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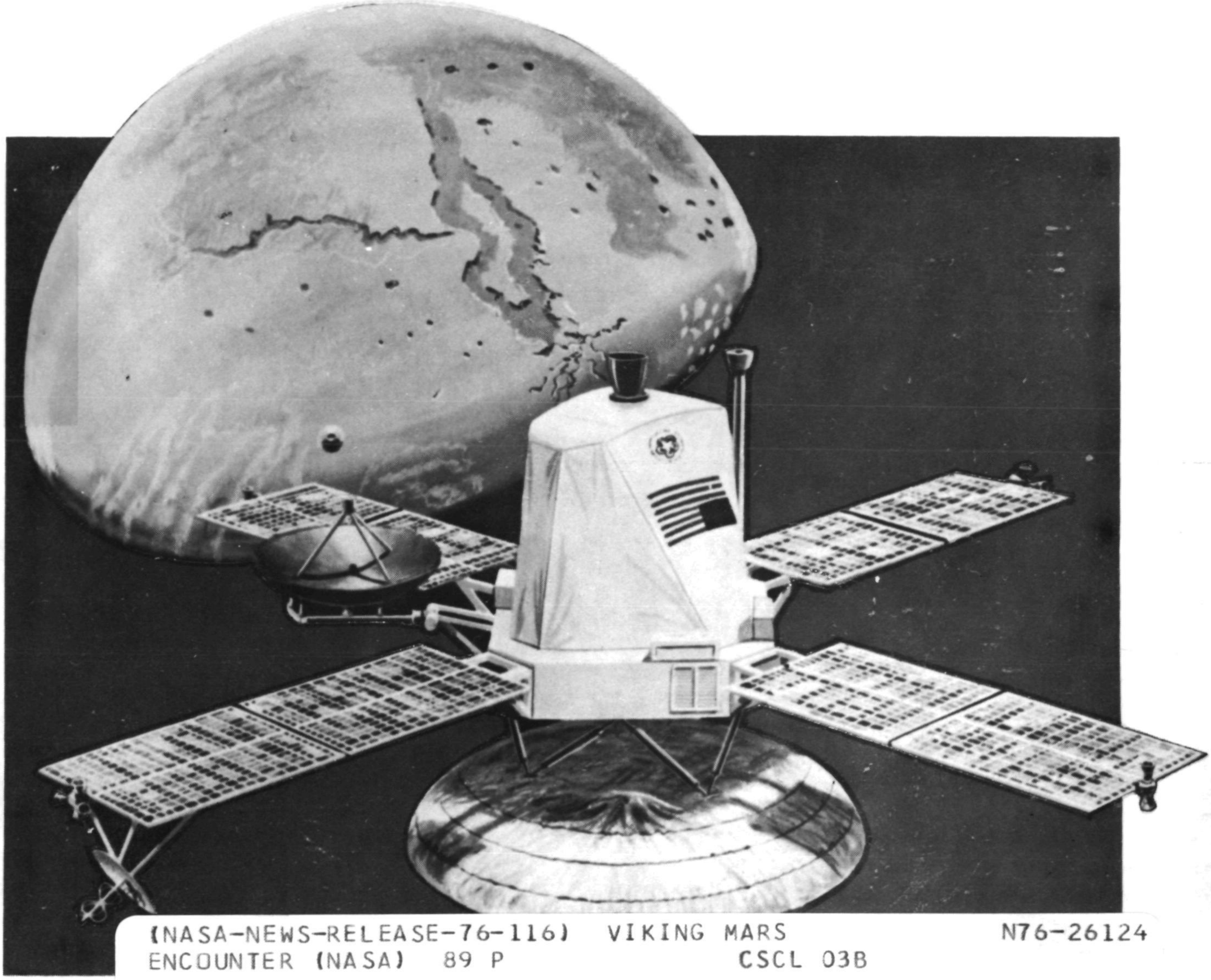

(NASA-NEWS-RELEASE-76-116) VIKING MARS ENCOUNTER (NASA) 89 P CSCL 03B N76-26124

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VIKING PRESS HANDBOOK

NASA
National Aeronautics and Space Administration

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NOTE TO EDITORS: This press handbook contains detailed descriptions of the various phases of planetary operations related to the Viking mission to Mars. It may be used as a source of information independently, or in conjunction with the Viking Encounter Press Kit.

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RELEASE NO: 76-116

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VIKING MARS ENCOUNTER

APPROACH PHASE: June 9 Through June 19, 1976

Operations

A final course correction is made 10 days before Viking 1 is scheduled to enter orbit around Mars. This approach midcourse correction maneuver (AMC) consists of a small change in velocity and direction to ensure that the Mars orbit insertion maneuver (MOI), some 10 days later, results in an orbit that permits coverage of the prime landing site (A-1) in Chryse. The orbit will be adjusted as required after MOI.

Instructions for MOI were sent to the spacecraft and loaded into its computer on May 22 and are enabled a day after the final AMC. These instructions are sufficient for the spacecraft to enter an orbit around Mars even if no further commands can be sent to it before the date of the MOI. This safeguard is essential to the mission because Viking has only one opportunity to enter orbit around Mars. Should this be missed the spacecraft would fly by the planet and continue on its orbit around the Sun.

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

During the interplanetary cruise phase of the Viking mission radio science investigations using a dual frequency downlink from the spacecraft on Earth (X-band and S-band) measured properties of the interplanetary medium, particularly the total electron content and its variations, are determined by analyses of the differences in signal properties on the two downlink frequencies. From these measurements, the intensity, size and distribution of electron streams from the Sun and from solar storms are studied to increase understanding of the Earth-Mars region of the interplanetary space.

Basic tracking data to navigate Viking towards Mars consisted of very precise measurements of distance (range) and line of sight velocity (range-rate) between the spacecraft and the Earth-based tracking stations. Range and range-rate measurements are the primary data used to determine orbit and trajectory characteristics.

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Now during the final approach to Mars, the radio signals are used to determine the precise path of the spacecraft after the final AMC so that it can be commanded into the correct orbit around Mars by the MOI maneuver.

The instructions for MOI can be updated five days before it takes place. This allows for use of the additional radio-derived navigational and orbital data obtained after the final AMC to refine the change in velocity and spacecraft orientation needed to enter the required orbit about Mars. A final correction, based on optical navigation through use of the TV cameras aboard the Orbiter, as described later, may be made, about 16 hours before MOI.

Science

Five days before MOI the approaching spacecraft starts science experiments directed to Mars itself and to optical navigation.

Now, TV images are obtained of the whole disc of Mars, of star fields, and of a satellite of Mars. Infrared scans of the planet give gross determinations of surface temperatures and concentrations of water vapor in the Martian atmosphere in preparation for more precise measurements to come.

There are four reasons for the science experiments during final approach to Mars:

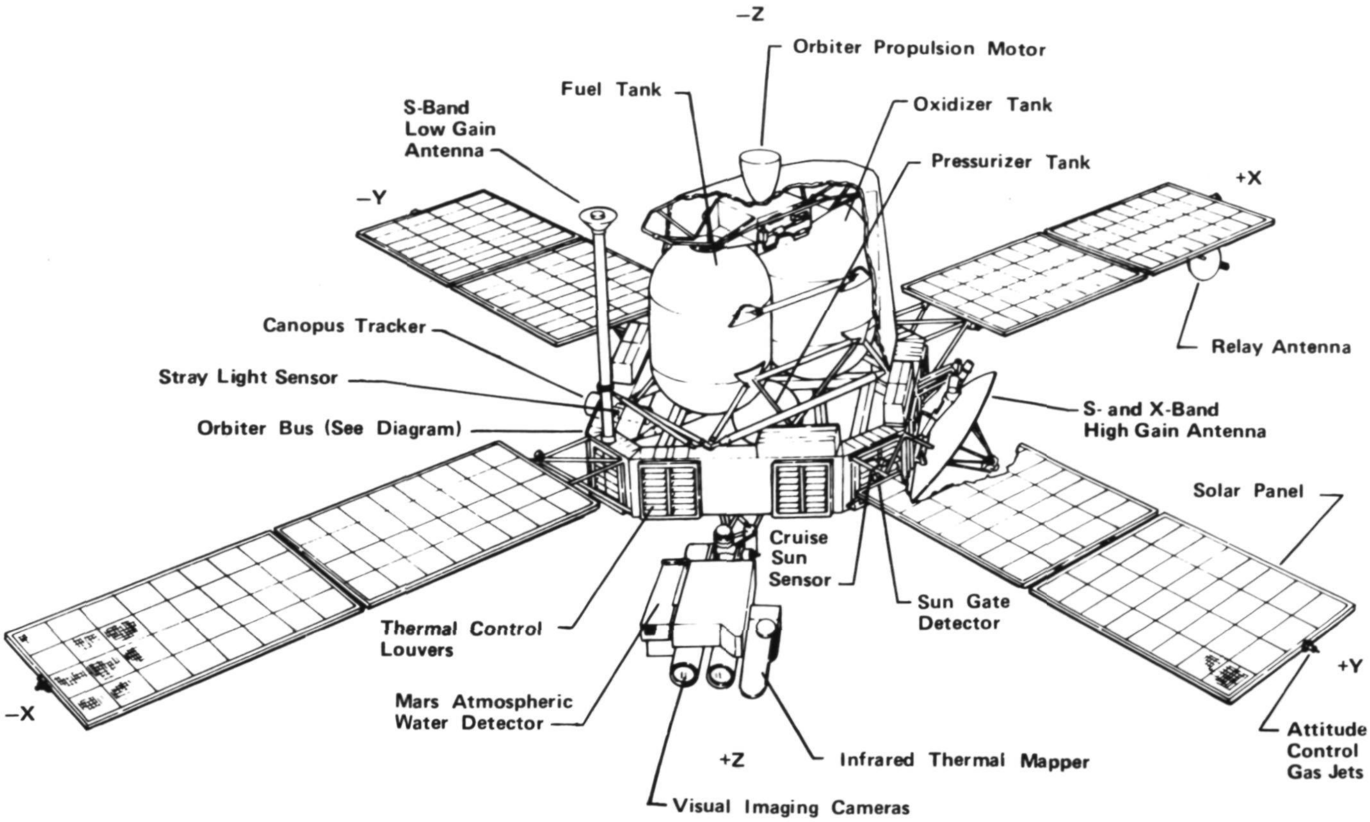
- Instruments can now be calibrated for the first time with Mars as a target.

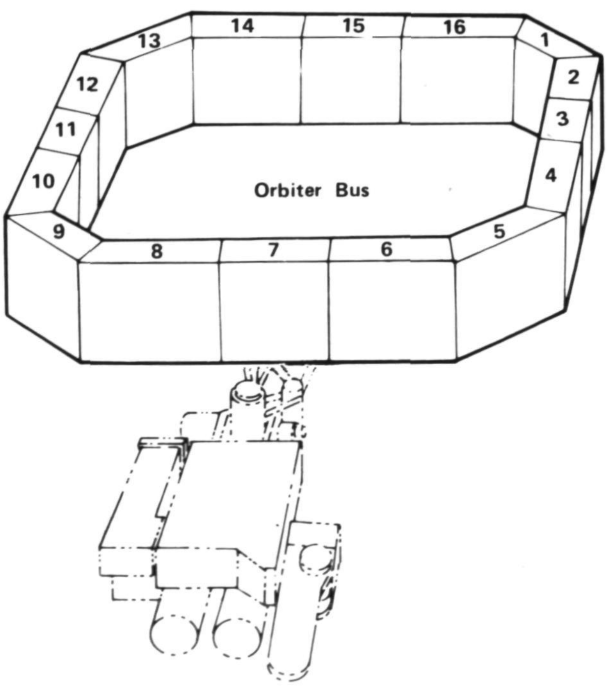
- Some scientific measurements can only be made at this stage of the mission, such as color pictures of the disc of Mars. Later Viking will be too close to the planet.

- Observations of Mars' small moon Deimos against a star background provide final, very precise navigational data needed for an accurate MOI.

- Look for changes to markings and present condition of planet.

Eight images (frames) of the whole disc of Mars are taken on June 14 using red and violet filters. The final series of optical navigation pictures begin on June 15.





Bay	Subsystem/Components
1	Radio Frequency Subsystem, Modulator Demodulator Subsystem, X-Band Transmitter
2	Computer Command Subsystem
3	Reaction Control Assembly High Pressure Module
4	Data Storage Subsystem
5	Attitude Control Subsystem and Articulation Control Subsystem
6	Flight Data Subsystem
7	Scan Platform Subsystem
8	Visual Imaging Subsystem, Mars Atmospheric Water Detection Subsystem
9	Battery Assembly
10	Power Source Electronics Assembly
11	Reaction Control Assembly High Pressure Module
12	Power Processing and Distribution Assembly
13	Battery Assembly
14	Digital Tape Recorder Assembly
15	Relay Radio Subsystem, Relay Telemetry Subsystem Pyrotechnic Control Subassembly
16	Radio Frequency Subsystem

Orbiter Details and Equipment Location

The two TV cameras aboard the spacecraft alternately photograph Mars and a star background. Alternate cameras are used because of the great difference between the exposure needed for Mars and the stars. If one picture only were taken with Mars in the same frame as the starfield and given sufficient exposure to record the stars, the disc of Mars would be so overexposed as to make measurement of its position relative to the stars impossible. But since the axes of the two cameras are known precisely, 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. Just before MOI 37, photographs of Deimos, one of the small moons of Mars, against the star background will provide additional navigational information.

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

Calibration of the imaging system during final approach is needed because the cameras are susceptible to changes during the 11-month flight through interplanetary space.

Approach pictures of Mars will show the rotation of the planet on its axis. Some are repeated in three colors -- so that colored pictures can later be reconstructed. These initial color pictures are expected to be spectacular because Mars should be free of major dust storms -- the planet is close to aphelion, its greatest distance from the Sun, while the global dust storms are observed to take place around peri helion when Mars is closest to the Sun. The pictures will not show a full disc because the spacecraft is approaching Mars in such a way that its cameras see the planet as a half-moon phase. This is a view of Mars that can never be obtaine from Earth.

Extending from 50 to 24 hours before MOI, the sequence of pictures gradually changes, from views of Mars in detail similar to that seen in the best Earth-based telescopes to views showing craters and a wealth of surface detail, including a first look by Viking at the landing sites.

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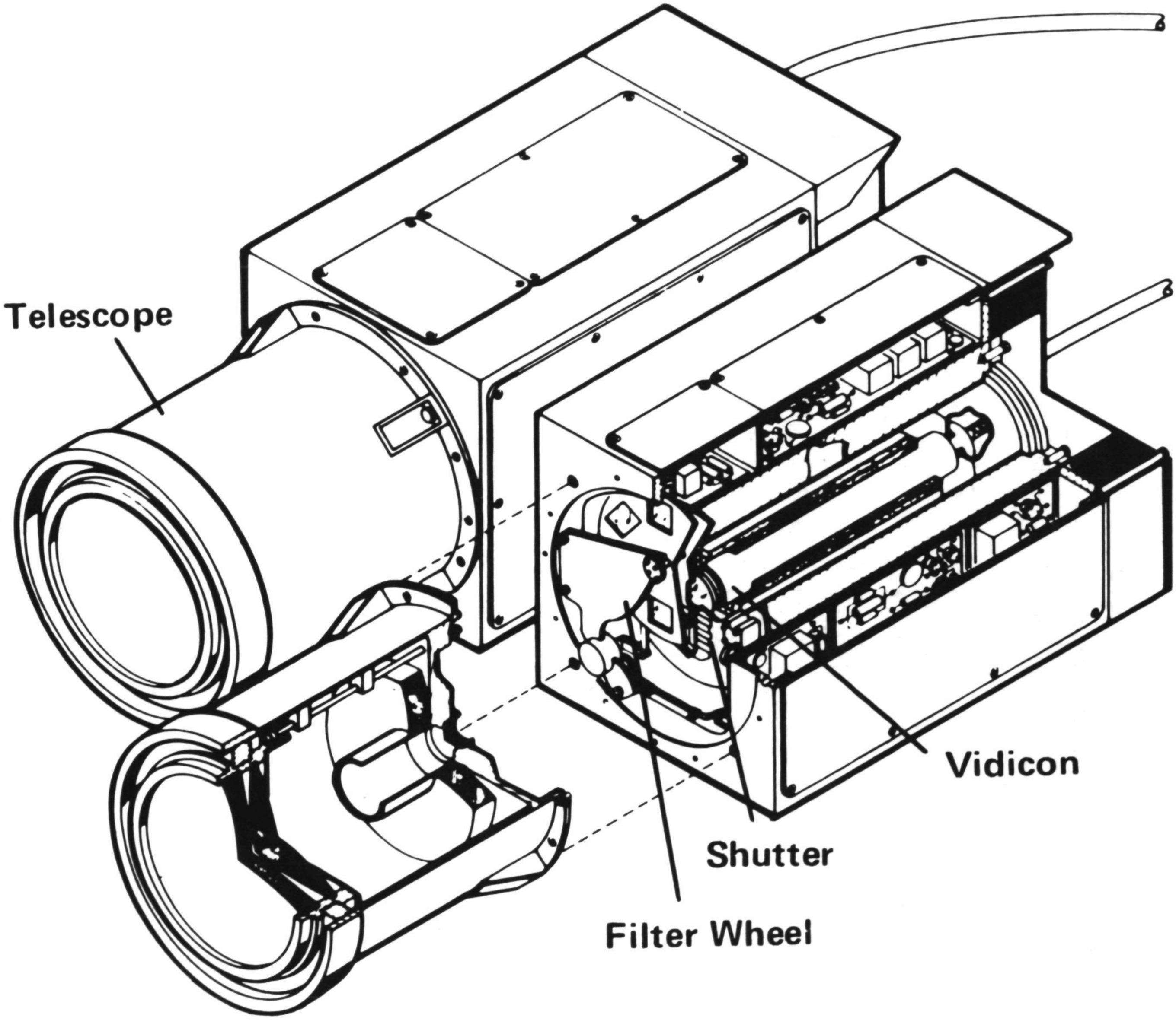


Orbiter Camera

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

Fifteen days before MOI, the infrared thermal mapping instrument (IRTM) which is mounted on the same scan platform as the cameras, goes through alignment and calibration testing. In the final day before MOI this instrument is used for low resolution thermal mapping of the Martian surface, i.e., 20 samples across the planet at a range of 193,000 kilometers (115,000 miles) for longitude coverage of temperature changes of the surface of Mars.

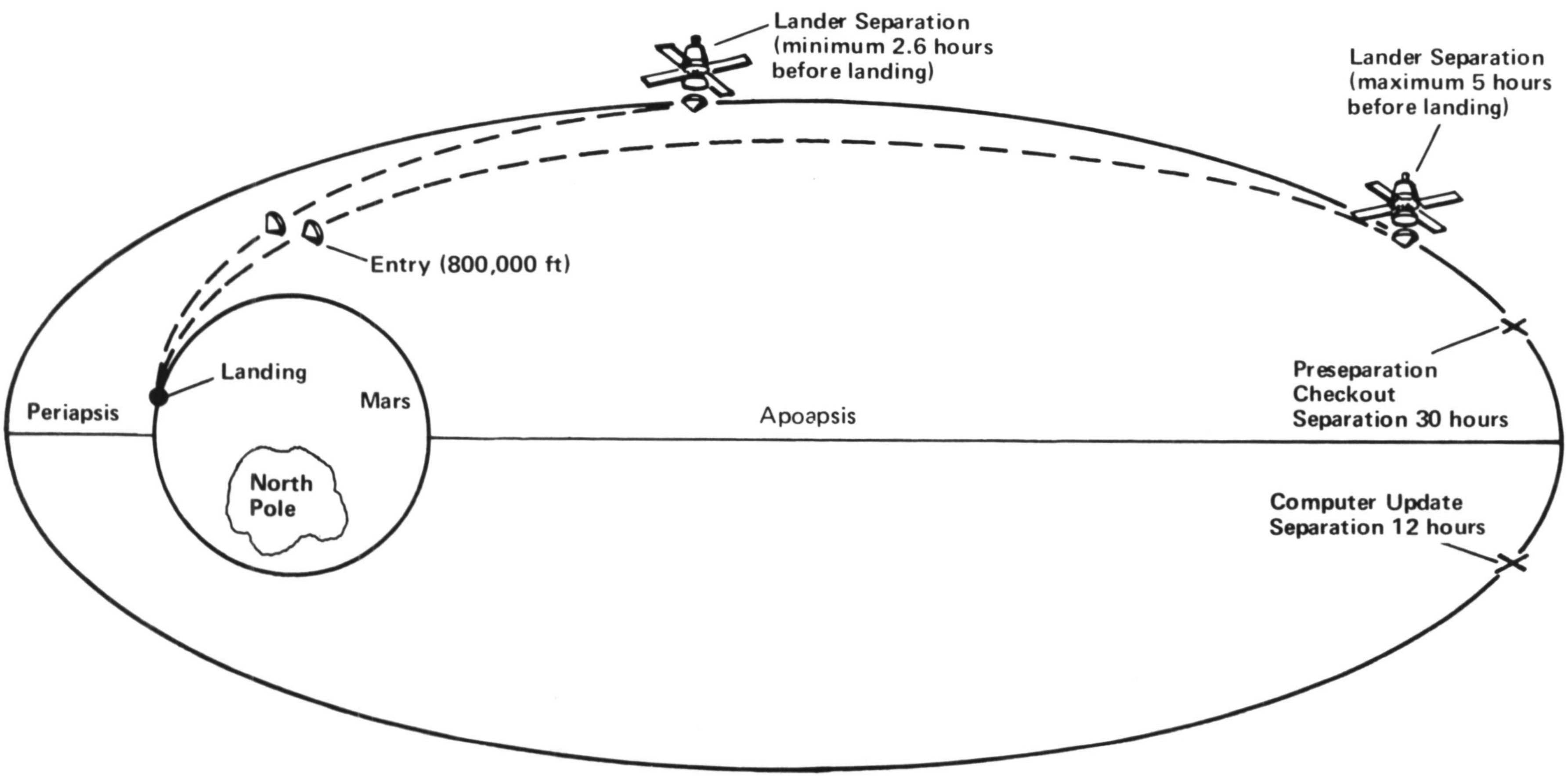
Five days before MOI the infrared water vapor experiment -- Mars Atmosphere Water Detector (MAWD) -- also on the scan platform makes a first scan of the planet. A similar scan is then repeated daily. The best water vapor data are obtained within the period of one and a half days before MOI when several scans are made.

MARS ORBIT INSERTION: June 19, 1976

The purpose of this maneuver is to place the spacecraft in an orbit that requires only minor corrections to permit the Viking Lander to touch down later in the Chryse landing site, when this site is certified as safe by observations from orbit.

The spacecraft is first rolled, then yawed, then rolled again to facilitate alignment of the high-gain antenna toward Earth so that good communications can be maintained with the spacecraft in the burn attitude at its great distance of 380 million km (236 million mi.) from Earth. While no science experiments take place during MOI, engineering data continue to flow back to Earth except for the brief period between the two roll maneuvers when communications are temporarily interrupted as the high gain antenna points away from Earth. When the engineering telemetry data are again received at Earth this is a good indication that the spacecraft has oriented itself ready for the burn. First indication of a successful burn is the abrupt change in the Doppler residual graph which is displayed on screens to mission controllers and others, showing that the trajectory has changed from that followed before the burn started.

After the MOI burn the spacecraft reorients itself ready to make its science experiments in orbit.



Mission Events, Orbit Insertion, Separation, Deorbit and Entry

PRELANDING ORBITAL ACTIVITIES:

June 19 (MOI) Through July 4 (Separation)

After Viking has achieved orbit around Mars, it performs three major activities:

- Transmits data for site certification.
- Navigates to the landing site chosen for Lander 1.
- Checks out the Lander and updates its memory with commands for it to descend automatically to the surface of Mars and undertake a successful mission even without further commands from Earth.

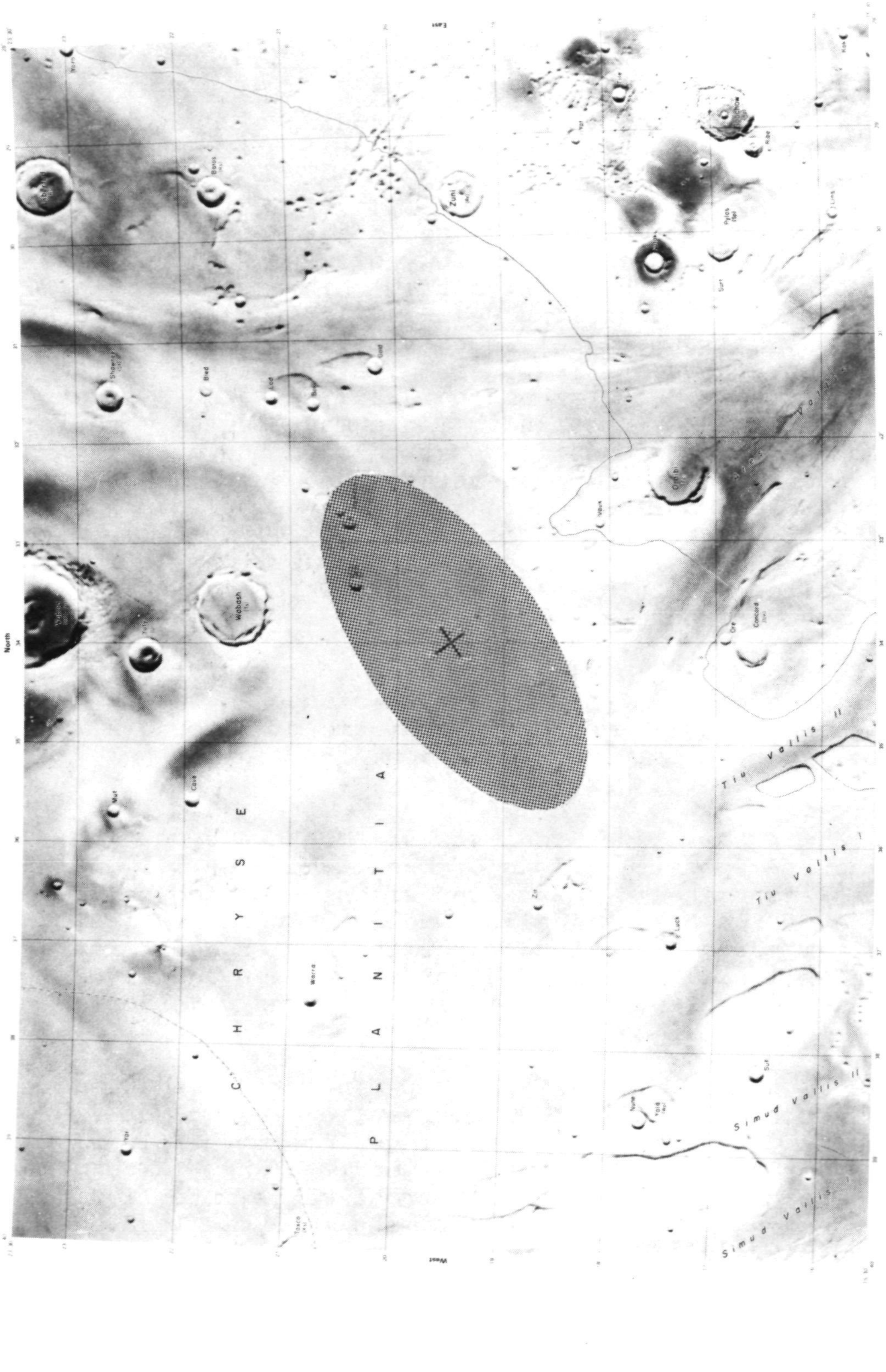
There are only 15 Earth days from MOI to the scheduled time of Lander separation from the Orbiter. One of the major activities during this time is to certify the chosen landing site for the Viking 1 Lander as being safe. This is done by use of the science instruments aboard the Orbiter to supplement radar data obtained by Earth-based observations.

