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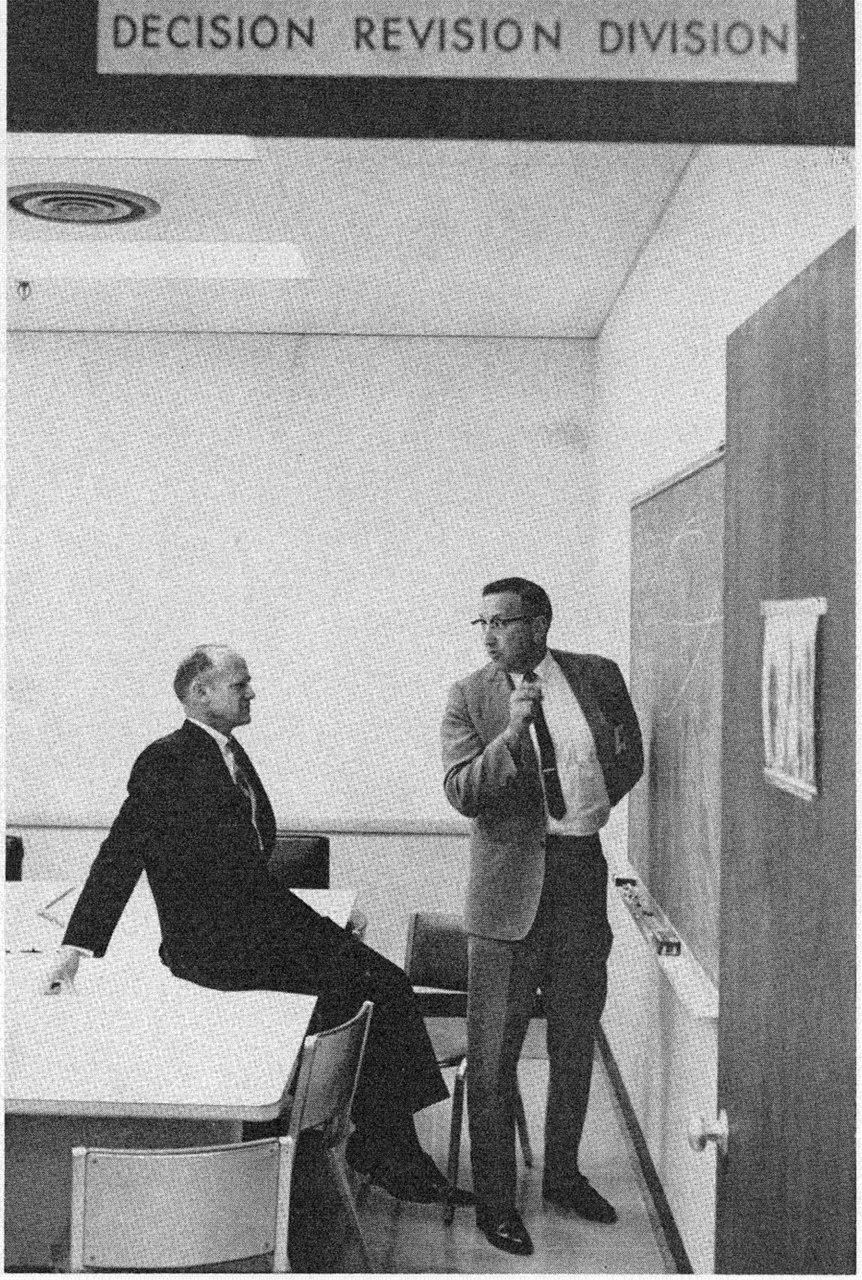


