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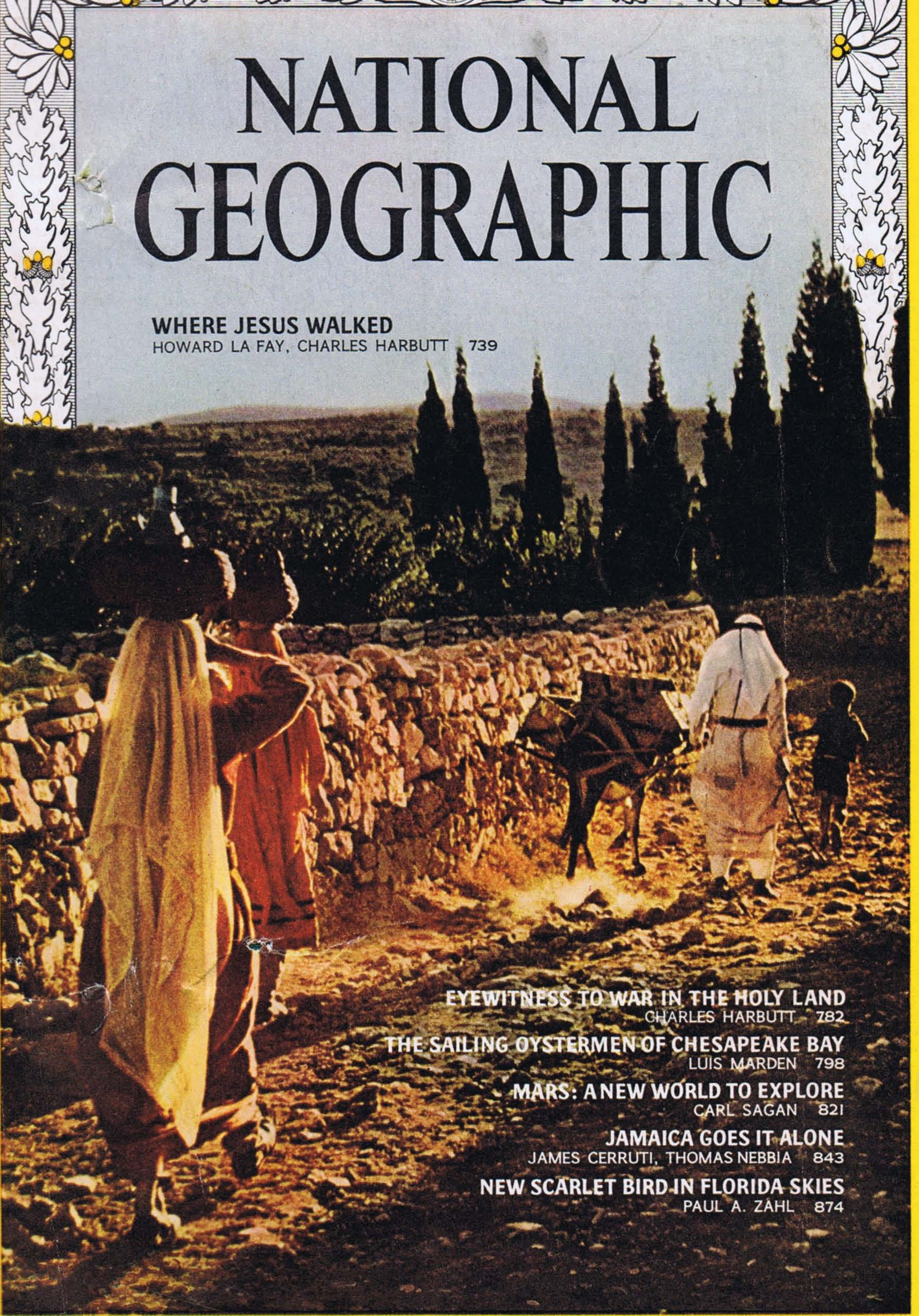

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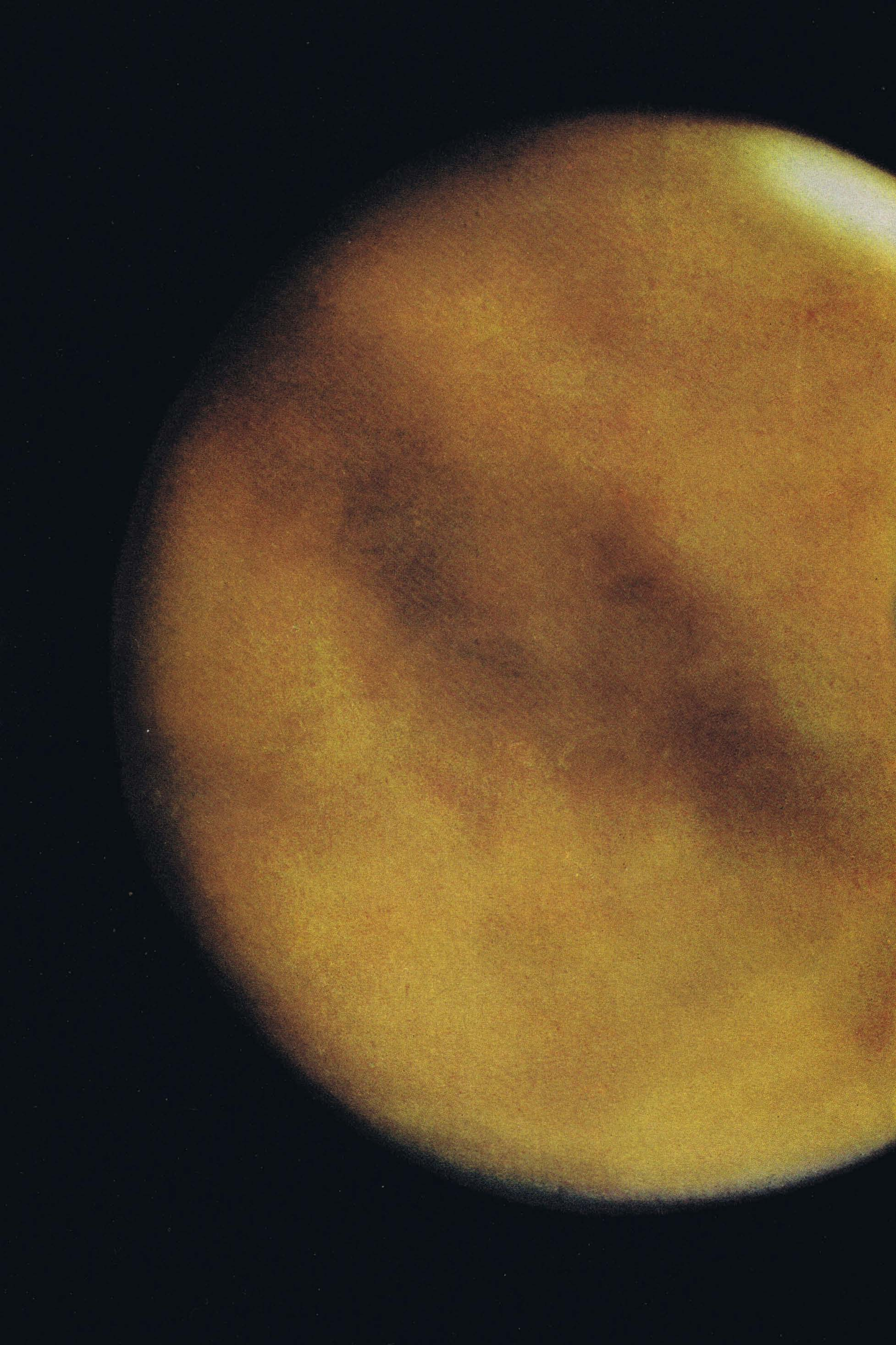
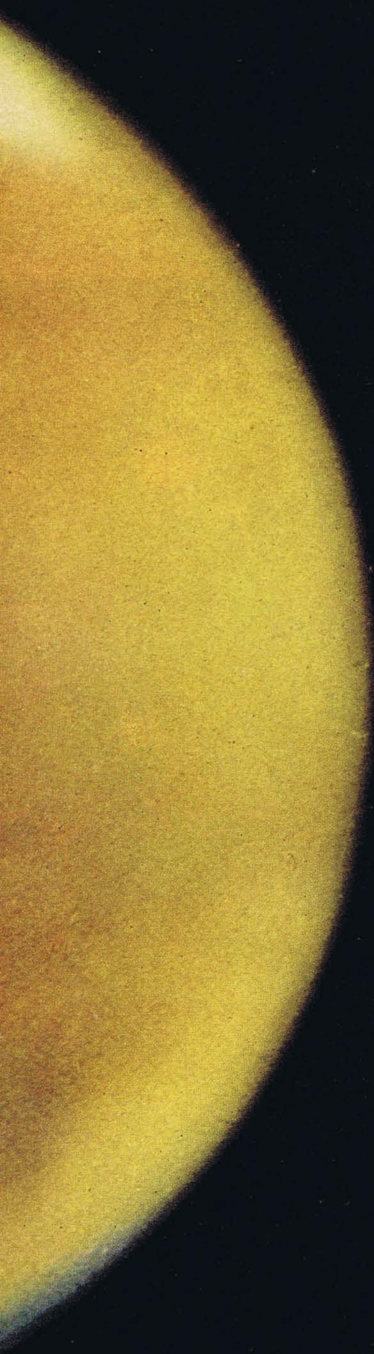




MARS A New World to Explore

By CARL SAGAN

FOR THOUSANDS OF YEARS the red planet Mars has filled man with awe and stirred his imagination. Its unwinking, baleful gleam, at times one of the most brilliant sights in the night sky, spelled death and disaster to the ancients. They gave it the name of their god of war, and sacrificed human lives to propitiate its wrath. A joined spear and shield became its symbol. And its two tiny moons came to bear the names of the war god's attendants, Phobos and Deimos—Fear and Terror.

