.) and has a minimum spatial resolution of 8 km (5 mi.) on the surface.

The large number of detectors (28) is chosen to provide good coverage of the Martian surface, and to allow several infrared "colors" to be sampled. Differences in the apparent brightness of a spot on the planet in the various colors imply what kinds of rocks (granite, basalt, etc.) are present. The temperatures themselves may indicate the composition of clouds and the presence of dust in the atmosphere.

The spatial resolution available to the thermal mapper will permit reliable determination of the frost composition comprising the polar caps. The close spacing of infrared detectors and the spacecraft scanning mode improves the ability to identify possible local effects such as current volcanic activity or water condensation.

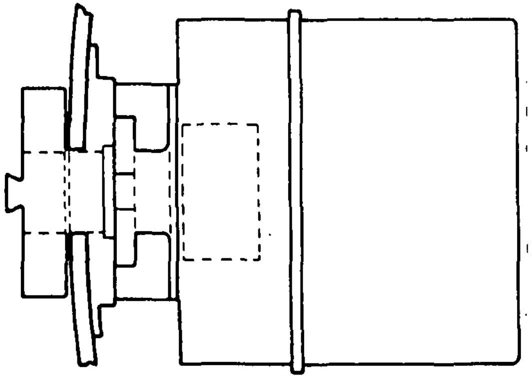
The Thermal Mapping investigation team leader is Dr. Hugh H. Kieffer of the University of California at Los Angeles.

## Entry Science

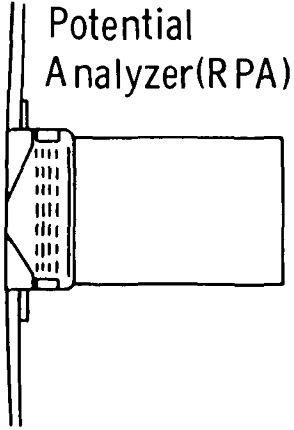
The Entry Science investigation is concerned with direct measurements of the Martian atmosphere from the time the Lander and Orbiter separate until the Lander touches down on the planet's surface. Knowledge of a planet's atmosphere, both neutral and ionized components tells much about the planet's physical and chemical evolution, and it increases understanding of the history of all planets, including that of Earth.

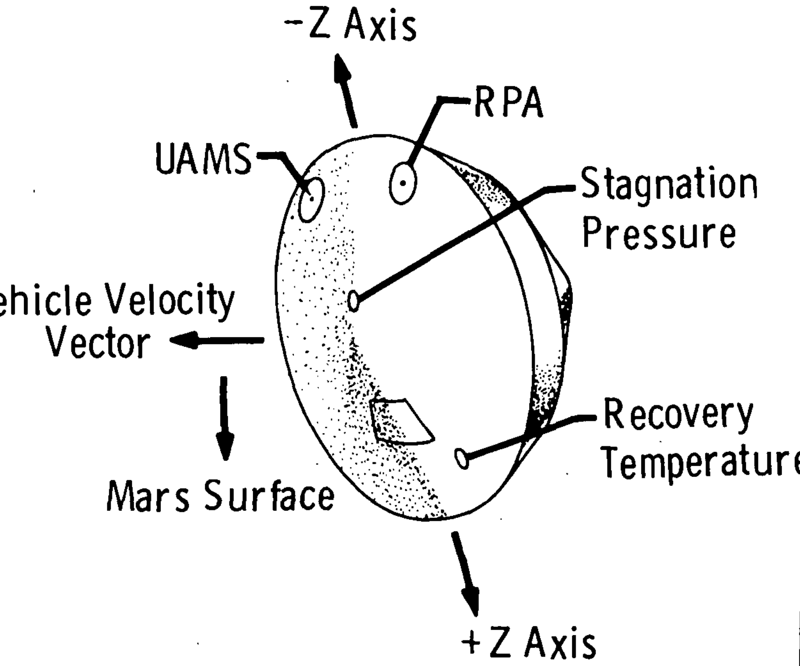
# ENTRY SCIENCES AEROSHELL INSTRUMENTATION

Upper Atmospheric Mass Spectrometer (UAMS)

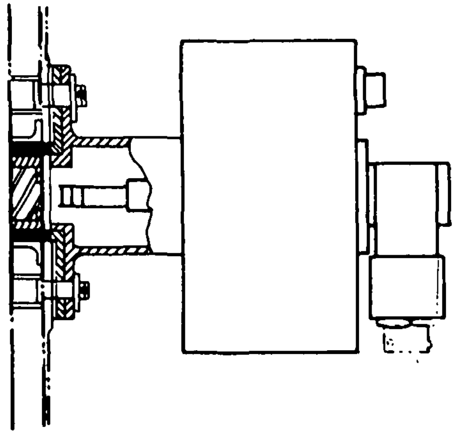


Retarding Potential Analyzer(RPA)

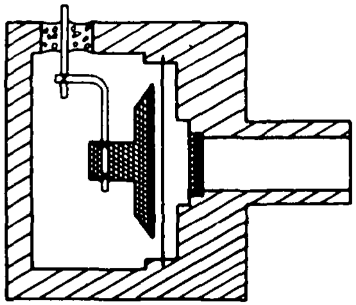




Recovery Temperature Instrument



Stagnation Pressure Sensor Cell



NOTE:
ACCELEROMETERS LOCATED INTERNALLY IN THE INERTIAL REFERENCE UNIT (GUIDANCE & CONTROL S/S)

The question of the atmospheric composition of Mars is of immediate interest to scientists. Nitrogen, believed essential to the existence of life, has not yet been measured on Mars by remote sensing methods. Measurements of atmospheric pressure and temperature, plus winds, are important in understanding the meteorology, just as observations made with weather balloons in Earth's atmosphere supplement surface observations.

Upper Atmosphere. Studies of the Martian upper atmosphere composition begin shortly after the Lander leaves the Orbiter. The first measurements are made so high above the surface that only charged particles can be detected. These measurements are made with a Retarding Potential Analyzer (RPA) that will measure electron and ion concentrations and temperatures of these components. Measurements continue down to about 100 km (60 mi.) above the planet's surface, where the pressure becomes too high for the instrument to operate.

On Mars, which has a weak magnetic field compared with that of Earth, charged particles streaming from the Sun (called the solar wind) and interacting with the upper atmosphere may be important in determining the nature of the lower atmosphere.

At the very highest altitudes, the analyzer will study the interaction of the solar wind with the Martian atmosphere. Measurements at lower altitudes will make important contributions to knowledge of the interaction of sunlight with atmospheric gases, a matter of great significance in understanding the photochemical reactions that take place in all planetary atmospheres, including Earth's.

Another analyzer will be turned on several thousand kilometers above the Martian surface, but the neutral atmosphere at high altitudes is so thin that measurements will not begin until the Lander drops to an altitude of around 300 km (180 mi.) above the surface. Measurements on the neutral constituents of the atmosphere are made with the Upper Atmosphere Mass Spectrometer (UAMS).

The mass spectrometer will sample and analyze the atmosphere as the Lander passes through. Inside the instrument, the gas to be analyzed is ionized by an electron beam, and the ions formed are sent through an appropriate combination of electric and magnetic fields to determine the amounts of the various molecular weights by which the various gases can be identified.

From remote measurements, carbon dioxide is known to be the principal atmospheric constituent on Mars. The mass spectrometer should be able to detect 0.1 per cent of nitrogen and even a smaller amount of argon. Argon's principal isotope is a radioactive decay product of potassium, an important constituent in many minerals. About one per cent of the Earth's atmosphere has come from the radioactive decay of potassium in the Earth's crust.

The mass spectrometer will also look for molecular and atomic oxygen, carbon monoxide and other common gases that may be present in the Martian atmosphere. It may tell if the isotope composition in elements such as carbon, oxygen and argon is the same as on Earth, thereby providing measurements needed to understand planetary evolution.

Lower Atmosphere. The lower atmosphere begins at about 100 km (60 mi.) altitude, where the analyzer and mass spectrometer become inoperative. The bulk of the atmospheric gases reside below this altitude. On Mars the surface atmospheric pressure is only about 1.5 per cent as great as on Earth.

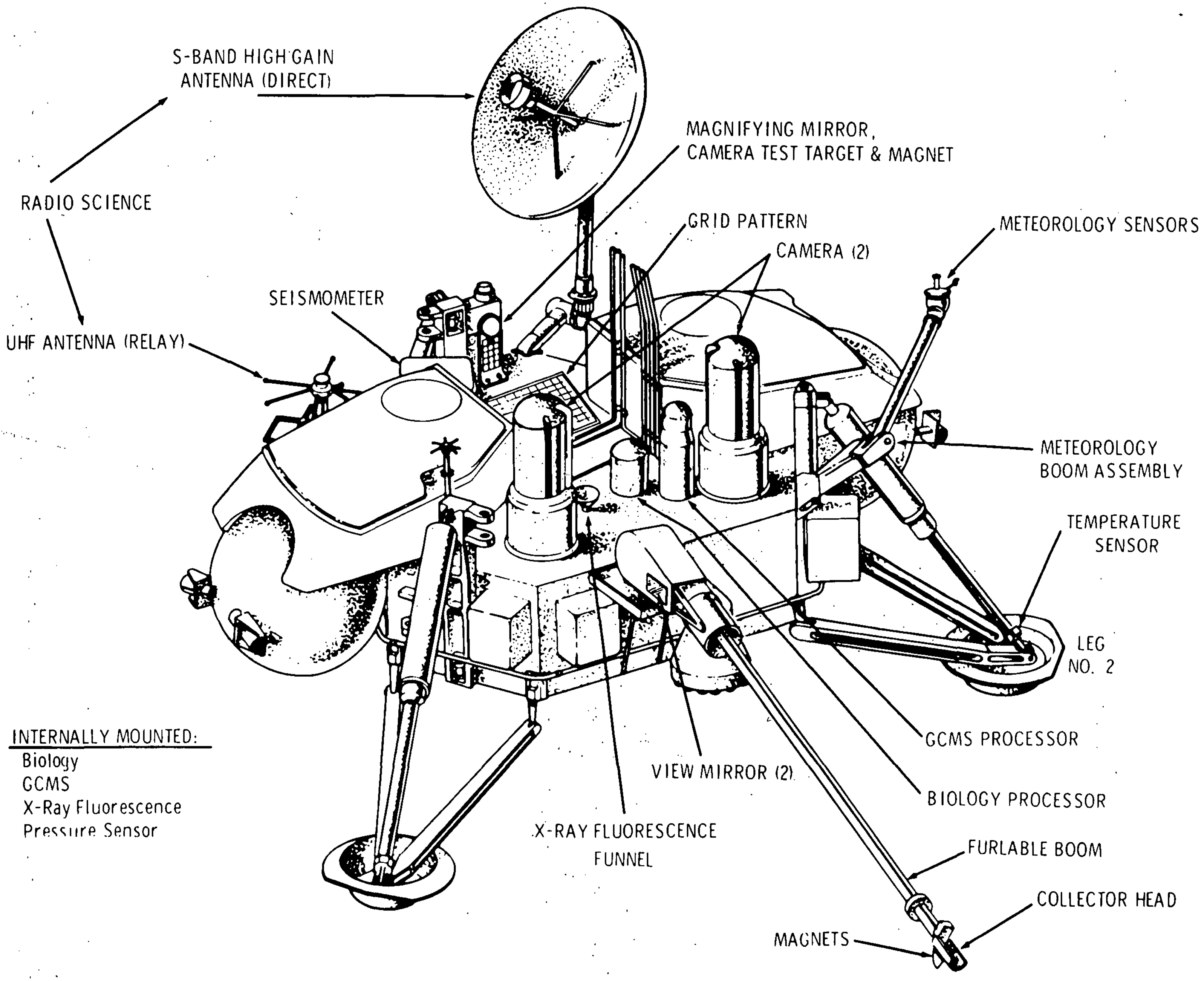
Measurements of Mars' surface pressure are all based on remote observations, principally alteration by the atmosphere of radio waves from Mariner spacecraft as they flew behind the planet. Viking will obtain direct pressure and temperature measurements in the lower atmosphere and on the surface.

In passing through the atmosphere from 100 km (60 mi.) to the surface, the Landers will obtain profiles of the properties of the atmosphere: pressure, density and temperature. First measurements will be by sensitive determination of the aerodynamic retardation of the Lander, from which atmospheric density can be derived.

The density profile with altitude permits the weight (pressure) of the atmosphere above any given level to be calculated. Given atmospheric composition, pressure and density will define the structure of the atmosphere from roughly 100 to 25 km (60 to 15 mi.) altitude. Below 25 km, sensors can be deployed to directly measure the pressure and temperature, although these measurements have to be done with specially designed sensors because of the low pressure in the atmosphere.

The importance of the profiles is that they are determined by solar energy absorption and vertical heat flow. Heat can be transported either radiatively or convectively (by infrared emission or absorption) or by currents and winds.

# VIKING LANDED SCIENCE CONFIGURATION



INTERNALLY MOUNTED:
- Biology
- GCMS
- X-Ray Fluorescence
- Pressure Sensor

The atmosphere of Mars appears to be windy compared to Earth's lower atmosphere. This is a result of the low density of the atmosphere, which permits it to change temperature rapidly, and causes large temperature variations from day to night and seasonally. There are large contrasts in temperature of the atmosphere, precisely the condition to create winds.

One evidence for high winds is the frequently severe dust storms, such as the long-lasting one that greeted Mariner 9. These storms are a puzzle, since it takes even stronger winds than those now calculated by computer models of the atmospheric circulation (18 to 46 m per second; 40 to 100 mi. per hour) to raise dust in this tenuous atmosphere.

The vertical profiles of temperature will provide additional evidence of the thermal balance of the atmosphere and, it is hoped, of forces that drive the winds. Winds also will be measured directly in the parachute phase by tracking the motion of the Lander over the surface as it drifts, carried by local winds. These measurements will extend to an altitude of 6 km (3.7 mi.).

The Entry Science investigation team leader is Dr. Alfred O. C. Nier of the University of Minnesota.

## Lander Imaging

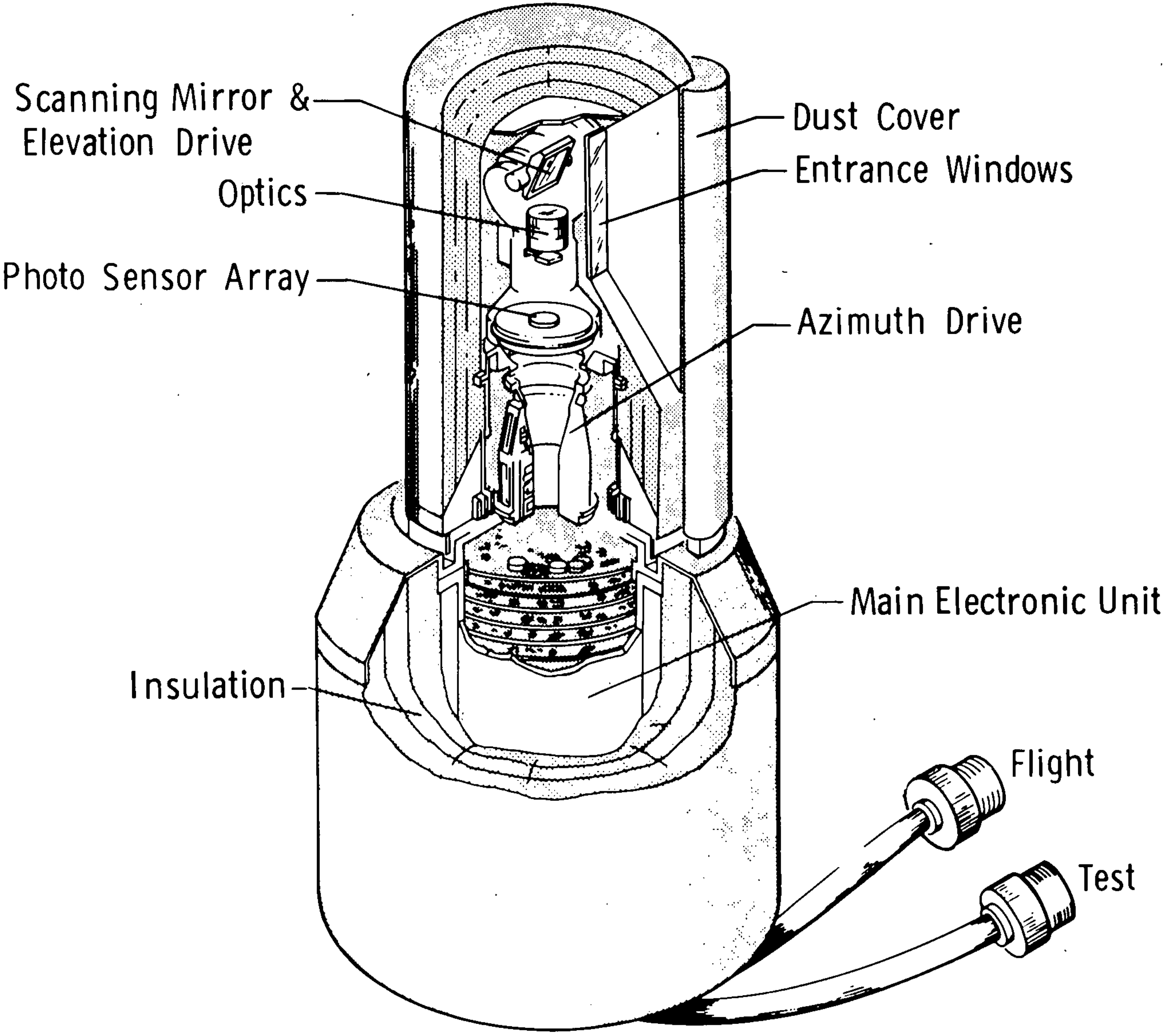
As a person depends on sight for learning about the world, so cameras will serve as the eyes of the Lander and, indirectly, of the Viking scientists.

Pictures of the region near the Lander will be studied to select a suitable site for acquiring samples that will be analyzed by other Lander instruments. The cameras will also record that the samples have been correctly picked up and delivered. From time to time, the cameras will examine diferent parts of the Lander to see that components are operating correctly.

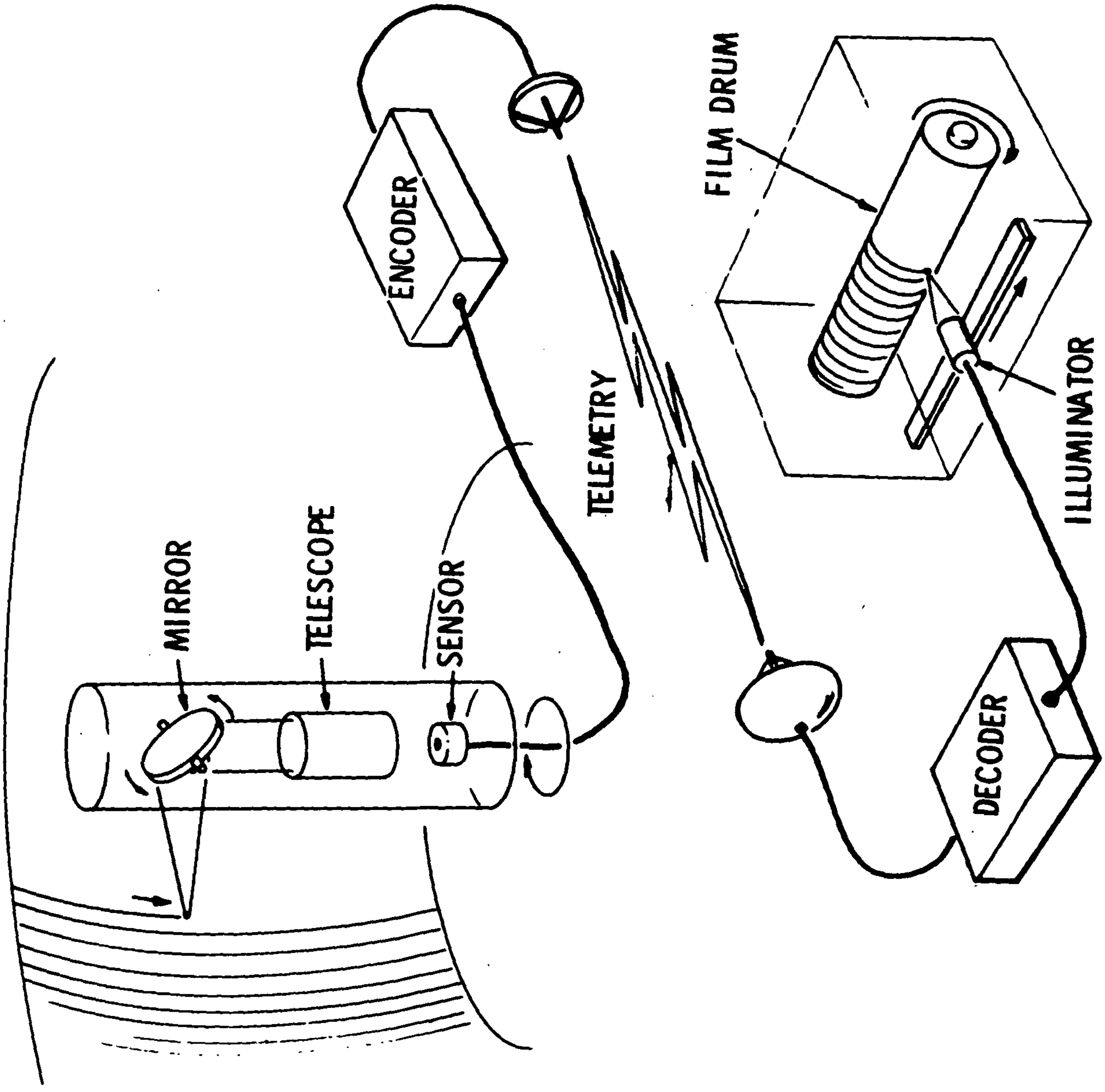
One category of the Lander imaging investigation is the study of general geology or topography. Pictures of the Martian surface visible to the cameras are of the highest scientific priority. The first pictures will be panoramic surveys, and then regions of particular interest will be imaged in high resolution, in color and in infrared.

- more -

# LANDER CAMERA SYSTEM DIAGRAM



## LANDER IMAGING CONCEPT



Stereoscopic views are obtained by photographing the same object with two cameras, providing photos in which three-dimensional shapes can be distinctly resolved. Putting together this information, scientists can tell much about the character of the Martian surface and the processes that have shaped it.

One can imagine finding shock-lithified rocks (as on the Moon), igneous boulders, wind-shaped boulders (ventifacts), sand ripples, or a lag gravel deposit. Each of these possible objects could be resolved in pictures; each would bespeak a particular kind of surface modification.

The advantage of operational flexibility is important. Scientists will study the first pictures and, on the basis of what they reveal, select particular areas for more detailed examination. This method will require sending new picture commands to the Lander every few days.

Used as photometers, the cameras will yield data that permit inferences about the chemical and physical properties of Martian surface materials. Color and IR diodes will collect data in six different spectral bands. Reflectance curves constructed from these six points have diagnostic shapes for particular minerals and rocks. For example, differing degrees of iron oxidation cause varying absorption in the range from 0.9 to 1.1 micron wavelengths.

Another goal will be to spot variable features. Changes in features can be determined by taking pictures of the same region at successive times. The most probable change will be caused by the movement of sand and silt by the wind. Mariner pictures have revealed large-scale sediment movement; similar Lander observations are anticipated.

A grid target has been painted atop the Lander; one aim of the variable features investigation is to see if the target is being covered by sediment. The cameras' single-line scan will be used each day to detect any sand grains saltating (hopping) along the surface.

The most spectacular variable feature would be one of biological origin. Many scientists are skeptical about the probability of life on Mars; very few expect to see large forms that can be recognized in a picture. The possibility will not be discounted, however. If there are organic forms, they might be difficult to identify in a conventional "snapshot." Their most recognizable attribute might be motion, and this motion might be uniquely characterized by the single-line-scan mode of operation.

- more -

Another area of camera investigation is atmospheric properties. Pictures taken close the horizon at sunset or sunrise will be used to determine the aerosol content of the atmosphere. Some pictures will also be taken of celestial objects: Venus, perhaps Jupiter, and the two Mars satellites, Phobos and Deimos. The brightness of these objects will be affected by the interference of the atmosphere, and the cameras can provide a way to measure aerosol content.

The cameras can also be used in the same way as more conventional surveying instruments. Pictures of the Sun and planets can be geometrically analyzed to determine the latitudinal and longitudinal position of the Lander on Mars.

Each Lander is equipped with two identical cameras, positioned about 1 m (39 in.) apart. They have a relatively unobstructed view across the area that is accessible to the surface sampler. The cameras are on stubby masts that extend 1.3 m (51 in.) above the surface.

The imaging instruments are facsimile cameras. Their design is fundamentally different from that of the television cameras that have been used on most unmanned orbital and flyby spacecraft. Facsimile cameras use mechanical instead of electronic scanning.

In a television camera the entire object is simultaneously recorded as an image on the face of a vidicon tube in the focal plane. Then the image is "read" by the vidicon through the action of an electron beam as it neutralizes the electro static potential produced by photons when the image was recorded. In a facsimile camera, small picture elements (called pixels) that make up the total image are sequentially recorded.