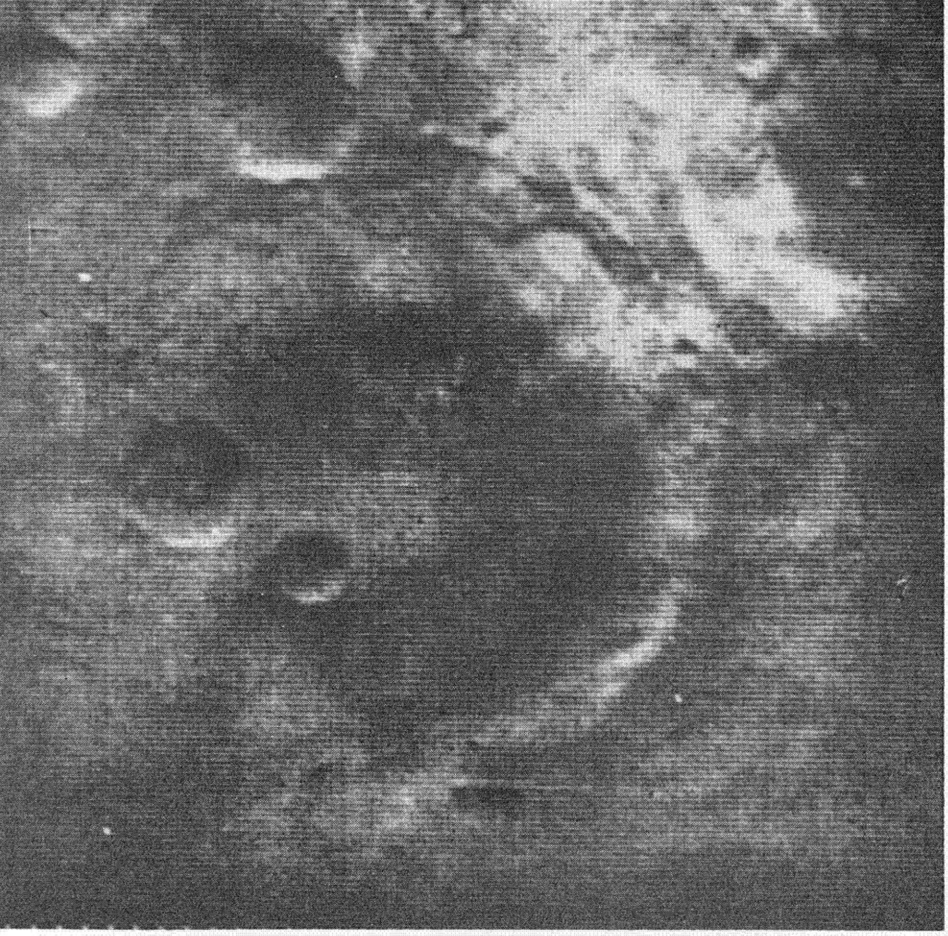
MARINER TO MARS

William H. Pickering, director of Caltech's Jet Propulsion Laboratory, and Dan Schneiderman, Mariner Project manager, in the room where they spent many tense hours during the eight-month mission.

Mariner IV, launched on November 28, 1964, was man's most ambitious and, perhaps, most rewarding effort at space exploration to date. It provided the scientific community with exciting new information about Mars, and confirmed and refined earlier measurements made from Earth; it also demonstrated that modern engineering was able to design and build a complex system capable of operating with high precision at truly astronomical distances. The results of the scientific experiments will be studied for many years, and the engineering lessons will be used in future space probes.

Mariner's task was to perform eight experiments – six of them continuously during the flight, and two (television and occultation) at the time of encounter. That six (including the two at encounter) were successful more than 130 million miles from Earth is indeed remarkable and gratifying. The most spectacular was, of course, the television experiment, which returned 22 pictures that covered Mars from limb to terminator. Other experiments provided measurements of the atmospheric conditions, magnetic field phenomena, and cosmic dust.

In addition to providing scientific data, Mariner set deep-space endurance and long-distance communication records. Caltech's Jet Propulsion Laboratory continued to receive telemetry data until October 1, 1965, when the Earth left the range of Mariner's high-gain antenna; the last command given switched Mariner's broadcast to an omnidirectional antenna which will permit the Earth to receive the carrier signal through the 210-foot antenna currently under construction at the Goldstone Tracking Station. Tracking data received will permit corrections to basic measurements of the relative positions of Earth and the other planets, to the benefit of future space navigation. The Earth will be within range of Mariner's high-gain antenna again in September of 1967, at which time an attempt will be made to re-establish contact with the spacecraft.



Picture Number 11 – "one of the truly great scientific photographs of our age, maybe of all time," according to Robert P. Sharp, chairman of Caltech's Division of Geological Sciences and one of the television investigators on the Mariner Project. This shows the largest (120 kilometers) and smallest (6 kilometers) craters seen on any of the photographs, as well as some curious dome-like bulges near the center of the picture. The area covered here is 170 miles wide and 150 miles high. The picture was taken from a slant distance of 7800 miles.

