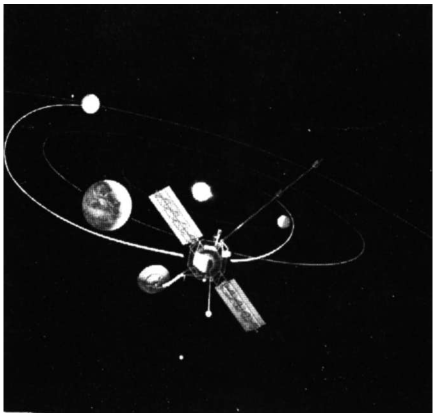
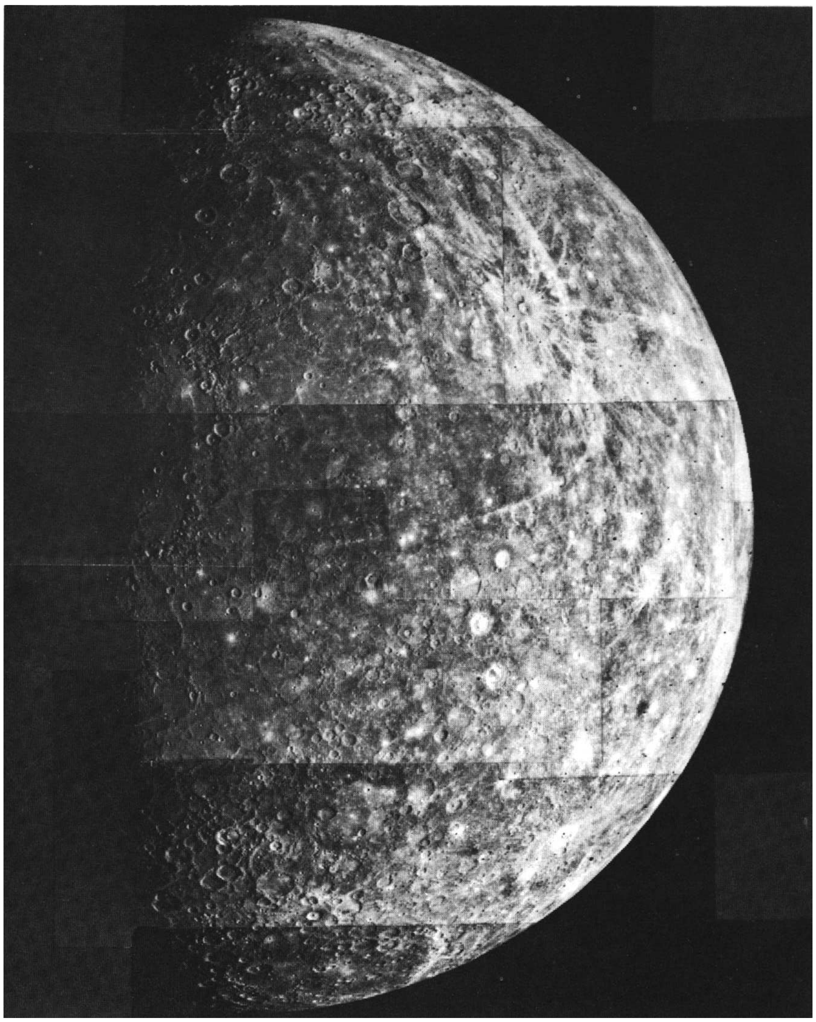


