Apr 1st, 8:00 AM

The Science Of The Viking Missions

Gerald A. Soffen

Viking Project Scientist, NASA Langley Research Center, Hampton, Virginia

Follow this and additional works at: https://commons.erau.edu/space-congress-proceedings

Scholarly Commons Citation

https://commons.erau.edu/space-congress-proceedings/proceedings-1974-11th-v2/session-4/1

This Event is brought to you for free and open access by the Conferences at Scholarly Commons. It has been accepted for inclusion in The Space Congress Proceedings by an authorized administrator of Scholarly Commons. For more information, please contact commons@erau.edu, wolfe.309@erau.edu.
INTRODUCTION

The NASA's next missions to Mars are to land two unmanned spacecraft on the surface in 1976 to perform scientific experiments. This pair of missions called Viking consists of two identical spacecraft each launched from a Titan/Centaur in the summer of 1975. Each spacecraft consists of a Lander and an Orbiter combination and together carry 13 scientific investigations. The Orbiter carries its Lander to the planet and then acts as a relay to return the telemetered data to Earth. Following the launches in the summer of 1975, there is an 11-month cruise to the planet. The spacecraft are injected into highly elliptical synchronous orbits about the planet. The periapsis of about 1500 km is selected to be over the appropriate preslected landing site. The missions are separated by about 2 months so that the missions can be handled consecutively. For each spacecraft, after the landing site is certified and the orbit is trimmed, the Lander is released. The nominal landing target is an ellipse about 100 by 500 km. The Lander enters the Martian atmosphere at about 15° traveling about 5 km/sec. The initial deceleration is from the aerodynamic drag of its 12-foot aeroshell. At about 5 km above the surface, a parachute is deployed as the second braking system. At 2 km as sensed by an onboard radar, three retro-rockets are fired and the Lander is soft landed onto the surface (see Fig. 1).

The scientific experiments aboard the Lander require several months of operation; the nominal length of the mission is 60 days. Power for this period on the Lander is obtained from two 35-watt radiisotope thermoelectric generators. The data from the experiments are telemetered by relay up to the Orbiter and back to Earth or may be telemetered directly from the Lander to the Earth at a lower rate. Commands to both the Lander and Orbiter will be sent over the deep space net. A tape recorder aboard the Lander will allow storage of data for subsequent transmission, thereby permitting events to be recorded independent of the positions of the Orbiter or Earth.

The Project is assigned by the Office of Space Science, NASA Headquarters, and is managed by Langley Research Center. The Orbiter is being built by the Jet Propulsion Laboratory, Pasadena, California; Lander by Martin Marietta Aerospace, Denver, Colorado; Launch Vehicle is the responsibility of Lewis Research Center and Launch Operations by Kennedy Space Center. Numerous subcontractors supply the scientific instruments and other hardware.

MARINER 9 RESULTS

The scientific goals of the Viking were established at the beginning of the Project in 1969, based on the previous decade of discussions and the results of the earlier Mariner fly-by. In 1972, the results of Mariner 9 confirmed the significance of the Viking goals which focuses on the atmosphere and surface and places special emphasis on the biological question of the search for life on Mars. What emerged from Mariner 9 was the heterogeneity of the planet. Prior to Mariner there was speculation that Mars is "like the Moon." Now we know that Mars is very different from the Moon. Mars has extraordinary volcanoes of apparently recent origin, a giant valley several thousand km long and 6-8 km deep, and flat wind-swept plains. There are cratered regions that have been impacted by meteors, regions of tectonic activity, regions dominated by erosion, and some features that appear to have been caused by flowing water. A great deal of literature has emerged recently discussing the possibility of rivers in the recent past, since they can no longer exist. Indeed, the state of water and its chemistry and physics on Mars has engendered several Colloquium. The legacy of Mariner 9 is to pose several important scientific questions of which some answers will come from Viking. The other important derivative of Mariner is a detailed set of maps of the Martian surface at 1 km resolution that permits the selection of landing sites based upon maximum scientific interest and a high confidence of engineering safety.

The scientific questions that dominate our current ideas are:

1. Is there life on Mars? There is no evidence, the Mariner pictures are at too low a resolution. Our knowledge of the atmosphere and surface temperature indicates a hostile but not fatal climate for terrestrial type organisms. The absence of liquid water is the most problematic condition. Biologists conjecture that if there is life it is of a microscopic type.

