Return to Mars — Economy Class

Five years after the first successful Mars landing, planners of follow-up missions are thinking small

BY JONATHAN EBERHART

July 20 marks the fifth anniversary of the first fully successful landing on Mars. On that date in 1976, when a spidery robot craft was detached from the Viking 1 orbiter and sent down toward the surface of the planet, Viking officials had more reasons for worry than just the uncertainties of the maiden U.S. attempt at such a feat. Over the preceding half-decade, at least five Soviet tries had failed.

The initial Soviet effort, in 1971, never got out of earth-orbit. All the rest had their troubles at Mars, where the Viking 1 lander was now heading for a spot chosen on the basis of inadequate photos and imperfectly understood radar data. The first of the Russian landers to reach Mars had simply crashed. The second mysteriously stopped transmitting after sending only 20 seconds of data from the surface. The third try shut off before even reaching the ground, and the fourth missed the planet completely.

The Viking 1 orbiter not only reached the surface in good working order — it is *still* working, after 20 times its official "design lifetime," and it is programed to keep doing so through the end of 1994. Its messages to earth come about once a week (actually five times every 37 Martian days), each lasting an hour and including one photograph and some atmospheric temperature and pressure readings.

The picture schedule has been selected to match the seasons and lighting angles of past lander images, in hopes that identical photographic conditions will reveal any subtle changes in the terrain and the dust-laden atmosphere between one 687-day Martian year and the next. Mars is a much simpler, more predictable meteorological laboratory than the earth, largely because of its lack of oceans, but that does not mean that successive annual weather patterns are identical. The lander has now been through nearly three Martian years, the first of which saw two major, global dust storms, the second only a hint of one and the third none at all. Thus the photos and other data offer hope of finding out what kinds of long-term cycles are present in the planet's weather. (Also extracted from the lander's radio signals are Doppler and ranging measurements, which by now span enough time that scientists can identify slight, seasonal variations in Mars's rotation rate, believed by some researchers to reflect mass redistributions caused by seasonal changes in the extent of the polar caps.)

Yet the lander's present studies, conducted automatically by its computer (there is virtually no Viking team left at the control center in Pasadena's Jet Propulsion Laboratory), are only a fraction of what went on during the mission's first year, when biology, mass-spectroscopy and other investigations required overtime efforts from hundreds of scientists and engineers. The four-spacecraft Viking project (including a second lander and two orbiters, all now out of service) revealed far more about the planet in a few months than all the previous centuries of Mars-watching. Shelves full of scientific books and papers have been published, and a fourth international symposium about Mars will begin in late August at Caltech, all driven by the impetus of Viking.

Major questions, however, remain. Extremely limited seismic data have left the planet's interior largely a mystery. The orbiters, though equipped with water detectors and thermal-mapping devices, provided so little atmospheric data that researchers are still trying to unearth new findings from data provided by an ultraviolet spectrometer aboard the Mariner 9 spacecraft a decade ago. Before the Viking armada even got to Mars, in fact, its scientists were already thinking of newer, more elaborate missions for the future — landers with wheels (or treads) that could carry them "over the next hill," automated geochemistry laboratories to which such roving landers could deliver samples for analysis, two-way missions that would return Mars samples to earth, and more.

But don't hold your breath.

