Operation Red Planet

In mere days, four spacecraft and 750 people will begin the most elaborate interplanetary study ever attempted, highlighted by the first U.S. landing on Mars

BY JONATHAN EBERHART

On Oct. 10, 1960, with only eight prior launches for experience (compared with 56 for the United States), Soviet space engineers made the first attempt to send a spacecraft to the planet Mars. It did not get far enough even to orbit the earth. Four days later, a second probe met the same fate. Three more times they tried, and three times they failed, before the U.S. joined the quest in 1964 with Mariner 3. Trapped behind a stuck shroud, Mariner never even got to aim its instruments at its target; it now drifts mutely in a path around the sun.

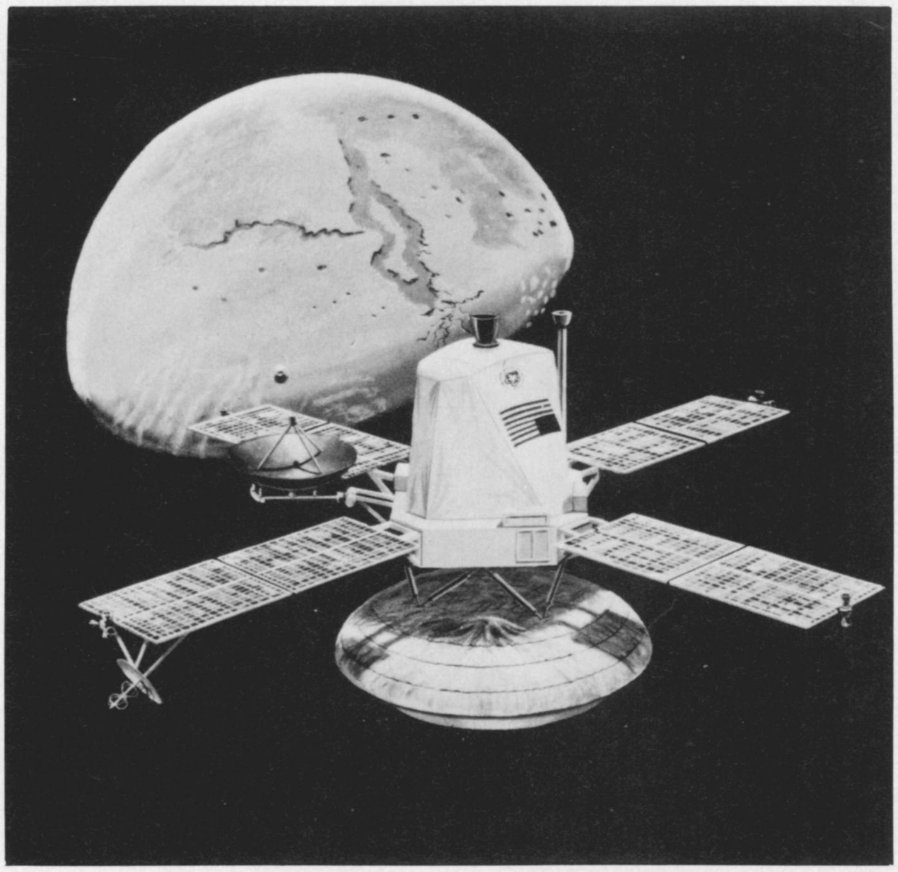
But Mars is like a magnet. Centuries of observation and speculation have earned it the laurels of the most tantalizing planet in the solar system. Mariner 4 finally completed the journey successfully in 1965, snapping photos as it flew within 9,800 kilometers of the Martian surface. Prior to last year, no fewer than 20 spacecraft had been aimed at the ruddy world, at least half of them costly failures. Four attempts at landing there (all of them Soviet) have resulted in one complete miss, one and possibly a second crash, and 20 seconds of data—enough to transmit less than half of a single television image. There have certainly been successes, crowned by nearly a year of orbital operations by Mariner 9 in 1971 and 1972, but the real Martian spectacular is just about to happen. If all goes well, it will dwarf the pioneering efforts of its predecessors, adding more to the knowledge of Mars than all the previous centuries of study. Its name is Viking.