2. What is the degree of chemical differentiation of the surface? This is related to the history of
of the planet. Scientists have begun to understand the distillation processes that take place in the formation of a planet in separating the light and heavy elements. The surface chemistry will determine the degree of those processes.

3. What is the history of the atmosphere? Since Mars' atmosphere is 95 percent or more carbon dioxide it is known to be a secondary atmosphere. The subject of the formation of this atmosphere is a key to the understanding of the planet's evolution. In particular, it is important to know the fate of nitrogen since none has yet been detected in the atmosphere.

4. What are the dynamic conditions that govern the present-day processes? Since finding the different features of the planet and because we know that it has seasons there is extreme interest in understanding contemporary meteorological and seismological events. This is of particular interest in relating the processes to those same kind affecting the Earth.

INVESTIGATIONS

Orbiter

The Orbiter as shown in Figure 2 carries three instruments all mounted on a common scan platform. The platform can be aimed at a particular target. The three instruments, a pair of TV cameras, an IR radiometer, and an IR spectrometer are all borsighted so that the data collected is common to all. This permits a better interpretation of the feature or phenomenon being observed. The data from the Orbiter instruments are used to verify and certify the landing sites, to monitor those areas during operation of the Lander, and can be used to look at other regions of the planet. These data may also help in the interpretation as well as to gain information for future missions.

TV Cameras

The Orbiter will carry a pair of high-resolution TV cameras. The picture will be used to understand the physics and dynamic characteristics of the surface. The atmospheric and surface changes in the vicinity of the Lander will be followed to allow for planning the Lander operations. The position of the Lander will be located by correlation of large-scale features seen by both Lander and Orbiter. Viking cameras are about double the resolution of the high-resolution Mariner 9 cameras (about 40 meters), but mainly they are used in a different way. Mariner cameras were used for mapping the planet or sampling regions. Viking cameras will obtain high-resolution coverage centered around the landing site. We will obtain a swath of the area as the Orbiter flies over. This has required the development of a new tape recorder, since the data are taken at a rate never before experienced. Working together, the two cameras each take a 40- by 40-km picture. While one camera is taking its picture, the other is reading it out alternatively. The contiguous swath is then 80 km wide and may be several hundred km long on a single orbital pass. The pictures will reveal permanent geological features and in the course of the mission the seasonal changes in those features. Of particular interest is the polar regions. Mariner data indicate the permanent polar caps to be a laminated terrain probably formed by deposition of layers over a long time. The Viking missions arrive at Mars at the onset of Martian summer in the northern hemisphere. The polar cap will be reeded and as the season progresses we should see the onset of the polar cap as it begins to form.

Water Mapping

The second instrument on the Orbiter is an IR spectrometer designed specifically to measure the abundance of water in the atmosphere. We know from Earth telescopic data that there is water in the atmosphere of Mars. What we don't know is how much, where it comes from, how it interacts with the surface, and how it circulates as a function of time of day and season. Water is of particular interest to the biologist, since it is likely to be the limiting nutritional substance on Mars. To search for life is to go to the wettest place. In addition, if we are to understand the relationship of Martian chemistry and biology to its environment, it is important to understand the water cycle.

The instrument operates at an absorption band of 1.35 micrometers and is designed to scan the surface across the tract of the spacecraft. Each frame of 3 km by 24 km is taken continuously side by side covers the same area as the TV camera. This gives a band 45 km wide and the length of the swath.

IR Radiometer

The third instrument on the Orbiter is a thermal mapping experiment. A similar experiment was flown on Mariner and from it we were able to learn the temperature of the surface, the poles, and the equatorial regions. The Viking radiometer is a refinement. Instead of the single point measurement, we will scan the surface with a set of detectors at different wave numbers. This array of detectors will permit a set of thermal measurements of the surface. These measurements can be overlaid on the pictures to produce a kind of thermal map. The objective of this investigation is to determine the surface kinetic temperature and the thermal balance. The surface and atmospheric temperature are closely linked, and from these measurements we can make certain determinations of the roughness of the surface and the nature of the physical structure. Especially with appropriate measurements from the Lander giving the ground truth, these details will be useful in confirming the area near the Lander and also allow for interpretation of other areas of the planet. Thermal anomalies will be of particular interest in light of the degree of suspected recent internal activity of the planet.
Lander

The Lander is a three-legged device (Fig. 3) with an onboard computer, tape recorder, telemetry system direct to Earth and another link up to the Orbiter. It carries nine scientific investigations. The experiments are conducted at differing times during the mission, which will take place from July through mid-November 1976. At that time Earth/Mars undergoes solar conjunction and telemetry is lost for about a month. Following that month, if the Lander is still functioning, there may be an opportunity to continue to gather data.

