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The Search for Martian Life Begins: 1959–1965

The search for extraterrestrial life was a direct by-product of 20th century biochemists' quest for the origins of life on Earth. Instruments proposed by scientists to determine if there were detectable life forms or the organic matter necessary for such life forms to exist elsewhere in the solar system were based on the assumption that the laws governing the evolution of life on Earth are universally applicable, as are the laws of physics. When the Viking spacecraft was launched to Mars in 1975, they carried three biological experiments and a gas chromatograph–mass spectrometer, instruments with an intellectual and technological history reaching back to the early days of American space science. In fact, the development of life-detecting devices predates the availability of both spacecraft and launch vehicles.

As with many aspects of modern biology, the search for extraterrestrial life begins with Charles Darwin. His classic work, *On the Origin of Species* (1859), sparked considerable discussion of evolution, but it also led to speculation over the original source of life. In the 1860s, Louis Pasteur concluded that the spontaneous generation of microbes was not possible; all life on Earth came from preexisting life. What was the origin of those life forms? The Darwinian theory led many scientists to believe that the multiplicity of plant and animal species had a common source. In an 1871 letter, Darwin suggested that perhaps Earth's atmosphere, too, had evolved.

> It is often said that all the conditions for the first production of a living organism are now present, which could ever have been present. But if (and oh! what a big if!) we would conceive in some warm little pond, with all sorts of ammonia and phosphoric salts, light, heat, electricity, etc., present, that a protein compound was chemically formed ready to undergo still more complex changes, at the present day such matter would be instantly devoured or absorbed, which would not have been the case before living creatures were formed.[1]

In his speculation, Darwin rejected the premise that Earth's environment had always been static.

Most scientists disagreed with the theory that life on Earth had its beginnings in a prebiotic environment, until the idea was simultaneously revived in the 1920s by two biochemists, J. B. S. Haldane of Great Britain and Aleksandr Ivanovich Oparin of the Soviet Union. Haldane and Oparin independently asserted that although it was very unlikely for life forms or organic molecules to appear abiologically in an oxygen-rich atmosphere, such compounds could have appeared millions of years ago in a very different environment. They postulated that in a prebiotic, sterile era organic compounds of ever-increasing complexity accumulated in the seas and eventually by random combinations produced a living molecule. On the nature of that prehistoric atmosphere, Haldane and Oparin disagreed.

Haldane favored a combination of ammonia, carbon dioxide, water vapor, and little or no oxygen. Organic compounds were synthesized by energy from ultraviolet light. Gradually the evolutionary process produced more complex molecules capable of self-duplication. Oparin's primordial atmosphere consisted of methane, ammonia, water vapor, and hydrogen. According to his theory, an abundance of organic compounds in the seas, given enough time, would permit the formation of organic molecules that would be the foundation for yet more complex life forms. Despite their work, most other biochemists through the 1940s insisted on attempting to synthesize organic compounds in oxygen-rich environments. In the 1950s, the focus shifted to the production of amino acids.

As with improved astronomical instruments, new biochemical techniques, such as paper chromatography,* opened new doors. One door led to the study of amino acids, the building blocks of protein. Biochemists believed that amino acids might hold clues to the origin of life, since primeval forms of life were assumedly protein-centered. Melvin Calvin commented on the logic behind these early studies: "We had every reason to suppose that the primitive Earth had on its surface organic molecules." If one went further and postulated a "reducing," or oxygen-poor atmosphere, "most of the carbon was very largely in the form of methane or carbon monoxide, . . . the nitrogen was mostly in the form of ammonia, there was lots of hydrogen, and oxygen was all . . . in the form of water." Given these simple molecules, was it possible to create more complex ones in the laboratory? Calvin and several other scientists began to experiment with reduced atmospheres containing primarily carbon compounds.[2]

Stanley L. Miller, while pursuing his doctoral studies at the University of Chicago, was the first to produce amino acids in a reducing atmosphere. Working under Harold Urey, he developed a closed-system apparatus into which he introduced a mixture of methane, ammonia, water, and hydrogen. When subjected to a high-frequency spark for a week, milligram-quantities of glycine, alanine, and alpha-amino-*n*-butyric acid were pro-

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*The process of separating a solution of closely related compounds by allowing a solution to seep through an absorbent paper so that each compound becomes absorbed in a separate zone.

duced. Apparently, he was on the right track. Miller reported his early results in *Science* magazine in May 1953.[3] Norman Horowitz, a biologist from the California Institute of Technology, commented: "This experiment on organic synthesis in simulated primitive earth atmosphere is the most convincing of all the experiments that have been done in this field."[4]

Six years later Miller and Urey reported further on the implications of their research. The absence of hydrogen in Earth's present atmosphere was a clue. They had begun their study assuming that cosmic dust clouds, from which presumably the planets had been formed, contained a great excess of hydrogen. "The planets Jupiter, Saturn, Uranus, and Neptune are known to have atmospheres of methane and ammonia," they noted, similar to primitive Earth's atmosphere. Given the lower temperatures and higher gravitational fields of these outer planets, time had not been sufficient for the excess hydrogen to escape. Miller and Urey held that Earth and the inner planets had "also started out with reducing atmospheres and that these atmospheres became oxydizing, due to the escape of hydrogen." Their production of amino acids in the laboratory indicated that before the development of an oxygen-rich atmosphere (the result of biological activity), the primitive environment was conducive to the formation of many different complex organic compounds. As soon as oxygen began to replace the hydrogen, experiments indicated that the spontaneous production of those compounds (amino acids) ceased.[5]

Miller's experience in the laboratory spurred further research, and with it speculation reappeared about the presence of life on other planets. As Miller and Urey pointed out in 1959, living matter does not require oxygen to grow and flourish; it was "possible for life to exist on the earth and grow actively at temperatures ranging from 0°C, or perhaps a little lower, to about 70°C. . . . Only Mars, Earth, and Venus conform to the general requirements so far as temperatures are concerned."[6] Because of the opacity of the heavy clouds on Venus, little could be deduced about the planet. Mars, on the other hand, had a clear atmosphere. Seasonal changes observed on the Martian surface suggested the possibility of vegetation.

The Red Planet became very important to the scientists searching for the origins of earthly forms of life. "If we find life on Mars, for example, and if we find that it is very similar to life on earth yet arose independently of terrestrial life, then we will be more convinced that our theories are right." Miller went on to argue:

> The atmosphere of Mars would have been reducing when this planet was first formed, and the same organic compounds would have been synthesized in its atmosphere. Provided there were sufficient time and appropriate conditions of temperature, it seems likely that life arose on this planet. This is one of the important reasons for the tremendous interest in finding out if living organisms are on Mars and why most of all we want to examine these organisms. We want to examine them in biochemical detail, and this would involve bringing a sample back to the

> earth. What are the basic components of these organisms? Do they have proteins, nucleic acids, sugar? If they are completely different, then our theories about the primitive earth and the results of this experiment seem not at all convincing. If Martian organisms are identical to the earth's organisms in basic components, then there seems to be the possibility that some cross-contamination occurred between the earth and Mars. But, if Martian organisms have small but significant differences, then it would seem that theirs was probably an independent evolution, under the kind of conditions that we envision as those of the primitive earth.[7]

In 1959, Miller and Urey concluded, "Surely one of the most marvelous feats of the 20th-century would be the firm proof that life exists on another planet." They could have been addressing NASA when they added, "All the projected space flights and the high costs of such developments would be fully justified if they were able to establish the existence of life on either Mars or Venus."[8]

Especially significant for the search for extraterrestrial life were developments in the field of comparative biochemistry. Nobel-Prize-winning geneticist Joshua Lederberg told a Stockholm audience in the spring of 1959 that "comparative biochemistry has consummated the unification of biology revitalized by Darwin one hundred years ago." For many years, Lederberg noted, there had been a "pedagogic cleavage of academic biology from medical education." Lederberg cited two other specialists in the field in making his point: "Since Pasteur's startling discoveries of the important role played by microbes in human affairs, microbiology as a science has always suffered from its eminent practical applications. By far the majority of the microbiological studies were undertaken to answer questions connected with the well-being of mankind." By the late 1950s, however, research into the chemical and genetic aspects of the microbiological world led medical and biological investigators to realize that their work had much in common. "Throughout the living world we see a common set of structural units—amino acids, coenzymes, nucleins, carbohydrates and so forth—from which every organism builds itself. The same holds for the fundamental processes of biosynthesis and of energy metabolism."[9] This global perspective on the underlying unity of life on Earth, together with the common chemical origin of the planets, made it not unreasonable to postulate the possibility of life on other bodies in the solar system. Furthermore, the discovery of life elsewhere would give biological theory a long-sought universality. The origin of life studies and the work in comparative biochemistry formed the intellectual foundation that permitted respectable scientists to discuss the possible existence of extraterrestrial life.

THE RISE OF EXOBIOLOGY AS A DISCIPLINE

As earth-bound biologists began to consider the existence—past or present—of life forms on other planets, two themes developed, detection and protection. How do you detect something whose nature and existence are unknown? How do you protect one planet from contamination by the biota of another? Detection and protection of life in the solar system were the subjects of considerable debate and investigation during the decade (1959-1968) that preceded the selection of biology experiments for Viking. Concern about possible contamination of other bodies by terrestrial organisms that might stow away aboard space probes got an impetus with the launch of Sputnik in 1957.

Planetary Protection

Josh Lederberg was one of the first scientists to express publicly his worries about improperly sterilized spacecraft being the source of cosmic pollution. In 1961, he noted, "a corollary of interplanetary communication is the artificial dissemination of terrestrial life to new habitats."[10] His interest in planetary protection went back three years to the orbiting of *Sputnik 1*.