In a facsimile camera an image is produced by observing the object through sequential line scans with a nodding mirror which reflects the light from a small element of the object into a diode sensor. Each time the mirror nods, one vertical line in the field of view is scanned by the diode. The entire camera then moves horizontally by a small interval and the next vertical line is scanned by the nodding mirror. Data that make up the entire picture are slowly accumulated in this way.

Because each element (spot) in the field of view is recorded on the same diode, opposed to different parts of the vidicon tube face the facsimile camera has a photometric stability that exceeds most television systems. Relatively subtle reflectance characteristics of objects in the field of view can be measured.

There are actually 12 diodes in the camera focal plane; each diode is designed to acquire data of particular spectral and spatial quality. One diode acquires a survey black-and-white picture. Three diodes have filters that transmit light in blue, green and red; together these diodes record a color picture. Three more diodes are used in essentially the same way, but have filters that transmit energy in three bands of near-infrared.

Four diodes are placed at different focal positions to get the best possible focus for high-resolution black-and-white pictures. (This results in a spatial resolution of several millimeters for the field of view closest to the camera--objects the size of an aspirin can be resolved.) The twelfth diode is designed with low sensitivity so it can image the Sun.

The survey and color pictures have a fixed elevation dimension of 60 degrees; high-resolution pictures have a fixed dimension of 20 degrees. The pictures can be positioned anywhere in a total elevation range of 60 degrees below to 40 degrees above the nominal horizon. The azimuth of the scene is adjustable; it can vary from less than one degree to almost 360 degrees to obtain a panorama.

The facsimile camera acquires data relatively slowly, line by line. Rapidly moving objects, therefore, will not be accurately recorded. They might appear as a vertical streak, recorded on only one or two lines. This apparent liability can be turned into an asset.

If the camera continues to operate while its motion is inhibited, the same vertical line is repetitively scanned. If the scene is stationary, the reflectance values between successive lines will be identical, but if an object crosses the region scanned by the single line, the reflectance values dramatically change between successive scans. The single-line-scan mode of camera operation, therefore, provides an unusual way of detecting motion.

As the mission proceeds, pictures will be acquired and transmitted three ways: the first Lander pictures will be sent directly to the Orbiter for relay to Earth. On successive days, pictures will be acquired during the day and stored on the Lander's tape recorder for later transmission to the Orbiter. Pictures can also be transmitted directly to Earth at a lower data rate.

The number of pictures that will be sent to Earth each day will vary according to the size of the pictures, amount of data to be transmitted by other instruments, and length of the transmission period. A typical daily picture budget for one Lander might be one picture directly transmitted to Earth at low data rate, two pictures transmitted real time through the Orbiter, and three pictures stored on the tape recorder and later relayed to Earth.

The Lander Imaging investigation team leader is Dr. Thomas A. (Tim) Mutch of Brown University.

## Biology

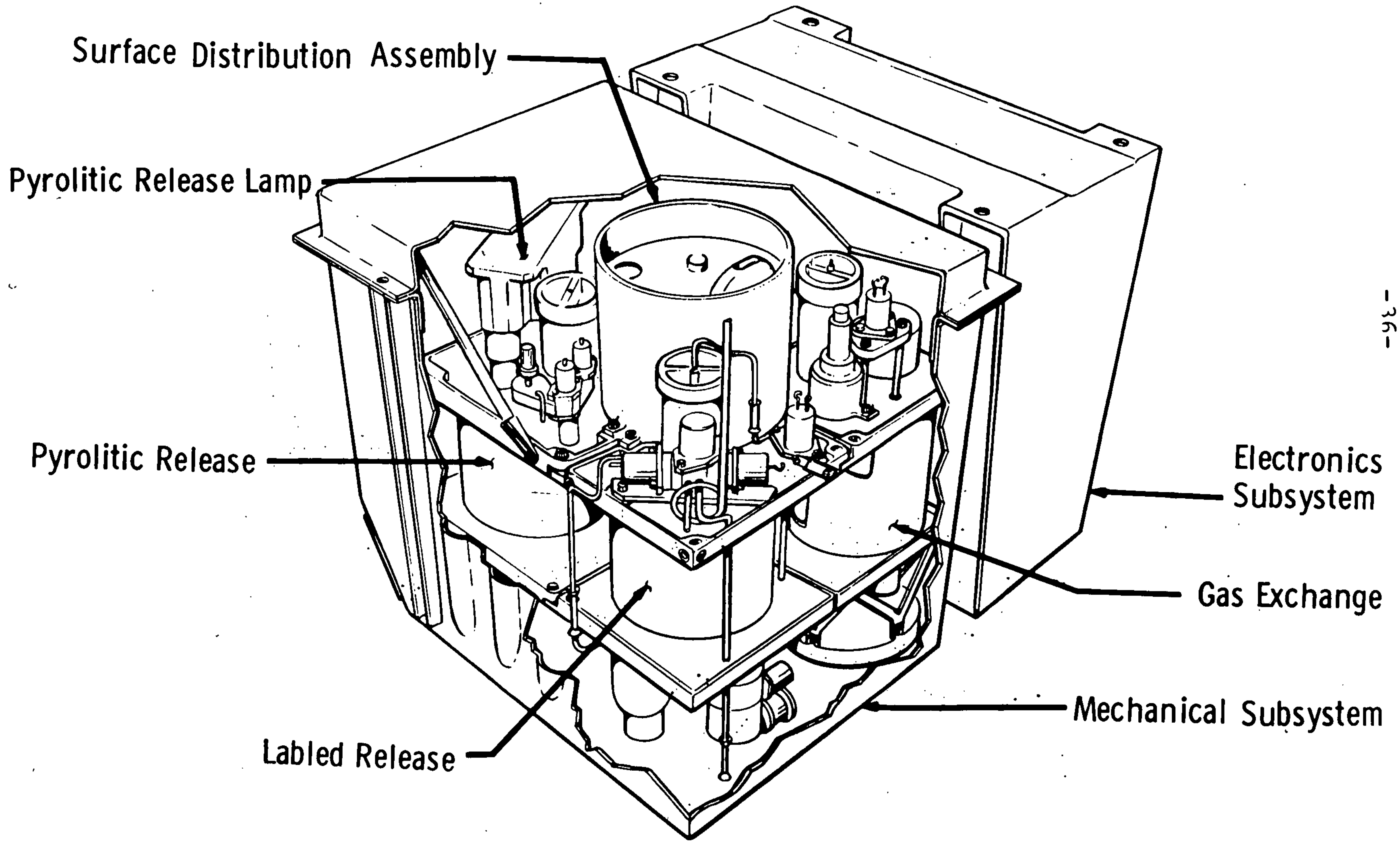
Biology investigations will be performed to search for the presence of Martian organisms by looking for products of their metabolism. Three distinct investigations will incubate samples of the Martian surface under a number of different environmental conditions. Each is based on a different fundamental assumption about the possible requirements of Martian organisms; together they constitute a broad range of ideas on how to search for life on Mars. The three investigations are Pyrolytic Release (PR), Labeled Release (LR) and Gas Exchange (GEX).

Martian soil samples acquired by the surface sampler, several times during each landing, will be delivered to the Viking Biology Instrument (VBI). There the samples will be automatically distributed, in measured amounts, to the three experiments for incubation and further processing.

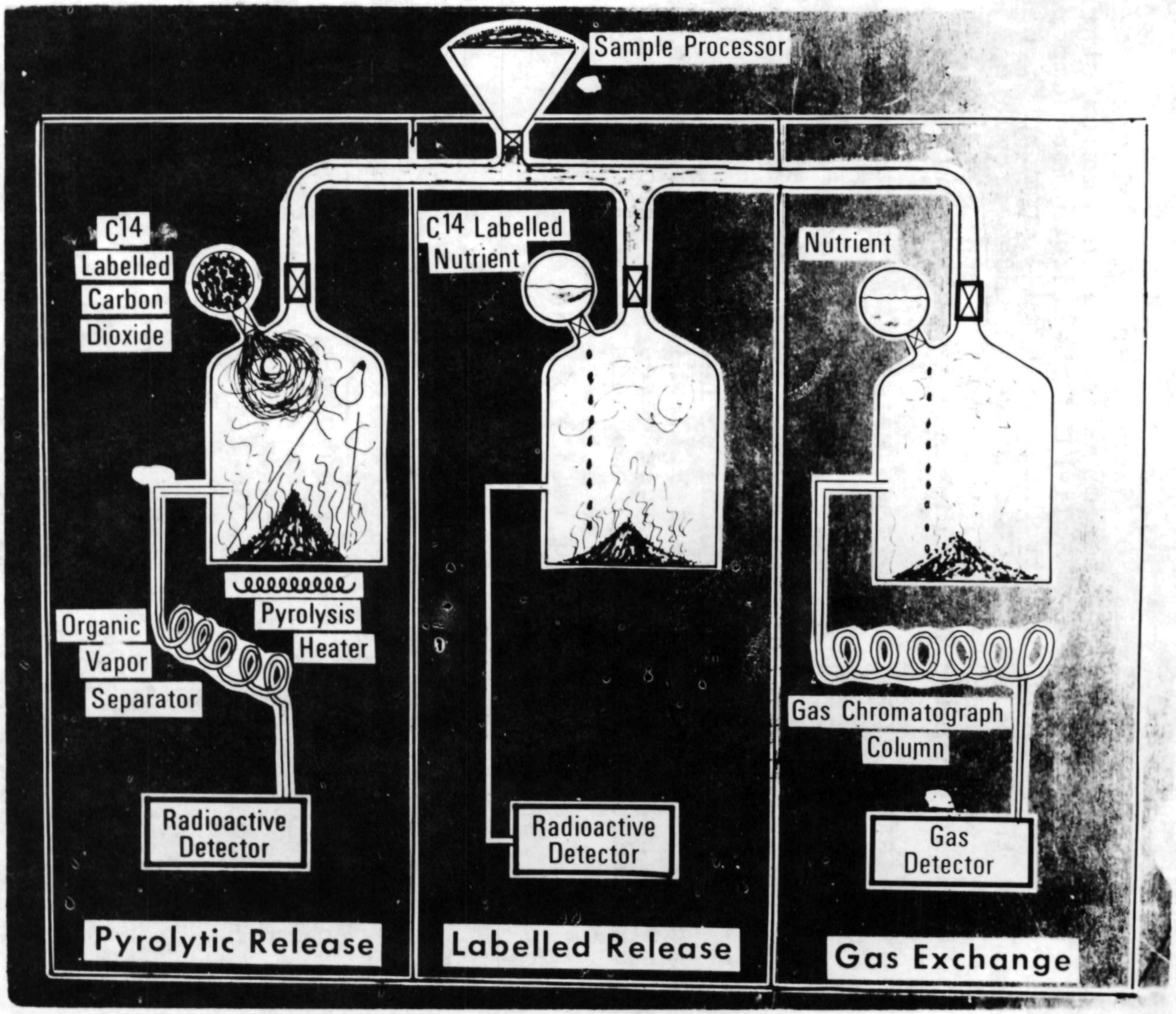
Within the biology instrument, a complex system of heaters and thermo-electric coolers will maintain the incubation temperatures between about 8 and 17 degrees C (46 to 63 degrees F.) in spite of external temperatures that may drop to minus 75 degrees C (minus 103 degrees F.) or internal Lander temperatures that may rise to 35 degrees C (95 degrees F.).

Pyrolytic Release. The Pyrolytic Release (PR) experiment contains three incubation chambers, each of which can be used for one analysis. This experiment is designed to measure either photosynthetic or chemical fixation of carbon dioxide ($CO_2$) or carbon monoxide (CO). The main rationale for this is that the Martian atmosphere is known to contain $CO_2$, with CO as a trace component. Any Martian biota (animal or plant life) are expected to include organisms capable of assimilating one or both of these gases. It also seems reasonable that at least some organisms on Mars would take advantage of solar energy, as occurs on Earth, and that Martian soil would include photosynthetic organisms.

# BIOLOGY INSTRUMENT DIAGRAM



# INTEGRATED BIOLOGY INSTRUMENT



The experiment incubates soil in a Martian atmosphere with radioactive CO and $CO_2$ added. Then, by pyrolysis (heating at high temperatures to "crack" organic compounds) and the use of an organic vapor trap (OVT), it determines whether radioactive carbon has been fixed into organic compounds. This experiment can be conducted either in the dark or light.

For an analysis, 0.25 cc of soil is delivered to a test cell, which is then moved to the incubation station and sealed. After establishing the incubation temperature, water vapor can be introduced by ground command if desired. Then the labeled $CO_2$/CO mixture is added from a gas reservoir and a xenon arc lamp, simulating the Sun's energy, is automatically turned on during the five-day incubation.

After incubation, the test cell is heated to 120 degrees C (248 degrees F.) to remove residual incubation gases, which are vented to the outside. Background counts are made, after which the test cell is moved from the incubation station to another station.

Here pyrolysis is done by heating the test cell to 625 degrees C (1,160 degrees F.), while purging the test cell with helium gas. The purged gases pass through the OVT, designed to retain organic compounds and fragments, but not $CO_2$ or CO. The radioactivity detector at this stage will sense a "first peak" consisting mainly of unreacted CO2/CO. This first peak is regarded as non-biological in origin.

After this operation, the test cell is moved away from the pyrolysis station, the detector is heated and purged with helium, and background counts are taken once more to verify that the background radiation is down to pre-pyrolysis levels. The trapped organic compounds are then released from the OVT by heating it to 700 degrees C (1,290 degrees F.), which simultaneously oxidizes them to $CO_2$. These are flushed into the detector. A significant second radioactive peak at this point would indicate biological activity in the original sample.

Labeled Release. The Labeled Release (LR) experiment is designed to test metabolic activity in a soil sample moistened with a dilute aqueous solution of very simple organic compounds. The rationale for this experiment is that some Martian organisms, in contact with an atmosphere containing $CO_2$, should be able to break down organic compounds to $CO_2$. The experiment depends on the biological release of radioactive gases from a mixture of simple radioactive compounds supplied during incubation.

The test cell is provided 0.5 cc of soil sample and is moved to the incubation station and sealed. The Martian atmosphere is established in the test cell in this process. Before the radioactively-labeled nutrients (a mixture of formate, glycine, lactate, alanine, and glycolic acid; all compounds uniformly labeled with radioactive carbon) are added, a background count is taken. Then approximately 0.15 cc of nutrients are added, and incubation proceeds for 11 days.

The atmosphere above the soil sample is continuously monitored by a separate radioactivity detector throughout the incubation, after which the test cell and detector are purged with helium. The accumulation of radioactive $CO_2$ (or other radioactive gases) indicates the presence of life metabolizing the nutrient. Data are collected for 12 days. These data will produce a metabolic curve as a function of time. The shape of the curve can be used to determine if growth is taking place in the test cell.

Gas Exchange. The Gas Exchange (GEX) experiment measures the production or uptake of $CO_2$, nitrogen, methane, hydrogen and oxygen during the incubation of a Martian soil sample. The GEX experiment can be conducted in one of two modes: in the presence of water vapor, without added nutrients, or in the presence of a complex source of nutrients.

The first mode is based on the assumption that substrates (foodstuffs) may not be limiting in the Martian soil and that biological activity may be stimulated when only water vapor becomes available. The second mode assumes that Martian soil contains organisms metabolically similar to those found in most terrestrial soils and that these will require organic nutrients for growth.

A single test cell is used for the experiment. After receiving 1 cc of soil from the distribution assembly, the test cell is moved to its incubation station and sealed. After a helium purge, a mixture of helium, krypton and $CO_2$ is introduced into the incubation cell and this becomes the initial incubation atmosphere. (Krypton is used as an internal standard; helium is used to bring the test chamber pressure to approximately one-fifth of an Earth atmosphere.)

At this point either 0.5 or 2.5 cc of a rich nutrient solution can be introduced. Using the lesser quantity, the soil does not come into contact with the solution, and incubation proceeds in a "humid" mode. An additional two cc allows contact between the soil and the nutrient solution, which consists of a concentrated aqueous mixture of nineteen amino acids, vitamins, other organic compounds, and inorganic salts. Incubation initially is planned to be in the humid mode for seven days, after which additional nutrient solution will added. For gas analyses, samples (100 microliters) of the atmosphere above the incubating soil are removed through a gas sampling tube. This occurs at the beginning of each incubation and after 1, 2, 4, 8 and 12 days.

The sample gas is placed in a stream of helium flowing through a coiled, 0.7 m (23 ft.) long, chromatograph column into a thermal conductivity detector. The system used in the GEX experiment is very sensitive and will measure changes in concentration down to about one nanomole (one-billionth of a molecule).

After a 12-day incubation cycle, a fresh soil sample can be added to the test cell to begin a new incubation cycle; the medium can be drained and replaced by fresh nutrients; and the original atmosphere is replaced with fresh incubation atmosphere. The latter procedure will be used if significant gas changes are noted in the initial incubation, on the assumption that if these changes are due to biological activity, they should be repeatable and should be enhanced. If of non-biological origin, they should not reappear.

Each incubation station also contains auxiliary heaters that can be used to heat soil samples to approximately 160 degrees C (320 degrees F.). The heaters will be activated for three hours in case one or more of the experiments indicates a positive biological signal, after which the experiment will then be repeated on the "sterilized" soil samples. This is the control for the experiment. The detection of life would only be acknowledged if there were a significant difference between the "control" and the experiment.

An electronic system within the Viking Biology Instrument, containing tens of thousands of components, will automatically sequence all events within the experiments, but will be subject to commands from Earth. The electronic subsystem will also obtain data from the experiments for transmission to Earth.

In addition to the electronic subsystem, each biology instrument contains four compartments, or modules, within a volume of just over one cubic foot. The common services module is a reservoir for the three other modules. It contains a tank of pressurized helium gas to move the incubation chambers from one place to another, to purge pneumatic lines used in the experiments, and to carry other gases as required.

The Biology investigation team leader is Dr. Harold P. Klein of NASA's Ames Research Center, Mountain View, Calif.

## Molecular Analysis

The Molecular Analysis investigation will search for and identify organic (and some inorganic) compounds in the surface layer (the first few centimeters) of Mars. It will also determine the composition of the atmosphere near the surface and monitor composition changes during part of a Martian season.

Organic compounds on Earth are substances that contain carbon, hydrogen (almost always) and often oxygen, nitrogen and other elements; all are attached to one another. All but the most simple ones contain a series of carbon atoms attached to each other. On Earth carbon has the tendency to form a variety of long-chain molecules. This may happen on Mars, although it's possible that the situation may be different on another planet.

The question of whether there are organic compounds in the surface of Mars and, if so, what is their chemical structure, is of interest for several reasons. Organic substances produced by purely non-biological processes (such as thermal, photo-chemical or radiation-induced reactions) would tell something about the occurrence of these processes, and would allow speculation about precursors (carbon dioxide, carbon monoxide, ammonia, water, hydrogen sulfide, etc.) that could produce the substances detected.

The possibility also exists that the planet abounds with chemical compounds produced by living systems. Their chemical nature, distribution and structural uniqueness could be used to argue the presence of living organisms on Mars.

The wide area between these two extremes may represent manifestations of various levels of chemical evolution, or even of a planet that carried living systems that died gradually or through a catastrophic event.

Identification of the relatively small and simple organic molecules in the surface of Mars may enable comparison of the present chemistry of the planet to chemistry we assume existed on Earth a few billion years ago. Conversely, compounds may be encountered that resemble the composition of petroleum. From the distribution of individual structures, speculation can be made whether or not these hydrocarbons represent chemical fossils remaining after the decomposition of living systems of earlier times (a theory favored for the origin of petroleum on Earth).

While the major constituent of the Martian atmosphere is known to be carbon dioxide, there is a conspicuous absence of terrestrially important gases like oxygen and nitrogen, at least at the level of more than about one per cent.

Recent Soviet measurements indicate the possibility of an appreciable amount of argon. The concentration would tell something of the early history of Mars. Information about minor constituents like carbon monoxide, oxygen, nitrogen, and possibly even traces of small hydrocarbons or ammonia is important to an understanding of the chemical and possibly biological processes occurring at the surface of the planet. Periodic measurements during the day and during the entire landed phase of the mission are required for this purpose.

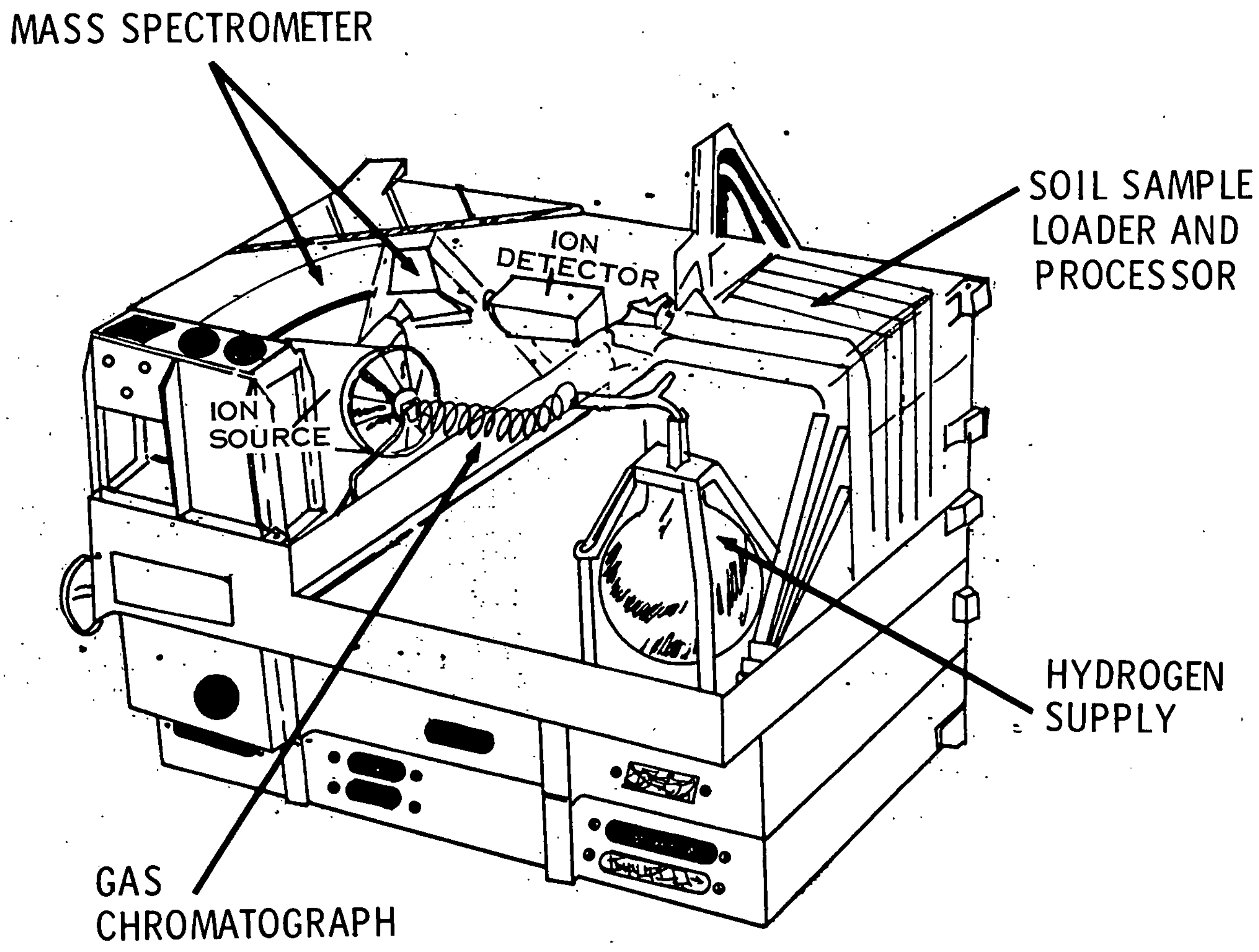
Finally, because of the absence of nitrogen in the atmosphere, it is of interest to search for nitrogen-containing inorganic substances such as nitrates or nitrites in the surface minerals.

A Gas Chromatograph Mass Spectrometer (GCMS) was chosen for these experiments because of its high sensitivity, high structural specificity and broad applicability to a wide range of compounds. Because mass spectra can be interpreted even in the absence of reference spectra, detection is possible of compounds not expected by terrestrial chemists.

The spectrometer will be used directly for analysis of the atmosphere before and after removal of carbon dioxide, which facilitates the identification and quantification of minor constituents.

Identification of organic substances probably present in surface material is a complex task because little is known about their overall abundance (which may be zero), and because any one of thousands of organic substances, or any combination thereof, may be present.

# GCMS INSTRUMENT



During the experiment, organic substances will be vaporized from the surface material by heating it to 200 degrees C (392 degrees F.), while carbon dioxide (labeled with 13 C, a non-radioactive carbon isotope) sweeps through. The emerging material is carried into a gas chromatographic column (tenex), which is then swept by a carrier gas (hydrogen). While passing through this column (a thin tube filled with solid particles) substances entering the column are separated from each other by their different degrees of retention on this solid material.

After emerging from the column, excess carrier gas is removed by passing the stream through a palladium separator that is permeable only to hydrogen; the residual stream then moves into the mass spectrometer. This produces a complete mass spectrum (from mass 12 to 200) every 10 seconds for the entire 84 minutes of the gas chromatogram. The data are then stored and sent to Earth.