TELEVISION EXPERIMENT

Mars, more amenable to telescope observation than Venus, with its constant cloud cover, has been the planet that most excited man's imagination since the time of Galileo. As a penalty for its popularity, however, it has suffered from a wide divergence of descriptions and observations. Even in the scientific community there has been considerable disagreement as to what the first explorer might find. According to Robert Leighton, professor of physics at Caltech and principal investigator for the television experiment, "The total range of opinion on the nature of the surface of Mars was so broad that it didn't really help much to know that the truth might lie hidden somewhere within it."

The initial surprise expressed by the Mariner scientists when the television pictures were finally seen may have been due to the extent of the destruction of the Mars surface by meteorites, or it may have been unspoken disappointment at the prospects for finding life there similar to that on Earth. While no signs of life were detected, it should be pointed out that it was never intended for the pictures of Mars to reveal life, but rather to show the terrain and topographic features. Essentially, the pictures removed certain matters from the realm of controversy and focused attention on new opportunities and new problems.

As an indication of how hard it is to detect life in such pictures, at the Caltech-JPL Lunar and Planetary Conference held on the Caltech campus in September, Carl Sagan, professor of astronomy at Harvard, showed a picture of the northern Atlantic seaboard, taken from a Nimbus satellite. This picture was comparable in detail to a Mars picture; it showed familiar topographic features, such as Cape Cod and Long Island; but Sagan defied anyone to detect signs of life. No identifiable objects, no highways, no railways were visible at this resolution. In fact, out of a thousand such pictures of Earth, only two showed any signs of life, and even these signs would not have been seen if certain contrasts had not been brought out by an overnight snowfall. So, obviously, the pictures of Mars can neither confirm nor deny the existence of life there. The experiment of detecting life on Mars still remains to be done.

What can be said with certainty is that at least part of the Mars surface is covered with large craters. If the Mariner pictures, which constitute, after all, only one percent of the whole surface, are representative, then future explorers can expect to find more than 10,000 craters of the size seen. Mars may, indeed, resemble the Moon more than it does the Earth.

The present surface is probably very old, and may not have changed appreciably (except for meteorite impact) for a billion years or more because of an almost complete lack of erosion; the little ero-

Members of the television experiment team wait out the arrival of the first pictures from Mars—Robert Nathan (PhD '56), JPL; Bruce Murray, associate professor of planetary science at Caltech; Robert P. Sharp; Robert Leighton; and Clayton La Baw, JPL. Television data were transmitted at a very low rate—eight hours to complete one picture—to preserve intelligibility over the 130-million-mile distance.

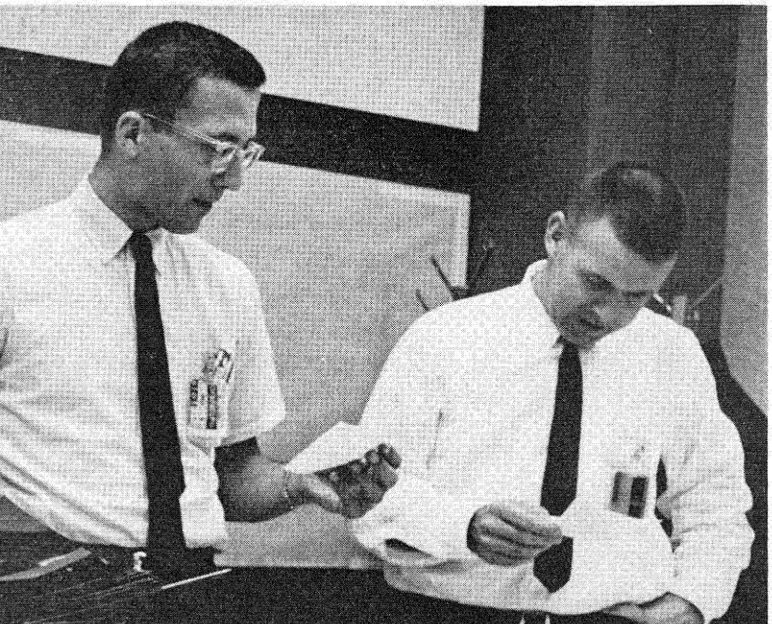
sion that can be seen can probably be attributed to dust and sand storms. Significantly, no signs were seen that water had ever flowed over the present surface. This, together with the very low erosion rate, argues against the possibility that any great bodies of water have existed on Mars since the present surface was formed, for the presence of so much water *anywhere* on Mars would have resulted in severe erosion *everywhere* on the planet, as it does on Earth. The lack of evidence of large bodies of water has prompted some people to conclude that there is little or no likelihood of life on Mars; without water, which serves as a kind of external circulatory system for primitive organisms, it would seem to be very difficult, if not impossible, for life to evolve.