On his way back to the United States from a year as a Fulbright lecturer in Melbourne, Australia, Lederberg stopped to visit for a few days with Haldane, who was teaching in Calcutta. Lederberg recorded his recollections of a dinner party given on 6 November 1957, an evening on which another Soviet space spectacular seemed likely in celebration of the 40th anniversary of the Russian Revolution.

> The night of our arrival was the occasion of a lunar eclipse which was regarded as an important religious festival in Calcutta. It was also the occasion for a good deal of dinner table conversation. . . . Many members of the group were quite strongly pro-Soviet in their inclinations and they were almost gleeful at the prospect that the Soviet Union would follow up its October 4th triumph with another launch, perhaps even directed at the moon during the lunar eclipse. So, [we] even stayed up to see if there would be such a demonstration although we were well aware of the physical difficulties of arranging for something that could be visible from earth.* That occasion led me to think very sharply about the extent to which political motives would outweigh scientific ones in the further development of the space program. . . .[11]

When he returned to the Univeristy of Wisconsin where he was chairman of the medical genetics department, Lederberg circulated among the scientific community several editions of a memorandum expressing his concern over lunar and planetary contamination. His thoughts were subsequently formulated in a paper presented in May 1958 at the Satellite-Life Sciences Symposium, sponsored by the National Academy of Sciences, the

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*Ironically, Jet Propulsion Laboratory proposed detonation of an atomic bomb on the lunar surface in response to the orbiting of Sputnik. William H. Pickering to Lee A. DuBridge, with summary of Red Socks proposal, 25 Oct. 1957, JPLHF 2-581.

American Institute of Biological Sciences, and the National Science Foundation, and in an article for *Science*.[12]

At the National Academy of Sciences, Lederberg's interest further stimulated concern over possible biological contamination in outer space. The Academy noted that improperly sterilized spacecraft might "compromise and make impossible forever after critical scientific experiments." Resolutions adopted in February 1958 by the Academy Council urged scientists "to plan lunar and planetary studies with great care" and called for the International Council of Scientific Unions "to encourage and assist the evaluation of such contamination and the development of means for its prevention." The Academy further intended to participate in the planning of "lunar or planetary experiments . . . so as to prevent contamination of celestial objects in a way that would impair the unique . . . scientific opportunities."[13]

An ad hoc Committee on Contamination by Extraterrestrial Exploration, formed by the International Council of Scientific Unions, met in May 1958 to draw up a code of conduct that would permit lunar and planetary exploration but at the same time prevent contamination. After being circulated throughout the scientific community, the proposed standards were adopted in October 1958. During the remaining months of 1958 and throughout 1959, the International Council of Scientific Unions' Committee on Space Research (COSPAR) and the U.S. Space Science Board continued to develop guidelines for the sterilization of space probes.[14]

The Space Science Board also expanded its activities into the field of life sciences in 1959 as the board members became interested in experiments that would investigate "the viability of terrestrial life forms under extraterrestrial conditions" and the implications of contamination.[15] The group's ad hoc committee on the subject, chaired by Lederberg, concluded that sterilization was technically feasible and that effective procedures could be developed, provided sufficient emphasis was given the problem. Toward that end, the Space Science Board sent suggestions to NASA and the Advanced Research Projects Agency on 14 September 1959. NASA Administrator Glennan assured the Space Science Board that the space agency had "adopted the general policy of sterilizing, to the extent technically feasible, all space probes intended to pass in the near vicinity of or impact upon the moon or planets."[16] Moveover, Abe Silverstein requested that JPL, Goddard Space Flight Center, and Space Technology Laboratories begin coordinated work on sterilization techniques.

While NASA Headquarters, its field centers, and contractors worked toward protecting the moon and planets from terrestrial microorganisms, the agency was studying more closely its participation in the life sciences.[17] To determine NASA's role in that field, Glennan established an ad hoc Bioscience Advisory Committee in July 1959. Chaired by Seymour S. Kety of the Public Health Service, the advisory board* reported 25 January 1960

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*Other members included W. O. Fenn, D. R. Goddard, D. G. Marquis, R. S. Morison, C. T. Randt, and C. A. Tobias.

that life sciences had and would continue to have an important place in the American space program. The objectives of space research in this area were twofold—"(1) investigations of the effects of extraterrestrial environments on living organisms including the search for extraterrestrial life; (2) scientific and technologic advances related to manned space flight and exploration."[18] Kety and his colleagues also noted that existing space-related life-science activities were predominantly in applied medicine and applied biology. These activities were important, but support of more basic research in the biological, medical, and behavioral sciences was more crucial.

Besides supporting an Office of Life Sciences at NASA and arguing vigorously for the complete independence of life-science research from the military, the committee urged the space agency to search for extraterrestrial life on Mars. Kety and his colleagues recognized that a basic study of extraterrestrial environments would further man's understanding of the fundamental laws of nature. The origin of life and the possibility of its presence elsewhere in the universe were indeed challenging issues.

> For the first time in history, partial answers to these questions are within reach. Limited knowledge acquired over the past century concerning atmospheric and climatic conditions on other planets, the topographical and seasonal variety in color of the surface of Mars, the spectroscopic similarities . . . have suggested the presence of extraterrestrial environments suitable for life and permitted the formulation of hypotheses for the existence there of some forms of life at present or in the past.

The Kety committee believed that within the foreseeable future these hypotheses might be tested, indirectly at first by astronomical observations and by samplings taken mechanically from other planets, and finally by direct human exploration. The discovery of extraterrestrial life, or its absence, "will have important implications toward an ultimate understanding of biological phenomena."[19] Although these specialists believed that biological studies would "not be complete until the scientist himself is able to make meticulous investigations on the spot," they realized that manned missions to Mars belonged to the distant future.

As NASA went about establishing its Office of Life Sciences in the spring of 1960, the agency found itself with a 10-year plan that called for planetary missions in 1962 and 1964 and a recommendation from the Bioscience Advisory Committee to search for life. Given the scientific interest in Mars and the apparent feasibility of sending probes to that planet by the mid-1960s, it would have been difficult to argue against the idea. In August 1960, NASA authorized JPL to study spacecraft concepts for a mission to the Red Planet, a mission that would land a capsule on the surface and initiate the search for life beyond Earth. Although the Kety committee in 1959 and the Space Science Board's summer study at Iowa State University in 1962 both called for the biological investigation of Mars, a 1964 summer study sponsored by NASA and the Space Science Board was a further step in articulating the essential issues for exobiology as a field of inquiry.

1964 Summer Study

Professional biological interest in the search for life elsewhere in the universe had been growing for at least half a dozen years before the 1964 Summer Study gave exobiology the intellectual respectability needed to draw bright young scientists to the field. The "old-timers"—Lederberg, Colin Pittendrigh, and Wolf Vishniac, in their 30s and 40s—all had substantial and estimable careers in biology behind them before they launched into their quest for biota on Mars. Commenting on his early years in exobiology, Lederberg noted that his Nobel Prize for work on the genetics of bacteria had given him professional stability, which made it possible for him "to stay in a non-reputable game. Not disreputable, mind you, but non-reputable. It might have been very, very difficult otherwise and it would [have been] very hard for a capable young scientist who's had a lot of risks to take in his career to hitch it to something as uncertain as exobiology."[20] Gerald A. Soffen's experience is an example of the personal turmoil that could result from wishing to pursue the field of exobiology.

Jerry Soffen had begun his scientific career as a biologist. After earning a zoology undergraduate degree at the University of California in 1949, Soffen went on to study biology at the University of Southern California. Two books influenced the course of his subsequent career. One was A. I. Oparin's *The Origin of Life*. Soffen believed that Oparin was addressing himself to genesis—the origins of life, "the origins of me." Oparin's book started Soffen thinking about the beginnings of life, but Harold F. Blum's *Time's Arrow and Evolution* was even more influential. Blum's concept was simple and elegant—evolution conformed to the second law of thermodynamics. The universe's supply of energy is slowly diminishing, and all biological forms must adapt to lower, less satisfactory energy sources. Simple organisms present in a more primitive age when the oceans supplied them with a very rich nutrient broth had to develop more specialized and complex mechanisms for gathering energy (nutrients) as the ocean environment became less rich. Evolution is not a random process, since organisms must make orderly changes to survive in a changing world. This process leads to more complex, not simpler, organisms. Furthermore, organic evolution on Earth must be viewed as but a small part of the evolution of the entire universe.[21]

Soffen was so overwhelmed by the philosophical implications of Blum's work that he went to Princeton to do his doctoral work under Blum. During his doctoral studies, Soffen heard Stanley Miller summarize his investigations into the origins of life on Earth. As were many of his contemporaries, Soffen was taken by the brilliance and simplicity of Miller's theory. But the crucial factor for Soffen was the dawn of the era of spaceflight. Men could now reasonably talk of exploring the planets, and the search for life on other worlds was no longer just a dream. Soffen's interest in space exploration and the search for life on Mars brought him to another crossroads in his career while he was doing postdoctoral work at the New York State University School of Medicine in 1960.

Would Soffen pursue a safe, respectable career in biology studying mollusks, or would he gamble and undertake the study of exobiology, a new field not accepted as legitimate by many scientists? Soffen did not have fame or a Nobel Prize, as did Josh Lederberg, to give him academic security, and many professionals warned him against entering the new discipline. One physicist, Leo Szilard, told Soffen he was the wrong person from whom to seek advice. Instead, Soffen must ask himself what he wanted from life; no one else could decide the best course for him to follow. Soffen made his choice in 1961 when he joined the staff at the Jet Propulsion Laboratory, and he spent the next eight years managing the development of biological instruments, including exobiological detectors for spacecraft.[22] A wish to counter some of the professional risks associated with committing a career to exobiology was one of the reasons NASA convened the 1964 Summer Study at Stanford University.