Entry Science

During the descent to the surface there will be a set of measurements made to determine the atmospheric structure and composition. This will be done with several instruments. Mounted on the aeroshell are two instruments: a retarding potential analyzer for measuring ions and electrons in the upper atmosphere and a mass spectrometer for measuring the neutral species. A mass spectrometer, which is a magnetic sector instrument, will measure gases of mass range from 1-50 amu. These instruments will begin to function when the Lander just senses the atmosphere and will continue to obtain a profile down through the aeroshell phase of the descent at somewhere about 20,000 feet. These in situ data are particularly important in confirming and developing our models of the Mars atmospheric composition. They will be used to understand the interaction of the solar wind on the upper atmosphere, the internal chemistry of the atmosphere, and begin to reconstruct the history of the atmosphere. Pressure and temperature will be measured as a function of altitude to complement the compositional data. These together with measurement of the accelerometer of the descending spacecraft will allow construction of a model of the density of the atmosphere, important not only for science but also to engineers designing entry systems for Mars.

Cameras

Two cameras are mounted on the lander at an elevation of 1.3 meters above the surface. Together they provide complete panoramic coverage around the Lander, stereoscopic coverage of the site from which surface samples will be taken by a digging device, coverage of the landing foot pads, and certain targets on the spacecraft proper. The cameras are identical facsimile type devices. Using a scanning mirror and a single point detector, they scan one vertical line at a time by nodding the mirror. The whole camera is moved in azimuth line by line to create the picture. The resolution of the camera is several millimeters at the base of the spacecraft. The cameras have several channels that allow for color photography and one channel dedicated to the IR portion of the spectrum. This will be used for certain crude estimates of the mineral composition. Pictures of the vicinity of the landing site will include both high resolution of the immediate area and lower resolution shots of the distant terrain. During the several months on the Martian surface, it is anticipated that we may see several kinds of changes due to seasonal effects, diurnal effects, or high intensity winds.

Surface Sampler

The Lander carries a 10-foot extendable boom with a sampling device at the end. This will be used to gather surface material for several of the experiments that are housed inside the spacecraft; the boom can swing in a 120° arc and obtain samples from the immediate vicinity of the landing foot pads, out to 10 feet. This permits considerable selection in the samples to be taken. The sampling arm is used in conjunction with the pictures of the sampling area for the final choice of the material to be tested. The sample collector is a digging scoop that can capture a wide variety of soil classes from loose dust to highly consolidated material. The sample will also be used to determine the physical properties of the surface by digging in the surface, lifting and dropping rocks, and exerting compression on the surface.

Biology

The search for life on Mars, a major theme of the Viking mission, will be done with three instruments: the cameras, an organic analysis, and a direct active biology experiment. The direct experiment consists of three physiological techniques for detecting life. In each of these experiments a small soil sample is placed in a closed chamber and exposed to certain incubation conditions. Measurements are made of the chemical products of biological activity. In one experiment a test is made for carbon fixation. This is done by labeling CO and CO₂ and determining the newly formed organic compounds in the presence of light, as in photosynthesis, as well as in the dark. This experiment has the most Mars-like conditions. In a second experiment, a dilute organic aqueous media is used for the incubation and a determination made of the CO₂ coming off. This is the main product of respiration for terrestrial organisms. In the last experiment a rich mixture of nutrients is used for the incubation and the exchange of gases between the aqueous and gaseous phase is measured. This should be a measure of the gaseous products of metabolism. Each of these experiments has a companion control experiment in which an identical soil sample is tested in the same way after being heat sterilized. This is to insure that the result is of biological nature and not due to reactions of the soil itself.

Molecular Analysis

This investigation consists of a chemical analysis of the organic fraction of the soil, and also an analysis of the atmosphere. The instrument, called a GC/MS, is very sensitive, operating in the parts per million range, and uses a mass spectrometer (12-200 amu) as the detector. For the first several days of the mission the instrument will make diurnal measurements of the atmosphere. Both major and minor constituents will be measured by using a device for removing carbon dioxide, the principal component. Minor constituents will be of

4-3
significant biological, chemical, and photochemical importance. For the analysis of the soil, the samples to be tested are introduced into sealed chambers in the instrument. The chamber is a small oven. When heated the organic component volatilizes or ultimately pyrolyzes, and this gas is introduced first into the gas chromatograph where it is separated, and then into the mass spectrometer where it is measured. The data of the molecular fragments are used to deduce the identity of the parent material in the original soil sample. These data may be very important in corroborating the biological result.