More than 10,000 people have worked on the project—a whole town's worth of scientists, engineers and technicians—many of them since long before it even had a name. A billion dollars, a hundred major technological advances—the numbers are more like those of a moon landing than an unmanned visit to a distant speck in the sky. At Jet Propulsion Laboratory in Pasadena, from where the mission's four (*four!*) spacecraft will be controlled, the team in charge of day-to-day scientific and engineering decisions numbers 750 people, three times the complement of typical previous interplanetary programs. Viking, in fact, has more than a little in common with an Apollo lunar mission, in which one astronaut would orbit overhead in the command module, taking pictures and other data, while the other crewmen would descend to the surface aboard the lunar module to sample the soil and deploy a range of scientific instruments. Viking has no astronauts, but it will take the same dual vantage points.

Viking 1, the collective name for the first orbiter and the first lander, left Cape Canaveral last Aug. 20, bound on a 304-day journey that will put it into an orbit around Mars on Saturday, June 19. The first priority for the next 10 days will be to help pass judgment on a patch of Martian surface beneath it, located at 19.5°N, 34°W in a region known as Chryse (rhymes with "icy"). It is the leading candidate for the site of the most important single event in the entire Viking program: the landing of the first U.S. spacecraft on Mars.

Chosen years ago from the photos and data provided by Mariner 9, the site lies near the northeastern end of an awesome canyon network, long enough to span the United States, known as Valles Marineris. The canyons bear all the visual signs of being the dry beds of former rivers of flowing *something* (what if not water?), and Viking scientists hope that the deposits near their delta will reveal a variety of surface materials. But the site also had to be safe enough—no cliffs to fall from, no boulders to be upended by, no deep dust layers to sink into—among other qualifications (SN: 8/2/75, p. 76). Dramatic as the Mariner 9 photos are, their limited resolution is no guarantee that features perhaps as large as 100 meters will not be present at the precise landing spot. Unlike the lunar module with human pilots, once the Viking lander starts its descent, its path—and target—are immutable.

So a backup site was chosen, at Tritonis Lacus (20°N, 252°W), and just in case the lander *should* fail, the second lander, due a month later, will be diverted from its own prime and backup sites to a third, "super safe" site (4.25°S, 43.75°W) in the Martian highlands. The first 10 days in orbit will be largely devoted to making sure that the prime site is suitable—or, if it's not, more time may be needed to check out the others. Cameras aboard the orbiter, equipped with red, green, violet,



clear, blue and "minus-blue" filters, will photograph the terrain in a variety of ways including stereoscopically.

A heat sensor called the Infrared Thermal Mapper (IRTM) will also be a key helper, since it may be able to reveal the characteristic size of the chunks in the landing site terrain, even though they are likely to be much smaller than the cameras can see: big boulders, fist-sized rocks or sand. "By taking the temperature of the surface at several points during the day and night, and particularly just before dawn," says the University of California's Hugh H. Kieffer, head of the IRTM team, "we can determine how well the surface material of the landing site holds heat. The smaller the particle size, the more rapidly it dissipates heat absorbed during the day." The IRTM will also take conventional temperature measurements and, combined with the cameras and the orbiter's other scientific instrument, a water-vapor sensor called the Mars Atmospheric Water Detector (MAWD), it will help to provide what amounts to weather reports for the landing site. This includes keeping an eye out for dust storms like the huge one that was blanketing the planet when Mariner 9 got there in 1971. Such storms are believed to be unlikely when Mars is far from the sun (with less solar influx producing smaller temperature differentials and less atmospheric turbulence), as it will be during Viking's visit (Mariner 9 arrived near perihelion), but the dust-watch will continue throughout the mission.