After the usual staff work by Orr Reynold's Bioscience Programs Division, NASA got the summer study proposal moving by sending, in February 1964 over Homer Newell's signature, a letter to Chairman Harry Hess of the Space Science Board. Newell reminded Hess that "one of the prime assignments" of the space agency was "the search for extraterrestrial life," and he noted that the report of the Iowa City Summer Study of 1962 also described this undertaking as "the most exciting, challenging, and profound issue not only of the century but of the whole naturalistic movement."[23] There were those within and without the space science community who would question that priority, but even the most skeptical admitted that the discovery of life on a distant planet would have scientific, sociological, and theological implications of the first magnitude.[24]

Newell's letter set in motion a series of meetings between NASA and Space Science Board staff members. By mid-April, the board had readied its proposal for a summer study. Dean Colin Pittendrigh, professor of biology at Princeton, and Joshua Lederberg were appointed cochairmen of the study, and a distinguished group of scientists were named to the steering committee and the working group of participants for the June discussions (of the 37 persons who made up the core of the 1964 Summer Study, 9 would become key figures in the Viking Project). The summer meetings provided a much-needed forum where scientists could advise NASA as to what research they wanted the agency to support.

Some, Lederberg among them, had begun to worry about relations between the Space Science Board and NASA. Such sessions as the one in 1964 at Stanford were important decision-making exercises. But who would participate in such studies other than the interested and the enthusiastic, he mused? Thus, he viewed their reports as basically reputable, authoritative, and responsible endorsements, but also biased. While the views expressed that summer were generally those of proponents, the fact that they had been made publicly did achieve at least two things. First, the thinking of the participants who proposed a search for life on Mars had been sharpened, since their ideas were to be exposed to the critical evaluation of the larger scientific community. That is, those ideas became explicit targets for critical discussion. Second, the proposals had to be advanced in language that would permit broad discussion by legislators and laymen, as well. The study permitted NASA to discover how much scientific interest and support existed for the search for Martian life and to obtain the endorsement of the specialists for what the agency's advance planners wanted to do. Once a report with the Space Science Board–National Academy of Sciences imprimatur appeared, the space agency could move ahead.[25]

Those who participated in the 1964 Summer Study were believers and enthusiasts. Basic to their inquiries was a wish to know if life on Earth was unique. They could not prejudge the likelihood of life on other planets. While a speculation that it might exist was a relatively reasonable one, the biological community had no firm basis for assuming that other planets would be either fertile or barren. According to the 1964 summer conferees, "At stake in this uncertainty is nothing less than knowledge of our place in nature. It is the major reason why the sudden opportunity to explore a neighboring planet for life is so immensely important.[26]

Mars was a scientifically likely abode for life, the most Earthlike of all the planets. Although the Martian year was 687 days, the length of the day was "curiously similar to that of Earth, a fact that to a considerable degree ameliorates an otherwise very severe environment." The Red Planet had retained a tenuous atmosphere with surface pressures variously estimated from 10 to 80 millibars; the gaseous composition of that atmosphere was still a mystery in 1964. But scientists had concluded that oxygen was virtually nonexistent: "Oxygen has been sought but not detected; the sensitivity of measurement implies a proportion not greater than 0.1 per cent by volume." Water was also scarce. Water vapor had been measured spectroscopically with only traces detected in the atmosphere.

Table 6
Physical Properties, Mars and Earth (1964)

Property		Earth	Mars
Atmospheric pressure:		1000 millibars	10–80 millibars
Gaseous composition:	oxygen	20.00%	<00.1%
	carbon dioxide	.03%	5–30%
	nitrogen	78.00%	60–95%
Water vapor:		3 g cm^{-2}	$2x10^{-3}$ g cm^{-2}

On Mars, surface temperatures overlapped the range on Earth. At some latitudes, daily highs of +30°C had been measured, and ranges of 100° within a 24-hour period were not unknown.[27]

But knowledge of the Martian surface had not progressed much beyond Lowell's observations at the beginning of the century. There was general agreement that the polar caps were frozen, but whether it was water or carbon dioxide was still a matter "of some controversy." Nor was there any understanding of a transport mechanism that could account for the seasonal alterations of the poles. "Our knowledge of what lies between the polar caps is limited to the distinction between the so-called 'dark' and 'bright' areas and their seasonal changes." The bright areas were generally believed to be deserts, with their "orange-ochre," or buff, appearance. The green color attributed to the darker regions was likely an optical illusion due to the contrast with the bright regions. Of biological interest were the seasonal changes in the dark areas. As was noted in the 1964 summer session report:

> In several respects they exhibit the kind of seasonal change one would expect were they due to the presence of organisms absent in the "bright" (desert) areas. In spring, the recession of the ice cap is accomplished by development of a dark collar at its border, and as the spring advances a wave of darkening proceeds through the dark areas toward the equator and, in fact, overshoots it 20° into the opposite hemisphere.[28]

The authors of *Biology and the Exploration of Mars* were quick to point out that the seasonal changes did not require the presence of living organisms. "Indeed, the question is whether the Martian environment could support life at all; and further, whether its history would have permitted the indigenous origin of life." Those were clearly two different questions.

One of the "more rewarding exercises" the summer study participants engaged in was the "challenge to construct a Martian ecology assuming the most adverse conditions indicated by present knowledge." That task posed no insuperable problems. Life forms could be conceived to exist with little or no oxygen. Some terrestrial organisms can survive freeze-thaw cycles of +30°C to -70°C. Others cope well with very low humidity, deriving their water supply metabolically. The intense ultraviolet radiation at the surface of Mars did not seem to be an insurmountable problem either, as some members of the study believed that organisms might exploit that radiation as an energy source. "The history of our own planet provides plenty of evidence that, once attained, living organization is capable of evolving adjustments to very extreme environments."[29]

Does life in fact exist on Mars?—this was a question of a different sort. That life forms *could* subsist on the planet was no kind of proof that life had actually emerged there. But the members of the study held that, "Given all the evidence presently available, we believe it entirely reasonable that Mars is inhabited with living organisms and that life independently originated there. However, it should be clearly recognized that our conclusion that the biological exploration of Mars will be a rewarding venture does not depend upon the hypothesis of Martian life." Two essential scientific questions should not be prejudged:

> a. Is terrestrial life unique? The discovery of Martian life, whether extant or extinct, would provide an unequivocal answer.
>
> b. What is the geochemical (and geophysical) history of an Earth-like planet undisturbed by living organisms? If we discover that Mars is sterile we may find answers to this alternative and highly significant question.[30]

Scientific Aims of Martian Exploration

Having established that Mars was a worthy object of study, the summer study scholars addressed the precise aims of an investigation. "We approach the prospect of Martian exploration as evolutionary biologists." Whereas the emergence of organisms "was a chapter in the natural history of the Earth's surface," these scientists sought to test the generalized hypothesis that the evolution of life "is a probable event in the evolution of all planetary crusts that resemble" the Earth. Thus, they conceived the overall exploration of Mars "as a *systematic study of the evolution of the Martian surface and atmosphere* [italics in original text throughout unless noted otherwise]." Their aims in the summary were:

> (1) determination of the physical and chemical conditions of the Martian surface as a potential environment for life,
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> (2) determination whether life is or has been present on Mars,
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> (3) determination of the characteristics of that life, if present, and
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> (4) investigation of the pattern of chemical evolution without life.[31]

As biologists, they had as "much interest as the planetary astronomers in a thorough study of the meteorology, geochemistry, geophysics and topography of Mars." Whatever the ultimate outcome of the search for life, its full meaning would be understood only within the broader context.

Four basic avenues of approach were suggested for the exploration of Mars, with the first three tasks ultimately leading to the fourth:

> (a) laboratory work needed to develop techniques for planetary investigations and the knowledge needed to interpret their findings;
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> (b) Earth-bound astronomical studies of Mars;
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> (c) the use of spacecraft for the remote investigation of Mars; and
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> (d) a direct study of the Martian surface by landing missions.[32]

But by 1964, especially with the difficulties in planning Mariner B, it was apparent to all that defining lander payloads was a "complex and demanding task."

The planners needed more information about the structure of the Red Planet's atmosphere. Would parachutes work? Would retrorockets be necessary? They hoped *Mariner 3* and *4*, scheduled for launch in November 1964, would provide some answers on which spacecraft designers could base their plans. But even if complete knowledge for safely landing an instrumented package existed, the "principal design difficulty would remain: it concerns the problem of life detection. *What minimal set of assays will permit us to detect Martian life if it does exist?* A debate on this question for the past several years has yielded a variety of competing approaches." Each alternative was directed to monitoring some manifestation of life according to cues taken from terrestrial biology. An examination of life-detection concepts as they had evolved by 1964 provides an understanding of the problems facing the exobiologists, as well as the implied "Earth chauvinisms"[33] (a term popularized by Carl Sagan to describe the tendency to assume that living beings anywhere would be similar to those on Earth).