Landing Sites

The landing site for Viking 1 was selected some time ago on the basis of Earth-based observations and Mariner 9 photography.

Following study by a panel of geologists and other scientists four sites were selected on Mars for landing of the Viking spacecraft -- two prime sites and two backup sites. The sites were selected on the basis of safety with the requirement that they should be geologically different to provide two types of Martian surface for sampling. They should be at low altitude, where atmospheric pressure is great enough to help the landing and where there can be a chance of minute amounts of liquid water. Additionally, the sites were chosen in areas of Mars that appear to provide a most varied opportunity to look into the planet's evolution and where the two Landers could be expected to observe the same Martian seismic events -- marsquakes.

The sites 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 to blow at less than 255 kmph (160 mph).



TOPOGRAPHIC MAP OF THE CHRYSE REGION OF MARS

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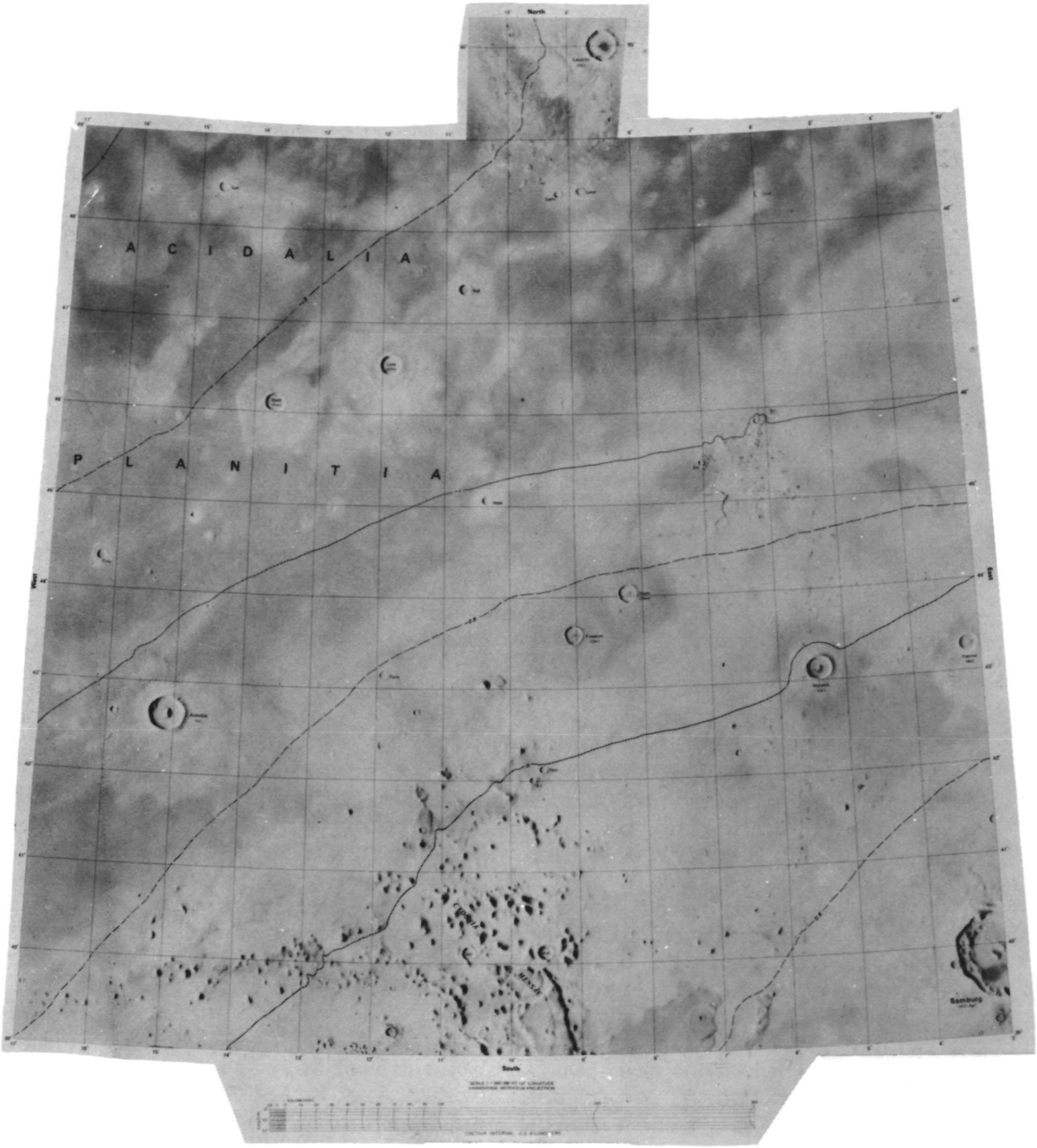
The first Viking is aimed for a landing site at 19.5 degrees north latitude and 34 degrees west longitude, in a region of Mars called Chryse.

The southern half of the Chryse area consists mostly of deeply dissected plateaus, possibly of material deposited from volcanoes. But much material from this area seems to have been swept northward along well-defined channels to a low area of only slight relief where the Viking Lander is expected to touch down. Scientists believe that the surface at this site is nearly everywhere partially covered by dust deposits transported by the wind. There may also be material washed from the canyons and interspersed with the dust layers. The wind-driven deposits may consist of sand dunes, each hundreds of meters across and covered with tiny ripples. The channel deposits might consist of slightly rolling hills with small channels and low sandbanks, each perhaps tens of meters wide. This site is within a region where water may have flowed in copious quantities in the past.

The second Viking will be targeted to land farther north in an area called Cydonia, a flat stretch of the northern basin plains. Cydonia is the name of a town in Crete which, in turn is named for Kydon, the son of the greatest king of Crete, Minos.

The landing site area consists of smooth and mottled rolling plains -- possibly flows of basalt covered by windborne debris and volcanic dust. The site is located 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, as well as the windborne and waterborne debris.

There is a band around Mars, between latitudes 40 and 55 degrees north, where liquid water may be present for a short period at the end of winter. Thus life might fluorish for a brief period here each Martian year, taking up its water from the Martian soil as permafrost melts into liquid. The second landing site, known as prime site B, is located in this band, at 44.3 degrees north latitude and 10 degrees west longitude.



TOPOGRAPHIC MAP OF THE CYDONIA REGION OF MARS

Both prime sites have backup sites to be used if the first sites are rejected following close observations from orbit before the actual landings. The backup to site A is in a region known as Tritonis Lacus, at 20 degrees north latitude and 252 degrees west longitude. The site B backup is in the region of Alba at 44.2 degrees north latitude and 110 degrees west longitude, a low volcanic plateau. All the sites are thus in a variety of plains in the northern lowlands, comparable to the 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 best samples to test current theories about the evolution of Mars.

The TV images obtained by Viking will have about the same resolution as the Mariner 9 pictures. They will show details of the surface of Mars larger than 83 meters (250 feet).

Earth-based radar cannot look at the Chryse landing site until just before the landing. In 1967 less powerful radar did look at the area and showed that this A site and its backup have different radar characteristics.

From May 29 through June 12, the Goldstone 64-m (210-ft.) antenna will periodically bounce radar echoes from the A primary site region and from May 11 to June 15 from the A backup site region. An even larger antenna at Arecibo, Puerto Rico, examines the sites also. The Goldstone antenna works at X-band and the Arecibo antenna at S-band (approximately 8400 MHz for X-band and 2400 MHz for S-band).

The surface of Mars is known to be about five times as rough as that of the Moon. This applies to major elevations from place to place on Mars and to small scale surface effects revealed by radar reflectivity. But there appears to be no conclusive match between the radar results and the pictures from orbit. However, recent studies have revealed some ties between the two methods of observation. Plains 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 looking 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.

Extreme radar scattering in the Martian highlands may be caused by tiny channels like dry washes in Arizona. This too, is suggested by observations of terrestrial features from altitude and comparing the radar return signal's characteristics with those of signals returned from Mars.

Radar probing of the sites had to wait until just before the arrival of Viking at Mars because the position of Mars on its orbital trajectory and the tilt of the planet's axis did not allow the landing sites to face directly toward Earth earlier so that a radar echo could be received from them. Even so, the distance of Mars is so great -- 380 million km (228 million mi.) -- when the geometry is right, that the signal-to-noise ratio is poor. It is, nevertheless, the only opportunity to probe the sites with radar before attempting a landing. For Viking new methods have been devised so that the radar data can be interpreted quickly enough for use in the site certification process.

The prime landing site which seems to be safe, from preliminary scientific analysis, is at the mouth of the big channel system of Mars. The reason for this choice is that the channels appear to have been formed by running water. If so, material at the mouth should represent that gouged from the highlands to the south. The site, therefore, provides a good place to search for complex organic molecules and a good place to look for both wind and water modifications to the Martian terrain.

The Lander cameras may be able to see water-modified material such as pebbles. Wind erosion is readily identified as different from water erosion since it produces facets on pebbles, and keels or sharp boundaries between adjacent facets.

Site selection is an interplay between safety and science -- the potential of the site to provide scientific information about Mars and its history, and the structure and density of the surface at the site which affects the ability of the Viking to land upon it without serious hazard.

No landing site has been found that appears completely free of hazards; the task during site certification is to compare all data and try to minimize the hazards to the Viking Landers. And, as with Apollo, there is likely to be site adjustment as the Viking missions unfold especially for the landing of the second Viking.

Preliminary commitment has been made. Final commitment is made just before separation of each Lander from its Orbiter. The final go-no-go decision is made on the basis of weather conditions on the planet at the chosen site. Theoretically, the landings are being made at a quiet time and weather should be good. However, no chances will be taken. Bad Martian weather, if observable, could delay the landings.

Imaging From Orbit for Site Certification

On June 20, soon after orbit insertion, the first of a series of exposure tests to calibrate the cameras begins. Next the cameras are tested in producing stereo pictures of the Martian surface. All these tests take place at close range while the Orbiter is near to periapsis and to 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 initial orbit following MOI is close to the desired orbit, these pictures should include the A landing site in their fields of view. Starfield pictures are taken to verify alignment of the scan platform on which the cameras and science instruments are mounted.

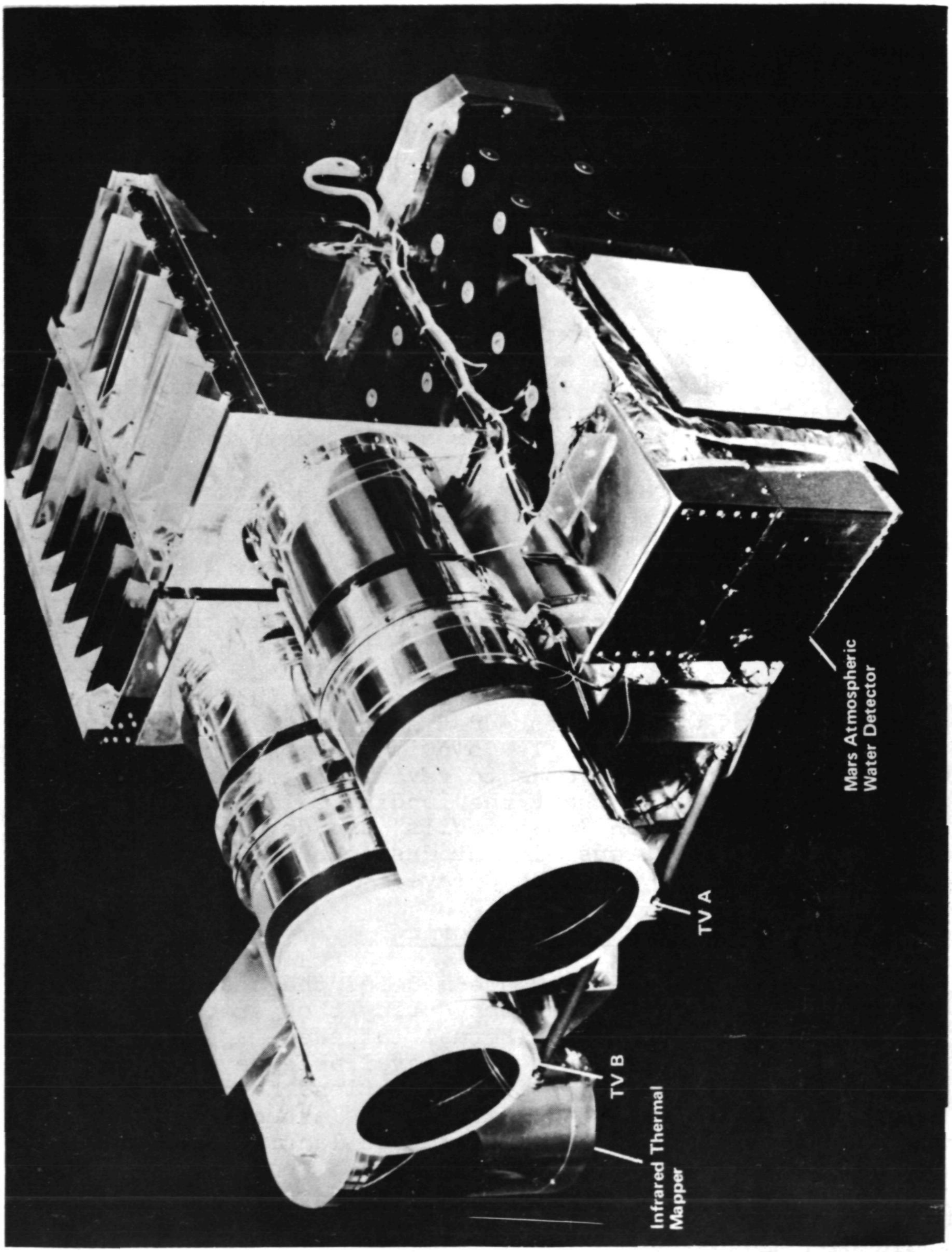
NOTE: After MOI has been achieved, activities on the Orbiter are timed in relationship to orbital revolutions (Revs) which are counted from the first apoapsis.

Activities during Rev 1 are devoted to acquiring these test data.

Rev 2 is assigned for orbital corrections which are described later.

Rev 3 concentrates on photography of the Chryse landing site, to provide a quiltlike pattern of slightly overlapping pictures of the Martian surface permitting coverage of an area that includes the region around the site. This photo series of Rev 3 provides basic data for site certification.

Rev 4 concentrates on stereo coverage of the Chryse site which is in the daylit hemisphere about 30 degrees from the terminator when the Orbiter flies over the site at periapsis; i.e., it is late afternoon, Mars time, at the landing site.



Moveable Scan Platform

Although the angle of sunlight shining on the Martian surface at the site is not small enough to produce long shadows that would show surface irregularities in sharp relief, geologists anticipate that they will be able to determine from these pictures whether the surface is too rough for landing. To try to take these site certification pictures with the site closer to the terminator would demand much longer exposures which, at the low altitude of the Orbiter, would result in smear and loss of detail.

Rev 5 is reserved for a second orbit trim maneuver.

Rev 6 is used to extend the coverage of Rev 4. North of the chosen site, the surface is believed to develop into sand dunes. The Chryse site is thought to be a relatively flat area between the large boulders at the canyon mouth and the region of sand dunes further downstream from the channels.

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

Rev 8 repeats the stereo coverage of Rev 4 as a backup or takes additional coverage of adjacent areas. At this stage all necessary data have been gathered by the camera system for site certification. From then on the cameras of the Orbiter are used daily until separation of the Lander, to monitor conditions on the surface, checking particularly for evidence of wind and for dust storms. Variable surface features, such as dust tails downwind of obstructions might be used as natural windsocks to reveal direction and intensity of Martian winds about the landing site. Watch is also maintained 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.

Infrared Observations and Monitoring

Infrared observations are made of the planet's surface during this same period, except during those revs reserved for orbit trim maneuvers. Thermal infrared maps of the Martian surface are made during each available rev for more than half the orbital period, some observations being necessarily from high altitude as the Orbiter moves around Mars. The high altitude thermal maps include the landing area when it is close to dawn and the geometry is not good for observing it. From high altitude the whole planet can be thermally mapped in infrared in about 20 minutes, whereas from periapsis whole-planet mapping is impossible.

	INVESTIGATIONS	INSTRUMENTS
ORBITER	Visual	2 TV Cameras
	Water Vapor Mapper (atmospheric)	Infrared Spectrometer
	Thermal Mapper (surface temperatures)	Infrared Radiometer
ENTRY	Atmospheric Composition Atmospheric Structure One Science Topic	Mass Spectrometer, Retarding Potential Analyzer, Pressure and Temperature Sensors, Accelerometers and Radar Altimeter
LANDER	Visual	2 Facsimile Cameras, Color/Stereo Capability
	Biology	3 Analyses for Photo-synthesis, Metabolism and Growth
	Molecular Analysis (organic) . .	Gas Chromatograph Mass Spectrometer (GCMS)
	Mineral Analysis (inorganic) . . .	X-Ray Fluorescence Spectrometer
	Meteorology	Pressure, Temperature, Wind Velocity and Wind Direction Sensors
	Seismology	3-Axis Seismometer
	Magnetic Properties of Soil . . .	Magnet Array on Soil Sampler, Cameras Used for Visual Study of Particles
	Physical Properties of Soil . . .	Analysis of Visual and Engineering Data from Applicable Instruments and Experiments: • Cameras—Visual Study of Soil Characteristics (e.g., clumping, grain size, cohesion, adhesion, etc) • Soil Sampler—(with cameras) Trenches, Engineering Force Measurements, Porosity, Bearing Strength
RADIO	Orbiter/Lander Location, Atmospheric and Planetary Data, Interplanetary Medium	Orbiter/Lander Radio and Radar Systems

Infrared thermal mapping consists of three types of coverage of the planet:

- From high altitude -- low resolution scanning maps over the whole of the planet.

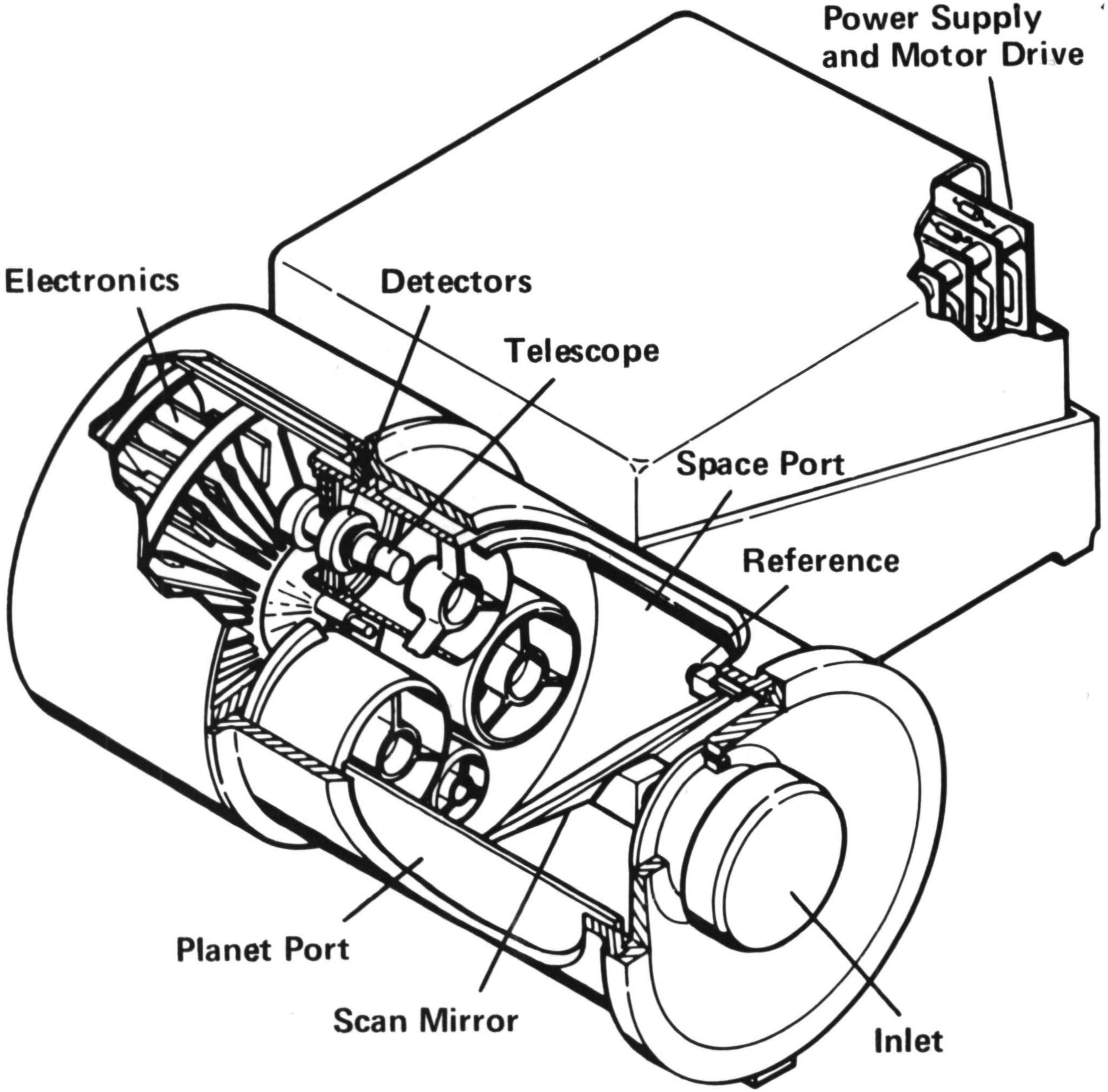
- From intermediate altitude -- better resolution scanning maps but slowly filling in details of the whole planet over several revs.

- From low altitude near periapsis -- highest resolution obtained at a fixed pointing of the instrument so that the spacecraft's motion carries the track across the planet's surface.

During the first 14 days following MOI, infrared mapping is directed toward site certification. On the first few revs the instrument obtains representative observations in the general area of the Chryse landing site to provide basic information about the surface of the planet at several different wavelength bands. The instrument has a resolution of about 8 km (5 mi.) at the landing site when observed from periapsis.

On Rev 4 through 8 detailed observations are made of the landing site and the surrounding area. The aim is to ascertain how the thermal properties of the surface vary around the site. Over a Martian day boulders have a different thermal profile from sand. Sand reaches higher daytime temperatures and lower nighttime temperatures than a boulder field. However, the sunrise and sunset temperatures are almost the same for both. Unfortunately when the Orbiter is over the landing site and obtains best infrared resolution, the time is sunset on Mars. Thus a direct temperature measurement does not readily determine whether the site has boulders or is a sandy surface. The site is also observed from the Orbiter before dawn, when a difference could be found, but then the Orbiter is far from the landing site and the resolution is not good.

The infrared instrument is also used to measure the temperature of the Martian stratosphere and to monitor this temperature every day. The temperature measured is typically at an altitude of 20 km (12 mi.), i.e., at the 0.3 mb pressure level when looking straight down through the atmosphere.



Infrared Thermal Mapper

The infrared instrument will make box scans of the atmosphere to determine the stratospheric temperature over areas of the planet. On Rev 3 one of these scans will begin a series of measurements to determine the atmospheric stability above the landing area, and this type of infrared atmospheric survey continues until one day before separation of the Lander from the Orbiter. If a large instability is detected the landing may be delayed.