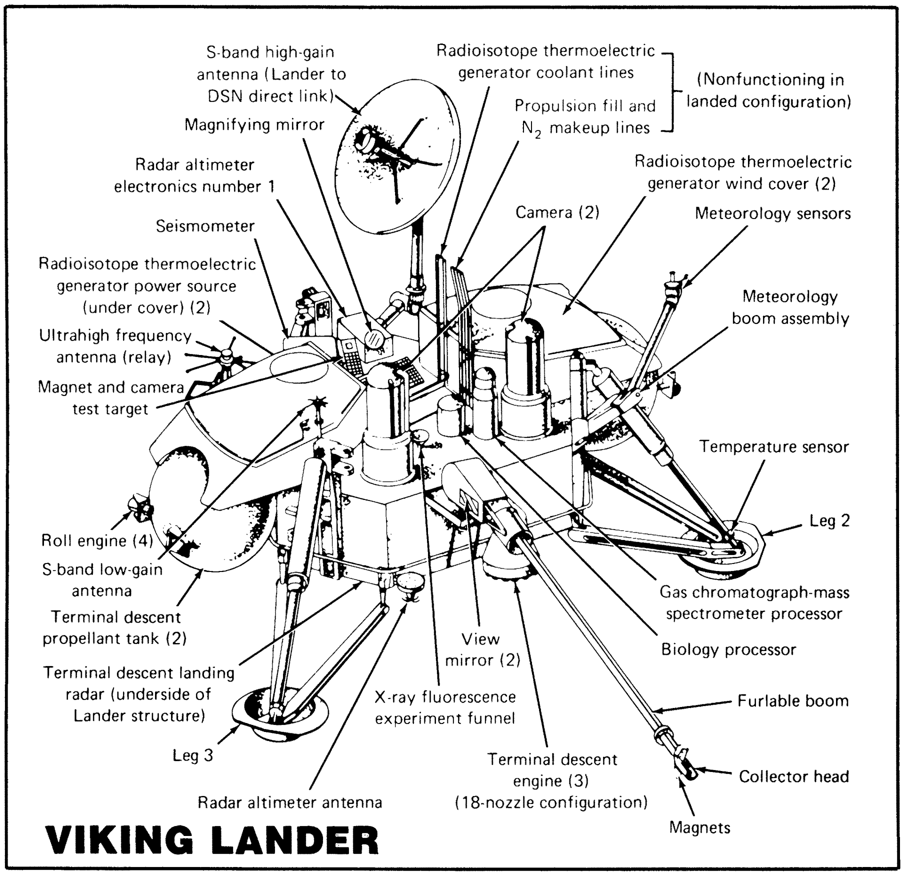
Ten days is the limit for verifying the conditions at the site if Viking officials are to make their final site selection by June 29 for a landing on the Fourth of July. It's just Bicentennialism, but the idea of commemorating the 200th anniversary of independence in the New World by landing on a new world was too much for NASA to pass up, since the mission timing, determined by planetary positions, was close anyway. "I haven't seen a Fourth-of-July-or-else memo," says one Viking official, "but the pressure is there, and it's strong." Getting down safely is the first priority, however, particularly in view of the Soviet mishaps, and the delay could be longer. The orbiter can coast along with the lander still attached for months if need be.

Under the present schedule, the last photos of the site before the landing will be taken on July 1. On July 2, flight controllers will complete the task of loading the lander's computers with the trajectory for the automated descent. (The 36-minute round-trip radio time to earth precludes flying the craft down "by hand.") With one day to go, the lander will receive its final checkout. The last chance to call the whole thing off—the absolute, final "go-no-go" decision—will come 63 minutes before the scheduled separation. The lander is scheduled to be separated from the orbiter at 3:38 p.m. PDT, and seven minutes later its engines will fire to begin a gradual descent lasting more than three hours through the outermost fringes of the Martian atmosphere. Touchdown should be at 6:58 p.m. PDT.

Viking's science-packed itinerary does not confine itself to measurements from orbit and the surface. During the descent, three instruments used at no other time will be "profiling" the atmosphere, providing the only directly measured, top-to-bottom data to link the readings from the orbiter and lander. Like the separation and landing activities, the studies during the descent will be controlled automatically by a device on the lander's computer called a sequencer, which meters out stored instructions without any intervention from earth. (The sequencer, in fact, will be packed with enough instructions to run the lander's surface studies, unattended, for two full months, just in case some malfunction should block communications from earth. Barring difficulties, the sequencer will be periodically reprogrammed once the lander is safely on the ground.)