In more modern—and more scientific—times, man lost some of his dread and began to speculate on the possibility that Mars is inhabited. Astronomers, peering through

DEAD OR ALIVE? ***Earth's atmosphere tauntingly blurs the ruddy face of Mars, seen 35,000,000 miles away through a telescope atop Mount Wilson, California. Scientists have long pondered the riddle of the planet's polar caps and ocher landscape that change with the seasons. Now space technology promises to reveal in the next decade whether earth's neighbor harbors life or spins through eternity as a sterile desert.***

KODACHROME BY DR. ROBERT B. LEIGHTON
CALIFORNIA INSTITUTE OF TECHNOLOGY © N.G.S.

telescopes at the fuzzy orange ball, sought on Mars an answer to the ancient haunting question: Is there life out there?

But at best the images seen through a ground-based telescope vary from moment to moment, and even from observer to observer. If simple visual observation were the only method at our disposal, Mars would remain an enigma, populated by the products of our wishes and our fears, unconstrained by much contact with the facts.

We may soon solve the riddle, however, for recent years have seen revolutionary improvements in astronomy. With radar we probe the topography of Mars; with spectroscope and polarimeter, with infrared and radio techniques, we analyze its radiations. Rockets and spacecraft now carry some of our instruments above earth's interfering blanket of atmosphere. Through the tools of modern physics we can now learn much about the Martian atmosphere and surface, its temperatures, even its winds.

And with the spacecraft Mariner IV we have secured the first close-up photographs of Mars, from less than 10,000 miles away

PAINTING BY

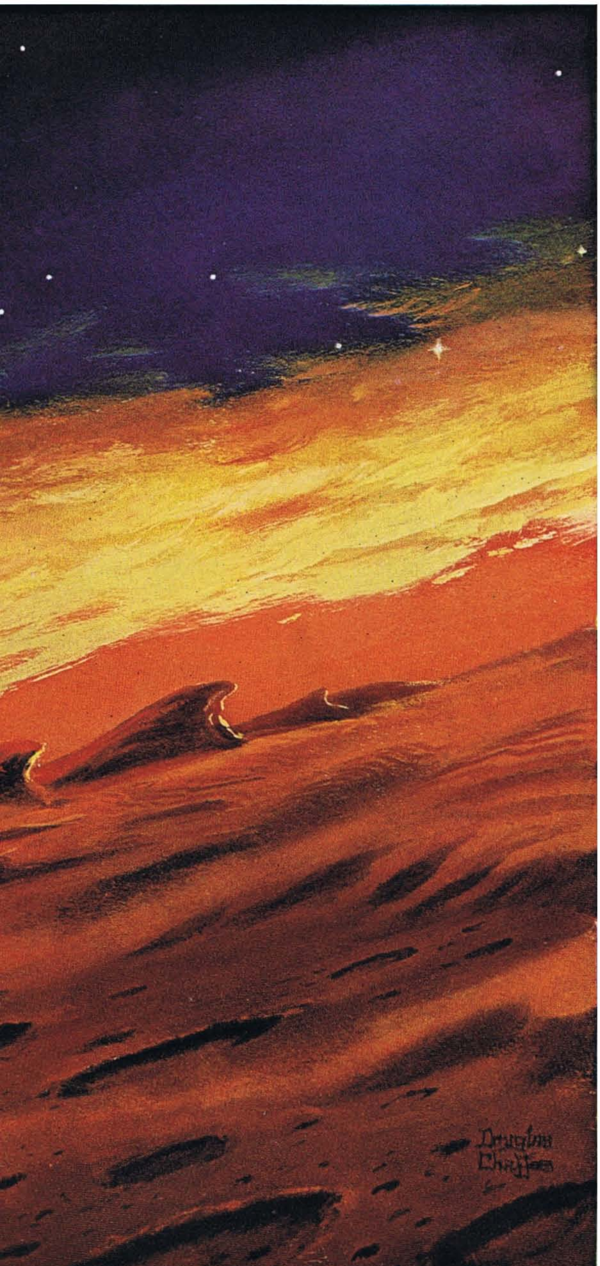
(next page). Today a portrait of our neighboring planet is taking shape that differs in many ways from the ideas held by astronomers only a few years ago.

Mars – Most Earthlike Planet

We know that the first men who land on Mars (we could be ready for interplanetary travel by the 1980's) will be able to move with comparative ease: Mars has only about half the diameter and a tenth the mass of earth; its gravitational pull is therefore lower, and a man on Mars will weigh only about 40 percent of his weight on earth.

Those first explorers, we also know, will need protection against the lack of oxygen, ultraviolet radiation from the sun, low atmospheric pressure, and extremes of cold. At the same time they may find Mars the most hospitable and earthlike of all our neighbors in the solar system. There they will find wind and water; carbon dioxide and sunlight; clouds, rolling hills, and deserts; winter frosts and balmy summer afternoons.

By contrast, other bodies in our solar system seem forbidding indeed. Our moon is airless

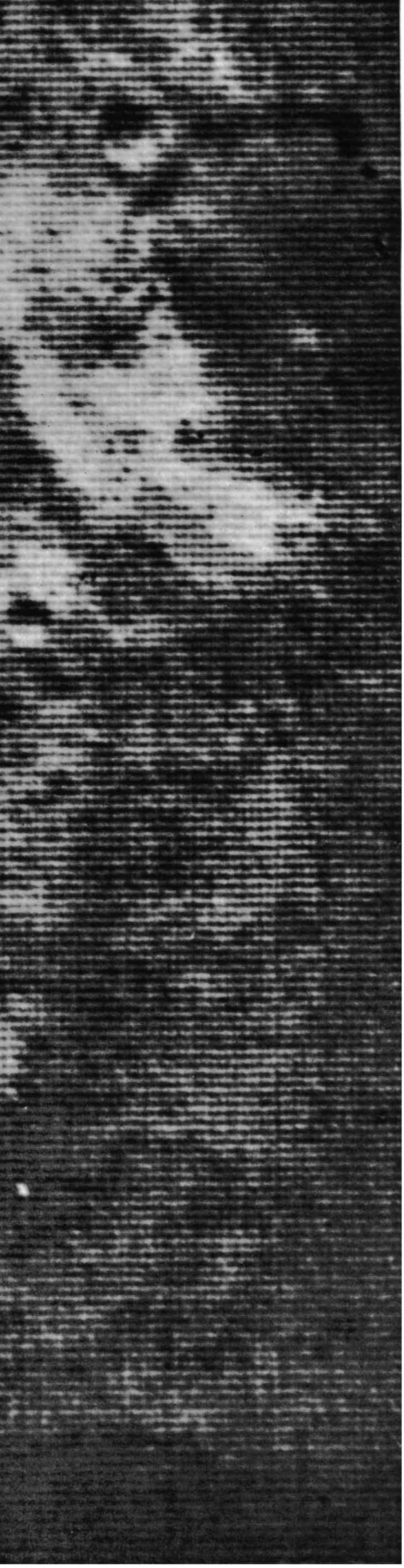


Puffs of "Mars dust"—actually samples of earth's own iron oxides on a sheet of glass—frame author Carl Sagan, who believes that Voyager (left) will find the Martian surface powdered with such rustlike substances. Today, knowledge of Mars remains a matter of scientific inference; in this article Dr. Sagan presents his views. His credentials: Assistant Professor of Astronomy at Harvard, staff member of the Smithsonian Astrophysical Observatory, and consultant to the National Aeronautics and Space Administration, the Air Force, and the National Academy of Sciences.

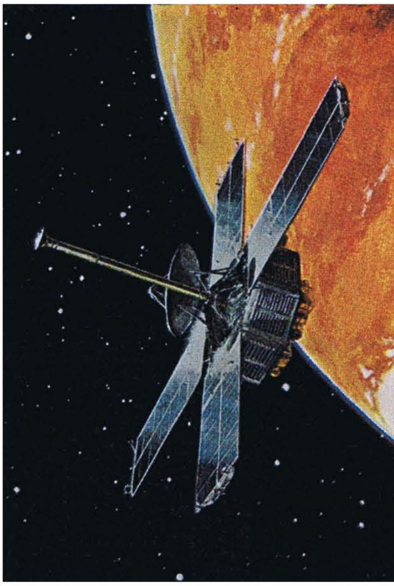
Space-age *Santa Maria,* braking its descent with rockets, eases onto the new world of Mars. Completing an eight-month voyage, the unmanned ship finds a surface pocked by meteorites and scoured by dust storms.

The time: possibly 1974, if things go well for the first of the yet-unborn generation of U. S. spacecraft named Voyager. Its complex scientific systems will "taste" the soil for mineral content and evidence of living matter; television cameras and other instruments will beam back to earth data that will, scientists hope, resolve questions vexing man since the time of the Babylonians, who associated the planet with war.

OUGLAS CHAFFEE; KODACHROME BY NATIONAL GEOGRAPHIC PHOTOGRAPHER BRUCE DALE © N.G.S.



Cratered surface, photographed by Mariner IV in its historic flyby of Mars in 1965, surprised some scientists. From 7,800 miles away, this picture of the Mare Sirenum area (lower map, page 831) revealed eroded, meteorite-blasted craters as small as 3 miles across. Other Mariner IV photographs showed even smaller features.



Second flyby of a Mariner, set for 1969, will pass within 2,000 miles of Mars. It will make wide-angle and high-resolution photographs of the planet, including close-ups with ten times the clarity of those from Mariner IV.

and waterless, alternately oven-hot and freezing-cold. Cloud-wrapped Venus, between us and the sun, suffers temperatures hot enough to melt lead. Daytime surface temperatures on airless Mercury, even closer to the sun, are also unbearably high. Jupiter and the other outlying planets are much too distant for exploration in our time.

And so, in the search for life outside our own planet, we look to Mars, only 34,600,000 miles away at its closest approach to earth. Its 56,000,000 square miles—comparable to the total land area of earth—represent an entire world awaiting its first explorer.