MARINER VENUS / MERCURY 1973

STATUS BULLETIN

MERCURY ENCOUNTER - PRELIMINARY SCIENTIFIC RESULTS

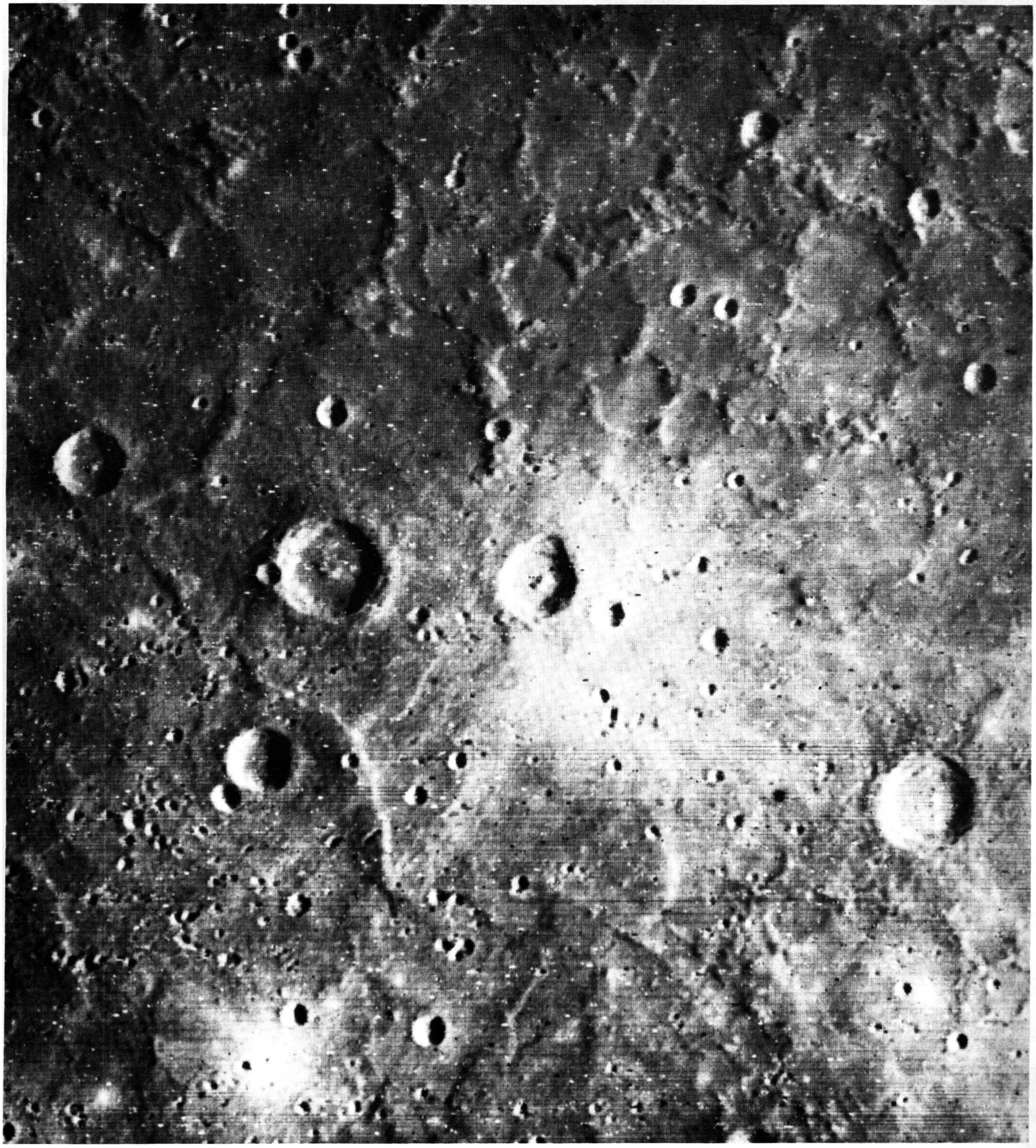


This photomosaic of Mercury was constructed of 18 photos taken at 42-second intervals by Mariner 10 six hours after the spacecraft flew past the planet on March 29. The north pole is at the top and the equator extends from left to right about two-thirds down from the top. A large circular basin, about 1300 kilometers (800 miles) in diameter, is emerging from the day-night terminator at left center. Bright rayed craters are prominent in this view of Mercury. One such ray seems to join in both east-west and north-south directions. Taken from a distance of about 210,000 kilometers (130,000 miles), the pictures were computer-enhanced at the Jet Propulsion Laboratory.