The very first grant NASA made in the area of biological science was to Wolf Vishniac for $4485 to develop "a prototype instrument for the remote detection of microorganisms on other planets." This money, awarded in March 1959 for work on what became known as Wolf Trap, initiated research in the field of life detection. Vishniac and his colleagues realized immediately that they faced a difficult task.[34]

Wolf Vladimir Vishniac was one of the pioneers in the search for extraterrestrial life. Born in Berlin in 1922, the son of Latvian parents who had fled the chaos of the Russian civil war, he was an associate professor of microbiology at the Yale University School of Medicine when he joined 18 other scientists* 19-20 December 1958 at the Massachusetts Institute of Technology to discuss the problems of detecting life on other planets and the possibility of contaminating those distant environments. The group, which took the name Panel on Extraterrestrial Life (or EASTEX, to distinguish it from a West Coast group led by Lederberg and called WESTEX, which met during 1959 and 1960 at Stanford University and JPL), was jointly sponsored by the National Academy of Sciences-National Research Council and the Armed Forces Committee on Bioastronautics. Melvin Calvin, professor of chemistry at the University of California at Berkeley, and Vishniac served as chairman and vice-chairman of EASTEX through 1961. At that first meeting in December 1958, one of the basic questions

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*Dean Cowie, Carnegie Institute of Washington; Richard Davies, JPL; George A. Derbyshire, Space Science Board; Paul M. Doty, Thomas Gold, W. R. Sistrom, and Fred L. Whipple, Harvard; H. Keffer Hartline, Rockefeller Institute; Martin Kamen, University of California, San Diego; Cyrus Levinthal, Bruno B. Rossi, and A. Luria, MIT; E. F. MacNichol, Johns Hopkins; Stanley Miller, Columbia; John W. Townsend, Jr., NASA; Bruce H. Billings, Baird-Atomic, Inc.; Herbert Freeman, Servo-Mechanisms Laboratory; and Richard S. Young, Army Ordnance Missile Command.

addressed by the physicists and biologists was what kinds of life forms they might reasonably expect to find away from their own planet.[35]

Four basic hypotheses were advanced as to the nature of that life. One might find (1) living things that were essentially the same as those found on Earth; (2) life forms with the same chemistry but with peculiarities resulting from evolution in a different environment—both at the present and in the past—(3) organisms with a chemical base other than carbon (for example silicon, however unlikely that appeared in the "carbon chauvinistic" understanding of chemistry); or (4) very primitive life forms representing the initial steps along the evolutionary path. Two other distinct possibilities also existed—that life had evolved only on Earth and all the other planets were sterile, or that life had once flourished, or at least begun, on other planets only to succumb to environmental factors that precluded successful adaptation and evolution. In December 1958, few of the scientists gathered in Cambridge would have fervently backed one of these six possibilities over any other.

How does a scientist detect that which he is uncertain exists and whose form he is unsure of? Vishniac and his colleagues had to make some basic assumptions, and one of them was that life elsewhere would have a carbon base. Early in the 1960s, Vishniac in an interview said that scientists were "not acquainted with any forms of life except those that are carbon-based. It may be that carbon is indeed the only useful element that provides the structural basis for life, because of its chemical versatility." There was the possibility that other elements or combinations of elements might take on similar functions. "For instance, silicon-based life has been suggested—but silicon will not make as large and as stable compounds as will carbon. Compounds must be stable enough to . . . serve as structural units and to preserve some kind of continuity from generation to generation." Furthermore, a life-base compound must be reactive enough to permit metabolism to take place. "Carbon is particularly suited for that because it combines with itself, and with many other elements, perhaps to a greater extent than does any other element." Vishniac and others concluded that the simplest assumption was to say that life "always will be based on carbon. It may turn out that we are deluding ourselves—that we are simply limited in our imagination because of our limited experience." That was the constant intriguing possibility inherent in space research.[36]

Accepting the assumption regarding carbon, the exobiologists were still faced with defining life forms. What is life? What is a living thing? Three NASA authors who sought to analyze the life-detection problem wrote:

> The difficulties associated with assigning an unequivocal definition to the phenomenon of life lead one to utilize various approaches to a better understanding of the living state. From the standpoint of the problem of the detection of life on extraterrestrial bodies, it may be pertinent to list and scrutinize closely the criteria most commonly attributed to living

> systems. *Thus the initial task of the exobiologist is to describe life in such a manner that tests can be devised that can demonstrate, unequivocally, the existence of extraterrestrial life.*[37]

These three scientists suggested five accepted manifestations of life: growth, movement, irritability, reproduction, and metabolism. Taken together, they provided an indication of living organisms, but the early students of exobiology had to determine which of these manifestations were primary to their search for living forms on other planets, "especially if those forms are exclusively microbes, as is suspected by some to be the case for Mars." A second factor to consider was the kind of detectors that might be sent to the planets. Given weight and size limitations, detectors that would test for the existence of microbiological life forms seemed more realistic than bulkier hardware created to locate larger organisms.[38]

When the exobiologists began developing life detectors, they built on the foundation provided by modern genetic theory, especially that relating to the cell as a living system. During the 1950s had emerged the revolutionary concept that the storage and transfer of basic biological information took place within the cell. A cell was "visualized as a society of macromolecules, bound together by a complex system of communication regulating both their synthesis and their activity."[39] If the cell could store and transmit biological information, it had to be able to reproduce and metabolize. Reproduction is the process which maintains biological information by its constant renewal. Metabolism has been characterized as "the fire that genetic material keeps going outside itself, to get the other material to work for it, in the service of its own distinctive goal: its own survival and replication."[40] Therefore, the minimum requirements of life can be represented as an interdependence among macromolecules, metabolism, and reproduction.

The exobiologists examined each of the three attributes to determine its relevance to the problem of detecting life. Many scientists working with Earth-bound experiments assigned top priority to reproduction. While there was certainly no argument that life could not exist very long without it, the exobiologist found it a difficult phenomenon on which to base an extraterrestrial experiment. It is a discontinuous process and "the reproductive rate varies enormously from species to species and, depending on environmental conditions, often within the species." Even at the macromolecular level, reproduction (replication) is often discontinuous in many life forms. With all the factors known to complicate observations of the reproduction of life on Earth, the detection of reproduction of life "in an exotic situation could be extremely difficult."[41]

Lederberg and others had proposed visual observations on Mars and Venus for microscopic and macroscopic life. But as with observations of reproduction, a living organism might not provide the scientist with motion or other visible clues during the short life span of an extraterrestrial experiment. The authors of the summer study report concluded that, as attractive as the idea of visual observation was, "we can easily imagine circumstances in which this type of observation would be inconclusive."[42] A more reliable basis was needed.

Metabolism appeared the most promising attribute on which to base life-detection experiments, primarily because it was a continuous process. "Even life forms that are considered to be in a highly inactive state (e.g., bacterial spores and plant seeds) carry on measurable, albeit extremely low, rates of metabolism." Metabolism also could be measured in several ways (changes in pH or temperature, the evolution of gases). But after "lengthy discussions and deep deliberation," the exobiological community agreed that "a truly meaningful life detection program must be based on [several] fundamental attributes of life."[43] Scientists would not be convinced by negative answers from any single life detector. They wanted some direct visual inspection by television and a program that would land an automated biological laboratory (ABL). While not fully defined in 1964, the ABL would permit a number of chemical analyses and a variety of biological experiments. Plans included an onboard computer by which a variety of programmed assay sequences could be initiated, contingent on results of prior steps, and a sustained discourse between the computer and investigators on Earth. By remote control of their mechanical surrogate, the scientists on Earth could carry out investigations much as they would in their terrestrial laboratories. It was "in short an ambitious concept," but "realizable with current technology."[44]

Mechanisms for Detecting Life on Mars

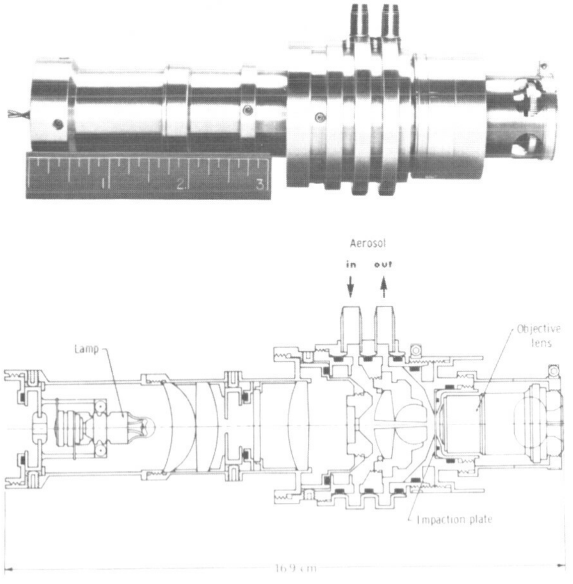
There was no shortage of life-detection concepts.[45] Speaking to this point at the beginning of the summer study on 15 June 1964, Lederberg compared the Mars life-search to the work that he and his colleagues normally did in their laboratories. In their everyday biochemical experiments, they were limited by approaches and hardware. Similarly, in the proposed exobiological studies, they needed to focus on the target and think about the best collective experiments for some years hence. The basic problem would come to deciding which instruments to develop. Scientists could quickly think of many experiments that might be done.[46] Once the redundant ideas were eliminated, a reasonable number of practical-looking concepts remained, among which were several that NASA had supported over the past several years. But translation of concepts into hardware was a challenge. In May 1963, NASA's Ames Research Center, Moffett Field, California, had been assigned the task of evaluating the many exobiology experiments. Ames had been serving as NASA's "in-house" life science research laboratory since the arrival of Richard S. Young in 1960, and in 1962 an Exobiology Division was established there. Hence, scientists at Ames were familiar with the issues the exobiologists were addressing their experiments to.[47]

Mars Surface Television. "The first thing man generally does in a new and strange environment is to look around." That was exactly what scientists wanted to do through one of the large Voyager-class landers, using television to view the topography immediately surrounding the craft. "There may be both geologic and biological surprises in the landscape. . . ." Television pictures would also permit the mission team to check out and monitor the condition of the lander. And not to be overlooked was the public-relations value of pictures as scientists and laymen alike shared a closeup view of Martian scenery.[48]

Vidicon Microscopes. A more sophisticated use of television cameras was the proposed microscope-television combination. Based on the suggestion of Joshua Lederberg, this idea was being pursued at his Instrument Research Laboratory at Stanford and in Gerald Soffen's facility at the Jet Propulsion Lab. "The detection of life by looking for it sounds elementary; however, this seemingly simple technique is extremely complex and involves numerous technical problems." Stanford and JPL scientists and instrument-makers were confronted by the difficulty and uncertainty in recognition and identification of microorganisms by microscope.[49] Beyond that, the large information return required to produce pictures of suitable quality appeared to be beyond computer capabilities projected for Mariner 1966. Although the Ames life-detection experiments team rejected the vidicon microscope for the Mariner flight, members of the summer study believed it had sufficient merit to be considered for a 1971 mission like Voyager.[50]