Does All Life Share a Common Origin?

Exploration of Mars holds immense significance. Such sciences as geology, meteorology, and biology base many of their laws on the single example of our own planet. By studying Mars, we can test these laws in other contexts, and perhaps derive more universal scientific principles.

As a case in point, an extraordinary fact has emerged in the past 20 years from developments in biochemistry and molecular biology. We have discovered that the basic similarities among organisms on earth are vastly more significant than the superficial differences. For example, all organisms—men and molds, shrikes and shrews, paramecia and poodles—use the same genetic molecules to store hereditary information, and break food down into usable form in virtually identical ways.

The source of these and many other astonishing regularities appears to be a common ancestry. All organisms on earth seem to arise from a single instance of the origin of life, dating back some four billion years to the remote recesses of our planet's past. Apparently we are all variations on the same biological theme.

But is there a repertoire of themes, or is there one tune only in the universe? Is our kind of biochemistry the only kind possible? No one yet knows, but we may find the answer on the planet Mars.

NASA (ABOVE); PAINTING BY DOUGLAS CHAFFEE © N.G.S.

KODACHROMES BY JONATHAN S. BLAIR (ABOVE) AND NATIONAL GEOGRAP

Duplicating harsh demands of the Martian environment, scientists test the hardiness of earthly life. Here biologist Paul H. Deal removes a rack of bacterial cultures from a freezer at NASA's Ames Research Center, Mountain View, California. Many of the bacteria thrived in a daily freeze-thaw cycle of minus 150° to plus 70° Fahrenheit.

And if we do discover life there, no matter how seemingly simple in form, everyone will recognize the immense philosophical as well as scientific significance of the discovery.

We are almost certain that many other stars have dark companions similar in mass to the planets of our solar system. Since we estimate that there are more than a billion galaxies, each with a hundred billion stars, we conclude that hundreds of billions of billions of planets may exist in the universe.

Can it be, then, in this vast array of possible habitats, that ours is the only inhabited planet? One way to answer such a question is to seek life on the nearby planets.

Let us consider, from what we have recently learned about Mars, how favorable an environment it may offer to living things.

For many years we have known that Mars has an atmosphere. In series of photographs taken at intervals, we can observe white clouds forming and dissipating. We can see dust storms raised by fierce Martian winds.

In the last few seconds before Mariner IV passed behind Mars, on July 14, 1965, radiotelescopes on earth measured the changes in the spacecraft's radio signals before they were finally blocked by the solid planet. Scientists were then able to deduce the density of the atmosphere that caused the signals to vary. They found that, at the surface, the Martian atmosphere is only about 1 percent as dense

In a plastic-domed "Mars jar," turtles easily endure one-tenth sea-level pressure. Research assistant Olive Daly uses a mechanical manipulator to handle one of thirty red-eared turtles that spent up to four months in this chamber at Union Carbide Research Institute, Tarrytown, New York. In another study, larvae of the common mealworm survived 70 days without oxygen.

Environment experimenter, Dr. Sanford M. Siegel prepares crayfish for a "Mars sojourn" at Union Carbide. In the cabinet, dwarf Swiss mountain pine and Peruvian apple cactus pass a test of no oxygen and a daily temperature range of 65° to minus 4° F.; rye and corn seeds sprouted under like conditions. Dr. Siegel feels his work supports the plausibility of life on Mars.

HOTOGRAPHER ALBERT MOLDVAY © N.G.S.

as that on earth—or about as tenuous as earth's atmosphere 20 miles up.

And what does this thin atmosphere contain? Unlike earth's air, which consists almost entirely of nitrogen and oxygen, the atmosphere of Mars appears to be largely carbon dioxide. It holds a tiny amount of water vapor, perhaps a few tenths of a percent of the water vapor in our air. If all this vapor were condensed, it would cover Mars with a film of water no more than a few thousandths of an inch thick.

Martian "Air" Lacks Oxygen

No other gases have been detected in the Martian atmosphere, though we think there may be some nitrogen and carbon monoxide.

The absence of oxygen anywhere near the surface does not, of course, exclude life. Scientists have good reason to believe, in fact, that oxygen was absent during the origin and early history of life on earth. Even today, certain familiar organisms live very well without oxygen; some, like the bacteria that cause tetanus, are actually poisoned by it.

Rocket observations show Mars to lack ozone, a variety of oxygen with three atoms instead of the usual two to each molecule. Ozone exists in small quantities high up in our atmosphere, and does earthly life a great service by absorbing most of the flood of deadly ultraviolet radiation from the sun. Otherwise, most familiar life would cease to exist; hospitals, in fact, commonly use ultraviolet light as a germicide.

Thus if no other absorber of ultraviolet light exists in the Martian atmosphere, most organisms from earth would be killed there in a matter of minutes, unless they found some kind of protective shielding. Curiously enough, however, the desertlike surface of Mars seems to contain large amounts of a mineral known as limonite, made up of iron oxides that absorb ultraviolet light. So if a Martian organism used a limonite shield, or if a small terrestrial organism hid under a grain of limonite, it might readily survive the searing solar ultraviolet radiation (page 833).

Mild Days and Bitter Nights

The climate on Mars, just as on earth, is affected by the length of the day, the length of the year, and the amount the planet's axis of rotation is tilted from the plane in which it moves about the sun.

By some quirk of nature, both the length of the Martian day (24 hours and 37 minutes) and the tilt of the axis (about 24 degrees) strikingly resemble those of earth. The similarity to earth's tilt of 23½ degrees gives Mars seasons of the same relative duration as ours. However, since Mars lies farther from the sun and travels about it more slowly, its year runs longer than our own—687 days.

We can determine temperatures on Mars by placing heat-detecting devices such as thermocouples or bolometers at the focus of a large telescope. They measure the infrared, or heat, radiation that Mars emits into space. In this way astronomers find that a typical ground temperature at the Martian equator on an early afternoon in summer might be a comfortable 70° Fahrenheit. But a few yards up, primarily because of the thinness of the atmosphere, it might be below freezing. And that night the temperature would drop to almost 150° below zero. So low, in fact, does the temperature fall that every morning a frost can be observed—the so-called dawn haze.

No one should be surprised that Mars is colder than earth. It is roughly half again as far from the heat-giving sun, and its thinner atmosphere and drier surface do not retain heat nearly so well as earth's.

Although earth's air usually distorts the telescopic image of Mars, in the same way that hot air rising from a toaster distorts your breakfast partner's face, sometimes the atmosphere temporarily steadies. Then come breathtaking moments of crystal-clear seeing.

Some observers spend long hours at their eyepieces waiting for such moments. When surface details of Mars suddenly pop into sharp focus, the astronomers quickly record their impressions in notes and sketches. (Photographs always seem to miss the finest details.) Many years of visual and photographic observations have clearly defined three kinds of areas on the Martian surface:

(1) Bright areas, buff or orange-ocher

(2) Dark areas, predominately orange-gray, although some scientists still see them as greenish or bluish-gray

(3) Brilliantly white polar caps

The first of these, the bright areas, seem to be regions of wind-blown sand and dust. Analysis of both ordinary and infrared light from Mars has led to the suggestion that these bright areas are composed in part of limonite—a kind of rust with water chemically bound to it. The manner in which light is reflected and energy emitted from Mars—as well as the existence of dust clouds—shows that the Martian surface is finely pulverized.

Limonite readily absorbs the blue and ultraviolet light from the sun, but reflects much of the red light, thus giving Mars its characteristic coloration. The ancients, as far back as the Babylonians of the second millennium B.C., identified the planet with the god of war—perhaps because of its blood-red appearance—and there is a certain logic in this connection. Mars is reddish because of limonite (if our conclusion is correct). Blood is red because of hemoglobin. Both limonite and hemoglobin contain iron. Thus iron links the god of war with the sun's fourth closest planet.

Mystery still surrounds the dark areas of Mars. They are often described as maria, or dry seas. However, I conclude that they are largely elevated and covered chiefly with pulverized material like that of the bright areas, except that the particles are larger. Such larger particles would reflect light more poorly and give a duskier hue.

Meteorite Craters Pock the Surface

Both dark and bright areas were named before the turn of the century by the Italian astronomer Giovanni Schiaparelli, who knew more Greek and Latin than most of us know today. So we find such place names on Mars as Mare Sirenum, Hellas, Xanthe, Mare Erythraeum, and even Utopia (maps, page 831). One day men will walk these places, and the names will be everyday words.

And when men do arrive, after an eight-month voyage through space, they will wander over a gently sloping landscape marked by sand dunes and by enormous numbers of eroded, flat-bottomed craters. When the spacecraft Mariner IV sent back to earth 22

EKTACHROME BY JACK FIELDS © N.G.S.

Blushing with a clue to its identity, a solution fluoresces in ultraviolet light. The reaction of a fluorometer tells Dr. Joon H. Rho that the tube contains chlorophyll. At the California Institute of Technology's Jet Propulsion Laboratory, the biologist hopes to design a compact device that could analyze Mars for compounds such as proteins, sugars, or chlorophyll, by measuring stimulation of soil samples under irradiation.

photographs of Mars, some scientists were startled to see the surface heavily pocked by craters (pages 824-5). Almost certainly, these were produced by huge meteorites—fragments from the asteroid belt, the ring of rocky and metallic debris that whirls around the sun between the orbits of Mars and Jupiter (diagram, page 831).

The white polar caps are the third of the familiar Martian areas. Each grows during winter, recedes in spring.

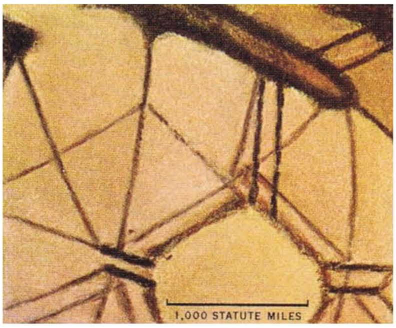
As a cap recedes, water vapor in the atmosphere above the pole appears to increase, suggesting that the caps consist of a very thin layer of frozen water—somewhat like earthly frost on a cold winter morning.