MARINER VENUS/MERCURY 1973 PROJECT OFFICE
Jet Propulsion Labratory California Institute of Technology
National Areonautics and Space Administration
Pasadena, California

4 APRIL 1974

BULLETIN NO. 28



A dark, smooth, relatively uncratered area on Mercury was photographed two hours after Mariner 10 flew by the planet on March 29 from a range of 86,800 kilometers (54,000 miles). Above and to the left of center is a surface similar to the mare material on Earth's moon. It embays and covers rougher, older heavily-cratered topography like that which can be seen in both upper corners of this picture. The history of heavy cratering seems to be followed by volcanic filling, similar to the process on the Moon. The prominent, sharp crater with a central peak (center) is 30 kilometers (19 miles) across. It is located on the upper left edge of a very bright surface area. The bright halo crater, to its right, is 10 kilometers (six miles) in diameter. The sun is from the right.

MAGNETIC FIELD EXPERIMENT

The NASA Goddard Space Flight Center magnetic field experiment consists of two 3-axis sensors located at different positions along a 6-meter boom.

The purpose of the two sensors is to permit the simultaneous measurement (at different distances from the spacecraft) of the magnetic field, which is the sum of the weak magnetic field in space (and near the planets) and the spacecraft magnetic field. By appropriate mathematical analysis using the known locations of the two sensors, it is possible to eliminate the spacecraft magnetic field from the results, thereby improving the accuracy of the results significantly. The method has worked very successfully throughout the entire mission.

In interplanetary space, the magnetic field strength is typically 6 gamma (at Earth's equator the field strength is 30,000). At the onboard sensor, the spacecraft field has been observed to vary from one to four gammas and change directions significantly. As Mariner 10 has approached the Sun, the interplanetary field strength has gradually increased to between 20 to 40 gamma at the location of Mercury's orbit.

The results obtained at Mercury encounter have been startling. It was expected that the planet would not have a magnetic field because of its slow rotation and because, unlike Jupiter, no radio emissions were observed from it. No radiation belts of charged particles would be expected if no magnetic field is present which could trap and contain the particles.

Thus, as the ionized gas from the Sun (the solar wind) flowed past the planet it was anticipated the results would be similar to those at the Moon (see Figure 1). There would be absorption of the solar wind by the planet and the creation of a void or cavity behind the planet, on the dark side. Only small and transient disturbances would result from the disturbance of plasma flow, and these would be located very close to the planet if a negligible atmosphere is assumed for Mercury.

However, very clear experimental evidence was obtained by the magnetic field experiment of the presence of a detached bow shock wave resulting from the deflection of solar wind flowing supersonically past the planet. The locations are shown in Figure 1. Not all data have yet been analyzed to provide a complete interpretation of these results, but it is clear that the obstacle to solar wind flow is "global" in size, i.e., somewhat larger than the planet.

As Mariner 10 approached closer to the planet, the magnetic field increased very smoothly to a maximum of 90 to 100 gammas at closest approach (750 km from the surface). Preliminary analyses suggest by extrapolation that the magnetic field on the surface is perhaps 100 to 200 gammas. This is more than sufficient to deflect the solar wind and create the observed bow shock.

The source of the magnetic field is not yet clear. It may be intrinsic to the planet and may represent the end result of an internal dynamo mechanism generating the field. As such it is about 100 to 1000 times smaller than the Earth's. The magnetic field may also be due to a complex mechanism associated with the solar wind interaction with the planet. In this model the sweeping of interplanetary field lines past the planet may generate an electrical current flow in the planet and/or a possible weak ionosphere which then generates the magnetic field observed. Mercury has provided us with quite a surprise in that no one anticipated or predicted the observed results!

