P76-10076

# NASA News

National Aeronautics and
Space Administration

Washington, D.C. 20546
AC 202 755-8370

(NASA-News-Release-76-74) SIX ARTICLES BY CARL SAGAN (NASA) 72 p

N76-74245
THRU
N76-74251
Unclas
00/98 28614

## SIX ARTICLES BY CARL SAGAN

This six-part series about the 1976 Viking mission to Mars has been prepared for publication consecutively, as a related sequence. However, any one of the six may also be used as a single, complete article.

Written by Prof. Carl Sagan of Cornell University, this material provides fresh, up-to-date information about NASA's mission to Mars this summer and early fall.

Dr. Sagan is professor of astronomy and space sciences and director of the Laboratory for Planetary Studies at Cornell. He serves on the lander imaging and landing site selection teams for the Viking mission to Mars. Sagan received the NASA Medal for Exceptional Scientific Achievement for his studies of Mars with the Mariner 9 spacecraft and is responsible for placing the celebrated plaques on the Pioneer 10 and 11 intersteller vehicles. Sagan has served on various advisory groups to NASA and to the National Academy of Sciences and in 1971 was chairman of the U.S. delegation to the joint conference of the U.S. National and Soviet Academies of Science on Communication with Extraterrestrial Intelligence. In 1975 he received the Joseph Priestley Award "for distinguished contributions to the welfare of mankind".

Illustrations accompanying each of these articles may be obtained as 8 x 10-inch black and white glossy prints by writing or phoning:

The Public Affairs Audio-Visual Office
Code FP/NASA Headquarters
Washington, D.C. 20546

Telephone: 202/755-8366

Miles Waggoner

Miles Waggoner
Director, Public Information
Office of Public Affairs

April 30, 1976

D/

# THE SEARCH FOR LIFE ON MARS
(First of a six-part series)

By Carl Sagan
Director
Laboratory for Planetary Studies
Cornell University, Ithaca, N. Y.

Legend has it that some 50 years ago a celebrated newspaper publisher sent this telegram to a famous astronomer: "Wire collect immediately," the telegram demanded,"500 words on whether there is life on Mars." The astronomer dutifully replied 250 times: "Nobody knows, nobody knows, nobody knows, ..." But despite this confession of ignorance asserted with dogged persistence by an expert, no one paid any attention; and, from that time to this, we hear authoritative pronouncements by those who think they have deduced life on Mars and by those who think they have excluded it.

The first purported evidence of life on Mars came almost exactly a century ago, in 1877, when an Italian astronomer, Giovanni Schiaparelli, peering at Mars through a new telescope outside of Milan and at a time when Mars was close to the Earth, saw to his astonishment a network of single and double straight lines which seemed to criss-cross the planet, "like the lines on a fine steel etching." Schiaparelli named them <u>canali</u>, which in Italian means channels or grooves. The word was promptly mistranslated into English as canals, a name by which they have been known ever since.



-more-

The American astronomer, Percival Lowell, was entranced by what he believed was the explanation of the canals, and erected a major observatory and devoted his life to the problem. The canals of Mars, Lowell eloquently argued, were canals: an intricate network of waterways constructed by a race of hydraulic engineers in a planet-wide water conservation project. The idea of a noble species of dedicated engineers gamely surviving through their technical ingenuity on an increasingly arid planet caught the romantic imagination of the public, particularly after it passed into popular fiction in the works of Edgar Rice Burroughs and others.

The only trouble is that the canals of Mars do not exist. The Mariner 9 spacecraft orbited Mars for a full year in 1971-72, and photographed the planet pole to pole with a discrimination of fine detail 100 times better than the astronomers of Lowell's time could possibly have managed. Mariner 9 was only 1,600 kilometers (1,000 miles) from the Martian surface compared with the 40 million kilometers (25 million miles) which separate Earth and Mars at their closest approach, and Mariner 9 did not have to look through the ocean of air which hampers astronomical observations from the surface of our planet.

-more-

A few of the canals may be great rift valleys, or the accidental alignment of impact craters, or linear streaks of dark dust; but no canal network as described by Schiaparelli and Lowell exists on Mars and the most generous assessment of the "canal problem" is to mark it down to the imprecision of the human hand-eye-brain combination: The canals were drawn at the telescope during brief moments of relative steadiness of the Earth's turbulent atmosphere.

Likewise, astronomers of Lowell's time observed seasonal changes, an increasing contrast, a sharpening of boundaries between adjacent bright and dark markings on the planet's surface. Some also reported color changes. These variations were called the "wave of darkening," which was reported to move from the shrinking polar cap in early spring towards and across the equator in the summer. Lowell and others attributed these seasonal changes to the growth and proliferation of Martian plants imagined to constitute the dark areas, and likened the wave of darkening to the sprouting of vegetation and the growth of leaves on deciduous trees in the Earth's Northern Hemisphere. Again Mariner 9 has dampened this interesting idea. Close observations have shown that the changes almost certainly are due to the redistribution of bright and dark dust by Martian winds, varying with the seasons.

-more-

A number of other supposed proofs of life on Mars -- the "green" color of the dark areas, the reappearance of the dark areas after being covered by bright powder during a Martian dust storm, and the supposedly anomalous motion of the innermost moon of Mars -- all turn out to have other explanations. Is life on Mars therefore excluded? Not at all. Mars is certainly colder than the Earth, it has a thinner atmosphere, less oxygen, less ozone (ultraviolet light from the Sun reaches the surface of the planet) and no abundant liquid water. These are environmental conditions which would instantly kill an unprotected human being on Mars. But life is not the same as human life and there are a wide variety of terrestrial microorganisms able to survive indefinitely under Martian conditions; and if they are provided, even briefly, with a little liquid water they are able to reproduce. Since terrestrial microbes which have evolved on the Earth are able to survive and possibly grow under Martian conditions, Martian organisms, if any, should be much better adapted to the apparent inclemencies of the Martian environment.

-more-

For some reason it is thought to be a sign of caution to admit the possibility of microbes on Mars but to exclude peremptorily the possibility of macrobes -- organisms large enough for us to see unaided were we on Mars. But there seems to be no evidence for or against Martian macrobes, and, for all we know, there is a thriving population of large organisms on the planet. Nothing in our present understanding of Mars excludes this possibility. A hundred thousand years ago the Earth was burgeoning with life -- indeed because the number of humans was still small, there was then a much richer variety of organisms than there is today. But had Mariner 9 been put into orbit about the Earth a hundred thousand years ago, it would have been able to photograph no clear signs of life whatever. Today the situation is different because human engineering enterprises, both urban and agricultural, have remade the landscape of the Earth.

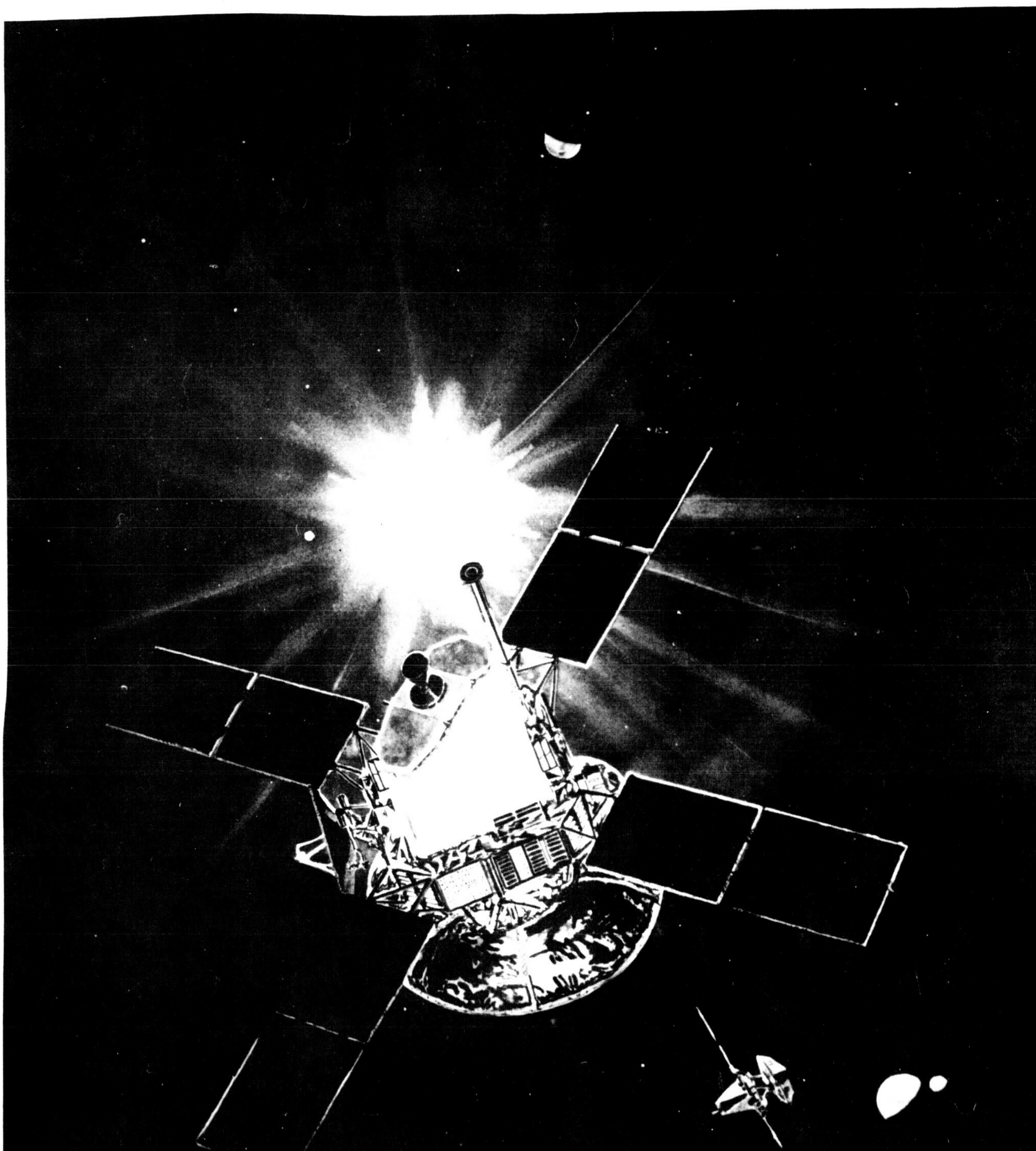
-more-

Mars today might have a dense population of varied and robust organisms, both microbes and macrobes. If so, we have no way to predict what those organisms are like except that evolution seems clearly to imply that they would not closely resemble the organisms of Earth -- they have spent too long adapting to an extremely different environment to be much like us. Mars might have life which is tenuously hanging on in a world enveloped in what looks very much like an ice age. Perhaps there are spores and hibernating forms awaiting the return of more Earth-like conditions; or perhaps there is no life at all, but only fossils and other signs of a now-extinct biology. Alternatively, Mars might be lifeless today and lifeless in the past. We simply do not know which of these circumstances characterizes the planet.