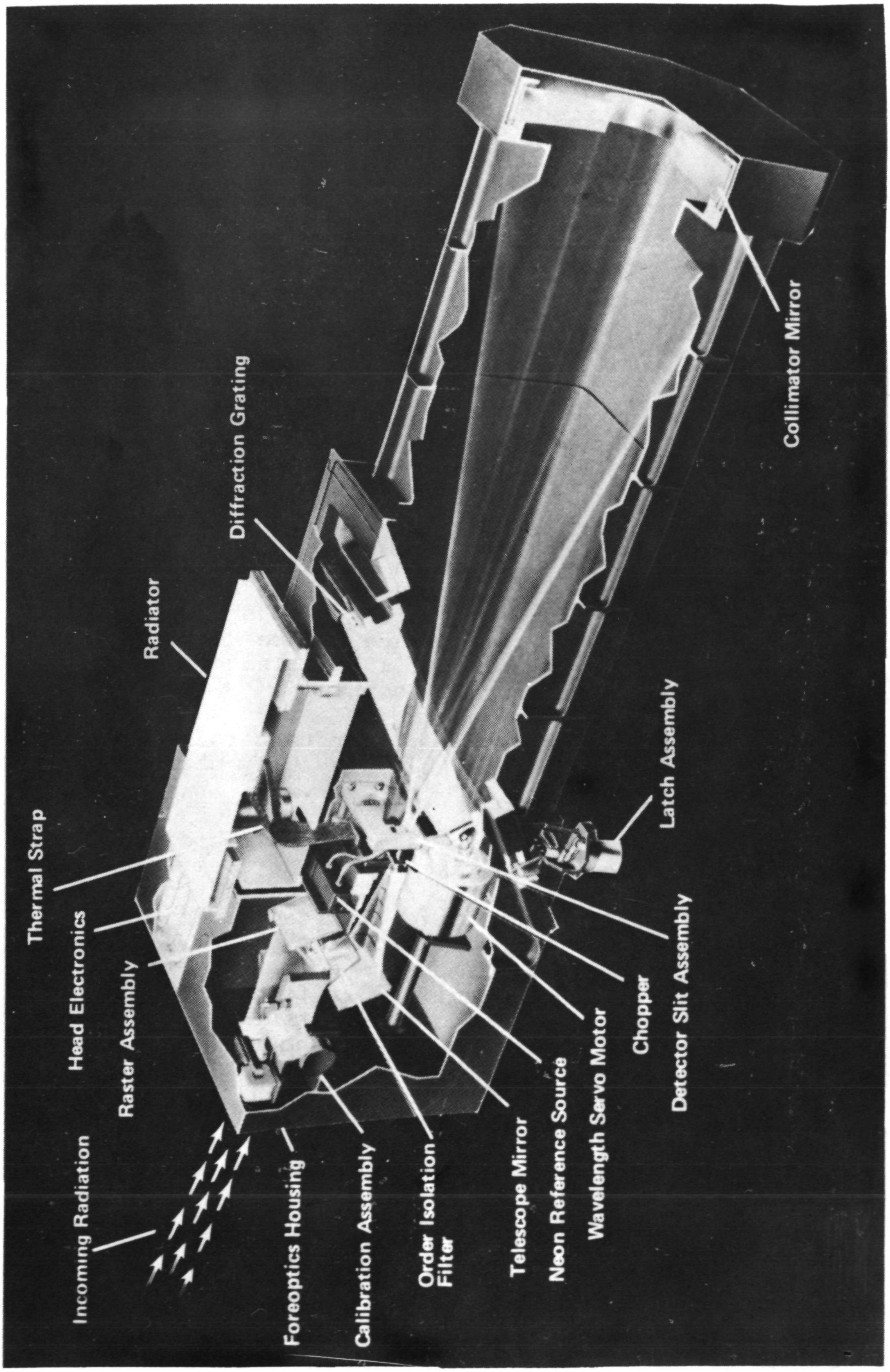
Although water vapor information is not critical to the certification of the landing site for Mission 1, the MAWD experiment obtains data prior to separation. Scans of the planet on Rev 1 provide instrument calibration. Then the instrument takes a first detailed look at the concentration of water vapor, several times a day, in the atmosphere above the Tharsis-Coprates area. These observations continue until separation with the objective of establishing the diurnal variation of water vapor in the Martian atmosphere in this area which is similar to the Lander 1 landing site. The landing site can only be seen in the late afternoon.

This mission will continue with a landing at Prime Site A unless something negative is revealed by the site certification observations from orbit and from Earth. In addition to the Earth-based radar data, Earth-based optical telescopes keep close watch on Mars to check for major dust storms. This planetary patrol activity started years before Viking's approach to Mars organized by the planetary patrol program centered at Lowell Observatory, Ariz.

Orbit Trim

A series of three orbit trim maneuvers can take place between MOI and Lander separation. The first takes place at periapsis on Rev 2 to remove an error in the period of the orbit and to synchronize the Orbiter period with the rotation period of Mars. The trim also adjusts the orientation of the orbit, if this is required, so that the orbit's periapsis point in space is directly over the landing site, and the landing site is directly beneath this at the same time. The Orbiter must arrive at its periapsis at precisely the same time that the landing site, carried around the planet by planetary rotation, arrives beneath the periapsis of the elliptical orbit of Orbiter.

A second trim maneuver takes place on Rev 5, to further adjust the orbit period and orientation.



Water Vapor Mapper

On Rev 10, if needed, a small trim maneuver can take place at periapsis to correct the altitude of the periapsis and to fine tune the period of the orbit to the exact timing required for the landing.

Pre-Separation Activities

With the landing site certified and the orbit adjusted, the landing can be attempted. First, at about 36 hours before the scheduled separation time -- i.e., on Rev 13 (July 3) -- a set of commands is transmitted to the Lander for it to enter the Martian atmosphere and reach the surface at the landing site.

This same set of commands is transmitted to Martin Marietta Aerospace, Denver, Colo., where it is used on a computer to fly a test version of the Lander spacecraft down to a hypothetical Mars. This computer simulation takes place to ensure that there are no mistakes in the command sequence.

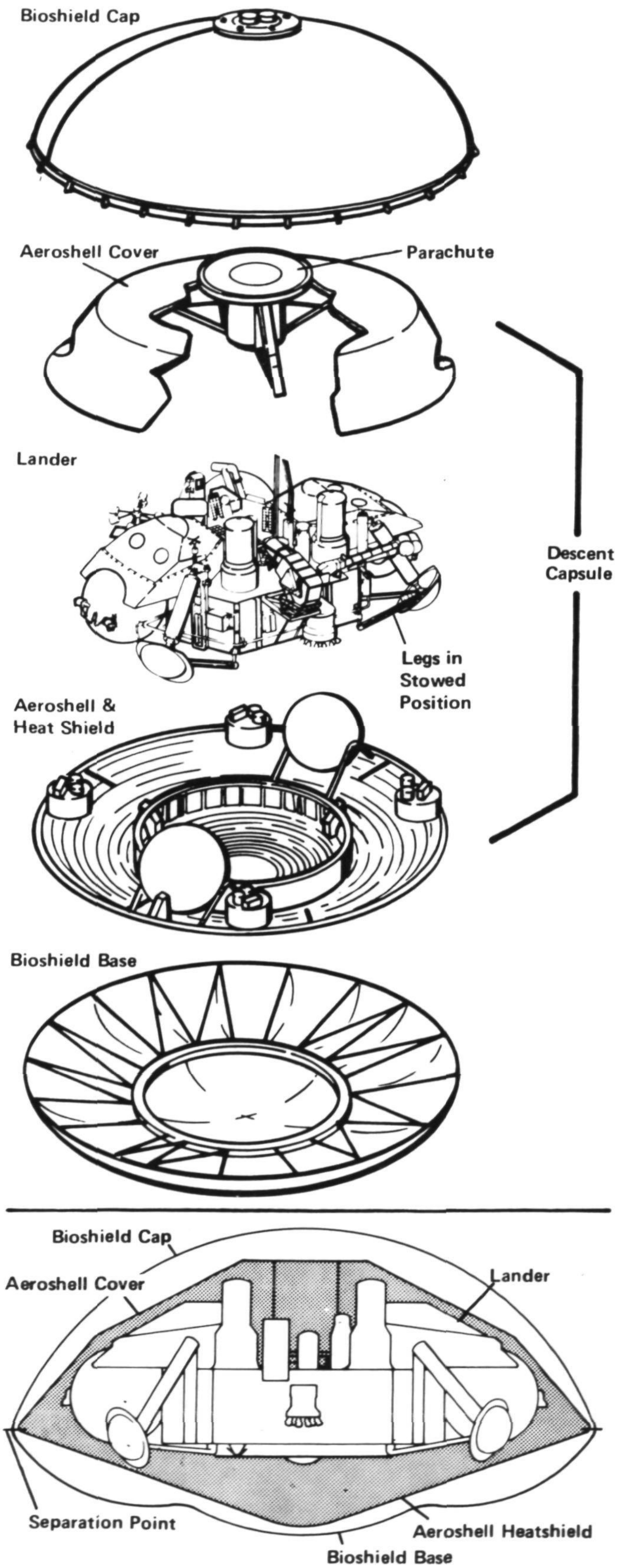
Thirty hours before separation the Lander switches on its power systems. A pre-separation checkout of the Lander then takes place. This is very similar to the checkout made before Viking was launched from Kennedy Space Center and to a flight check made during November 1975. This pre-separation checkout takes about five hours to complete.

Immediately afterwards the Orbiter recharges the batteries of the Lander so that they are fully charged prior to separation.

On Earth, engineers analyze all the telemetered data returned from the checkout to make sure that everything is functioning correctly on the Lander. Navigation calculations are also made to double check the elliptical orbit of the Orbiter and the landing trajectory for the Lander. At nine and a half hours before separation the command instructions within the spacecraft can be modified if found necessary. There is a final option to update the instructions and refine the landing sequence at three and a half hours before separation. This acts as a backup in case the modifications failed to get to the spacecraft at the nine-and-a-half-hour transmission.

Any modifications to the landing instructions are also verified by the hybrid computer-spacecraft simulation at Martin-Denver before they are used in the real spacecraft.

About one and a half hours before separation, the Lander is again powered up and all is now ready.



Landing Capsule Systems

SEPARATION: July 4, 3:38 p.m. PDT

(Times include 18 minutes radio transmission time from Mars to Earth)

The separation sequence loaded in the Orbiter and Lander is fully automatic. But before it can be initiated the Orbiter has to receive a "go" signal from Earth, a signal which is transmitted about 45 minutes prior to separation time. Should this signal not get through to the spacecraft, the separation cannot be executed and the landing is aborted. Another five days then have to elapse before the landing can be tried again. This is the time needed for Lander temperatures to stabilize, to repeat the pre-separation checkout and to instruct the spacecraft on a new descent trajectory.

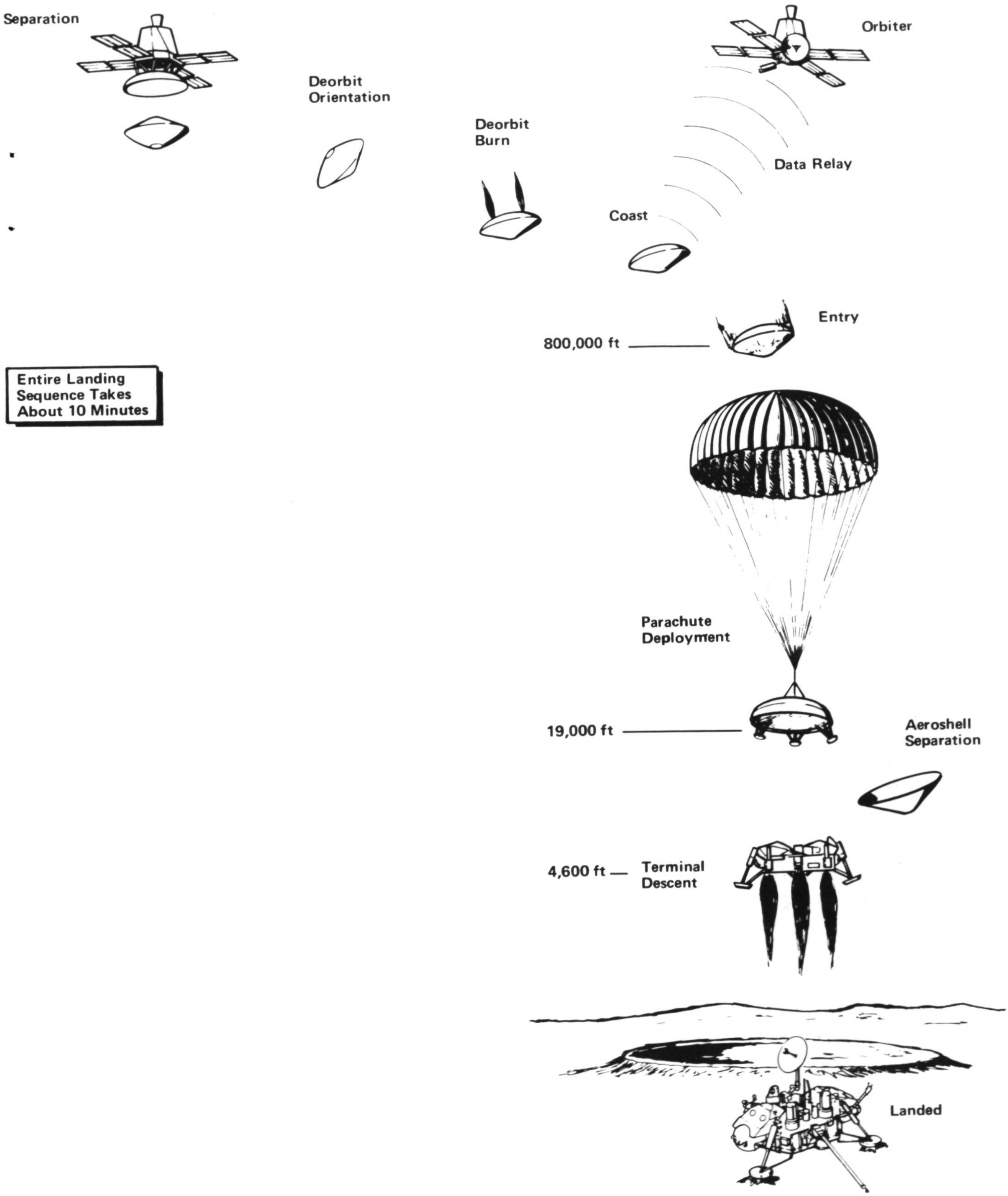
When the separation command is received by the spacecraft, the automatic sequence begins. At separation time pyrotechnic devices fire and release the Lander from the Orbiter. Springs then push the two spacecraft apart. Commands to orient to a certain attitude for the de-orbit burn and the duration of the de-orbit rocket thrust have been stored in the Lander. At the pre-programmed time the de-orbit engines on the aeroshell burn for about 20 minutes and decelerate it from the elliptical orbit it pursued with the Orbiter. The Lander commences its three-hour coast toward atmospheric entry. The new path is an ellipse which carries the spacecraft into the atmosphere of Mars on a path leading to the landing site.

DESCENT AND LANDING:

July 4, 3:38 p.m. PDT (Separation) to 6:58 p.m. PDT (Touchdown)

Operation

Following the de-orbit burn, the spacecraft coasts along its descent ellipse. Telemetered data are sent in short bursts via the Orbiter which transmits them to Earth at the 4 kilobit per second rate. The Deep Space Network (DSN) station receiving the data during descent is Goldstone in the Mojave Desert, Calif. The transmission in short bursts requires quick lock-on to the signal each time it is received at the antenna.



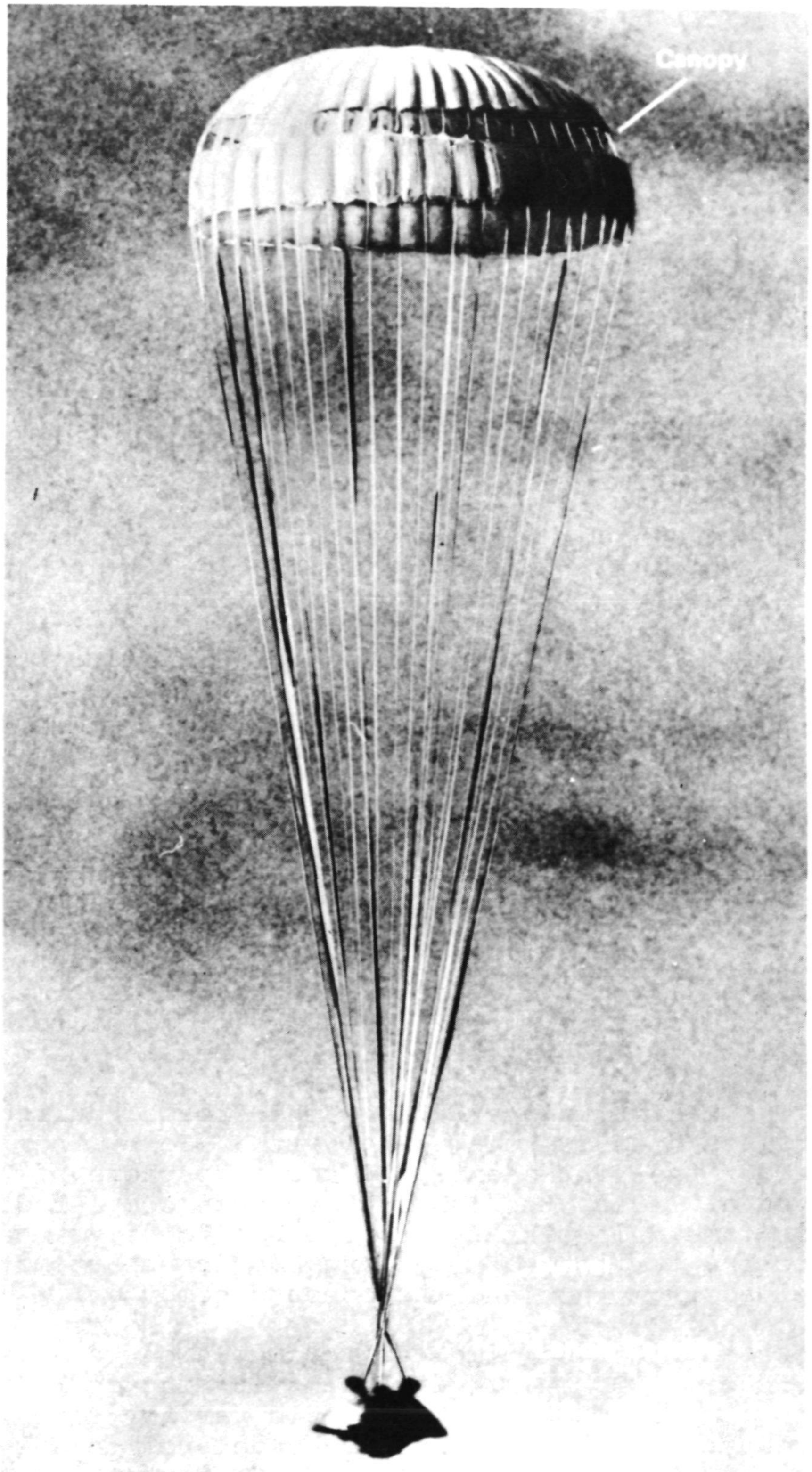
Separation, Deorbit, Entry and Landing Sequence

Six minutes before entering the atmosphere, the stored commands orient the spacecraft for its encounter with the rarefied upper atmosphere of Mars. The x-axis is aligned so that the spacecraft has a -20 degree angle of attack; i.e., the x-axis is 20 degrees below the velocity vector.

This angle is needed for science purposes. Just before entry into the upper atmosphere at about 243,000 meters (800,000 feet) above the surface a preprogrammed pitch places the spacecraft in a -11 degree orientation which is automatically maintained until aerodynamic forces cause the spacecraft to maintain this -11 degree angle of attack.

In this attitude the spacecraft experiences a lift so that it does not plunge in too steeply so as to overheat. As soon as the atmosphere decelerates the spacecraft by .05 g (as sensed by an on-board accelerometer) the pitch/yaw attitude control of the spacecraft is disabled. Now the spacecraft's control concentrates on damping any pitch or yaw motions. Aerodynamic forces are in general sufficient to maintain the spacecraft in its correct attitude, but the damping action is required to prevent any aerodynamic instabilities from developing.

The spacecraft continues to be slowed down by atmospheric drag, its protective aeroshell preventing the entry heat from penetrating to the Lander. Gradually the entry velocity of 4,600 m/s (15,000 ft/s) is reduced until at 6,000 m (20,000 ft.) above the Martian surface the spacecraft has slowed to about 250 m/s (820 ft/s). At this point a supersonic parachute is deployed and the aeroshell is jettisoned. The parachute slows the Lander until it is traveling at about 65 m/s (200 ft/s) at an altitude of 1,200 m (4,000 ft.). Then the three throttleable rocket engines are started and the parachute is jettisoned. Deployment of the parachute and start of the rocket engines is controlled by an onboard navigator which uses an altimeter and other measurements aboard the spacecraft. The Lander continues toward the surface using the descent rockets to slow its speed further and to maintain its attitude. These three engines orient the spacecraft so that their combined thrust vector opposes the velocity vector of the spacecraft.



Parachute

-more-

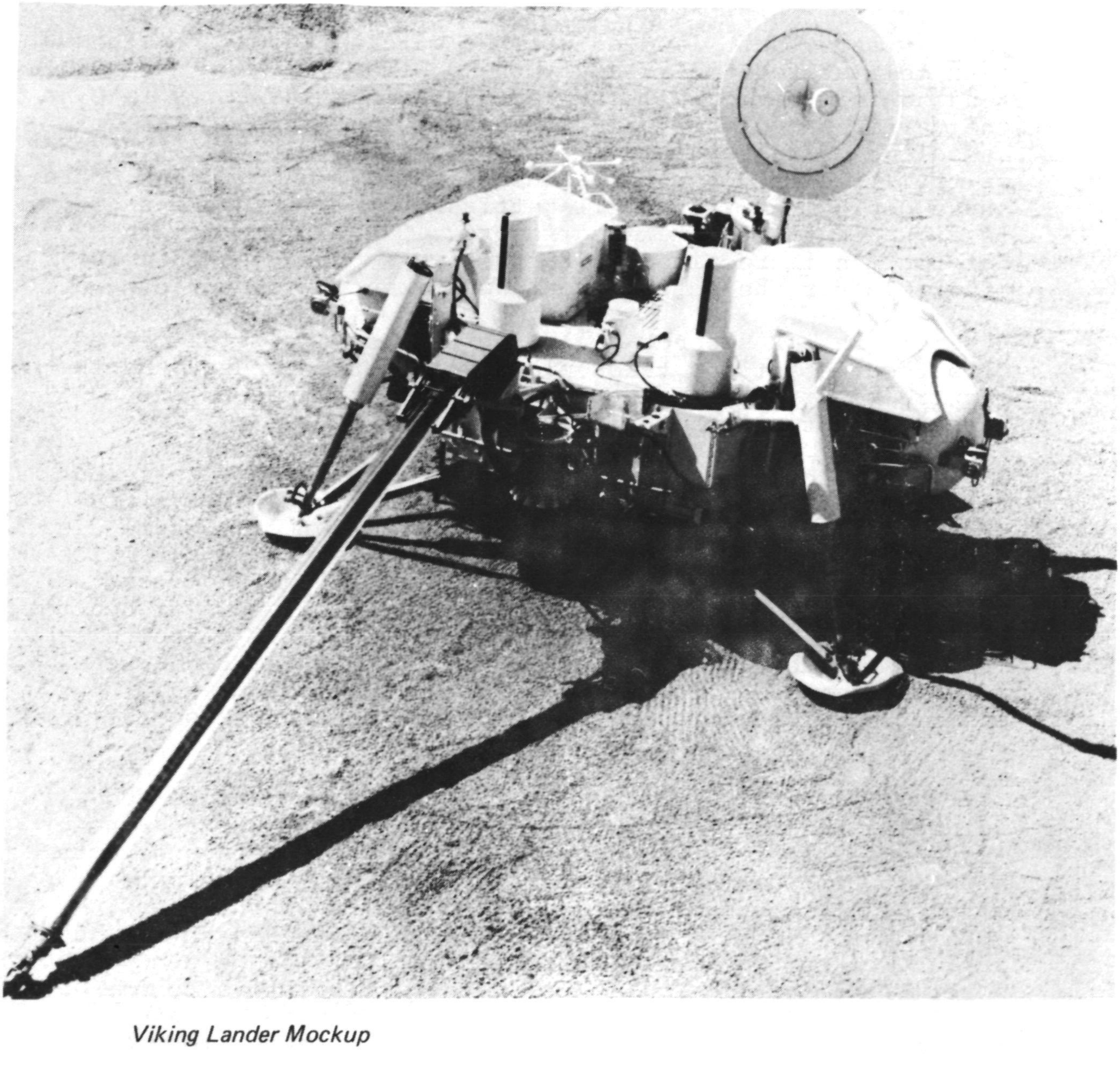
Two limiting altitude/velocity profiles had been stored in the computer memory of the spacecraft before separation from orbit. These represent permissible limits of velocity at each altitude based on the amount of propellant stored in the spacecraft and the thrust capability of the rocket engine. Applying too great a deceleration early in the descent would bring the spacecraft's velocity to its terminal value too high above the Martian surface with insufficient propellant left for descent. Applying too small a thrust would let the spacecraft impact the surface with plenty of propellant still unused. Either would be disastrous to the mission but, if the Lander's velocity at each altitude is kept within the limits, it can land safely.

If the Lander enters its descent phase under conditions of no wind, its onboard computer allows it to veritably "coast" to the upper contour of altitude versus velocity and then to follow this contour to the surface like a pilot follows a glide path indicated by an airplane's instruments. If however there is wind, the spacecraft follows a contour that is an interpolation between the two limits, like a pilot adjusting for a cross wind. In either case, the Lander reaches a height of about 16.8 m (55 ft.) above the Martian surface with a remaining velocity of 2.4 m/s (8 ft/s) and continues down to the surface at this terminal velocity. As soon as a sensor on any one of the three footpads touches the surface, the rocket engines are switched off.

Viking has landed. On Earth we won't know of this until almost 18 minutes later because of the time it takes radio signals traveling at the speed of light to bridge the 380 million km (236 million mi.) gap between Mars and Earth.

The Lander relays data to the Orbiter during its descent. This data is relayed to Earth. So by the time the data about the Viking entering the atmosphere of Mars are received at Earth, the landing has been completed. Because of this time delay it is not possible to "fly" the Lander down to the surface. Everything has to be automatically controlled from the Lander's onboard computer.