The magnetic field experiment was conducted by a team of scientists form the NASA-GSFC Laboratory for Extraterrestrial Physics: Dr. Norman F. Ness is Principal Investigator, Co-Investigators are Drs. K. W. Behannon and R. P. Lepping, Dr. K. H. Schatten of Victoria University, New Zealand, and Y. C. Whang of Catholic University.

PLASMA SCIENCE EXPERIMENT

Up to this time, we have had definitive information on the nature of the interaction between the solar wind and the Earth, the Moon, and Venus. All of these interactions are very different. It was generally believed, prior to the Mariner 10 encounter, that the interaction with Mercury would prove to be similar to that of the solar wind and the Moon. That is, it was expected that the plasma particles incident on the surface would be absorbed and roughly cylindrical cavity or plasma shadow was expected to extend in roughly the antisolar direction. Instead, Mercury has a well-developed bow shock close to the planet, a region of transitional flow filled with hot shocked plasma, and instead of a plasma cavity a magnetosphere-like region in which plasma electrons are accelerated to energies above a kilovolt. These accelerated electrons provide a source for the nightglow.

The properties of the planet which give rise to these effects are not yet understood. It is possible that Mercury has an intrinsic magnetic field, or it may be that an induced field is produced by the solar wind via "unipolar induction" in the ionosphere or (if the surface is a good electrical conductor) in the surface of the planet.

The Mariner 10 Plasma Science Experiment is a cooperative effort by several laboratories. The experiments include K. W. Ogilvie, R. E. Hartel and J. D. Scudder (GSFC), J. R. Ashbridge, S. J. Same and W. C. Feldman (LASL), G. L. Siscoe (UCLA) and H. S. Bridge and A. J. Lazarus (MIT).

CHARGED PARTICLE TELESCOPE EXPERIMENT

High-energy electron fluxes have been discovered in the magnetic field of Mercury. The electrons have an energy of approximately one million electron volts. They are distributed continuously from a distance of approximately 5000-km above the planetary surface (equivalent to 2 Mercury radii above the surface) to the closest approach of the spacecraft to the planet (approximately 700 km). The peak intensity was found near the closest approach. These electrons were energized in the external magnetic field of Mercury. However, from the preliminary data available at this time, it is not certain whether the electrons are accelerated at the planet and escape to space, or whether the electrons are from a trapped radiation region close to the planet. The electron intensities are below the level required to produce radio emissions which could be detected at Earth by radio telescopes.

Data returned in playback from the interval when the spacecraft was occulted by Mercury, and only processed and analyzed in a preliminary way, show electron fluxes even greater, by a factor of more than 100, than the data provided in real time before occultation. These fluxes and their distribution are quite inconsistent with the simple model of Mercury's interaction which was generally believed before the Mariner 10 mission.

The measurements were made with charged particle telescopes in an instrument designed for this experiment and interplanetary studies by Professor J. A. Simpson and J. E. Lamport in the Laboratory for Astrophysics of the Enrico Fermi Institute at the University of Chicago.

CELESTIAL MECHANICS AND RADIO SCIENCE EXPERIMENT

The geometry at Mercury during the Mariner 10 occultation as seen from Earth is shown in the attached figure. Conduct of the experiment is nearly identical to that described for Venus encounter. The Doppler variations for Mercury encounter, which contain much of the CMRS data are shown in the second figure.

Since this is the first flyby of the planet Mercury, the Celestial Mechanics Experiment Team expects to greatly improve some basic physical constants describing the planet. Our knowledge of the mass of Mercury should be improved by at least 100 times our present knowledge. Since the encounter doppler data are of very high quality, if the oblateness of Mercury should be as small as a hundredth that of the Earth, we should be able to detect this in the data.

The extremely refined mass which will be deduced from the Mariner 10 data will allow us to more precisely compute the motion of planets on which Mercury exerts an influence and thus improve our knowledge of planetary motions within the solar system. This will have an immediate and strong impact on the relativity solutions contained in data from previous missions such as Mariners 6, 7 and 9.