-more-

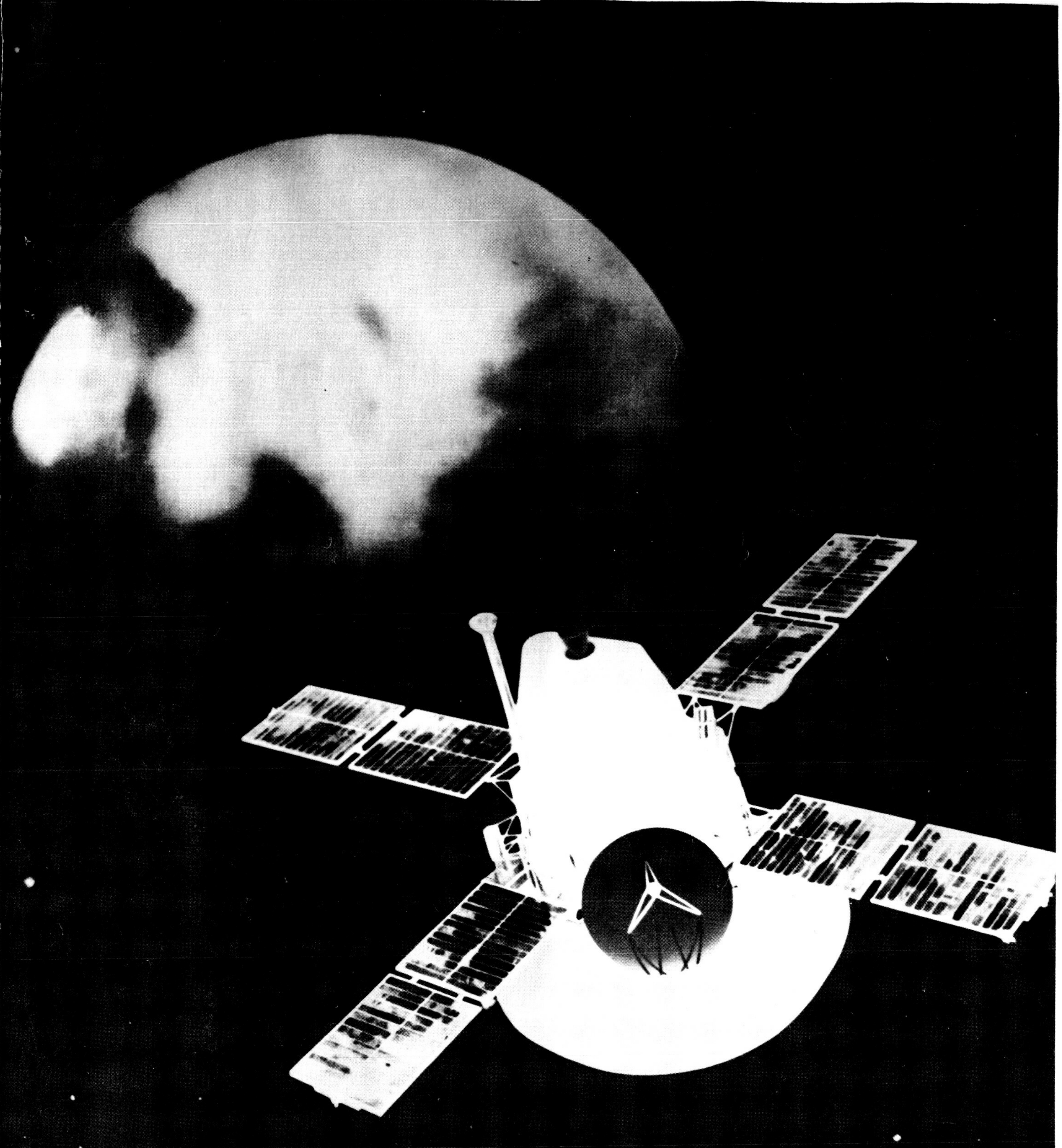
But any one of these cases is of substantial interest. If Mars has now or ever had living things, we will have for the first time in human history an opportunity to test the generality of the process which on Earth we call life. We will be able to determine how different from Earthly organisms life can be. Whatever form of life exists on Mars its implications for biology and for our view of ourselves would be breathtaking: because if life has independently arisen on two rather different adjacent planets, the argument that life is a commonplace in the Milky Way Galaxy will become almost compelling. If on the other hand Mars proves to be lifeless, we have the classic scientific situation, the experiment and the control. We will then be able to approach the important question of why life arose on the Earth but did not on Mars. The answer to that question is bound to illuminate profoundly our understanding of the origin of life.

Fortunately, the epoch of ambiguity about Martian biology, the time when the only responsible answer is "nobody knows," is drawing to an end. Because in the summer of 1976, if all goes well, two exquisitely instrumented landing capsules called Viking will land on the Martian surface, there to search directly for the possibility of life.



This is an artist's symbolic representation of the Viking mission to Mars. Two spacecraft, each composed of an orbiter and a lander, are now on a 460-million-kilometer (736-million-mile) journey to the Red Planet.

NASA Photo: 75-H-1099



Artist's concept of the Viking spacecraft in Mars orbit. The four-ton Viking divides into an orbiter and a lander. The orbiter, circling the planet, will photograph and map its surface. The lander will touch down gently on the surface and conduct an intricate scientific examination.

NASA Photo: 75-H-1048

D2

VIKING AND LIFE ON MARS
(Second of a six-part series)

By Carl Sagan
Director
Laboratory for Planetary Studies
Cornell University, Ithaca, N. Y.

In the summer of 1976, if all goes well, an epochal event in human history will take place -- the first search on the surface of another planet for extraterrestrial life. Two unmanned intelligent machines named Viking will make landfall on the Red Planet and proceed to search for life. Their activities will be monitored from Earth. New information can be transmitted to the Viking Landers, their memories and instructions can be reprogrammed. They will be like hands and eyes, ears and noses and mouths, set down on Mars and connected back to us here on Earth via a radio link tens of millions of miles long.

The bulk of the Viking Lander is shaped like a stubby triangle with projections both up and down. Extending downwards, there are three legs which will take some of the strain of the landing impact; extending upwards, a variety of scientific instruments, power sources, and antennae.

-more-

Viking has seismometers to listen for the rumble of marsquakes; if any are found we will have acquired information of vital importance for understanding the interior structure of the planet and its evolution. Does Mars have a crust, a mantle, and a core like the Earth? Is it geologically active as its numerous immense volcanoes suggest? Some of these questions can be answered even with a very low level of seismic activity on Mars. If we are very lucky, there may be a major marsquake during the year-long operational lifetime of the Mars landers. Our knowledge of the deep interior of the planet might then be enormously enhanced.

Viking has a set of meteorological instruments to determine wind speed, atmospheric pressure and temperature, the sorts of measurements that terrestrial weather stations routinely make. But now we will have a weather station at two locales on the planet Mars.

Beginning in the summer of 1976 and lasting for about a year we may even have a Martian addendum to the weather report on the evening news: "The high today in the United States was in Needles, Calif. where the temperature was 33 degrees Celsius (95 degrees Fahrenheit); the low in Duluth, Minn., was minus 23 degrees C (minus 10 degrees F.). On Mars, the mid-day temperature in Chryse was minus 9 degrees C (plus 15 degrees F.); but the pre-dawn temperature in Cydonia was minus 133 degrees C (minus 180 degrees F.). Skies are expected to be clear tomorrow in Cydonia but gusts of up to 225 kilometers per hour (140 miles an hour) can be expected in Chryse."

Viking is equipped with an elegantly designed sample arm which will extend out to some previously selected spot as much as 3 meters (10 feet) from the lander, and, with a kind of jerky backhoe and very noisy motion, gobble up a handful of Martian surface sand and dust, slowly and creakingly telescope upon itself until it is only a foot or two long, and then swivel about its axis so that the soil sample can be dropped into a set of hoppers on the top of the lander, which lead to a variety of scientific experiments. Inside the wire mesh entry ports there is something like a set of little electric train cars which transport the soil to the appropriate experiments.

-more-

One experiment will examine the inorganic chemistry of the Martian surface material. The best present guess is that the surface of Mars is some mixture of volcanic basaltic rock and clays, all stained red by a rusty "desert varnish." But these are only guesses, made inferentially by remote observations of Mars. Viking will perform the first direct measurements of what will surely be a complex and illuminating surface chemistry. If we know what the Martian surface material is made of we may be able to infer a great deal about the past history of the planet.

Another hopper goes to an experiment in organic chemistry, to determine whether the Martian surface material contains molecules produced by living organisms or molecules which in the early history of the Earth led to the origin of life. Some organic molecules fall on Mars in meteorites. The same meteorites on Earth clearly contain organic molecules produced in their cometary or asteroidal parent bodies. Further, in the oxygen-poor Martian atmosphere, it is possible that small quantities of simple organic molecules are being made by ultraviolet sunlight.

There will also be a source of contamination of organic molecules because the retro-rockets of the Viking landing system will produce certain such molecules during landing. But the principal interest is in organic molecules formed in the earlier history of Mars either by biology or by other processes, and organic molecules produced by living organisms on the planet today. It will be the task of the scientists working with the organic chemistry experiment to disentangle all of these possibilities and to characterize whatever organic molecules may exist. The Viking organic chemistry experiment can detect many molecules with an abundance of only one part in a million. It is a marvel of miniaturization containing, in a cubical box 30 centimeters (one-foot) on a side, all of the analytic power of an instrument in my laboratory at Cornell which fills the better part of a room.

Then there are three experiments to search for Martian microbiology. In one, a Martian soil sample is dropped into an aqueous mixture of organic molecules which we hope the little Martians will like to eat. The carbon in this food is radioactively labelled with the isotope carbon-14, which we know from spectroscopic studies is not abundant on Mars any more than it is on Earth.

If Martian microbes find our food tasty and -- as many terrestrial microbes do -- release carbon dioxide in metabolizing the food, the radioactive carbon dioxide will be detected by a Geiger counter behind a baffle and the rate of generation of radioactive $CO_2$ radioed back to Earth. This is a very sensitive experiment if it works. But Martian microbes must like the food we send to them and must oxidize it to $CO_2$ for us to get positive results. The food molecules sent are not chosen arbitrarily: They are abundant in terrestrial biology and they are commonly produced in the early history of all planets. But there is no guarantee that this experiment will work. For all we know the Martian microbes might find our little gift of food unpalatable and meanwhile be placidly munching on the zirconium paint on the exterior of the spacecraft.

In a second experiment in microbial biology, an unlabelled aqueous nutrient medium is dropped on the soil sample and the subsequent uptake or output of simple gases monitored. If the Martian organisms exchange even relatively exotic gases with the atmosphere this experiment might detect the exchange.

In a final microbial biology experiment, the soil sample is exposed dry to radioactively labelled $CO_2$. Ordinary nonradioactive carbon dioxide is the principal constituent of the Martian atmosphere. There is a light source which can be made to shine on the soil sample. Afterwards the soil sample is heated to a high temperature and it is determined whether any labelled carbon comes off the fried soil. If so, the existence of Martian organisms able to fix carbon dioxide from the Martian atmosphere -- as green plants fix carbon dioxide from the terrestrial atmosphere -- will have been demonstrated.

Now these are moderately sophisticated biological experiments, but in the absence of any prior knowledge of what Martian organisms might be like there is no guarantee of their success. The first two at least have the advantage that they can detect very rapidly life on Earth -- even in such inhospitable places as the Mojave Desert. These are hardly definitive experiments for life on Mars, but considering the weight constraints on Viking and the fact that no biology experiments have ever before been flown in unmanned spacecraft to another celestial body, they represent a significant and courageous first attempt.

-more-

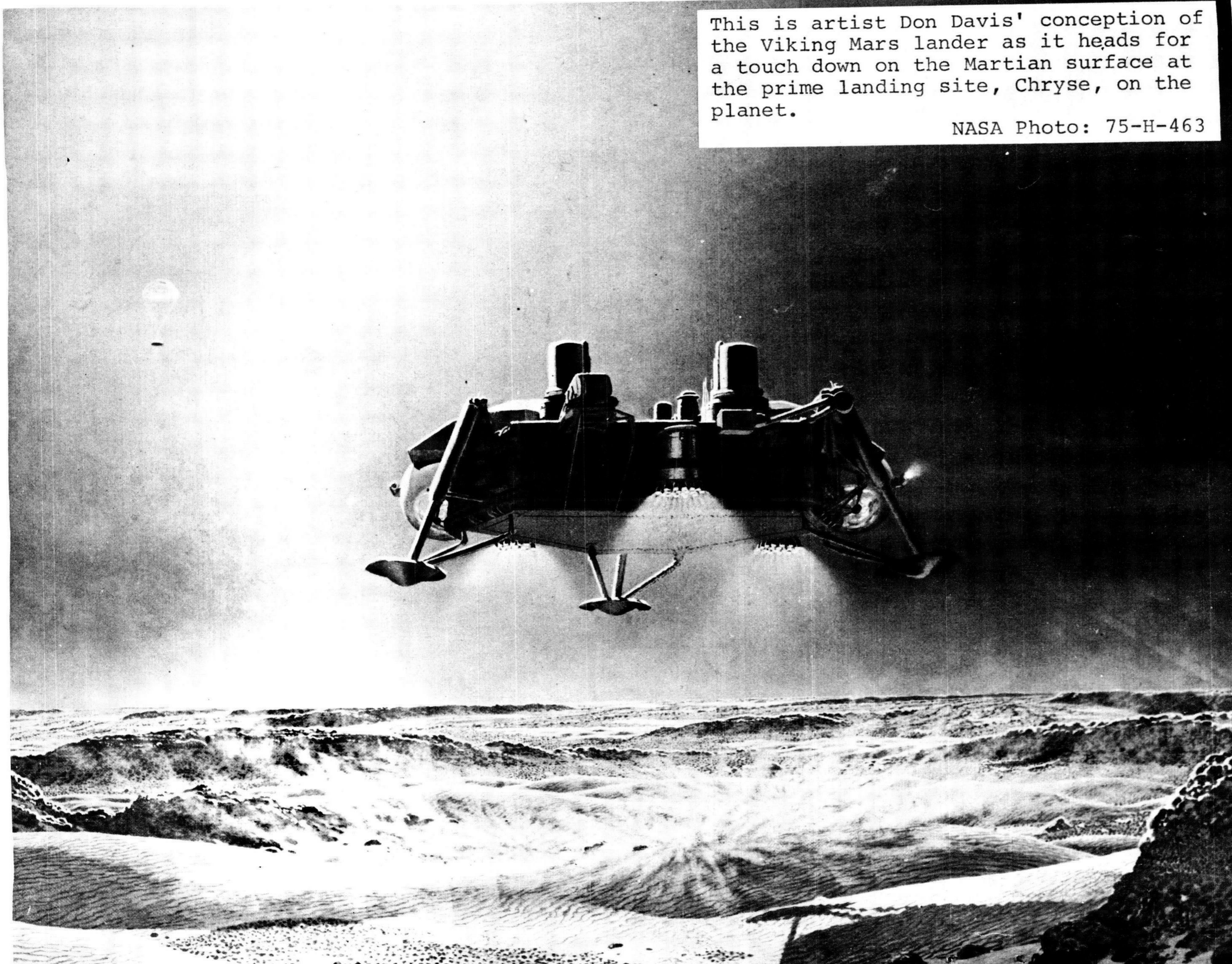
There is one other experiment which might possibly bear on life on Mars, the lander cameras. They will be able to see about as well as a human being would on Mars, but further into the infrared and with better depth perception. They will examine the nearby rocks, the distant sand dunes, the clouds, the moons of Mars, other celestial objects and whatever else there is around the landing sites that we do not now know enough about to describe today. The cameras will also examine the Martian soil in the trenches which the arm has dug. If there are Martian macrobes ranging in size from ants to giraffes the lander cameras have a fair chance of seeing them.