Earth-received time for touchdown on Mars is scheduled for 6:58 p.m. PDT July 4 including 18 minutes radio transmission time from Mars. This could vary by five minutes either way. Should the landing be delayed to July 5 or 6, the landing time changes by about 36 minutes later for each day of delay.



Viking Lander Mockup

Landing is scheduled for about 4:00 p.m. Mars time, on Sol 0 (each Sol, Mars day, is 24.6 Earth hours long). The first midnight at the landing site following the time of landing is designated the start of Sol 1.

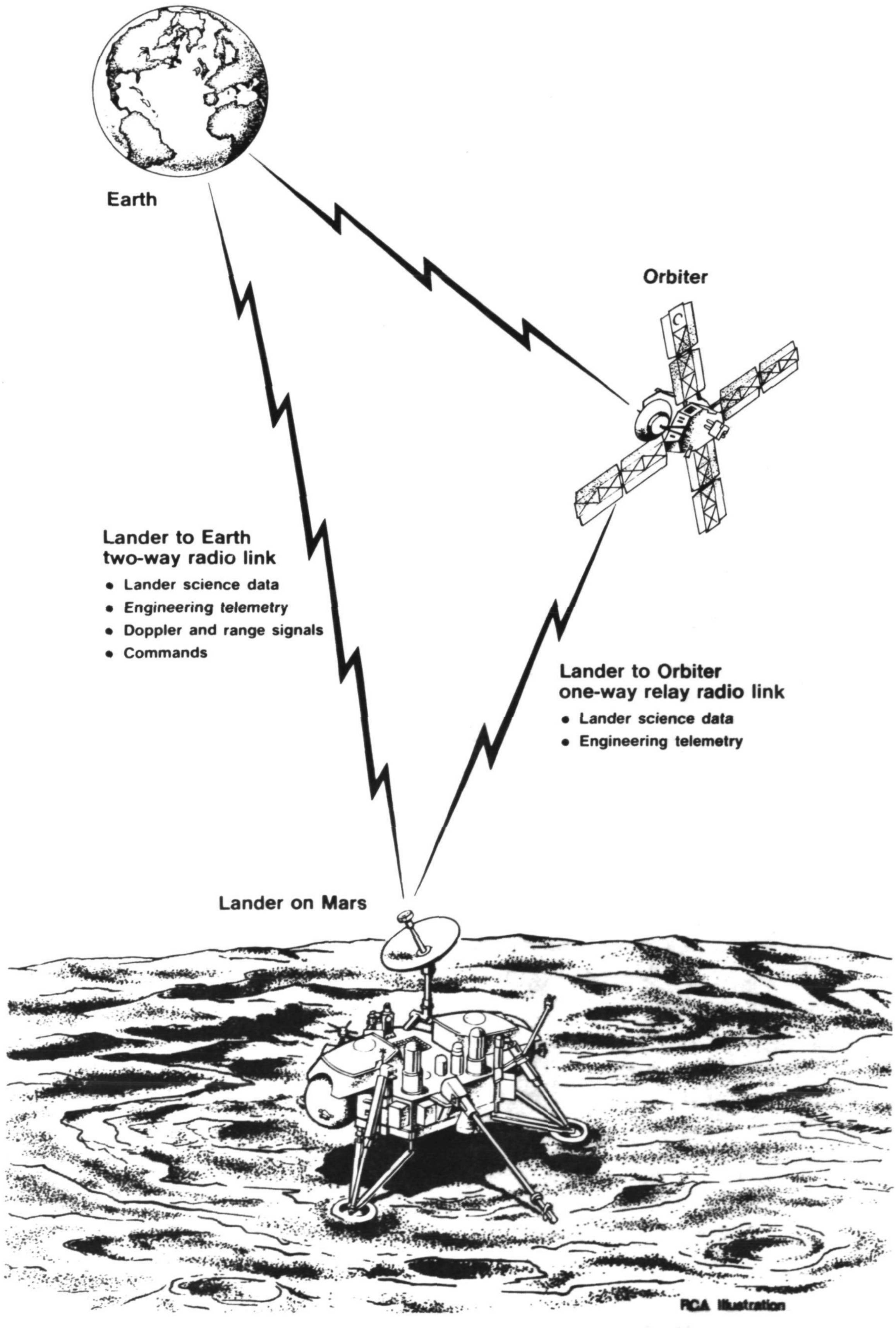
A safe, soft landing will be quickly known from the data telemetered to Earth via the Orbiter. Viking has been sending information all the way throughout its entry into the Martian atmosphere and descent to the surface. As well as science data, engineering information about the attitude of the spacecraft and the sequential landing operation, parachute deployment, aeroshell jettison, landing engine start, is given in the telemetered record. But, of course, this information is received at Earth always just less than 20 minutes after the actual event has taken place at the Lander.

In the 12 seconds following touchdown a quick series of automatic actions takes place within the Lander, and the occurrence of these events on the telemetry record are the first indications that all is well.

The closing of any one of the three footpad switches turns off the rocket engines and then their heaters; this is signalled in the telemetry record. This switch closure also starts a landed initiation sequence aboard the Lander which turns on certain items of equipment within the spacecraft. The radio relay system from Lander to Orbiter is switched to increase the bit rate from 4 kilobits/sec to 16 kilobits/sec. The command detectors are activated so that the Lander can receive commands directly from Earth. The computer is instructed where to start its sequence for landed operations.

The Inertial Reference Unit (IRU) which has helped guide the Lander safely to the surface is allowed to run for 12 seconds after the landing. This provides reference data about the orientation of the Lander so that the computer can move the high-gain antenna from its stowed position and, within one minute of landing, point it toward Earth from the surface of Mars. The IRU information can also be used to determine the attitude of the spacecraft relative to the local vertical. Thus the plane of the Martian surface at the landing site can be determined if the Lander footpads have each penetrated the surface about the same amount. The meteorology boom is opened up ready to start experiments. The cameras, which may have been shaken from a stowed position during the landing, are commanded back to the stowed position.

Viking Lander Communications



The first signs of a safe landing to be received at Earth can be recognized from the data displays or announcements over the communications network.

- The data rate during descent is 4 kilobits/sec to the Orbiter from the Lander. The landed initiation sequence changes this data rate to 16 kilobits/sec. Twelve seconds after touchdown the change to the 16 kilobit rate should be reported, and confirm a safe landing.

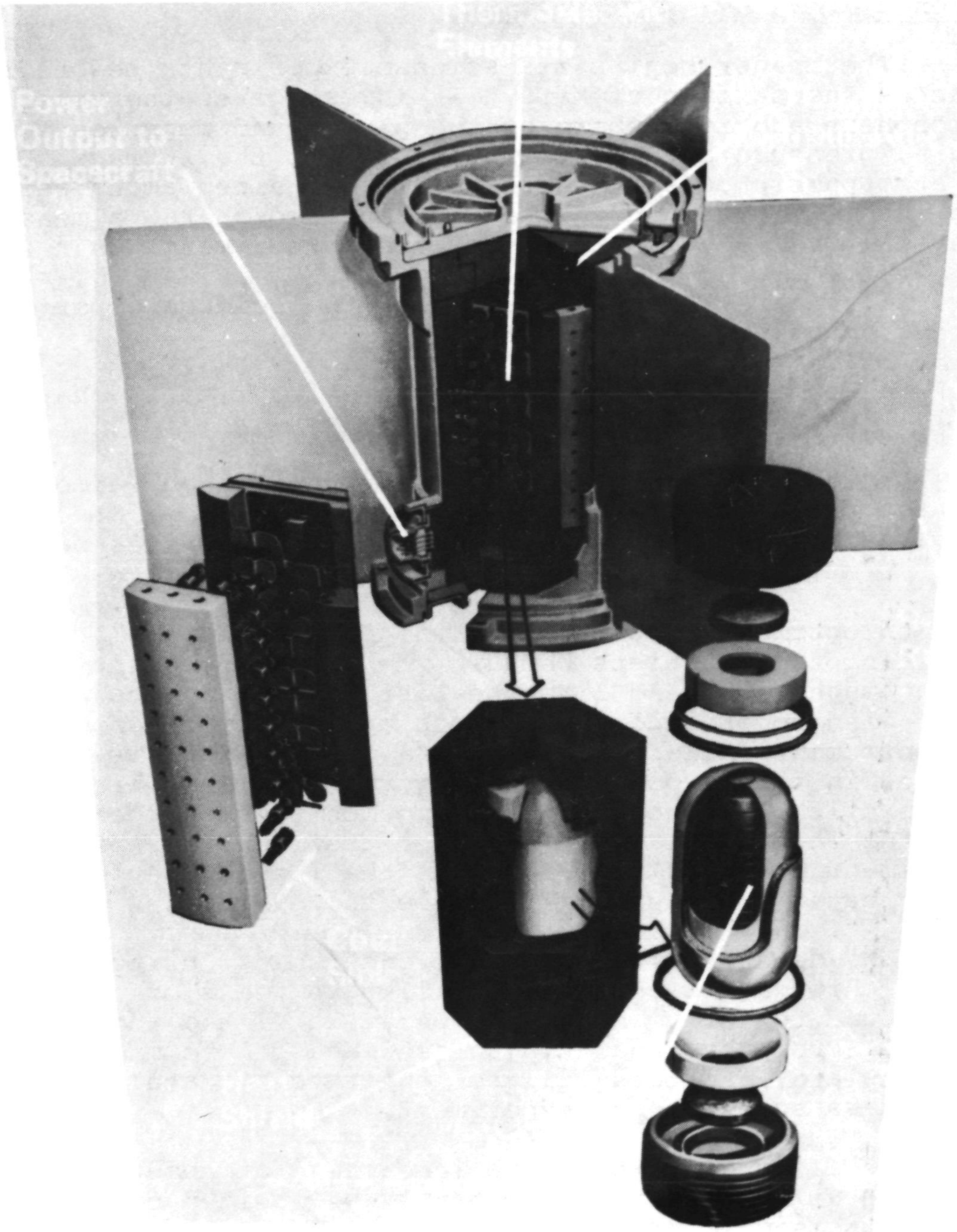
- A data bit, called ENABLET, is displayed on screens giving the status of the Lander. It is "off" all the way through descent. Within one second of a good touchdown it automatically changes to "on". This is a discrete bit signifying the state that the Lander's computer is in and indicates when this state changes. When it changes from off to on it is a very good indication that Viking has made a soft landing, the footpad switch has closed, and a signal has been passed to the computer to start the landed sequence.

- Another display shows the word ENGON, indicating the status of the heaters for the rocket engines of the Lander. This bit shows on during the descent. But the heaters are turned off and the bit shows off as soon as a footpad switch is closed by a landing.

- Another display shows the voltage and current of the power bus of the nuclear-powered Lander. The current drawn is significantly reduced immediately on landing because all of the equipment used for the descent is suddenly turned off. When the number of amps drawn from the power bus drops considerably, this is another good indication of a safe landing.

- Continued telemetry of IRU data for 12 seconds after landing also indicates a good landing.

However, the data link could be lost for some unexpected reason. So the non-receipt of the above telemetry signals does not necessarily imply that Viking has not landed safely. The data link could be regained later, even on a subsequent orbit of the Orbiter.



Radioisotope Thermoelectric Generator

Science

The Lander begins its science experiments before it reaches the surface of Mars. It investigates the upper atmosphere and ionosphere of the planet and measures temperature, pressure and acceleration down to the surface. Details of atmospheric constituents are also obtained among which are the quantity of argon in the Martian atmosphere, a measurement that is very important to later experiments on the surface.

There are three categories of the science experiments during entry:

- Properties of the ionized or electrically charged upper atmosphere.
- Constituents of the neutral (un-ionized) atmosphere.
- Temperature, pressure and density profiles of the atmosphere during the parachute phase.

Electrical properties of the Martian atmosphere are important to scientists because the planet does not have a strong magnetic field like the Earth yet it reacts with the solar wind to produce a bow shock and a pseudomagnetopause. An instrument called a Retarding Potential Analyzer (RPA) is located in the aeroshell facing forward in the direction of motion of the spacecraft. This motion rams charged particles into the instrument which measures their energy spectrum. The experiment measures the energy of the ions. Heavier ions have greater energies for the same temperature.

The data returned from the instrument during the brief flight through the ionosphere will take weeks of analysis on the ground to determine the temperature of the ions and their masses. From this analysis an estimate can be made of what the ions are, and this will be confirmed by data from a separate mass spectrometer experiment.

It is expected that the ionosphere at about 150 km (95 mi.) will consist predominantly of ionized oxygen molecules with some ionized oxygen atoms and ionized carbon dioxide molecules. At even higher altitudes there may be hydrogen and helium ions detected. Radio occultation experiments made with Mariner spacecraft determined that the ionized particles peak in number at an altitude of about 150 km (95 mi.). The highest ionized layer on Earth is the F-layer which provides an ion peak at about 300 km (190 mi.) varying with time of day and with season.

There is not enough oxygen on Mars for such an F-layer to form in the Martian atmosphere, and the ionized layer at 150 km (95 mi.) is thought to be a similar layer to the lower terrestrial layer called the E-layer (at 115 km or 69 mi. on Earth).

The experiment also detects electrons as well as ions. Two classes of electrons are expected to be recorded by the instrument; low energy ionospheric electrons and high energy solar wind electrons. However, since the instrument was designed for the detection of ions its electron detection capabilities are still to be demonstrated in a practical application at another planet.

The Martian ionosphere is not shielded, as is that of Earth, from the solar wind -- the flow of charged particles streaming into interplanetary space from the Sun. There is, however, a bow shock at Mars (unlike the Moon where the solar wind impinges directly onto the lunar surface). A question to be answered is whether Mars has its own low intensity magnetic field that holds off the solar wind or whether the bow shock is produced by current flows within the ionosphere generating a magnetic field. There have been many theories put forward to account for how the solar wind interacts with Mars. It is expected that the electron data obtained during the descent of the Viking Lander may provide better information about this interaction and precisely where the boundaries are between the solar wind and the pseudomagnetopause, i.e., how close to the planet the solar wind electrons penetrate.

The discontinuity of the bow shock may be identified quickly from the returned data, but full analysis of the complex data will take some time. Although a Russian orbiter of Mars produced data that implied that the planet has a magnetic field, the spacecraft was not in the best region to make this observation. The Viking Lander however, penetrates the shock front almost at the sub-solar point so it is in an excellent position to observe the change from the solar wind to the pseudomagnetopause.

Viking instruments record the whole region through the solar wind, the bow shock, the pseudomagnetopause and the peak of ionospheric activity.

Observations from Lander of the constituents of the neutral atmosphere are important to subsequent experiments on the surface of Mars. These are made with the Upper Atmosphere Mass Spectrometer (UAMS) which identifies atoms and molecules in the atmospheric gases. Earth-based and spacecraft experiments suggest that the neutral atmosphere of Mars is predominantly carbon dioxide with minor constituents of carbon monoxide and oxygen. There could be as much as 5 per cent nitrogen in the Martian atmosphere but this would not have been detected by these earlier experiments. There may also be inert gases such as argon in the Martian atmosphere. This, too would have been missed in the earlier experiments.

The mass spectrometer carried by Viking Lander records atmospheric particles, atoms and molecules, with mass numbers between 1 (hydrogen) and 50 (to include carbon-dioxide at 44) and in doing so reveals not only basic elements and molecules but also the isotopic variations of common elements.

The argon question is important. Its solution has top priority during entry science. There is indirect evidence from a Soviet spacecraft of a large amount of argon in the atmosphere of Mars. Mars 6 carried a mass spectrometer which was operated during the parachute descent phase to sample the Martian atmosphere in regions of relative high pressure. The mass spectrometer had to be evacuated of gas for it to operate. Sputter ion pumps incorporated in its design used the principle of gettering with titanium to attain a high vacuum in the instruments. But this process is inhibited if there are rare gases such as argon present, because they do not enter into chemical reactions and cannot be taken from the pump by titanium gettering. Since the Soviets did not obtain the expected pumping of their instrument they concluded that a rare gas must be present in large quantities in the Martian atmosphere to reduce the operation of the pump. They concluded that argon is the most likely gas.

The effect of argon on the Gas Chromatograph Mass Spectrometer (GCMS) carried by the Lander to sample the Martian atmosphere and later to make organic analysis of the Martian soil could be disastrous. This instrument has a pump that would be affected by the argon and would be made ineffective. The strategy for use of the GCMS was originally planned so that it would first complete its atmospheric analyses before making the organic analyses. This strategy ensured that the instrument would not be contaminated by organic samples from the soil before it sampled the atmospheric gases.

However, if argon is present in substantial quantities in the atmosphere of Mars, the GCMS strategy of experimentation must be changed. So a top priority during entry science is to find out how much argon is present.

The argon question also has important scientific implications in connection with the evolution of Mars and its atmosphere. On Earth the origin of argon and carbon dioxide is believed to be from outgassing. The carbon dioxide has been mostly removed from the terrestrial atmosphere by natural processes while the argon has remained. This argon is of three isotopes (chemically identical atoms having different atomic weights); argon 36, 38 and 40. Argon 40 is the end product of the radioactive decay of potassium 40. Argon 36 and 38 are believed to be original isotopes from the condensation of the solar nebula; they are in cosmic abundance. The Earth's atmosphere has 300 times as much argon 40 as argon 36, and five times as much argon 36 as argon 38. It is thought that without the presence of potassium 40, a planet would end up with its argon being all argon 36 and argon 38.

The science questions are, therefore; how much argon 40 is present in the atmosphere of Mars? Is there the same isotopic abundances as found in Earth's atmosphere?

If the atmosphere of Mars formed in recent geological time there would not have been time for quantities of argon 40 to build up in it. However, if Mars has developed its atmosphere over a long period of time, as is believed for the terrestrial atmosphere, a proportion of the argon 40 isotope similar to that on Earth would be expected.

Fortunately, the UAMS is extremely sensitive to argon and the experiment should easily detect the several isotopes of this element. The instrument is also sensitive to nitrogen which may be another important constituent of the Martian atmosphere previously undetectable. On Earth nitrogen is believed to have originated from outgassing of the terrestrial rocks. The volcanic features of Mars suggest that Mars, too, must have experienced periods when rocks were outgassed by these volcanoes. The UAMS can detect expected quantities of nitrogen (a few tenths of a per cent) quite easily.

The strategy of examining the data about the neutral atmosphere is:

- Determine if there is argon present, and how much.
- Ascertain its isotopic composition.
- Look for mass 14 to check if the Martian atmosphere contains nitrogen or carbon monoxide, or both.
- Look at all the other peaks on the curves of data from the mass spectrometer to determine the combinations of atmospheric constituents that produce such patterns.

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

The third important experiment during entry is to determine the profiles of temperature, pressure and density of the Martian atmosphere as a function of altitude above the Martian surface. Two techniques are used: direct measurements derived from pressure and temperature gauges carried on the Lander, and indirect deductions from the deceleration of the Lander as it plunges through the atmosphere.

The scientific view of the Martian atmosphere has changed radically over the last decade. Before spacecraft flew by Mars, Earth-based observations of gas molecule scattering suggested a surface pressure of 80 mb (8 per cent that of Earth). However, scientists quickly amended this to account for the effects of dust which would produce similar scattering in a less dense atmosphere.

Absorption spectroscopists suggested that there was 5.5 mb of carbon dioxide present in the Martian atmosphere, but other constituents were unknown. The broadening of the spectral lines of carbon dioxide implied that the total atmospheric pressure might be as high as 18 to 25 mb.

Then spacecraft flew by the planet and radio occultation experiments showed that the maximum pressure might be only 6 mb. The spectroscopists were forced to give ground, but they still held out for a pressure of 20 mb.

The latest uncertainty is the argon question. If as much potassium were present in the crust of Mars as in Earth's crust, then a 3 mb partial pressure of argon might be expected in the Martian atmosphere. This leaves 5.5 mb for carbon dioxide, and possibly some nitrogen as gases emitted from volcanoes. Nitrogen can be held thermally on Mars because the planet has a relatively cool exosphere; i.e., nitrogen atoms are not thermally accelerated to high enough speed for them to reach escape velocity (5,000 m/s) from Mars.

Data from occultations of spacecraft and from infrared measurements made from Mariner 9 are somewhat erratic and display no readily recognisable pattern of variation of atmospheric temperature with altitude. This could imply either that variations are not within the limitations of the measurements techniques or that there are rapid variations. The observations also showed temperatures reaching below 140 K, which is 10 to 15 K less than the condensation temperature of carbon dioxide. The question then is: why does the carbon dioxide not condense from the Martian atmosphere? The only way to prevent this would be some kind of atmospheric lag in the temperature cycle.

The aim of the new atmospheric science with Viking is two-fold: to improve the precision of earlier measurements, and to extend the measurements over a wider range of altitudes.

A key reason for knowing the temperature profile in the Martian atmosphere is because temperature differences drive winds. It is known that there are strong winds on Mars and this would imply that there are large differences in atmospheric temperatures. Dust storms also engulf the whole planet at times, and these require strong winds for their initiation. How strong is questionable. It is estimated that winds of velocity 100 m/sec are needed to generate the dust storms, yet temperature profiles used to compute circulation models of the atmosphere have so far resulted in computed wind speeds of only 25 m/sec maximum.

Based on current knowledge of Mars it is difficult to account for the dust storms and how the necessary winds can be generated. Although the Lander is designed for winds up to 100 m/sec, knowledge of the actual winds are important to achieving a safe landing.

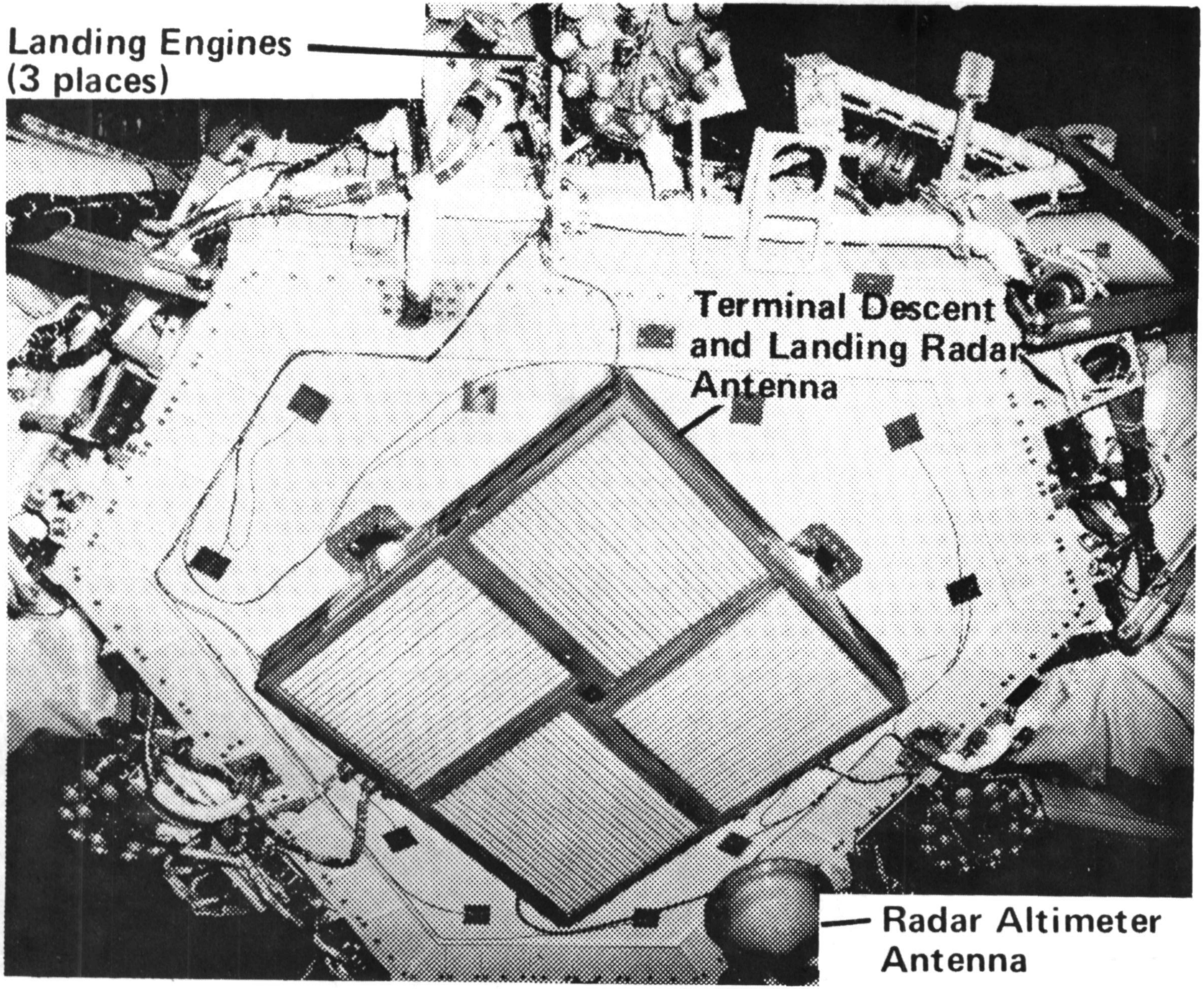
Onboard the spacecraft is a Terminal Descent Landing Radar (TDLR) which uses four radar teams, each slightly offset from the vertical. This equipment measures the drift of the spacecraft as it descends on its parachute, and determines mean velocity of winds between altitudes of 6,000 and 1,500 m (20,000 and 5,000 ft.).

At higher levels the difference between the predicted trajectory and the actual trajectory, as determined from the internal gyro system, is used to measure high altitude winds. The Lander x-axis adjusts itself aerodynamically to the velocity vector. Its normal attitude is 11.2 degrees trim, but a wind rotates the spacecraft, and this rotation is detected by the gyros. If the wind is strong its effects are revealed in this way up to an altitude of 30 km (19 mi.) above the surface.

While the temperature and pressure and density data are available soon after landing, the wind data take longer to evaluate. Trajectory measurements can also be derived from the temperature, pressure and density measurements.