The ultimate sensitivity of the radio science experiment to an ionosphere and atmosphere is about 100 electrons/cubic centimeter and 1/100 of a millibar, respectively. Thus if the atmosphere were as large as a hundred thousandth of the Earth's, it should be detectabie by Mariner 10's radio system.

Immersion occurred approximately at the equator on the night side of Mercury. Within the sensitivity of the experiment neither an ionosphere nor an atmosphere was detected. The day-side high-latitude emersion data are only partially available. At the present time it can be said that no interaction was detected above 100 km altitude. Open-loop data, now being processed, hold the clue to any dayside interaction. If there is an ionospheric layer or layers on the day side, it exists below 100-km altitude.

The Celestial Mechanics and Radio Science Experiment was conducted by a team of investigators from three institutions: H. T. Howard, Team Leader, and G. L. Tyler from the Center for Radar Astronomy, Stanford University. G. Fjeldbo, A. J. Kliore, G. S. Levy, D. L. Brunn, R. Dickinson, R. E.

Edelson, W. L. Martin, R. B. Postal, B. Seidel, T. T. Sesplaukis, D. L. Shirley, C. T. Stelzried, D. N. Sweetnam, G. E. Wood, A. I. Zygielbaum from Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California. P. B. Esposito and J. D. Anderson of Jet Propulsion Laboratory. I. I. Shapiro and R. D. Reasenberg from the Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts.

ULTRAVIOLET SPECTROSCOPY EXPERIMENT

The ultraviolet experiment on Mariner 10 found definite evidence for helium in the atmosphere of Mercury. Its concentration is significantly higher than concentrations observed in the lunar atmosphere. If gas is formed primarily by radioactive decay of uranium and thorium, the observation can be interpreted to yield information on the concentrations of these elements in the crustal rocks of the planet. Preliminary analysis suggests that Mercury may contain concentrations of uranium and thorium comparable to those found on Earth.

Weak luminosity detected on the dark side of Mercury appears to indicate the presence of additional gases in the atmosphere, including argon, neon and possibly xenon. The occultation mode of the experiment allows one to set an upper limit on the total gas content of the planetary atmosphere. The surface pressure on Mercury is less than that of Earth by a factor of 10^{11}. The albedo of Mercury at ultraviolet wavelengths is similar to that of the Moon.

The Ultraviolet Spectroscopy Experiments were conducted by A. Lyle Broadfoot and M. J. S. Belton, of Kitt Peak National Observatory, and M. B. McElroy of Harvard University.

INFRARED RADIOMETER EXPERIMENT

The Mariner 10 Infrared Radiometer has measured the surface temperature of Mercury from the blistering heat of the day side to the extreme cold of the unilluminated hemisphere, finding that the uppermost layers of the soil are porous and highly insulating. The thermal properties of Mercury are thus similar to those of the Moon. The night-time temperatures, which are crucial for the determination of the nature of the soil, have never before been measured.

The Infrared Radiometer, constructed by Santa Barbara Research Center, consists of twin 1-inch telescopes with detectors sensitive to the thermal radiation from Mercury. The short-wave telescope can measure temperatures in the range from 700 to 200°K (about 800 to -100°F), and the long-wave telescope is sensitive from 300 to 80°K (about 80 to -320°F). The linear resolution at the surface of Mercury varies from 10 to 50 km, depending on the distance of the spacecraft from the planet. Data were obtained during the hour in which Mariner swept past the planet, extending from the illuminated part of the planet across the night side and back again to the sunlit surface. Over the latter part of this scan the spacecraft was in Earth occultation, and the observations were tape-recorded for later transmission to Earth. The data presented here is limited to the observations received in real time, spanning the near-equatorial temperatures from mid-afternoon until nearly midnight of Mercury local time. (Since the rotation rate of Mercury is very slow, the length of a Mercurian day is equal to that of 176 terrestrial days. Thus an "hour" of local time of Mercury corresponds to more than seven days on Earth.