The first of the descent instruments to go on, about 40 minutes after separation, will be an ionospheric probe called a retarding potential analyzer, designed to measure charged particles in the upper atmosphere. Because Mars has a much weaker magnetic field than the earth, it is likely that charged particles from the solar wind are able to get closer to the surface. The analyzer will report on the interaction between the atmosphere and the solar wind, as well as on photochemical processes and other phenomena that could affect the atmosphere closer to the surface. The neutral, or noncharged, components of the atmosphere are rare at the highest altitudes, so the mass spectrometer that will measure them will not go on until 2 hours 20 minutes after separation, about 300 kilometers above the surface. It will sweep through a range of atomic masses from 1 to 50 every five seconds, reporting on the bulk composition including such elements as nitrogen, undetectable from earth but believed critical to life processes. It will provide detailed measurements of the amount of carbon dioxide, primary constituent of the Martian atmosphere and related to the all-important issue of water, since water would be expected to have trapped much of the CO_2 being outgassed from Mars in the form of carbonate rocks.

A particularly important task for the device will be to measure the amount of argon in the atmosphere. When the Soviet Mars 6 spacecraft reached the Martian surface in 1974, it stopped working after less than one second. In its brief radio bleep, however, it indicated that its mass spectrometer was having trouble pumping itself empty, suggesting that a noble gas such as argon, which would have been nearly immune to the pumping process, was present in large amounts. Soviet scientists have calculated from the limited datum that there may be as much as 35 percent argon in the atmosphere. Since argon is a decay product of potassium,



VIKING LANDER

produced at a fixed rate, a large amount of it could mean that the decay process has been going on for a long time, and, by inference, that the rarefied Martian atmosphere may once have been much more dense than it is today. Besides its implications for the early climate of the planet, a large argon content would have serious implications for the Viking mission. The lander's Gas Chromatograph/Mass Spectrometer (GCMS), to be used on the surface, is presently scheduled to study a sample of the atmosphere on its third day on the ground. A lot of argon, however, would "clog" the GCMS pump just as it did the Soviet instrument, making the device useless for later soil analyses. Thus if Viking's descent-phase instrument reports a high percentage of argon, mission scientists plan to delay the surface-based atmospheric study until after the soil analysis—an unhappy alternative, since it will make precise measurements of certain gases difficult to run afterward.

With about 100 kilometers to go, a little more than six minutes before touchdown, the upper-atmospheric instruments will shut off. The remaining measurements will only be temperature, pressure and density profiles, but their value is substantial. Because the Martian atmosphere is so thin, it changes temperature rapidly, thus bringing about the large temperature contrasts that play a major role in driving the high Martian winds. The profile data, both from direct measurements and from analyses of the behavior of the lander as it descends, should reveal inversions and other thermal structures that reflect the amount of incoming solar energy and the ways in which it is transported; in other words, a measurement of the energy balance.

About 5.8 kilometers up, the lander's parachute will be deployed. Then the craft's protective shell will be jettisoned, and a moment later the three braking rockets will ignite, each diffused through 18 separate nozzles so as to have a minimal effect on the soil beneath the spacecraft. With 3 meters to go, the descent engines will cut off, leaving the craft to take up the remaining landing shock in its three shock-absorbing legs. Mars at last!

The first sign in the JPL control room of a successful landing will be a signal, relayed from the lander through the orbiter to earth, indicating that contact has been made with a switch on one of the lander's feet. The very first task, unlike past lunar landings both manned and unmanned, will be to take a picture, beginning only 25 seconds after touchdown before even any systems checks or other preliminaries. If the lander is going to break down, blow up or do anything else that is not on the schedule, Viking officials want at least one close-up of the Martian surface that they have worked so hard to reach. Before even looking up at its surroundings, one of the two cameras, still controlled by the sequencer, will take one quick shot of its own foot and the soil around it, a first look that could reveal a lot about grain sizes, erosion and other surface conditions—priceless if it is also the last. Only then, about six minutes later, will a camera venture to look up for a panoramic scan of the terrain, giving the Viking team the first visual sign of where the lander lies (since it's too small for the orbiter to notice).