If an erratic temperature profile is found, this might be related to atmospheric turbulence as seen in the Earth's atmosphere. When a similar experiment to that on Viking was tested by firing an atmospheric probe on a Scout rocket from Wallops Island, Va., two kinds of turbulence were seen, convective cells and wind turbulence. Both may be present on Mars as they are on Earth and will be identified.

When the Lander reaches the surface, the sensitive accelerometer carried by the entry experiment allows scientists to determine if there are non-homogenieties in the Martian crust about the landing site. The Lander can measure an acceleration of 10 to 100 ppm in the gravity field which is sufficient to determine the planetary radius at the landing site to within 17 to 170 m (55 to 550 ft.) which is better than radar measurements from Earth. The pressure measured at the surface as the spacecraft lands depends upon the elevation of the surface. The Chryse site is about 3 km (10,000 ft.) below the mean surface level of Mars. The entry pressure measuring instrument is able to measure surface pressure and thereby determine the true elevation of this landing site.



Landing Radar Antennas

SURFACE OPERATIONS:

Sol 0 July 4, 6:58 p.m. PDT through July 5 0:20 a.m. PDT

Immediately after the Lander touches down on the Martian surface events take place rapidly. Following the first few seconds of operations on the surface, as described earlier for initiating the Lander sequence, this sequence follows, during which engineering data are telemetered to provide a status review of the various pieces of engineering equipment on the Lander. Immediately following this, Viking starts its first picture taking sequence. Since the conditions on the surface of Mars are not known exactly at the time of the landing, only one camera is opened to the Martian environment. This is Camera 2. The other camera is left in the stowed position, its window protected against the Martian environment until Camera 2 has operated successfully without damage.

Twenty-five seconds after touchdown, Camera 2 starts its first high resolution scan. Following the preprogrammed instruction in the Lander's computer, the camera is directed to start its picture at a camera azimuth of 200 degrees and to sweep toward the right through about 60 degrees so as to include the footpad #3 and its leg. The camera view is directed downward from -40 degrees to -60 degrees elevation so as to provide a close-up view of the Martian soil and how the footpad has affected this soil during the landing. As it is taken this picture is sent in real time at the 16 K bit/sec rate from the Lander to the Orbiter where it is stored on tape memory aboard the Orbiter.

This first picture is directed to show the Martian surface in as much close detail as possible because in the absence of prior knowledge about the surface structure of Mars it is important to know quickly how the footpad interacted with the surface. From this interaction it is possible to calculate approximately how much energy was absorbed by the soil. The touchdown parameters are of vital importance in determining the relationships of the horizontal plane of the spacecraft, the plane of the surface on which it has landed, and the Martian horizon plane.

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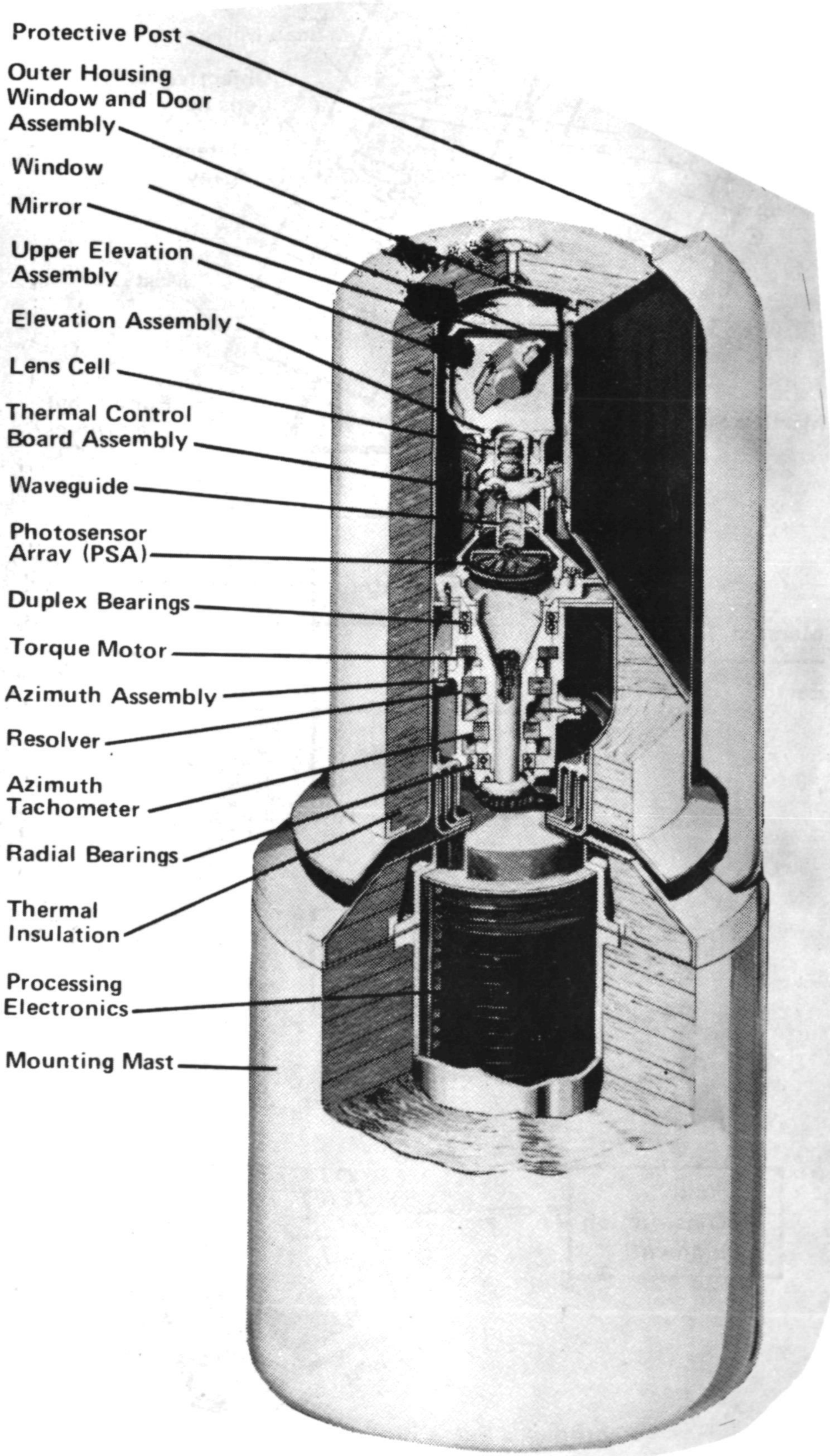
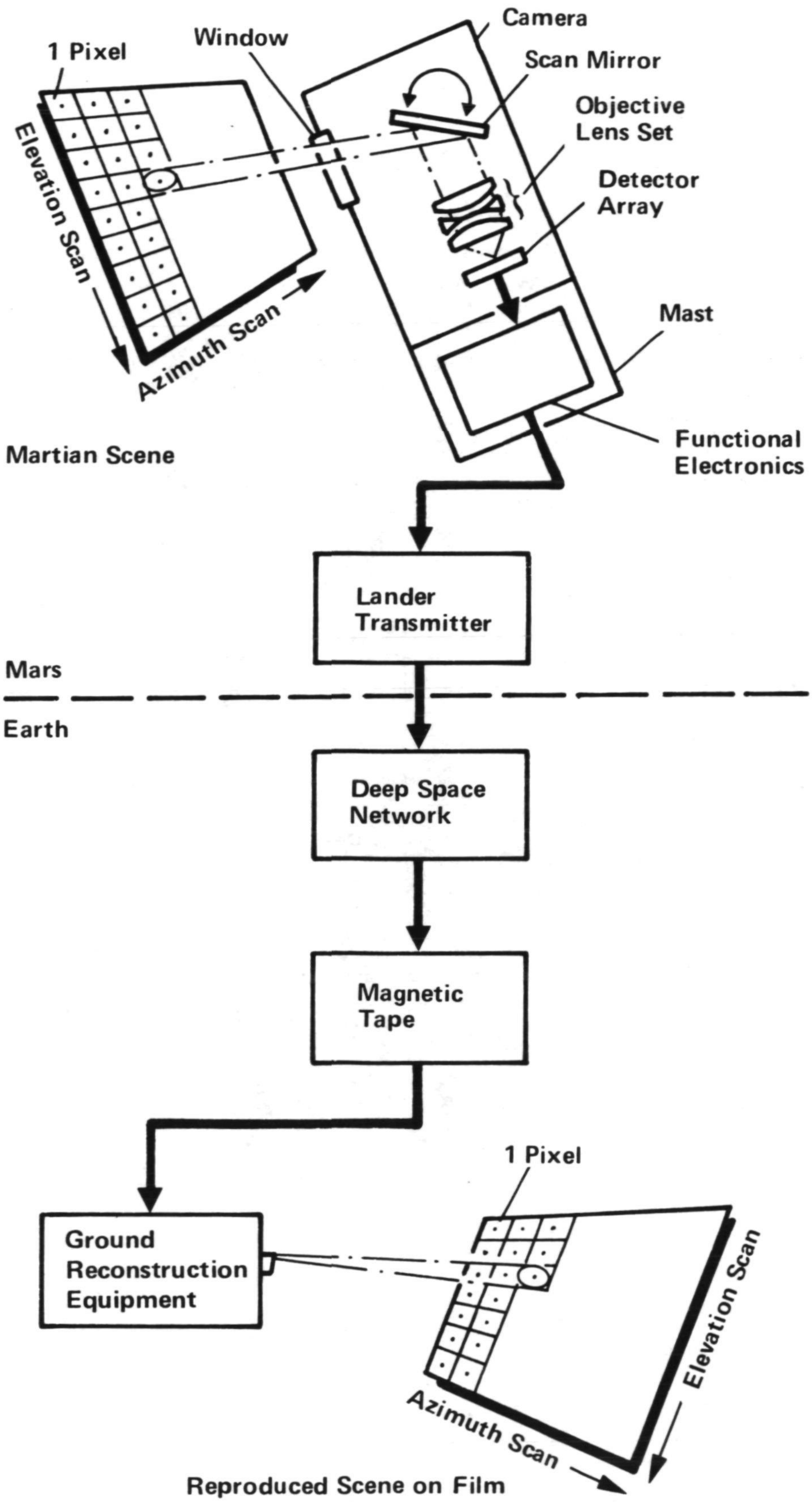


Lander Camera



Lander Camera System of Operation

To help in establishing these planes quickly, the next picture, also with the number 2 camera, is a wide-angle panorama starting at 105 degrees and sweeping as far to the right as the data link allows before communication from Lander to Orbiter is lost for Sol 0. This second picture begins at 6 minutes, 8 seconds after touchdown, and the nominal link between Lander and Orbiter ends 6 minutes, 25 seconds later, but the camera is not turned off until almost three minutes later to take advantage of communications lasting beyond the end of the nominal link.

The total width of the second picture is 300 degrees and its height is 60 degrees; +20 degrees (above) to -40 degrees (below) the horizontal plane of the spacecraft. 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 second picture.

If the horizon is not in this position, analysis can use its position with the tilt of the spacecraft to determine the slope of the ground on which the spacecraft is resting.

These first pictures are black and white because they are taken close to sunset on Mars when the low Sun will not illuminate the scene adequately for a color picture. Three times as much coverage of the Martian surface can be obtained in black and white as could be obtained in a color photo because a color photo requires three individual black and white photos taken through three separate color filters.

After these first pictures have been taken and relayed to Earth, meteorology science starts on the Lander and continues at planned intervals throughout each Sol thereafter. The meteorology instruments operate in short intervals of two minutes duration spaced two hours apart over each Martian day, 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.

There are 20 observation periods for meteorology each Sol and by the end of Sol 20 the meteorology team expects to have a very good idea of the diurnal variations of the meteolorological measurements. These measurements are not only of scientific interest but also of practical importance to the other experiments. For example, diurnal variations of wind speed may be such that the sampling boom cannot be safely extended at certain times of the day when it may be found that the wind speed is always too high.

Very precise surface measurements of pressure are expected since a twin of the pressure sensor has been operating for many months on Earth and has not deviated from its nominal reading by one count. It is rock steady in its operation.

The meteorology of Mars poses an interesting question about the pictures to be returned from the Martian surfaces; 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. The sunlight heats the surface of the planet but this heat cannot readily be conducted or convected into the atmosphere. Radiation is absorbed by the carbon dioxide but not as effectively as by water vapor in the terrestrial atmosphere. The effect is that it is very difficult for the hot Martian surface to heat the atmosphere above it. Scientists expect that Martian surface conditions are such that "wet road" type mirages may be seen on flat plains of Mars in the early afternoon. Water sheet mirages may appear as lakes at distances of one to one and a half km from the Lander. This is further than the usual distance of such mirages on Earth -- about 100 m (110 yd.) -- because the atmosphere of Mars is so much thinner. The most likely time for the Martian mirages to occur is noon to 2:00 p.m., so they are not expected on the first panorama of Sol 1 which is taken in late afternoon. But they may show up on pictures taken on subsequent Sols.

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. Later, as this calibration progresses, the instrument is reconfigured -- taking several Sols to do so -- so that its gain settings are best suited to the natural environment of Mars and it can search effectively for true seismic events. Since it is not possible to predict in advance what the background or the seismic activity will be, the first few Sols of seismology are very exploratory. The winds of Mars affect the seismometer. The seismic team works closely with the meteorology team in subsequent interpretation of data so that the background noise due to the 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. Since the instrument is extremely sensitive to the presence of argon, this calibration test is expected to reveal the presence of argon in the atmosphere of Mars and confirm the earlier UAMS determination, so important to effective operation of the GCMS during subsequent sols.

There is an advantage in checking for argon at the surface in this way. The UAMS experiment cuts off high in the atmosphere, and its detection of argon applies to the upper atmosphere. While there is no reason to believe that the proportion of argon in the Martian atmosphere varies with altitude, the surface test gives added confidence to making the decision on how the GCMS should be used.

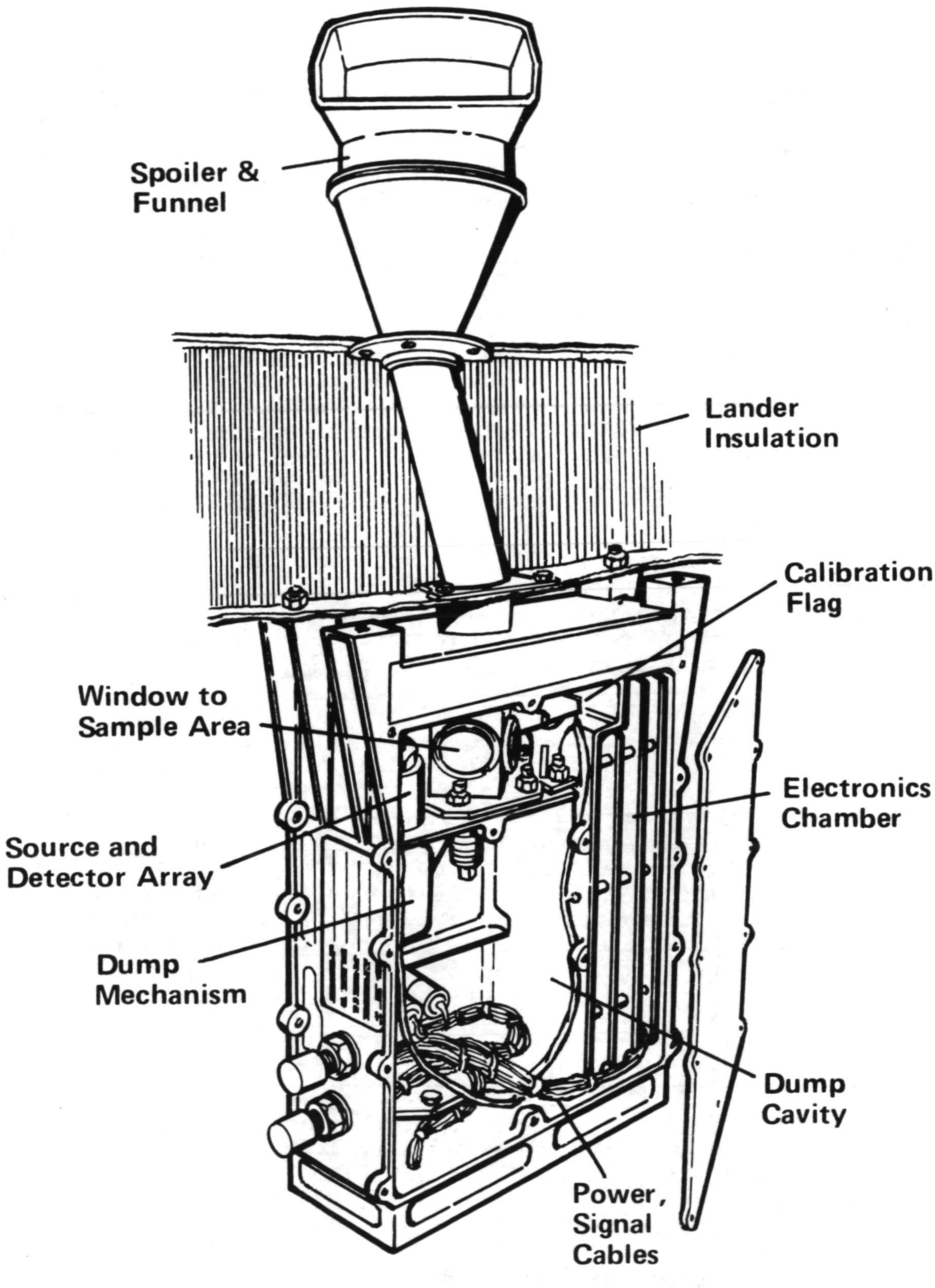
The calibration of the instrument is also important to ensuring that there have been no changes to the X-ray spectrometer as a result of the landing stresses imposed on the Viking spacecraft. Any necessary changes to the instrument will be made by Sol 7, ready for it to start its sampling of the surface materials.

As the Sun sets at the Lander site on Mars on this first day, scientists have looked at the Martian surface and the panorama of the landing site; they know that the Lander is operating.

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

Sol 1 Through Sol 7 (July 5 Through July 12)

This period of Lander operations on the surface concentrates first on certifying the site from which the sampler is to scoop its samples for the biology, organic analysis, and X-ray fluorescence experiments. A sample site is included among the programmed instructions within the computer memory of the Lander. But this site has to be evaluated before the Lander starts operations to pick up samples there. Additionally the Lander commences several of its scientific surface experiments during this sample site certification period.



X-Ray Fluorescence Spectrometer

Sample Site Certification

Sample site certification relies heavily upon the imaging capabilities of the two cameras carried by the Viking Lander. When Viking reached the surface its computer carried instructions for it to operate independently of commands from Earth for 58 Sols and to perform all its scheduled experiments. But this initial computer load for a preprogrammed surface mission has two constraints:

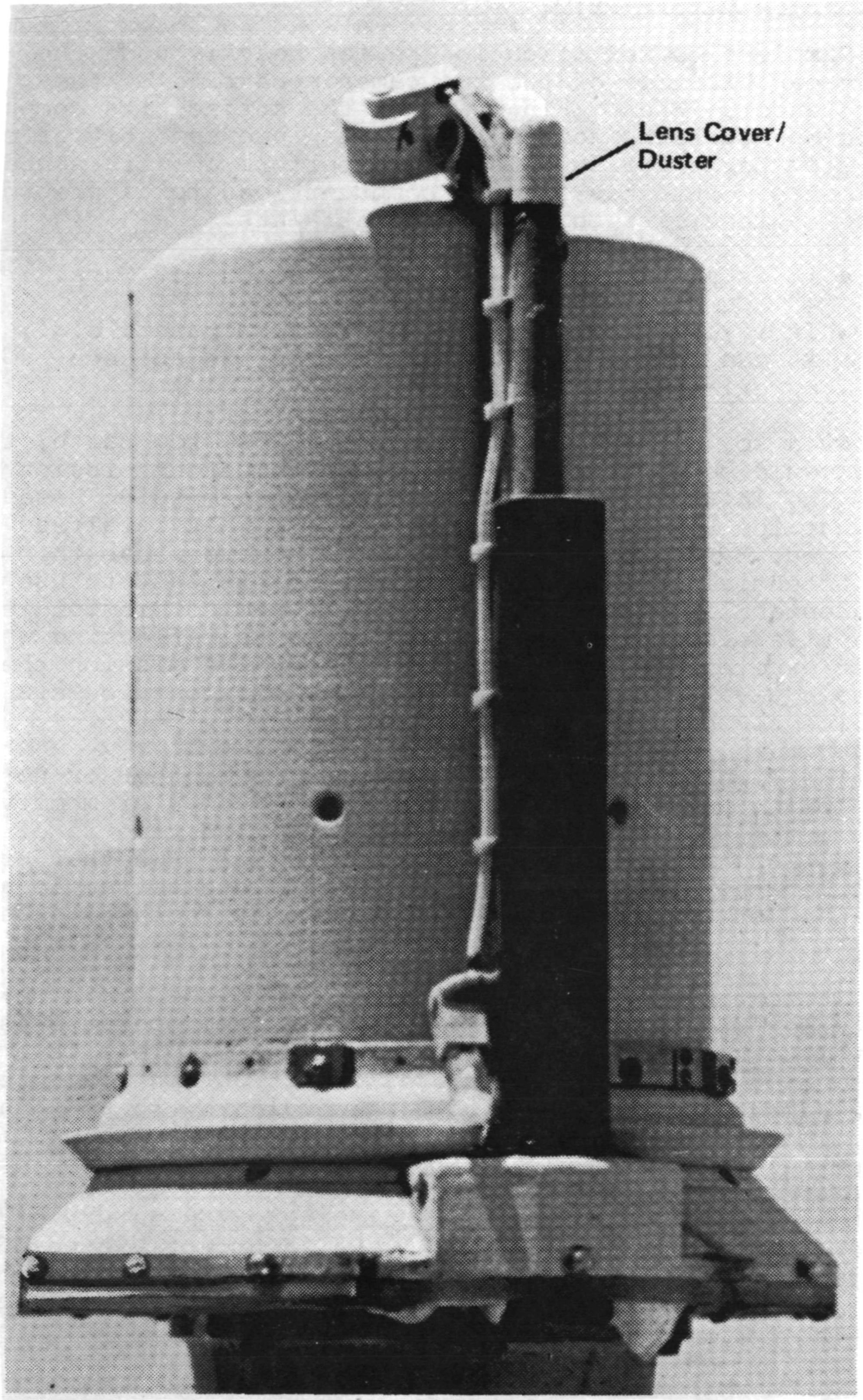
- It is predicated on current knowledge of Mars.
- It is limited by the size of the computer, e.g., it can only complete one cycle of the science experiments.

Even so, without any further commands from Earth, the Lander would be expected to complete a competent mission on Mars. The initial computer load provides a mission based upon what the Lander should do in view of what is already known about Mars. The Viking mission, however, has the great potential of adaptability. Scientists want to use this adaptability to convert the preprogrammed mission into an adaptive mission; subsequent experiments reflecting what earlier experiments reveal. Such an adaptive mission then becomes equivalent to a whole series of missions to Mars for the price of one mission.

The first question to be answered is whether or not the sampling sequence programmed into the computer memory will aim the sampler toward a safe site. And time is of essence, for the decision has to made by Sol 5 whether or not to let the initial computer load continue to sample as preplanned or change it to take a sample at another, safer site.

There are several factors that affect the decision; the sampler on the end of its extendable boom operates as a shovel to scoop up Martian soil. If the sample site proves to be hard rock, the shovel cannot obtain a sample. If the sample site consists of large boulders, these cannot be sampled. The ideal site has a mixture of particles like terrestrial dirt.

The first two pictures of Sol 0 show the nature of the soil, but they could very well be incorrectly exposed; too light or too dark. Moreover, they do not give an accurate impression of the distance of objects from the Lander. Experienced photointerpreters can estimate the location of the sampling site to within one foot from the pictures.



Camera Housing and Lens Duster Apparatus

In tests on Earth, it was found necessary to wait until the first stereo pictures were obtained on Sol 3 before safe measurement of distances of objects at the sample site could be derived.

On Sols 1 and 2 photography continues with Camera 2 only, until more information has been obtained about the Martian environment.

When the second picture for a stereo pair becomes available on Earth for evaluation, a special computer program allows an operator to run a track-ball over the stereo image. He manipulates hand controls so that the spot of the track-ball appears to move over the surface where the sample boom will stretch out to obtain its sample for the preprogrammed mission. The computer is then able to derive coordinates along three dimensions for the surface of Mars along this azimuth line. In tests on Earth with a full scale Viking Lander on a mockup of a hypothetical Martian surface model in the Atrium at the Jet Propulsion Laboratory, the process was demonstrated as providing an extremely accurate determination of the ridges and valleys and obstructions on that surface. In this way, the sampling site selected in the preprogramming can be proved out for safety before the sampler begins its automatic operation. Hazards to the sampler include jabbing it into hard material or lowering the boom onto a rock or a high ridge between the Lander and the sample site. Since the cameras are at a high elevation, the danger from such a ridge or a rock could not be anticipated fully without evaluation of the stereo pairs.

If the preselected site is hazardous to the sampler -- it could be a hard rock or a miniature cliff-like surface -- the initial program is then altered. The extension stroke of the boom can be shortened, or the boom can be commanded to a completely new site, which has also been evaluated from the stereo pictures. Finally, if necessary, the whole sequence can be cancelled. This would require a longer time to resequence and would delay the sampling and many of the subsequent experiments.

On Sol 1 the camera produces high resolution black and white pictures and low resolution survey pictures in color. These pictures show the sample site and also the color-coded test chart number two on the Lander which is used for calibration purposes.