On the illuminated side of Mercury, the temperature is extremely high, ranging from about 570 to 700°K (about 560 to 800°F), depending on the distance of the planet from the Sun. (The orbit of Mercury is more eccentric than that of any other planet except Pluto, resulting in substantial variations in distance from the Sun, and hence in the surface temperature at local noon). Venus is the only planet that is hotter than Mercury. At the time Mariner reached Mercury, it was near its maximum distance from the Sun, so that the noon temperature was near the lower limit of the above range. The planet temperature at mid-afternoon, was 460°K (about 370°F). As the instrument's field of view swung past the terminator into the night side, the temperature plumetted rapidly to below 150°K (about -200°F), and then declined slowly and steadily, just as would be expected for a thermally insulating surface. At local midnight, the equatorial temperature was down almost to 100°K (about -280°F), and an extrapolation of our data to just before dawn, where the Sun has not shone for nearly three Earth-months, gives a minimum temperature of approximately 90°K (about -300°F). Thus, the range of equatorial temperature during a Mercurian day is about 1000°F, much greater than that on any other planet.

The surface temperature of a planet, and particularly the rate of cooling of the surface during the night, are sensitive to the physical properties of the upper few inches of the surface soil. In a sense, then, the radiometer experiment has an extraordinarily high resolution, for it allows us to isolate and investigate the nature of this very thin surface layer of the planet. In general, the lower the temperature at night the more insulating is this surface layer; like a blanket, an insulating layer of dust keeps the heat in and results in a cold surface. The very low temperatures observed on the night side of Mercury, which are nearly the same as the night temperatures on the Moon, show that the thermal conductivity of the soil of Mercury is similar to that of the Moon. For both objects, this thermal conductivity is much lower than we encounter on Earth, where moisture and wind compact the soil and increase its ability to conduct heat. Only in the near vacuum at the surfaces of Mercury and the Moon can the continuous "gardening" of the soil by meteoric impacts maintain the low-density dust layer required to match the observed temperatures.

When examined in detail, the temperature scan across Mercury reveals small variations (up to 2 degrees) from the smooth temperature decline expected for a completely homogeneous material. Such variations were anticipated and are seen also on the Moon. Since the observed fluctuations are so small, however, it is concluded that in the part of Mercury observed in this experiment the surface is generally homogeneous in the upper few inches, with few outcropings of rocks that are not blanketed by the pervasive layer of insulating dust.

Quantitatively, the main parameter of the soil that was derived from the measurements of the night-side temperature is the inverse thermal inertia, a quantity proportional to the reciprocal of the square root of the thermal conductivity and the density. For Mercury the value of this thermal parameter is 600 ($cal^{-1} cm^{2} s^{1/2} {}^{\circ}K$); for comparison, its value is about 800 for the Moon and 150 for Mars. The opacity of the soil to microwave radiation is almost exactly the same as that of the Moon, and the density of the upper few inches of the Mercurian soil is between 1.0 and 1.5 times that of water. The porosity of the soil must therefore be about 50%; probably it has an appearance and bearing strength very similar to that of the lunar soil.

The members of the Mariner 10 Infrared Radiometer Team are: Stillman Chase of Santa Barbara Research Center; Ellis Miner of JPL; David Morrison of the University of Hawaii; and Guido Munch and Gerry Neugebauer of the California Institute of Technology.

TELEVISION EXPERIMENT

A picture is worth a thousand words. The results of the television experiment are shown in the photographs in Status Bulletins.