The cameras themselves would be considered remarkable even if they were not controlled by computer. They can provide pictures in black and white, color and infrared, any of them in stereo if desired. They can take sweeping, 342° panoramic

VIKING MISSION CHRONOLOGY

Date	Time (PDT)*	Event
Aug. 20, 1975		Viking 1 (V-1) launched
Sept. 9, 1975		Viking 2 (V-2) launched
Apr. 12, 1976		V-1 first photo of Mars, 9.5 million miles from planet
June 14		V-1 first pre-orbit scan by atmospheric water detector
18		V-1 first pre-orbit scan by infrared thermal mapper
19	9:36 a.m.	V-1 reaches orbit around Mars
20		V-1 orbital operations begin: first landing site photos, color photo tests, water detector, infrared mapper
21		V-1 study of atmosphere over prime landing site
22		V-1 first of many photo sequences of 10° latitude and 83° longitude to study diurnal variations
23		V-1 first stereo photo-mapping of prime landing site
24		V-1 engine firing to attain synchronous orbit over site
29		V-1 landing site selection
July 1		V-1 commit to landing site
2		Calculate V-1 lander (VL-1) descent trajectory
3		Preseparation checkout of VL-1
4	3:38 p.m.	Separation of V-1 lander and orbiter (VO-1)
	6:50 p.m.	VL-1 entry begins at about 155-mile altitude
	6:56 p.m.	VL-1 parachute deploys about 3.65 miles above mean surface
	6:58 p.m.	VL-1 landing on Mars
	6:59 p.m.	First VL-1 photo, B&W, showing footpad and soil
	7:05 p.m.	First VL-1 panoramic photo, B&W, showing horizon
	7:18 p.m.	Picture transmission to earth begins
	7:45 p.m.	VL-1 first photo complete on monitors
	8:11 p.m.	VL-1 meteorology operations begin
	8:17 p.m.	VL-1 second photo complete on monitors
5		Mars Day 1 ("Sol 1"): 24 hrs. 36 min., 1 Martian day
	2:50 a.m.	VL-1 seismometer operations begin
	3:26 a.m.	VL-1 meteorology operations begin
	3:29 p.m.	VL-1 first color photo, recorded on lander
	7:15 p.m.	VL-1 begins data relay to VO-1 (daily procedure)
	7:56 p.m.	VO-1 begins playback to earth (daily procedure)
6		Argon decision (see story)
7	5:47 a.m.	VL-1 biology gas-exchange checkout (empty) analysis
	4:03 p.m.	VL-1 GCMS atmosphere analysis begins (if argon ok)
9		VL-1 soil-sampling site decision
12		First VL-1 soil samples collected for biology, GCMS and X-ray fluorescence spectrometer; experiments begin
13		VL-1 GCMS analysis at 200°C
19		VL-1 GCMS analysis at 500°C
24		First VL-1 biology cycle ends
27		Viking 2 final course correction; last chance to change latitude of VL-2 landing site
Aug. 1		Approximate start of VL-1 second biology cycle
7		V-2 reaches orbit around Mars
8		VL-2 site certification begins
20		Approximate start of VL-1 third biology cycle
Sept. 2		Start "reduced mission" for VL-1
4		VL-2 lands on Mars; first VL-2 photos
7		VO-1 begins "Global Science Walk"
13		First VL-2 soil samples collected; experiments begin
21		VO-1 becomes available as relay station for VL-2
26		First VL-2 biology cycle ends
28		VO-2 orbital plane change to allow polar observations
Nov. 8		Solar conjunction begins

*Times include 18-minute Mars-to-earth transmission time.
Later dates and times may change.

shots and look up and down over a 46° range. They have withstood 268 hours of 254°F temperatures during sterilization, as well as 11 months of the hard vacuum of space. They are designed to operate in temperatures ranging from —200° to 125°F, steady winds as high as 150 kilometers per hour and dust-laden gusts of up to 300 kilometers per hour. Besides looking at the rocks and soil of the planet, they will scan the sky for clouds, storms and other meteorological phenomena. Yet it is not the cameras that have been garnering the publicity.