The imaging experiments make no assumptions on the biochemistry of Martian organisms. If we see an array of peculiar tree-like forms or a spindly organism 6 meters (20 feet) high, we should be able to detect them independent of their internal biochemistry. Thus the Viking life detection experiments represent a compromise between microbiology experiments of high sensitivity which, however, make many assumptions on what the Martians must be like; and television and chemistry experiments of lower sensitivity but which make fewer assumptions.

We do not know what Viking will find. But our previous space experience is that every time we look more closely at Mars we find astonishments and delights.

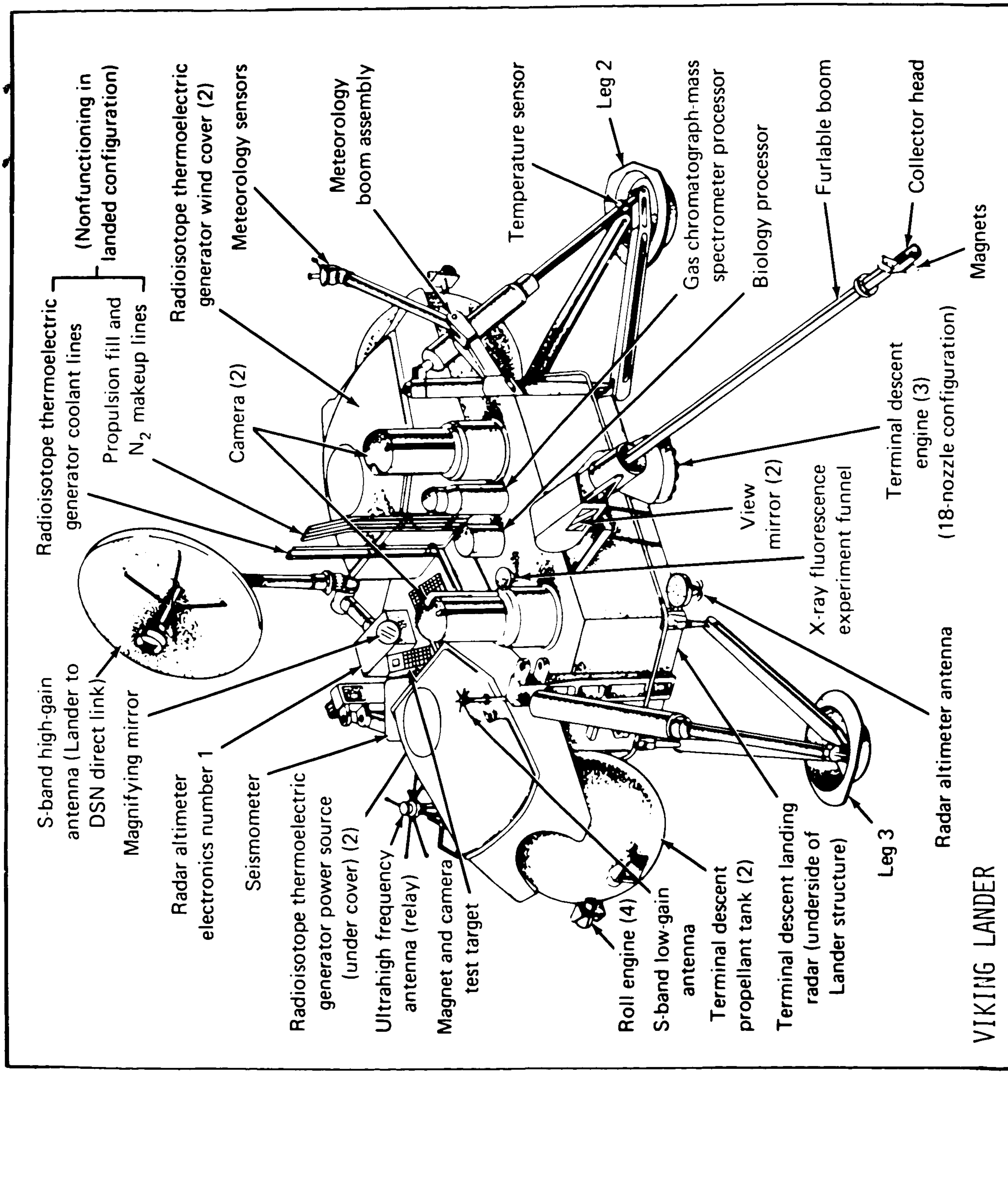
The year 1977 is the centenary of the finding of the "canals." By 1977 the Viking results should be in. In a hundred years we will have gone from vague observations and wishes disguised as conclusions to the first rigorous detailed and scientific examination of the surface of another planet. Viking represents the opening of a new era in planetary exploration.

AMERICAN REVOLUTION BICENTENNIAL 1776-1976



This is artist Don Davis' conception of the Viking Mars lander as it heads for a touch down on the Martian surface at the prime landing site, Chryse, on the planet.

NASA Photo: 75-H-463




VIKING LANDER

NASA Photo: 75-H-453

# THE CLIMATE OF MARS
(Third of a six-part series)

By Carl Sagan
Director
Laboratory for Planetary Studies
Cornell Universtiy, Ithaca, N.Y.

The planet Mars is very cold. Its atmosphere is very thin. In the tropics the temperature drops by more than 80 Celsius (150 Fahrenheit) degrees every night. The coldest temperatures ever recorded anywhere on Earth in the last few thousand years are higher than average mid-latitude Martian temperatures. At the poles the temperatures are low enough for carbon dioxide to freeze out from the sparse polar air, and the polar caps are at least in part immense deposits of dry ice.

Spectroscopic analysis of sunlight reflected off Mars shows the presence of tiny quantities of water vapor in its atmosphere and immense quantities of water chemically bound up in the surface rocks. There are probably large amounts of water ice in the polar caps and vast quantities frozen subsurface at lower latitudes as permafrost.

Thus there is water vapor and water ice and chemically combined water but -- except for small amounts in tiny pores in the Martian soil -- there can be no liquid water on Mars today.

-more-

The reason is very simple. For a material to remain liquid it must satisfy two conditions. First, its temperature must be between its freezing point and its boiling point. Equatorial daytime conditions on Mars satisfy this condition for liquid water. But in addition there must be enough atmospheric pressure to keep the material liquid. A liquid exposed to a vacuum will evaporate very rapidly. Molecules would meet no impediment when escaping from its surface and soon the liquid will have evaporated away. There is so little atmosphere on Mars that the boiling point is very close to the freezing point and in any case evaporation will occur very rapidly. Open pools of pure liquid water, flowing rivers of water, cannot exist on Mars today.

And yet there seems to be evidence of running water on Mars. One of the most astonishing findings of the United States' Mariner 9 mission to Mars was that the planet is covered with thousands of sinuous tributaried channels. The largest are 100 to more than 1,000 kilometers (60 to more than 600 miles) long; have tight meanders; tributaries running in the correct direction downstream; teardrop shaped islands, correctly oriented with the sharp point downstream; and with complex braided patterns of silt. The smallest ones -- vastly more numerous -- are only a few miles long with vague sinuosities and few tributaries.

The channels of Mars correspond neither in position nor in form to the "canals" which we now know to be due to errors of human perception in pre-spacecraft times. Some of the smaller channels may be valleys not produced by running water. Some of the larger channels -- particularly those which begin in a jumbled chaotic terrain -- may be produced by breakout flooding of ice-dammed subsurface water. Many of the channels seem to be produced by rainfall. No alternative liquid besides running water has been proposed which is reasonable for the physical conditions of Mars. We thus are faced with an apparent paradox: The environment of Mars does not permit running water; and yet the surface of Mars is covered with signs of running water.

But how old are the channels? The only tool for dating them which we have at present -- and it is a poor tool -- is counting the number of impact craters in and around the channels. We can estimate the population of impacting debris on Mars through its history: The higher the number of impact craters the longer the channel must have been around to accumulate them. In this way it has been determined that some of the larger channels are hundreds of millions of years old. Others may be, for all we know, much older or much younger.

A solution to the paradox then becomes evident: The climate of Mars varies. Today Mars is plunged into deep ice age conditions. But at least once and possibly many times in its past it has experienced higher pressures, balmier temperatures and abundant running liquid water. There are many interesting implications of this idea. If Mars can undergo such enormous climatic variations can this shed any light on the climatic variation which the Earth has experienced? Two million years ago the site of present-day Chicago was under glaciers several miles high. Does the Martian experience provide us with some cautionary reminders about how not to change the environment of the Earth? And also there is the question of life. Do those more clement early conditions suggested by the channels mean that Mars once had an environment entirely suitable for life? Could there be life on Mars today evolved from those more clement conditions and awaiting the end of the long winter?

Before these questions are addressed we must be sure that the channels were in fact carved by liquid water and that the climate of Mars is in fact variable. We need more information. There is no trouble in hiding a dense earlier atmosphere on Mars today. The enormous thickness of the polar caps correspond to a very thick atmosphere. According to one estimate, if the polar cap were vaporized it would correspond to an atmospheric pressure over the whole planet as thick as that on Earth today. But we do not know very well the age of the various polar deposits. Crater counts by the high resolution cameras on the Viking orbiter next summer could help resolve this issue.

The present plan is to set the first Viking lander down in a region called Chryse near the confluence of four major Martian channels. It may be possible to check directly the idea that the channels were produced by running water -- for example if the inorganic chemistry experiment detects great quantities of salts typically moved by rivers.

But Viking will perform another and in a way a much more interesting test. If in its remote past Mars had a much denser atmosphere, where could that atmosphere be today? I have already mentioned that it could be frozen away in the polar caps if the polar temperatures are below the freezing point of the atmosphere. Or it could have chemically combined with the surface of Mars if that early atmosphere underwent such chemical reactions. Or it might have all escaped to space from the top of the Martian atmosphere, if it were composed of sufficiently light gases.

Now there is one particular gas which will do none of these things. It is called argon. Its freezing point is far below the coldest temperatures on Mars. It is a so-called noble gas which does not engage in any chemical reactions of note whatever.

And it is so heavy that it could not possibly have escaped from Mars. If in its early history the gurglings and rumblings of the Martian interior outgassed a great atmosphere, many of the constituents may have been lost by one or another of these mechanisms. But not argon. If there was once a dense atmosphere, argon should be present in the Martian atmosphere still. (On Earth it comprises about one per cent of our atmosphere for just these reasons.)

In 1973 the Soviet Union made an unsuccessful attempt to land a Viking-class spacecraft on the surface of Mars, a spacecraft called Mars 6. It mysteriously failed within one second of landing. Among its instruments was a device called a mass spectrometer, designed to analyze the composition of the Martian atmosphere after landfall. On the way down to the surface, the mass spectrometer was busy scrubbing itself clean of residual gases leaking in from the Martian atmosphere during descent.

-more-

The pressure in the device was monitored. To the surprise of the Soviet investigators the scrubbing mechanism worked very poorly and a high residual pressure remained.

Now this might be caused by a malfunction such as a leak, but it would have to be a very special sort of leak. The alternative is that the Martian atmosphere contained unexpectedly large amounts of a gas immune to the scrubbing. The most likely such gas turns out to be argon. The Soviet investigators have concluded that the present Martian atmosphere comprises 35 per cent argon with an uncertainty of about 15 per cent. The remainder of the atmosphere is almost exclusively carbon dioxide.

