pass over a specific area at a particular time of day. If the orbit is Mars synchronous (i.e., a period of $24^h 37^m$) the viewing interval will be one day. Intervals of two or more days can be readily achieved with orbits of somewhat longer periods, permitting more than one area to be revisited frequently under similar lighting conditions.

Landers

The techniques described so far—ground-based observations, flybys, and orbiters—will necessarily use remote sensing methods. They will make valuable contributions to our understanding of the atmosphere and surface, and may also produce results that are suggestive of an indigenous biota (e.g., the presence of atmospheric constituents in nonequilibrium amounts and inexplainable by abiological processes). However, it is generally agreed that in order to detect unequivocally the presence or absence of life, we must land on the surface and make direct measurements. This stage we are now entering with the Viking Project.

The Viking Project consists of two combination orbiter-lander missions in 1973. The orbiter's role has not been completely determined, but it will work with the lander as a team. It can accomplish this in at least three different ways: (1) by surveying possible lander sites before the lander is detached from the orbiter, (2) by observing the atmosphere and surface in the neighborhood of the lander in order to relate the lander's measurements to its environment, and (3) by serving as a high capacity data relay link between the lander and earth. Once its primary mission is over, the orbiter may be used to extrapolate the detailed findings of the team to other areas of the planet and to do site survey work for future landers. The orbiter payload will not be determined until at least December 1969. However, it is expected that high priority measurements will be visible imagery and ir observations to determine water vapor and surface temperature.

The most exciting part of this mission is certainly the lander. After separation from the orbiter, the lander capsule will enter the atmosphere, slow down by aerodynamic braking, deploy a parachute, and finally jettison the parachute and turn on retro-rockets for a soft landing. During descent, measurements of atmospheric structure, including composition by a mass spectrometer, are envisioned.

After a soft landing, a variety of investigations will be carried out. Final selection of the payload will not be made until December 1969. Typical of what could constitute the actual payload are:

Facsimile camera: both high and low resolution pictures.
Surface sampler—pyrolyzer-gas chromatograph mass spectrometer: organic analysis of the soil, analysis of the atmosphere.
Direct biology measurement: measure various life-related functions such as metabolism, growth, etc.
Meteorological sensors: measure winds, pressure, temperature.

Other high priority instruments for this first lander are a three-axis seismometer and a uv photometer.

The lander's life is a minimum of three days with a goal of ninety days. Power will come from batteries, with either solar cells or a radioisotope thermoelectric generator (RTG) serving as the source for periods longer than the three-day minimum.

Other Missions

NASA plans to place a small spin-stabilized spacecraft, called a planetary explorer, in orbit around Mars in 1973. The objective of this mission will almost certainly be investigations of the solar wind interaction with the planet and of the ionosphere. Thus, it will be of minor interest for exobiological studies.

Additional exploration of the surface by lander, including rovers, is clearly desirable. However, it is premature to present a schedule and capabilities for such missions.

Some Exobiological Speculations

In putting this issue together, I requested Joshua Lederberg to offer some comments on the theoretical aspects of exobiology. His contribution is brief, but significant, since it gives the flavor of the subject. Rather than include it as a separate paper, I have added it to this Introduction.

Mars Through a Crystal Ball

J. Lederberg

The editor of this feature had asked me to comment on the theoretical expectations for the character of life on Mars, if any, and how this might be revealed by the missions of 1969 and 1971 which emphasize optical methods of analysis.

Such a comment was much easier to write a few years ago[1,2] when the chance of experimental verification was less imminent. It must also be added that our growing knowledge of the Martian environment since 1965 (Mariner IV) has made it difficult to paint any facile picture of Martian life. The most difficult obstacle is the apparent lack of water, according to several lines of evidence. On the other hand, since the average subsurface temperature of Mars is about −60°C, the Martian crust might contain any amount of water (as ice) in the range of milligrams to kilotons per square meter.[3] The extent of the solid phase is, of course, immaterial to the equilibrium with the observable atmosphere and consistent with any observation so far. It is, however, quite crucial to any plausible models of biological systems on the planet. An important challenge to forthcoming reconnaissance missions is the evaluation of subsurface ice (permafrost). It is, however, not easy to predict just how such a feature will be revealed, if at all, to remote observation. At subkilometer resolutions, it is barely possible that volcanic formations and associated clouds might be delineated photographically and confirmed by ir mapping. More comprehensive land form observations or analysis of diurnal and seasonal changes might also be contributory.

In the face of these discouragements, most biologists (including myself) have been quite conservative in our stated expectations about Martian life (always with the qualification, "if any"). Published speculations center on "primitive vegetation." In fact, this view is no better justified than any other. The contemporary life system is surely coupled to solar energy, but it might have originated "in the beginning" from cosmic rather than atmospheric processes.[4] The aridity and thin atmosphere of Mars do not, then, necessarily bear on the likelihood of the origination of life or on its initial complexity. If solar uv flux is high at the surface, organisms will need shielding, but this is easily available with a few microns' thickness of iron oxides. However, the conveyance of solar energy from the surface with moisture a meter below will require an elaborate structure (like the root system of a leafy plant) or as an alternative, a food chain of mobile microorganisms.

Once this is granted, however, there are no theoretical limits to the evolution of herbivores and their predators, roughly analogous to animal life on earth. Nor is there any rigorous argument against intelligent life which, indeed, might have sequestered all the available moisture in more congenial, subsurface habitats.

To assert these possibilities is not to express any deep-seated conviction for or against them. It speaks rather to the need to keep an open mind and an open eye for the unexpected that will be the main harvest from the missions now initiated.

Recent analyses of the Mars atmosphere are trying to offer some more concrete possibilities for the metabolic system (which has a limited bearing on the over-all complexity of any organisms). Carbon may be present on Mars in many different forms, but only CO and CO_2 are now revealed by direct measurement.[5] With both compounds present, however, it is hard to imagine that their metabolic interconversion is excluded from Martian life. (That CO is a general cell poison on earth is immaterial; note that terrestrial bacteria are known that also oxidize CO.)

In fact, the exergonic reaction: $2CO + H_2O \rightarrow CH_2O + 22$ cal might allow for the synthesis of carbohydrate without photosynthesis within the organism, being driven ultimately by the inorganic photolysis of CO_2.

It is not obvious how the actual occurrence of such reactions could be verified short of a lander mission.

At this stage, such proposals are hardly more than idle speculations. However, they illustrate the way in which more detailed, rigorous information about the Martian environment can guide our efforts to frame the most reasonable designs for detecting that elusive Martian life, if any.[6]

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Donald G. Rea is the editor of the feature on exobiology and the exploration of Mars, the first part of which appears in this July issue. The second part will be published next year. Dr. Rea is deputy director of Planetary Programs of NASA's Office of Space Science and Applications.