Inorganic Chemical Analysis

One of the fundamental scientific questions of Mars is the nature of its surface composition. This reflects not only the current dynamic processes but also the thermal events of the history of the planet. An X-ray fluorescence instrument will be used to determine the elemental composition of the surface. This will cover a range of elements from aluminum and above. The lighter elements such as nitrogen, oxygen, carbon, and so forth, are not detected separately by this instrument and will be lumped together. The heavier ones like silicon, aluminum, magnesium, iron, and so forth, will be analyzed to a high degree of accuracy. The instrument uses isotopic iron and cadmium to produce X-rays which irradiate the sample. The fluorescing radiation is measured with appropriate detectors and geometry. The design of the instrument permits the analysis of 10 or so different samples.

Meteorology

Since Mariner 9 data are very suggestive of a complex Martian climate, it is appropriate that Viking perform a meteorological investigation. Pressure, temperature, wind speed, and wind direction will be measured periodically during each diurnal cycle. The sensors are mounted on a boom in order to avoid interference from the body of the Lander. The investigators recognize the limitations of determining global events from only two points on the planet. The data will be used in collaboration with several other experiments, orbital imaging, thermal and water mapping, and Lander imagery in order to improve the understanding of the data and extend the model. The science derived from this investigation is likely to bear on our understanding of terrestrial processes which are more complex than Mars, and therefore more difficult to model.

Seismology

Each Lander will carry a small seismometer for measuring surface motion. This instrument operates at 1-4 Hz and is coupled to the ground through the landing legs. In its listening mode it will measure periodically over the entire time of the life of the Lander. In the event of a seismic event, the instrument will trigger into a high data rate mode and measure that particular event. Since it is impossible to predict when such an event will take place, and because of the importance of these data, the seismology has a high priority of stopping other activity on the Lander. However, this is not allowed to interfere with certain critical activities such as performing the biological experiment or transmitting certain essential engineering or science data.

Magnetic Properties

A small array of magnets are mounted on the sampling arm. This array can pick up magnetic material on the surface which is then photographed by the camera. By controlling the strength of the fields of the magnets it is possible to cover a range of magnetic materials. In conjunction with this investigation there is a small magnifying mirror that is used to improve the ability to see the material that is picked up.

Physical Properties

A number of engineering measurements can be used to make certain determination of the surface properties. The motor currents of the sampling area, pictures of the foot pads taken after landing, measurement of the stroke of the landing leg, a variety of temperatures measured, and so forth, are illustrations of these.

Radio Science

As have been previously done for the Mariner spacecraft, the performance of the communication systems will be used to make measurements of the atmosphere of the planet and determine certain celestial mechanics. It will also be useful in locating the Lander on the surface and performing some experiments in relativity. The available links are Lander to Earth and Orbiter to Earth on S band, Lander to Orbiter on UHF, and an Orbiter to Earth on X-band frequency.

Summary

Viking will consist of a pair of spacecraft to be orbited and landed on the surface of Mars. They will carry 13 scientific investigations that deal with the search for life, determination of the atmospheric properties and composition and its meteorology, and measurements of the surface. The surface will be studied on a global scale by the Orbiter and detailed chemical and physical analysis of samples will be performed by the Lander.
Figure 1

LANDER DESCENT PROFILE

SEPARATE

DEORBIT

COAST

PEAK DECELERATION
(24,384 - 30,480 METERS)
(80,000 - 100,000 FT.)

DEPLOY PARACHUTE
JETTISON AEROSHELL
(About 6,400 METERS)
(21,000 FT.)

ENGINE IGNITION
PARACHUTE JETTISON
(About 1,215 METERS)
(4,000 FT.)

ENTRY TO
LANDING
(6-13 MINUTES)
SPACECRAFT CONFIGURATION IN CRUISE MODE
(sunlit view)

- LOW GAIN ANTENNA
- PROPULSION MODULE
- SCIENCE PLATFORM
- CRUISE SUN SENSOR & SUN GATE
- VIKING ORBITER
- RELAY ANTENNA
- VIKING LANDER CAPSULE
- HIGH GAIN ANTENNA
- ATTITUDE CONTROL GAS JETS
- SOLAR PANEL
- SOLAR ENERGY CONTROLLER
- ORBITER BUS

Figure 2
Figure 3