RESEARCH FACILITIES AND PROGRAMS

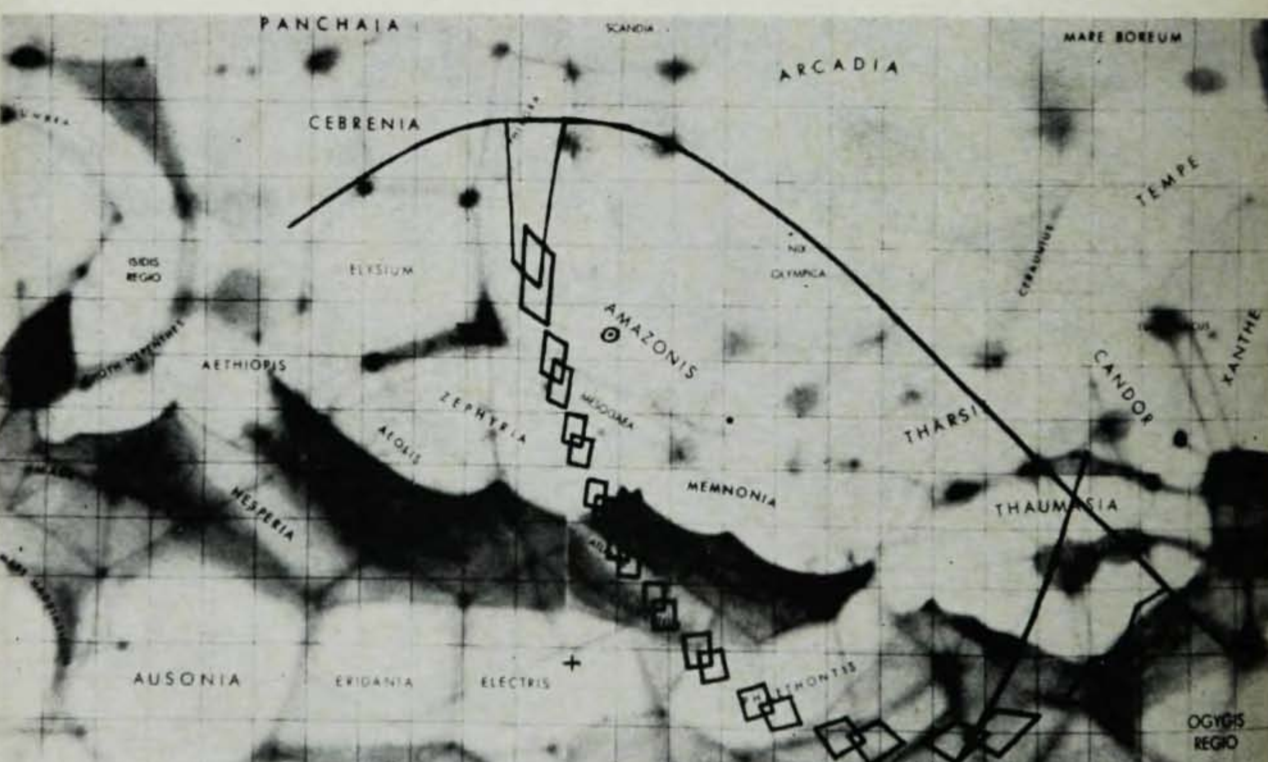
Mars photos

All 22 of the photographs taken by the Mariner IV space probe were released to the public at the end of July, together with a preliminary analysis of the information obtained from the photographs. This was followed by a paper in the August 6 issue of *Science* by Robert B. Leighton and his collaborators at the California Institute of Technology. The photographs were taken on July 15 as Mariner passed Mars at a distance ranging from 17 000 to 20 000 km. Pictures from the beginning and end of the series seem to lack definition, probably because of lighting effects (brightness at the beginning and darkness as the probe crossed the planet's sunset terminator), but surface features show up clearly in the images belonging to the middle of the series, and these yielded the big surprise: impact craters.

The presence of the craters argues that the terrain configuration is very old and has not been subject to erosion, thus spiking speculations that there might be significant amounts of surface water on Mars. Both the existence of the craters and their generally uneroded state support the contention that the Martian atmosphere is extremely rare and has been so for the estimated age of the surface—2 to 5×10^9 years. The absence of surface features attributable to dynamic processes in the interior of the planet seems to indicate that the core of Mars is inert. This impression is strengthened by the fact that Mariner IV observed no significant magnetic field.

More than seventy craters have been seen in the photos, ranging in diameter from 4 to 120 km. The craters have rims rising about 100 meters above the surrounding terrain, and their bottoms are several hundred meters below the rims. Crater walls so far measured have slopes up to about 10°. If the sample is representative, more than 10 000 such craters should exist on the surface of the planet. The number per unit area and the size distribution are both very close to those measured for the moon.

Although the probe passed over several of the "canals" seen from time to time by terrestrial observers, no trace of these features was found. The authors, however, cautioned that the visibility of such features from the earth varies with time. The probe did not pass over the polar regions, but in the winter hemisphere some craters appeared to be rimmed with frost. This would confirm the belief of some ground-based observers that



Map of the Martian area photographed by NASA's Mariner IV spacecraft. The longest curve represents the edge of Mars as viewed from the Mariner IV during the 25 minutes that photographs were taken. Four-sided figures represent the photographs, and areas to the right of the lower curved line are in the Sun's shadow.

daylight ground temperatures are below freezing in the Martian winter. (Air temperature on the surface of Mars is thought to be below freezing at all times.)