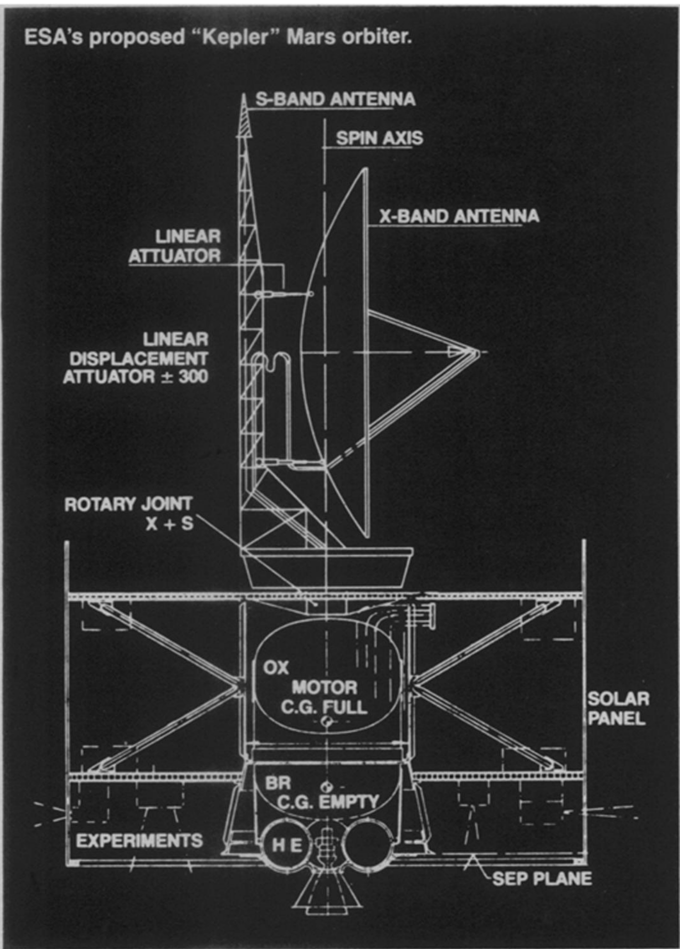
Each year following Viking's success, scientists looked in vain at the National Aeronautics and Space Administration's budget for signs that a next step was being taken. Since lander 1's momentous arrival on Mars, only a single U.S. mission to *any* planet has been initiated — the Galileo orbiter and probe of Jupiter (the Voyager and Pioneer-Venus projects were already underway by 1976) — and it is now imperiled anew by rising costs and upper-stage-rocket problems facing the space shuttle. As for other major missions envisioned in recent years, such as the Venus-Orbiting Imaging Radar and a Saturn orbiter that would send probes into the atmospheres of both the planet and its satellite Titan....

At least for now, says Harold Masursky of the U.S. Geological Survey, "all the big ones are dead and gone." Masursky is now a member of the Solar System Exploration Committee, a panel formed last year by NASA to help the agency get a grip on its interplanetary future — a future that already looks more constrained than even most of the committee's members would have anticipated three or four years ago. "What we're trying to do," Masursky says, "is take a new look at how you might do things in a more cost-effective way."

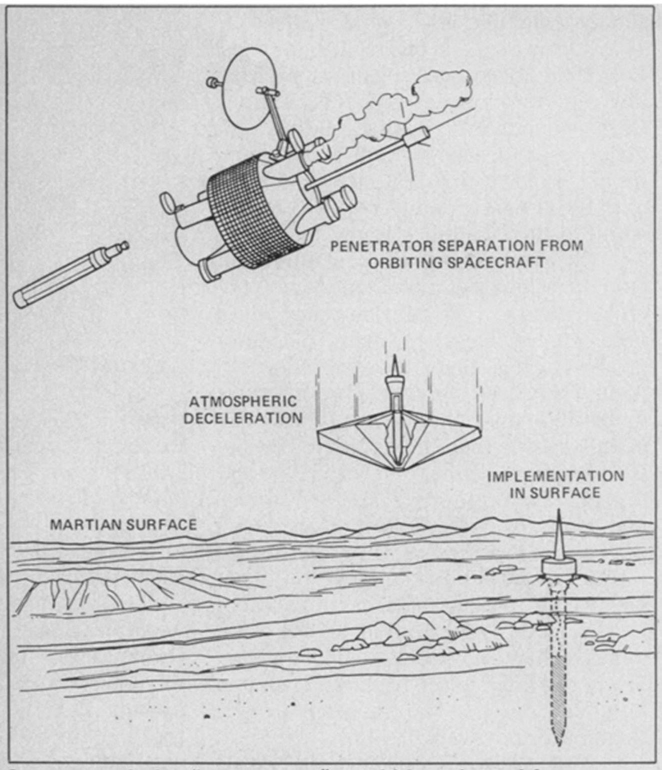
But there's more to the change than just thinking cheap. The philosophy of large-scale planetary missions has been part of NASA and (its scientific constituency) for many years, in large part because planners could never be sure that a mission with