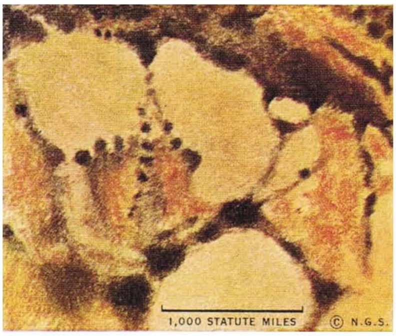
Actually they may contain more dry ice than ordinary ice. It is calculated that the poles reach temperatures as low as minus 200° F., at which point carbon dioxide would also freeze out of the Martian atmosphere.

We may learn for sure in 1969, when the National Aeronautics and Space Administration expects to send two Mariner spacecraft

Bleak stretch of Sahara near Sinkat, Sudan, may be one answer to a Martian puzzle. Dark straight streaks in this aerial photograph resemble the network of "canals" that some astronomers have seen cobwebbing the surface of Mars (below). Here black dolerite resists wind erosion better than surrounding rock, and forms ridges that drifting sand alternately covers and uncovers.

KODACHROME BY KINGSLEY C. FAIRBRIDGE © N.G.S.





Opposing views of "canals": Italian astronomer Giovanni Schiaparelli drew the top one in the 1880's after observing what seemed a lacing of continuous lines about Elysium. Years later E-M. Antoniadi, a Greek observer using a more powerful telescope in France, pictured the same area as marked by strings of disconnected detail.

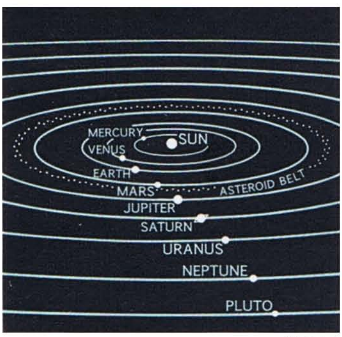
Schiaparelli called the features he observed *canali,* or channels. But others translated the Italian word as canals. Percival Lowell, an American astronomer, concluded that a race of intelligent beings dug the canals to irrigate Mars with melt from its polar caps. His convictions stimulated scientific interest in Mars, and inspired English novelist H. G. Wells to write *The War of the Worlds*. In 1938 a radio adaptation of that science-fiction classic panicked listeners who accepted the drama of a Martian invasion as a news report.

Pieced together from centuries of meticulous observations, these maps locate the three basic Martian features: dark areas, bright areas, and the frostlike cap that covers each of the polar regions in winter.

Like earth, Mars experiences seasons. Spring causes polar caps to recede, and a wave of darkening sweeps from them toward the equator. Once scientists considered dark regions bodies of water, describing them in Latin as *mare*—sea, *lacus*—lake, and *sinus*—gulf. But the author believes dark areas generally correspond to highlands; bright ones, he thinks, are dusty basins analogous to earth's ocean basins.

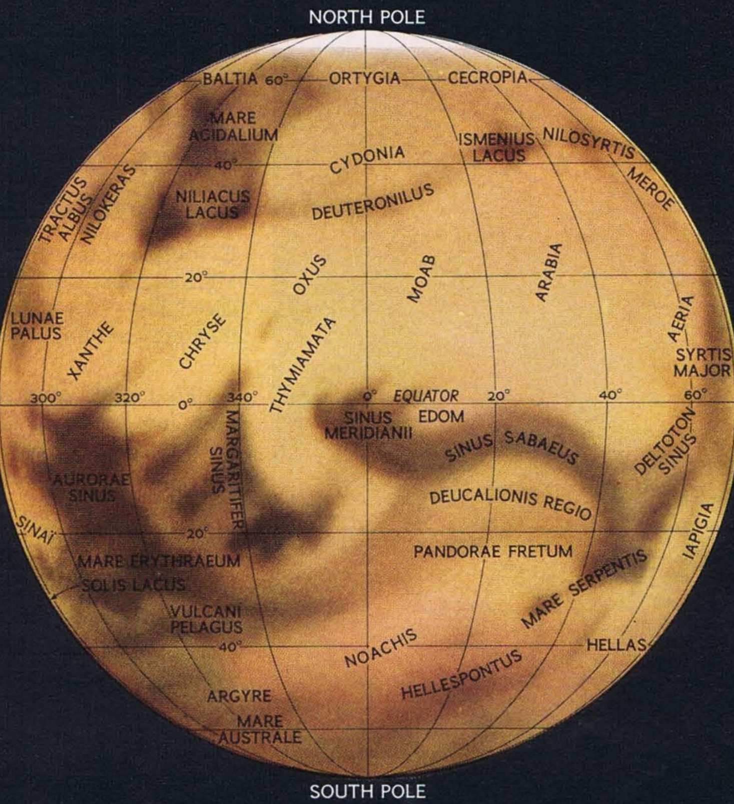
Mars measures some 4,200 miles in diameter. It has only a tenth of earth's mass, but exerts a gravitational pull about 40 percent that of earth. Infrared readings indicate surface temperatures at the Martian equator vary daily from 70° to minus 150° F. A Martian day lasts 24 hours, 37 minutes, 22.7 seconds.

Mariner IV—beeping signals through Mars' atmosphere—helped scientists calculate the surface air density to be about 1 percent of earth's. They think this tenuous atmosphere is composed largely of carbon dioxide, with only a trace of water vapor.

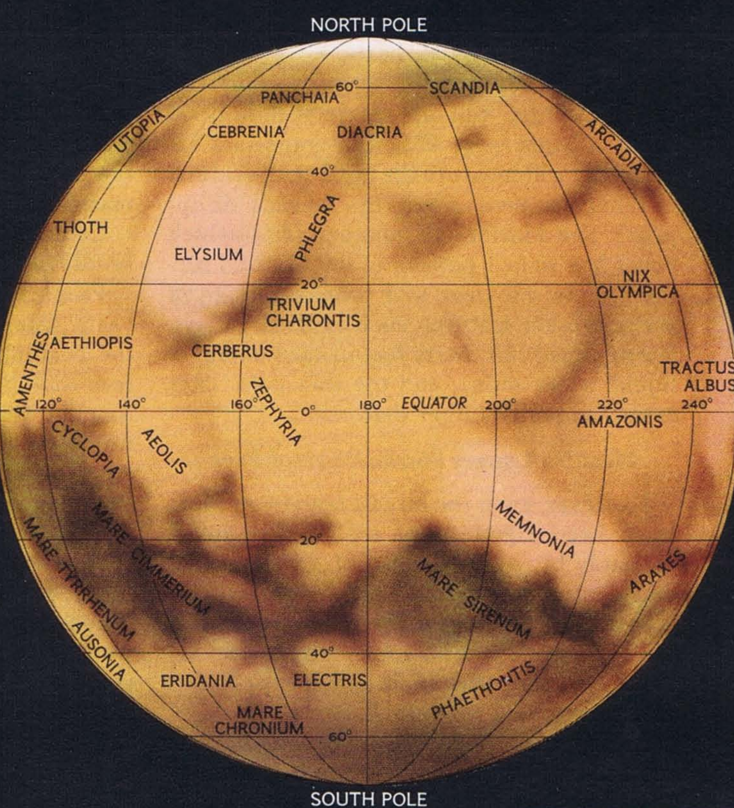


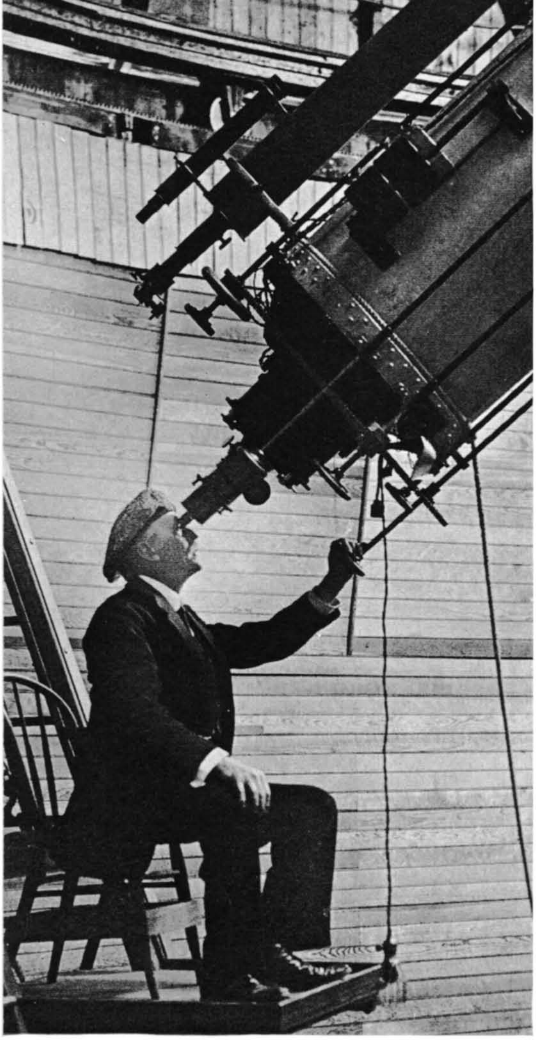
In stately orbits, planets revolve about the sun. Farther out and slower than earth, Mars takes 687 days to make one circuit.

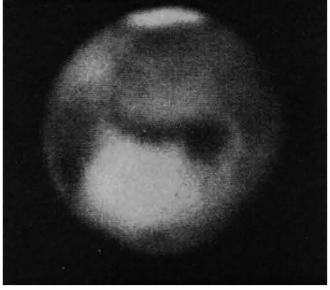
Unlike maps, photographs are usually reproduced with Mars' south pole at the top, because telescopes invert images. Hazy bluish cloud over the north pole on pages 820-21, called the polar hood, appears in late fall.