In this part of the experiment, materials that are volatile at 200 degrees C (392 degrees F.) will be measured. The same sample is then heated to 500° C (932° F.) to obtain less volatile materials and to pyrolyze (crack by heating) those substances that are not volatile enough to evaporate.

The results of the organic experiment will consist of three parts: interpretation of the mass spectra to identify compounds evolved from the soil sample; reconstruction of the molecular structures of those substances that were pyrolyzed and gave only mass spectra of their pyrolysis products; and correlation of the compounds detected in the surface material with hypotheses of their generation on the Martian surface.

The detection of inorganic gaseous materials such as water, carbon dioxide or nitrogen oxides, produced upon heating the soil sample, may permit conclusions on the composition of minerals that comprise the inorganic surface material. Results of the inorganic experiment are expected to help in this correlation and vice versa.

Atmospheric analyses are relatively simple and don't require much time, power or expendable supplies, but organic analyses are more involved. They consume a considerable amount of power, produce a large amount of data that must be sent to Earth, and involve materials that are limited (labeled carbon dioxide and hydrogen). For these reasons only three soil samples will be analyzed during each of the two missions. Considering the limited source (the area accessible to the surface sampler), this should be an adequate number of tests.

The Molecular Analysis investigation team leader is Dr. Klaus Biemann of the Massachusetts Institute of Technology.

## Inorganic Chemistry

Scientific questions, ranging from the origin of the solar system to the metabolism of microbes, depend largely on knowledge of the elemental chemical composition of surface material. The Inorganic Chemical investigation will greatly expand present knowledge of the chemistry of Mars, and it is likely to provide a few clues to help answer some of these questions.

The conditions under which a planet condenses are thought to be reflected in its overall chemical composition. The most generally recognized relationship is that planetary bodies forming closer to the Sun should be enriched in refractory elements such as calcium, aluminum and zirconium, relative to more volatile elements such as potassium, sodium and rubidium.

To be truly diagnostic, ratios of volatile/refractory elemental pairs must represent planet-wide abundances, which will certainly be distorted by local differentiative geochemical processes (core/mantle formation, igneous and metamorphic differentiation, weathering and erosion, etc.). On the other hand, gross variations should be apparent. More detailed information on local processes (from other experiments as well as this one) will help reduce the effects of distortion.

Weathering in a watery environment (especially one highly charged with carbon dioxide, as is Mars' atmosphere) leads to fairly distinctive residual products, whose nature should be inferable from the inorganic chemistry data. This is especially so in concert with data from the Gas Chromatograph-Mass Spectrometer (GCMS) (on the presence and perhaps the identity of hydrate and carbonate minerals) and the Magnetic Properties experiment (on oxidation states of iron). We hope, therefore, to obtain data of at least a corroborative sort bearing on the question of the possible former existence of abundant liquid water on Mars.

The experiment, reduced to essentials, consists of exposing samples of Martian surface materials to x-rays from radioisotope sources, which stimulate the atoms of the sample to emit "fluorescent" x-rays. Each chemical element emits x-rays at a very few, extremely well-defined energies. This effect is analogous to the emission of visible light by certain fluorescent minerals when illuminated with "black light." By analyzing the energy of the fluorescent x-rays, the elements in the sample and their relative abundances can be ascertained.

Because of characteristics inherent in the technique, elements lighter (i.e., earlier in the Periodic Table) than magnesium are not individually measured. While several of these elements (e.g., nitrogen, carbon, oxygen) may be abundant and very important for biological processes, their precise abundance in surface materials is of relatively minor interpretative value. Gross abundances should be deducible from x-ray data combined with data from other experiments, notably the GCMS and Magnetic Properties investigations.

The sample delivered to the x-ray Fluorescence Spectrometer (XRFS) by the surface sampler may be coarse-grained material up to 1.3 cm (0.5 in.) in diameter (the opening of a screen in the funnel head) or fine-grained material that has been passed by vibratory sieving through 2 mm (0.08 in.) circular openings in the surface sampler head.

The spectrometer contains a sample analysis chamber, x-ray sources, detectors, electronics, and a dump cavity. The unit weighs two kilograms (4.5 pounds). Facing each window of the chamber are two sealed, gas-filled proportional counter (PC) detectors flanking a radioactive source.

These sources (radioactive iron and cadmium) produce x-rays of sufficient energy to excite fluorescent x-rays from the elements between magnesium and uranium in the Periodic Table. Elements before magnesium in the table can be determined only as a group, although useful estimates of their individual abundances may be indirectly achieved.

The output of the detectors is a series of electrical pulses with voltages proportional to the energy of the x-ray photons of the elements that produced them. A determination of the energy level identifies the presence of that element and the intensity (count rate) of the signal is related to its concentration.

A single-channel analyzer circuit divides the output of each detector into 128 energy levels and steps through each level, recording the accumulated count for a fixed period of time. A continuous plot of the count rate in each level produces a spectral signature of the material.

Mounted on the walls opposite the windows of the sample chamber are two calibration plaques ("A" is metallic aluminum; "B" is silver with a vertical, wedge-shaped central strip of zinc oxide). Signals from these plaques, with the chamber empty, monitor possible electronic drift, gas leakage from the detectors, radiation from the Lander's nuclear generators and/or cosmic rays, cross contamination of the windows between samples and, after sample delivery, the level of filling within the chamber. A calibration flag can be interposed on command in front of the radioactive iron source to provide additional calibration.

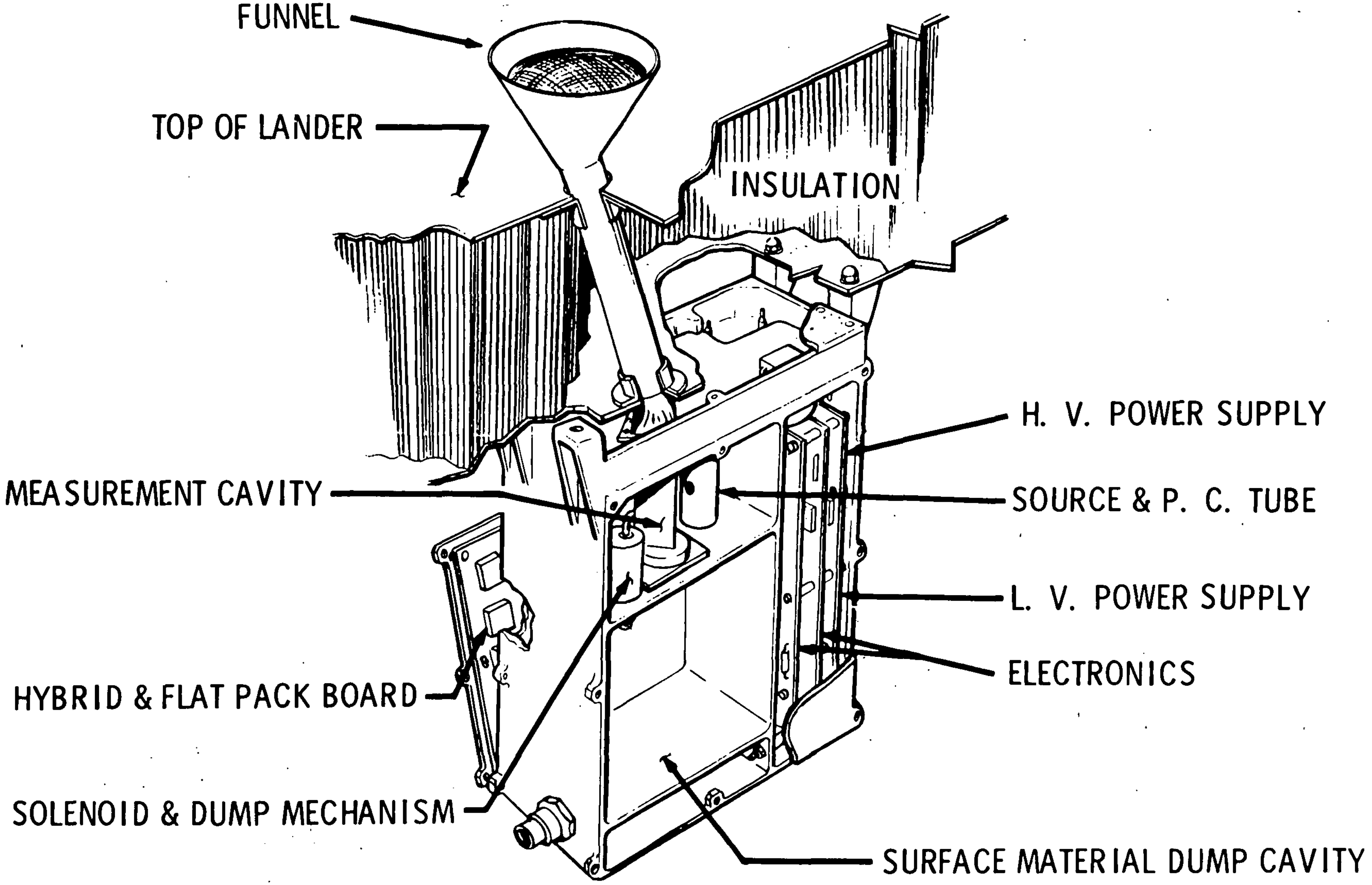
Spectral signatures obtained from spectrometer response to a variety of rock types are a part of an extensive library of reference spectra being accumulated, to which spectra of Martian material will be compared. Computer analysis of the spectra, to derive concentrations of the elements, is based on a semi-empirical model of the instrument response, including corrections for absorption and enhancement, PC tube response and backscatter intensity. By matching spectra to a mathematical model of the instrument's response, it is possible to calculate element concentrations.

All spectra are normalized by reference to the backscattered primary radiation to make comparisons uniform between spectra. The integrated intensity of the backscatter peak also provides data on the bulk density of the sample and the amounts of elements lighter than magnesium.

Toward the end of the Lander 1 mission, the x-ray Fluorescence Spectrometer will repeatedly analyze a single sample, to achieve a higher order of precision than will be possible in the earlier part of the mission.

The inorganic Chemistry investigation team leader is Dr. Priestley Toulmin III of the U.S. Geological Survey, Reston, Va.

# X-RAY FLUORESCENCE SPECTROMETER DIAGRAM



## Meteorology

Meteorology science measurements on Mars will be obtained primarily from sensors mounted on a boom attached to the Lander. Measurements will include wind speed, wind direction and temperature. Atmospheric pressure will be measured by a sensor located inside the Lander and vented by a tube to the outside. Readings will be obtained during approximately 20 periods every Sol*(Mars day), each period consisting of several instantaneous measurements.

The Meteorology investigation is designed to increase understanding of how the Martian atmosphere works. It will be man's first opportunity to directly observe the meteorology of another planet that obeys the same physical laws as does Earth's atmosphere. The opportunity to extend and refine comprehension of how an atmosphere works, driven by the Sun's radiation and subject to rotation of the planet, should give better understanding of Earth's atmosphere.

Scientific goals of the experiment are to:

- Obtain the first direct measurements of Martian meteorology with instruments placed in the atmosphere. Until now all information on wind speeds, for example, has come from theoretical calculations of the circulation of the atmosphere, or from calculations of the wind speed needed to raise dust.

- Measure and define meteorological variations during the daily cycle (Sol). The validity of existing theories that predict these diurnal (daily) variations can be compared with measurements and the theories revised as needed.

- Measure some of the turbulent characteristics of the planetary boundary layer. The boundary layer is the main brake on atmospheric circulation, and this circulation cannot be adequately understood until more is known about the turbulent dissipation of energy in the boundary layer.

- Verify whether such well-known terrestrial phenomena as weather fronts and dust devils occur on Mars by observing the behavior of the atmosphere as these things pass near the Landers.

- Support other Lander science experiments by providing information needed for other experiments. Meteorology results during the first few days, for example, should provide information on the best time of day to deploy the surface sampler boom to avoid damage from high winds.

- more -

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*24 hours, 39 minutes

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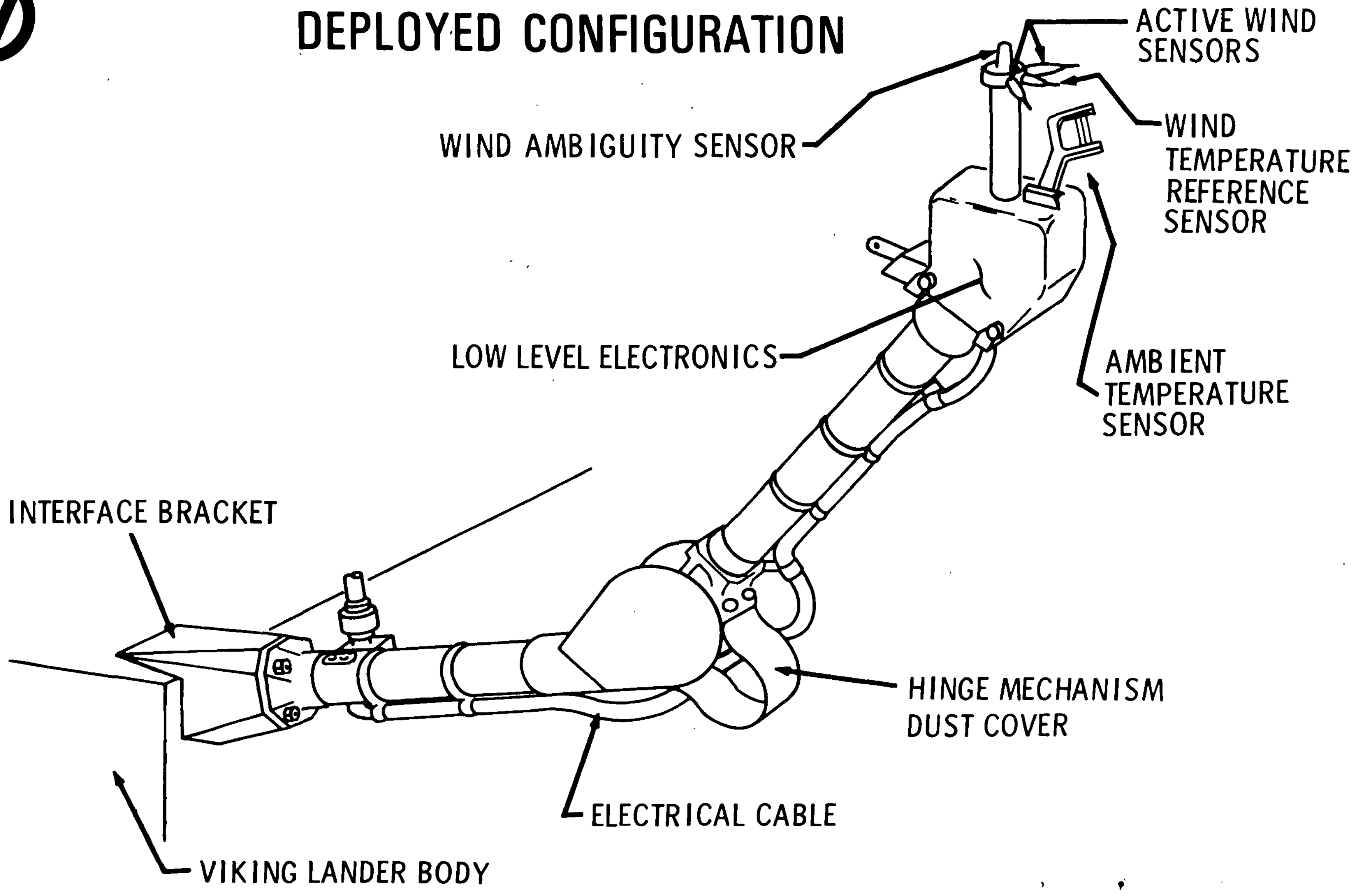
# METEOROLOGY BOOM AND SENSORS DEPLOYED CONFIGURATION



The experiment's primary wind sensors are hot-film anemometers, two glass needles coated with platinum and overcoated with a protective layer of aluminum oxide. An electric current is passed through the platinum films to heat the needles, while the wind takes away the heat. Electric power needed to maintain these sensors at a fixed temperature above the surrounding air is the measure of the wind speed.

The device measures wind speed perpendicular to its length, so two devices, mounted 90 degrees apart, are necessary to find the total wind. A third identical sensor is mounted between the two, and it is used to determine air temperature and, through automatic circuitry, control the power applied to the active sensors.

The sensors give the same readings for winds from opposite directions, so an uncertainty remains as to wind direction. This problem is solved by a quadrant sensor, an electrically heated core surrounded by four thermocouples (located every 90 degrees). Heat taken away from the core by the wind affects the thermocouples enough to eliminate uncertainty about wind direction.

The quadrant sensor can also measure wind speed, so readings are combined from the hot-film anemometers and the quadrant sensor. A sophisticated computer program produces the best available determinations of both wind speed and direction.

Air temperature is measured by three fine-wire thermocouples in parallel. They are extremely thin to quickly respond to temperature fluctuations, but this makes them more subject to being broken by blowing sand. Each of the three thermocouples can operate independently, so breakage of one or two will not be catastrophic.

The pressure sensor consists of a thin metal diaphragm mounted in a case. A vacuum is maintained on one side of the diaphragm while the other side is exposed to the atmosphere. As air pressure varies, the diaphragm moves slightly in response to the fluctuating force upon it. This movement is detected by an electrical sensor and its output is converted to a pressure reading.

The Meteorology investigation team leader is Dr. Seymour L. Hess of Florida State University.

## Seismology

The Seismology investigation will determine the level of seismic or tectonic (crustal forces) activity on Mars and its internal structure. Waves from naturally occurring Marsquakes spread throughout the planet and will be detected by seismometers on the surface.

Each Lander has miniature seismometers that will measure motion in three perpendicular directions. Two instruments, and the three-axis nature of each, allows a crude triangulation to be made to locate a seismic event. Regions of active tectonism can be identified and associated with surface manifestations of faulting.

The basic question: Is Mars a tectonically active planet or are the various surface features remnants of an earlier active period? The Earth is a tectonically active planet, primarily due to the motions of large crustal plates on its surface. Mars may be starting a phase of continental breakup or it may be a seismically dead planet. Either way, studying Mars will help scientists understand better the processes that cause quakes and plate motions in Earth.

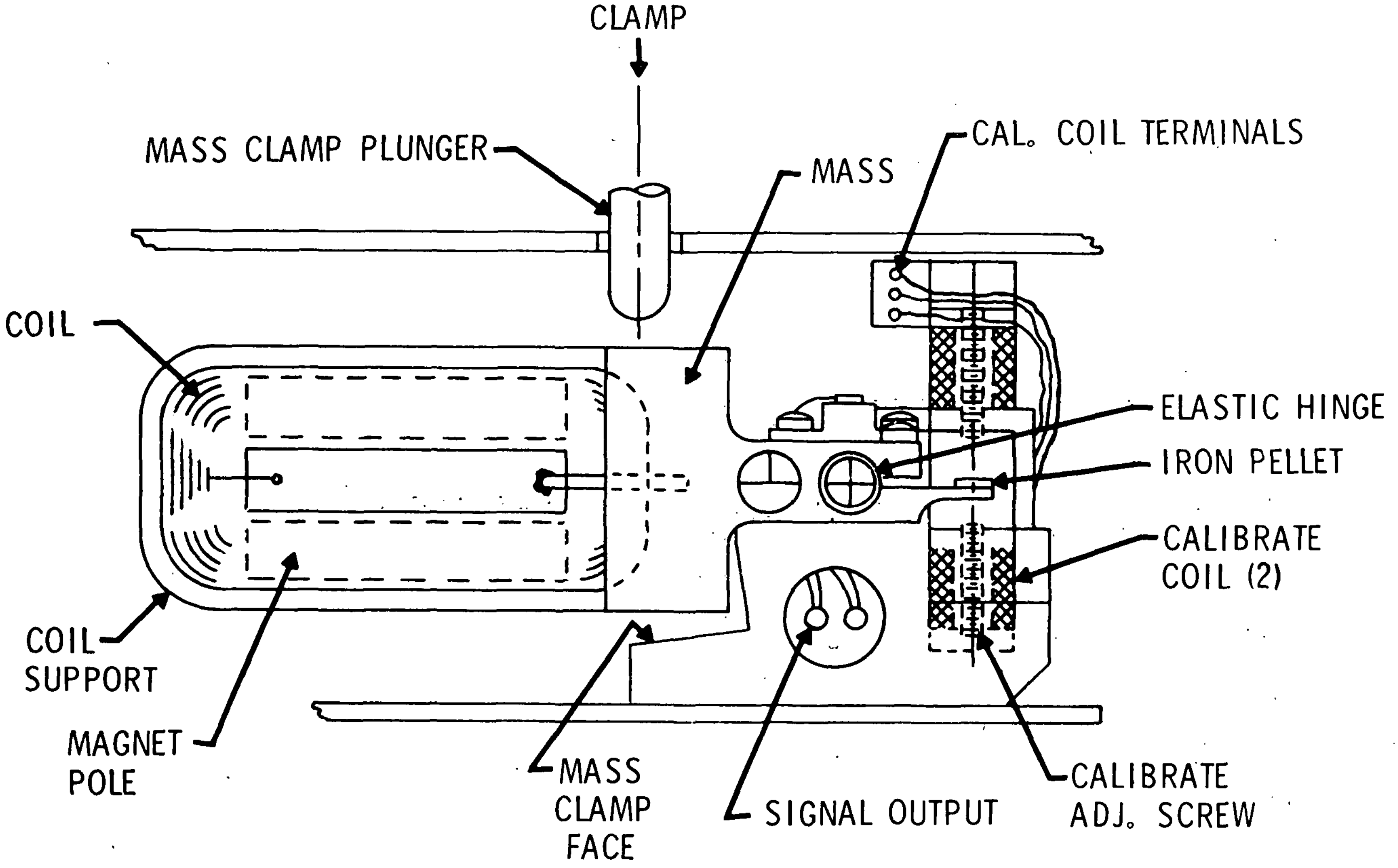
If there are abundant Marsquakes, scientists can begin to unravel the internal structure of the planet. Seismic waves are used to map deep discontinuities and to determine seismic velocities as a function of depth, and would help determine if Mars has a crust and a core like Earth. This knowledge is important in understanding Earth's early evolution and the evolution of the atmosphere.

The seismology instrument consists of an approximately cubical package, about 15 cm (6 in.) on a side that weighs about 2.3 kg (5 lbs.). In the package are three miniaturized seismometers for sensing ground motion, and electronic circuitry for amplifying, conditioning and compressing data.

The seismometers are arranged in a mutually perpendicular manner to sense the components of motion in three directions. They consist of a 20-gram (0.7-ounce) mass with an attached coil, elastically pivoted from the instrument frame on a short boom, so the coil projects into a magnet mounted on the frame. Relative motion of the coil and magnet, induced by the mass's reaction to ground motion, generates a varying voltage that is applied to the input of an amplifier.

Modes of operation may be changed by command from Earth to accommodate whatever seismic environment might be found on Mars; the modes may also be automatically cycled by internal controls.

# SEISMOMETER SENSOR SCHEMATIC



Modes include selection of various filters to determine frequency content of seismic data, or to adjust for the best possible reception of specific types of data; a low sampling rate for reading the general level of activity; a high data rate for more detailed examination of events; and a compressed, medium rate for continuous monitoring of Marsquakes. This last mode normally will be dormant, with the system operating at low rate until activated by a quake event.

Since the amount of raw data produced by the seismometer is much greater than the capacity of telemetry, data must be compressed to reduce quantity without seriously degrading quality. Normally, many samples are required for high-frequency data.

Data compression is done in two ways. First, normal ground noise (microseisms) is observed by averaging its amplitude over a 15-second period as it is passed through selectable filters. Its average amplitude and frequency content can be indicated by one sample every 15 seconds.

Second, when a Marsquake event occurs, a trigger activates a higher data rate mode that samples, not oscillations in the data, but amplitude of the overall event envelope. This varies at a much lower rate than individual oscillations and requires only one amplitude sample per second to indicate its shape.

At the same time, crossing of the zero axis by the oscillations (change in polarity of the data signal) is counted and sampled once per second. The shape of the envelope and its incremental frequency content can be transmitted to Earth with relatively few data samples and reconstructed to approximate the original event.

The Seismology investigation team leader is Dr. Don L. Anderson of the California Institute of Technology.

## Physical Properties

The Physical Properties investigation group frequently has been called "the team without an instrument." While the statement is not quite true, the investigation mainly will use available engineering data. Hardware for the investigation includes two mirrors (mounted on the surface sampler boom), stroke gauges on each Lander leg, a grid on the Lander's top, ultraviolet degradable coatings, and current-measuring circuits in the surface sampler.

Besides engineering data, selected images will be taken by the Lander cameras to determine properties of the Mars surface such as grain size, bearing strength, cohesion, and eolian transportability (how easily surface material is moved by the wind). Other properties to be examined include thermal inertia (how quickly surface temperature changes) and the ultraviolet flux levels.