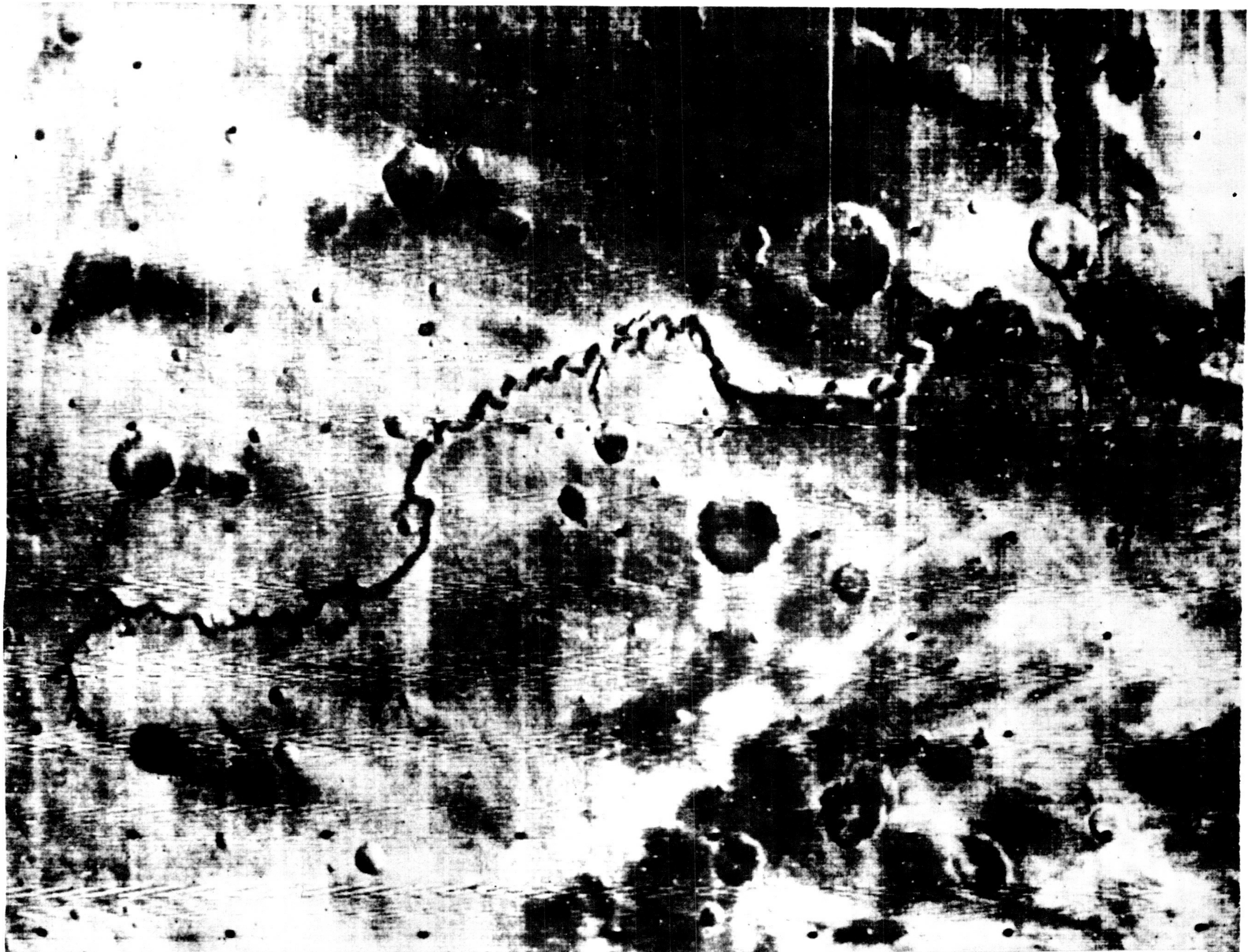
This is precisely the result we would expect if Mars had a very dense early atmosphere. But the Mars 6 measurement is indirect and has an alternative explanation. Three instruments onboard Viking, two of them mass spectrometers, will be capable of checking the argon abundance. If Viking works well we should have clear-cut evidence on the argon abundance and the past history of Martian climate.

We seem to be on the verge of being able to compare the past climatic histories of other planets with our own. In a few months we may be able to check out the tantalizing idea than in an earlier epoch in Martian history, the sky was blue and not black, the winds were mild, the air was thick, the temperatures relatively balmy and the gurgle of streams and the mighty roar of cascading rivers could be heard abundantly on the surface of the Red Planet. And if in the past, why not in the future? Might we be able at some future time to prod Mars into returning to its pleasant past environment and -- if there is no indigenous life -- hosting immigrants from the distant planet Earth?

A channel thought to have been formed by running water in Mars' geologic past is seen in this mosaic of three pictures of the planet taken July 1, 1972, by Mariner 9.

NASA Photo: 73-H-30

TOP



An unexpected feature on the Martian surface is this sinuous valley photographed by Mariner 9 from 1,666 kilometers (1,033 miles) during the spacecraft's 133rd revolution of the planet in 1972. NASA Photo: 72-H-109

724

LANDING ON THE PLANET MARS
(Fourth of a six-part series)

By Carl Sagan
Director
Laboratory for Planetary Studies
Cornell University, Ithaca, N.Y.

The Soviet Union has an extremely active program of unmanned planetary exploration. Every year or two the relative positions of the planets permits a launch at minimum energy of a spacecraft to Mars or Venus. Since the early 1960s the U.S.S.R. has missed only two or three such opportunities. Soviet persistence and engineering skills have eventually paid off handsomely. Three spacecraft -- Veneras 8, 9 and 10 -- have landed on Venus and successfully returned data from the surface of that planet. Since Venus is at a broiling 480 degrees Celsius (900 degrees Fahrenheit) with a crushing atmosphere 95 times as dense as the Earth's and with significant quantities of corrosive atmospheric acids, landing and returning data from that planet is no insignificant feat. Yet, despite many attempts, the Soviet Union has been unsuccessful in attempts to land on Mars -- a place which superficially seems to be much easier: lower temperatures, a thinner atmosphere and no corrosive gases.

-more-

In 1971, the Mars 3 spacecraft entered the Martian atmosphere. According to the information automatically radioed back, it successfully deployed its landing systems during entry, oriented its ablation shield correctly downward, properly unfurled its great parachute and fired near the end of its descent path its retrorockets. According to the data returned by Mars 3, it should have successfully landed on the Red Planet. But after landing the spacecraft returned to Earth a 20-second fragment of a featureless television picture and then mysteriously failed. In 1973 a quite similar sequence of events occurred for the Mars 6 lander, but in this case, the failure occurred within one second of touchdown. What is the source of these failures? Is there something special about the Martian environment which makes landing on that planet particularly difficult?

The first illustration I ever saw of Mars 3 was a Soviet postage stamp (denomination 16 kopeks) which depicted the spacecraft descending through a kind of purple muck. The artist was trying, I think, to illustrate dust and high winds: Mars 3 entered the Martian atmosphere at a time of an enormous global dust storm which roared over the planet.

-more-

We have evidence from the United States Mariner 9 mission that near surface winds of more than 200 miles per hour -- more than half the speed of sound on Mars -- occurred. Both our Soviet colleagues and we think it likely that these high winds caught the Mars 3 spacecraft with parachute unfurled, giving it a very high velocity parallel to the surface, so that it landed gently in the vertical direction but with breakneck speed in the horizontal direction. A spacecraft descending on the shrouds of a large parachute is particularly vulnerable to horizontal winds. After landing Mars 3 may have made a few bounces, hit a boulder or other example of Martian relief, tipped over, lost the radio link with the carrier "bus" spacecraft, and failed.

But why did Mars 3 enter in the midst of a great dust storm and high winds? The answer is that the Mars 3 mission was rigidly organized before launch. Every step it was to perform was loaded into the on-board computer before it left Earth. There was no opportunity to change the program as the extent of the great 1971 dust storm became clear. In the jargon of space exploration, the Mars 3 mission was preprogrammed, not adaptive.

The failure of Mars 6 is more mysterious. There certainly was no great global sand and dust storm when it entered the Martian atmosphere; and no reason to think that there was a local storm then -- as sometimes happens -- at the landing site. Perhaps there was an engineering failure just at the moment of touchdown; although the coincidence makes this explanation a little unlikely. Or perhaps there is something dangerous about the Martian surface.

The combination of Soviet successes in landing in so inhospitable an environment as Venus and Soviet failures at landing on Mars naturally causes some concern about the United States Viking mission to Mars. Two Viking orbiter-lander combinations are well on their way to Mars, having performed so far with remarkable success. They are scheduled for landings in the summer of this year. If Viking works, it will be the first serious attempt in human history to search for life on another planet. But like its Soviet predecessors, the Viking landing maneuver involves an ablation shield, a parachute and retrorockets. Under what circumstances will Viking fail its critical landing maneuvers?

-more-

Because the Martian atmosphere is only one per cent as dense as the Earth's, a very large parachute -- 18 meters (55 feet) in diameter -- is deployed to slow down the spacecraft as it enters the Martian atmosphere. The atmosphere is so thin that if Viking lands at a high elevation there will not have been enough atmosphere to adequately brake the descent and the spacecraft will crash. One requirement, therefore, is that the landing site be in a low-lying region. The Viking entry maneuvers are thought to be so accurate that an oval-shaped region about 300 kilometers (200 miles) long can be positioned almost anywhere on the planet and landed in. This "landing ellipse" can be positioned onto many low-lying areas on the planet. And from Mariner 9 results and ground-based radar studies of Mars, we know many such low-lying areas.

To avoid the probable fate of Mars 3, we want Viking to land in a place and time when the winds are low. The winds which will make the lander crash are probably already large enough to lift dust off the surface. If we can check that the candidate landing site is not covered with shifting, drifting dust, we have at least a fair chance of guaranteeing that the winds are not intolerably high.

This is one reason that the Viking lander is carried into Mars orbit with the orbiter and descent is not made until the orbiter checks out the landing site. We discovered with Mariner 9 that characteristic changes in bright and dark patterns on the Martian surface occur during times of high winds. We certainly would not certify the landing site as safe if orbital photographs showed such patterns. But our guarantees cannot be 100 per cent reliable either. For example, we can imagine a landing site on which the winds are so strong that all mobile dust has already been blown away. We would then have no indication of the high winds which might be there. Detailed weather predictions for Mars are, of course, much less reliable than for Earth. (Indeed one of the many objectives of the Viking mission is to improve our ability to understand the weather on both planets.)

Because of communications and temperature constraints, Viking cannot land at high Martian latitudes. Farther poleward than about 45 or 50 degrees in either Martian hemisphere, either the time of useful communication of the spacecraft with the Earth or the time that the spacecraft experiences above intolerably low temperatures would be awkwardly short.

We do not wish to land in a place which is too rough. Landing in a field of boulders each a few feet across is likely to have unpleasant consequences. The spacecraft might tip over and crash or, at the least, its mechanical arm to acquire Martian soil samples might be wedged beneath it or waving helplessly above it. Likewise, we do not want to land in places which are too soft. If the three landing pods sink well into a loosely packed Martian surface, various undesirable consequences would follow; one of which, if the spacecraft sinks too far, would be immobilization of the sample arm. But we do not want to land in a place which is too hard either: if we land in a vitreous lava field, for example, with no powdery surface material, the mechanical arm will be unable to acquire samples vital for the chemistry and biology experiments.

Now it is not easy to determine the roughness or softness of a candidate landing site. The best photographs of Mars -- available from the Mariner 9 orbiter -- show features no smaller than 90 meters (100 yards) across. The Viking orbiter pictures will improve this figure only slightly. Boulders one meter (3 feet) across will be entirely invisible in such photographs, but could have disastrous consequences for the Viking lander. Likewise, a deep, soft powder might be indectable photographically.

Fortunately, there is a technique which permits us to determine the roughness or softness of a landing site. That technique is radar. A very rough place will scatter radar off to the sides and therefore appear poorly reflective. A very soft place will also appear poorly reflective because of the many interstices between individual sand grains. While we may be unable to distinguish between rough places and soft places, we need not make such a distinction for the Viking landing purposes. Both are dangerous. Preliminary radar surveys suggest that as much as a quarter to a third of the surface area of Mars may be poorly reflective to radar and therefore dangerous for Viking. But not all of Mars can be viewed by Earth-based radar -- only a swath between about 25 degrees N. and about 25 degrees S. The Viking orbiter contains no radar system for mapping the planetary surface.

This is a very large number of constraints. Our landing sites must be low, not too windy, not too close to the pole, not too hard or soft or rough. It is remarkable that there are any places at all on Mars which satisfy simultaneously all of these safety criteria. What is even more remarkable is that some of these candidate landing sites are of intense scientific interest.