Wolf Trap. Wolf Vishniac originally developed this device in 1958–1960 to demonstrate the feasibility of automatic remote detection of the growth of microorganisms. He wanted to prove that such an instrument could be built, and having once committed himself to the experiment he seemed unable to set it aside for other ideas that might have been more fruitful. Defending this first exobiological instrument became part of Vishniac's promotional work on behalf of the Mars biology program.[51]

In a 1960 issue of *Aerospace Medicine,* Vishniac explained that microorganisms "are responsible for the major amount of turnover of matter on earth and . . . life of the higher plants and animals is inconceivable in [their] absence."[52] The object of Wolf Trap was the growth of Martian microbes, if they existed and could be trapped. At the heart of the instrument was a growth chamber with an acidity (pH) detector and light sensor; the former would sense the changes in acidity that almost inevitably accompany the growth of microorganisms, while the latter would measure the changes in the amount of light passing through the growth chamber. Microorganisms, such as bacteria, turn a clear culture medium cloudy (turbid) as they grow, and the light sensor would detect such changes. The pH measurement would complement the turbidity measurement, providing an independent check on growth and metabolism.



A vidicon microscope, January 1965, being considered for future use in seeking extraterrestrial life had no moving parts. An aerosol for carrying particles was injected into the instrument and onto the impaction plate through a nozzle in the condenser lens. The objective lens and lamp were fixed in relation to the plane of focus. The sample was collected through a gas-operated aerosol aspirator.

By mid-1963 Vishniac, with the assistance of C. R. Wilson and others, had progressed from a simple feasibility model to a more complex breadboard* design. A contract with Ball Brothers Research Corporation for the development of the second-generation instrument was let by the University of Rochester in 1961. Late in 1963, the Ames life-detection experiments team report noted several problems still unresolved, notably the likelihood of false signs of growth resulting from the sampling technique, and said the experiment probably could not be ready for 1966 but might be a 1969 candidate.[53]

Multivator. Conceived by Joshua Lederberg and worked out in prototype form by Elliott Levinthal and his assistants in the Instrumentation Research Laboratory at the Stanford School of Medicine, multivator was intended to be a miniature multipurpose biochemical laboratory in which a

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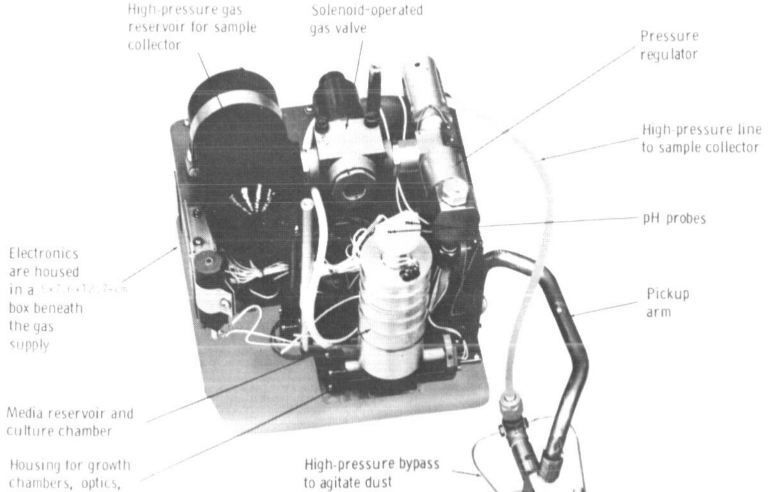
*An assembly of parts used to prove the workability of a device or principle without regard to the final configuration or packaging of the parts.



Model of Wolf Trap life detection device with cover removed.

series of simple measurements could be made on samples of atmospheric dust. A variety of measurements was studied, and they all included testing a small sample of dust with a fluid reagent and reading out a simple optical or electrometric measurement. Lederberg and his associates originally hoped to cultivate Martian microorganisms in a defined culture medium, as in Wolf Trap, but they concluded that the brief communication times between a Mars lander and Earth monitoring stations would limit the opportunities of observing changes based on growth. Enzymatic activity might be a more realistic behavior to study. Thus, they began to concentrate on detecting the action of enzymatic phosphatase on phosphate containing chemicals that become fluorescent following removal of the phosphate grout. When enzymatic activity took place, the resulting glow would be determined by a detector, perhaps photoelectrically.[54] The Ames team evaluating the multivator in August 1963 decided that the instrument was maturing rapidly but that the experiments it would house would require "a great deal more effort" before they would be ready to be sent off on a mission to Mars.[55]

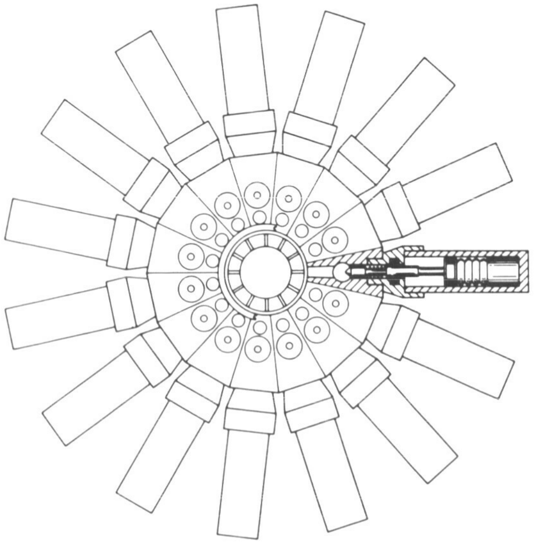
Minivator. A variant on the multivator concept, devised by Jerry L. Stuart of JPL, minivator had an improved sample-collection device. Driven by gas-powered turbine, the sample collector separated large and small particles by centrifugal action. Again, the instrument development was ahead of work on the experiments it would house. The Ames team assumed that the best features of the multivator and minivator would be combined.[56]

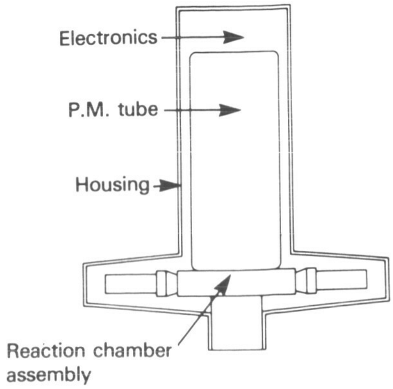
Gulliver. Named after Jonathan Swift's fictional traveler to strange places, the Gulliver instrument was the work of Gilbert V. Levin. After many years in the public health field, where he sought better methods for detecting bacterial contaminants in polluted water, Levin asked T. Keith Glennan, NASA's first administrator, if the agency would be interested in developing life-detection instruments for use on space probes. A contract for the work was let in 1961.[57]

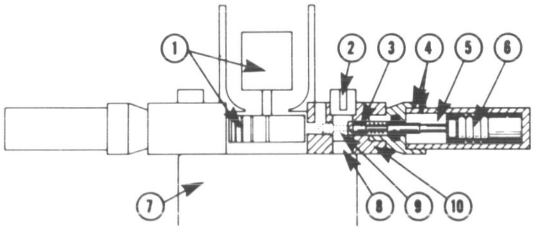
Gulliver consisted of a culture chamber into which a sample of soil could be introduced. In the chamber was a broth whose organic nutrients were labeled with radioactive carbon. If microorganisms were put into the broth, they would metabolize the organic compounds, releasing radioactive carbon dioxide that could be trapped on a chemically coated film at the window of a Geiger counter. The radioactivity readings would be relayed to Earth by the spacecraft's radio transmitter. Gulliver had the virtue of being able to detect growth, as well as metabolism, since the rate of carbon dioxide production would increase exponentially with growing cultures.

Sample acquisition was the early Gulliver's unique feature. The instrument had a mechanism consisting of two 7.5-meter lengths of kite line wound around small projectiles in the manner of harpoon lines to prevent snagging. The string was coated with a sterile silicone grease to make it sticky. After the lander arrived on Mars, the projectiles would be

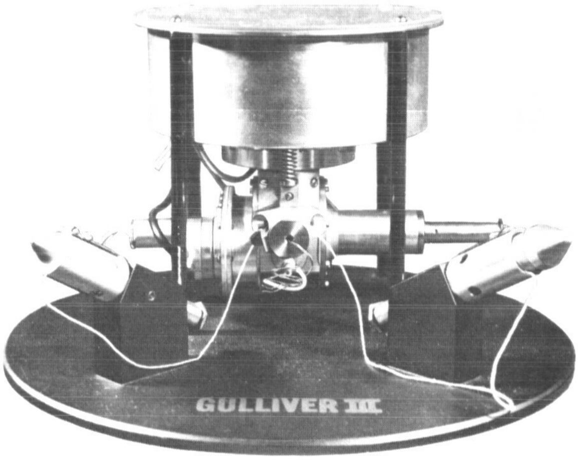
Multivator Chambers







1. Motor and impeller
2. Light source
3. Valve stem and piston
4. Injector-seal unit housing
5. Solvent chamber
6. Bellows motor
7. Photomultiplier tube
8. Window
9. Reaction chamber
10. Reaction chamber unit block