The bearing strength of the Mars surface will be one of the first characteristics determined. Immediately after landing, a panoramic picture will be taken that will include the Lander's number 3 footpad and its impression in the surface. This picture, data on Lander velocity and attitude at landing, and the amount of leg stroke (compression) will be used to calculate the surface bearing strength, an important fundamental parameter. The footpad impression will also give preliminary data on the cohesion of the surface material.

Early in the landed mission, the surface sampler collector head will eject its protective shroud. Following the ejection, the camera will image the spot where the shroud hits the surface, using the boom-mounted mirror (the area under the retro-engine), and again photograph the footpad and its impression on the surface. This image will be analyzed like the one taken after landing to better define critical surface properties of bearing strength, cohesion and eolian transportability.

While the surface sampler is acquiring samples for the analytical instruments, the physical properties investigation will automatically be acquiring data by measuring the sampler motor currents and taking pictures of the surface markings generated by the sampler. Even the pile of excess sample dumped by the sampler after giving the instruments all they need will be of interest to the Physical Properties scientists.

When the sample for the Gas Chromatograph-Mass Spectrometer (GCMS) is comminuted (ground) the comminutor motor current will be recorded for analysis by the scientists to determine grain size, porosity and hardness.

The team has defined several unique experiments to better understand surface properties. These include digging trenches, examining material in the collector head jaw with the magnifying mirror, piling material on the grid atop the Lander, picking up and dropping a rock or clod on the surface, pressing the collector head firmly into the surface and using the collector head thermal sensor to measure surface temperatures.

Another very simple experiment for the Physical Properties investigation is the addition of ultraviolet degradable coatings on the camera reference test charts. These coatings darken in the presence of ultraviolet and the amount of darkening, to a certain limit, is proportional to the total amount of ultraviolet received.

The investigation will provide valuable information to complement the results of other studies, such as geology and mineralogy. Knowledge concerning the structure of the surface can be very helpful in understanding apparently conflicting data and grasping the significance of otherwise unexplainable findings.

The Physical Properties investigation team leader is Dr. Richard W. Shorthill of the University of Utah.

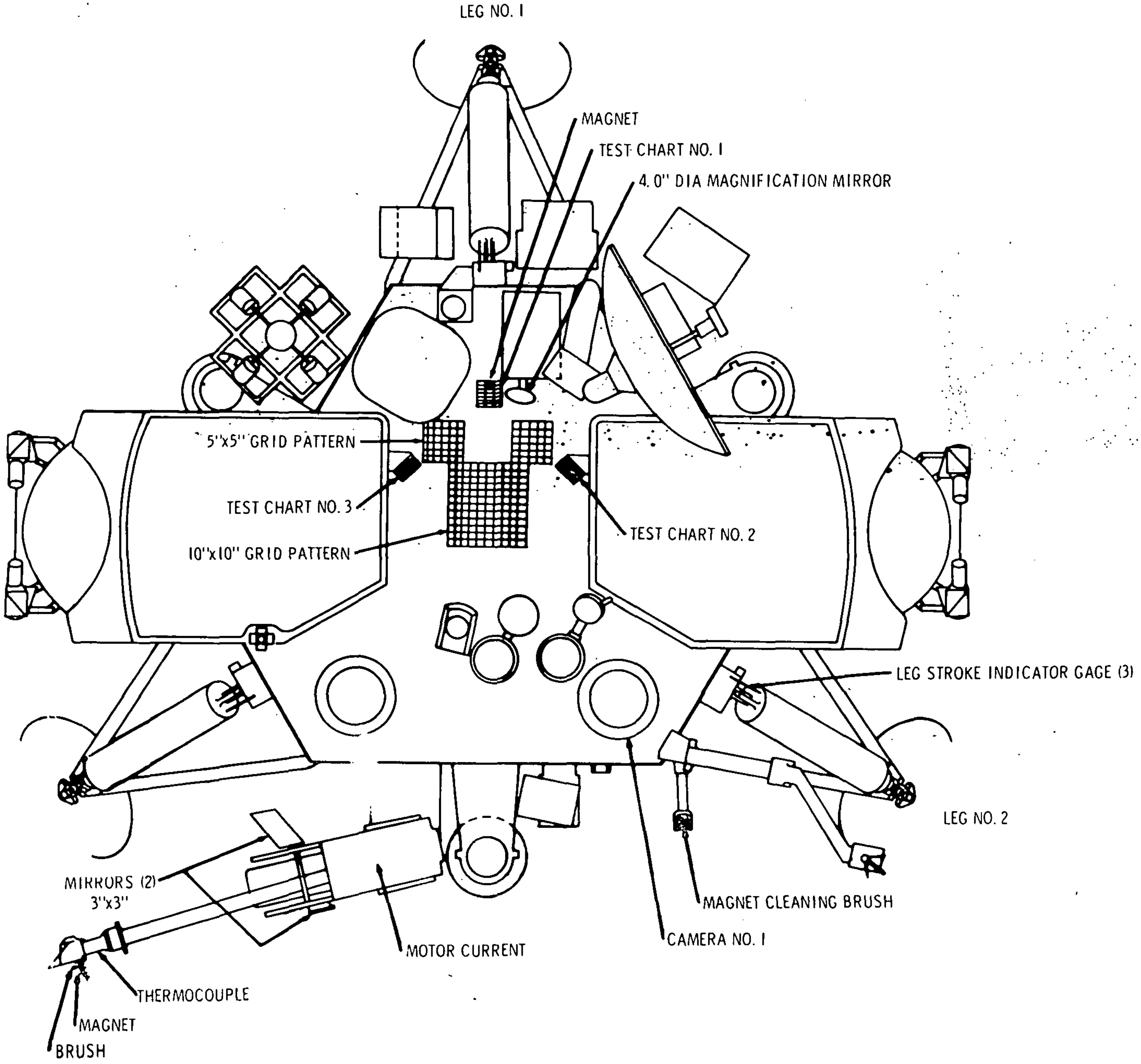
## Magnetic Properties

The Magnetic Properties investigation will attempt to detect the presence of magnetic particles in the Mars surface material, and determine the identity and quantity of these particles.

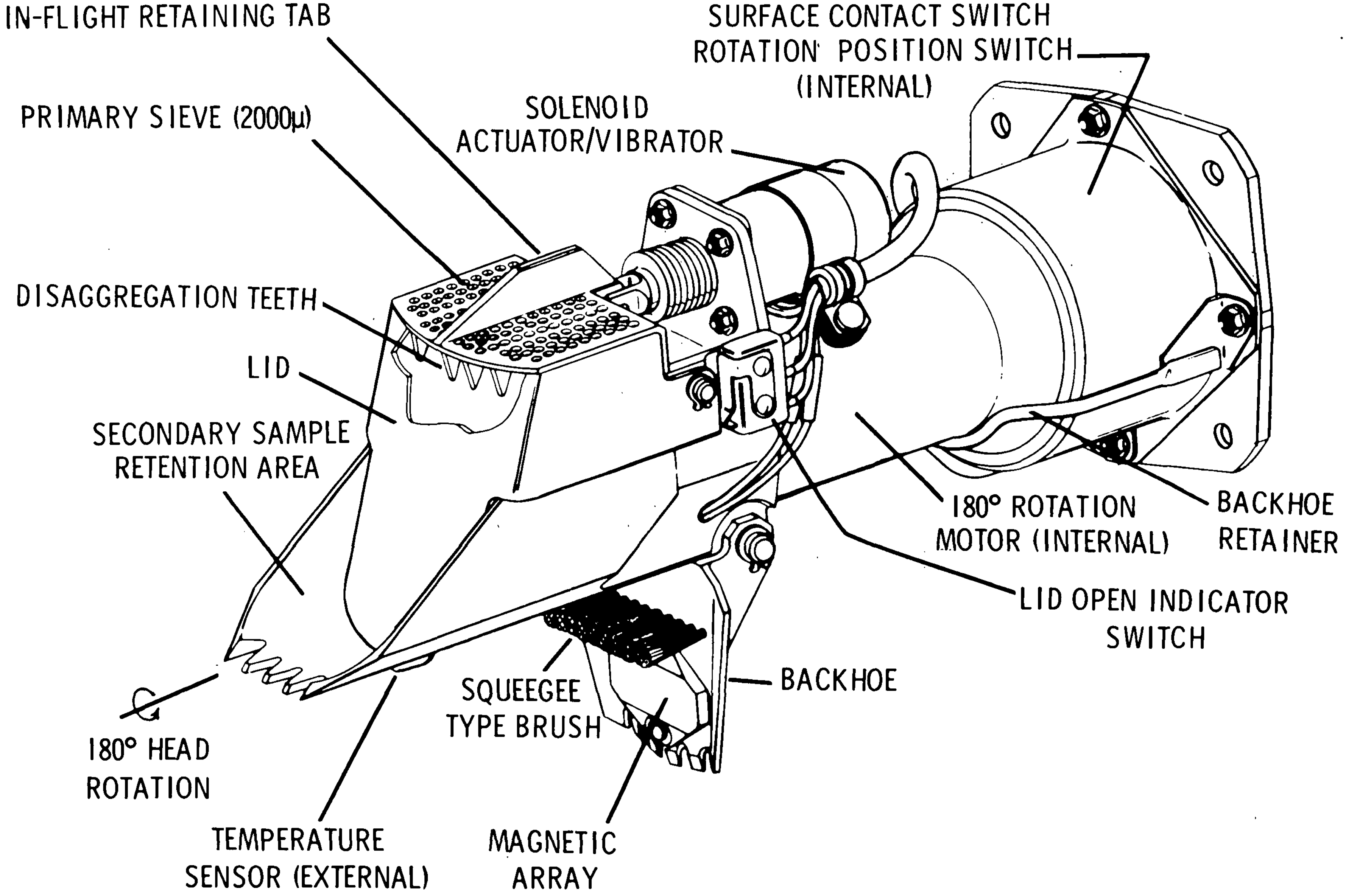
Iron in magnetic minerals is usually an accessory phase in naturally occurring rocks and surface materials on Earth, on the Moon and in meteorites. The chemical form in which this magnetic iron occurs on a planetary surface may vary from elemental metal to more complex iron compounds (i.e., ferrous oxide magnetite, highly oxidized hematite, the hydrates goethite and lepidocrocite). The abundance and chemistry of the accessory iron minerals on the surface have bearing on the degree of differentiation and oxidation of the planet, the composition of its atmosphere, and the extent of interaction between the solid surface materials and the atmosphere.

This investigation uses a set of two permanent, samarium-cobalt magnet pairs, mounted on the back of the surface sampler collector head. Each pair consists of an outer ring magnet, about the size of a quarter, with an inner core-magnet of opposite polarity. These are relatively strong magnets. (The maximum field obtained is approximately 2,500 gauss. A gauss is a unit of magnetic field intensity.)

# PHYSICAL PROPERTIES OF MARTIAN SURFACE USING ENGINEERING MEASUREMENTS



# SURFACE SAMPLER COLLECTOR HEAD DIAGRAM



The magnets are mounted at different depths from the outer surface of the backhoe to ensure a gradient in magnetic field strength.

In addition, a similar magnet pair is mounted on the photometric target atop the lander, where it will be automatically photographed when the camera system is calibrated. The magnets in this location should attract any magnetic particles that might be present in windblown dust.

In acquiring samples, the collector head will dig into the surface; and any magnetic particles will tend to adhere to the magnets. The collector head can be directly imaged with the camera system. A five-power magnifying mirror can also be used for maximum resolution in black-and-white or color. These images will be the scientific data return on which the conclusions will be based.

The Magnetic Properties principal investigator is Dr. Robert B. Hargraves of Princeton University.

## Radio Science

The objectives of the Radio Science investigation are to conduct scientific studies of Mars using the Orbiter and Lander tracking and communications systems that are required for spacecraft operations and data transmission.

Scientific uses of the systems evolved from recognition of the potential applications of the data, and developments in data analysis to extract scientific results from information contained in the radio signals.

The science investigations will provide new and improved determinations of the gravity field, figure, spin axis orientation, and surface density of Mars; pressure, temperature and electron profiles in the planet's atmosphere; and properties of the solar system.

Radio science applies the principles of celestial mechanics and electromagnetic wave propagation to relate tracking and communications systems signals to physical parameters.

The investigation has no specifically dedicated instruments except the Orbiter's X-band transmitter, which provides a dual-frequency capability on the downlink. This is unique to Viking, compared with previous Mars missions, and is especially important for the Radio Science investigations.

Radio science characteristically deals with small perterbations or changes in spacecraft orbits, deduced from tracking data analysis, and with small variations in frequency, phase or amplitude of received signals. The investigations are intimately involved with data analysis, using complicated analytical procedures and associated computer programs to determine the physical effects that produce the observed variations. Data must sometimes be collected for an extended period to produce results.

The basic tracking data consist of very precise measurements of distance (range) and line-of-sight velocity (range rate) between the spacecraft and Earth tracking stations. Range and range rate measurements are the primary data used to determine global Mars gravity field and local gravity anomalies, precise Lander locations and radii of Mars at the landing sites, spin axis (pole) orientation and motion, and the ephemerides (assigned places) of Mars and Earth. Variations in the signal and other characteristics determine Mars atmospheric and ionospheric properties during occultation experiments.

During Viking's cruise phase, properties of the interplanetary medium, particularly the total electron content and its variations, can be determined by analyses of differences in signal properties on the two downlink frequencies. From such measurements intensity, size and distribution of electron streams from the Sun and from solar storms can be studied to increase understanding of the Earth-Mars region of interplanetary space.

While the Orbiters are being gradually maneuvered to pass over the landing sites, large local gravity anomalies might be detectable in the tracking data. If such anomalies appear near the landing sites or elsewhere they will be of considerable interest with respect to the geology and internal structure of the planet.

After landing, tracking data will be used to define precise Lander locations, including the radius of Mars at these sites. Tracking is also used to define the spin axis (pole) direction, and possibly variations in the spin axis related to the global internal density distribution of Mars.

As the Orbiters rise and set with respect to the Landers, the signal amplitude received at the Orbiter on the Lander-to-Orbiter communication link is expected to vary. An attempt will be made to analyze these variations to determine dielectric properties of the regions near the Landers; these properties can be related to surface density.

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After Orbiter 1 has been in Mars orbit for about 80 days, it will be placed in a non-synchronous orbit to make a global survey of the planet. Tracking data taken near periapsis will be used to determine the global gravity field and local gravity anomalies.

Several times during the missions, Mars passes near the line-of-sight between Earth and a quasar (an intense extragalactic radio source). Radio signals from an Orbiter and the quasar will then be alternately recorded at two tracking stations at the same time. This is a very long baseline interferometry (VLBI) experiment that yields a precise measurement of the angular separation of the two sources.

With suitable data analysis, the results give the precise location of the spacecraft, Mars and Earth with respect to the fixed, inertial frame defined by the very distant quasar. By making such observations over a period of years, in various spacecraft missions, the precise orbits of Mars and Earth with respect to the inertial frame can be determined. One application of such information is to determine the relativistic advance of the perihelion of Mars, providing a test of the general theory of relativity.

In October 1976 Orbiter 1 passes behind Mars, as viewed from Earth, during a portion of its orbit. The spacecraft signals are gradually cut off or occulted, by the planet. Variations in signal properties (frequency, phase and amplitude) as the spacecraft enters or emerges from occultation are used to infer atmospheric and ionospheric properties. Occultations for Orbiter 2 start in January 1977.

Mars and Earth will be in conjunction Nov. 25, 1976. As the planets approach conjunction radio signals from Viking spacecraft pass closer and closer to the Sun and are gradually more affected by the solar corona, particularly the electron content.

Signal variations, again measured with the dual frequency downlinks, will yield new information on the properties of regions close to the Sun, including the characteristics of any timely solar storms (Sun spots) or high activity events. Spacecraft signals are also affected by the intense gravitational field of the Sun, so a precise solar gravitational time-delay test of general relativity theory will be done in the conjunction time period.

Tests to resolve small differences in the Einstein formulation of general relativity, as compared with more recently proposed formulations, can have an important impact on fundamental physical laws and on studies of the Universe's evolution.

The Radio Science investigation team leader is Dr. William H. Michael, Jr. of Langley Research Center, Va.

## VIKING SCIENTISTS

The Viking scientists represent an outstanding cross-section of the scientific community. They were selected from universities, research institutes, NASA centers and other government agencies.

The scientists are divided into investigation teams, each headed by a team leader or principal investigator. The teams are led by a Science Steering Group, consisting of a chairman, vice chairman, the leaders of each team and two other members.

The scientists have worked closely with Viking engineers in designing the science instruments. Considerations of weight, power, data constraints and the necessary flexibility of the investigations were developed through cooperation between the two groups.

Team leaders are listed first in each group.

### Science Steering Group

Dr. Gerald A. Soffen, Chairman, Langley Research center, Hampton, Va.
Dr. Richard S. Young, Vice Chairman, NASA Headquarters, Washington, D.C.
A. Thomas Young, Langley Research Center
Dr. Conway W. Snyder, Jet Propulsion Laboratory, Pasadena, Calif.

### Orbiter Imaging

Dr. Michael H. Carr, U.S. Geological Survey, Menlo Park, Calif.
Dr. William A. Baum, Lowell Observatory, Flagstaff, Ariz.
Dr. Geoffrey A. Briggs, Jet Propulsion Laboratory
Dr. James A. Cutts, Science Applications, Inc., Pasadena
Harold Masursky, U.S. Geological Survey, Flagstaff, Ariz.

### Orbiter Water Vapor Mapping

Dr. C. Barney Farmer, Jet Propulsion Laboratory
Dr. Donald W. Davies, Jet Propulsion Laboratory
Daniel D. La Porte, Santa Barbara Research Center, Goleta, Calif.

## Meteorology

Dr. Seymour L. Hess, Florida State University, Tallahassee
Robert M. Henry, Langley Research Center
Dr. Conway Leovy, University of Washington, Seattle
Dr. Jack A. Ryan, McDonnell Douglas Astronautics, Huntington Beach, Calif.
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## Inorganic Chemistry

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Harry J. Rose, Jr., U.S. Geological Survey, Reston, Va.

## Seismology

Dr. Don L. Anderson, California Institute of Technology
Fred Duennebier, University of Texas Medical Branch, Galveston
Dr. Robert A. Kovach, Stanford University
Dr. Gary V. Latham, University of Texas, Galveston
Dr. George Sutton, University of Hawaii, Honolulu
Dr. M. Nafi Toksöz, Massachusetts Institute of Technology

## Physical Properties

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Dr. Henry J. Moore II, U.S. Geological Survey, Menlo Park
Dr. Ronald F. Scott, California Institute of Technology

## Magnetic Properties

Dr. Robert B. Hargraves, Princeton University, Princeton, N.J.

## Radio Science

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Dan L. Cain, Jet Propulsion Laboratory
Dr. John G. Davies, University of Manchester, England
Dr. Gunnar Fjeldbo, Jet Propulsion Laboratory
Dr. Mario D. Grossi, Raytheon Co., Sudbury, Mass.
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*Associates

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Dr. Stillman C. Chase, Santa Barbara Research Center
Dr. Ellis D. Miner, Jet Propulsion Laboratory
Dr. Guido Munch, California Institute of Technology, Pasadena
Dr. Gerald Neugebauer, California Institute of Technology

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Dr. William B. Hanson, University of Texas, Dallas
Dr. Michael B. McElroy, Harvard University, Cambridge, Mass.
Alvin Seiff, Ames Research Center, Mountain View, Calif.
Nelson W. Spencer, Goddard Space Flight Center, Greenbelt, Md.

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Dr. Alan B. Binder, Science Applications, Inc., Tucson, Ariz.
Friedrich O. Huck, Langley Research Center
Dr. Elliott C. Levinthal, Stanford University, Palo Alto, Calif.
Dr. Sidney Liebes, Stanford University
Dr. Elliot C. Morris, U.S. Geological Survey, Flagstaff, Ariz.
Dr. James A. Pollock, Ames Research Center
Dr. Carl Sagan, Cornell University, Ithaca, N.Y.

## Biology

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Dr. Norman H. Horowitz, California Institute of Technology
Dr. Joshua Lederberg, Stanford University
Dr. Gilbert V. Levin, Biospherics, Inc., Rockville, Md.
Vance I. Oyama, Ames Research Center
Dr. Alexander Rich, Massachusetts Institute of Technology,
Cambridge, Mass.

## Molecular Analysis

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Dr. DuWayne M. Anderson, Polar Programs Office, National
Science Foundation
Dr. Alfred O. C. Nier, University of Minnesota, Minneapolis
Dr. Leslie E. Orgel, Salk Institute, San Diego, Calif.
Dr. John Oró, University of Houston, Tex.
Dr. Tobias Owen, State University of New York, Stony Brook
Dr. Garson P. Shulman, Casa Loma College, Pacoima, Calif.
Dr. Priestly Toulminn III, U.S. Geological Survey, Reston, Va.
Dr. Harold C. Urey, University of California at San Diego,
La Jolla, Calif.

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# VIKING PLANETARY OPERATIONS

## Approach Phase

Ten days before Viking 1 is scheduled to enter orbit around Mars, a final course correction is made. This approach midcourse correction (AMC) consists of a small change in velocity and direction to ensure that the Mars Orbit Insertion (MOI) maneuver, scheduled for June 19, results in an orbit that permits coverage of the prime landing site (A-1). The orbit will be adjusted as required after MOI.

MOI instructions, sent to the spacecraft computer one day after AMC, will enable Viking to enter Mars orbit even if no further commands can be sent before MOI. This safeguard is essential because Viking has only one opportunity to enter Mars orbit. If this is missed, the spacecraft would fly by the planet and continue on its orbit around the Sun.

The commands tell the Orbiter how to orient itself so its rocket engine can thrust in the right direction, how long the engine must thrust, and how the Orbiter is to be reoriented after engine firing is completed.

Radio signals are used during approach to determine the precise path of the spacecraft after AMC so it can be commanded into the correct orbit by the MOI maneuver.

Instructions for MOI can be updated five days before the maneuver takes place to allow the use of additional radio-derived navigational data to refine the velocity change and spacecraft orientation needed to enter the required Mars orbit. A final correction, based on optical navigation with the Orbiter TV cameras, can be made about 16 hours before MOI.

Five days before MOI, Viking starts optical navigation and science experiments directed to Mars. TV images are obtained of the whole disc of Mars, of star fields and of Deimos, one of two moons of Mars. Infrared scans of the planet give gross determinations of surface temperatures and concentrations of water vapor in the atmosphere in preparation for more precise measurements to come.

The science experiments are made during final approach because:

- Instruments can be calibrated for the first time with Mars as a target.

- Some scientific measurements can only be made at this time, such as color pictures of the full disc; later Viking will be too close to Mars.
- Observations of Mars, Deimos and the star background provide final, precise navigational data for an accurate MOI.
- Look for changes in markings and present condition of the planet.

Eight images (frames) of the Mars disc are taken June 14, using red and violet filters. The first optical navigation pictures are obtained June 15 by the two Orbiter TV cameras, alternately photographing Mars and a star background. Alternate cameras are used because of the great difference between exposures needed for Mars and for the stars. Since the axes of the cameras are precisely known, the position of Mars in the image from one camera, and the positions of stars in the image from the other, can be accurately related.

During the approach to Mars, science data are roughly equivalent to data expected during a flyby of the planet. This science will supplement earlier observations made by Mariners 6 and 7 in 1969. The approach of Mariner 9 to Mars orbit in 1971 did not provide such science coverage because the planet was shrouded in a global dust storm.

The approach pictures of Mars will show the planet's rotation on its axis. Some pictures are repeated in three colors for later reconstruction. These initial color pictures should show Mars free of major dust storms; at MOI the planet is close to aphelion (greatest distance from the Sun), and global dust storms are observed to take place around perihelion (closest distance to the Sun). The pictures will not show a full disc because Viking is approaching Mars in such a way that its cameras see the planet in a half-moon phase, a view of Mars that can never be obtained from Earth.

The picture sequence, extending from 50 to 24 hours before MOI, will gradually change from views of Mars similar to those seen by the best Earth-based telescopes to views that show craters and a wealth of surface detail, including a first look by Viking at the landing sites.

A similar picture sequence is repeated by Viking 2 as it approaches Mars seven weeks after Viking 1, providing valuable science information about large-scale changes on the planet in the period between arrival of the two Vikings.

Fifteen days before MOI, the Infrared Thermal Mapper (IRTM) instrument will be aligned and calibrated. In the final day before MOI, the IRTM does low resolution thermal mapping of the Martian surface. Five days before MOI the Mars Atmosphere Water Detector (MAWD) will make a first scan of the planet and repeat a similar scan each day. The best water vapor data are obtained within the period one and a half days before MOI, when several scans are made.

## Mars Orbit Insertion

The June 19 MOI maneuver places Viking 1 in an orbit that later requires only minor corrections to permit the Lander to touch down in the prime landing site. MOI is a critical event, but it is based on experience with only one earlier spacecraft put in orbit about Mars -- Mariner 9 -- plus experience gained orbiting the Moon in the Lunar Orbiter program.

The spacecraft is first rolled, then yawed, then rolled again to facilitate alignment of its high-gain antenna toward Earth. This maneuver will maintain good communications while the spacecraft is in a burn attitude at its great distance, 380 million km (236 million mi.), from Earth.

No science experiments take place during MOI, but engineering data continue to flow to Earth, except during the brief period between the two roll maneuvers, when communications are interupted as the high-gain antenna points away from Earth.