MARSBOUND: A HISTORY

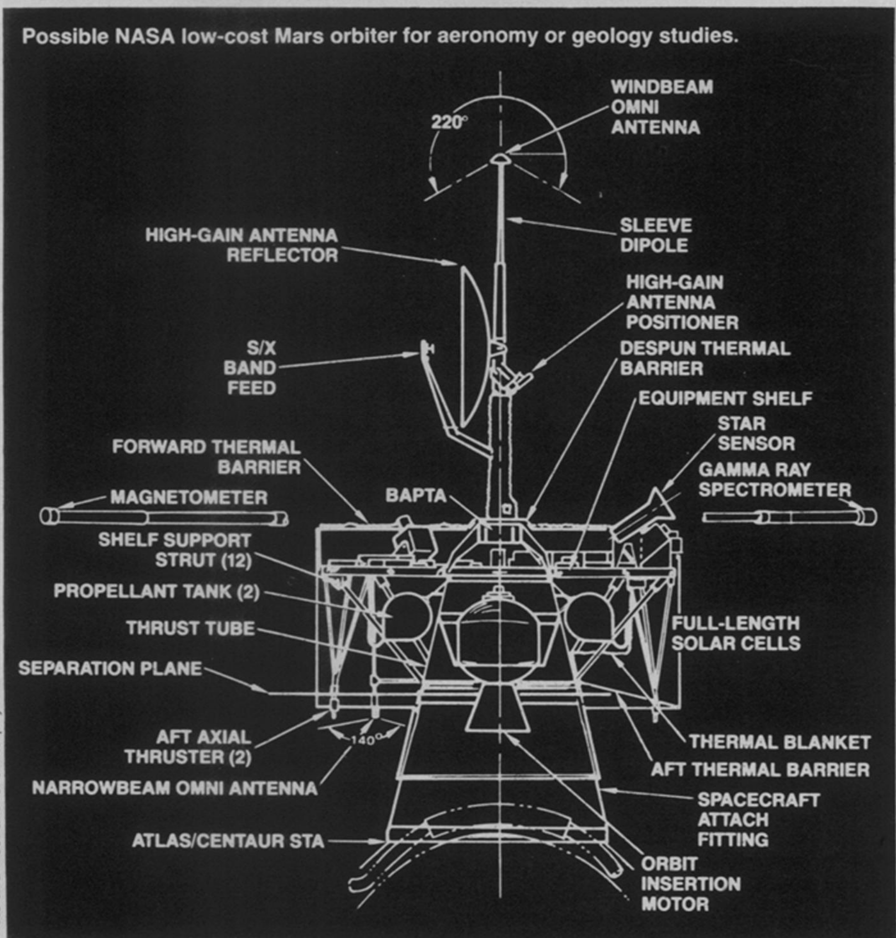
LAUNCH DATE	ORIGIN	SPACECRAFT	MISSION	ENCOUNTER: DATE OR FATE
Oct. 10, 1960	USSR	unannounced	flyby	failed to reach earth orbit
Oct. 14, 1960	USSR	unannounced	flyby	failed to reach earth orbit
Oct. 24, 1962	USSR	unannounced	possible flyby	failed to leave earth orbit
Nov. 1, 1962	USSR	Mars 1	flyby	communications failed
Nov. 4, 1962	USSR	unannounced	flyby	failed to leave earth orbit
Nov. 5, 1964	U.S.	Mariner 3	flyby	stuck shroud prevented flyby
Nov. 28, 1964	U.S.	Mariner 4	flyby	July 14, 1965, @ 9,920 km
Nov. 30, 1964	USSR	Zond 2	flyby	communications failed
Mar. 27, 1967	USSR	unannounced	possible flyby	failed to reach earth orbit
Feb. 24, 1969	U.S.	Mariner 6	flyby	Jul 1, 1969, @ 3,437 km
Mar. 27, 1969	U.S.	Mariner 7	flyby	Aug. 5, 1969, @ 3,551 km
May 8, 1971	U.S.	Mariner 8	flyby	failed to reach earth orbit
May 10, 1971	USSR	Cosmos 419	orbiter/lander	failed to leave earth orbit
May 19, 1971	USSR	Mars 2	orbiter/lander	Nov. 27, 1971; lander crashed
May 28, 1971	USSR	Mars 3	orbiter/lander	Dec. 2, 1971; lander transmitted 20 sec.
May 30, 1971	U.S.	Mariner 9	orbiter	Nov. 13, 1971
July 21, 1973	USSR	Mars 4	orbiter	Feb. 10, 1974; failed to enter Mars orbit
July 25, 1973	USSR	Mars 5	orbiter	Feb. 12, 1974
Aug. 5, 1973	USSR	Mars 6	flyby/lander	Mar. 12, 1974; lander descent data only
Aug. 9, 1973	USSR	Mars 7	flyby/lander	Mar. 9, 1974; lander missed planet
Aug. 20, 1975	U.S.	Viking 1	orbiter/lander	June 19/July 20, 1976
Sep. 9, 1975	U.S.	Viking 2	orbiter/lander	Aug. 7/Sep. 3, 1976