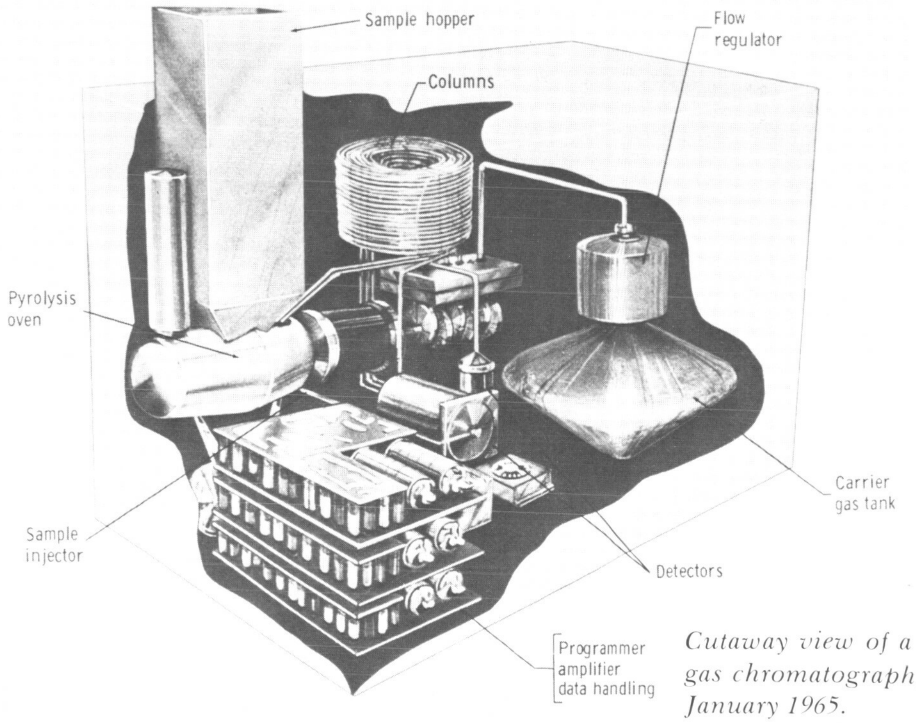


Multivator, above in January 1965, was a miniature laboratory for biochemical experiments on Mars. Gulliver III, at left, also in January, carried sticky strings and projectiles to be fired and retrieved with dust and loose particles to be tested for production of carbon dioxide indicating life.

fired in mortar fashion and then reeled in together with adhering soil particles. After the lines were retrieved, Gulliver would be sealed and an ampule broken, releasing the sterile radioactive nutrients onto the samples.

The Ames life-detection experiments team gave Gulliver high marks because, unlike other experiments of the time, it had a sampling mechanism. But they also raised questions about the nature of the technique, since samples delivered to the growth and control chambers would not be identical. The chambers would contain a metabolic poison to serve as a check on chemically produced radioactive carbon that might otherwise be interpreted as signs of metabolism, and experimental control to prevent false results required a common sampling source. The Ames team concluded that sample acquisition might be a problem. It further noted that Gulliver was the most advanced experiment in terms of hardware development and the only one likely to be ready for flight in 1966.[58] Other life-detection concepts are listed in table 7.

Given the conclusion that no single life detector would be sufficiently accurate and conclusive in its results, an automated biological laboratory containing several experiments was the prudent choice. But before such sophisticated, expensive hardware was landed on Mars, a successful orbiter program was necessary; scientists and engineers needed more data regarding the planet's atmosphere (density and chemical composition) and surface. An orbiter's sustained seasonal observations would permit thorough evaluation of features considered suggestive of life and a better informed selection of landing sites for the laboratory.



Cutaway view of a gas chromatograph, January 1965.

Table 7
Ames Life-Detection Team Evaluation of Proposed Biology Instruments—Development Status, 1963

Experiment	Status	Date Available	Manpower Support to Meet 1966 Date	Monetary Support to Meet 1966 Date
Vidicon microscope	Science—conceptual. Device—none.	?	?	?
Wolf trap	Lab feasibility model. Engineering is conceptual.	April 1963	Univ. of Rochester will need 1 Ph.D. & 4 techs. Subcontractor requirements unknown.	Double present funding.
Multivator	Science—functional feasibility. Device—conceptual.	? 1 Sept. 1963	Sufficient available. Sufficient available.	Sufficient available. $10 000 for development of Mark II. $200 000 for flight hardware.
Minivator	Science—none. Device—flight-sized breadboard.	— Now	— 3 engineers. 4 technicians.	— $200 000 for flight prototype. $40 000 for test & evaluation.
Gulliver	Advanced breadboard demonstrated. Ready to start work on prototype.	With proper funding and interface definition, 1 yr from contract award.	10 persons required in engineering area	Between $250 000 and $350 000, depending on required experiment configuration
Optical rotation	Some functional feasibility demonstrated.	14 mos from contract start.	—	$274 652
"J" band	Science—functional feasibility. Device—conceptual.	1 Aug. 1963. 1 Aug. 1964 for flight prototype.	2 scientists. 4 technicians. 8-10 persons 1 yr.	$100 000 $300 000-400 000
Gas chromatograph	Feasibility breadboard.	Nov. 1964.	Additional: 4 engineers and 5 technicians.	$425 000
Mass spectrometer	Conceptual.	May be ready 1966 launch date.	2 assistants for Dr. Biemann and services of Consolidated Systems Corp.	$350 000

Table 7
Ames Life-Detection Team Evaluation of Proposed Biology Instruments—Development Status, 1963, Continued

Comments	Weight (kg)	Volume (cu cm)	Power Required (av/peak, watts)	Possible Lifetime	Sterilizable by 150°C for 24 hrs
Data rate requirements demand power available only with much larger boosters. Development of sample handling, methods for discrimination of biologicals requires more work.	Not defined	Not defined	10	Not defined	Yes
	1.1-2.3	2460-3280	0.25/1	10-hr minimum	Yes
Depends on stability of phosphatase assay substrate. Can accomodate wide variety of biochemical experiments including some already proposed.	1.4	1558	0.5/3-5	Days–week	Yes
Science input lacking; accommodation similar to Multivator.	2.3	Not defined	1-2/5-10	2 wks	Yes
	3.2-5.4	4920-9840	2-3/4-5	Not defined	Yes
	2.4	2132	0.5/1.1	Not defined	Yes
Sample acquisition and handling development not begun.	Not defined	Not defined	2-3/10	Weeks	Yes
	3.04	3280	?/14.5	Not defined	Yes
Support requirements appear to be underestimated by experimenter.	—	—	—	—	—

SOURCE: Based on data presented in NASA, Ames Research Center, Life-Detection Experiments Team, "A Survey of Life-Detection Experiments for Mars," Aug. 1963, pp. 70-71.

When looking into automated biological laboratories, the summer study group had to consider how such advanced landers would be scheduled in relation to Mariner flights. Mariner flyby spacecraft were slated for launch in November 1964 by Atlas-Agena. Replacing the ill-fated Mariner B, Mariners E and F, approved in December 1963 for combination flyby and probe missions, were planned for 1966 (as Mariner 1966) if Atlas-Centaur were operational by that time. Thus, the members of the 1964 Summer Study preferred "a gradualistic approach" to the ultimate goals of landing a large automated laboratory on Mars and eventually returning samples for study. The scientific community favored exhausting all avenues of research, Earth-based observations and nonlanding missions, before committing itself to that big step.

However, the summer study members saw several "constraints to proceeding in a completely unhurried step-by-step fashion." Those included a "combination of celestial mechanics and the operational realities of space research." Preparation for flight required years of experimental design and spacecraft development and the coordination of effort among large numbers of persons in a wide range of disciplines. As individual scientists, accustomed to following their own idiosyncratic process of trial and error in designing laboratory experiments, they found the world of space research filled with tightly controlled schedules and very specific dos and don'ts. They noted further that the scientist was "plagued by the prospect of investing years of work only to encounter a mission failure or cancellation in which it is all lost—at least until a new opportunity arises, perhaps years hence." While the scientists might "chafe under these circumstances," it was the nature of the enterprise.

Added to the technological and scientific limitations was the small number of launch opportunities for flights to Mars. The "attempt to develop a systematic and gradualistic program is thus constrained to some extent by the fact that, while favorable opportunities occur in the 1969-1973 period, they will not return before 1984-1985." Therefore the summer study members argued for "a substantial program" that would exploit the Saturn launch vehicles during the 1969-1973 launch window. Explicit in their recommendations was concentration on activities that would lead to landings. "The first landing mission should be scheduled no later than 1973, and by 1971 if possible."[59]

THE RESULTS OF MARINER 4

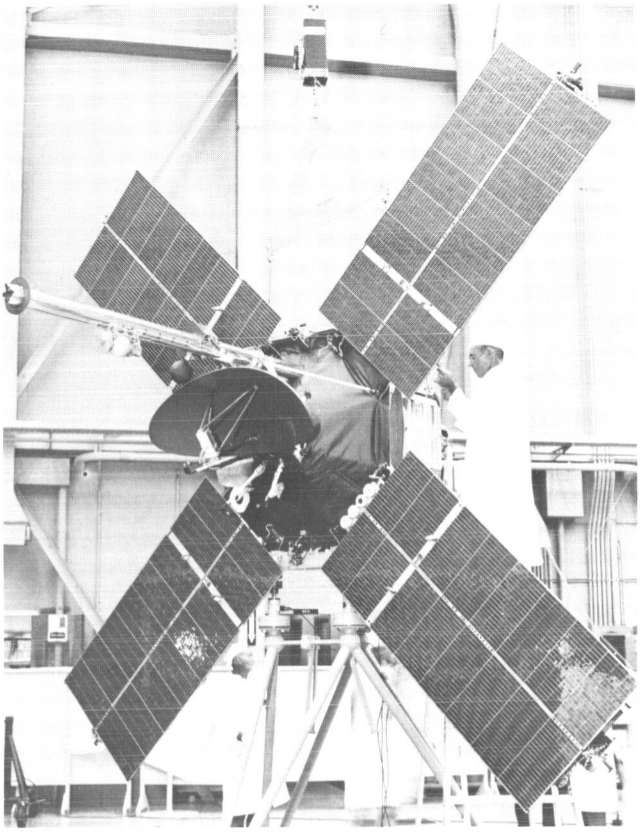
Whereas 1964 was a year of optimism for the burgeoning field of exobiology, 1965 was one of external criticism and reappraisal. New scientific information provided by the *Mariner 4* flyby mission altered perceptions of the Red Planet and raised serious questions about the search for life there. Criticism of NASA's exobiology program came from two quarters, members of the *Mariner 4* science team and scientists who were critical of the space program in general terms.