The resumption of telemetry data to Earth will indicate that Viking has oriented itself for its engine burn. First indication of a successful burn is an abrupt change in a graph, displayed on screens to mission controllers, showing that the trajectory has changed. After the MOI burn, the spacecraft reorients itself, ready to begin its science investigations in orbit.

## Pre-Landing Orbital Activities

After Viking achieves orbit around Mars, it conducts three major activities:

- Certifies the landing sites.
- Navigates to the site chosen for Lander 1.
- Checks the Lander and updates its computer with commands to automatically descend to the Mars surface and begin its mission even without further commands from Earth.

There are only 15 Earth days from MOI (June 19) to the scheduled Lander separation from the Orbiter (July 4). Landing site certification is of highest priority, accomplished with the Orbiter science instruments and supplemented by radar data obtained from Earth-based observations.

## Landing Sites

The landing site for Viking 1 was selected several years ago, based on Earth observations and Mariner 9 photography. A panel of geologists and other scientists picked four sites: two prime and two backup. They were selected to provide two geological types of Martian surface for sampling, to provide unobstructed areas for meteorology and to be at low altitudes, where atmospheric pressure is great enough to help landing and where there is a possibility of liquid water.

The sites were also chosen in areas of Mars that appear to provide a varied opportunity to study the planet's evolution and where the Landers may be expected to observe Marsquakes. They had to be between 25 degrees south and 50 degrees north latitude, at locations where there are only gentle slopes with few large protuberances and surface rocks, and where winds are expected at less than 99 km per hour (160 mph).

Viking 1 is aimed for a landing site at 19.5 degrees north latitude and 34 degrees west longitude, in a region called Chryse.

The southern half of the Chryse area consists mostly of deeply dissected plateaus, possibly of volcano-deposited material. Much material from this area seems to have been swept northward along well-defined channels to a low area of only slight relief, where Viking 1 will land. Scientists believe the surface at this site is partially covered by wind-transported dust deposits. There may also be material washed from the canyons and interspersed with dust layers. This site is within a region where water may have flowed copiously in the past.

The second Viking is targeted to land farther north in an area called Cydonia, a flat stretch of the northern basin plains. Known as prime site B, this site is 44.3 degrees north latitude and 10 degrees west longitude.

The area consists of smooth and mottled rolling plains, possible basalt flows covered by wind-borne debris, volcanic dust and water-borne sediments. It is on the eastern side of the Mare Acidalium, where the plains units of the Martian northern lowlands abut the higher equatorial plateaus and hills. There may be volcanic cones and lava flows in the area, and wind- and water-borne debris.

The prime B site is inside a band around Mars between latitudes 40 and 55 degrees north. In this band liquid water may be present for a period of time during the summer. Life might briefly flourish each Martian year, taking its water from the soil as permafrost melts into liquid.

Both prime sites have backup sites if the prime sites are rejected after observations from orbit. The backup to site A is in a region known as Tritonis Lacus at 20 degrees north latitude and 252 degrees west longitude. The backup to site B is in the Alba region at 44.2 degrees north latitude and 110 degrees west longitude.

All four sites are in a variety of plains in the northern lowlands, comparable to Earth's ocean floor basins, close to the margins of the Martian continents. The A sites are where the highlands drained, so samples there should provide regional highland material. The B sites are in low flat basins. This combination gives the best possibilities for fossil and present water, and the best samples to test theories about Mars' evolution.

TV images obtained by Viking from orbit will not have significantly better resolution than Mariner 9 pictures. They can only show details of the surface larger than about 83 m (250 ft.), although the theoretical limit with the optimum contrast is 40 m (130 ft.).

Another problem is that Earth-based radar cannot look at the Chryse site until just before landing. Less powerful radar looked at the area in 1967 and showed that the A site and its backup have different radar characteristics.

The 64-m (210-ft.) Deep Space Network antenna at Goldstone, Calif., bounces radar echoes from the prime A region May 29 through June 12, and from the backup A region from May 11 to June 15. A larger antenna at Arecibo in Puerto Rico also examines the sites. The Goldstone antenna works at X-band and the Arecibo antenna at S-band frequencies.

The surface of Mars is about five times as rough as that of the Moon, in both major elevations from place to place on Mars and in small-scale surface effects revealed by radar reflectivity. There appears to be no conclusive match between radar results and pictures from orbit, but recent studies reveal some connection between the two methods of observation. Plains areas that show extreme radar scattering are believed to have large slopes at sizes below the resolution of optical images. Some of these rough plains could be sand dunes, since radar experiments that look down at Earth show similar scattering from dune fields. The decrease in returned signal power is about the same from terrestrial sand dunes as from Mars' rough plains.

New processing methods have been devised for Viking so radar data can be interpreted quickly enough for use in the site certification process.

Radar probing of the sites must wait until just before the arrival of Viking at Mars because the planet's position in its orbit and the tilt of its axis did not earlier allow the landing sites to face directly toward Earth so a radar echo could be received.

The prime landing site that seems safest and of high scientific priority, based on preliminary analysis, is at the mouth of the big channel system of Mars. The channels appear to have been formed by running water, and material at the mouth should represent material gouged from the highlands to the south. The site provides a good place to search for complex organic molecules and to look for both wind and water modifications to the Martian terrain.

No landing site appears completely free of hazards. The site certification task is to compare all data and try to minimize hazards to the Landers. As with the Apollo missions, there is likely to be site adjustment as the Viking missions unfold, especially for the second landing.

## Site Certification

The first of a series of tests to calibrate the Orbiter cameras begins June 20. The cameras are tested in producing stereo pictures of the surface at close range while the Orbiter is near periapsis and the Chryse landing site. The pictures include views looking forward, toward the landing site, and backward after passing over the site to provide good stereo pairs. If the first orbit after MOI is close to the desired orbit, these pictures should include the A site in their fields of view.

After MOI, Orbiter activities are timed in relation to orbital revolutions which are counted from the first periapsis.

Revolution 1 is devoted to acquiring test data on the cameras and some infrared observations of the surface, globally and at the Chryse site.

Revolution 2 is assigned to orbital corrections.

Revolution 3 concentrates on photography of the Chryse site, to provide a quilt-like pattern of slightly overlapping pictures of the surface to cover an area that includes the region around the site. The Revolution 3 photo series will provide basic data for site certification.

Revolution 4 concentrates on stereo coverage of the Chryse site, which is in late afternoon, Mars time. The angle of sunlight on the surface at the site is not small enough to produce long shadows that would show surface irregularities in sharp relief, but geologists anticipate that they will be able to determine from these pictures whether the surface is too rough for landing.

Revolution 5 is reserved for a second orbit trim maneuver.

Revolution 6 is used to extend the coverage of Revolution 4. North of the chosen site the surface is believed to develop into sand dunes.

Revolution 7 -- Infrared observations and a set of high altitude pictures of the landing site will be taken.

Revolution 8 repeats the stereo coverage of Revolution 4. All necessary camera data have now been gathered for site certification. The cameras are then used daily until Lander separation to monitor surface conditions and to particularly check for evidence of wind and dust storms.

Variable surface features, such as dust tails downwind of obstructions might be used as natural windsocks to reveal wind direction and intensity about the landing site. Watch is kept for Martian "dust devils" and development of local dust storms. If serious wind or dust conditions develop at the site, the landing will be delayed.

Thermal infrared maps of the surface are made on each available revolution for more than half the orbital period. IRTM mapping includes:

- High altitude, low-resolution scanning maps over the whole planet.
- Intermediate altitude, better resolution scanning maps that slowly fill in details of the whole planet during several revolutions.
- Low altitude (near periapsis), highest resolution maps obtained with a fixed pointing of the IRTM so the spacecraft's motion carries the track across the planet's surface.

During the first 14 days after MOI, infrared mapping is directed toward site certification. During the first few revolutions, the IRTM obtains representative observations in the general area of the Chryse site to provide basic information about the surface at several different wavelength bands.

On revolutions 4 through 8 detailed observations are made of the landing site and its surrounding area to ascertain how surface thermal properties vary around the site. When the Orbiter is over the landing site and obtains the best infrared resolution, the time is Mars sunset.

The IRTM will also measure and monitor the temperature of the Mars stratosphere each day, typically at an altitude of 20 km (12 mi.). A box scan on Revolution 3 will determine the atmospheric stability above the landing area. This type of survey continues until one day before separation.

Water vapor information is not critical to site certification, but the MAWD instrument obtains data before separation. Scans of the planet on Revolution 1 at different wavelengths seek to confirm the spectrum of water vapor. The MAWD then takes a detailed look at water vapor concentration above the Tharsis-Coprates area, with highest resolution obtained over the Chryse site. These observations continue until separation to establish the diurnal variation of water vapor in the atmosphere of the landing area.

Lander 1 will land at prime site A unless something negative is revealed by site certification observations from orbit and from Earth. Radar data are augmented by Earth-based optical telescopes that keep close watch on Mars to check for major dust storms. This planetary patrol activity began months before Viking's approach to Mars.

A series of three orbit trim maneuvers can take place between MOI and Lander separation. The first takes place at periapsis on Revolution 2 to remove an error in the orbit period and to synchronize the Orbiter period with the rotation period of Mars. The trim also adjusts the orientation of the orbit, if required, so its periapsis point in space is directly over the landing site.

A second trim maneuver, if required, can take place on Revolution 5 to further adjust the orbit period and orientation. A third small maneuver can take place on Revolution 10, at periapsis, to correct the periapsis altitude and fine-tune the orbit period to the exact timing required for landing.

## Pre-Separation Activities

About 36 hours before the scheduled separation (on Revolution 13), a set of commands is transmitted from Earth to the Orbiter. It consists of a navigational instruction to the Lander to enter the Martian atmosphere and reach the surface at the landing site.

The set of commands is also transmitted to the Martin Marietta Aerospace plant in Denver, where it is used in a computer to fly a test version of the Lander. This computer simulation will insure that there are no mistakes in the command sequence.

Thirty hours before separation, Lander switches on its power systems. A five-hour pre-separation Lander checkout then takes place, similar to ones made before Viking was launched and one made during cruise in November 1975. The Orbiter then recharges the Lander batteries.

Engineers on Earth analyze all telemetered data from the Lander checkout to make sure everything is functioning correctly. Navigation calculations are made to double-check the Orbiter's elliptical orbit and the landing trajectory for the Lander. At nine and a half hours before separation, command instructions within the spacecraft can be modified if necessary.

A final opportunity to update the instructions and refine the landing sequence is available three and a half hours before separation. This is a backup in case modifications fail to get to the spacecraft at the nine-and-a-half-hour transmission. About one and a half hours before separation, the Lander is again powered up, ready for separation.

## Separation

Separation is scheduled for 3:20 p.m. PDT* July 4. The separation sequence is fully automatic, but the Orbiter must receive a "go" signal from Earth before the sequence can be initiated. If the signal, transmitted about 45 minutes before separation time, doesn't get to the spacecraft, the separation cannot be executed and the landing is aborted. The landing cannot be attempted again for five days, the time required to repeat the Lander pre-separation checkout and give the spacecraft a new descent trajectory and for Lander temperatures to stabilize.

At separation, pyrotechnic devices fire to release the Lander from the Orbiter, and springs push the two craft apart. The Lander then orients itself for its de-orbit engine firing.

The Lander's three small attitude control engines burn for about 20 minutes to decelerate it from its orbit, and it begins a three-hour coast toward entry of the Mars atmosphere.

## Entry Phase

After its de-orbit burn, the Lander coasts along its descent ellipse, telemetering data in short bursts through the Orbiter, which transmits them to Earth at a four-kilobit rate.

Midway along the descent path, the Lander executes a command to change attitude under gyro control. It rolls through 180 degrees to expose its base cover to solar ultraviolet rays to sterilize it. The cover will be jettisoned and falls to the Mars surface. The roll makes sure no terrestrial life forms are carried there. (The Lander was sterilized before launch, then kept free of contamination within its aeroshell.)

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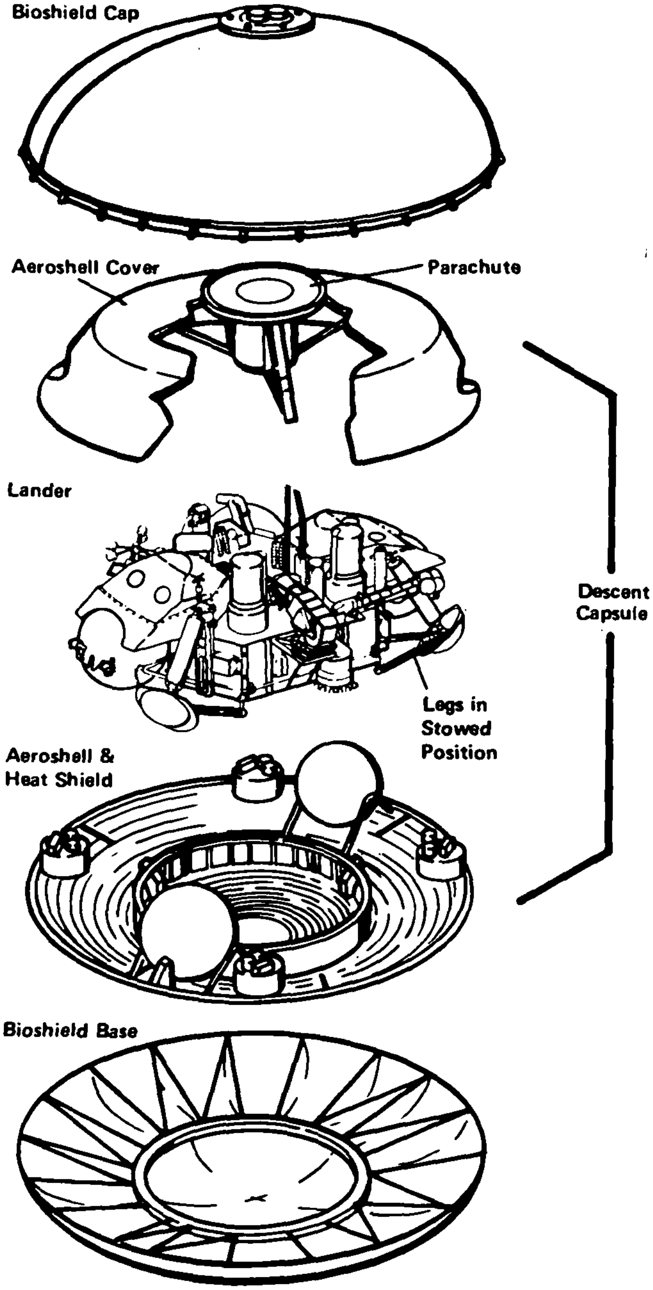
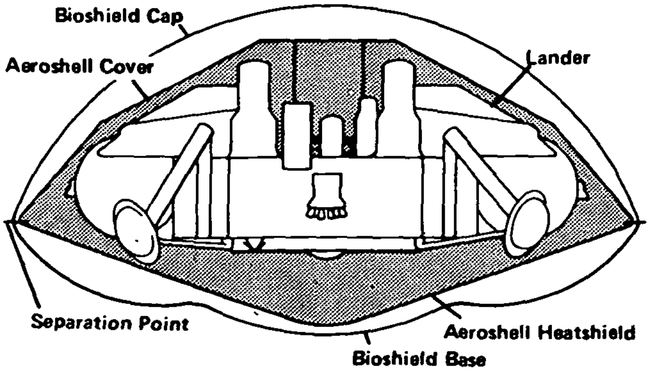
*Plus 18 minutes transmission time from Mars to Earth.


Bioshield Cap
Aeroshell Cover
Parachute
Lander
Descent Capsule
Legs in Stowed Position
Aeroshell & Heat Shield
Bioshield Base


Bioshield Cap
Aeroshell Cover
Lander
Separation Point
Aeroshell Heatshield
Bioshield Base

Six minutes before entering the atmosphere, commands orient the Lander for its encounter with the rarefied upper atmosphere of Mars. The x-axis is aligned so the Lander has a minus 20 degree angle of attack, need for scientific purposes. Just before entry into the upper atmosphere, at about 30.5 km (100,000 ft.), a programmed pitch places the Lander in a minus 11 degree orientation. Aerodynamic forces coupled with an offset center of gravity then cause the spacecraft to maintain this angle of attack.

In this attitude the Lander experiences a lift so it does not plunge too steeply and overheat. As soon as the atmosphere decelerates the Lander by 0.5 gravity force (sensed by an onboard accelerometer), the pitch/yaw attitude control is disabled, and control now concentrates on damping pitch or yaw motions to prevent any aerodynamic instabilities.

The Lander continues to be slowed by atmospheric drag, and its aeroshell prevents entry heat from penetrating the Lander. Entry velocity of 16,500 kmph (10,300 mph) is gradually reduced until, at six km (20,000 ft.) above the surface, the Lander has slowed to about twice the speed of sound.

A supersonic parachute is now deployed to further slow the Lander to about 220 kmph (135 mph) at an altitude of 1.2 km (4,000 ft.). The aeroshell is jettisoned just after parachute deployment, and the Lander's legs are extended.

Three throttleable, terminal descent engines (TDE) are started and, once idling correctly so they can control Lander attitude, the parachute is jettisoned. Parachute deployment and start of the TDE is controlled by an altimeter aboard the spacecraft.

The Lander continues toward the surface, using its TDE to further slow its speed and maintain its attitude. The engines orient the Lander so their combined thrust vector opposes the spacecraft's velocity vector and the terminal descent phase can begin.

Two limiting altitude/velocity profiles in the Lander computer are permissible limits of velocity at each altitude, based on the amount of Lander propellant and the thrust capability of the TDE.

If the Lander enters its descent phase under conditions of no wind, its computer allows it to "coast" to the upper contour of altitude versus velocity, then follow this contour to the surface as a pilot follows a glide path indicated by his airplane instruments. If there is wind, the Lander follows a contour that is an interpolation between the two limits, as a pilot adjusts for a cross-wind.

Either way, the Lander reaches a height of about 16.8 m (55 ft.) above the surface with a remaining velocity of 8.8 kmph (5.5 mph) and continues to the surface at this terminal velocity. As soon as a sensor on any of the three landing leg footpads touches the surface, the TDE are switched off.

## Entry Science

The Lander begins its science investigations of Mars while in its entry phase. Its science instruments will investigate the upper atmosphere and ionosphere for three categories of experiments:

- Electrical properties of the ionized or electrically charged upper atmosphere.
- Constituents of the neutral atmosphere, including details on the quantity of argon in the atmosphere, an important measurement for later experiments on the surface.
- Temperature, pressure and density profiles of the atmosphere from high altitudes down to the surface.

An instrument called a Retarding Potential Analyzer (RPA), located in the Lander aeroshell, will measure the temperature of ions in the atmosphere, and is expected to detect low-energy ionospheric electrons and high-energy solar wind electrons.

Constituents of the neutral atmosphere will be observed with an Upper Atmosphere Mass Spectrometer (UAMS), which identifies atoms and molecules in atmospheric gases. Previous experiments suggest that the neutral atmosphere of Mars is predominently carbon dioxide, with minor constituents of carbon monoxide and oxygen. There could be as much as five per cent nitrogen, and there may be inert gases such as argon.

The argon question is important, and its solution has top priority during entry. Indirect evidence from a Soviet spacecraft revealed the possibility of a large amount of argon in the Mars atmosphere. The Soviet Mars 6 carried a mass spectrometer that was opened during parachute descent to sample the Martian atmosphere in regions of relatively high pressure. The mass spectrometer had to be evacuated of gas to operate, and its sputter ion pumps used the principle of gettering (introducing a substance into a partial vacuum to combine with residual gas and increase the vacuum) with titanium. This process does not work if there are rare gases present such as argon, because they do not enter into chemical reactions and cannot be taken from a pump by titanium gettering.

The Soviets did not obtain the expected pumping of their instrument, so they concluded that a rare gas must be present in large quantities in the atmosphere to block operation of the pump. They concluded that argon is the most likely gas.

The effect of argon on the GCMS instrument, designed to sample the Mars atmosphere and later make organic analysis of the soil, could be disastrous. This instrument has a pump that would be made ineffective by a high concentration of argon.

The original plan for the GCMS was that it complete its atmospheric analyses before making organic analyses. This insured that the instrument would not be contaminated by organic soil samples before it sampled atmospheric gases. If argon is present in substantial quantities in the atmosphere, however, the GCMS plan must be changed.

The UAMS instrument, fortunately, is very sensitive to argon, and it should easily detect the several isotopes of this element.

The amount of argon will be determined within a few hours after landing. The other science questions will not be answered until returned data have been thoroughly analyzed.

The third important entry experiment category is determination of the profiles of temperature, pressure and density of the atmosphere as a function of altitude above the surface. Direct measurements will be made by pressure and temperature gauges on the Lander, and indirect measurements will be made from deceleration of the Lander as it plunges through the atmosphere.

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Drift of the Lander during descent of its parachute and mean wind velocity will be measured by the terminal descent landing radar (TDLR). An accelerometer on the Lander will help determine the planetary radius at the landing site to within 17 to 170 m (56 to 560 ft.), better than radar measurements from Earth. An entry pressure measuring instrument can measure surface pressure and determine the true elevation of the Chryse landing site, which is about three km (10,000 ft.) below the mean surface level of Mars.

## Touchdown

Touchdown on Mars is scheduled for 6:40 p.m. PDT July 4 (plus 18 minutes transmission time), but the time could vary by five minutes either way. If the landing is delayed, the landing time will change by about 36 minutes later each day of delay.

Sol 0. (Each Sol, or Mars day, is 24.6 Earth hours long.) The first midnight at the landing site after touchdown is the beginning of Sol 1.

No single display light will signal touchdown, but a quick series of automatic actions takes place within the Lander during the first 12 seconds after touchdown. Occurrence of these events will be received by several data displays or communication network announcements. First signals of a safe landing will include:

- Change of the Lander-to-Orbiter data rate from four to 16 kilobits per second. The change would not occur if the landing was hard.
- Display of a data bit called ENABLET. It is off all through descent, and within one second of a good landing it automatically goes on. This indicates that Viking has made a soft landing, that the footpad switch has closed and that a signal has been passed to the computer to start the landed sequence.
- Display of the word ENGON, indicating status of the TDE heaters. ENGON is on during descent, but the heaters are turned off as soon as a footpad switch is closed by landing. If a disastrously hard landing occurs, the engines might be switched off by a switch closure, but the closure would probably not also pass its signal through the computer to turn off the heaters.

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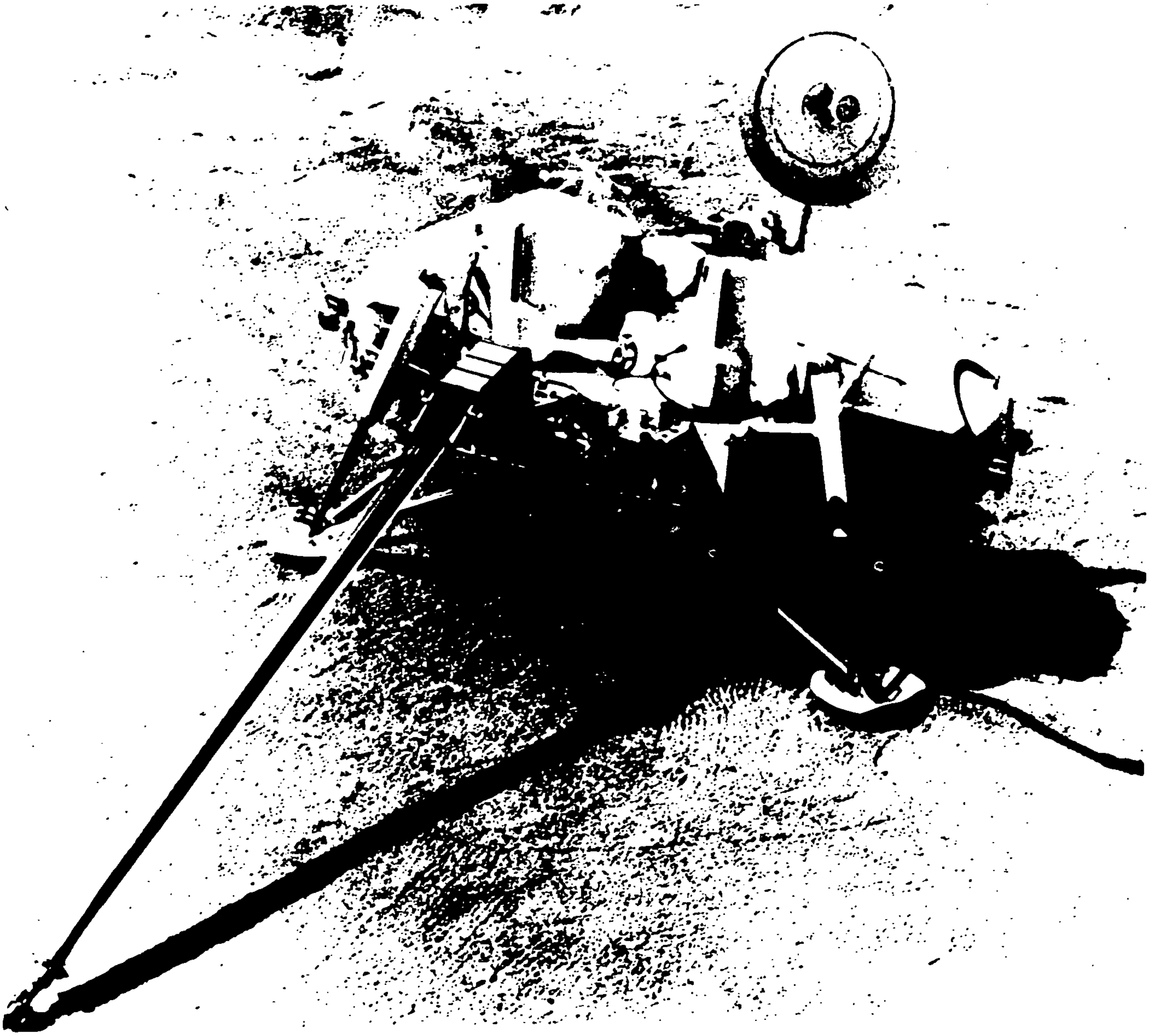

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- Display of voltage and current of the Lander bus. Current drawn is significantly reduced immediately at landing because all equipment used for descent is suddenly turned off.