The other striking observation of Mars was the lack of surface features (such as mountain chains and volcanoes) of the kind that are associated on Earth with internal dynamism. Indeed, this simple observation strongly agrees with what Mariner's magnetic measurements also indicated — that Mars has a solid center and, hence, no magnetic field to speak of.

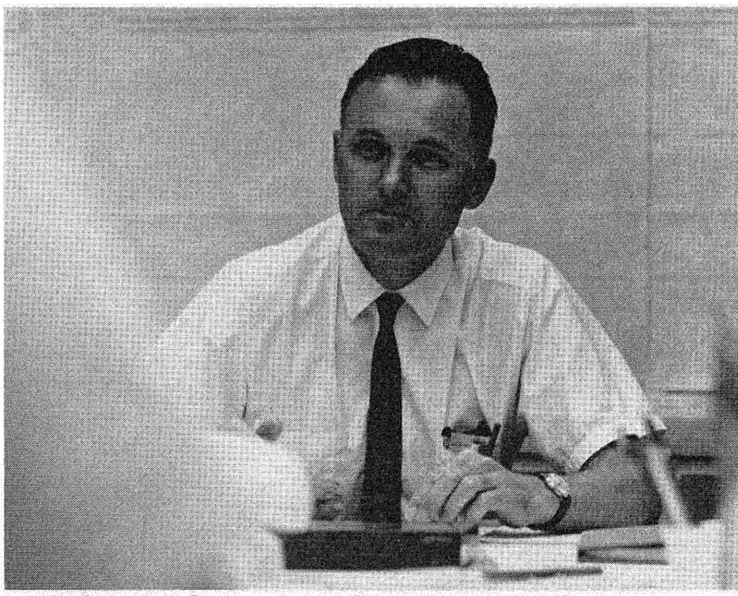
View of Earth, taken from a Nimbus satellite, comparable in resolution to Mariner's pictures of Mars. In addition to Cape Cod, Long Island, and Chesapeake Bay, it shows water and clouds—good signs that life could exist. Actual proof of life on Earth? None.

MARINER MEN

Bill Collier, assistant Mariner Project manager; Dan Schneiderman; John Casani, spacecraft system manager; and W. H. Pickering.



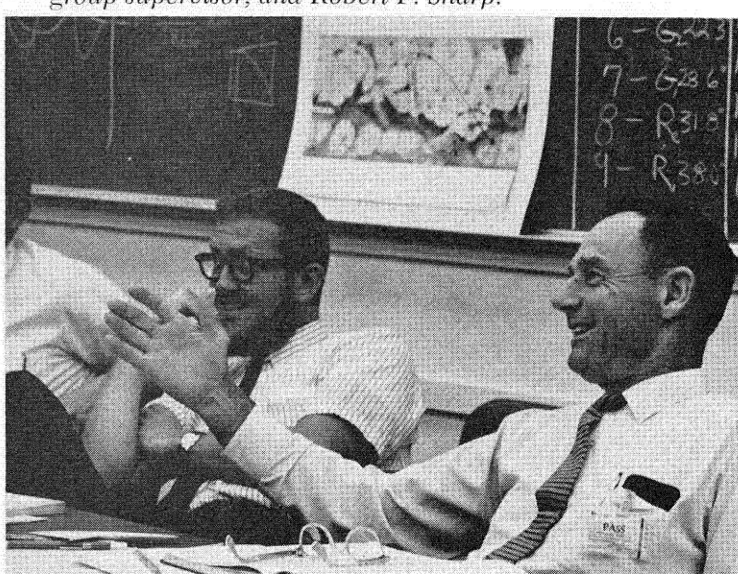
Television experiment investigators — Dick Sloan (MS '56, PhD '64), senior scientist at JPL; and Bruce Murray.



Robert Leighton, principal investigator for the Mariner television experiment.