-more-

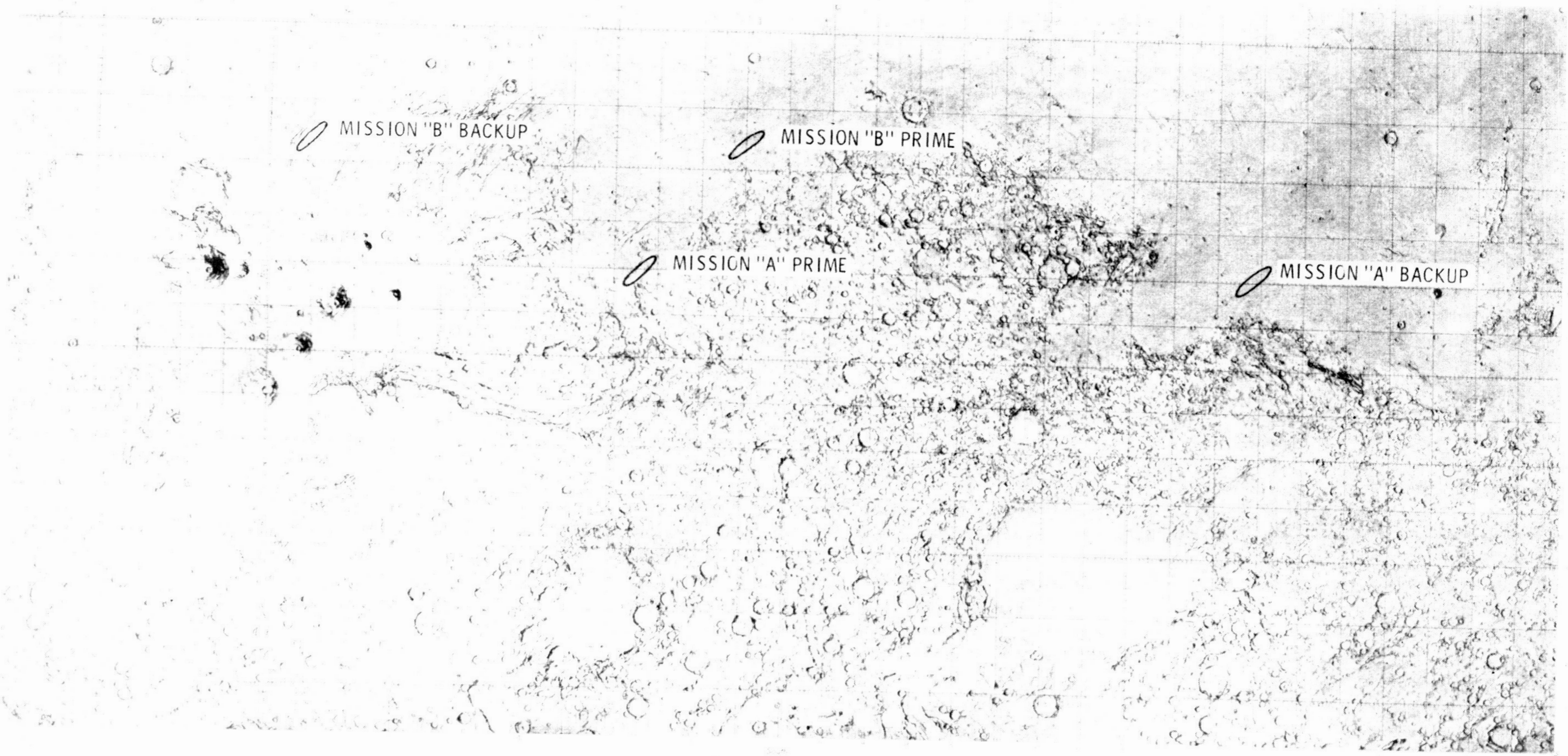
When a Viking orbiter-lander combination is inserted into Martian orbit it is forever after committed to landing at a certain latitude on Mars. For example, if the low point in the orbit is at 21 degrees Martian north latitude, the lander must touch down at 21 degrees north latitude, although -- by waiting for the planet to turn beneath it -- it can land at any longitude whatever. Thus, the Viking teams have selected candidate latitudes on which there are more than one promising site. Viking 1 is now targeted for 21 degrees N. The prime site is in a region called Chryse which is near the confluence of four sinuous channels thought to have been carved in previous epochs of Martian history by running water. The site in Chryse (which is Greek for the land of gold) seems to satisfy all of the safety criteria. But radar observations have so far been made only nearby, not in the Chryse landing site. The appropriate radar observations can be made -- because of the geometry of Earth and Mars -- for the first time only a few weeks before the nominal landing date of July 4, 1976. There is going to be a great deal of very active work in analyzing the radar observations in June and July 1976. The backup site for Viking 1, while scientifically less interesting, seems to satisfy all safety criteria.

The present candidate latitude for Viking 2 is 44 degrees N. The prime site for this second landing is in a locale called Cydonia, chosen because -- according to some theoretical arguments -- there is a significant chance of small quantities of liquid water here at least at some time in the Martian year. Since the Viking biology experiments are strongly oriented towards organisms which are comfortable in liquid water, some scientists hold that the chance of Viking finding life on Mars is substantially improved at 44 degrees N. On the other hand it is argued that, on as windy a planet as Mars, microorganisms should be everywhere if they are anywhere. There seems to be merit to both positions and it is difficult to decide between them. However, what is quite clear is that 44 degrees N. is completely inaccessible to radar site certification; therefore we must accept a significant risk of failure of Viking 2 if it is committed to high northern latitudes. It is sometimes argued that if Viking 1 is down and working well we can afford to take a risk with Viking 2. But I can imagine circumstances in which Viking 1 fails before its biology experiments are completed and Viking 2 crashes becauses it lands in a radar uncertified site. To at least improve the Viking options, additional landing sites in the radar certified region over 4 degrees south latitude have also been selected. A decision on whether Viking 2 sets down at high or at low latitude will be made virtually at the last minute.

The nineteenth century British prime minister, Benjamin Disraeli, was asked to define the difference between a calamity and a catastrophe. "If my opponent, Mr. Gladstone, fell into the Thames, that would be a calamity," he said. "If someone pulled him out, that would be a catastrophe." If Viking failed to find life on Mars because it did not land in a wettish place, that would be a calamity. But, I think, if Viking failed to return any data at all, that would be a catastrophe.

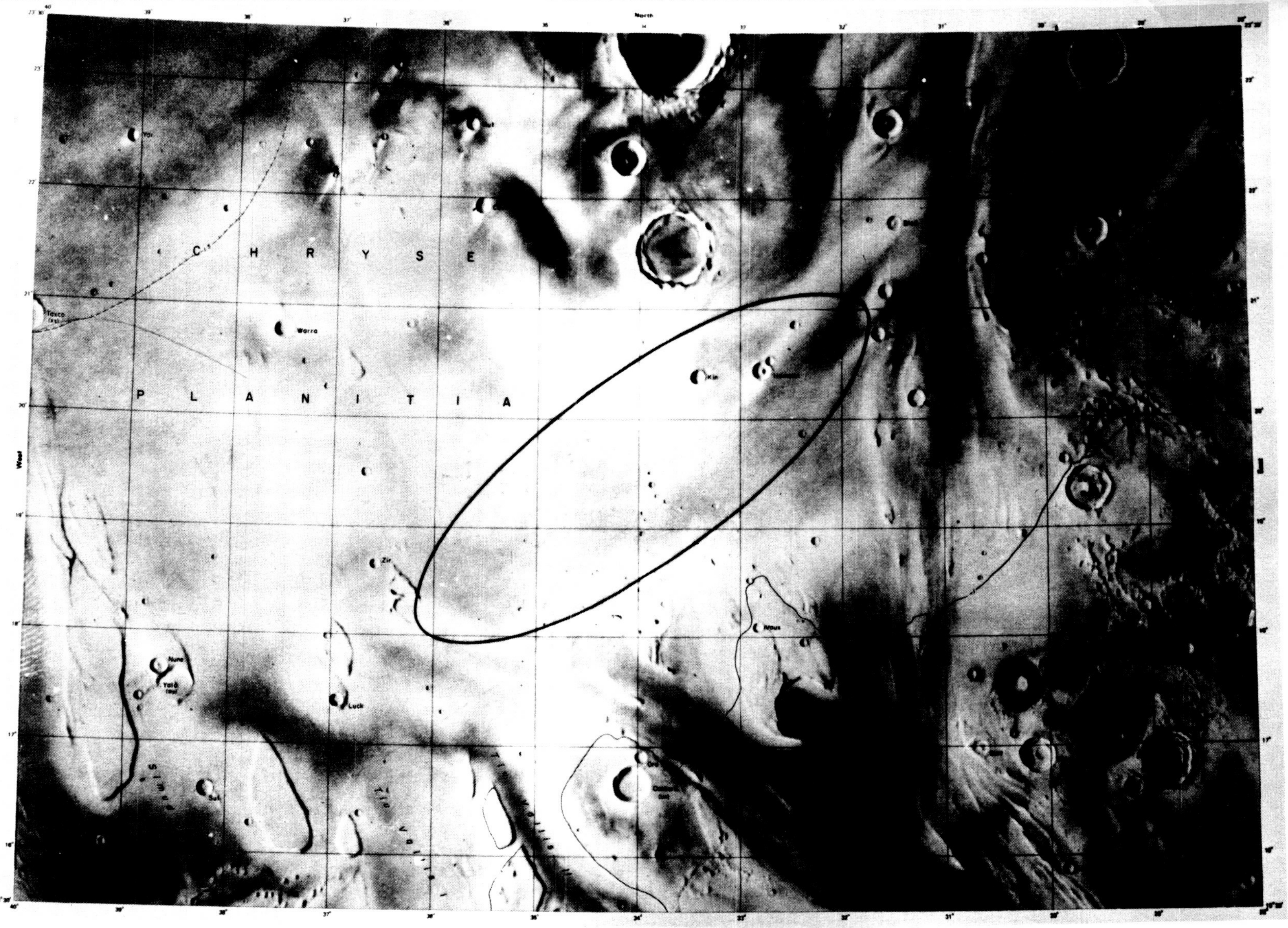
If Viking lands successfully on Mars it will be due in considerable part to the great skill devoted to its design, fabrication and testing and to the abilities of the spacecraft controllers. But it will, I think, for so dangerous and mysterious a planet as Mars, also be due to at least an element of luck. I know all of the scientists involved with Viking will breath a great collective sigh of relief when the landers successfully touch down. We will then be able to get on with the job of finding out what Mars is like.

VIKING LANDING SITES




The regions indicated on this map of Mars have been tentatively selected by NASA as the primary and backup landing sites for NASA's 1975-76 unmanned Viking expedition.

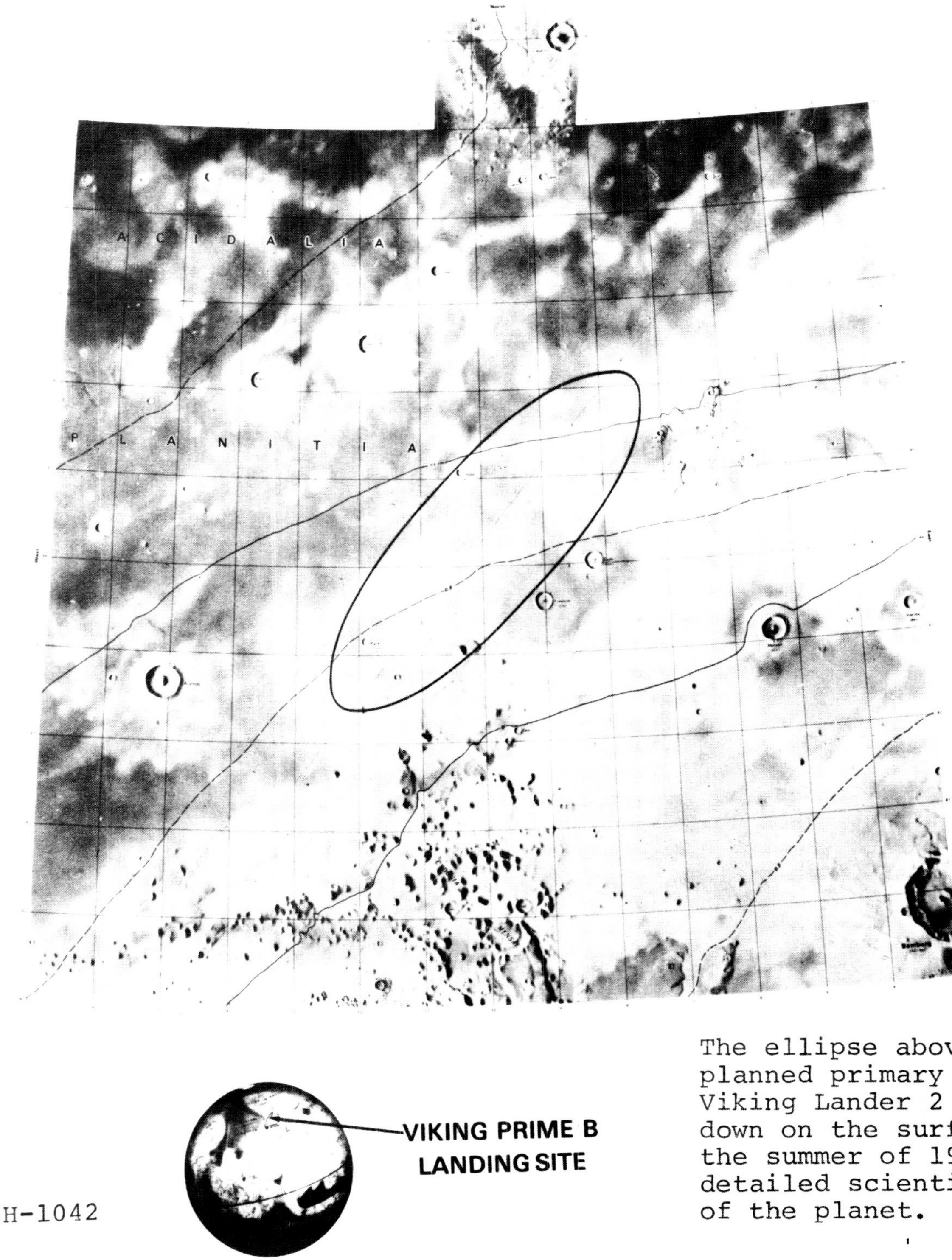
NASA Photo: 73-H-327





NASA Photo: 75-H-1044

The ellipse above indicates the planned primary landing site for Viking Lander 1 when it touches down on Mars in the summer of 1976 to begin a detailed scientific examination of the planet, including a search for life. The site is in a region of Mars called Chryse.