- Continued telemetry data from the inertial reference unit (IRU). The IRU runs for 12 seconds after landing to provide reference data about Lander orientation so the computer can move the high-gain antenna from its stowed position and point it toward Earth.

If the data link is lost for an unexpected reason, lack of receipt of these telemetry signals does not necessarily mean that Viking has not landed safely. The data link could be regained, even on a later pass of the Orbiter.

## Landed Operations

As soon as the Lander touches down on Mars and telemeters to Earth a status review on its engineering equipment, it begins its scientific investigations.

The first picture-taking sequence begins 25 seconds after touchdown with a high-resolution, black-and-white photograph of footpad number 3, its leg and the soil surrounding it. The picture, taken by Camera 2, will show how the footpad has affected the Martian soil during landing. It will provide about the same detail as would be seen by a person sitting on the Lander at the Camera 2 position.

The same camera will take a second picture at six minutes, eight seconds after landing. This image will be a wide-angle panorama starting at 105 degrees and sweeping as far to the right as possible in about nine minutes. Total width of the picture will be about 300 degrees, and its height is 60 degrees -- 20 degrees above to 40 degrees below the horizontal plane of the Lander. If the spacecraft is level and on level ground, the horizon will be 20 degrees, or one-third of the frame, below the top of this picture.

These first two pictures will have priority over other data, and they will be sent to the Orbiter as quickly as possible for immediate relay to Earth.

Buildup of the pictures on TV monitors at the Jet Propulsion Laboratory should begin about 7:37 p.m. PDT. Hard copies should be available about a half-hour later, within four hours of their being taken on Mars.

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After these first pictures have been taken, meteorology science starts and continues at intervals throughout each Sol. The meteorology instruments operate in short intervals of two minutes duration, spaced two hours apart each Sol, with some long observations lasting up to one hour twice each Martian day. The sequence of observations of temperature, pressure, wind speed and wind direction is slowly moved in Martian time so that data are ultimately gathered to cover a whole day's changes.

By the end of Sol 20 the meteorology team expects to have a very good idea of the diurnal variations of meteorological measurements. They are of scientific interest and practical importance to other experiments.

Very precise surface measurements of pressure are expected because a twin of the pressure sensor, operating for many months on Earth, has not deviated from its nominal reading by one count.

The meteorology of Mars poses an interesting question about the pictures to be returned from the surface: will they show mirages? Mirages are expected on Mars because of great temperature differences between the ground and the atmosphere, as a result of the thin atmosphere of carbon dioxide.

Two other instruments are calibrated during the first Sol: the seismometer and the X-ray fluorescence instrument. This calibration is part of the first task of the seismology team to determine the seismic background of Mars, to ascertain the frequencies of vibrations of the Martian surface (e.g., the background noise produced by winds). As this calibration progresses, the instrument is reconfigured so its gain settings are best suited to the natural environment of Mars and it can effectively search for true seismic events.

The first few Sols of seismology are very exploratory. The seismic team works closely with the meteorology team in data interpretation so that background noise caused by wind can be understood.

The first calibration of the X-ray fluorescence spectrometer instrument after landing operates the instrument without a sample and uses a calibration plaque within the instrument. The instrument is extremely sensitive to the presence of argon, so this calibration is expected to reveal the presence of argon in the atmosphere of Mars and confirm the UAMS entry determination, so important to effective operation of the GCMS.

Calibration of the instrument is important to ensure that there have been no changes to the X-ray spectrometer caused by landing stresses on the spacecraft. Necessary instrument changes will be made by Sol 7, to prepare it to start its sampling of surface materials.

As the Sun sets at the Lander site on this first Martian day, scientists have looked at the surface and the panorama of the landing site, they know the Lander is operating and that several of its instruments are functioning correctly.

The Lander carries instructions within its computer memory for a 58-Sol mission in the event it cannot be commanded from Earth. During the next few days, early data sent from Mars must be analyzed by Earth controllers to determine how much this program of activity is to be changed. This analysis begins while the Lander enters its first Martian night.

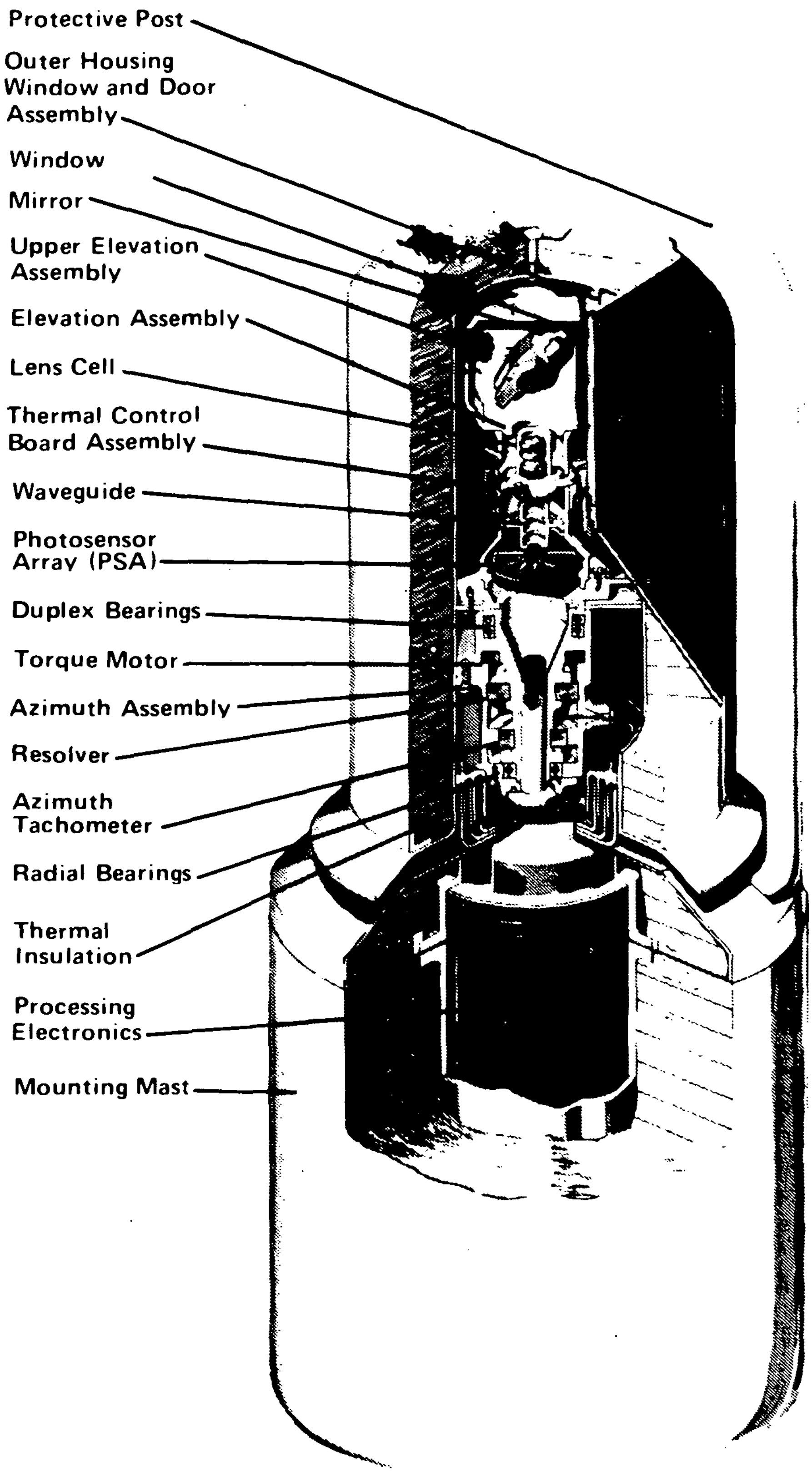
## Sols 1 Through 7 (July 5-12)

This period of landed operations concentrates first on certifying the site from which the soil sampler will scoop samples for the biology, organic analysis and X-ray fluorescence experiments.

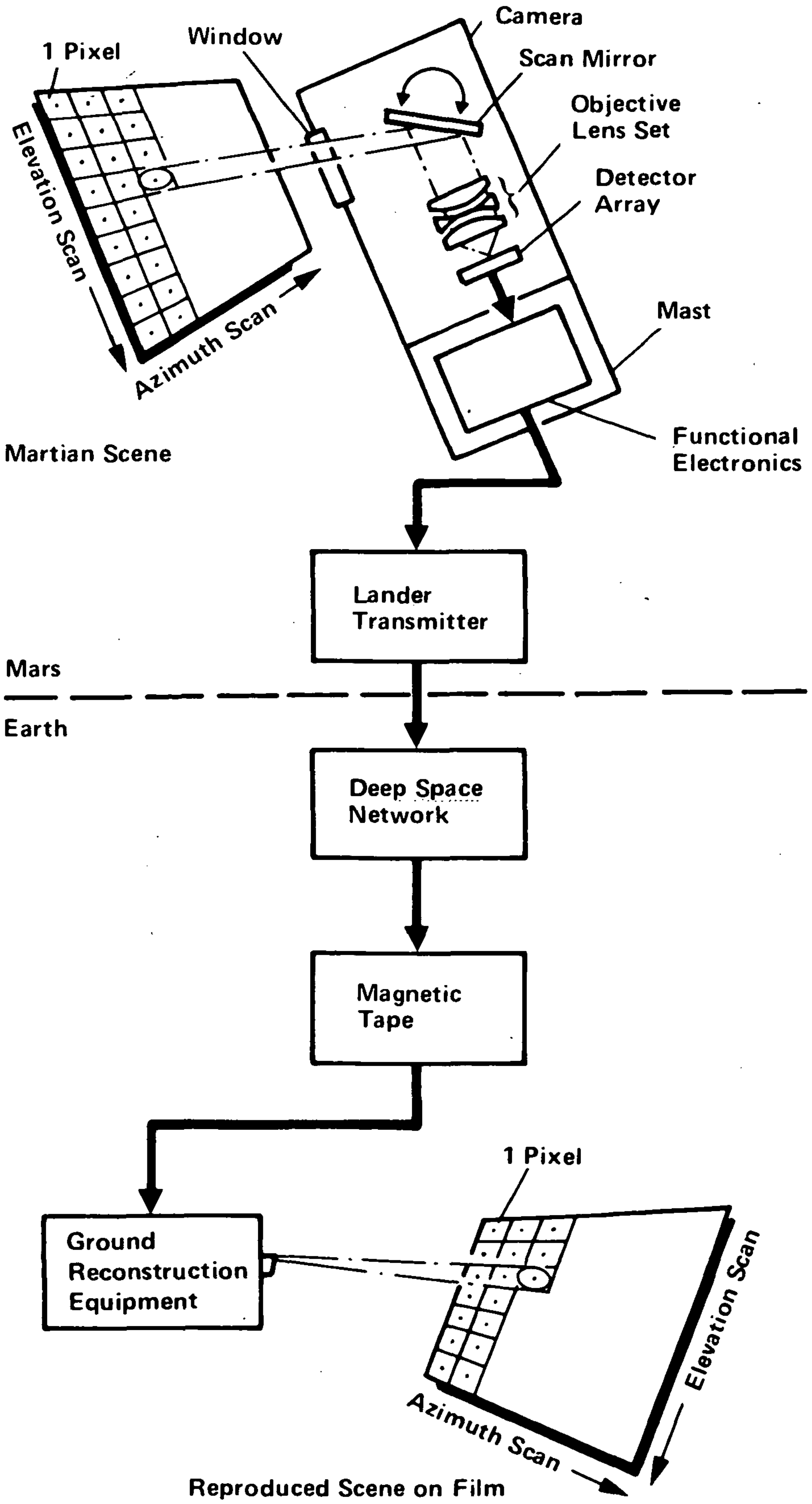
Sample site certification relies heavily on the imaging capabilities of the two Lander cameras. Although the programmed 58-Sol mission includes a sample site, it must be evaluated before actually being used. The scientists want to use Viking's adaptive potential to convert the programmed mission into an adaptive mission. Later experiments will reflect what earlier experiments reveal.

The first question to be answered is whether the sampling sequence programmed into the computer will aim the sampler toward a safe site. A decision must be made by Sol 5 whether to let the computer program continue to sample as planned or change it to take a sample at another, safer site.

The first two pictures on Sol 0 show the nature of the soil, but they could be incorrectly exposed, and they don't give an accurate impression of the distance of objects from the Lander. Experienced photo interpreters can estimate the location of the sampling site to within one foot from the pictures.



LANDER CAMERA



LANDER CAMERA SYSTEM OF OPERATION

Photography continues on Sols 1 and 2 with Camera 2. On Sol 1 the camera produces high-resolution black-and-white pictures and low-resolution survey color pictures. These show the sample site and the color-coded calibration test chart (number two) on the Lander.

On Sol 2 the protective cannister cover on the sampler collector head is ejected onto the surface, close to the Lander footpad that was photographed on Sol 0. The area is now rephotographed to provide further information about the surface from observed interaction of the cover with the soil.

Camera 1 is first operated on Sol 3. If conditions are not dangerous, the camera is moved from behind its protective dust cover and photos are taken to repeat the survey of picture number 2 (Sol 0) and the high-resolution coverage within the sampling area obtained during Sols 1 and 2.

The area photographed just after touchdown may show changes caused by wind, but the stereo effect is still suitable for an analysis of the sampling site. One of the mirrors mounted on the sampler housing is included in the field of view which provides a reflected image of the surface beneath the Lander, showing how one of the multi-nozzle rocket engines has disturbed the surface during landing.

If the selected site is hazardous to the sampler, the initial program will be altered. The extension stroke of the boom can be shortened, or the boom can be commanded to a completely new site. The whole sequence can also be cancelled, but this requires a longer time to resequence and would delay sampling and later experiments.

The decision to keep the initial sampling program or to modify the commands should be made by Sol 6 if the first sample is to be collected early on Sol 8. All commands that affect temperature, power or mechanical motion at the Lander must arrive there in time to be verified by a radio response before they are executed.

After pictures have been obtained for sampling site certification, the Lander cameras continue to obtain other images.

The cameras will do spectral analysis of the surface to try to objectively answer the question: What is the true color of Mars? Is it really red?

This is important in understanding the processes that have molded the surface and how the Martian crust has reacted with the atmosphere (e.g., does the crust contain iron oxides?). Although pictures are transmitted from the Lander to the Orbiter at 16 kilobits per second (kbps), pictures are only transmitted directly from the Lander to Earth at a 250 bits-per-second rate. A direct link is used daily to send real time images to Earth. These images are also sent to the Orbiter, where they are stored in its tape memory for later transmittal to Earth at a high bit rate.

If there are not large amounts of argon in the atmosphere, atmospheric analyses with the GCMS should be done in the first three Sols, before the instrument is used for organic analyses of surface materials. If there are large amounts of argon, as much as 40 per cent, atmospheric analyses cannot be made because the argon will comtaminate the instrument. The Lander programmed mission calls for three organic analyses. The presence of argon in large quantities will reduce the number of atmospheric samples that can be analyzed before those organic analyses are made.

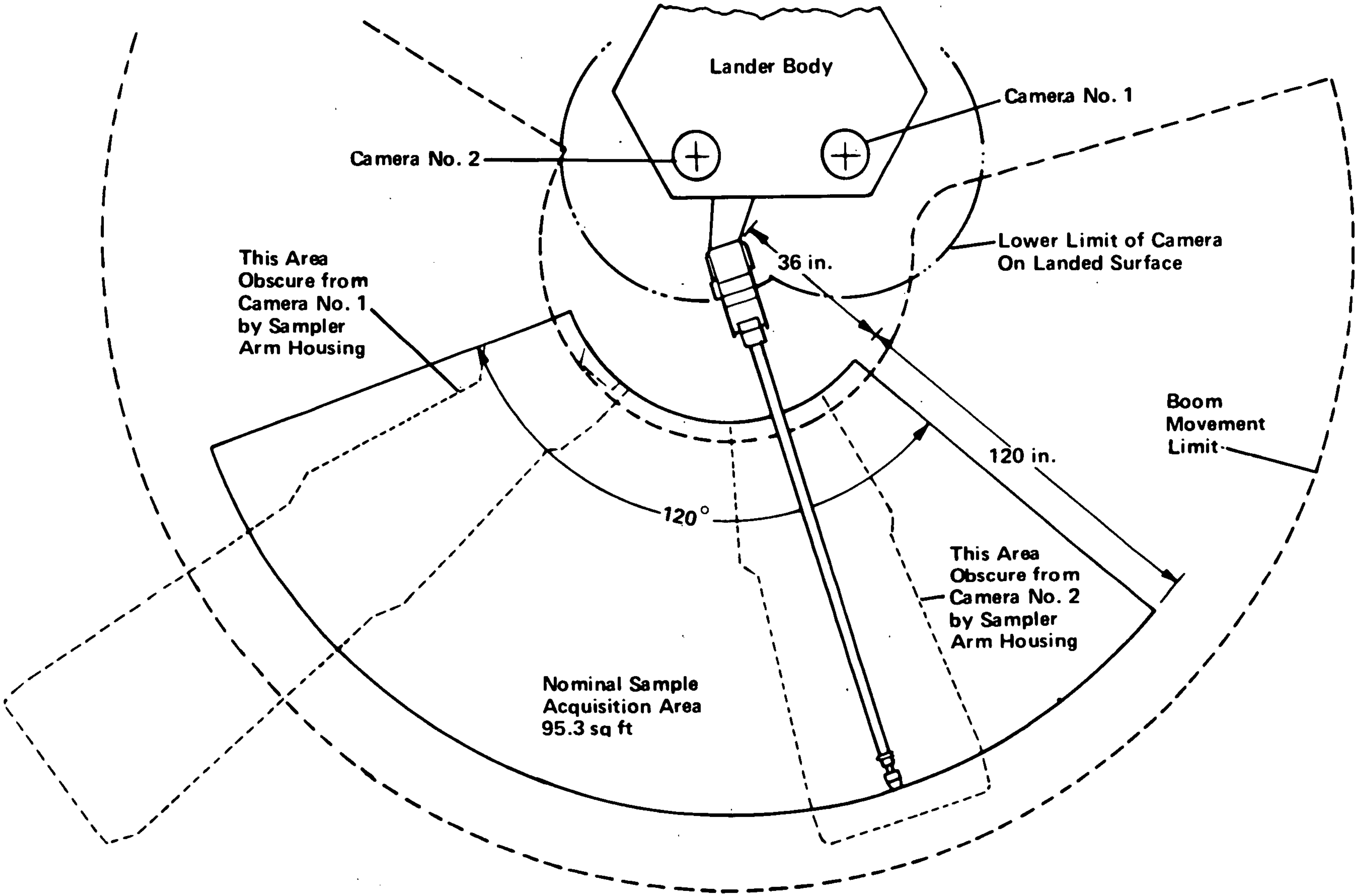
After the atmospheric analyses, if any, are made, the GCMS is prepared for its organic analysis. On Sol 6 the analysis column is conditioned and the gas chromatograph cleaned for its organic analyses, which start as soon as a sample is delivered on Sol 8.

Preparation begins on Sol 2 for the biology experiments. Equipment is set up and its readiness checked to receive samples on Sol 8. On Sol 3 a 16-minute test analysis takes place with the gas exchange biology experiment.

## Surface Sampling on Sol 8 (July 12)

The first surface sample, to be taken for the bilogy investigation, is scheduled at 2:46 p.m. PDT July 12 (6:45 a.m. on Sol 8). The collector head will attempt to take between four and six cc of Martian soil and place it in the sample hopper atop the Lander body.

If a detector in the hopper does not sense any delivered soil, the sampler automatically tries two more times at the same site. If there is still no sample, it tries one more time before it shuts down to await the next sampling try for the organic analyses about an hour later. The biology analysis begins at 4:16 p.m., PDT, if a sample is delivered with the first cycle, taking 12 days to complete.



*Sampler Arm Area of Operation*

The soil is distributed to the three biology experiments: pyrolytic release, labeled release and gas exchange. The first experiment is the pyrolytic release, using a dry soil sample illuminated by simulated Martian sunlight.

No food or water is provided to the sample, and it is incubated for five days (to Sol 13). The first cycle of the experiment ends at about 9:00 a.m. Mars time on Sol 20. If a positive result is obtained, a control sample, half of the original sample, is sterilized by heat and put through the same test. If the first test is negative, the next cycle of the experiment repeats the test several Sols later, but the sample is provided with some water.

A second biology experiment, the labeled release experiment, begins with measurement of the radiation background from the sample in its test chamber. The background test is made from 2:50 p.m on Sol 8 to 4:50 a.m. on Sol 10 (Martian times). Background radiation is then sampled over the seven Sols, and the experiment is continued for two and a half more Sols.

If a positive result is obtained, a second half of the original sample, retained as a control, is sterilized and put through the same test sequence. If this control produces positive results, the experiment has not likely revealed the presence of organic life on Mars. If the control shows negative results, the experiment may have detected a Martian life form.

The third biology experiment is the most complex. The gas exchange experiment provides several choices, and assumes that living systems must affect their environment as they live, breathe, eat and reproduce.

A soil sample is incubated for one week or more, beginning about 4:00 a.m. on Sol 9. The test chamber atmosphere is checked daily for evidence of metabolism (i.e., looking for the presence of hydrogen, nitrogen, oxygen and methane, and for changes to the amount of carbon dioxide). Analyses are made and data from them returned at about 8:00 a.m. each Mars day.

Each biology experiment can be done three times on each Lander. If positive results are not obtained until the third test sequence, a fourth test is possible within the biology package to provide a control test. All biology samples are essentially samples from the top layer of soil.

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The first sample for the Gas Chromatograph Mass Spectrometer (GCMS) organic analysis is obtained at 4:20 p.m. PDT July 12 (on Sol 8). The experiment seeks to establish whether organic molecules are present in the soil of Mars, but it is not expected to give a clearcut answer such as could be obtained with an inorganic experiment.

The second sample for the GCMS experiment is expected to be gathered on Sol 22 and analyzed by Sol 27 or 28. This sample is from below the surface, from the bottom of a trench made by the backhoe sampler head. Data from these first two samples are used to plan the third sampling, scheduled for about Sol 38.

But on Sol 8 the third experiment sample is for inorganic analysis of soil with the X-ray fluorescence experiment. The sample is obtained at 6:03 p.m. PDT July 12. It should ideally consist of 30 cc of particles, all less than 12 mm in diameter, to fit through the mesh of the screen. If the sampler arm can only reach areas of sheet rock, a sample might still be obtained for the experiment by waiting for wind-blown dust or pebbles to gather. The sampler arm might even be used as a deflector to cause wind-blown material to fall into the sample funnel.

A second X-ray spectroscopy sample is taken on Sol 27, after the second biology sample. The plan is to analyze each sample many times, during which the sensitivity of the spectrometer is moved to different parts of the spectrum for each analysis.

Five samples are planned for a normal mission. More could be taken, depending on the size of earlier samples. The limitation is the capacity of the cavity into which samples are dumped after their analysis is completed.

The X-ray spectroscopy experiment is expected to supply basic data about the elemental composition of the Martian surface and to enhance the interpretation of other experiments and determine general physical properties of the surface.

At the end of the first sampling period, when the sampler boom is in use for about four hours, it is left to rest for at least two weeks because it is essential for later cycles of the biology, organic analysis and inorganic analysis experiments.

After its use for these priority experiments, the sampler is used for other science experiments on the surface and in the atmosphere. For example, it establishes bench marks for x, y and z coordinates to support the Lander cameras in topographic mapping of the landing site. If a camera should fail, the shadow from the sampler boom can be used as an aid to stereo assessment of the landing site.

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During this period of science activity on Mars, the U.S. Geological Survey will take the topographical map constructed from Viking information and recreate the surface features of the landing site in the atrium of the von Karman Auditorium at JPL -- a section of Mars on Earth.

The seismology experiment continues during this period, but not until three weeks after landing is it operating continuously for a substantial part of each day. Data quantity limitations constrain operation of the seismometer. Early in the mission the need for many images of the surface uses much of the available transmission time. Seismic data also require much transmission time, and must be delayed until more urgent experiment data are collected.