MARS



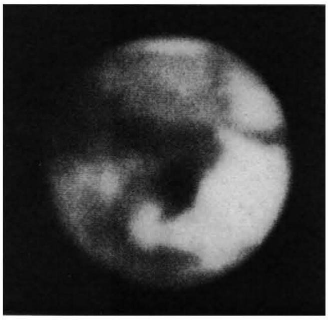


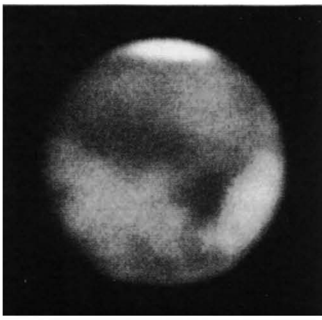


Evidence of seasons: As the polar cap recedes, between the Martian months of May (left) and July (right), a wave of darkening sweeps toward the equator, increasing the contrast between bright and dark areas.

Seeking signs of intelligent life on Mars, Percival Lowell peers into a 24-inch telescope at Flagstaff, Arizona, in this old photograph. The observatory he founded there in 1894 has long been a leading center of Mars study.

Mysterious areas of darkness show up in nonseasonal changes. From the dark center patch of Syrtis Major in March, 1954 (left), a curving band extends toward the lower left. The feature was barely discernible in April, 1907 (right).





PHOTOGRAPHS COURTESY LOWELL OBSERVATORY

on flybys that will approach within 2,000 miles of Mars (page 825). One important experiment will measure the polar temperature.

What happens when the icecaps disappear? The Mariner IV photographs—which cover less than 1 percent of the Martian surface—show no clear and prominent sign of water-erosion features, such as river valleys. We expected this. Mars has no open bodies of liquid water today, and the thin polar caps simply vaporize rather than melt.

Mars No Longer Shows Original Face

However, even the largest craters on Mars have been significantly eroded and filled, probably by wind-blown dust, by expansion and contraction under huge daily temperature changes, and by new craters. Because of the erosion, we can no longer see the original surface of Mars. Perhaps in earlier eons oceans of a sort lapped Martian shores.

In any case, large bodies of liquid water are not required for the origin of life; in many respects, shallow pools or underground lakes provide better environments. We cannot exclude the possibility that even today, below the arid Martian surface, lies a layer of permafrost, with liquid water still deeper.

Could life exist on Mars, in the apparently hostile environment we have described?

People have thought so for several hundred years. One of the arguments, advanced about the beginning of the century, hinged on the fact that people looking through telescopes thought they detected green areas. This is now known to be partially an optical illusion. Also, green does not prove vegetation—nor does lack of it prove there is none. Plants, if any, on Mars may be a different hue.

Another argument centers about the famous "canals." In the 1870's and 1880's Schiaparelli discovered through his telescope a network of delicate dark lines that occasionally stood out "like the lines on a fine steel etching," as a later observer described them. The lines seemed straight and proceeded for hundreds of miles across bright areas, connecting distant dark regions with one another.

Schiaparelli called them *canali*—by which he meant simply "channels." But the lines were interpreted, especially by the American astronomer Percival Lowell, as waterways of a race of intelligent beings.

Lowell and his followers believed that the Martians constructed the canals to bring water from melting polar icecaps to parched cities near the Martian equator. Some even described Martian hydraulic engineering and placed the political capital of the planet in Solis Lacus—Lake of the Sun.

Canals: A Trick of the Eye?

Scientists today differ on whether the lines exist. Those who do recognize them have found that, when earth's atmosphere becomes exceptionally clear and steady, the lines break down into fine but disconnected detail, rather like dotted lines. Psychologists explain that when the eye sees such disconnected markings at a distance, the brain characteristically ties them together and remembers them as unified lines (page 830).

So, although we do not now believe in canals created by intelligent Martians, we still must explain why the disconnected fine details are arranged in such long, straight lines—something quite remarkable in itself.

Mariner IV photographs did record narrower lines, invisible from earth. Some appear as ridges, others as depressions. Their relation to the classical "canals" is in dispute.

Another set of enigmatic observations which seems to argue for life on Mars concerns the seasonal changes in the dark areas. As the polar caps retreat each year, releasing water vapor into the atmosphere, we observe a wave of darkening, increasing the contrast between bright and dark areas and progressing steadily toward the equator (opposite).

What would be more reasonable than to conclude, as did the French astronomer E. L. Trouvelot in 1884: "Judging from the changes that I have seen to occur from year to year in these spots, one could believe that these changing grayish areas are due to Martian vegetation undergoing seasonal changes"?

Many other scientists have accepted this hypothesis. Among them was the late Dr. E. C. Slipher of Lowell Observatory at Flagstaff, Arizona, who from 1905 to 1964 devoted

If Martian life exists, its higher forms might look somewhat like these, the author conjectures. Shielded from ultraviolet radiation by a glassy shell, an animal gorges on mossy ground cover among plants with cabbagelike tops. Outer leaves close at night to protect buds from cold. Like the ground cover, these plants have developed an ultraviolet tolerance. Others, lacking such immunity, wear transparent bubbles.

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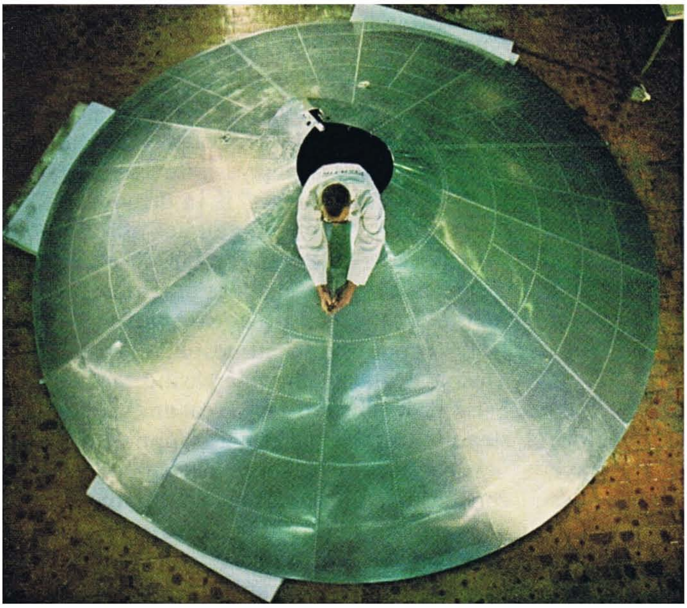
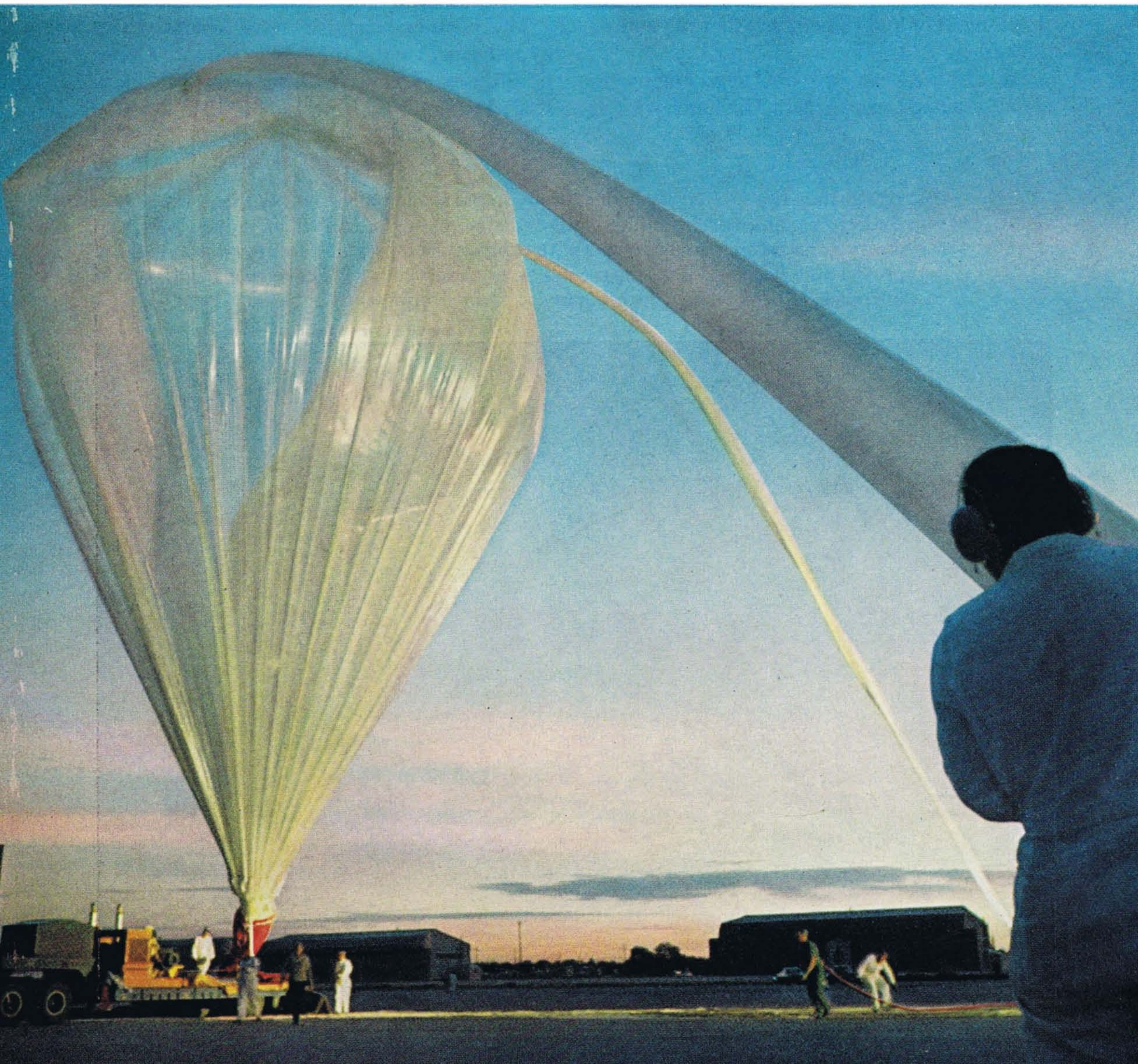
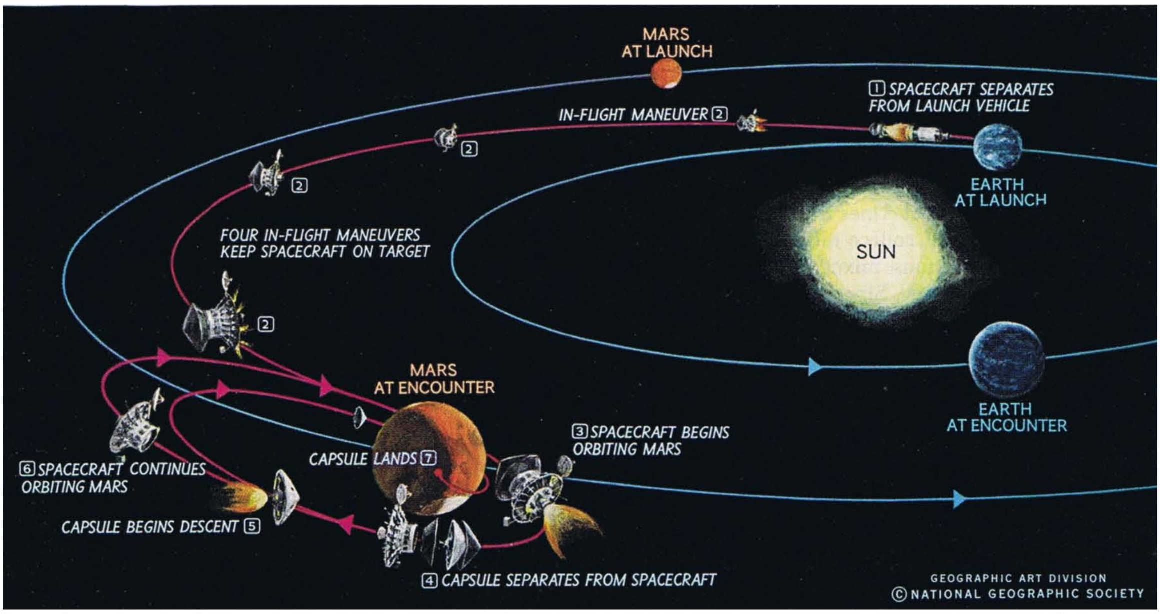