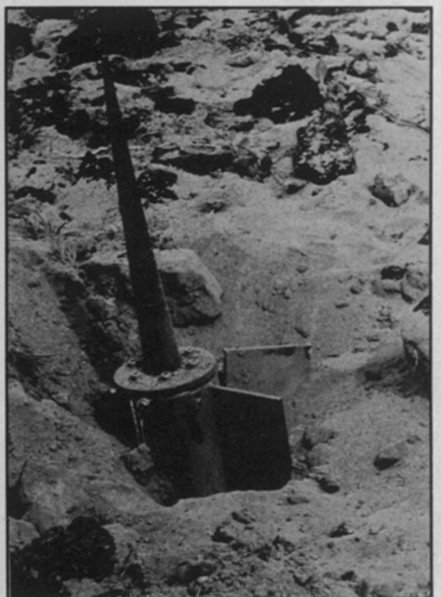
ESA's proposed "Kepler" Mars orbiter.



Instrument-laden "penetrators" would be released from an orbiting spacecraft (above) in a proposed low-cost mission to establish a network of Martian surface stations. A 1976 drop-test into a California lava field (below) contributed to findings that relatively high-impact landings can be survived by reasonably sophisticated instrument packages equipped to monitor seismic, meteorological and other phenomena (bottom).



Possible NASA low-cost Mars orbiter for aeronomy or geology studies.



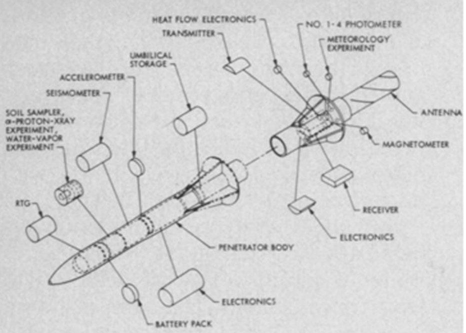


Photo and Illustrations: J. Murphy/NASA

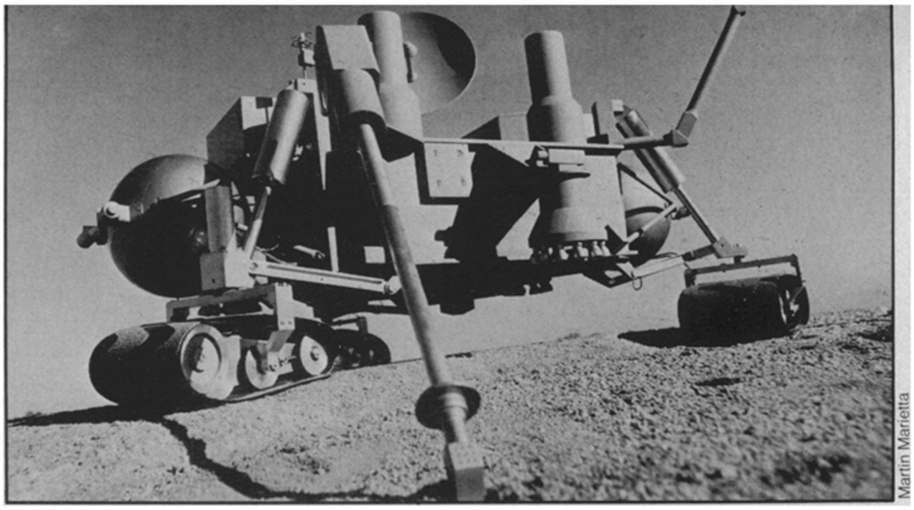
limited scientific goals would indeed be followed by a second one to fill in the gaps. Less than a year ago, engineers studying low-cost missions at one NASA center were saying that some space agency officials would prefer to "soft-pedal" such proposals for fear that larger-scale projects would be endangered. Now that worry is almost a moot point. The uncertainties about being able to follow up small missions (let alone large ones) are greater than ever — but there may be no other choice. "Economy-class" planetary missions are getting a new, hard look.

As a target for an expensive, full-scale exploration mission, a return to Mars has been somewhere in the distant future, behind Venus radar-mapping, probes of Saturn, multi-asteroid surveys, comet studies and more. Now the priorities are being re-evaluated, as researchers look to see where limited funds can make the most useful contributions. Mars has not miraculously moved to the front of the line — the line is a shambles — but no longer is it so firmly relegated to the back. As a result, a number of low-cost Mars missions are getting new or renewed attention.

One, says James Murphy of NASA's Ames Research Center, is a "Mars water mission," which would concentrate on the water and carbon dioxide that have had such major effects on the planet's evolution and appearance. Initiated by Charles Barth of the University of Colorado, the plan calls for a spin-stabilized spacecraft (less costly than Viking's three-axis, gas-jet system) that would carry as few as four scientific instruments and cost an estimated $75 million to $100 million. (The Viking project cost $1 billion). No one is lobbying to push the mission into the next NASA budget, says Murphy; instead, it is more of a "straw man," conceived to give the Solar System Exploration Committee a basis for analyzing a typically specific low-cost mission idea in depth.