The seismometer experiment is a long-term investigation; it will continue to operate as long as the two Landers remain operational.

Meteorology is another continuing experiment. The first 20 days on Mars are not too fruitful for meteorology because other experiments have higher priority. Meteorological experiments increase in scope as biology and imaging investigations complete their major tasks.

The meteorology investigation has been described as a net stretched in time, rather than space, to catch interesting events on Mars. This is quite different from terrestrial meteorology, where nets of many stations are spread about the planet. Mars will have only two stations, and these have to wait for meteorological events to pass by them Major results from meteorology experiments on Mars come from extended observations on the surface, ideally extending over a complete Mars year (two Earth years).

## Orbital Activities

After Lander separation, science investigations continue from the Orbiter. The first experiments are directed to learning more about the geology of Mars. The surface near and southeast of the landing site is covered by overlapping photographs during several orbital revolutions. High resolution imaging provides information to help determine how the Mars channels were formed. Stereo swaths across the channel mouths allow better estimates of the volume of water that must have flowed.

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The next area to be covered is along the track of the Orbiter southwest of the landing site. The Viking 1 orbit covers some of the most interesting terrain of Mars, the boundary between the two hemispheres of cratered and volcanic terrain.

Some of the coverage is in stereo, which is of great use in analyzing surface features such as knobby terrain. A few color images are also obtained, important because color differences between lava flows in lunar photographs were related to chemical differences among the flows. Inferences can be drawn about the chemical composition of much greater areas of Mars than can be sampled by the Landers. Targets of special interest are investigated when revealed on the images.

Every 20 days the Orbiter photographs the whole disc of Mars from high altitude and in color. Toward the end of the first Lander's planned mission, on Sept. 7, the Orbiter rocket engine fires a trim maneuver to cause the spacecraft to orbit the planet slight out of synchronization with the Mars rotational period. The Orbiter now "walks" around the planet so all of its surface can be imaged in great detail. Orbital surveillance of Mars can continue through a whole Martian year, until June 1978.

Thermal mapping also continues after separation. The IRTM instrument is extremely sensitive to the presence of dust in the Martian atmosphere and can follow the development and progress of dust storms. Atmospheric dust can be detected even when it is not visible to the cameras.

Volcanic activity might also be detected, and another experiment will try to obtain details of grain sizes of material along the bottoms of the Martian canyons.

The MAWD instrument will obtain data to seek answers to questions about water on Mars. What is the source of water vapor observed in the Mars atmosphere, and where does it go? How much water is trapped in the polar caps, and is there a large amount of water locked in the surface? Why is there not more water vapor in the atmosphere? Has there been a greater abundance of water in the past?

The MAWD investigations will try to develop a water budget for Mars on a daily, seasonal and epochal basis. If present quantities of water vapor in the atmosphere were converted to ice at the poles, for example, a layer several meters thick would build up every 1,000 years.

The A and B sites are good places to look for evidence of the exchange of water vapor between surface ice and the atmosphere.

Radio investigations will use signals from the Landers and Orbiters throughout the mission. Radio signals from Viking 1 on the surface of Mars will be used to determine, with great precison, the distance from Earth to Mars.

Global gravity surveys are made by the radic science investigation during the Orbiter "walks" around the planet, based on the fact that periapsis is the orbital position most affected by gravitational anomalies, and the walk moves periapsis around the planet.

When the orbiting spacecraft pass behind the limb of Mars into occultation, as seen from Earth, radio waves penetrate the Martian atmosphere and provide details of the properties of the ionosphere, and of atmospheric temperature, pressure and density.

During the period of conjunction with the Sun, radio experiments probe the solar corona to ascertain its electron content. A relativity test is made to determine how much the Sun's mass bends radio waves coming from the Viking to Earth, delaying their passage.

The masses of Mars' moons, Deimos and Phobos, will be more accurately determined as the Orbiter passes within 30 to 40 km (18 - 25 mi.)of Deimos in December and Phobos in January and March 1977.

Orbiter 2's experiments have an additional sequence. When Lander 1 completes its 58 Sols of operation, Orbiter 1 is moved to act as a relay for Lander 2. The Orbiter has its orbit changed to an inclination of 75 degrees so its cameras and infrared instruments can observe the polar regions.

At this period of the Martian year, the north pole is clear for observation, without its hood, and the south pole is in the middle of winter and dark.

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## VIKING LANDER

The Lander spacecraft is composed of five basic systems: the Lander body, the bioshield cap and base, the aeroshell, the base cover and parachute system, and Lander subsystems. Operational design lifetime for the Lander is 90 days after landing.

The completely outfitted Lander measures approximately 3 m (10 ft.) across and is about 2 m (7 ft.) tall. It weighs approximately 576 kg (1,270 lbs.) without fuel.

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

### Lander Body

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

The box is built of aluminum and titanium alloys, and is insulated with spun fiberglass and dacron cloth to protect equipment and to lessen heat loss. The hollow container is 1.5 m (59 in.) wide and 46 cm (18 in.) deep, with cover plates top and bottom.

The Lander body is supported by three landing legs, 1.3 m (51 in.) long, attached to the short-side bottom corners of the body. The legs give the Lander a ground clearance of 22 cm (8.7 in.).

Each leg has a main strut assembly and an A-frame assembly, to which is attached a circular footpad 30.5 cm (12 in.) in diameter. The main struts contain bonded, crushed aluminum honeycomb to reduce the shock of landing.

### Bioshield Cap and Base

The two-piece bioshield is a pressurized cocoon that completely seals the Lander from any possibility of biological contamination until Viking leaves Earth's atmosphere.

The two bioshield halves generally resemble an egg, and the shield's white thermal paint heightens the resemblance. It measures 3.7 m (12 ft.) in diameter and is 1.9 m (6.4 ft.) deep. It's made of coated, woven fiberglass, 0.13 mm (0.005-in.) thin, bonded to an aluminum support structure.

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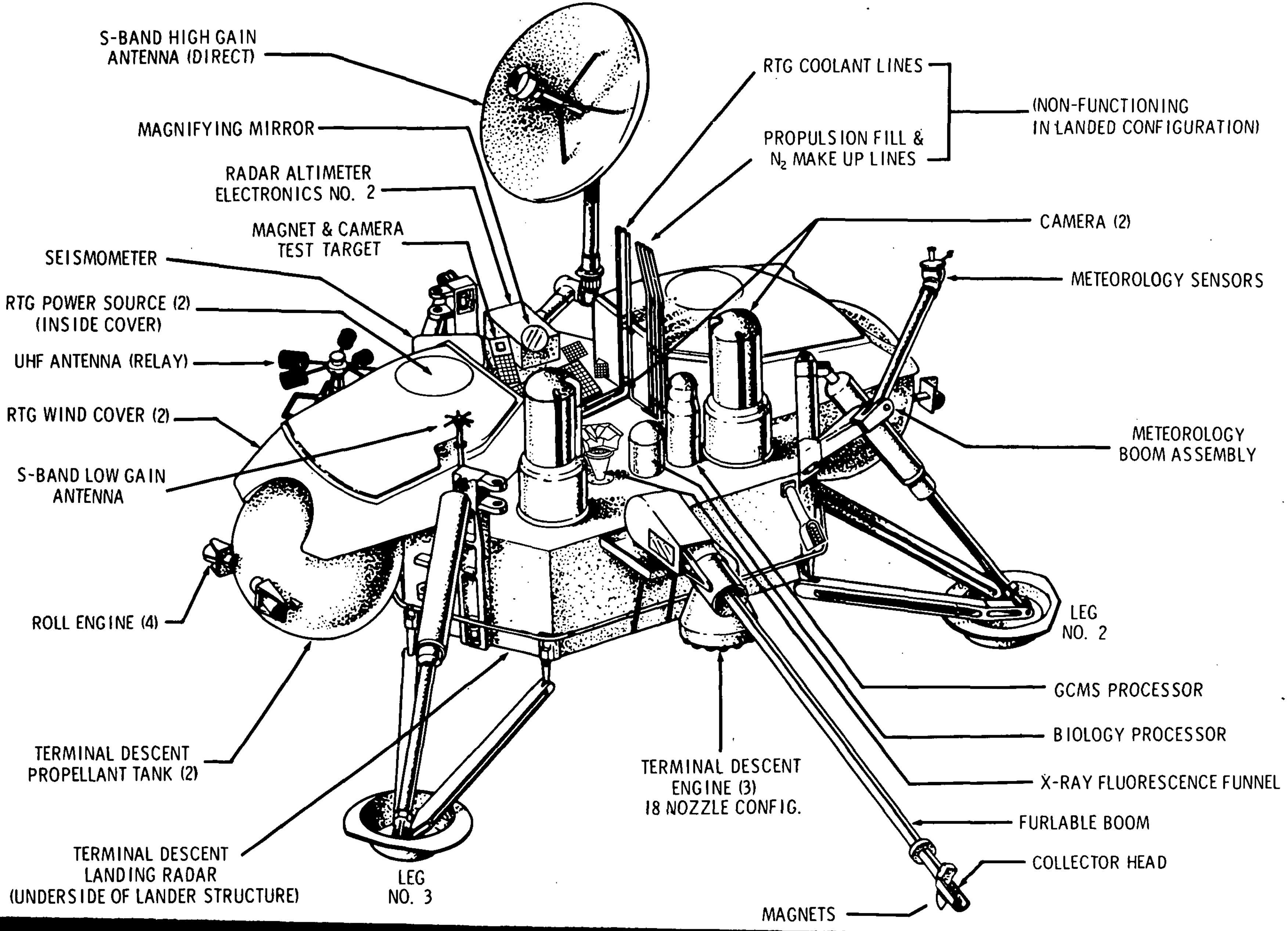
# VIKING LANDED CONFIGURATION



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

## Aeroshell

The aeroshell is an aerodynamic heat shield made of aluminum alloy in a 140-degree, flat cone shape and stiffened with concentric rings. It fits between the Lander and the bioshield base. It is 3.5 m (11.5 ft.) in diameter and its aluminum skin is 0.86 mm (0.034-in.) thin.

Bonded to its exterior is a lightweight, cork-like ablative material that burns away to protect the Lander from aerodynamic heating at entry temperatures which may reach 1,500 degrees C (2,730 degrees F.).

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

The engines control 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 provides power from the Orbiter to the Lander; housekeeping data also flow through this connection.

The aeroshell also contains two science instruments -- the Upper Atmosphere Mass Spectrometer (UAMS) and the Retarding Potential Analyzer (RPA) -- plus pressure and temperature sensors.

## Base Cover and Parachute System

The base cover fits between the bioshield cap and the Lander. It is made of aluminum and fiberglass; the fiberglass allows transmission of telemetry data to the Orbiter during entry. It covers the parachute and its ejection mortar, and protects the Lander's top during part of the entry phase.

The parachute is made of lightweight dacron polyester 16 m (53 ft.) in diameter. It weighs 50 kg (110 lbs.).

The parachute is packed inside a mortar 38 cm (15 in.) in diameter, mounted into the base cover. The mortar is fired to eject the parachute at about 139 km per hour (75 mph). The chute has extra-long suspension lines that trail the capsule by about 30 m (100 ft.).

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## Lander Subsystems

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

## Descent Engines

Three terminal descent engines (TDE) provide attitude control and reduce the Lander's velocity after parachute separation. The 2,600-newton (600-lb.) throttleable engines are located 120 degrees apart on the Lander's sidebeams. They burn hydrazine mono-propellant.

The engines use an advanced exhaust design that won't alter the landing site environment. An unusual grouping of 18 small nozzles on each engine will spread engine exhaust over a wide angle that won'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, feed the TDEs from an 85-kg (188 lb.) hydrazine propellant supply.

Four small reaction control engines use hydrazine monopropellant thrusters to control Lander roll attitude during terminal descent. The engines are mounted in pairs on the TDE propellant tanks and are identical to those used on the aeroshell.

## Communication Equipment

The Lander is 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 receives Earth commands through the S-band system.

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

The UHF relay system transmits data to the Orbiter with a radio transmitter that uses a fixed antenna. The UHF system will operate during entry and for the first three days of landed operations. After that it will only operate during specific periods.

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## Landing Radars

The radar altimeter (RA) measures the Lander's altitude during the early entry phase, alerting the Lander computer to execute the proper entry commands. The RA is a solid-state pulse radar with two specially designed antennas: one is mounted beneath the Lander and one is mounted through the aeroshell. Altitude data are received from 1,370 km down to 30.5 m (740 mi. to 100 ft.).

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

The terminal descent landing radar (TDLR) measures the horizontal velocity of the Lander during the final landing phase. It is located directly beneath the Lander and is turned on at about 12 km (4,000 ft.). It consists of four continuous-wave Doppler radar beams that can measure velocity to an accuracy of plus or minus one meter per second.

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

## Guidance and Control

The "brain" of the Lander is its guidance control and sequencing computer (GCSC). It commands everything the Lander does through software (computer programs) stored in advance or relayed by Earth controllers.

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

Among other programs, the computer has instructions stored in its memory that can control the Lander's first 58 days on Mars without any contact from Earth. These instructions will be updated and modified by Earth command once communication has been established.

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## Power Sources

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

The SNAP 19 Viking generator is 147 cm (23 in.) across the housing fin tips, 96 cm (15 in.) in length and weighs 15.3 kg (34 lbs.).

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 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 5 science stations left on the Moon by the Apollo 12, 14, 15, 16 and 17 astronauts. The continuing operation of these generators is providing new dimensions of data about the Moon and the universe. Four SNAP 19 nuclear generators are providing the electrical power for each of the two NASA pioneer Jupiter fly by missions (Pioneers 10 and 11) currently in space.

The generators will provide 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 minus 120 degrees C (minus 184 degrees F.).

The generators use thermoelectric elements to convert heat from decaying plutonium-238 into 70 watts of electrical power.

"Waste" or unconverted heat is conveyed by thermal switches to the Lander's interior instrument compartment, when required. Covers over the RTGs prevent excess heat dissipation into the environment.

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

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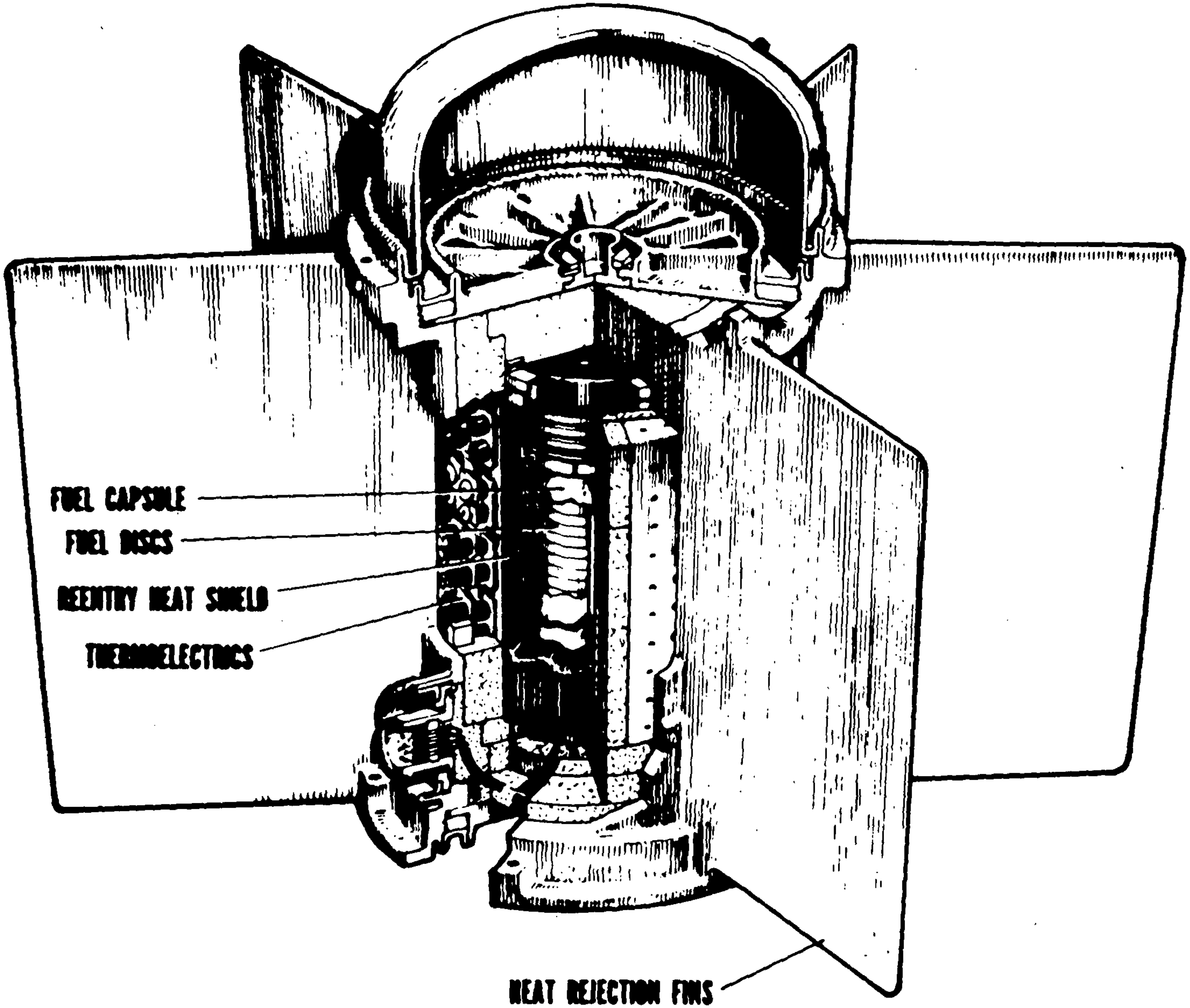
## Data Storage

This equipment collects and controls the flow of Lander scientific and engineering data. It consists of a data acquisition and processing unit (DAPU), a data storage memory and a tape recorder.

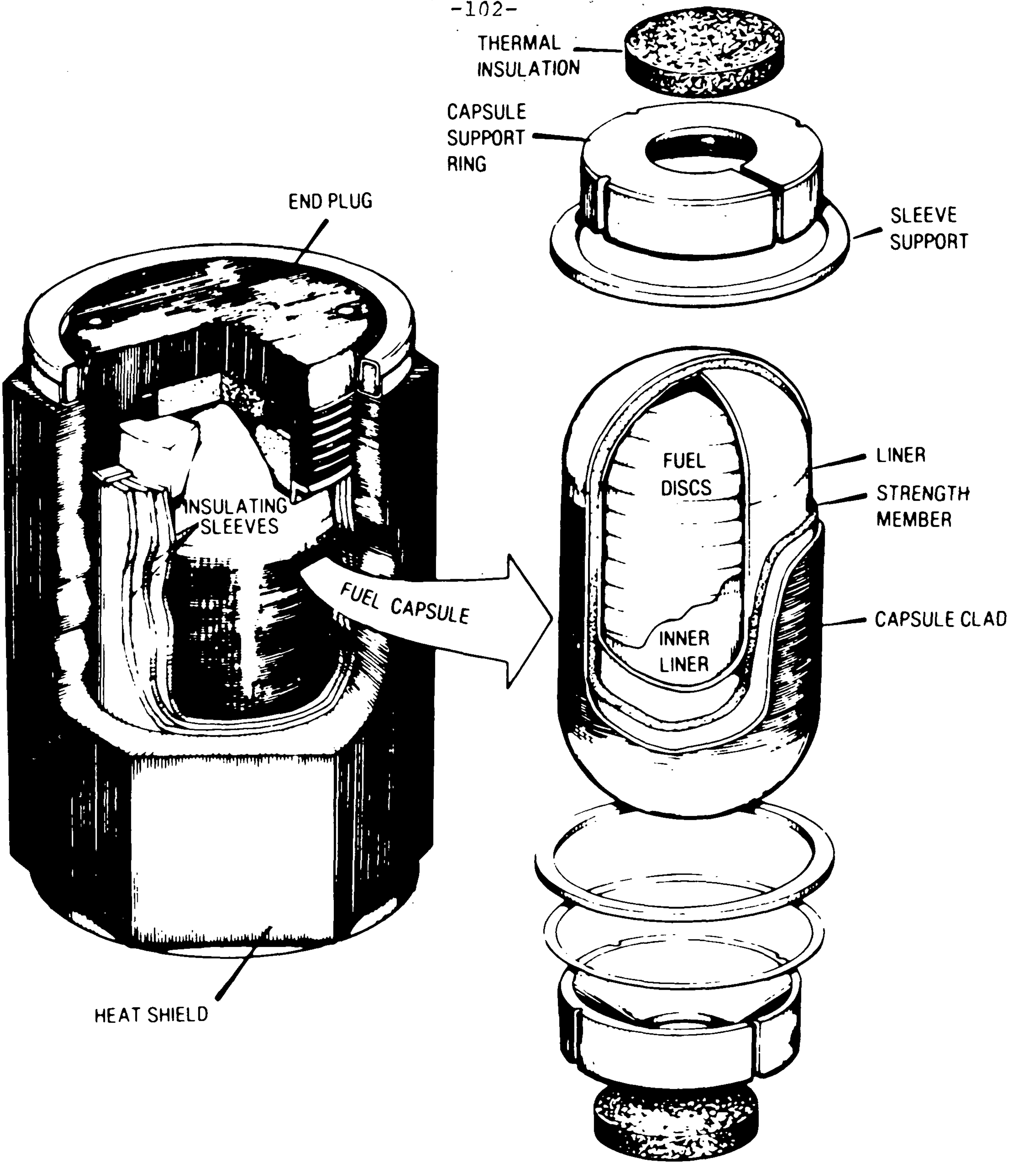
The DAPU actually collects the science and engineering information and routes it to one of three places: to Earth through the S-band HGA, to the data storage memory or to the tape recorder.

Information will be stored in the data storage memory for short periods. Several times a day the memory will transfer data to the tape recorder or back to the DAPU for further transmission. The memory has a storage capacity of 8,200 words.

Data are stored on the tape recorder for long periods. The recorder can transmit at high speed back through the DAPU and the UHF link to an Orbiter passing overhead. It can store as many as 40 million bits of information, and it can record at two speeds and play back at five.



SNAP 19/VIKING RADIOISOTOPE THERMOELECTRIC GENERATOR



SNAP 19/VIKING HEAT SOURCE

## VIKING ORBITER

The Viking Orbiter is a follow-on design to the Mariner class of planetary spacecraft with specific design changes for the Viking mission. Operational lifetime requirements for the Orbiter are 120 days in orbit and 90 days after the landing.

### Orbiter Design

The design of the Orbiter was greatly influenced by the size of the Lander, which dictated a larger spacecraft structure than Mariner, increased propellant storage for a longer burn time for orbit insertion, and upgrading of the attitude control system with additional gas storage and larger impulse capacity.

The combined weight of the Orbiter and Lander was one factor that contributed to an 11-month transit time to Mars, instead of 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.

### Structure

The basic structure of the Orbiter is an octagon approximately 2.4 m across (8 ft.). The eight sides of the ring-like structure are 45.7 cm (18 in.) high and are alternately 1.4 by 0.6 m (55 by 22 in.).

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

The Orbiter is 3.3 m (10.8 ft.) high and 9.7 m (32 ft.) across the extended solar panels. Its fueled weight is 2,325 kg (5,125 lbs.).

Combined area of the four panels is 15 square m (161 square ft.), and they provide both regulated and unregulated direct current power; unregulated power is provided to the radio transmitter and the Lander.

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

## Guidance and Control

The Orbiter is stabilized in flight by locking onto the Sun for pitch and yaw reference and onto the star Canopus for roll reference. The attitude control subsystem (ACS) keeps this attitude with nitrogen gas jets located at the solar panel tips. The jets fire to correct any drift. A cruise Sun sensor and the Canopus sensor provide error signals. Before Sun acquisition four acquisition Sun sensors are used and then turned off.

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

If Sun lock is lost the ACS automatically realigns the spacecraft. In loss of Canopus lock, the ACS switches to roll-inertial and waits for commands from the spacecraft computer. The nitrogen gas supply for the ACS can be augmented by diverting excess helium gas from the propulsion module, if necessary.

Two on-board general-purpose computers in the computer command subsystem (CCS) decode commands and either order the desired function at once or store the commands in a 4,096-word, plated-wire memory. All Orbiter events are controlled by the CCS, including correction maneuvers, engine burns, science sequences, and high-gain antenna pointing.

## Communications

The main Orbiter communications system is a two-way, S-band, high-rate radio link providing Earth command, radio tracking and science and engineering data return. This link uses either a steerable 1.5 m (59 in.) dish high-gain antenna (HGA) or an omni-directional low-gain antenna (LGA), both of them on the Orbiter. The LGA is used to send and receive near Earth, the HGA as distances increase. An X-band link is used for radio science through the HGA.

S-band transmission rates vary from 8.3 or 33.3 bits per second (bps) for engineering data to 2,000 to 16,000 bps for Lander and Orbiter science data.