Real flying saucer: A conical metal aeroshell such as this may shield an instrumented package entering Mars' thin atmosphere. A Martin Marietta Corporation technician at Denver inspects riveting on the aluminum cone.

Inhaling helium through two ducts, the world's largest balloon lifts its head at Walker Air Force Base, New Mexico. As the plastic balloon rises in the rarefying air, the gas expands to fill the main body—here a bright streak on the ground—to a 410-foot bubble. It carries an aeroshell 25 miles into an atmosphere as thin as that 7½ miles above the Martian surface. There the aeroshell, fired by rockets, will test a parachute's ability to slow descent in a Mars landing.





PAINTING BY DOUGLAS CHAFFEE; EKTACHROMES BY KENYON COBEAN (LOWER LEFT) AND LOWELL J. GEORGIA © N.G.S.

Voyager races Mars to an encounter on the other side of the sun, following a Cape Kennedy launch in the 1970's. After the spacecraft enters an orbit about its target, a cone-shaped capsule called the "lander" detaches from the "orbiter." Braking by aerodynamic drag, possibly with a parachute, and by retrorockets, the lander touches down on Mars (page 822). It radios findings to earth either directly or by relay through the orbiter, itself making observations from above.

a lifetime to observing and photographing the planets. Much of his work was aided by the National Geographic Society.

In 1955 Dr. Slipher wrote of the waxing and waning dark areas, "To me, the best hypothesis still seems to be . . . vegetation able to grow through the yellow dust deposited upon it from time to time." *

Another astronomer, the Frenchman Audouin Dollfus, observing the polarization of sunlight reflected from Mars, has concluded that the wave of darkening is accompanied by a change in the sizes of the particles which make up the dark areas. In other words, we see bigger grains in spring than in winter.

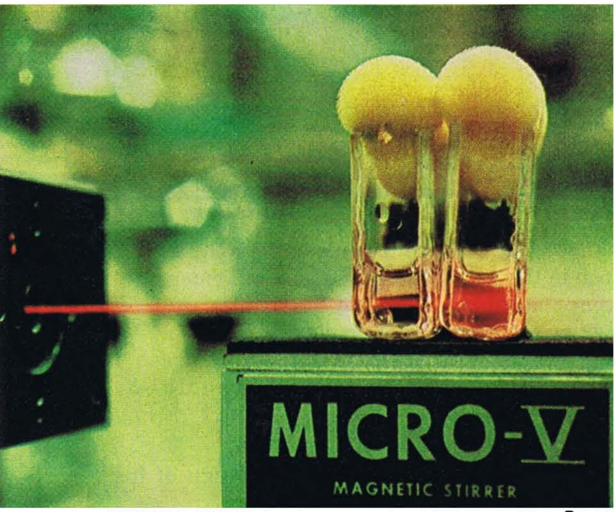
If the wave of darkening *is* biological, we may actually be seeing the growth and reproduction of Martian organisms only about the size of the period at the end of this sentence. These, perhaps, would be comparable to the algae and lichens we know on earth.

My colleague James B. Pollack and I, at Harvard University and the Smithsonian Astrophysical Observatory, have been working on nonbiological explanations of several of these Martian enigmas. Formerly scientists thought the dark areas were lowland basins, but we have analyzed radar signals bounced off Mars, as well as other evidence, and have found indications that many dark areas are gentle slopes reaching heights of as much as ten miles. We think the bright areas tend to be lowlands, similar to our ocean basins, but filled with dust rather than water. And the canals that cross these dusty seas, and at least some of the finer lines found by Mariner IV—as we interpret the evidence—turn out to be ridges comparable to the oceanic ridges and seamounts that lace ocean bottoms on earth.†

*See "New Light on the Changing Face of Mars," by E. C. Slipher, NATIONAL GEOGRAPHIC, September, 1955.

†Such topography marks the special map supplement, **Indian Ocean Floor,** distributed with the October, 1967, GEOGRAPHIC.

Piercing laser beam finds life. It passes intact through a glass container of sterile solution, but micro-organisms in a second container diffuse the crimson shaft. The NASA experiment at Ames Research Center shows how a light source might be used to test similar solutions mixed in a Voyager biological laboratory. Since microscopic life exists universally and abundantly on earth, researchers feel such minute game offers the best hunting for traces of Martian life.



KODACHROME (OPPOSITE) BY J. R. EYERMAN; EKTACHROMES BY JACK FIELDS © N.G.S.

The idea that the bright areas are lowlands makes sense in several ways. For one thing, as the polar caps retreat, they leave islands of frost behind, more often in the bright than in the dark areas. If the bright areas are lowlands, we expect that the winds would not be quite so violent there and that the vaporizing frost would not be blown away so readily.

Also, on a planet where the winds blow fine dust about, we would expect the finer and brighter particles to tend to settle in the lowlands. Aerial photographs in the Sahara, where the wind blows fine dust off the highlands, show such reddish dust-filled lowlands and darker highlands (page 830).

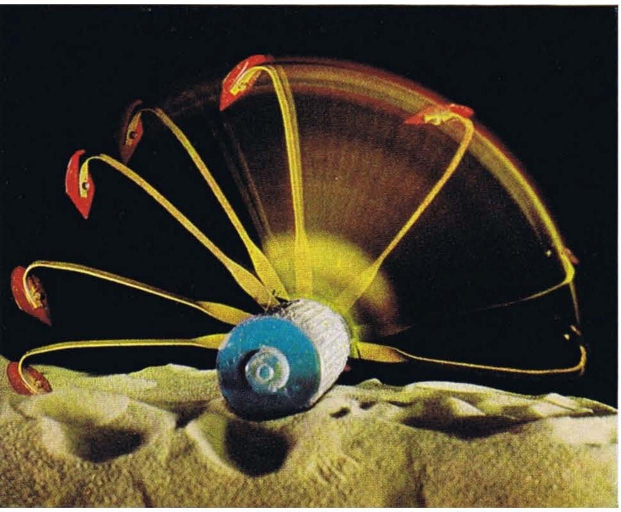
We often observe erratic changes in the shapes of the dark areas. I think we can explain them as drifting sand and blowing dust that cover and uncover the lower slopes.

The seasonal changes, the wave of darkening, may be caused by springtime winds that scour the finer, brighter particles off the hills. The more furious winter winds, blowing well over a hundred miles an hour, then drive small particles uphill again, making the highlands somewhat less dark.

Thus wind-blown dust, and not living plants, may explain these intriguing changes on Mars (page 832).

But even if we discard the "evidence" of the green coloration, of the canals, and of the

Dropping anchor, a sampler digs into simulated Martian soil with a hoe-tipped arm, swinging in this multiple exposure. Spinning independently of the arm, the perforated cylinder sucks in grit for later analysis. To roll elsewhere, the sampler flips back the arm and lets it drag behind.



Ingenious snares for signs of life lie on a 12,000-foot granite-strewn height of California's White Mountains. Such experimental paraphernalia help shape concepts for the scientific package that Voyager will deliver to Mars.

The picture-taking mast of an automated laboratory—here a quarter-scale model—periscopes to 16 feet. As a microphone listens for sounds, samplers collect soil for chemical analysis. Gas chromatographs examine the material for molecular content, while another device attempts to grow cultures of any micro-organisms captured. Thirty-five separate experiments measure environment as well as seek characteristics of life.