Leverett Davis, professor of theoretical physics at Caltech, and an investigator for the planetary and interplanatary magnetic fields experiment; and Herbert Bridge, research physicist at MIT, and principal investigator for the solar plasma probe experiment.

Television investigators Denton Allen, JPL engineering group supervisor; and Robert P. Sharp.



OCCULTATION EXPERIMENT

As the path of the radio signal from Mariner intersected with the Martian atmosphere (just before disappearing behind Mars for 54 minutes), the signal's frequency, phase, and amplitude changed. Comparison of the changes with the precisely known parameters of the signal in free space permitted determination of some properties of the atmosphere through which the signal was passing.

Previous observations from Earth suggested that Mars had a low atmospheric surface pressure, somewhere in the range from 20 to 75 millibars (as opposed to about 1000 millibars at the surface of the Earth). Mariner showed that the pressure was about 5 millibars, equivalent to the Earth's atmosphere at about 150,000 feet.

The other important fact gleaned from this experiment was that the atmosphere of Mars probably consists almost entirely of carbon dioxide, based on a combination of Earth and Mariner measurements.

The obvious implication of the thin atmosphere in terms of future exploration is to make it difficult to achieve a soft landing on the surface without using braking rockets (which could alter the very surface features that the vehicle is being sent to investigate). The air, because it is so thin, is quite cold (about -100°C), which explains the extreme dryness of the Martian atmosphere as previously measured from Earth.

MAGNETIC PARTICLE EXPERIMENTS

Trapped electrons and a magnetic moment

Just as high-energy charged particles are trapped in the Earth's upper atmosphere by action of the magnetic field, it was reasoned that a Martian magnetic field would have a similar effect. The trajectory of Mariner passed through regions that would have exhibited three types of characteristic radiation caused by charged particles: bow shock (characteristic of the interaction of the solar wind and the planetary magnetosphere), a transition region, and a magnetospheric boundary – all of which could trap particles for a wide range of Martian magnetic moments. No particles were detected in any of the regions. If it is assumed that the same physical processes leading to acceleration and trapping of electrons in the Earth's magnetic field would be found in a Martian magnetic field, then an upper limit on the magnetic moment of Mars can be set at 10^{-3} that of the Earth.

Search for radiation belts

While there is no quantitative theory of the origin of a planet's radiation belts, it is believed that if the planet is magnetized strongly enough and exposed to the solar wind, belts will exist. Therefore, the failure to detect a radiation belt around Mars would seem to indicate a negligible magnetic field; from this experiment it was concluded that the magnetic field of Mars is less than 10^{-3} that of the Earth.

Magnetic field measurements

It was assumed that the interaction of the solar wind and a Martian magnetic field would produce effects geometrically similar to those observed near the Earth, but with a scale determined by the magnitude of the dipole moment of Mars. Failure to detect a magnetic field implies an upper limit on the value of the Martian magnetic field of between 3×10^{-4} and 10^{-4} that of the Earth.

On the basis of the most widely accepted theory of planetary magnetism, which says that a planet must be endowed with both rotation and a liquid, electrically conducting core, it appears that Mars must lack the fluid core. This may be a reflection of Mars' mass, which is only about 11 percent that of the Earth.

The absence of a magnetic field allows the solar wind to have a direct interaction with the Martian atmosphere, which very likely has an effect on its physical state. The energy and momentum fluxes are large enough that if they interact with moderate efficiency with the Martian atmosphere at the level where ion pressure balances the stagnation pressure of the solar wind, they will remove atmosphere at a rate that is significant in any treatment of its evolution. It is not clear if the present Martian atmosphere has a lifetime comparable to the age of the planet. The absence of high-altitude charged particles means that cosmic radiation and solar-flare protons will reach the top of the Martian atmosphere with their full intensity. Because the atmosphere is so thin, the particles interact with the ground surface, and the entire secondary production of particles from high-energy interactions takes place below the Martian surface.

The success of the Mariner project paves the way for future, perhaps even more spectacular, lunar and planetary exploration. Surveyor, an unmanned but very active outpost to be landed on the Moon, is near completion under JPL's direction, and may have its first test flight late this year. Another project, whose debt to Mariner is incalculable, is JPL's Voyager, which will land an instrument package on Mars sometime near the end of this decade. Voyager will be designed to answer the big question: Does life in some form exist on Mars?