MARS MISSIONS: A HISTORY

Launch	Origin	Name	Encounter	Results
10/10/60	USSR			Failed to reach earth orbit
10/14/60	USSR			Failed to reach earth orbit
10/24/62	USSR			Failed to leave earth orbit
11/ 1/62	USSR	Mars 1	6/19/63	Communications failure; passed Mars @ 193,000 km
11/ 4/62	USSR			Failed to leave earth orbit
11/ 5/64	US	Mariner 3		In solar orbit; shroud failure precluded flyby
11/28/64	US	Mariner 4	7/15/65	Passed Mars @ 9,800 km
11/30/64	USSR	Zond 2	8/ 6/65	Communications failure; passed Mars @ 1,500 km
7/18/65	USSR	Zond 3		Believed late launch; passed far from Mars
2/24/69	US	Mariner 6	7/31/69	Passed Mars @ 3,400 km
3/27/69	US	Mariner 7	8/ 5/69	Passed Mars @ 3,400 km
5/ 8/71	US	Mariner 8		Launch vehicle failure
5/10/71	USSR	Kosmos 419		Failed to leave earth orbit
5/19/71	USSR	Mars 2	11/27/71*	Reached orbit around Mars; lander crashed
5/28/71	USSR	Mars 3	12/ 2/71*	Reached orbit around Mars; lander lasted 20 sec.
5/30/71	US	Mariner 9	11/13/71	Reached orbit around Mars; operated until 10/27/72
7/21/73	USSR	Mars 4	2/10/74	Failed to enter orbit around Mars; flew by @ 2,200 km
7/26/73	USSR	Mars 5	2/12/74	Reached orbit around Mars
8/ 6/73	USSR	Mars 6	3/12/74*	Reached orbit around Mars; lander descent data only
8/ 9/73	USSR	Mars 7	3/ 9/74	Flyby released lander, which missed Mars by 1,380 km

*landing date

It is the search for life. The Viking landers are the first spacecraft ever sent to another world with equipment specifically designed to search for alien life forms. Packed into a box of less than a single cubic foot, each lander carries an array of three experiments, representing years of development and a $50 million investment (half the cost of the entire Mariner 10 Venus-Mercury mission), motivated by the hope that Mars may harbor some kind of microscopic life. On its eighth day on the surface, the lander will extend a telescoping, claw-like scoop, retrieve a sample of the Martian soil and deposit it in a hopper leading to a lazy-Susan device that meters it out to the three experiments. A carbon-assimilation experiment provides a carbon-14-labeled nutrient for any life forms that may exist by photosynthesis or chemotrophy. After five days, the test chamber is flushed to remove any excess carbon 14, then the soil sample is heated to see whether any gases released contain carbon 14 that was taken in by life forms in the soil. A second experiment looks for metabolic activity by "feeding" the soil with a similar labeled nutrient, then monitoring any gases given off for signs of the labeled component, rather like a drunkometer test for alcohol in the bloodstream. The third experiment uses no labeled tracers; it simply incubates its sample in a plain nutrient and periodically checks the atmosphere of the test chamber for signs of change. Like the other experiments, the gas-exchange device can be run up to four times with different samples. But, if results are promising, a given sample can be analyzed a second time as a control. There are only four chances, each one precious, points out Viking project scientist Gerald A. Soffen, and interpreting the results will be a tricky business requiring caution, concentration and consultation despite the pressure of the press, public and other scientists. But, says Soffen, if a control run is even attempted, it will be a sign that the scientists on the biology team are excited—with perhaps the greatest scientific discovery in history waiting in the wings. (See p. 374, and for a more detailed description of the experiments, see SN: 8/2/75, p. 77.)

Yet, says Soffen, "perhaps we've oversold the biology." How can he, a biologist himself, chief scientist of the most elaborate interplanetary venture ever undertaken, say such a thing about such a staggering possibility? The answer is that, for all its towering potential (against terrible odds), biology is just a small part of the Viking mission. Not even the staunchest advocates of the biology experiments would presume to justify a billion-dollar mission on that single longshot. There will be at least a dozen other scientific investigations going on, all of which stand to make major contributions to the body of knowledge of Mars.

Scarcely eight hours after the landing, for example, a week before the biology gadgets even get their dirt, a miniature weather station and a seismometer will get underway. Atmospheric surface pressure, temperature, and wind speed and direction measurements all relate to other Viking studies, such as that of how a planet with barely one percent of earth's atmospheric pressure manages to throw around enough dust to occasionally blanket the entire globe, or to radically change huge markings that have confounded astronomers for centuries. Certain photographic tasks, such as measuring the optical clarity of the atmosphere, can only be done under known weather conditions, and the seismometer would be useless on such a wind-blown world without a way to separate the effects of air and ground movements. Besides finding out if Mars is still tectonically active, which some scientists believe it is, the seismometer is expected to greatly improve theoretical models of the Martian interior, revealing among other things whether it has a crust-mantle-core structure similar to that of the earth.