NASA Photo: 75-H-1042

The ellipse above indicates the planned primary landing site for Viking Lander 2 when it touches down on the surface of Mars in the summer of 1976 to begin a detailed scientific investigation of the planet.

D5

VIKING: THE MISSION STRATEGY
(Fifth of a six-part series)

By Carl Sagan
Director
Laboratory for Planetary Studies
Cornell University, Ithaca, N.Y.

This is the summer of the Viking launch to Mars. If all goes well, two landers and two orbiters will be sent there in an event unique in human history -- the first extended and closeup reconnaissance of the surface of another planet.

The Viking spacecraft includes orbital experiments for imaging, infrared thermal mapping, infrared water vapor detection, and radio science; atmospheric entry experiments for analysis of the neutral and ionized components of the Martian upper atmosphere; and lander experiments for imaging of the surface, atmosphere and other astronomical objects, for inorganic chemistry, meteorology, seismometry, magnetic properties of sand grains, organic chemistry of surface samples and analysis of the lower atmosphere, plus three compact biological experiments designed to search for any Martian microorganisms.

-more-

Viking is an expensive mission, costing almost a billion dollars; it has occupied hundreds of scientists and engineers for many years, some of us for more than a decade; and if it works, it promises to revolutionize the planetary sciences in general and the study of Mars in particular.

While the orbital television system will obtain photographs of Mars with a resolution of two to three times better than the best images from Mariner 9, the prime function of the orbiter is lander support: to act as a radio link to Earth for the lander and to help certify preselected landing sites. The orbiters do not have, for example, the infrared and ultraviolet spectrometers that were so successful on Mariner 9. The primary objective of the mission is to search for life on Mars, and this is not something easily performed remotely.

The key elements in both orbiter and lander are their onboard computers. The lander possesses -- like a human being with his corpus callosum cut -- two identical brains. Each has an 18,000-word memory, with 24 bits per word, stored on two coupled magnetic wires. A memory of 18,000 words is quite large. Basic English, which is alleged to be serviceable in many layers of American society, consists of fewer than 1,000 words.

A scientific and engineering protocol is already in the Viking memory banks. Each lander's computers will be checked by a data dump to see how well they remember and understand their program. In each case, the computer that has forgotten the least will be put in charge. A third computer on Earth selects the winner. The loser will be put to sleep, but will wait in readiness; in case of an accident or senility in the winner it may be called upon later.

While it is certainly large, an 18,000-word vocabulary is inadequate for everything the Viking lander may be asked to do. (The sample arm motions alone require several hundred words.) Only 5,000 of its words are for functions to be performed exclusively after landing. The remainder are for executive matters, involving the structure of the entire computer program; checkout of engineering functions; and functions performed during descent to the Martian surface.

For this reason, the mission controllers have devised a "primary design", according to which every six days a set of new commands, comprising hundreds to thousands of words, will be radioed uplink from Earth to Mars.

But this corresponds to a very sluggish response to what may be astounding discoveries made on the planet's surface, and an "adaptive design" (update every three days) seems to be the first mission design in which it will be possible to perform appropriately responsive experiments on the surface.

One clear lesson from past spacecraft is that enormous scientific payoffs follow from the ability to do new experiments on the basis of what we have just learned. Many of the most famous discoveries made by Mariner 9 -- the great volcanoes, the surfaces of Phobos and Deimos, variable features, great sand-dune fields and details of the large sinuous channels -- required the space probe's adaptive mode. An entirely preprogrammed Viking mission would be relatively feeble scientifically. It could not even select with the lander cameras the place where the sample arm is to dig. But a Viking mission in which we can perform an experiment tomorrow on the basis of what we learned the day before yesterday -- that is a scientific capability of stunning potentialities.

Both Viking launches took place in August and September 1975 from Pad 41 at the Kennedy Space Center, Cape Canaveral, Fla.

Any launch later than about September 20 would have seriously degraded the mission, and might have required a 23-month "hold" until the next opportunity in 1977. NASA has a very good launch record, but there has never been as complex a scientific mission as Viking. The launch vehicle is the Titan 3E, a Titan booster with a Centaur second stage, a configuration that had been tried only twice before.

In the nominal mission, the A orbiter-lander combination is injected into orbit around Mars on June 19, 1976, giving it 15 days for landing site certification before the July 4 landing. After certification, several propulsion maneuvers are required to make the orbit Mars-synchronous, with a 24.6-hour period and a low point in the orbit of about 1,500 kilometers (900 miles) over the landing site. The orbit is highly elliptical. The Viking 2 mission arrives in the vicinity of Mars on August 7, 45 days after the Viking 1 configuration. It has about 30 days to orbit for Viking 2 lander site certification and scientific investigations before its lander deboosts.

Lander 1 has a nominal working lifetime on Mars' surface of 58 days; Lander 2, 62 days (although the spacecraft are likely to work for a full year). The resources available to the Viking mission will apparently permit almost no simultaneous operation of major scientific experiments on the two landers.

This is a great pity, since synoptic observations are the kev to a variety of fundamental problems. The difficulty is not spacecraft capability, but rather money to pay for ground personnel and mission control computers. Despite its high cost, Viking is severely hampered by lack of funds.

The descent maneuver begins when a mechanical spring separates the orbiter and the lander, giving a relative velocity of a meter (slightly more than a yard) or two per second. The two follow essentially the same orbit for two hours, during which the lander orients itself for entry and examines the thin upper atmosphere of the Red Planet. It radios its findings to the nearby orbiter, which relays them directly to Earth as well as recording them on tape recorders for future playback. The entire descent sequence is under control of the active lander computer; the ground "controllers" will be able only to bite their fingernails.

After an initial rocket burn, the lander enters the denser atmosphere, ablation shield first. After this burns off, the parachute is deployed and then, under control of the accelerometers with backup timing devices, is jettisoned. Finally, the terminal-descent rockets burn, to be turned off only about 3 meters (10 feet) above the Martian surface.

The entire delicate landing maneuver is actively controlled by the lander, relying on its descent radar and other instruments and maintaining a careful attitude control. It is an intricate servomechanism, making decisions on the basis of its sensory information, as we do. The lander free falls the final few feet and -- many of us sincerely hope -- safely lands on its three spring-loaded footpads on the surface of distant Mars.

## The Lander Program

Immediately upon setting down, at about 4:30 in the afternoon Chryse standard time, the spacecraft initiates a range of engineering and housekeeping functions. It asks itself if it is feeling well. The lander will relay data to Earth via the orbiter (when that is above the lander's horizon) at 16,000 bits per second; and at other times directly to Earth, but at the much slower rate of 500 bits per second. During the next three days, it principally takes seismometric and meteorological data, as well as the first closeup pictures of the Martian terrain.

The meteorology package, on a small boom, will examine other atmospheric properties including wind velocity and direction. Evening weather reports on American television in the summer of 1976 may include reports on meteorological conditions at the two locales on Mars.

We know that, despite the thinness of the Martian atmosphere, winds are occasionally strong enough to raise enormous clouds of sand and dust and it would be very interesting to correlate wind speeds as measured by the meteorology experiments with the amount of atmospheric dust as measured from above by the orbiter, and from below by the two Viking television cameras. The cameras will be able to see dust clouds in the vicinity of the spacecraft and at the horizon, and will also determine the mobility of samples of dust and sand dumped by the sample arm on a specially prepared grid on the horizontal surface of the spacecraft.

The lander cameras will be able to see detail about as well as a human being standing on Mars. In some respects it will be superior. It will be able to image as far as 1.2 microns into the infrared and it will be able to perform much better stereo imaging than human eyes can because the two cameras will be placed much farther apart than our characteristic few inches. There will be color stereoscopic panoramic photographs of two landing sites on Mars, horizon to horizon, perhaps even stretched out over a period of many months.

The Mariner 9 experience is that quite new sets of features appear on Mars as we are able to see smaller and smaller detail. No one is able to predict what we will see within a few yards of the Viking landers. For all we know there may be amazing discoveries as we take the first closeup images of Mars.

On the third day after landing, the first set of uplink commands arrives. By the sixth day, a decision will have been made on where to obtain the first soil sample with the sample arm. On the eighth day, after the onboard computer has demonstrated that it truly understands its newly arrived instructions on where to dig a hole, the sample arm gingerly extends itself towards the surface. It can reach a soil sample (or a more interesting object) as much as 3 meters (10 feet) away. With a nervous jittery backhoe motion it lifts its sample into the air and gradually retracts, telescoping itself until it is only a few inches from the lander's main body. Photographs are taken before, during and after the sampling operation. The arm then positions itself over one or more of the three entry bays. One is for the X-ray fluorescence experiment, to examine the inorganic chemistry of molecules with atoms heavier than about mass number 20; another is for the gas chromatograph-mass spectrometer (GCMS) to examine the organic chemistry of the samples; and the last is for the three different microbiology experiments.

The arm opens its little claw, shakes itself and deposits the sample into a funnel which is covered by a wire mesh screen. Experimenters back on Earth will have decided whether they want the same sample for each experiment.

The experiments then do their stuff, which may take some days. The biology experiments, for example, require an incubation period before the results can be radioed downlink to Earth. In all, three samples will be examined by each of the three biology experiments, four by the GCMS, and five by X-ray fluorescence, all during the nominal mission of each lander.

We will be examining the properties of the Martian surface near the lander fairly thoroughly. The sample arm will be able to dig trenches and with Viking's eye-hand combination, we will perform simple experiments on surface properties. The Viking 1 mission is scheduled to land near the banks of old sinuous valleys thought to have once been mighty rivers. If we are very lucky we might get some information on the ages and mechanisms of the channel cutting process. The deeper interior of the planet will be investigated by an elegant seismometer which will listen for marsquakes if there are any. Since from our Mariner 9 experience we know that Mars has recently been tectonically active, we expect much higher levels of seismic activity than were detected by seismometers on the Moon.

-more-

An X-ray fluorescence spectrometer should provide insights into the mineralogy and geochemistry of the Martian surface, and an indication of what sorts of geological processes have been operating. For example, it is possible that this experiment might be able, from an examination of salt content, to check whether liquid water once flowed on Mars.

If there is life on Mars we may see characteristic chemical signatures of its presence from the GCMS experiment. Alternatively there may be organic compounds there from carbonaceous chondrites, organic-rich meteorites originating in the asteroid belt and falling now and then on Mars. Finally there may be non-biological synthesis of organic matter by ultraviolet light in the present oxygen-poor Martian atmosphere. It is hoped that the GCMS experiment will be able to distinguish among these possibilities. It will also search for time variations in the chemistry of the Martian atmosphere. The microbiology experiments range from one which makes very specific assumptions about Martian microbial metabolism but which has very high sensitivity to one which makes only very general assumptions but which has a much lower detectivity.

The GCMS and biology experiments are by far the most expensive scientific instruments ever flown in the unmanned planetary program. But the questions being asked are very fundamental. We do not know beforehand the nature of Martian life, if any, and there has been no previous experience in designing, testing and flying space vehicle experiments oriented towards organic chemistry and microbiology. We get what we pay for, by and large. With these instruments developed, the incremental cost of future investigations of the organic chemistry and biology on Mars will be much less.

The Viking lander cameras may also be used for biological investigations if there are organisms large enough to see. No one knows if this is the case. If it is, Martian organisms may be detectable independent of any assumptions we make on their biochemistry. The range of Viking investigations directed towards the search for life on Mars is of course not perfect. But it seems to be an excellent mix for the first preliminary biological reconnaissance of another planet. If all works well, Viking is almost sure to find a great deal that is of meteorological and geological interest. And, if we are lucky, we may hit the cosmic jackpot and find something of biological interest.

After the Viking 2 lands, high-data-rate transmission from the Viking 1 lander is turned off for the economy reasons mentioned above. Only low-data-rate experiments on the direct link to Earth can be performed, chiefly seismometry, meteorology and single-line video scans. The Viking 1 orbiter, freed of its relay responsibility for its lander, now exuberantly explores Mars from orbit. Many questions posed by Mariner 9 may be answered at this stage.