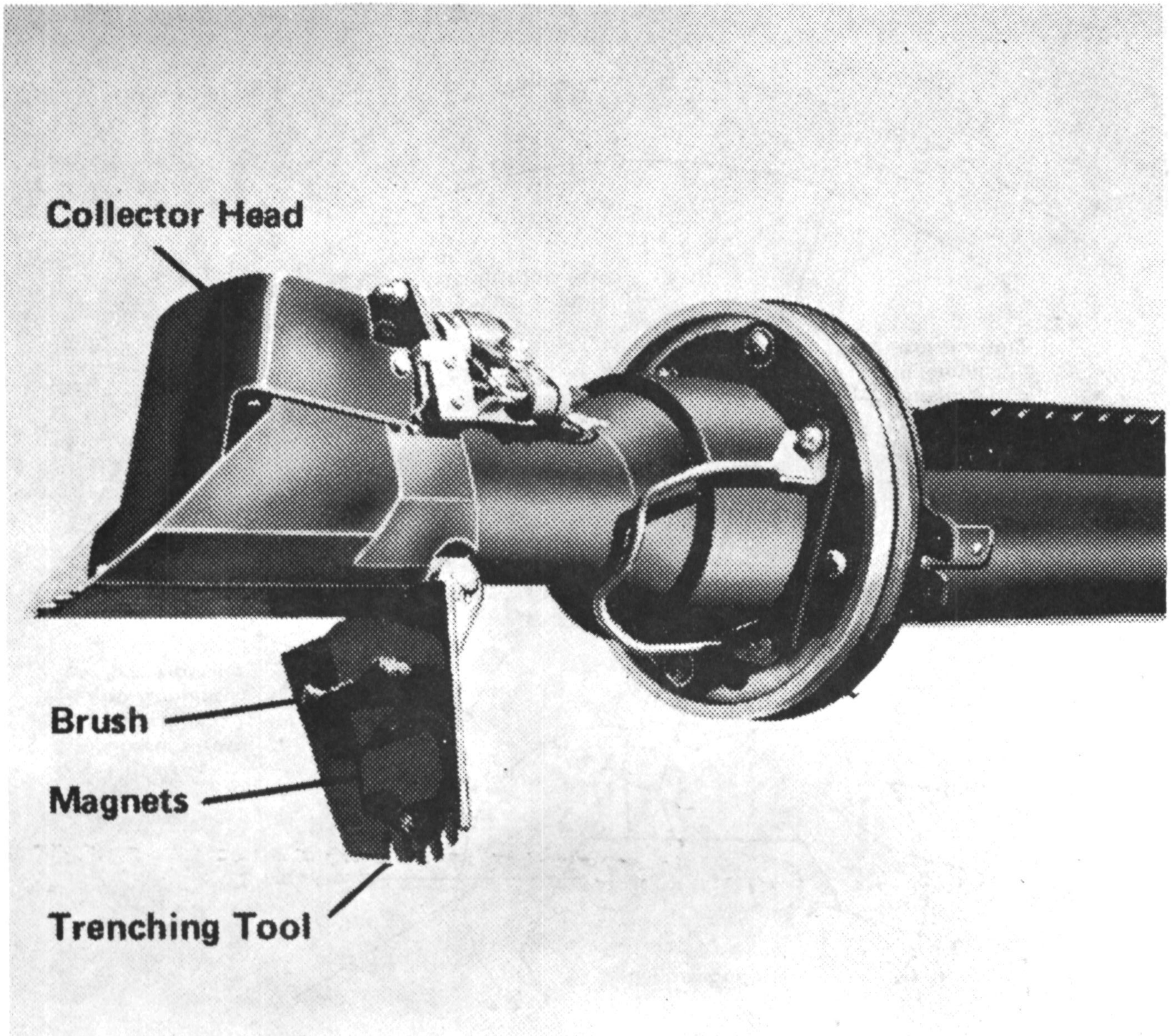
On Sol 2 the protective cannister cover on the sampler collector head is ejected onto the surface of Mars close to the Lander footpad that was photographed on Sol 0. The area is now photographed again to provide further information about the surface from the observed interaction of the cannister cover with the Martian soil. Other pictures obtained on Sol 2 are high and low resolution black and white views, covering the sampling site and a 25 x 25-cm (10 x 10-in.) grid pattern on the top of the Lander's body. The latter is to study the motions of dust particles from the landing.

If conditions are suitable for use of the cameras without danger to them, camera 1 is first operated on Sol 3. It is moved from behind the protective dust cover, and photographs 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. Two pictures are in color, two more in black and white. The Sol 3 camera operations provide a key picture event in producing the second of a stereo pair of pictures to be used in evaluating the sampling site in detail.

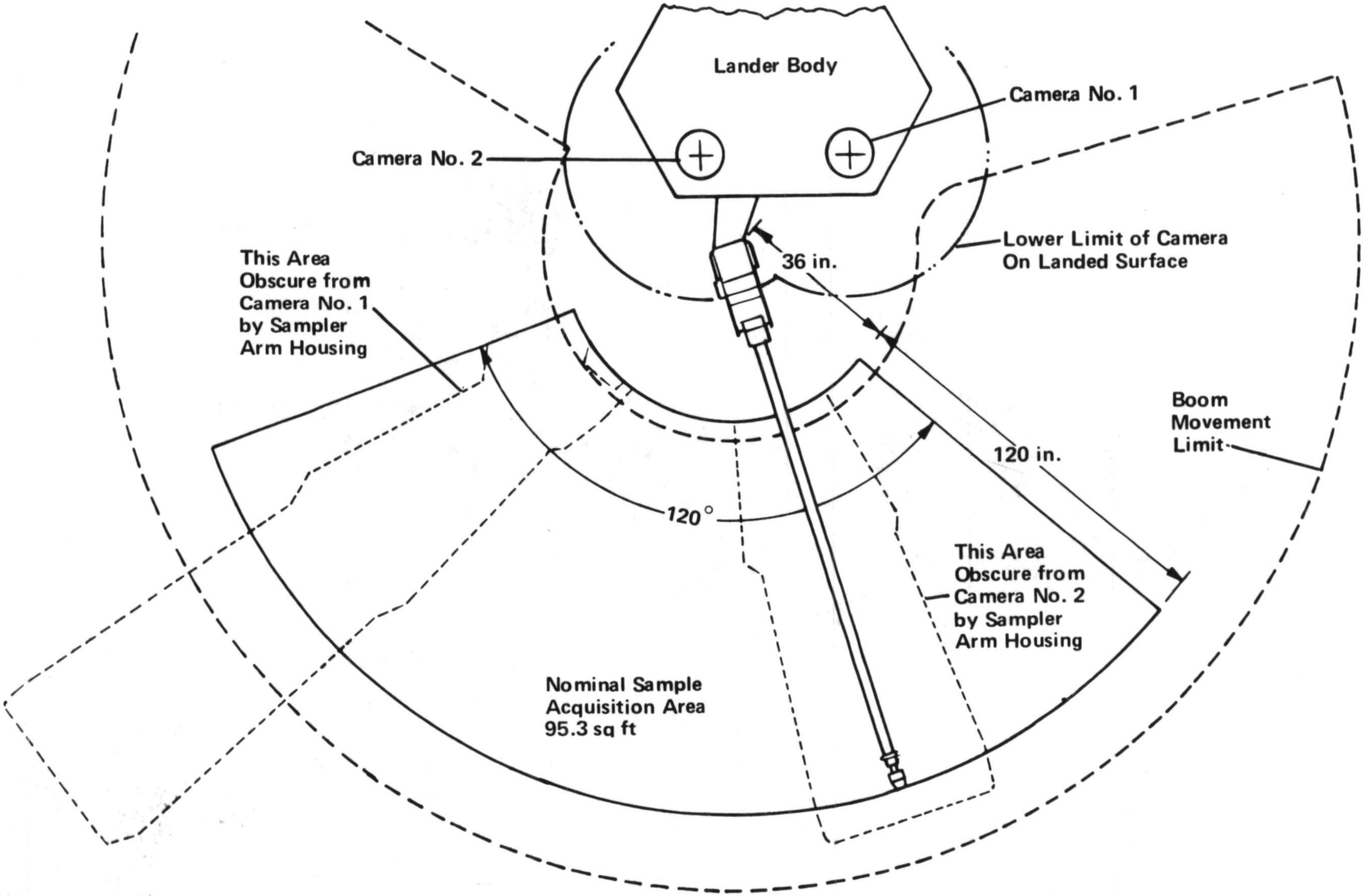
This same area photographed just after touchdown may now show changes as a result of wind; however, the stereo effect is still suitable for an analysis of the sampling site. One of the mirrors mounted on the sampler housing is included in the field of view which provides a reflected image of the Martian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

The decision whether to keep to the initial computer load for directing the sampling or to modify the commands has preferably to 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 have to be sent to the Lander in sufficient time for them to be verified by a radioed response before they are executed. The two days provide opportunity to do this safely. A change command could be sent on Sol 7 but there would be no opportunity to repeat it if for some reason it did not reach the spacecraft.

After the pictures have been obtained for sampling site certification, the cameras continue obtaining other images associated with the general Lander imaging experiments.



Powered Collector Head



Sampler Arm Area of Operation

Science Experiments

A capability of the cameras is their ability to obtain images over six spectral bands extending into the near infrared. This is comparable with Landsat capabilities and it allows "false color" pictures to be generated of Mars to reveal features that might otherwise be missed on a normal color rendering. The potential for spectacular color in such pictures is immense.

One aim of the spectral analysis of the surface with the cameras is to try to obtain an objective answer to the question: is Mars really red? This is important to an understanding of the processes that have molded the surface and how the Martian crust has reacted with the Martian atmosphere; e.g., does the crust contain iron oxides?

Pictures are transmitted from the Lander to the Orbiter at 16 kilobits/sec. Pictures are transmitted directly from the Lander to Earth at 250 or 500 bits/sec only. A direct link is used every day for real time images to be sent directly to Earth.

Limit to the operation of the cameras is sandblasting from Martian dust. The cameras can be stored behind protective shields if dust storms develop. Also, to prevent fine dust from adhering to the camera windows and obscuring the view, carbon dioxide jets can be directed on command against the windows to blow it off.

While the normal picture taking mode is a scan sequence which requires several minutes to build up a complete picture and thus is not able to reveal motion of any object in the field of view, the cameras can be operated in a single-line-scan mode. Scanning a single line continuously and laying the scan lines side by side as in a normal picture, results in a picture in which differences along the line scan are smeared across the whole picture. However, should there be any movement along that line scan during its repetition, the complete picture graphically draws attention to it by a clear distortion of the smeared strips.

The line-scan mode can also be used where it is not possible, because of data rate limitations, to take a whole series of pictures, say to show color changes over several hours; for example, at sunrise or sunset. By using the single line scan and a slow data rate the colors can be monitored for an hour or more to check how the sky changes over those interesting periods of time at the beginning and ending of a Martian day.

The question of the quantity of argon in the atmosphere of Mars has earlier been discussed in connection with science experiments during entry. If there are not more than a few per cent of argon in the atmosphere, it is advantageous to perform atmospheric analyses with GCMS on Sols 3, 4 and 5 before using the instrument for organic analyses of surface materials. However, if there is a large amount of argon, the atmospheric analyses will not be performed because the argon will interfere with the operation of the instrument.

Because the amount of argon cannot be determined until the Lander is actually on the surface, the atmospheric sampling is omitted from the preprogrammed mission. A gap in the program is left so that if the quantity of argon is small enough a command sequence can be sent to the Lander to make the atmospheric analyses without having to change the whole of the preprogrammed mission by an insertion of new commands. The argon uncertainty is expected to be resolved within the first two Sols.

The atmospheric analysis is directed toward establishing the relative abundances of carbon dioxide and other gases in the Martian atmosphere with a view toward a better understanding of how that atmosphere evolved. The results are expected to confirm a bulk constituent of carbon dioxide with minor amounts of carbon monoxide and oxygen and probably some argon. Nitrogen, too, will be searched for since this gas is important to the evolution of life on Mars. A high argon concentration would imply that the Martian atmosphere was once much denser than it is now because argon is a chemically inert gas that has to accumulate in a planetary atmosphere because it cannot enter into chemical reactions with surface materials. It is also a heavy gas that cannot escape from the planet. Its continued production from the decay of radioactive potassium leads to a gradual concentration in the planetary atmosphere. A high concentration means that a lot of atmosphere has been produced on Mars over its history and implies that atmospheric pressures on Mars may have been much greater than they are now. Such high pressures could have accounted for past periods of plentiful liquid water on the surface of Mars which, in turn, could have accounted for the sinuous channels and other liquid erosional features widespread on Mars today.

Following 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 chromatograph cleaned up for its organic analyses due to start as soon as a sample is delivered on Sol 8.

On Sol 2, preparation begins for the biology experiments by setting up equipment and checking its readiness to receive samples on Sol 8. On Sol 3, a 16-minute test analysis takes place with the Gas Exchange Biology Experiment.

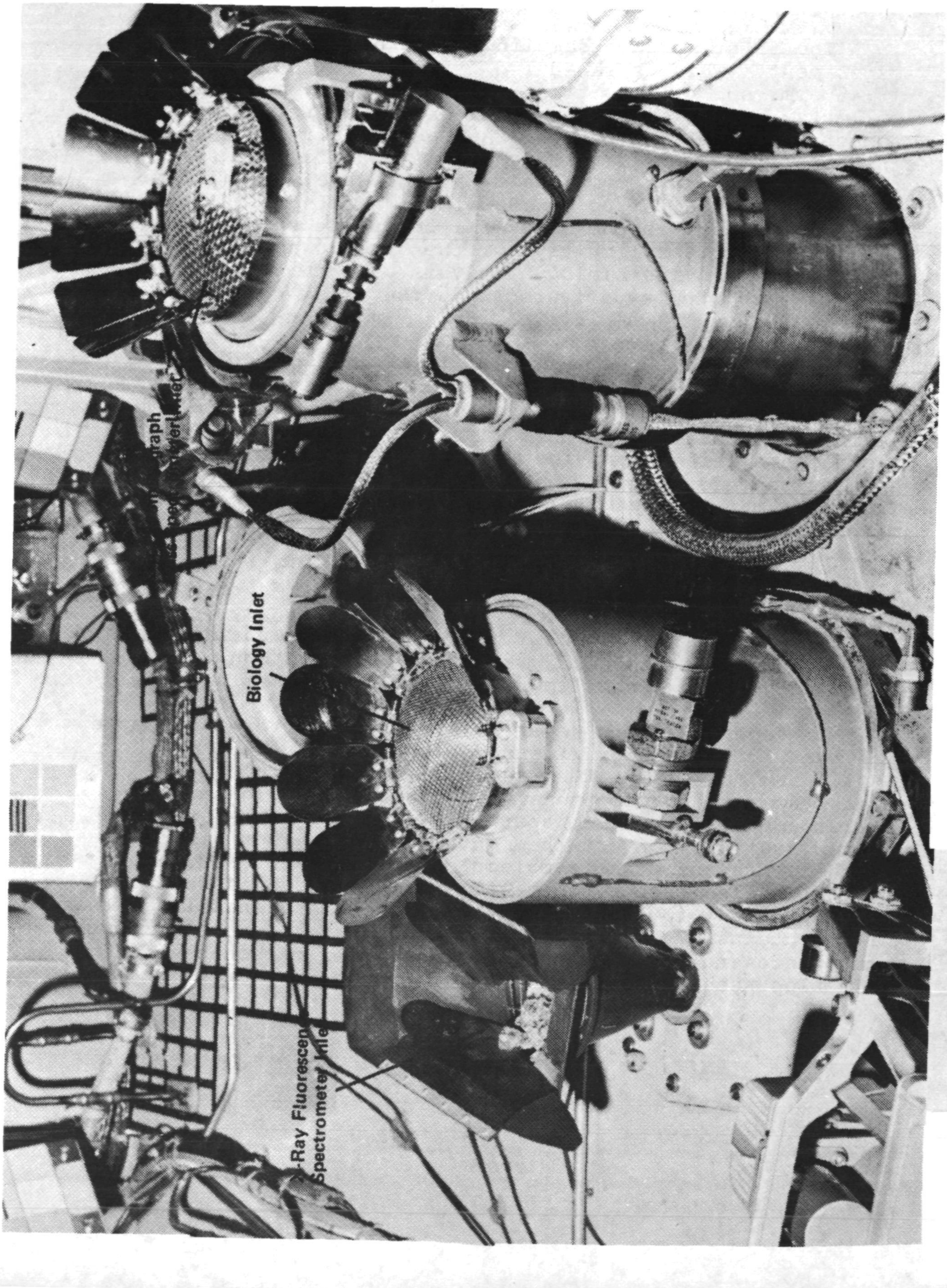
SURFACE SAMPLING AND OPERATIONS STARTING SOL 8 (July 12)

The first surface sampling is taken for the biology experiment. This is scheduled for 2:46 p.m. PDT on July 12 (6:45 a.m. sol 8, Mars time). The collector head will collect a sample of Martian soil and place it in the sample hopper on top of the body of the Lander. If a detector in the hopper does not sense any delivered soil, the sampler tries again twice automatically at the same site (it can be preprogrammed for up to 15 tries). If there is still no sample, it tries one more time before it shuts down to await the next sampling try for the organic analysis about one our later. The biology analysis begins at 4:16 p.m. PDT, if a sample is delivered with the first cycles, taking 12 days to complete.

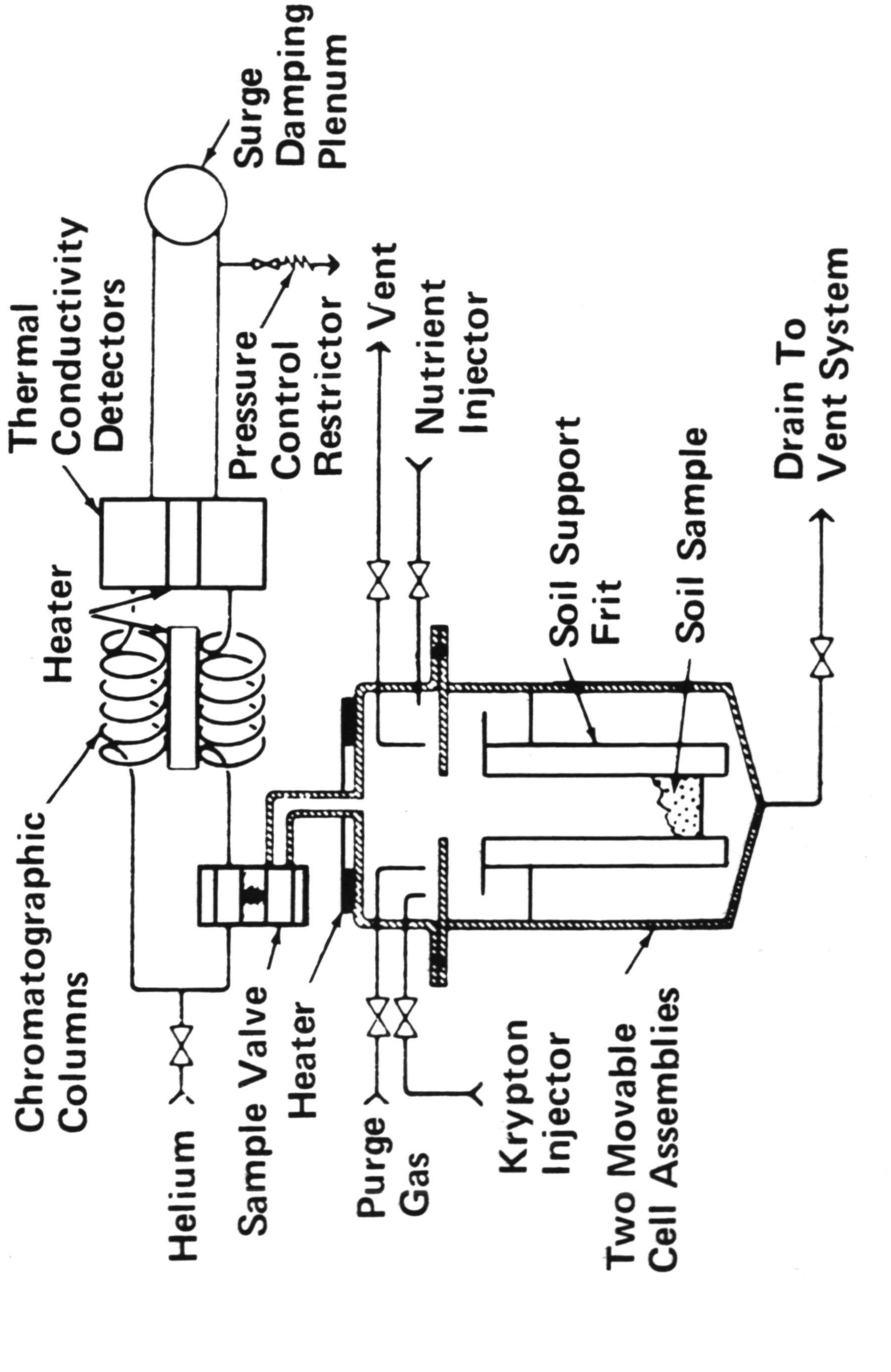
The soil is distributed to the three biology experiments; gas exchange, pyrolitic release, and labeled release. The first experiment is the pyrolytic release using a dry soil sample illuminated by simulated Martian sunlight. Carbon dioxide and carbon monoxide labeled with radioactive carbon 14 are introduced into the test chamber and the experiment incubates the sample until sol 13 to check if any radioactive carbon 14 is removed from the atmosphere.

This experiment is based on a characteristic of many terrestrial life forms that need carbon dioxide to synthesize complex carbon compounds for use in the living system. The small sample of Martian soil placed in the incubation chamber in its atmosphere labeled with radioactive carbon 14 is illuminated by a xenon lamp.

No food or liquid water is provided. After the sample has been incubated for five days (to sol 13) the atmosphere is flushed out of the test chamber and the sample heated to break the organic compounds into gases. These gases are collected on an organic vapor trap. The organics are then heated again to convert them into labeled carbon dioxide gas. If there are any organic molecules in the pyrolyzed sample having labeled carbon, they will be measured by a detector. The experiment thus shows whether or not Martian soil at this site contains living systems that can extract carbon from the atmosphere and incorporate it into complex carbon-based molecules needed for their life processes.



Surface Sample Inlets



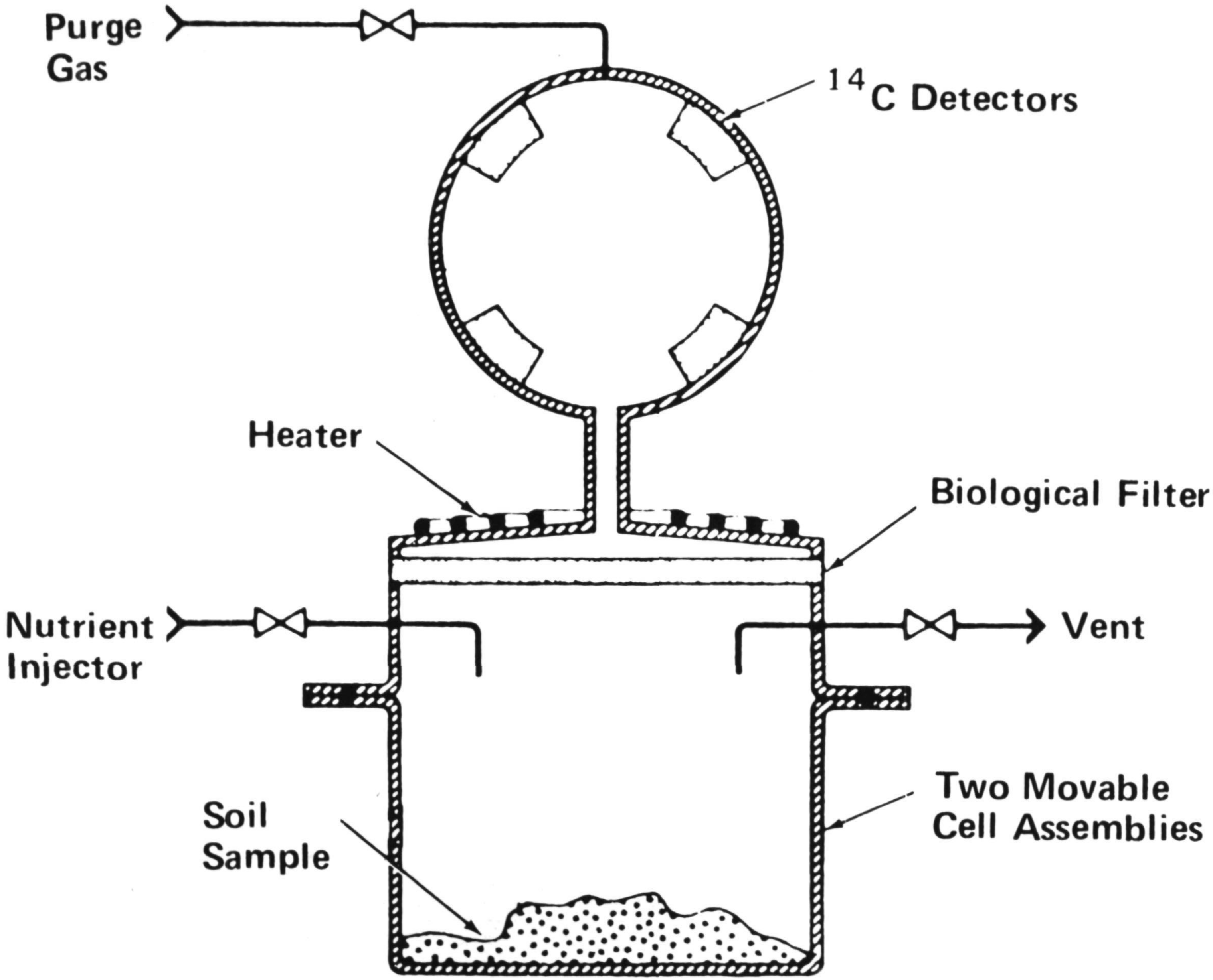
Gas Exchange Experiment

The first cycle of this 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 next sterilized by heat and put through the same test. If the result of the first test was, indeed, due to living organisms in the Martian soil, the second control test should produce negative results. If it, too, produces positive results, the effects cannot be attributed to carbon-based Martian life forms. Some other explanation has to be found. If the first test is however, negative, the next cycle of the experiment several sols later repeats the test, but with the sample provided with some water vapor.