One of the most complex of the lander instruments is the GCMS, a hundredth the size of the laboratory instrument it replaces but capable of remarkable discriminations among organic compounds. If, for example, the biology instrument fails to find life because Martians live by a chemistry unanticipated by the experiment designers, the GCMS can, in the words of team leader Klaus Biemann of MIT, "cover all the oddball compounds which might be present," at least indicating grounds for looking in a different way. (The only known malfunction on the Viking spacecraft so far is an apparent short circuit that would mean that each GCMS can conduct only two, rather than three, soil analyses.) The GCMS will also, of course, conduct its atmospheric study, though its place in the timeline will depend on the danger of argon "strangulation."

While the GCMS is studying the soil's fancier molecules, an X-ray fluorescence spectrometer will be doing the less spectacular but equally vital job of cataloguing, element by element, its composition. The data will tell a lot about the mineral-

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Cover Date Late?

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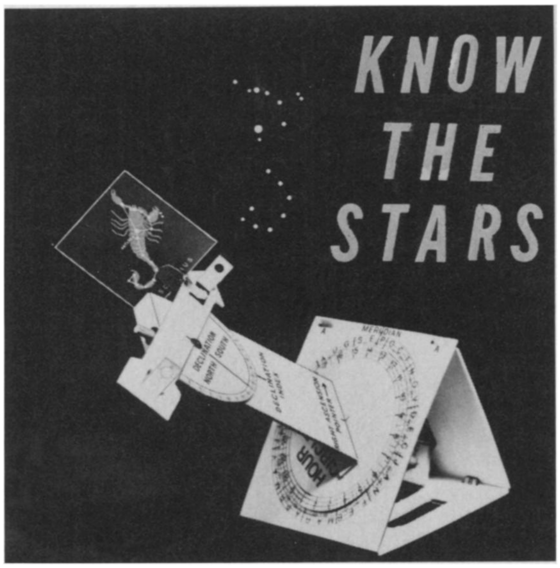

. . . Viking

ogy of the surface material—including such forms as hydrates that represent trapped water—and enable inferences about the climatic history that might have produced given types of weathering.

All the instruments—and scientists—will be working together. A magnet on the scoop will reveal traces of iron, but the cameras will have to be there to see it, while the spectrometer measures its different forms in the soil and other studies contribute to knowledge of why it is or isn't oxidized. And if there is one word that the scientists feel to be the key to the mission, it is "adaptive": Rather than follow preset timelines for weeks at a time, Viking has been planned so that new developments can be followed up in as little as three days. That may not sound like much, but it is the difference between having to trust everything to a robot and being able to step in and take advantage of developing experience. It's not the easy way—Viking rehearsals have often been frenetic, frustrating affairs—but no scientist in the program would have it otherwise.

On Aug. 7, the mission will suddenly get even trickier. On that day, Viking 2, launched 333 days earlier on Sept. 9, 1975, will reach its circum-Martian orbit. It is scheduled to spend two weeks longer than its predecessor surveying its landing site, because instead of going by Safety First (assuming the first lander is alive and well), lander 2 will be sent on a priority search for signs of water at a site (44.3°N, 10°W) in an area called Cydonia near the southern fringe of the Martian north polar hood. It is also a very low-altitude site, since the mean atmospheric surface pressure of about 5.5 millibars is too low for liquid water to exist on Mars. The pressure at Cydonia is about 7.8 millibars, though no one expects the lander to touch down in a lake. A greater likelihood is that, if there is water at all, it will be beneath the surface in a layer of permafrost, but the possibility of detecting some sign of its presence is tempting.

Early in September, now with two orbiters and two landers to contend with, Viking officials plan to put lander 1 on a less-busy schedule, just before lander 2 touches down. Orbiter 1 will then be sent off on a two-week "Global Science Walk," its orbit adjusted so that, instead of being fixed over its lander, it will see the entire planet drift beneath it. When that is over, orbiter 1 will become the relay for lander 2, while orbiter 2 gets its orbit shifted to carry it near the poles to observe the polar caps and look for water. Mission officials hope that all this will be out of the way well before the early-November beginning of solar conjunction, when Mars and earth are on opposite sides of the sun, thus blocking communications. But after conjunction, it's back to work, with planners envisioning a total mission lasting as long as two years. ☐