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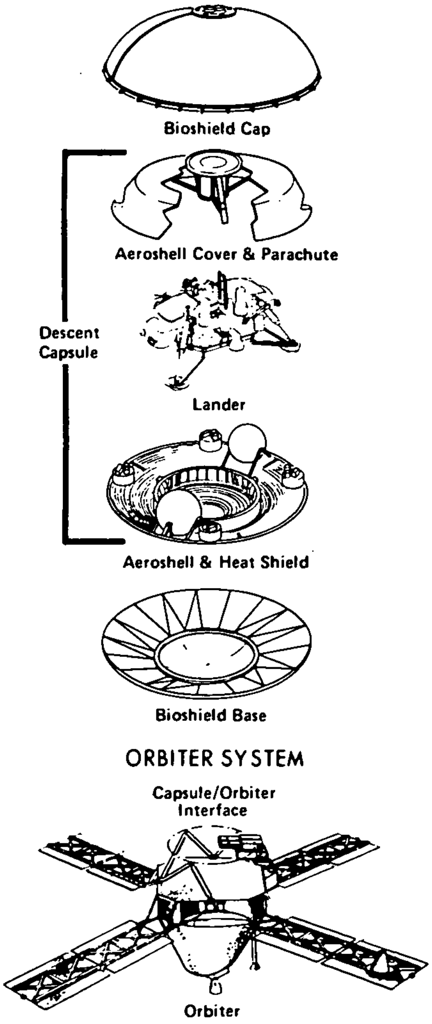
Relay from the Lander is through an antenna mounted on the outer edge of a solar panel. It will be activated before separation and will receive from the Lander through separation, entry, landing, and surface operations. The bit rate during entry and landing is 4,000 bps; landed rate is 16,000 bps.

## Data Storage

Data are stored aboard the Orbiter on two eight-track digital tape recorders. Seven tracks are used for picture data and the eighth track for infrared data or relayed Lander data. Each recorder can store 640 million bits.

Data collected by the Orbiter, including Lander data are converted into digital form by the flight data subsystem (FDS) and routed to the communications subsystem for transmission or to the tape recorders for storage. This subsystem also provides timing signals for the three Orbiter science experiments.



# LAUNCH AND CRUISE ACTIVITIES

## Launch Phase

Vikings 1 and 2 were successfully launched from Cape Canaveral, Fla., Aug. 20 and Sept. 9, 1975, aboard Titan/Centaur III launch vehicles.

Viking 1 lifted off at 5:22 p.m. EDT, nine days later than planned. The launch delay was caused by two problems. The first occurred less than two minutes before the planned launch time on August 11 when a thrust vector control valve on the Titan solid rocket's booster stage did not properly respond during checkout. The launch was cancelled for the day. The valve was one of 24 that help maintain directional control on the vehicle during initial liftoff. Mission controllers decided to replace the faulty valve and reschedule the launch for August 14.

On August 13, however, technicians preparing to charge the Orbiter batteries discovered that the batteries' normal charge had dropped from 37 volts to nine volts. The batteries had been drained because a motorized rotary switch aboard the Orbiter had moved to the "on" position sometime after the August 11 launch postponement. The switch should have remained in the "off" position until seven minutes before launch.

Controllers decided that the entire Viking spacecraft had to be removed from the launch vehicle and returned to its assembly facility for de-encapsulation and trouble shooting of the Orbiter.

At the same time, the second Viking spacecraft was removed to the launch complex and prepared to replace its ailing mate for the first launch.

The drained batteries on the first Orbiter were replaced with new units. Extensive checks were made on each subsystem to insure that the low voltage did not cause any damage to the Orbiter's electronics.

Viking 1 was successfully launched August 20. Every aspect of the launch sequence was normal, and the Titan/Centaur vehicle precisely inserted Viking 1 into its planned trajectory.

A mid-course maneuver of Viking 1 was commanded from the Jet Propulsion Laboratory August 27, to change the spacecraft's direction and velocity just enough to bring it within the desired targeting area near Mars that will allow its insertion into orbit. The original aiming point was purposely biased a considerable distance from Mars to avoid any possibility of the spacecraft impacting the surface if either Viking was inoperable after separation from the launch vehicle.

Back at Cape Canaveral, the second Viking encountered problems when the receiver sensitivity of the S-band radio subsystem suddenly degraded. Efforts to isolate the problem and work around it were not successful, so the spacecraft was sent back to its assembly building for detailed troubleshooting. All Orbiter radio frequency coaxial hardware was replaced with new equipment.

Viking 2 was successfully launched at 2:39 p.m. EDT September 9. A mid-course maneuver to correct spacecraft trajectory was done September 19.

## Cruise Phase

Viking 1's interplanetary cruise from Earth to Mars will last 304 days; the Viking 2 cruise will last 333 days. Both spacecraft will reach Mars during the summer season in Mars' northern hemisphere. At that time Earth and Mars will be at maximum distance apart, about 380 million km (236 million mi.).

Only two mid-course maneuvers are necessary to correct the launch aim bias, possible trajectory errors and insure Viking's arrival in the proper location at the right time for Mars Orbit Insertion (MOI).

During cruise the Vikings are kept on their proper trajectories by a combination of ground tracking, star tracking and Sun sensing. NASA's Deep Space Network (DSN) tracks Viking through the spacecraft's radio signal. The DSN determines Viking's position and velocity, and checks the condition of both Orbiter and Lander. Orbiter solar panels are kept pointed toward the Sun and the craft's star sensor acquires the star Canopus.

Orbiter high-gain antennas are repositioned each day to keep the narrow radio beams aimed directly at Earth. Although the distance from Earth is many millions of miles, the relative movement of Earth, as seen from the spacecraft, is great enough to necessitate daily antenna changes. As spacecraft distance from Earth increases, changes become less frequent.

Orbiter science instruments are checked during cruise, and the Canopus star tracker calibrated. The Orbiter's two television cameras, the Mars Atmospheric Water Detector (MAWD) and the Infrared Thermal Mapper (IRTM) were periodically checked and some test TV pictures were taken of Earth and Mars. Orbiter gyroscope drift calibrations were made, and some signal-to-noise ratio and radio subsystem threshold tests were completed.

The Viking Landers remained quiet during cruise, except for some venting of science instruments and routine tape recorder maintenance. Lander 1's batteries were given a full charge October 19 as part of their conditioning for future operations.

Initial battery conditioning of Lander 2 was scheduled to begin October 31, but the battery charger did not turn on in response to a command from Earth. Further attempts were made to charge batteries, but the charger did not respond. After detailed analysis, controllers tried charging one Lander battery with a backup charger. The attempt was successfully made November 5, and all four batteries received full charges.

During a checkout test of the Lander 2 gas chromatograph-mass spectrometer (GCMS) in January, one of three small ovens inside the molecular analysis instrument apparently did not operate. Data from the tests showed that oven number 1 either failed to heat or that data are faulty from a timing device that indicates if an oven is on.

After the assumed oven failure, mission controllers examined pre-launch test results on the GCMS ovens aboard Lander 1 and found a similarity in data on one of its ovens, leading them to suspect a second failure. Telemetry from a monitoring device associated with the ovens may be faulty, however, and the final test will occur on Mars when soil samples are placed in the ovens.

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The ovens, three in each GCMS instrument, are designed to heat Martian soil samples to 500 degrees C (932 degrees F.) to release organic constituents in the soil for analysis by the instrument.

The loss of one oven on each experiment will not affect instrument operation, but it will result in the analysis of two, rather than three, soil samples by each instrument.

During the cruise phase, radio science investigations used a dual frequency downlink from the spacecraft to Earth to measure small perturbations or changes in the spacecraft orbit, deduced from analysis of tracking data and small variations in frequency, phase or amplitude of signals received from Viking. Basic tracking data to navigate the spacecraft toward Mars consist of precise measurements of distance (range) and line-of-sight velocity (range-rate) between Viking and tracking stations on Earth.

Viking 1 arrives at Mars orbit June 19, only one day later than originally planned. Viking 2 will arrive at Mars August 7, the exact day originally scheduled. This compensation for the late launches is made possible by introducing minute corrections to the trajectory aiming points, launch vehicle burn durations and injection velocities while the spacecraft were still near Earth. Small changes early in the mission caused big differences after journeys of more than 400 million miles.

## MISSION CONTROL AND COMPUTING CENTER

The focal point of all Viking flight operations is the Viking Mission Control and Computing Center (VMCCC) at the Jet Propulsion Laboratory. The Viking Flight Team (VFT) is housed in the VMCCC, and data from the Orbiters and Landers will be processed and presented to the flight team for analysis.

Housed in two buildings at JPL, the VMCCC contains all the computer systems, communication and display equipment, photo processing laboratories and mission support areas for mission controllers, spacecraft performance analysts and science investigators.

By the time the first Viking spacecraft arrives at Mars, the facilities will house more than 750 flight team members, plus several hundred more VMCCC people who will operate the facilities, computers, laboratories, maintenance shops and communications networks.

The VMCCC's large and complex computer systems receive incoming Orbiter and Lander data, process them in real time, and display and organize them for further processing and analysis. Data are first received as radio signals by the Deep Space Network (DSN) stations around the world and are transmitted into the VMCCC computers, where processing begins. Software (programs) in these computers does the receiving, display and organizing of data.

Commands that cause the Orbiters and Landers to maneuver, gather science data and do other complex activities are prepared by the flight team. Commands are introduced into the computers through the team's control and are communicated to a DSN station for transmission to the appropriate spacecraft.

Three sets of computer systems are in the VMCCC. One is a complex of UNIVAC 1530, 1219 and 1616 computers that are designed to receive, process and display all Orbiter data in real time and do preliminary image reconstruction on video data taken from Orbiter cameras.

Another set is a system of IBM 360/75 computers that receive, process and display in real time all Lander telemetry and tracking data from the tracking stations. They are the means through which commands are sent to the Orbiters and Landers. They also do early image reconstruction and display of video data from Lander cameras on the surface and they provide computing capability for many programs that do command preparation, Lander data analysis and mission control functions.

Two large UNIVAC 1108 computers are used in non-real-time to do many detailed analyses such as navigation, science instrument data analysis and data records production.

Exposed film from the computers will be processed in the VMCCC photo processing lab. High-quality prints will be quickly made available. These pictures from Mars orbit and from the surface will be analyzed by scientists housed in the mission support rooms of the VMCCC.

The VMCCC system is the responsibility of JPL's Office of Computing and Information Systems.

## Image Processing Laboratory

JPL's Image Processing Laboratory (IPL) will correct all of the images (photo products) returned from the Lander and Orbiter spacecraft. Digital computer techniques are used to improve details of returned images and to correct distortions introduced into the images by the camera systems. Large mosaics will be constructed from the Lander and Orbiter images, using the IPL products.

Special techniques developed for Viking include a program that will display Lander images for stereo viewing. The three-dimensional images will be used to evaluate the terrain near the landing site before activating the surface sampler arm. IPL will also do the processing to obtain the best possible discriminability (details) of images acquired by the Orbiter during site certification before landing.

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## TRACKING AND DATA SYSTEM

Tracking, commanding and obtaining data from the Vikings are parts of the mission assigned to the Jet Propulsion Laboratory. The tasks cover all phases of the mission, including telemetry from the spacecraft, metric data, command signals to the spacecraft and delivery of data to the Viking Mission Control and Computing Center (VMCCC).

Tracking and communication with Viking, from the cruise phase until end-of-mission, is done by the world-wide NASA/JPL Deep Space Network (DSN). It consists of nine communications stations on three continents, the Network Operations Control Center in the VMCCC and ground communications linking all locations.

DSN stations are strategically located around the Earth: Goldstone, Calif.; Madrid, Spain; and Canberra, Australia. Each location has a 64-m diameter (210-ft.) antenna station and two 26-m (85-ft.) antenna stations. The three multistation complexes are spaced at widely separated longitudes so spacecraft beyond Earth orbit are never out of view.

Each DSN station is equipped with transmitting, receiving, data handling and inter-station communications equipment. The 64-m antenna stations in Spain and Australia have 100-kilowatt transmitters; at Goldstone the uplink signal can be radiated at up to 400 kw. Transmitter power at all six 26-m stations is 20 kw.

Nerve center of DSN is the Network Operations Control Center at JPL. All incoming data are validated here while being simultaneously transferred to computing facilities in VMCCC for real time use by the Viking Flight Team.

The global stations are tied to the control center by NASCOM. Low-rate data from the spacecraft are transmitted over high-speed circuits at 4,800 bits per second (bps). High-rate data are carried on wideband lines at 28.5 kilobits per second (kbps) and, from Goldstone, at 50 kbps. Commands to the spacecraft are generated in the VMCCC and sent in the opposite direction to the appropriate DSN station.

Ground communications used by DSN are part of a larger network, NASCOM, which links NASA's stations around the world. For Viking, NASCOM may occasionally provide a communications satellite link with the overseas stations.

Tracking and data acquisition requirements for Viking greatly exceed those of the Mariner and Pioneer projects. As many as six telemetry streams--two from both Orbiters and one or the other Lander--will be simultaneously received. Both Orbiters or an Orbiter and Lander will be tracked and commanded at any given time although the two Landers will not be operated at the same time.

In the 16 months of the primary mission, the critical period lasts at least five months, beginning with Mars approach. Early in this period, two sets of antennas will be communicating with Orbiter 1 and Lander 1 and conducting their respective missions. A third set of antennas will be required to track Viking 2, still mated and approaching at some distance. During this phase, the entire capability of the DSN is occupied with Viking.

Principal communications links between the Vikings and Earth stations are in the S-band (2,100-2,300 megaHertz.) The Orbiters will also carry X-band (8,400 MHz) transmitters. Operating with the Orbiter S-band system, the X-band transmitter will allow the network to generate dual frequency ranging and doppler data and will contribute to the radio science investigation at Mars.

Telemetry will be immediately routed from DSN stations to the VMCCC for distribution to computers and other specialized processors for data reduction and presentation to flight team engineers and science investigators. Simultaneously, range and range-rate information will be generated by DSN and transmitted to the VMCCC for spacecraft navigation computations.

Commands to Viking are transmitted from the VMCCC and loaded into a command processing computer at a DSN station for transmission to the proper spacecraft. Commands may be aborted and emergency commands may be manually inserted and verified at stations after voice authorization from VMCCC.

During planetary operations the network supports celestial mechanics experiments that may use very long baseline interferometry (VLBI), using DSN and other antennas outside the network.

All of NASA's networks are under the direction of the Office of Tracking and Data Acquisition. JPL manages DSN; STDN facilities and NASCOM are managed by NASA's Goddard Space Flight Center, Greenbelt, Md.

The Goldstone DSN stations are operated and maintained by JPL with the assistance of the Aeronutronic Ford Corp. The Canberra stations are operated by the Australian Department of Supply. The stations near Madrid are operated by the Spanish government's Instituto Nacional de Technica Aerospacial.

# VIKING PROGRAM OFFICIALS

## NASA Headquarters

| | |
|---|---|
| Dr. Noel W. Hinners | Associate Administrator for Space Science |
| Dr. Anthony J. Calio | Deputy Associate Administrator for Space Science |
| Dr. S. Ichtiaque Rasool | Deputy Associate Administrator,-Science |
| Robert S. Kraemer | Director, Lunar and Planetary Programs |
| Walter Jakobowski | Viking Program Manager |
| Dr. Richard S. Young | Chief Program Scientist for Viking |
| Loyal G. Goff | Viking Program Scientist |
| Robert A. Kennedy | Deputy Program Manager (Orbiter) |
| Rodney A. Mills | Deputy Program Manager (Lander) |
| Gerald M. Truszynski | Associate Administrator for Tracking and Data Acquisition |

## Langley Research Center

| | |
|---|---|
| Donald P. Hearth | Director |
| Oran W. Nicks | Deputy Director |
| James S. Martin Jr. | Viking Project Manager |
| A. Thomas Young | Deputy Project Manager (JPL Operations) |
| William J. Boyer | Deputy Project Manager (LaRC Operations) |
| Dr. Gerald A. Soffen | Project Scientist |

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### Jet Propulsion Laboratory

| | |
|---|---|
| Dr. Bruce C. Murray | Director |
| Gen. Charles H. Terhune | Deputy Director |
| Robert J. Parks | Assistant Director, Flight Projects |
| Henry W. Norris | Orbiter System Manager |
| George Granopulos | Mission Control and Computing Center Manager |
| Douglas J. Mudgway | Deep Space Network Manager |

### Viking Flight Team

| | |
|---|---|
| James S. Martin Jr., LaRC | Viking Project Manager |
| A. Thomas Young, LaRC | Mission Director |
| Robert L. Crabtree, JPL | Deputy Mission Director |
| Louis Kingsland Jr., JPL | Deputy Mission Director |
| Dr. C. Howard Robins, Jr., LaRC | Deputy Mission Director |
| Marshall S. Johnson, LaRC | Deputy MIssion Director |
| John D. Goodlette, MMC | Chief Engineer |
| Dr. Gerald A. Soffen, LaRC | Project Scientist |
| B. Gentry Lee, MMC | Science Analysis & Mission Planning Director |
| Dr. Peter T. Lyman, JPL | Spacecraft Performance & Flight Path Analysis Director |
| Marius J. Alazard, JPL | Mission Control Director |
| Robert J. Polutchko, MMC | Lander Support Office Chief (Denver) |
| G. Calvin Broome, LaRC | Lander Science Group Chief |
| Dr. Conway W. Snyder, JPL | Orbiter Science Group Chief |
| Dr. James D. Porter, MMC | Mission Planning Group Chief |
| Ronald A. Ploszaj, JPL | Orbiter Performance Analysis Group Chief |
| Rex W. Sjostrom, MMC | Lander Performance Analysis Group Chief |
| William J. O'Neil, JPL | Flight Path Analysis Group Chief |

## Kennedy Space Center

| | |
|---|---|
| Lee R. Scherer | Director |
| John J. Neilon | Director, Unmanned Launch Operations |
| Harold Zweigbaum | KSC Viking Representative |
| John D. Gossett | Chief, Centaur Operations Division |

## Lewis Research Center

| | |
|---|---|
| Bruce T. Lundin | Director |
| Dr. Seymour C. Himmel | Associate Director for Flight Programs |
| Andrew J. Stofan | Director, Launch Vehicles |
| Lawrence J. Ross | Acting Titan/Centaur Project Manager |

## Goddard Space Flight Center

| | |
|---|---|
| Dr. John F. Clark | Director |
| Tecwyn Roberts | Director of Networks |
| Donald L. Schmittling | Chief, NASCOM Division |
| Leonard Manning | Head, Communications Branch |

## Energy Research & Development Administration (ERDA) Division of Space Nuclear Systems

| | |
|---|---|
| David S. Gabriel | Director |
| Glenn A. Newby | Assistant Director |
| Harold Jaffe | Chief, Isotope Power Systems Project Branch |
| Vincent G. Redmond | Acting Viking Program Manager for ERDA |

## VIKING CONTRACTORS

### Orbiter Prime Contractor

Jet Propulsion Laboratory
Pasadena, Calif.

### Orbiter Subcontractors

| | |
|---|---|
| Martin Marietta Aerospace<br>Denver, Colo. | Propulsion System |
| Rocketdyne Corp.<br>Canoga Park, Calif. | Propulsion Engines |
| General Electric Co.<br>Valley Forge, Pa. | Attitude Control System |
| Honeywell Radiation Corp.<br>Lexington, Mass. | Celestial Sensor |
| Motorola, Inc.<br>Scottsdale, Ariz. | Relay Radio and Telemetry; Radio Subsystem |
| Aeronutronics Ford Corp.<br>Palo Alto, Calif. | S-Band and Relay Antennas |
| General Electric Co.<br>Utica, N.Y. | Computer Command System |
| Spacecraft, Inc.<br>Huntsville, Ala. | Computer Command System |
| Motorola, Inc.<br>Scottsdale, Ariz. | Flight Data Subsystems |
| Texas Instruments<br>Dallas, Tex. | Data Storage Subsystems; Electronics |

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## Orbiter Subcontractors cont'd.)

| | |
|---|---|
| Lockheed Electronics<br>Plainfield, N.J. | Data Storage Subsystem; Transporter |
| Electro-Optical Systems<br>Xerox Corp.<br>Pasadena, Calif. | Power Subsystem |

## Science Instrument Subcontractors

| | |
|---|---|
| Ball Brothers Research Corp.<br>Boulder, Colo. | Orbiter Imaging; Visual Imaging Subsystem (VIS) |
| A.T.C.<br>Pasadena, Calif. | Water Vapor Mapping; Mars Atmosphere Water Detector (MAWD) |
| Santa Barbara Research Center<br>Goleta, Calif. | Thermal Mapping; Infrared Thermal Mapping (IRTM) |
| Bendix Aerospace Systems Div.<br>Ann Arbor, Mich. | Entry Science; Upper Atmosphere Mass Spectrometer (UAMS), Retarding Potential Analyzer (RPA) |
| Hamilton Standard Div.<br>United Aircraft<br>Windsor Locks, Conn. | Lander Accelerometers |
| K-West Ind.<br>Westminster, Calif. | Aeroshell Stagnation Pressure Instrument |
| Martin Marietta Aerospace<br>Denver, Colo. | Recovery Temperature Instrument |

## Lander Prime Contractor

Martin Marietta Aerospace
Denver, Colo.

## Lander Subcontractors

| | |
|---|---|
| Schjeldahl, Inc.<br>Northfield, Minn. | Bioshield |
| Martin Marietta Aerospace<br>Denver, Colo. | Aeroshell |
| Goodyear Aerospace Corp.<br>Akron, Ohio | Parachute System |

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## Lander Subcontractors (cont'd.)

| | |
|---|---|
| Rocket Research Corp.<br>Redmond, Wash. | Landing Engines |
| Celesco Industries<br>Costa Mesa, Calif. | Surface Sampler |
| RCA Astro-Electronics Div.<br>Princeton, N.J. | Communications |
| Honeywell, Inc.<br>Aerospace Division<br>St. Petersburg, Fla. | Guidance, Control and Sequencing Computer (GCSC) and Data Storage Memory |
| Martin Marietta Aerospace<br>Denver, Colo. | Data Acquisition and Processing Unit (DAPU) and Landing Legs and Footpads |
| Teledyne Ryan Aeronatuical<br>San Diego, Calif. | Radar Altimeter and Terminal Descent and Landing Radar |
| Energy Research and Development Administration (ERDA)<br>Washington, D.C. | Radioisotope Thermoelectric Generator (RTG) |
| Lockheed Electronics Co., Inc.<br>Plainfield, N.J. | Tape Recorder |
| Hamilton Standard Div.<br>United Aircraft<br>Windsor Locks, Conn. | Inertial Reference Unit (IRU) |
| General Electric Battery Division<br>Gainesville, Fla. | Batteries |

## Science Instrument Subcontractors

| | |
|---|---|
| Itek Corp.<br>Optical Systems Div.<br>Lexington, Mass. | Lander Imaging; Facsimile Camera System |
| TRW Systems Group<br>Redondo Beach, Calif. | Biology Instrument |
| Litton Industries<br>Guidance & Control Systems<br>Woodland Hills, Calif. | Molecular Analysis; Gas Chromatograph Mass Spectrometer (GCMS) |

## Science Instrument Subcontractors (cont'd)

| | |
|---|---|
| Martin Marietta Aerospace<br>Denver, Colo. | Inorganic Chemistry; X-Ray Fluorescence Spectrometer (XRFS) |
| TRW Systems Group | Meteorology Instrument System |
| Bendix Aerospace Systems Div.<br>Ann Arbor, Mich. | Seismometer |
| Celesco Industries<br>Costa Mesa, Calif. | Physical Properties; Various Instruments, Indicator, Mirrors |
| Raytheon, Inc.<br>Sudbury, Mass. | Magnetic Properties; Magnet Arrays |

## Launch Vehicle Contractors

| | |
|---|---|
| Martin Marietta Aerospace<br>Denver, Colo. | Titan III-E |
| General Dynamics/Convair | Centaur |

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## CONVERSION TABLE

| | Multiply | By | To Obtain |
|---|---|---|---|
| Distance: | inches | 2.54 | centimeters |
| | feet | 0.3048 | meters |
| | meters | 3.281 | feet |
| | kilometers | 3281 | feet |
| | kilometers | 0.6214 | statute miles |
| | statute miles | 1.609 | kilometers |
| | nautical miles | 1.852 | kilometers |
| | nautical miles | 1.1508 | statute miles |
| | statute miles | 0.8689 | nautical miles |
| | statute miles | 1760 | yards |
| Velocity: | feet/sec | 0.3048 | meters/sec |
| | meters/sec | 3.281 | feet/sec |
| | meters/sec | 2.237 | statute mph |
| | feet/sec | 0.6818 | statute miles/hr |
| | feet/sec | 0.5925 | nautical miles/hr |
| | statute miles/hr | 1.609 | km/hr |
| | nautical miles/ hr (knots) | 1.852 | km/hr |
| | km/hr | 0.6214 | statute miles/hr |
| Liquid Measure, Weight: | gallons | 3.785 | liters |
| | liters | 0.2642 | gallons |
| | pounds | 0.4536 | kilograms |
| | kilograms | 2.205 | pounds |
| | metric ton | 1000 | kilograms |
| | short ton | 907.2 | kilograms |
| Volume: | cubic feet | 0.02832 | cubic meters |
| Pressure: | pounds/sq. inch | 70.31 | grams/sq. cm |
| Thrust: | pounds | 4.448 | newtons |
| | newtons | 0.225 | pounds |

June 4, 1976