A second biology experiment--the labeled release experiment--begins with measurement of the background of radiation from the sample in its test chamber. This experiment is predicated on the fact that given a food labeled with carbon 14, a Martian organism would be likely to ingest it and incorporate labeled carbon atoms into complex molecules of its living system. Moreover, some of the labeled molecules would later be released by the living system as waste products. This transfer of carbon from a nutrient solution through the living organism and back to the environment is searched for by this experiment. After the background test has been made from 14:50 on sol 8 to 04:50 on sol 10 (Martian time) a small amount of extremely dilute aqueous solution of simple nutrients containing carbon 14 labels is injected into the soil. The background radiation is then sampled over the next few sols; another injection is made and the experiment continued. Later, the sample is purged from the test chamber. Again, should a positive result be obtained, e.g. radioactive carbon 14 be transferred from nutrient molecules to the atmosphere, a second half of the original sample, which was retained as a control, is sterilized and put through the same test sequence. If this control produces positive results, it is unlikely that the experiment has revealed the presence of organic life on Mars. However, if the control shows negative results, the experiment may have detected a Martian life form.

The next sequence for a negative initial result of the labeled release experiment is to repeat the experiment, using a sample from a different sampling site in the second biology sequence.

This labeled release experiment complements the first experiment in that while the first looks for carbon dioxide passing from the atmosphere to a living organism, the second looks for carbon dioxide passing from the living organism to the atmosphere. Both are based on the assumption that Martian life forms, like terrestrial life forms, would be expected to cycle carbon dioxide through the atmosphere with perhaps an intermediate food stage.



Labeled Release Experiment

A third biology experiment is the most complex. The gas exchange experiment provides several options. It assumes that living systems must affect their environment as they live, breathe, eat and reproduce. Part of the soil sample is placed in the test chamber inside a small cup. The atmosphere is purged from the test chamber add replaced with a controlled atmosphere of helium krypton and carbon dioxide which is injected at about 4:00 on sol 9 (Mars time). Immediately afterwards 0.5 cc of a rich nutrient are placed in the test chamber below the cup. This amount is insufficient to contact the sample directly but provides a humid atmosphere. The soil sample is incubated for one week (or more) each day checking the atmosphere of the test chamber to seek evidence of metabolism; i.e. looking for the presence of hydrogen, nitrogen, oxygen and methane and for changes to the amount of carbon dioxide. These analyses are made at about 8:00 a.m. each Martian day.

In subsequent cycles of this experiment the nutrient liquid is increased so that it wets the sample. The atmosphere is again sampled for presence of gases that might be transferred into it by living organisms or loss of gases to the organism. The nutrient liquid used differs from that of the labeled release experiment in that it contains just about every important amino acid, every known vitamin and many trace elements and is highly concentrated.

Each of these biology experiments can be performed three times on each of the two Viking spacecraft. If positive results are not obtained until the third test sequence, a fourth test is within the capability of the biology package to provide for a control test to follow a positive third test. All biology samples are essentially samples from the top layer of soil.

The first sample for the gas chromatograph mass spectrometer's organic analysis is obtained on sol 8. This required only a small quantity of Mars' soil; less than 100 milligrams. The gas chromatograph is purged before the sampling. The experiment seeks to establish whether organic molecules are present in the soil of Mars and what kind. The experiment heats each soil sample and detects volatile components given off from the sample as a result of this heating. Higher temperatures break down even complex heavy organic molecules into lighter volatiles that can be detected by the instrument.

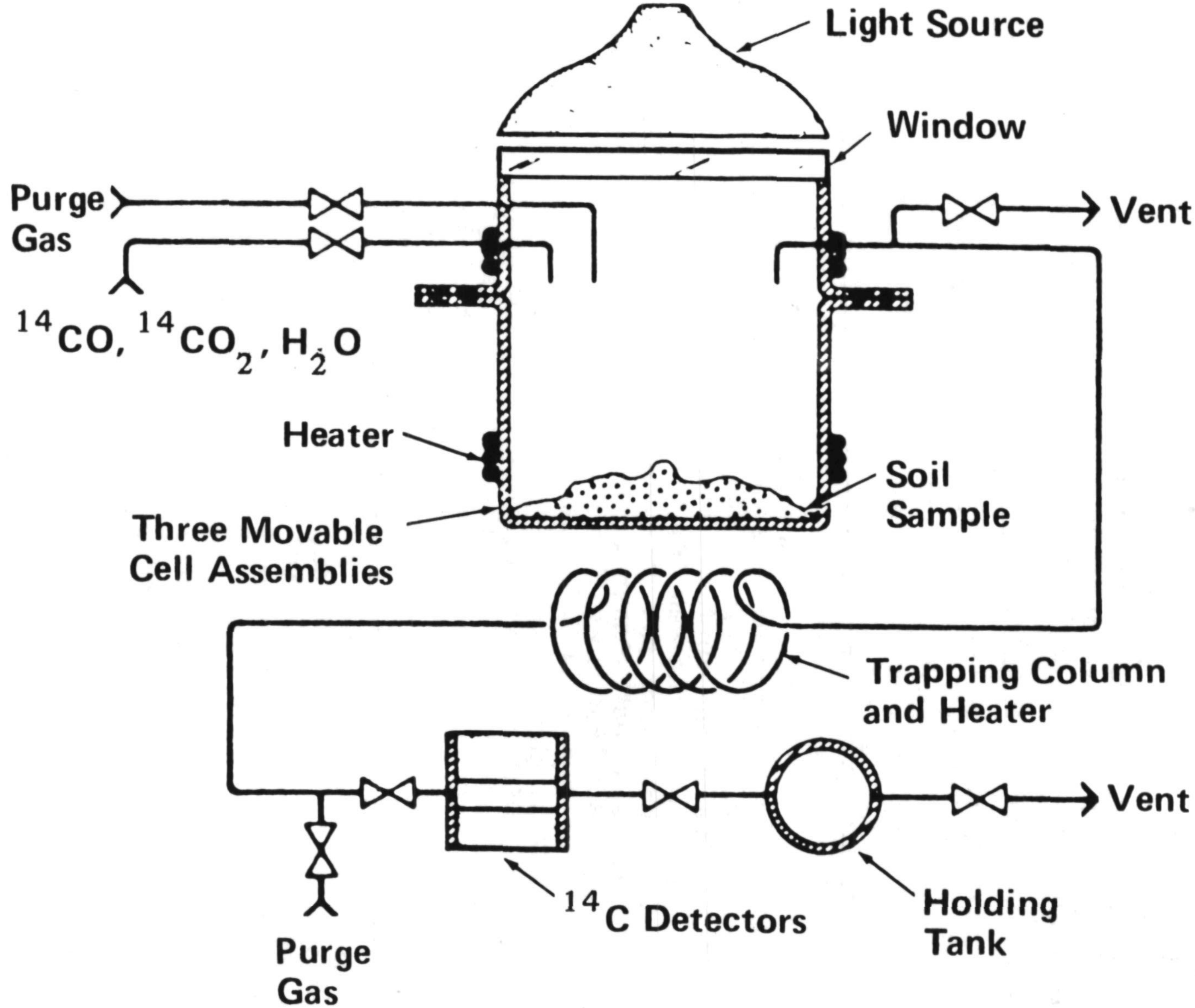
Analysis of the components of organic matter takes some time. A few abundant compounds can be quickly identified, but there are probably many components of low abundance which have to be separated from the background of the instrument itself, and it may take a considerable time to identify them. Organic compounds that are thermally unstable decompose under heating so that the GCMS records their pieces. The experimenters than have to try to derive what the original molecules were.

The next task is to try to ascertain how such compounds might have arisen on Mars; i.e. from physical, chemical, photochemical or biological processes. Even as far as terrestrial organic compounds are concerned there is still some controversy about their origin. The GCMS is not a life detection experiment; but its results have important implications to the search for life on Mars.

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

But on Sol 8, the third sample is for inorganic analysis of Martian soil with the X-ray fluorescence experiment. This sample is obtained at 6:03 p.m. PDT on July 12 (about 10:30 a.m. Mars time on Sol 8). Ideally it should consist of 30 cc (1.6 cu. in.) of particles all less than 12 mm (.48 in.) diameter to fit through the mesh of the screen: a sandy material is fine. If the Lander can only reach to areas of sheet rock a sample might still be obtained for this experiment by waiting for wind-blown dust or pebbles to gather there. The sample arm might even be used as a deflector to cause wind-blown material to fall into the sample funnel.

The experiment searches for elements in the sample and tries to determine their relative amounts. It detects elements with greater atomic weight than magnesium, but it cannot differentiate between isotopes of elements. Elements lighter than magnesium can only be detected as a group, but estimates can be made of their relative abundances. It may also be possible to estimate whether hydrates or carbonates are present on Mars.



Pyrolytic Release Experiment

A second X-ray spectroscopy sample is taken on Sol 27, i.e. after the second biology sample. The current 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. There are five samples planned for the nominal mission. More could be taken depending upon the size of the earlier samples. The limit is the capacity of the cavity into which samples are dumped after their analysis is completed. The experiment seeks understanding of the primary rock materials on Mars and the weathering processes that has changed them. Also the experiment tries to identify minerals on the planet. The effects of wind and water may have been to separate minerals into discrete areas of the Martain surface. If such areas can be recognized on images returned from the Lander they can be sampled.

The first step of the X-ray experiment is to normalize the data to the condition of the instrument as determined by the presampling calibration. Next a preliminary cut is made at chemical analysis. All that can be said during the first few weeks of operation on the Martian surface may be that the material looks like some terrestrial materials, or that luminite can be ruled out as a major component, or that the Martian material is consistent with a clay mineral, or that there is a certain titanium content. Later the spectra will be matched in detail with terrestrial synthetic compositions in a long and involved process of data analysis.

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

After the first sampling when the boom is in use for about 4 hours it is left to rest for two weeks at least, since the sampler is essential for obtaining subsequent samples for the biology, organic analysis and inorganic analysis experiments and following its use for these priority experiments it is used for other science experiments on the Martian surface and in the atmosphere above it. It carries two mirrors so that views can be obtained beneath the spacecraft as part of experiments to define surface characteristics. It is used to dig trenches on the surface for observations of how fast any wind-blown material fills them up. The magnet on the back of the hoe is used to seek magnetic particles in the Martian soil; ideally from several sampling sites. A thermocouple on the base of the sampler head is used for temperature measurements within the surface and in the atmosphere above the surface. Rotating the sampler head places the thermocouple in sunlight or shadow.

For imaging support the boom establishes bench marks for x, y, and z coordinates to assist in topographic mapping of the landing site. Rocks and surface material are moved and material deposited on the Lander body to see how it is winnowed by the Martian winds. If a camera should fail, the shadow from the boom can be used as an aid to stereo assessment of the landing site. The boom can even be used to produce an artificial eclipse to investigate the atmosphere and its suspended particles.

An interesting activity on Earth during this period of science activity on Mars is that the USGS takes the topographical map constructed from the Viking information and recreates the surface features of the landing site in the Atrium at the Jet Propulsion Laboratory; a section of Mars on Earth.

The seismology experiment continues during this same period, but it is not until three weeks after landing that it is operating continuously for a substantial part of each day. The constraint on operation of the seismometer is data quantity limitation--early in the mission the need for many images of the Martian surface uses up much of the available transmission time. Seismic data, also, requires the use of much data transmission time and accordingly has to be delayed until the priority experiments are completed.

Seismic experiments require large amounts of data because the vibrations have to be monitored continuously. To avoid tying up all the data capabilities of the Lander and its communication links, the seismic instrument averages the data at Mars and sends back only these averages to Earth. Even when an event occurs, averaging is still utilized and the instrument transmits to Earth the amplitude of the vibration and the number of zero crossings which is a measure of the frequency of the vibrations produced by the seismic event. A marsquake taking place near to the seismometer is expected to produce high frequency vibrations while one farther away produces low frequencies. A major marsquake cannot be identified until the background of seismic and other activity on Mars has been established. If such a marsquake takes place hundreds of miles deep within the lithosphere of Mars, this location may be established by having two seismometers on the surface (after Viking 2 has landed safely). The seismic experiment can not really start operating in full force until this second landing has taken place and seismic events can be observed from two locations on the Martian surface. The seismic experiment is also the only Viking lander experiment concerned with the interior of Mars.

The irregular gravity field of Mars and the high volcanic piles suggest that there may be larger stresses in the crust of Mars than in the crust of the Earth. There may also be tectonic activity and active fault zones. The seismic experiment should resolve whether these known stresses on Mars are today relieved by quakes or by slow creep of the crustal materials.

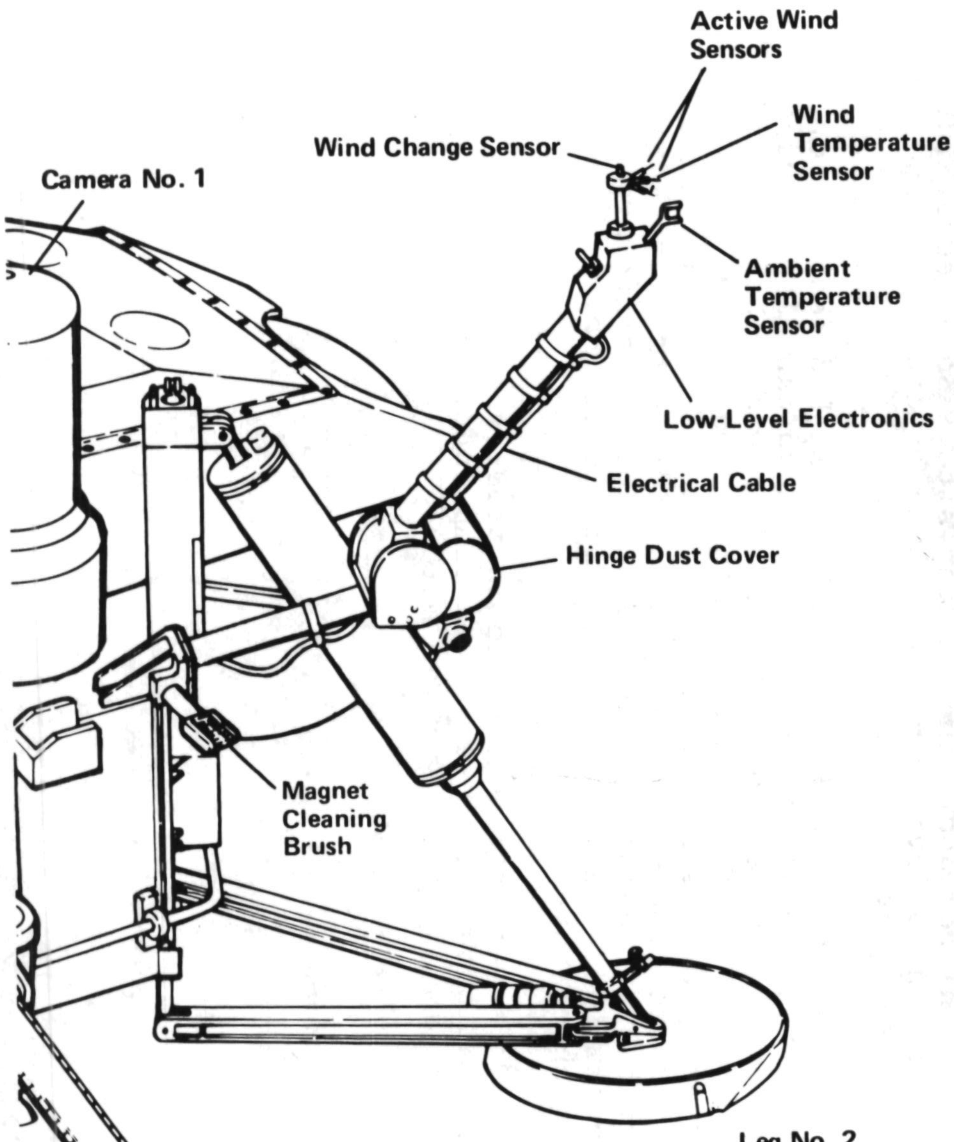
The seismometer experiment is a long-term experiment and will continue as long as the Landers continue to operate on Mars.

Meteorology is another continuing experiment. Although there is no water vapor sensor on the meteorology package water vapor can be seen from orbit. When it is observed at the landing site, the temperature will also be measured there by the meteorological instrument to determine the frost point temperature which is the Martian equivalent of the terrestrial dew point.

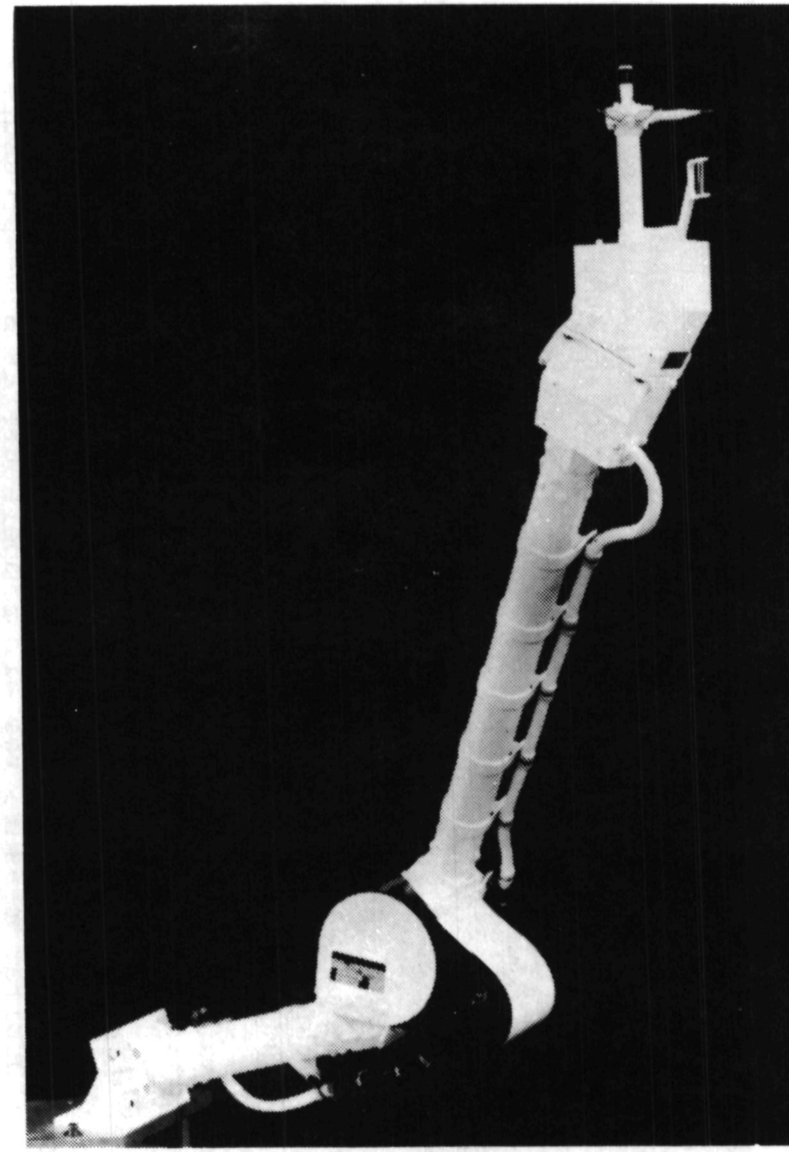
Also, while the Orbiter measures the soil temperature of Mars, the meteorolog package measures the air temperature just above the surface. Additionally, infrared observations from Orbiter measure the air temperature at 3 mb pressure, which is higher above the landing site. So a temperature profile can be developed and checked for diurnal changes and from day to day.

After the second biological sample has been taken, the temperature sensor on the collector head can also be used to supplement the meteorological experiments. The sampler boom, extended high above the Lander, can provide another temperature measurement, and its capability of movement can be used to complete a temperature profile from its maximum vertical extension down to the surface, passing through the elevation of the sensor on the meteorology boom which serves as a check point.

This temperature profile is predicted to be extraordinary compared with one on Earth. A temperature change of 50 to 60 degrees is expected over two meters.



Meteorology Boom



Temperature variation is important to understanding the atmospheric dynamics that produce winds. Wind speeds are, of course, measured directly by the meteorological instruments. Mars has a similar atmosphere to Earth from the standpoint of atmospheric dynamics, but is a simpler version of the Earth because there is less water on Mars. The dynamics of the Martian atmosphere are easier to predict than those of Earth's atmosphere. The Martian atmosphere reacts more quickly to changes in radiation; some ten times faster than Earth. One of these is a solar tide in which an atmospheric pressure wave due to the gravity of the Sun sweeps around Mars each day. The Martian winds change in response to this solar atmospheric tide. The effects are looked for with the pressure sensor of the meteorological instrument.

The meteorological experiment has been described as a net stretched in time rather than space to catch interesting events on Mars, such as cold fronts and dust devils. This is quite different from terrestrial meteorology where nets of many stations are spread about the planet. On Mars there will be only two stations and these have to wait for the meteorological events to pass by them. So the major results from meteorology experiments on Mars come from extended observations on the Martian surface, ideally extending over a complete Martian year, i.e. two Earth years.

If the surface pressure variations on Mars can be observed for a whole Martian year, information would bear on our understanding of the seasonal changes of the residual polar caps of Mars.

Another important long-term aspect on the meteorology experiment arises if Viking 2 lands at Cydonia--the prime B site. The northern polar cap approaches very close to this site during northern hemisphere winter on Mars and may even engulf it. Thus, a meteorological package will be available to measure arctic conditions on Mars and what happens at the edge of a polar cap. While Viking is not qualified to survive a Martian winter, its conservative design may allow it to continue to operate through much of this subzero cold period and obtain this interesting meteorological data in Earth's summer (northern hemisphere) 1977.

The two sites are virtually ideal from the meteorological viewpoint; they are both in the same hemisphere, they are reasonably close to each other for data comparison, and on reasonably flat sites away from mountainous regions.

Another group of scientific investigations that is of a long term nature is connected with the physical properties of the Martian surface. These investigations mainly rely upon data gathered by other experiments, except for magnets attached to the collector head which is used to attract soil particles with magnetic properties and some tests that may be made when primary mission experiments are completed. The data are used to determine the size of particles on the surface of Mars, the bulk density of the surface material, the bearing strength of the Martian soil and the dynamic loading of the surface. Much information is derived from the interaction of the Lander footpads with the surface, the amount their stroke gauges are depressed by the landing impact, and the way in which the rocket jets affect the surface at the landing. Other information is derived from inspection of the camera images and the current drain on the motor of the sampler boom as the collector head interacts with the surface materials.

This sampler activity provides information about the soil such as cohesiveness and its ability to remain in trench walls and how densely it is packed. To assess the size of soil particles, a magnifying mirror can be used with the sampling scoop to magnify pictures of soil inside the sampler's lip by about 4 times. Particles sizes may also be determined by the winnowing effects of Martian winds and by shaking samples through holes in the 2000 micrometer sieve. The falling particles form into a parabola on the surface and this shape can be used to determine the size of fine particles. Coarser particles can be sorted when the wind is not blowing, letting the fine particles fall out through the screen and then depositing the larger particles on a flat surface where they can be inspected by photography.

One experiment is to push the sampler collector head into the soil and observe the imprint, measuring the boom motor current until it declutches. Since such an experiment might damage the boom, it must be delayed until all the essential sampling work has been performed.

The camera images provide an opportunity to look at the shape of rocks and pebbles to see if there has been erosion by water as well as by wind. Rocks and rocky outcrops are examined closely. Filets behind rocks and the shape of the trenches dug by the surface sampler are inspected to see how they are modified by the wind. Layering of the surface is looked for along the walls of deeper trenches made by the surface sampler. A rock might be lifted by the surface sampler and allowed to fall so as to make a small crater. Some rocks will be turned over to see how their protected surfaces differ from the exposed surfaces.

The magnetic properties of surface materials are important to an understanding of the evolution of the planet. Magnets attached to the sampling head are used to pick up magnetic particles of soil, but only after two samples each have been gathered for biology, GCMS and XRFS. However, if magnetic particles do adhere to the magnet during the first sampling, these may be recognized in an image taken when the surface sampler places the soil sample into the funnel for the X-ray flourescence experiment on Sol 8. The magnets will be out of focus in the picture, but if soil particles are adhering to them they should be recognized. Another opportunity occurs on Sol 12 when an image of a magnet on top of the Lander may show particles attracted to it from wind-blown dust.

In terms of planetary evolution a primitive crust or material erupted from volcanoes is expected to have many magnetic minerals. Thereafter these react with the atmosphere and may become non-magnetic, leaving only a few grains of magnetic material. The volcanic piles of Mars could be rich in magnetic materials. If such materials are found at the Viking landing sites either the Martian atmosphere has not been able to oxidize the iron content of primary crustal materials, or the material is of such recent origin, i.e. from recent volcanic activity, that there has not been time for it to become oxidized.

If the inorganic analysis shows that there is iron present in the surface materials, but no magnetic particles are found, this will mean that the Martian iron has all been oxidized to a non-magnetic form. The amount of oxygen required to do this is very small compared with the amount now present in the Earth's atmosphere.

The water on Earth is thought to be the source of the oxygen of Earth's atmosphere. If there has been water on Mars there could also have been oxygen too. Since there is carbon dioxide on Mars, it would be expected that there would also be water. The question is what has happened to this water? One possibility is that it has reacted with surface minerals to form hydrated iron oxides which are non-magnetic. Whether or not the Martian minerals are hydrated is determined by the organic analysis experiment, since pyrolysis releases the water and it is detected in the experiment.

ORBITER SCIENCE AND RADIO SCIENCE

Following separation, science experiments continue in the Orbiter.