Bullet-shaped Gulliver detects metabolism, the conversion of food to energy and new cell structure by living organisms. It obtains testing matter by reeling in sticky lines shot out by projectiles.

Multivator, right foreground, breathes dust-bearing air into 15 cartridges that check for enzymes involved in metabolism.

Beside it sits a small model of a three-legged vehicle that might land Voyager's 860-pound laboratory (pages 822-3).

springtime darkening, we may still believe that life can exist on Mars.

For one thing, we do not expect that signs of life would be visible over interplanetary distances. The Mariner IV photographs of Mars do not detect features much less than two miles across. Weather-satellite photographs of earth, at about the same resolution, show virtually no signs of life on our planet.

For another thing, experiments in a number of laboratories suggest that the Martian environment does not rule out life. In our own laboratories, for example, we have designed special chambers where we can simulate the Martian environment. They are, of course, called "Mars jars." With earthly organisms, mainly bacteria, in the jars, we have reproduced the daily temperature variations, the low atmospheric pressure, the composition of the Martian air, and the ultraviolet radiation.

Earth Life Survives Martian Conditions

Most of the organisms quickly die. But in every sample of terrestrial soil we have found varieties of micro-organisms that survive the Martian conditions, some indefinitely.

They find the lack of oxygen and the temperature extremes to their liking. They find perfect safety, under small particles of soil, from the deadly ultraviolet light.

When the subsurface water content increases slightly, they thrive in the seemingly hostile environment, just as do such strange earthly creatures as iceworms that live on glaciers, algae that survive in scalding hot springs, or brine shrimp that easily take to the intense salinity of salt lakes.*

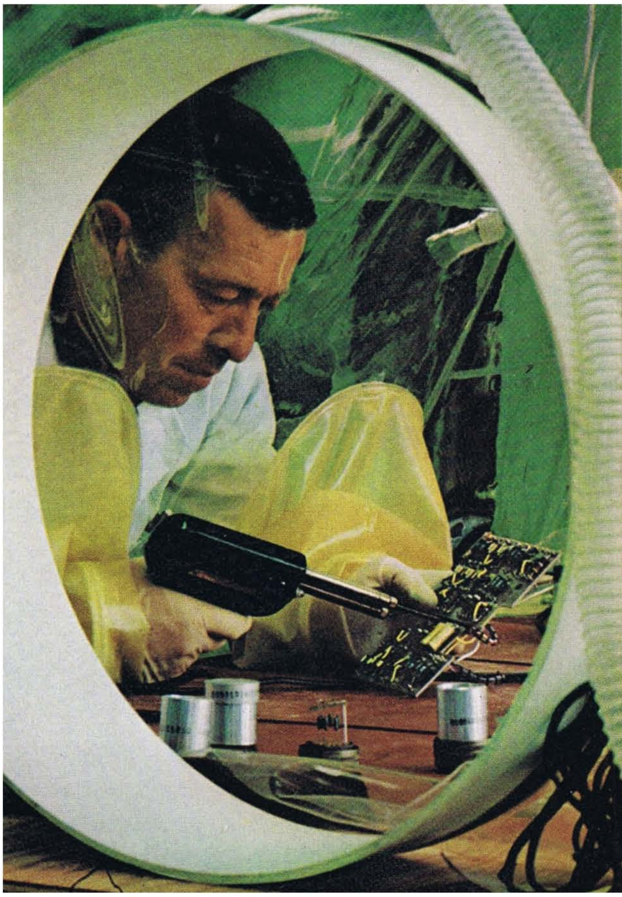
So it takes no great stretch of the imagination to believe that some earthly organisms would grow on Mars. And if terrestrial organisms can at least survive, native creatures should get along very nicely, for what seems to us to be a rigorous environment may not be rigorous at all for Martian life.

If there are Martian organisms—and scientists do not agree on this matter—we must expect adaptations there that do not occur here, because the histories of life on the two planets must have been widely divergent.

It may be that the oxygen bound in limonite is used for respiration. Perhaps some Martian enzyme is able to use the water chemically bound in the iron-rich soil. In fact, so much water is tied to the limonite that if the chemical bonds binding the water to the limonite can be tapped by Martian organisms, the bright areas on Mars may for them be oceans rather than deserts!

Sealed off from his work, a technician solders by using gloves built into an airtight plastic tent. At Denver, the Martin Marietta Corporation develops methods of repairing space parts under sterile conditions, since microbes, riding Voyager to Mars, could mislead life detectors and possibly set off a plague among any Martian life.

KODACHROME BY LOWELL J. GEORGIA © N.G.S.



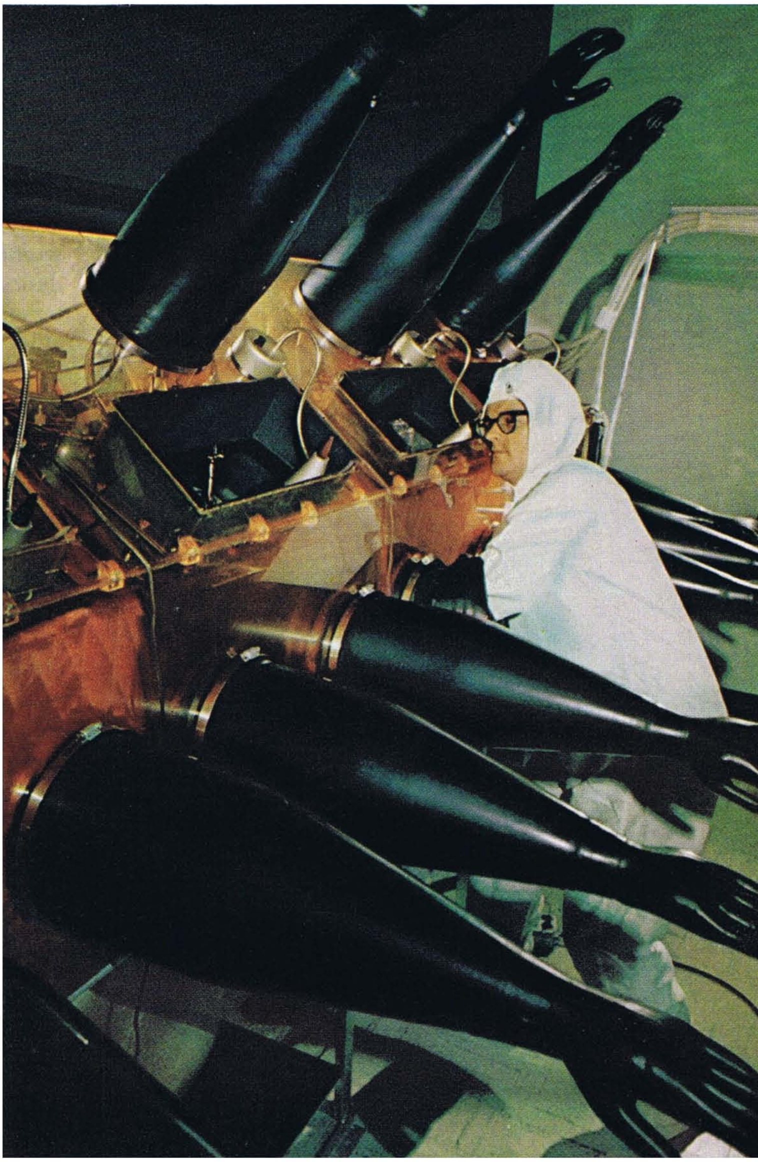
Aside from showing that life on Mars is within the realm of possibility, the Mars-jars experiments underline the problem of biological contamination of the planet.

Suppose an unsterilized spacecraft from earth crash-lands on Mars. Micro-organisms such as bacteria easily survive the crash. They escape and adhere to grains of surface material; winds spread them over the planet.

Some may find themselves in favorable environments, with neither competitors nor predators; they reproduce rapidly. In this way, descendants of just one micro-organism could, in theory, give Mars in a few years as many microbes as exist on earth.

*See "Life in a 'Dead' Sea—Great Salt Lake," by Paul A. Zahl, NATIONAL GEOGRAPHIC, August, 1967.

Many arms make germ-free work. Clad in sterile garb, William Butters uses rubber gauntlets to assemble electronic equipment inside a sealed chamber at McDonnell Douglas Corporation, St. Louis, Missouri. Air pressure keeps unused gloves extended and out of the way. To avoid polluting Mars, many companies study ways to keep Voyager uncontaminated while it is built and launched.



Revealing invasion of a sterile area, white gobbets show near the edge of a culture plate in a McDonnell Douglas test. Microbes burgeon into visible colonies in a nutrient coating on the plate.

KODACHROMES BY SCOTT DINE © N.G.S.