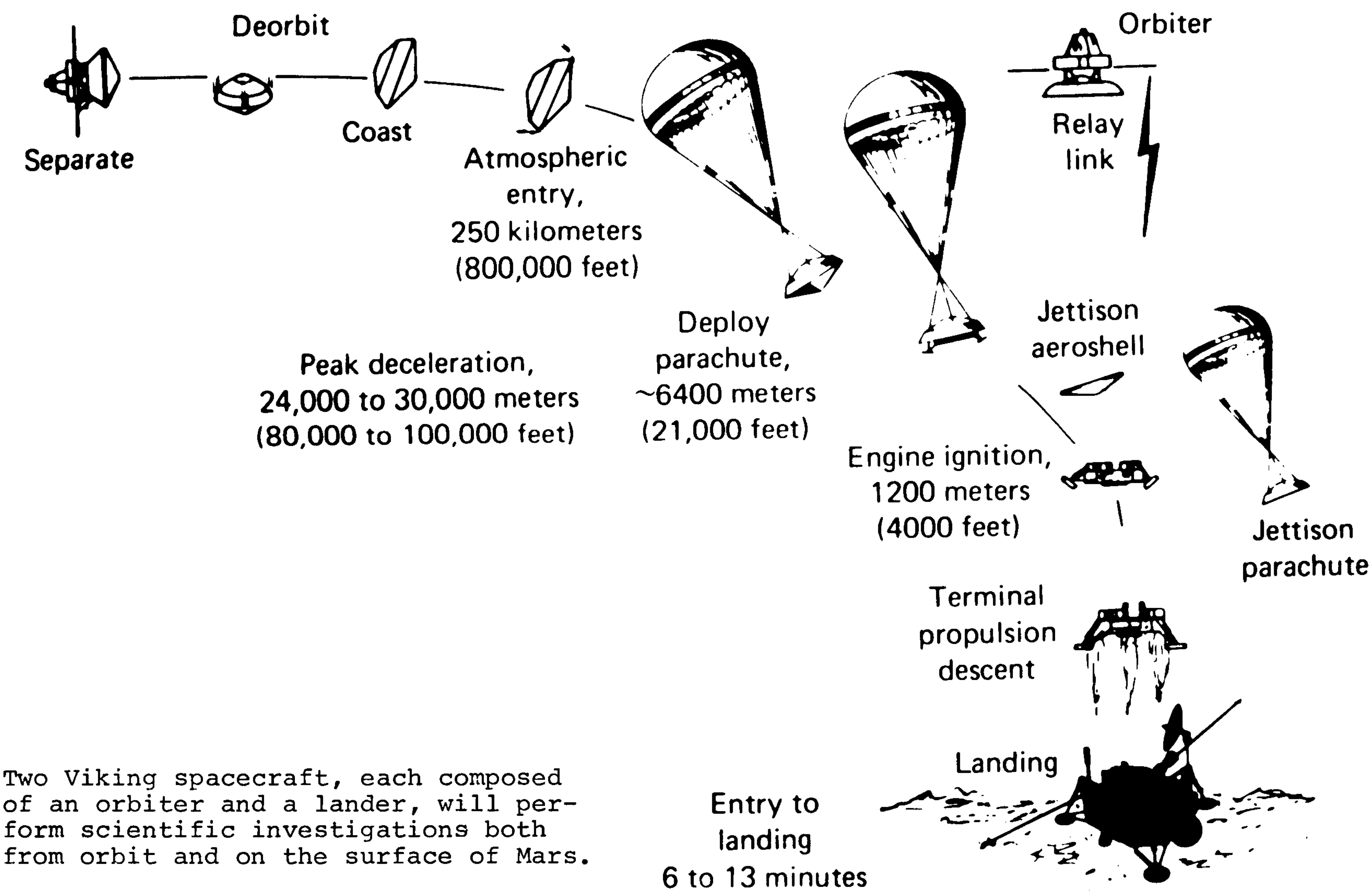
This is also the first time in the mission when radio occultation experiments will be performed, as the atmosphere and the planet intercept the transmission from orbiter to Earth. Eventually, the Orbiter 1 may be called back to service the Lander 2 (a function possible only if the longitudes of the nominal 1 and 2 landing sites are very nearly the same). If this occurs, the inclination of 2's orbital plane to the equatorial plane of Mars can be increased to 75 degrees, converting the Viking 2 orbiter into a Martian polar observatory. Many other comparably elegant combined mission strategies are possible.

Mars will be in solar conjunction on Nov. 25, 1976, when the Sun will be between the planet and the Earth. Communication with the Viking spacecraft will be interrupted from November 8 until about Christmas Day.

The generosity of nature is evident here: Viking scientists will finally be able to take time out from data gathering to ponder what the data mean. Many space missions never provide such an opportunity until they are over.

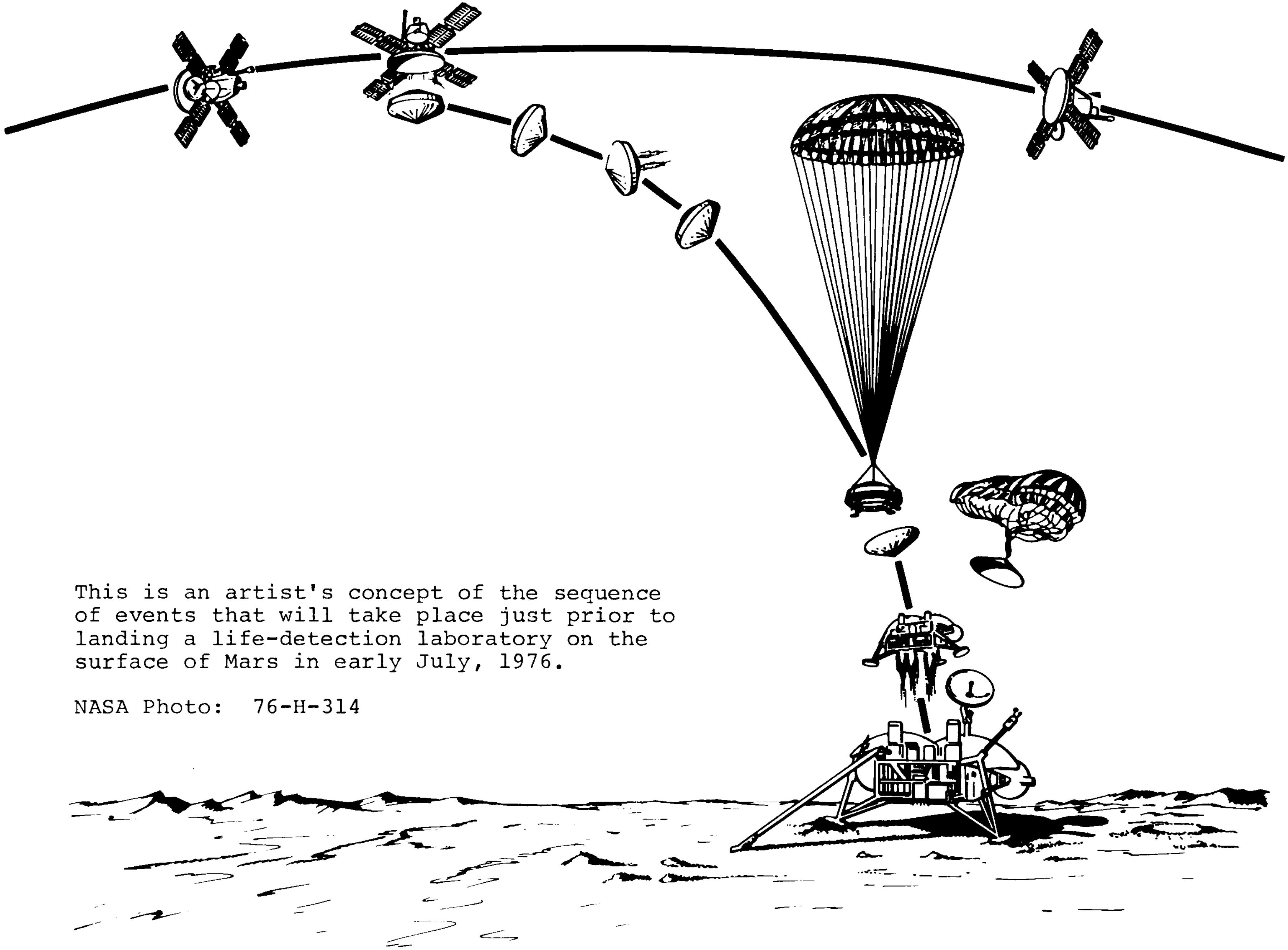
If all is still working well, the Viking Extended Mission may begin early in 1977. While the nominal lifetime of a Viking spacecraft is only about 90 days, Mariner 9, with a similar life expectancy, performed for a full year, failing only because it ran out of consumables. Viking's power source is independent of sunlight; it runs on the decay of radioactive plutonium. If it is as well engineered as Mariner 9 was, the really interesting part of the Viking mission may begin in January, 1977. In any case, if Viking works even moderately well, planetary astronomy will never be the same again.

If after a long series of post-Viking investigations of Mars we find no sign of life on the planet, we will then have discovered something of considerable importance about the unlikelihood of life originating and surviving on another planet not very dissimilar to our own, a finding which will underscore the preciousness and rarity of what has happened here on our small Earth. And if we are lucky enough to find life on Mars, that event will clearly open a new epoch in the history of biology, our view of ourselves and our place in the cosmos.



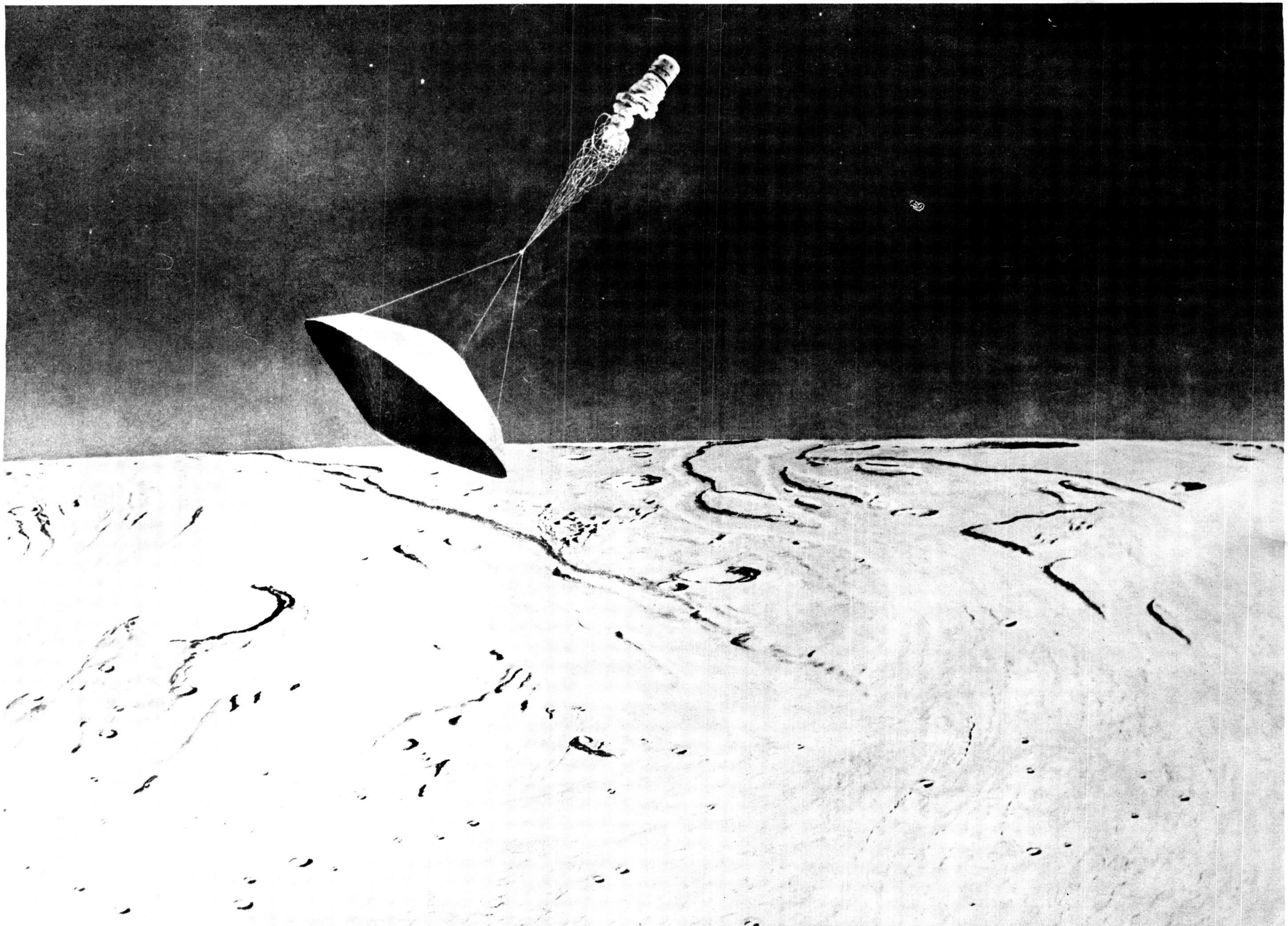

Two Viking spacecraft, each composed of an orbiter and a lander, will perform scientific investigations both from orbit and on the surface of Mars.

NASA Photo: 75-H-677



This is an artist's concept of the sequence of events that will take place just prior to landing a life-detection laboratory on the surface of Mars in early July, 1976.