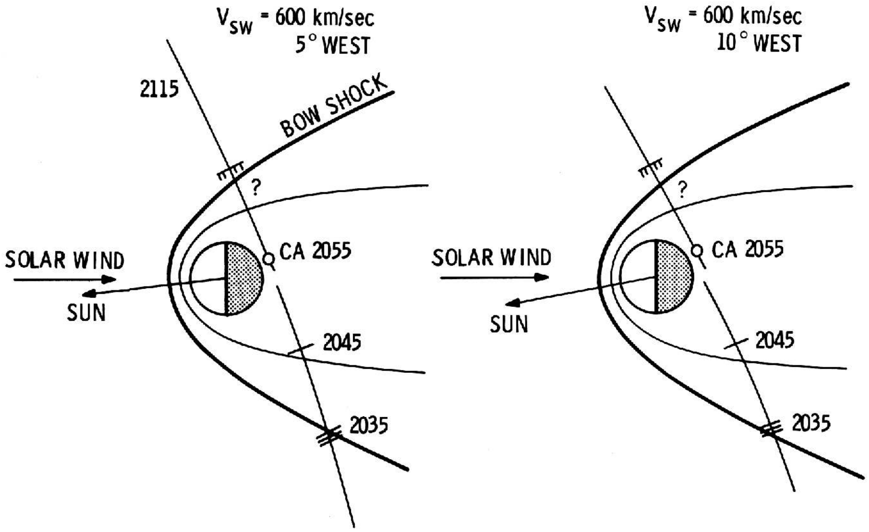
A mosaic of photos of Mercury's far side released at JPL and taken by Mariner 10 last Friday as it sped away from the planet shows features not seen in Mariner's photos of the other side of the planet taken during the spacecraft's approach. One feature is a large 800 mile diameter basin with lightly cratered flat plains similar to large lunar basins on the Moon's near side. A close-up photo of the far side shows a large number of old ghost craters filled in by later volcanic flows. Mariner is still operating well in spite of an over-heated power system which has now cooled slightly.Flight Engineers are making plans to keep Mariner and its two powerful telescope cameras in operating condition as it makes its 176 day circle of the Sun, and second flyby of Mercury next September 22.

Star photography for a navigation experiment is tentatively planned for Thursday and Friday.

The Navigation Team is also beginning studies for a possible sunline maneuver in mid May.

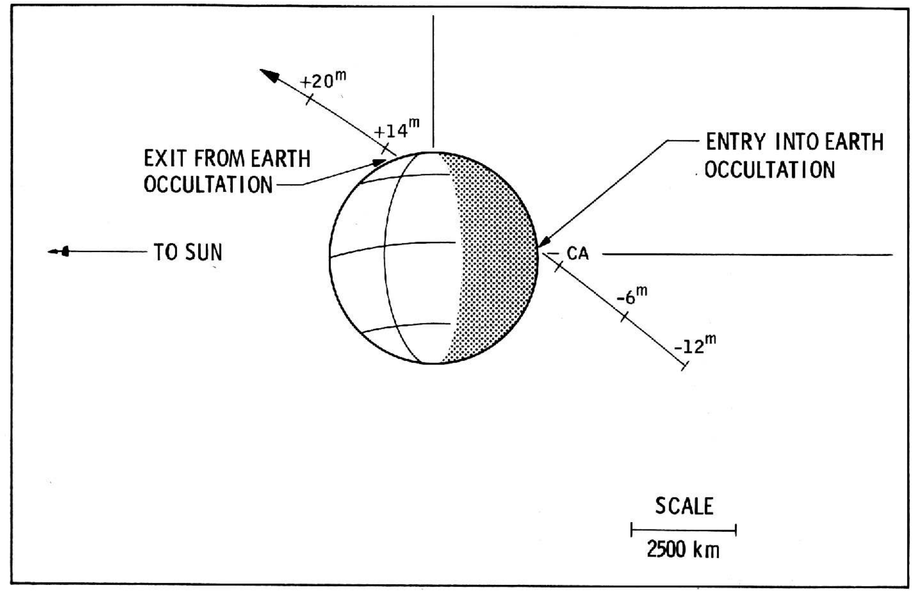
Mariner 10 is now a little over 3 million miles from Mercury and 102 million miles from Earth.