Another example is an orbiting spacecraft that might not make any scientific observations of its own whatsoever but serve merely as a carrier for a cluster of spear-like "penetrators" that would be deployed to various points on the Martian surface. For all their sophistication, the Viking landers have sampled only two spots (only one with a working seismometer); penetrators could provide a network of seismic, meteorological, soil-study (via alpha-backscatter techniques) and other sensors at half a dozen or more locations for relatively low cost, relaying their data through the orbiter. Penetrators have been studied for several years at Ames and other institutions such as Sandia Laboratories, with tests indicating that a range of instruments could survive impacts with the surface of as much as 20,000 g's.

Also under study is an aeronomy-oriented orbiter based on the Pioneer Venus orbiter design, as well as one dedicated to geochemical studies. The latter might include a radar altimeter among its sensors, providing a low-cost answer to what Masursky calls "the biggest gap" in Mars studies—knowledge of surface elevations. Accurate elevation measurements could reveal, for example, the direction in which the ancient Martian channels might have flowed. But the uncertainties are far greater. Stereophotographic techniques can indicate heights and depths of localized features, such as the caldera of the huge volcano Olympus Mons, but they are far less reliable over large areas. The overall height of Olympus Mons itself (which covers a horizontal area the width of New Mexico), says Masursky, is known only to be "between 18 and 27 kilometers."



This 3/8-scale model of a Viking lander equipped with treads for mobility was typical of the elaborate follow-up missions envisioned during Viking's heyday.

Similarly low-cost aeronomy and geochemistry Mars-orbiters are also being considered at JPL, where they are part of a group that also includes a polar-orbiting moon mission, a rendezvous with a near-earth asteroid, a comet rendezvous and even a Saturn orbiter (without the atmosphere probes of NASA's older, much more elaborate proposal). One approach to cost-cutting, says JPL's Donald Ray, is to plan missions whose technological developments can be applied to their successors. Since an unbroken succession of Mars missions seems rather unlikely, he says, the problem becomes one of analyzing seemingly disparate missions in sequences — which also complicates the task of setting priorities among the wide-ranging scientific questions to be addressed around the solar system.

A variation on this theme is simply to plan a number of missions that can make use of the same spacecraft design. An obvious saving in such a case would seem to result from purchasing the basic spacecraft in bulk, but Congress has not tended to fund NASA programs years in advance, and, says Ray, there is no reason to expect a change. Still, he notes, it might be possible to buy several of certain components — microcircuit chips, for example — for later use, since bulk purchases of such items could provide significant savings without a major overall outlay.

Somewhat surprisingly, however, Ray does not advocate building spacecraft from existing parts as a money-saving technique. "We do *not* intend to use off-the-shelf technology," he says. "We intend to *push* technology." With careful design planning, he says, performance can often be improved at no increase in cost, and sometimes at a saving. Data-compression techniques, for example, can allow a spacecraft to transmit virtually the same amount of information in a smaller number of "bits," thus reducing radiated-power requirements.

While small-scale planetary missions may represent a change in the U.S. space program, they are the only approach available under the limited finances of the European Space Agency, which has yet to fly even one. The first will be ESA's "Giotto" flyby of comet Halley, based on a weather-satellite design and limited by its batteries to four hours of data-gathering. Next year, the agency hopes to begin work on a second, selected from among half a dozen prospects that include a mission to Mars (SN: 6/13/81, p. 377).

Envisioned for launch in 1988 or 1990, the spacecraft, called Kepler, would be placed in a near-polar orbit from which it could study the entire planet, varying in altitude from 200 to 6,300 kilometers. Among other experiments, radar would map surface elevations, a suite of spectrometers would report on the composition of the atmosphere and ionosphere, and a magnetometer would report on the controversial question of the planet's magnetic field. None of these measurements were made from the Viking orbiters, and Kepler's highly elliptical orbit would also enable detailed studies of the solar wind's interaction with Mars.

Whether ESA chooses Kepler over its other candidates (such as an asteroid rendezvous mission) may depend in part on the likelihood that NASA will attempt a similar project. No new U.S. planetary missions are certain, of course, but if low-cost flights become NASA's way of the future, the U.S. space agency, too, may find itself forced to start taking into account the plans of a growing number of international competitors. □