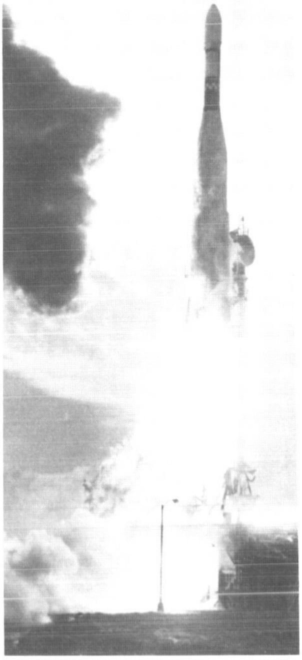
Variously known during its developmental phase as Mariner C, Mariner M, and Mariner 1964, *Mariner 4* was one of two spacecraft launched for Mars in 1964. Conceived in mid-1962 when NASA's advanced planners realized that the Centaur stage would not be ready for a 1964 mission, Mariner C was planned as a lighter Agena-sized spacecraft capable of a mission to Mars. As *Mariner 2* to Venus in 1962 had been a scaled-down Mariner A, the 1964 Mars craft was a revision of Mariner B without the lander.[60] Although smaller than either NASA or the scientists would have preferred, it would provide the first photographs of Mars, an exciting prospect. From November 1962 when the Project Approval Document was signed to liftoff of the two craft in November 1964, this first Mars mission was a challenging exercise. Constant battles against growing payload weights and difficulties with perfecting scientific instruments added a hectic air to preparations for the 1964 flights.[61]

As the launch date approached, trouble seemed to be the key word. *Mariner 3* was launched toward Mars about midday on 5 November. After a short delay while Agena circuits and relays were retested, the launch went normally, but an hour later telemetry indicated that while the scientific instruments were on there was no indication of power from the solar panels. Quickly the launch team determined that the cylindrical fiberglass nose fairing designed to protect the spacecraft during its initial ascent had failed to separate from it. Efforts to break the spacecraft free were frustrated when its circuits went dead after the batteries were drained. As *Mariner 3* blindly headed out into space, destined to enter solar orbit, NASA and contractor personnel searched for the cause of the problem and a quick solution before the 25th, the scheduled date for the second launch.[62]

Working around the clock for 17 days, a composite team from Lewis Research Center, Lockheed Missiles & Space Company, and JPL modified the nose fairing and produced a flawless launch of the second spacecraft on 28 November.[63] Everything went according to plan with *Mariner 4*. The Agena D separated from the Atlas at an altitude of 185 kilometers and went into a parking orbit. After coasting for more than 30 minutes, the Agena engine fired again and Mariner was on the path to Mars. With only 45 minutes elapsed since liftoff from Cape Canaveral, *Mariner 4* separated from Agena and continued its journey through space alone.

It took seven and a half months to travel the 525 million kilometers to Earth's neighbor. The 260-kilogram spacecraft began its brief encounter with the planet on 14 July 1965. Among other measurements, the vidicon television system during a 25-minute sequence took 21 full pictures and a fraction of a 22d of the Martian surface at distances of 10 000 to 17 000 kilometers. After being stored overnight on a tape recorder, the images were transmitted to Earth the next day. For eight and a half hours, JPL received





Mariner 4, *above, is prepared for a center-of-gravity test at Jet Propulsion Laboratory. At right, the spacecraft starts on its way from Kennedy Space Center on 28 November 1964.*

bits of electronic data that would be reconstructed into visual images. The pictures revealed a heavily cratered Mars[64]

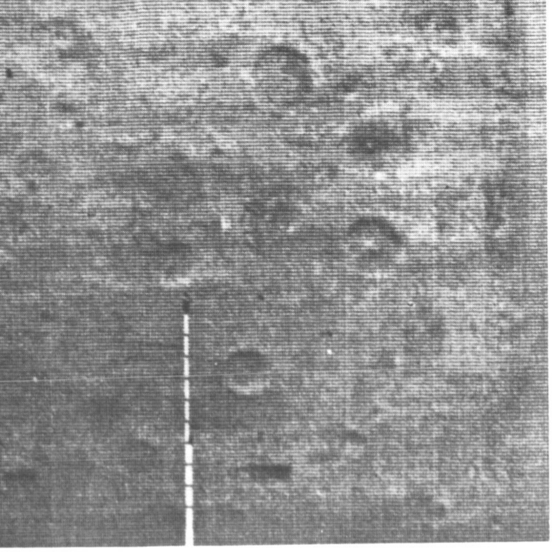
What could one learn from 21½ pictures of 1 percent of the Martian surface taken from an average distance of 13 000 kilometers? For *Mariner 4*, expectations helped color perceptions. On 11 January 1965, Robert B. Leighton, principal investigator for the television experiment and professor of physics at the California Institute of Technology, had written Glenn A. Reiff, Mariner project manager, commenting that the *Mariner 4* pictures would "be of enormous interest to the scientific community and the public at large," but proper interpretation of those pictures was as important as their initial acquisition.[65] From the outset, NASA and JPL officials had carefully informed the public that Mariner would not produce pictures of sufficient resolution to detect plant or animal life, but while reporters told their audiences that "the pictures are not expected to resolve the mystery of life on Mars," they would usually add such phrases as "but may answer long standing questions about the 'canals' of the red planet," hinting that *Mariner 4*'s photography might indeed be spectacular.[66]

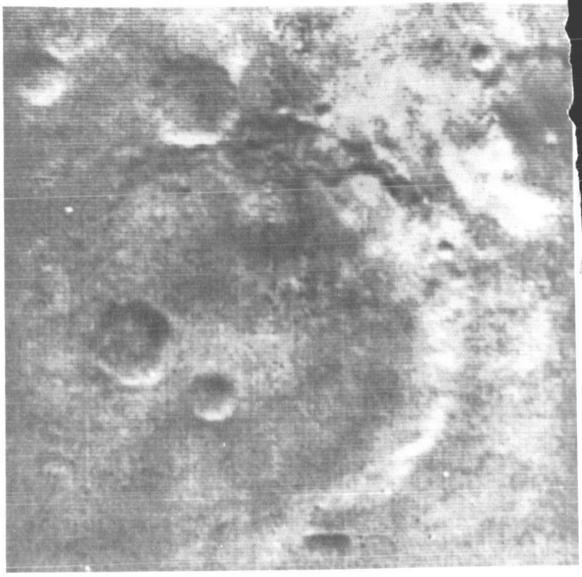
Before and during the flight, scores of articles about *Mariner 4*, the 1964 Summer Study, exobiology, Voyager, and other aspects of the exploration of Mars appeared in the American press.[67] Most carried the caveat that the 20-some photos would be equivalent to the best telescopic views of the moon from Earth and that "even the broadest earth river would not be visible at such a distance," but writers argued that it might still be possible to view the irrigated bands along the canals if any existed on Mars.[68] *Mariner 4* would not necessarily detect life, but the scientific community hoped it would provide additional insights into the likelihood of Martian biology. David Hoffman of the *New York Herald Tribune* commented on this dichotomy in an article on 14 July, the day the pictures were taken: "In what almost amounts to a non sequitur, NASA says the photo mission is not designed to answer 'the question of life on Mars.' But only to 'shed light on the possibility of extraterrestrial life.'"[69]

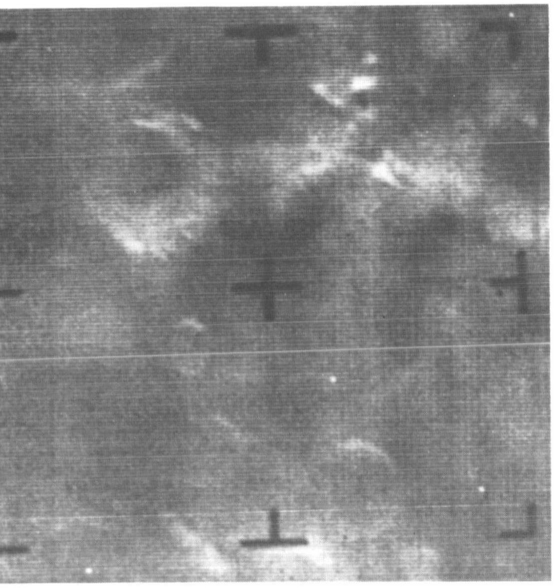
For believers in Martian canals and for scientists dedicated to the extraterrestrial life search, the pictures were disappointing. In a 29 July 1965 statement, the Mars television team led by Leighton summarized their first thoughts on the significance of the photographs: "Man's first close-up look at Mars had revealed the scientifically startling fact that at least part of its surface is covered with large craters. Although the existence of Martian craters is clearly demonstrated beyond question, their meaning and significance is, of course, a matter of interpretation." Their opinion was that the craters led "to far-reaching fundamental inferences concerning the evolutionary history of Mars and further enhances the uniqueness of Earth within the solar system." Seventy craters were clearly visible in photos 5 through 15, and they ranged in diameter from 4.8 to 120 kilometers. NASA specialists noted that it seemed likely that there were both larger and smaller craters in addition to those discerned in the photos. The rims of the craters appeared to rise as much as 100 meters above the surface, and the interiors seemed to descend to several hundred meters. The number of large craters was closely comparable to the densely cratered upland areas of the moon. They added that no Earth-like features, such as mountain chains, great valleys, ocean basins, or continental plates, were identifiable in the small region sampled by *Mariner 4*. And certainly no canals were seen.