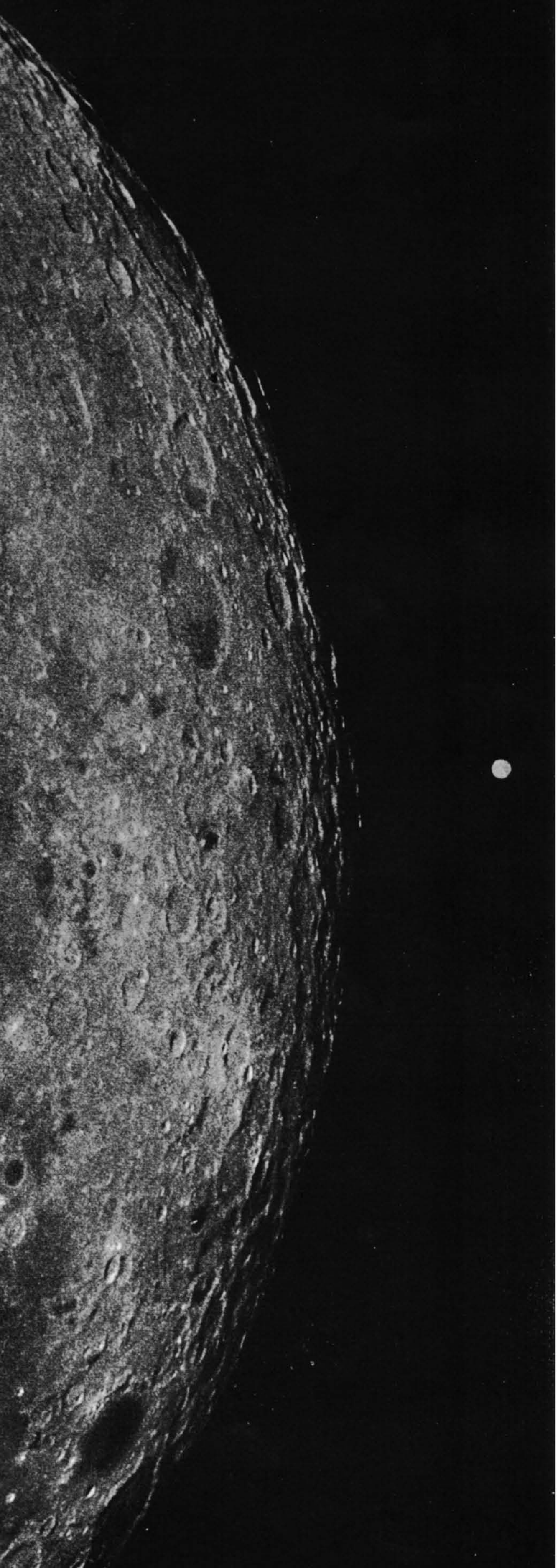
Now suppose we send an instrumented laboratory to Mars to search for native organisms (such laboratories are being developed in the United States and the Soviet Union). How can we possibly tell whether the bacteria we find are truly Martian, or alien contamination from earth?

Worse yet, suppose the invading bacteria produce a kind of plague, killing much of the native life. And even if there is no life on Mars now, there may be repositories of organic matter, created in the early history of that planet, still present because no organisms have appeared to eat them up. Contamination from the earth could destroy significant information about the early history of the solar system and the origin of life.

To avoid this danger, both the Soviet Union and the United States have established standards for sterilization of space vehicles. Costly but effective techniques include assembly of spacecraft in dust-proof clean rooms, dousing with germicidal gases, and heating at temperatures above the boiling point of water. The sterile spacecraft can then be enclosed in a shroud preventing contact with earth and its atmosphere.

Because of the contamination problem, we must learn much more about the environment and possible life on Mars before we land human beings, with their teeming populations of intestinal and skin micro-organisms.

And we can learn a great deal more from future probes orbiting Mars. Our instruments



can make temperature maps, seeking local hot spots; look for places of water abundance; detect organic chemicals that may be related to the presence of life.

For example, on earth the gas methane is produced by methane bacteria, such as live in the stomachs of cows. A spectrometer in orbit around earth would detect the gas, and would probably record an increased abundance over India, where live nearly a quarter of earth's cows. Now we would not be able to deduce from such an observation that there are cows on earth, but we would certainly suspect life in India.

Such experiments are in fact being planned for the Mariner space vehicles which will fly by Mars in 1969, and for the larger and more advanced Martian vehicles known as Voyagers, with which NASA hopes to orbit Mars and land an automatic biological laboratory in the 1970's (pages 835 and 837).

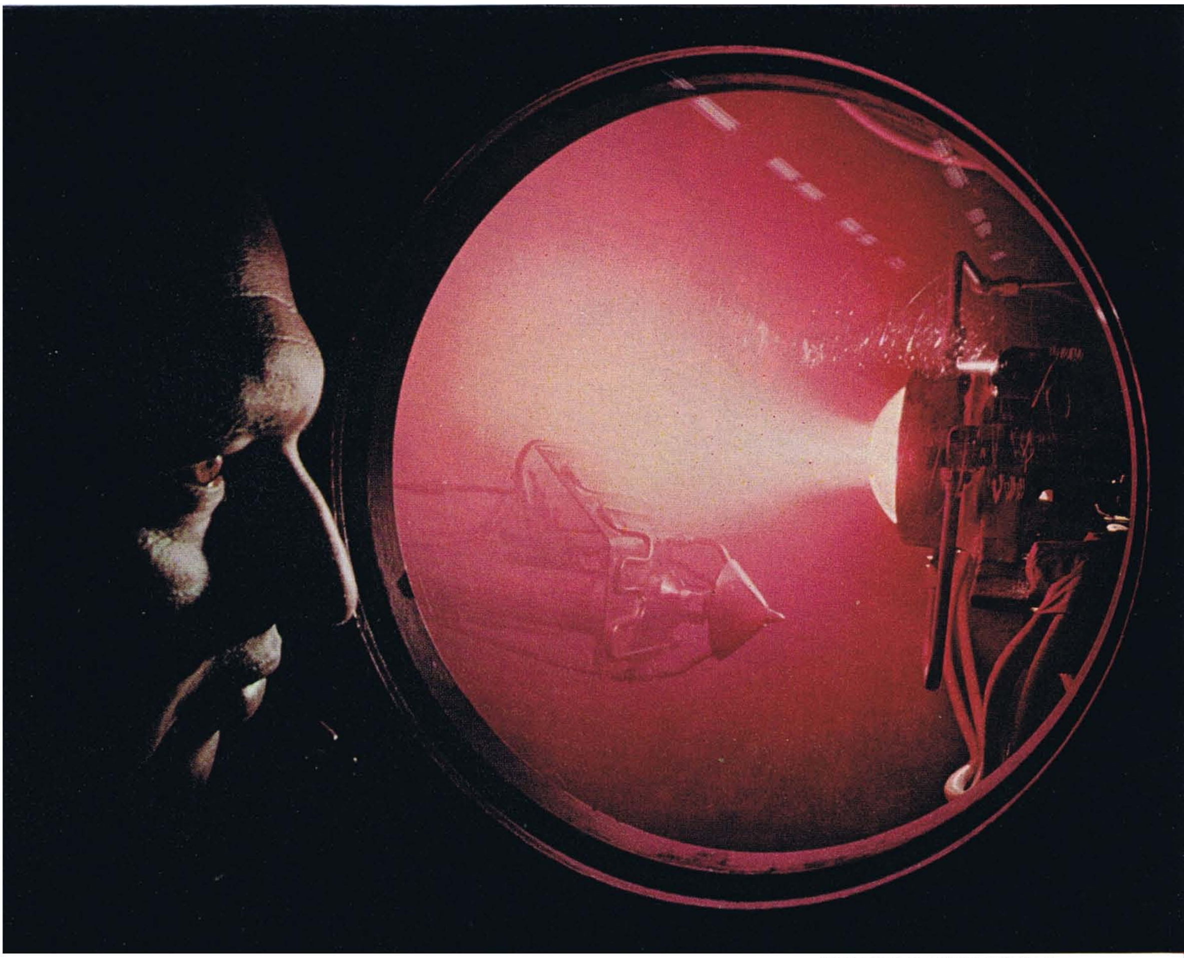
Only after such a graduated series of experiments, it seems to me, should we land men. But we can expect that one day human explorers and colonists will live and work on the sands of Mars.

Red Planet Challenges Man

We cannot measure the potential scientific return, both theoretical and practical, from the exploration of Mars. But beyond this reward stands a compelling reason that has to do with matters of the spirit. Man, on foot, on horseback, and carried through the air by contrivances of his own design, has penetrated the remotest corners of his small planet in the past million years. He has established outposts at the top of the Andes Mountains, at the bottom of the Red Sea, on ice islands in the Arctic, and in orbit around the earth. In less than a thousandth of the lifetime of earth, he has virtually mastered his planet—if not himself.

In all that time, man's vitality and exuberance have found outlet in an expansion to new territories. His philosophy and outlook have been broadened by the knowledge that elsewhere there existed strange lands and peoples of other tongues and customs.

The moon and beyond to Mars—man's goals at the threshold of space travel. This classic photograph, made at Lowell Observatory in 1911, emphasizes the limits of exploring space by telescope. Almost as close to earth as it ever comes, the red planet appears no larger than a medium-size lunar crater. PHOTOGRAPH FROM LOWELL OBSERVATORY



KODACHROME BY SCOTT DINE © N.G.S.

Spouting glowing ammonia into a vacuum chamber, this experimental thrustor, right, may someday help speed a man toward Mars. Apparatus to the left measures the engine's exhaust for a McDonnell Douglas researcher. A magnetic field draws the ammonia, charged by an electric arc, through a nozzle to produce long-sustained power. The collar of the thrustor is silhouetted against a second porthole.

But today the exploration of the earth's land surface is almost ended. Technology has made transportation and communication between the remotest parts of the world possible, even convenient. And we have now turned to the exploration of the ocean bottoms and of our neighboring worlds in space.

Space exploration is in the finest human tradition; many feel that it is a prerequisite for our continued survival as a species. The same technology that has conquered earth's surface now also permits the destruction of mankind. Our planet is in danger of becoming a vast closed society, with its tensions and enormous energies turned inward upon itself.

As the British author Arthur C. Clarke has written: "There is no way back into the past: the choice, as Wells once said, is the Universe—or nothing. Though men and civilizations may yearn for rest, for the Elysian dream of the Lotus Eaters, that is a desire that merges imperceptibly into death. The challenge of the great spaces between the worlds is a stupendous one, but if we fail to meet it, the story of our race will be drawing to its close. Humanity will have turned its back upon the still untrodden heights and will be descending again the long slope that stretches, across a thousand million years of time, down to the shores of the primeval sea."

It is our remarkably good fortune to live in the first moment in man's million-year history when we are capable of leaving our planet and exploring another world. Mars moves through our skies in its stately dance, distant and enigmatic, a world awaiting exploration. If we but choose, it waits for us.

THE END