NASA Photo:  76-H-314



This is artist Don Davis' conception of events some 6,666 meters (20,000 feet) above the Martian surface as the Viking lander (enclosed in an aeroshell) heads for a touch down on the plains of Chryse in July, 1976.
NASA Photo: 75-H-462

P76-10077

# NASA News

National Aeronautics and
Space Administration

Washington, D.C. 20546
AC 202 755-8370

For Release:
IMMEDIATE

RELEASE NO: 76-74A

NOTE TO EDITORS AND CORRESPONDENTS:

REVISION OF COPY -- Prof. Carl Sagan's Six-Part Series on Viking (NASA News Release No. 76-74)

The first paragraph in the fifth article in the series, titled Viking: The Mission Strategy should read:

This is the summer of the Viking landings on Mars. If all goes well, two landers and two orbiters will arrive at the planet during mid-1976 in an event unique in human history -- the first extended and closeup reconnaissance of the surface of another planet.

May 10, 1976

DC

# THE FUTURE EXPLORATION OF MARS
(Last of a six-part series)

By Carl Sagan
Director
Laboratory for Planetary Studies
Cornell University, Ithaca, N.Y.

There are some people who will bet on anything, gamblers by temperament, oddsmakers inveterate. Even some scientists have this gaming instinct and have been heard quoting odds on the chances of life on Mars and the prospect that this summer Viking will find it. The odds I have heard quoted range from even to a million to one against. When I hear such high odds, I always lay my dollar down. It is not that I am convinced there is life on Mars. In fact, I think, short of missions such as Viking, there is no way to find out. But when such high odds are offered the significance of a success, it seems to me, far outweighs the uncertainty of the issue: If I win, I win big; if I lose, I lose only a little.

The same is true about the Viking mission itself. The investment represented by the Viking mission is very large by scientific standards (but very small by military standards). If Viking succeeds, it will have been a great bargain. The mission will be asking one of the epochal questions in human history: Is there life on other planets? Is biology a cosmic commonplace? Or in some strange and poignant way is life a rarity in this vast and awesome universe in which we are imbedded?

- more -

But there are many other aspects of Viking besides biology. By determining the interior structure and surface chemistry of the planet Viking holds the promise of illuminating our knowledge of the formation and evolution of planets in general. By studying, both from lander and from orbiter, the meteorology of the planet, Viking has a significant chance of improving our knowledge of weather in general. The environment of Mars is significantly different from the environment of the Earth. Any theory which pretends to predict, much less control, weather must be able to account for the weather on Mars--a place with enormous temperature contrasts, no oceans, pronounced topographical relief and sand and dust storms on a colossal scale. Furthermore, Viking represents the development for the first time of a planetary lander capability by the United States and the ability to perform--without returning a sample to Earth--tests for organic chemistry and biology on distant worlds.

But even if the landing sites are safe and Viking works as hoped, it is difficult to gauge the probability of ultimate success. We do not know whether there is life on Mars. We do not know whether life on Mars, if it exists, is detectable by the Viking instruments. We also do not know whether life is present over the whole planet or only in a few favorable micro-environments. After all, we are only landing in two places on Mars. If we were landing in only two places on the Earth, how likely is it that we would be able to characterize thoroughly the geology or meteorology, much less the biology, of our planet?

An amusing exercise is to imagine the tables reversed, and Viking being sent from Mars to the Earth instead of the other way around. Suppose that the (hypothetical) martians have selected four places on Earth which have the same geographical coordinates as the two prime and two back-up landing sites which we have chosen for the landings on Mars. Of course, the choice of coordinates is entirely arbitrary. The zero degree meridian on a globe of the Earth is chosen to pass through Greenwich, England only because it is in Greenwich that a royal observatory was established in a time when Britain was master of the oceans. The zero degree meridian on Mars has been chosen, equally arbitrarily, by terrestrial astronomers to pass through a prominent dark marking which we call Meridian Bay. Had we chosen a different zero degree longitude, we would deduce some other equivalent landing places on Earth.

But the exercise is interesting. If the tables were reversed the prime landing site of the first Viking would be in the middle of the Atlantic Ocean. Since Viking is not equipped for operations in water, it would rapidly sink -- blub, blub, blub -- and would be considered a mysterious failure. The back-up landing site for Viking 1 would be in the Gulf of Tonkin -- familiar in recent terrestrial history--and would represent another mission failure. The prime landing site of Viking 2 would be in the North Atlantic. (Three out of the four landings in water corresponds well to the ratio of ocean to land on the planet Earth.) But the back-up site for Viking 2 would be not only on land, but at a dazzling place: the southwest entrance to Yellowstone National Park. If trees could be avoided during landing, the spacecraft would reap a rich harvest of scientific results: not only microorganisms but bears, rangers and tourists. Such a mission would undoubtedly be considered a success by the Martians.

- more -

This is one of many reasons why Viking is not a definitive search for life on Mars, but, rather, only a significant first step. This is true on many other levels. I have had several nightmares about the Viking mission. In one of them I dream we see footprints beside the lander every morning, but we never see anyone who makes the footprints. The situation could have been remedied had Viking included a search light for nighttime television. But despite its cost, Viking was severely constrained fiscally and a searchlight simply cost too much. Another nightmare I have is that a little more than 3 meters (10 feet) away from the lander is something astonishing -- say a regular purple geometric pattern on the ground -- something we would dearly love to scoop up and analyze. But the mechanical arm which retrieves such samples is only 3 meters long. The purple patch would remain tantalizingly out of reach. Viking is not a rover. It stays put where it lands.

These examples illustrate one important future direction for successor missions to Viking. A Mars rover is of extraordinary interest not only because it greatly enhances the scientific capability of the mission, but also because it could command public attention on a day-to-day basis -- a kind of cooperative, if vicarious, exploration of Mars by the American and world public.

Each day we would scan the surroundings, see what place seems of greatest interest, and then slowly roll on tractor treads to it. Is that a peculiar rock formation to the east or something else? Is that volcano active or are we seeing an afternoon cloud poised near its summit? Is that a dust cloud at the horizon or smoke? What will the ground look like when we move into quite a different geological region two weeks from now? A Viking rover could traverse many hundreds of miles during a reasonable lifetime and is, I think, a mission which could command worldwide attention and enthusiasm.

If biology is found on Mars by the Viking of 1976 the follow-on missions would, of course, be dedicated to characterizing life on Mars. What does it look like? What is its biochemistry? Is it based on the same sorts of molecules as life on Earth (where all of us--viruses, tadpoles, turnips, trees and human beings--work off two kinds of molecules called nucleic acids and proteins.) What are the similarities and differences in the evolution of life on the two planets? Is there really a much broader range of adaptations possible than we are familiar with on Earth? How does a martian work?

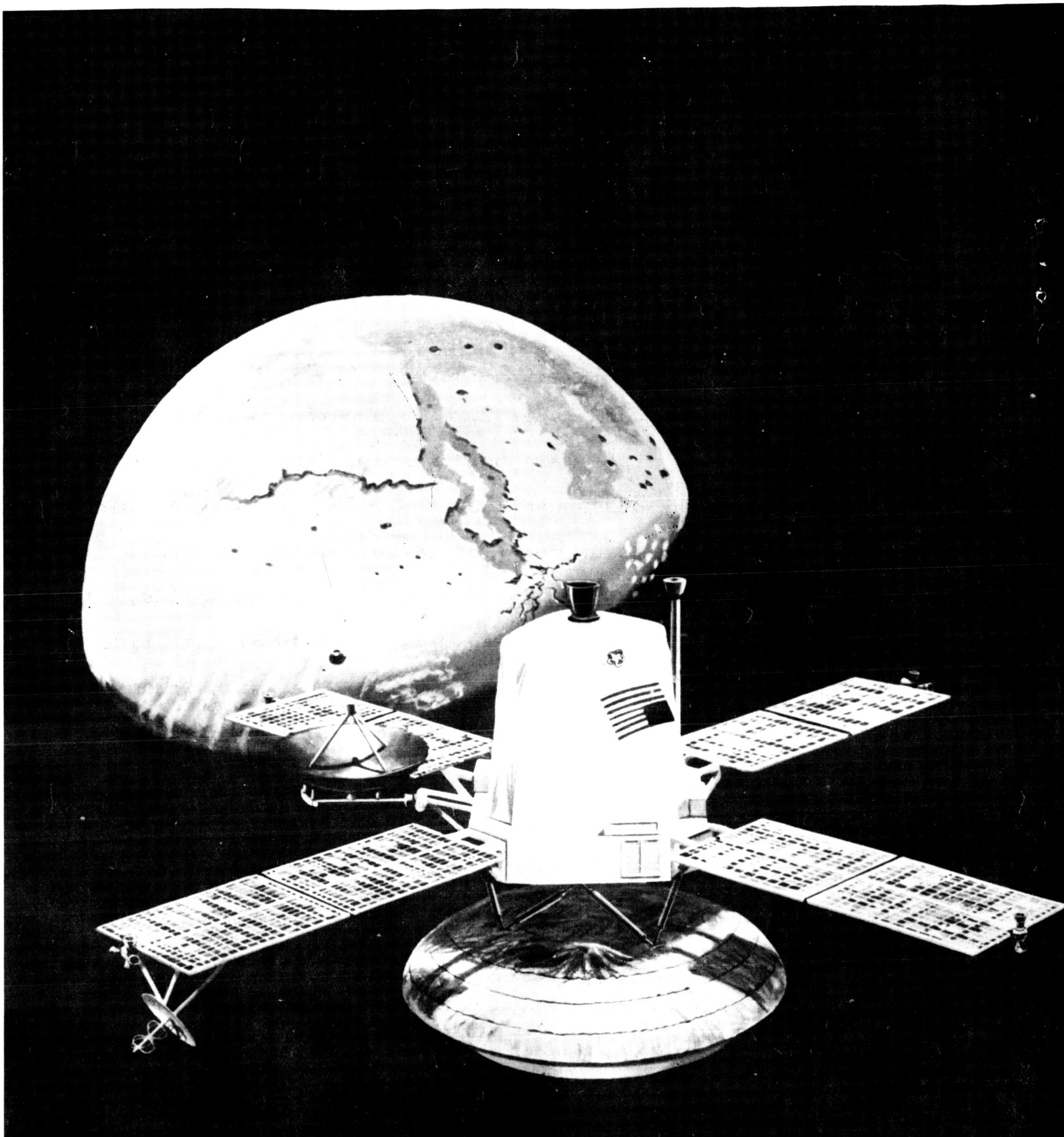
Eventually, whether or not we find life on Mars, we will want to return a sample of Mars to the Earth for more detailed study. There are some scientific instruments so complex, massive and expensive that it is difficult to envisage them being miniaturized and sent to Mars at any time in the foreseeable future. Returned sample missions are expensive--probably significantly more expensive than a Viking rover--but perhaps not ruinously so. However, a serious question about Mars returned samples is what is called back contamination. We do not know whether terrestrial microbes can survive and reproduce on Mars, but we consider it not impossible. It would be a ghastly error to send to Mars a spacecraft contaminated with terrestrial bacteria, which would then look for life on Mars and succeed only in detecting its own contaminants. There are also many scientists concerned that, for possible future human utilization of Mars, we should not implant terrestrial organisms which might proliferate if the martian climate could be induced to become more clement. For these reasons Viking and comparable Soviet spacecraft intended for Mars landings have been rigorously sterilized.

But now the opposite possibility exists as well. Could Martian microorganisms, if they exist, when transplanted to Earth cause disease and plague or ecological disruptions here? No one knows the answer to this question. Some think that, because of the evolutionary differences expected between terrestrial and martian organisms, there would be no chance for Martian pathogens to gain a foothold here. But others think that, precisely because of the lack of past evolutionary contacts between organisms from the two planets, terrestrial hosts will have inadequate biological defenses against Martian pathogens. This is again an issue where our uncertainty is large and the possible consequences immensely serious.

Some scientists hold that no unsterilized samples should be returned to Earth from Mars until we know a great deal more about Mars. Examining the sample in, for example, an orbiting space station around the Earth does not solve the problem because the scientists in the space station will eventually want to come back to Earth, and the latency period of diseases can be very long. The problem would be resolved if a foolproof method could be perfected for returning a contained Martian sample to a rigorously controlled terrestrial microbiology laboratory. But the reliability of such a return system would have to be demonstrated to the satisfaction of representatives of the whole Earth: back contamination is not an issue confined to any one nation.

For myself I would urge a vigorous program of unmanned exploration of Mars with roving vehicles, deferring the more expensive and possibly dangerous returned sample and manned missions to a later time.

But if we humans do not destroy ourselves through stupidity, greed or political miscalculation, I am confident that there will be such a later time -- a period where remoter worlds in the solar system are being explored by intelligent roving vehicles, the descendants of the first Vikings; a time when at least serious consideration is being given to the possibility of establishing human outposts on other worlds, the chief of which is likely to be Mars. People of that time will look back to this, I think, in the same way that we in America look back to the first voyages of exploration and discovery in the "New World." In fact the year of Viking is auspicious. It is the 500th anniversary of the first glimpse of the great untraversed Atlantic Ocean by a young Genoese sailor named Christopher Columbus. I believe that the ultimate historical importance of Viking, if it succeeds, is comparable to that of the Nina, the Pinta, and the Santa Maria.



This artist's symbolic representation of the United States Viking mission to Mars shows the spacecraft against a backdrop of the Red Planet.
NASA Photo: 76-H-67