Whatever water exists on Mars should thus be frozen most of the time, making the existence of any familiar biological forms extremely difficult. Nevertheless, William Pickering, director of Caltech's Jet Propulsion Laboratory, did not rule out the possibility of life on Mars. He remarked that the probe did not give evidence either way. Furthermore, the pictures could not have shown any works of intelligent life, past or present. He pointed out that the Mariner pictures have a resolution of two miles, and therefore artificial surface features would be unlikely to show up.

Microwaves from a tin sandwich

Three years ago, in England, a young graduate student quietly advanced the theory that supercurrents can be expected to flow across a sandwich consisting of two superconductors separated by an insulating barrier. Since then, a growing ripple of excitement has been stirring the solid-state physics community as the predictions contained in his theory have been verified one by one.

The theory had its origins in the fact that Brian Josephson, an experimentalist and a student of A. B. Pippard at Cambridge University, had become interested in the boundary effects of superconductivity. Suspecting that there would be important coherence and phase effects across a junction of superconductor, normal substance, and superconductor, Josephson made some calculations and then published the results. These appeared in *Physics Letters* in 1962, and later in the thesis he wrote to become a fellow of Trinity College at Cambridge. He is still there working on an experiment for his PhD thesis.

Josephson predicted that pairs of electrons could tunnel from one superconductor to another through a sufficiently thin insulator, and he showed that the tunneling current could have two forms. In its first form, a dc supercurrent could flow without any voltage across the junction. P. W. Anderson of Bell Telephone Laboratories, while visiting Cambridge, became interested in Josephson's work and applied his own theoretical talents to the subject. Shortly afterward, Anderson and J. M. Rowell reported the first observation of the dc Josephson effect.

Josephson also predicted that putting a biasing voltage, V, across the sample would cause pairs of electrons to tunnel from one superconductor to the other. Although this is a virtual process, such a system has oscillating currents of frequency $\Delta E/h = 2eV/h$. These currents interact with the electromagnetic field, causing real processes to occur in which a photon is emitted. These photons have recently been observed in experiments carried out independently in the United States and in the Soviet Union.

Josephson expected that if the ac supercurrent were modulated by an applied rf field, a dc supercurrent would be produced. This would show up as regions of zero slope in the current-voltage characteristic (using dc or low frequency) at bias voltages given by $nhf/2e$ (f is the radio frequency and n takes on integral values). This inverse effect was found and reported by S. Shapiro of Arthur D. Little, Inc., in July 1964.

Since the Josephson predictions, many physicists have been trying to detect the radiation associated with the ac supercurrent produced when a dc voltage is applied across a tunnel junction. The difficulty was in getting the fields out of the junction and into a conventional detector. Late in May of this year I. Giaever of General Electric reported the indirect observation of the ac supercurrent. He used two superimposed junctions, with the second junction acting as detector of the radiation being produced in the first junction. He was able to detect about 10^{-7} W of ac power from the first junction, but did not get the power out of the system of junctions.

Late in June, a group from the University of Pennsylvania (B. N. Taylor, D. N. Langenberg, D. J. Scalapino, and R. E. Eck) gave a post-deadline paper at the New York American Physical Society meeting, and followed this with a paper in the August 16th issue of *Physical Review Letters*. They reported the direct observation of radiation emitted by a Josephson junction, and detected 10^{-12} W outside the junction. Meanwhile, it was learned that a Soviet group (I. K. Yanson, V. M. Svistunov, and I. M. Dmitrenko of the Ukrainian Academy of Sciences) had reported a very similar experiment in the March issue of *Zhurnal Eksperimental' noi Teoreticheskoi Fisiki*, and detected 10^{-14} W outside the junction.

In both experiments a film of tin was deposited on a glass substrate, then a layer of oxide was formed on top, and finally a second layer of tin was deposited on top, forming a right angle. The Penn group used tin strips about 1 mm wide and an oxide layer of about 10 Å. The sample was placed in a rectangular waveguide, equipped with a short-circuiting plunger, and the whole system was placed inside a cryostat with liquid helium. A small magnetic field (about one gauss) was applied in the plane of the junction, perpendicular to the axis of the waveguide. This field produces a spatial variation in the phase difference beween the two superconductors and thereby turns the junction effectively into a driven microwave cavity.

To show how the magnetic field does this, the following explanation has been offered. Figure 1 shows an imaginary circuit through the junction. Let φ be the phase difference between the two superconductors at a particular point, z. The difference between φ at z_1 and z_2 is proportional to the flux enclosed in the circuit; one flux quantum $hc/2e$ corresponds to a phase difference of 2π. Thus grad $\varphi = (2e/\hbar c)\ d\ (\mathbf{H}\times\mathbf{n})$, where d is the effective penetration

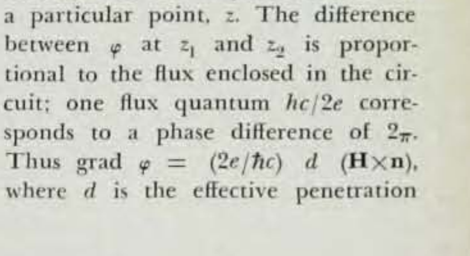


Fig. 1. Imaginary circuit through a Josephson junction.