From the pictures, the TV team thought some fundamental inferences could be drawn:

> 1. In terms of its evolutionary history, Mars is more Moon-like than Earth-like. Nonetheless, because it has an atmosphere, Mars may shed much light on early phases of Earth's history.
>
> 2. Reasoning by analogy with the Moon, much of the heavily cratered surface of Mars must be very ancient—perhaps two to five billion years old.
>
> 3. The remarkable state of preservation of such an ancient surface leads us to the inference that no atmosphere significantly denser than the present very thin one had characterized the planet since that surface was formed.







Mariner 4 *revealed a heavily cratered Mars, more like the moon than like Earth. Photos taken 14 July 1965, just before the closest approach of 9700 kilometers, were radioed back as digital data. At top left, Mare Sirenum, bordering on Atlantis. Above, Atlantis between Mare Sirenum and Mare Cimmerium. At left, bright region, northwestern Phaethontis. Below at the White House 31 July 1964, JPL Director William Pickering shows* Ranger 8 *photo of the moon to President Johnson. NASA Associate Administrator for Space Science and Applications Homer E. Newell is with him. Behind the president are Dr. Donald F. Hornig, special assistant to the president for science and technology, and Dr. Edward C. Welsh, executive secretary, National Aeronautics and Space Council.*

> Similarly, it is difficult to believe that free water in quantities sufficient to form streams or to fill oceans could have existed anywhere on Mars since that time. The presence of such amounts of water (and consequent atmosphere) would have caused severe erosion over the entire surface.
>
> 4. The principal topographic features of Mars photographed by Mariner have not been produced by stress and deformation originating within the planet, in distinction to the case of the Earth. Earth is internally dynamic giving rise to mountains, continents, and other such features, while evidently Mars has long been inactive. The lack of internal activity is also consistent with the absence of a significant magnetic field on Mars as was determined by the Mariner magnetometer experiment.
>
> 5. As we had anticipated, Mariner photos neither demonstrate nor preclude the possible existence of life on Mars. The search for a fossil record does appear less promising if Martian oceans never existed. On the other hand, if the Martian surface is truly in its primitive form, the surface may prove to be the best—perhaps the only—place in the solar system still preserving clues to original organic development, traces of which have long since disappeared from Earth.[70]

The fifth point notwithstanding, the findings of the TV team were a genuine blow to the exobiologists. Leighton, Cal Tech astronomers Bruce C. Murray and Robert C. Sharp, and JPL television experts Richard K. Sloan and J. Denton Allen presented an official report in the 6 August 1965 issue of *Science*, restating the same basic conclusions. The apparent absence of water over hundreds of millions of years, the very thin atmosphere, and extremely low temperatures were strong arguments against the hypothesis for life put forward during the 1964 Summer Study. New tabular data for the physical properties of Mars are shown in table 8.

Table 8
Physical Properties of Mars: Mariner 4 Findings

	Earth	Mars (1964 Summer Study)	Mars 1	Mars 2	Mars 3
			(alternative *Mariner 4* figures)		
Atmospheric pressure	1000 millibars	10-30 millibars	4.1-5.7	4.1-6.2	5.0-7.0
Gaseous composition of atmosphere:					
oxygen	20%	<0.1%	—	—	—
carbon	0.03%	5-30%	100%	80%	50%
nitrogen	78%	60-95%	—	20%[a]	—
argon	trace	trace	—	—	50%
Temperature range	58°C to -88°C	+30°C ±50°C	-93°C ±20°C	-98°C ±25°C	-103°C ±20°C

[a] Nitrogen plus argon.

SOURCE: NASA, *Mariner-Mars 1964: Final Project Report*, NASA SP-139 (Washington, 1967), pp. 321-22.

No matter which of the alternative atmospheric estimates from *Mariner 4* readings one chose, the possibility for life, past or present, seemed diminished.[71]

External Criticism of the Search for Life on Mars

Criticism of the American space program, latent for several years, burst forth in 1963-1965. The two most prominent fault-finders were Barry Commoner, a microbiologist at Washington University, St. Louis, and critic-at-large-of-scientific priorities; and Philip H. Abelson, a physicist and the editor of *Science*. Both scientists, long-time critics of Apollo's lunar goals, extended their remarks to the exploration of Mars.

Commoner attacked the search for extraterrestrial life in June 1963 on the eve of Abelson's appearance before the Senate Astronautical and Space Science Committee. The committee was seeking "Scientists' Testimony on Space Goals," and Commoner noted that Abelson was the only witness expected to express reservations about the nation's priorities in space research. Of the 10 who were scheduled to testify, all but Abelson had a direct financial interest in the space program.* While Abelson attacked Apollo specifically, Commoner was upset by the argument that the extraterrestrial life search was "the most exciting, challenging and profound issue. . . that has characterized the history of Western thought for 300 years." Believing the possibility of life on other planets was extraordinarily low, he thought that such rhetoric was "a weak prop for the serious decision given its profound economic and social consequences."[72]

Scientists Commoner and Abelson did not agree with NASA's scientific goals. Simply put, they would have preferred to spend Apollo and Mariner-Voyager dollars on other investigations. They were also worried about the "social consequences" of space research in a world that was underfed and potentially revolutionary. In a September 1963 speech to the American Psychological Association, Abelson said there were no predictable economic advantages to be derived from the exploration of the moon or Mars, arguing that "the half of the world that is undernourished could scarcely be expected to place a higher value on landing on the moon than on filling their stomachs."[73]

The exobiologists were accustomed to defending their work on scientific grounds, but they were understandably perplexed when they were criticized in a manner that combined scientific disagreements and differences in opinion over social and economic priorities. Lederberg and others were reasonably certain of Commoner's political motivations, but they were not sure of his scientific views, as he diverged from the origin-of-life hypothesis that underpinned the search for extraterrestrial life. Was it

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*The other nine were S. Ramo, H. C. Urey, P. Kursh, C. S. Pittendrigh, F. Seitz, L. V. Berkner, L. A. DuBridge, M. Schwarzchild, and H. H. Hess.

scientist Commoner or social-critic Commoner who opposed the extraterrestrial search?[74]

Abelson was even more difficult to understand. He was a long-time student of the extraterrestrial life question. In 1960, he had advised NASA that of all the near planets only Mars was a likely abode for life, but that the risk of contaminating the planet with Earth life-forms precluded our going there. By the next year, however, he was arguing persuasively that no place in our solar system other than Earth could support life as we know it. Thus, his editorial in the 2 February 1965 issue of *Science*, "the voice of American science," was particularly telling: "In looking for life on Mars we could establish for ourselves the reputation of being the greatest Simple Simons of all time."[75] Using the latest scientific information from *Mariner 4*, Abelson built a case against future expeditures of tax dollars to look for life on Mars; he was convinced life did not exist there. For a mixture of scientific and political motives, he effectively used *Science* as a forum for the scientifically based denunciations of NASA's goals.[76]

1964 Summer Study Revisited; or "Postscript: October 1965"

Against this background of scientific and political criticism, the discouraging new information provided by *Mariner 4* posed serious questions for those who believed that there might be life on Mars and that continuation of the search was respectable and worthwhile. Joshua Lederberg later looked back on October 1965 as a bleak time for exobiology. With most of the scientific community in agreement with a *New York Times* editorial saying that "Mars is probably a dead plannet," only a few "diehards" (Lederberg's decription of his associates of the 1964 Summer Study) refused to give up and accept Mars as a barren world.[77] In a postscript to *Biology and the Exploration of Mars*, those diehards held that, "during the interval between publication in March 1965 of the Summary and Conclusions of our Study and the appearance of this volume, our knowledge of Mars has been raised to an entirely new level by the success of the Mariner IV mission."[78] Lederberg and 25 other "desperate" persons met in late October 1965 to discuss the impact of *Mariner 4* on their proposed search for life: "The essence of our position was, and still is, the immense scientific importance of evaluating the uniqueness of life on Earth; of discovering facts that will permit more valid inference of its abundance in the Universe; and the fact that the new space technology allows us to obtain empirical evidence on the frequency with which living organization and its precursors emerge in the evolutionary history of planets." Even with the new Mariner data in hand, the scientists still thought "that life, even in essentially terrestrial form, could very well have originated on Mars and have survived in some of its contemporary micro-environments." While finding life clinging to the side of an inactive volcano or at the edge of some warm spring on Mars would be difficult, it was not totally unreasonable to expect.[79]

There was another justification for going to the Red Planet. The summer study participants believed it was "important to re-emphasize . . .

a major aspect of our position that critics have unaccountably missed; we sought to emphasize 'that our conclusion that the biological exploration of Mars will be a rewarding venture does not depend upon the hypothesis of Martian life.'" Throughout their deliberations, they had cast their questions in the broad context of the general evolutionary process in nature. "Our position is . . . fully justified even if life has not emerged there; but we will again be misunderstood if that emphasis is taken to mean we believe the chance of discovering fully fledged life is negligible."[80]

At the end of 1965, the scientists who believed that looking for life on Mars was a respectable enterprise faced those who were equally devoted to the proposition that such an exercise was foolishness of the gravest order. Voyager, with its goal of placing automated biology laboratories on Mars, would become the focus of the two groups' debate. Voyager would be scrutinized because of costs and general disenchantment with the space program, but the central issue would continue to be the validity of searching for life on the Red Planet. To that issue, scientists could bring only informed speculations. *Mariner 4* had provided only clues. No one could yet say with certainty that Mars was lifeless. And the search continued.