First experiments are directed towards obtaining increased understanding of the geology of the Martian surface. Systematically over several orbital revolutions, the area of the Martian surface adjacent to and southeast of the landing site is covered by overlapping photos. This area upstream of the channels was only mapped at high resolution in small parts by Mariner 9. High resolution imaging from Viking provides information to help determine how the channels were formed. Also stereo swaths across the mouth of the channels allow better estimates of the volume of water that must have been flowed.

The next area to be covered is along the track of the Orbiter over the surface, i.e. to the southwest of the landing site. This is a region of diverse geological features including eroded channels, chaotic terrain, canyons and the highlands on either side of them. Fortunately the orbit of Viking 1 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 to look at the surface features such as the nobby terrain.

A few images are also obtained in color. This is important because in lunar work color differences between lava flows were shown to relate to chemical differences among these flows. Thus, 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 these are revealed on the images.

Every 20 days, the Orbiter photographs the whole disc of Mars from high altitude and in two colors. These images are used in several ways. Obscurations caused by dust or ice in the atmosphere are recorded and their movements traced. Color variations on a gross scale show regional differences. South pole activity is monitored as weather patterns develop along the edge of the polar hood. The white cloud regions such as those at the edge of Tharsis are monitored to find out how they change during the course of a Martian day. Changes in albedo of the surface features are also recorded.

Toward the end of nominal mission of the first Lander, the Orbiter rocket engine is fired to cause the spacecraft to orbit the planet slightly out of synchronism with the period of rotation of Mars. In effect, the Orbiter now walks around the planet and allows the whole of the planet's surface to be imaged in great detail. The orbital trim maneuver to do this takes place September 7.

Thermal mapping of the planet also continues after separation. The instrument is extremely sensitive to the presence of dust in the Martian atmosphere and thus can follow the development and progress of dust storms. Atmospheric dust can be detected even when it is not visible to the imaging system. It has the effect of reducing low altitude temperature differences in the Martian atmosphere between day and night. The multi-band capability of the infrared thermal mapping instrument allows its use for mapping surfaces of different chemical composition if they occur on Mars as they do on the Moon.

Volcanic activity might also be detected. For Mariner 9 to have detected a molten lava field it would have had to be 1 km (.6 mi.) across. With Viking a major eruptive event that is still cooling would be detectable. But to be reasonably sure of Viking detecting volcanic hot spots during the mission, volcanic activity of Mars would have to be greater than that of the Earth.

Another experiment endeavors to obtain details of grain sizes of material along the bottoms of the Martian canyons. This was tried unsuccessfully with Mariner 9. The better spatial resolution of the Viking instrument is expected to provide information on the change of granularity with direction along the canyon. On large alluvial plains on Earth similar equipment can detect the differences between boulders and sand. If this is done on Mars it is a step towards showing which way the flow took place in the canyons; i.e., what was the normal sedimentation and was there a subsequent change to the grade since the flow occurred.

- more -

The water vapor mapping experiment obtains data to try to answer a whole series of questions about water on Mars. What is the source of the water vapor observed in the Martian atmosphere? Where does it go? How much water vapor is trapped in the polar caps? Is there a large amount of water locked in the Martian surface? Why is there not more water vapor in the Martian atmosphere? Has there been a greater abundance of water in the past?

The diurnal and seasonal variation in atmospheric water vapor are mapped over the period of the mission. The diurnal variation is important to understanding the release of water vapor into the Martian atmosphere, but the synchronous orbit does not allow this to be adequately investigated. During the walk-around, however, the experiment determines the variation in the amount of water vapor in the atmosphere throughout a Martian day, its vapor pressure, its height in the atmosphere, and the temperature of the vapor. Towards the end of the nominal mission, the Orbiter passes through the shadow of Mars on each orbit and as the sun rises and sets behind Mars as seen from Orbiter, a vertical profile of water vapor can be obtained.

Present evidence suggests that the water vapor is restricted to a layer close to the surface of Mars, the bulk of the water vapor may be within less than 1 km (.6 mi.) of the surface and thus confine Martian "weather" to the surface.

If the water vapor varies by a large amount diurnally, it most probably has to be mixed with the surface material as ice crystals. Because the surface is rough these ice crystals may behave much like light snow on a plowed field and would not be visible from above. The mechanism could be that ice crystals form on dust grains which then fall to the surface. Such an ice and dust mixture can actually pass through a liquid phase each day when the temperature rises after sunrise. If ice were exposed on the surface it would not become liquid but would rapidly sublime directly to vapor. But mixed with dust, the ice can pass through the liquid state and in this way may provide liquid water for a few hours each Martian day for a few days at the end of the Martian winter at the right latitudes.

Some delayed water release mechanism seems to apply on Mars because the water content of the Martian atmosphere, as observed from Earth, does not peak until long after mid-summer. Water does not appear to come from the polar cap melting but is somehow released in a controlled way weeks or months after mid-summer. How the polar caps are involved in the annual cycle of water vapor is not understood, but they may act as a trap, or sink, for vapor over long periods of time. One suggestion is that the water vapor cycles daily between the surface and the atmosphere. Some fraction reaches the polar caps and becomes trapped there until released by long-term changes to the orbit of Mars, when the permanant caps exchange from one pole to the other and all the carbon dioxide and water trapped in them is released for a short while into the Martian atmosphere. The amount then available for seasonal exchanges is much greater than at present. A fundamental question is the amount of water vapor that migrates to the polar caps each year and from where this amount is replaced. The aim of the MAWD experiment is to try to develop a water budget for Mars on a daily, seasonal and epochal basis. If the present quantities of water vapor in the atmosphere were converted to ice at the poles, this would build up a periodic layer. The appearance of water vapor at warm latitudes each year could be from seasonal water evaporated from ice on or within the surface material; it could also be water generated on a continual basis from geothermal activity which then exceeds the loss of water from the atmosphere to form ice at the poles.

Both the A and B sites are good locations at which to look for evidence of the exchange of water vapor between surface ice and the atmosphere.

Radio experiments use the signals from the Landers and Orbiters throughout the mission. The signals are used to determine with great precision the distance from Earth to Mars. The signals provide information on the dynamics of the rotation of Mars, precession, nutation, and when combined with global data, on the variation of the gravity field of Mars. This new information determines the internal properties of the planet. When both Landers are down and can be tracked simultaneously, there is a unique opportunity to measure the components of the rotation and precession. But the data will take a long time to process.

Global gravity surveys are made by the radio science experiment during the walks of Orbiter around the planet, based on the fact that periapsis is the orbital position most affected by gravitational anomalies. The walk moves periapsis around the planet. Mariner 9 provided gravity data along 18 degrees S latitude. Vikings 1 and 2 provided gravity data along 20 degrees and 44 degrees N latitude respectively, thus completing three gravity surveys of Mars. These gravity surveys do much to resolve the figure of Mars and to find out if the planet is in hydrostatic equilibrium or has convective cells within its structure.

When later in the mission the orbiting spacecraft pass behind the limb of the planet into occulation as seen from Earth, the radio waves penetrate the Martian atmosphere and provide details of the properties of the ionosphere and of temperature, pressure and density of the atmosphere. The dual frequency capabilities of the mission add greater details to the measurements made in these experiments. Of particular importance is an extended mission since it provides observations over many months of occultations beginning in January 1977 and extending over almost a complete season on Mars by use of the two Orbiters.

During the period of conjunction with the Sun, the radio experiments probe the solar corona to ascertain its electron content; and a relativity test is made to determine how much the mass of the Sun bends the radio waves coming from the spacecraft to Earth and delays their passage. The dual frequency capabilities of the Viking orbiter coupled with the Lander on the surface of Mars add confidence that the experiment may produce results that may resolve the controversy between the theories of Einstein and Dicke and others.

Close approaches to the small satellites of Mars allows their masses to be determined more accurately. Approaches to within 30 to 40 kms (18 to 24 mi.) are made of Deimos in December and of Phobos in January and March 1977.

VIKING 2

The second Viking spacecraft follows Viking 1 to Mars. It, too, undergoes a final AMC on July 27 before its MOI which is scheduled to take place August 7. Since the Orbiter of Viking 1 will have produced much information about the surface of Mars, and experience will have been gained from Lander 1 operations on the surface, a decision is made before MOI as to the site to which the Viking 2 will be targeted.

The preselected target is 44 degrees N and if this has to be changed, the final AMC has to reflect the changes needed. This final AMC is only 23 days following the touchdown of Lander 1.

A pacing feature is the upcoming conjunction of Mars with the Sun which for two weeks before and after Thanksgiving interrupts communications between the Landers and Orbiters and Earth. The nominal mission for Viking 2 is scheduled to take place before solar conjunction, but should more time be needed to make a final decision on where it is to land, the spacecraft may be left in orbit about Mars and be reactivated after conjunction for a landing then. This may arise not only because of uncertainties about the landing site but more likely because the data returned from Viking 1 proves so unusual or interesting that more time is needed to replan the mission of Viking 2 to take full advantage of what Viking 1 has discovered about Mars.

The nominal mission for Viking 2 is almost identical in conception to that for Viking 1, with site certification, separation, descent and landing, sample site certification, and subsequent experiments.

Under this nominal mission plan, landing is on September 4, and the initial computer load is for 24 sols; i.e. only one cycle of experiments.

Also the Orbiter experiments for Viking 2 have an additional sequence. Mariner 9 found that the north polar region of Mars is of great interest. The Orbiter of Viking 2 initially has an orbit inclination of approximately 50 degrees if landing is planned for the prime B site in Cydonia. When Lander 1 completes its cycle of 58 sols of operation, Orbiter 1 is moved so as to act as a relay for Lander 2. Orbiter 2 then has its orbit changed to an inclination of 75 degrees so that its cameras and infrared instruments can observe the Martian polar regions.

At this period of the Martian year, the north pole is clear for observation, without its hood. The south pole is in the midst of its winter and is dark. The north polar cap is also at its minimum and thus at the opposite season from when it was observed by Mariner 9. Details should be obtained of laminated terrain first observed at the south pole by Mariner 9, and the thickness of the layers, determined by stereo photography, should help understanding of how they were formed and whether there have been big climatic changes on Mars.

The thickness of the layers can also provide information on how much volatiles are captured in the polar cap. Since the north polar cap is the important cap at this epoch of Mars, this information is important towards determining what the atmospheric pressure might become when the dominant polar cap changes from one pole to the other.

The infrared thermal mapping instrument measures the polar cap temperatures to determine composition.

Since the Viking 2 operations may be considerably modified by the findings of Viking 1, a detailed press kit will not be issued until late July or early August.

DEEP SPACE NETWORK

The Viking mission presents a new and unique operational challenge to the Deep Space Network. At any one time three spacecraft are being handled simultaneously, two orbiters and one lander. Each spacecraft is transmitting two streams of telemetry data. All three spacecraft can be commanded independently from Earth.

Each of the spacecraft has one S-band transmitter frequency which has two subcarriers, each carrying a unique data stream. One subcarrier carries science data at bit rates that can be commanded from 1 to 16 kilobits per sec. for an orbiter, or 250 to 1000 bits per sec. for a lander. The other subcarrier carries engineering data at 8 1/3 or 33 1/3 bits per sec. for either orbiter or lander.

At the Earth receiving stations there are three separate receivers; one tuned to Orbiter 1, another to Orbiter 2, and the third to one of the landers (whichever is operating).

In addition, each orbiter carries an X-band transmitter which does not send telemetry data but is used for radio science purposes. At the receiving station the X-band and the S-band signals are received on the same antenna. The DSN antennas had to be modified with a dichroic reflector that separates simultaneous X-band and S-band transmissions. It consists of a filter that reflects S-band to one channel and passes X-band to another so that simultaneous signals can be separated and sent to different receivers for processing.

For the first time a space mission is using all the resources of the Deep Space Network simultaneously. All nine stations of the DSN are configured to support Viking; a 64-meter (210 feet) and two 26-meter (85 feet) antennas at each of the three worldwide stations at Goldstone, California, in Spain and in Australia.

The prime task of the DSN is to maintain radio contact with the spacecraft at the maximum Earth-to-Mars range of 400 million kilometers (240 million miles), and to receive data at the required bit rates. The antenna gain of 61-62 db and the signal noise temperature of 18-20 degrees K is adequate to maintain the bit rates.

The DSN continuously monitors the data streams coming to Earth to ensure that good data is being received.

There are two redundant command channels to all the 64-M stations from JPL. These go right to the transmitter at the DSN stations. If there should be a fault along one of these communication links so that a command cannot get through it to the transmitter, the transmitter can be immediately switched to the other line which gives it direct contact with a Model 360 computer sending the commands from JPL.

A special feature of the command system for Viking is an idling sequence. This is analogous to being able to lift your telephone and talk directly with a party without having first to dial a number. The idling sequence maintains the command detectors at the spacecraft in lock with the ground station whether commands are being transmitted or not. In this way time is not lost for a spacecraft to acquire a ground station before a command can be transmitted. This system saves time in locking the spacecraft command receivers; and where the travel time of a signal to the spacecraft is 20 minutes, this is valuable time saved.

The DSN has available a very high power transmitter for commanding the spacecraft. This 100-kw transmitter is available throughout the network in addition to the standard 20-kw transmitters. It may be required to provide an emergency command capability should the Lander twist around during touchdown or come to rest on a sloping surface in such a manner that its high-gain antenna is prevented from pointing toward Earth. The antenna is commanded in advance to point toward Earth in a normal landed attitude. But if it does not do this the high power transmitter may be needed to get first commands into the Lander and redirect the high gain antenna. There is no way to command the Lander through the Orbiter; it must be commanded from Earth.

The range of signals that the antenna has to pass through its feed horn is fantastic. The transmitter can handle 100 kw, which is 10^5 watts. The receiver signal coming into the same feed horn may be as low as -150 dBm, which is 10^{-21} watts.

The ratio between these two signals is 10^{23}, which is about the same as the relative sizes of a period in this text and the Milky Way galaxy.

This dynamic range of power is precisely controlled within the antennas and their recievers and transmitters and through 24-hours a day, 7 days a week in three countries of the world. The accent is on reliability of the equipment to function continuously when needed, maintainability so that it can be quickly repaired if a component should fail, and operability so that it is easy to operate through simple well-defined procedures.

Not only does the DSN provide facilities to command the spacecraft and receive data from them but also it provides tracking data for the navigation of the spacecraft in the form of Doppler and ranging data. New accuracies in tracking data needed to precisely navigate the spacecraft into their special orbits around Mars and to guide the Landers to specific points on the surface of the planet required all worldwide stations of the DSN to have exactly the same time. Their clocks are synchronized to within 20 microseconds to a master clock at Goldstone by bouncing time-synchronizing signals from the Moon to the stations in Spain and Australia.

At JPL there is a DSN operations control center which has three main functions. From this center operators talk to all the stations around the world and issue instructions for network operations. The center also monitors and evaluates the real-time data streams that are passed from it to the mission support areas. It is here, too, that a complete data record is generated of all the data received on Earth. This is delivered to the project as a magnetic tape after each pass to ensure that no data is lost. The real-time data stream might drop out some important data because of communications problems. The gap time is recorded, and after each pass computers automatically recall from the station's magnetic tape the missing data and fill in the gap. This is possible because for the first time DSN has provided, as a permanent part of its configuration, the important function of recording permanently all the telemetry data as it is received at the DSN station as close as possible to the antenna. So if data is lost by communications problems between the antenna site and JPL, it can later be provided to the experimenters or spacecraft engineers.

DATA HANDLING

The Viking Mission Control and Computer Center (VMCCC) contains large complex computer systems. These computers provide the means by which Viking data is collected, processed and made available for analysis by members of the Viking flight team. The various types of Viking data are transmitted to the VMCCC from the tracking stations of the DSN located throughout the world. Also, commands prepared by the VFT through the use of these computers may be transmitted to the tracking station for subsequent transmission to the Viking vehicles.

The computers of the VMCCC include several different types, assigned to perform data processing functions consistent with their particular capabilities. IBM 360/75 computers are used to receive VL telemetry data, all tracking data and transmit all commands in real time. These computers are also used for non-real time data processing functions relating to VL data analysis, Orbiter and Lander command generation, and Lander spacecraft performance analysis. There are three IBM 360/75 computers, one for non-real time processing, one for real time processing and a third for backup. UNIVAC 1530/1219 computer pairs are applied to collecting and processing all VO telemetry data in real time. There are three of these UNIVAC 1530/1219 pairs, one for each of two Orbiters, and the third for backup. Two UNIVAC 1108 computers are used to perform many non-real time data processing functions. These functions include the very complex navigation work, VO spacecraft performance analysis, VO and VL science data analysis.

Viking Orbiter telemetry data is directed to the UNIVAC 1530/1219 computers where synchronization of the telemetry stream is first established by the computer. By so doing, the computer is then able to identify sequences of "frames" of data. Once identified then the computer can identify the data contained within each frame through a process called decommutation. Data decommutated may then be displayed, printed, recorded or generally made available to analysts for interpretation. This VO telemetry data is transmitted from the Orbiters at any one of several rates, ranging from as low a rate as 8 1/3 bits/sec to 16,000 bits/sec. The UNIVAC 1530/1219 computer is capable of handling any of these rates.

Similarly, Viking Lander telemetry data is directed to the IBM 360/75 computer for real time processing. As in the Orbiter case, the VL data is synchronized to identify frames, and then decommutated to identify data. The VL is capable of producing frames of various sizes, most of the sizes determined by the types of data contained within. Also, as in the Orbiter, transmission rates of VL telemetry data may range from 8 1/3 bits/sec up to 1,000 bits/sec. In addition, since the VL is able to transmit data to the Orbiter circling above, which in turn can relay the Lander data at various rates up to 16,000 bits/sec, the IBM 360/75 must be capable of handling any of the various rates, those arriving directly and those relayed via the Orbiter.

Commands to either the Orbiters or Landers have their beginning in mission planning work, usually performed weeks in advance of the eventual use. As the planning becomes more firm and more precise, the sequences to be carried out by each vehicle become more clear. Eventually, these sequences become a series of commands. These commands, once transmitted to the spacecraft -- some for Orbiter, some for Lander -- will cause them to perform the prescribed functions. The entire process, from command preparation to transmission of commands to the tracking station, is performed on computers.

Early planning is done on the UNIVAC 1108 computers, testing and verifying commands is done on the non-real time IBM 360/75, and transmission of the commands to the tracking station is performed by the real time IBM 360/75. Testing of commands may be done in one of several ways. Computer programs which simulate the spacecraft (VO and VL) are capable of analyzing the effect of the proposed commands. Also, test vehicles (a real Orbiter and a real Lander) may be employed to test the proposed command sequences prior to their transmission to the spacecraft.

Tracking data is that data gathered by the tracking stations of the DSN as they track the Viking spacecraft. This data may be in any of several forms. Whichever form, it is sent to the IBM 360/75 computers of the VMCCC for processing. This processing includes identifying its type, time tagging, ordering and recording it on magnetic tape preparatory to further analysis. This data becomes the basis for navigation -- the process of determining the position and path of the vehicle as a function of time. The computer programs employed for the navigation functions largely operate on the UNIVAC 1108 computers and represent a very high technology capability for precise measurement of position and velocity of the spacecraft.

Imaging data constructed by the Orbiter cameras is transmitted by the Orbiter and is included in the stream of telemetry data. As mentioned earlier, this Orbiter telemetry data is directed to the UNIVAC 1530/1219 computers. Once it is identified as imaging data, it is separated from the rest of the data and recorded on magnetic tape. This tape is then mounted on another computer system for reconstruction of the pictures taken by the Orbiter cameras. The computer is a UNIVAC 1616. It is programmed and configured to process the data, prepare raw images, to enhance by adjusting contrast and other processes. It is then able to display the images on TV monitors and to expose film from which carefully controlled hard copy prints can be made. These are used by the imaging scientists for their analyses of the visual product of the Viking project.

Similarly, VL imaging data, generated by the Lander camera system, is incorporated in the VL telemetry stream, identified as such by the IBM 360/75 computer assigned to handle VL telemetry and prepared for processing. A computer program written for operation in the IBM 360/75 immediately begins the reconstruction process and produces raw or enhanced images of pictures of the surface of Mars taken by the VL cameras. These images can be displayed on TV monitors, or can be recorded on film for very precise analysis by imaging scientists.

As in the case of imaging data, data from all the experiments aboard the Orbiters and Landers can be processed, analyzed and displayed by those same computer systems. The data is thus put into a condition that makes it possible for scientists to examine and analyze the information collected during the conduct of this giant experiment, the Viking project.

Commanding and Controlling the Spacecraft

Viking is an adaptive mission; the essential feature for any good program of exploration. As information is obtained about the surface of Mars, operations and experiments can be adjusted to take advantage of the new knowledge.

Because of the complex nature of the Viking program, a decision suddenly made on Earth to do something on Mars cannot be implemented immediately. Irrespective of the nearly 20 minutes delay time for a command to reach Mars, the pre-programmed command sequence stored in each spacecraft must be carefully evaluated before changes can be made, since a change early in the sequence will probably affect the rest of the sequence.

Fourteen to 15 days ahead of any action required on Mars the process of planning must begin. Tradeoffs are discussed between science and engineering needs. Options have to be looked at, and relationships to firmly establish mission policies have to be recognized. The goal is always to get the most possible science information out of the mission.

The command generation process runs in cycles. A new cycle is started every six days, so that there are two full cycles during each shift. Depending upon what experiment needs to be changed, the action has to be taken at different times in these cycles. For example, an experimenter who wishes to change the location of an image while retaining the same image size can do it two days ahead of time (in 18 hours for an emergency). However, if experimenters wish to take more pictures than preprogrammed on a particular day, they must change the data distribution. This needs nine days. To start a new biology sequence where one is not already planned would require the full 15 days for the change.

The Lander computer has two nonconnected sections like separate hemispheres of a brain. Each has 18,000 words of memory. The two hemispheres of the Lander brain are redundant. If one should fail the other takes over. However, since there is no common memory, the hemisphere taking over must receive its memory from Earth.

When command sequences have been decided upon by science analysis and mission planning, the next step is to start the process of developing them into firm commands for the spacecraft. This takes place in the Spacecraft Performance and Flight Path Analysis Directorate (SPFPAD) where there are two major groups, Orbiter Performance Analysis (OPAG) and Lander Performance Analysis (LPAG). Each group has a two-team concept dealing with systems analysis to determine what the spacecraft is doing, and a command and sequencing team to generate a set of commands to instruct the spacecraft further. These two teams have the acronyms OSAT and OCAST respectively for the Orbiter, and LSAT and LCAST respectively for the Lander.

In assessing what the Orbiter is doing, OSAT looks in non-real time at the previous 24 hours of data returned by telemetry to make sure that the Orbiter performed as it had been commanded. The team looks for developing trends, such as a gradual rise in a temperature that might lead to a failure, and monitors the performance of science instruments from an engineering standpoint.

At critical periods such as final AMC, MOI and orbit plane change, the data from the Orbiter is analyzed in real time so that corrective action can be taken immediately if needed (with, of course, the 20 minutes transmission delay for the command to reach the distance of Mars).

Since the team is staffed for only one shift, the shift has to be moved around in Earth time to compensate for the slightly longer period of rotation of Mars compared with the Earth. This shift change is, in fact, a characteristic of the Viking mission and applies also to teams operating with the Lander and to scientists working with instruments on the Lander. A table of prime shifts and their Earth times is provided at the end of this handbook.

The OCAST group starts with a mission profile which is a set of events defining a set of science sequences originated from science analysis and mission planning (SAMP), and from this builds up a sequence of commands by use of four major software programs. The result is a magnetic tape containing these commands in a form suitable for transmission to the spacecraft. These commands are then checked by computer to match a simulated output with what was required to take place on the spacecraft. On board the Orbiter are two identical computers that can function independently or can check each other for critical maneuvers. Only when the computers agree is a command executed and both act to obtain a successful maneuver.

The organization of the groups to prepare commands for the Lander is similar and their operation very much the same as for commanding the Orbiter. But while the Orbiter telemetry data is returned 24 hours each day, the Lander telemetry comes back only twice each day; a direct link to Earth over S-band provides data for 55 minutes each day; data relayed from the Lander to the Orbiter by VHF is passed from the Orbiter to Earth at S-band. The link from Lander to Orbiter is open for about 17 minutes each day and passes data at 16 kilobits/sec. This is stored in the tape recorder of Orbiter and later relayed to Earth, typically at 4 kilobits/sec over a period of about 80 minutes each day. If the data is critical the Orbiter plays it back twice to two Earth stations.

The Lander to Earth data link is limited to 55 minutes only because temperature within the traveling wave tube amplifier of the Lander's transmitter gradually increases during operation. Fifty-five minutes is a conservative time to use the transmitter. Additionally there are power constraints and geometrical constraints on the transmission period.

A program takes the Lander data and builds files for the scientists, as explained earlier. The science data is delivered to SAMP several hours before each prime shift commences and a preliminary analysis prepares it for the scientists on their science meeting each day.

Prime Shift Schedule

The Martian day is longer than the Earth day which means that the Lander relay link data are received on Earth approximately one half hour later every day. Based on nominal landings and nominal direct links the following approximate shift schedule lists when major activities will take place each Earth day during the Viking mission.

Mission Days	Earth Dates	Earth Times
160-1941	June 8 - July 11	8:00 a.m.-4:30 p.m.
195-206	July 12 - July 23	4:00 p.m.-12:00 m
207-218	July 25 - August 5	12:00 m - 8:00 a.m.
219-236	August 6 - August 23	8:00 a.m.-4:30 p.m.
238-249	August 24 - September 4	4:00 p.m.-12:00 m
250-255	September 6 - September 11	12:00 m - 8:00 a.m.
256-273	September 12 - September 29	8:00 a.m.-4:30 p.m.
275-286	September 30 - October 11	4:00 p.m.-12:00 m
287-298	October 12 - October 24	12:00 m - 8:00 a.m.
299-EOM	October 25	8:00 a.m.-4:30 p.m.

June 17, 1976