BOW SHOCK AT MERCURY

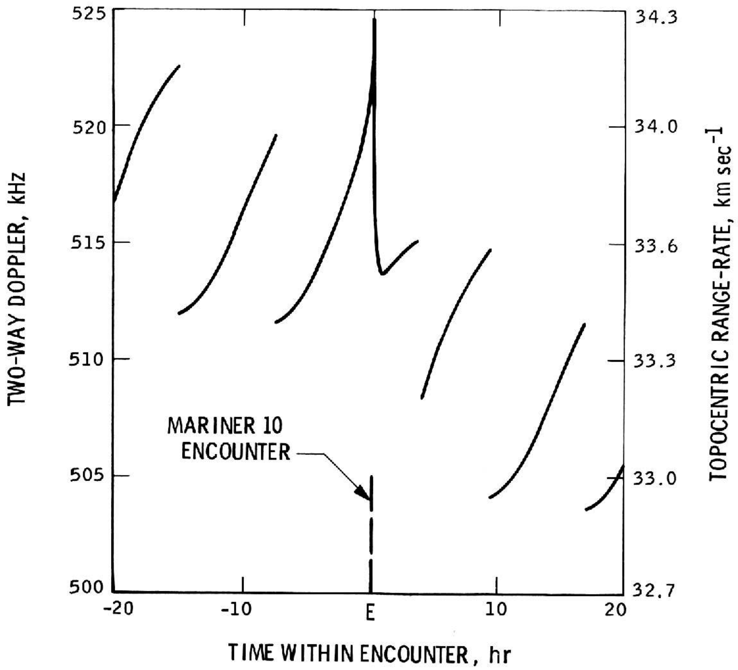


VIEW FROM EARTH; SHOWING EARTH OCCULTATION

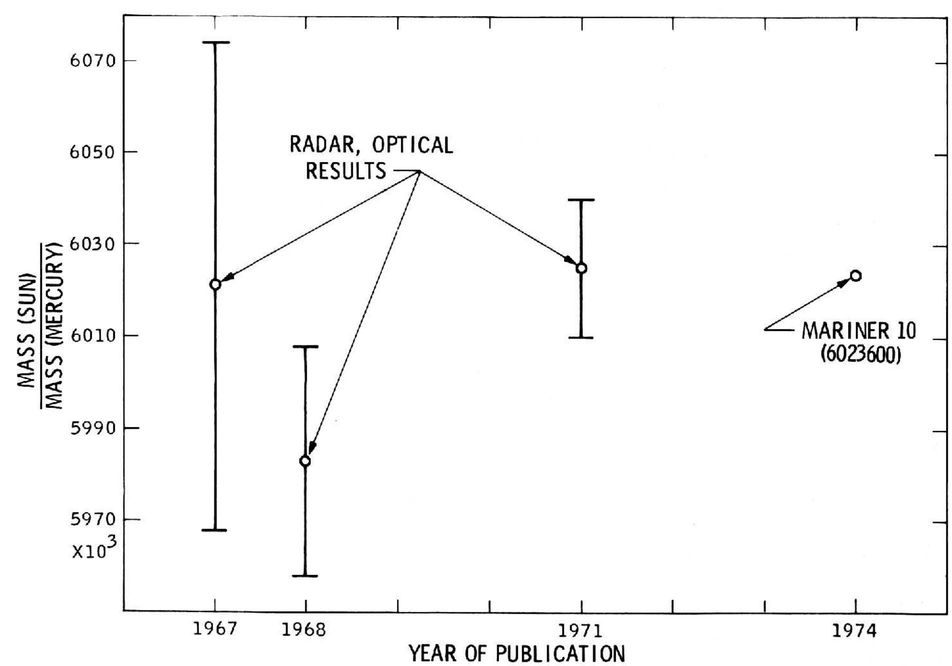
E -12^m TO E $+20^m$

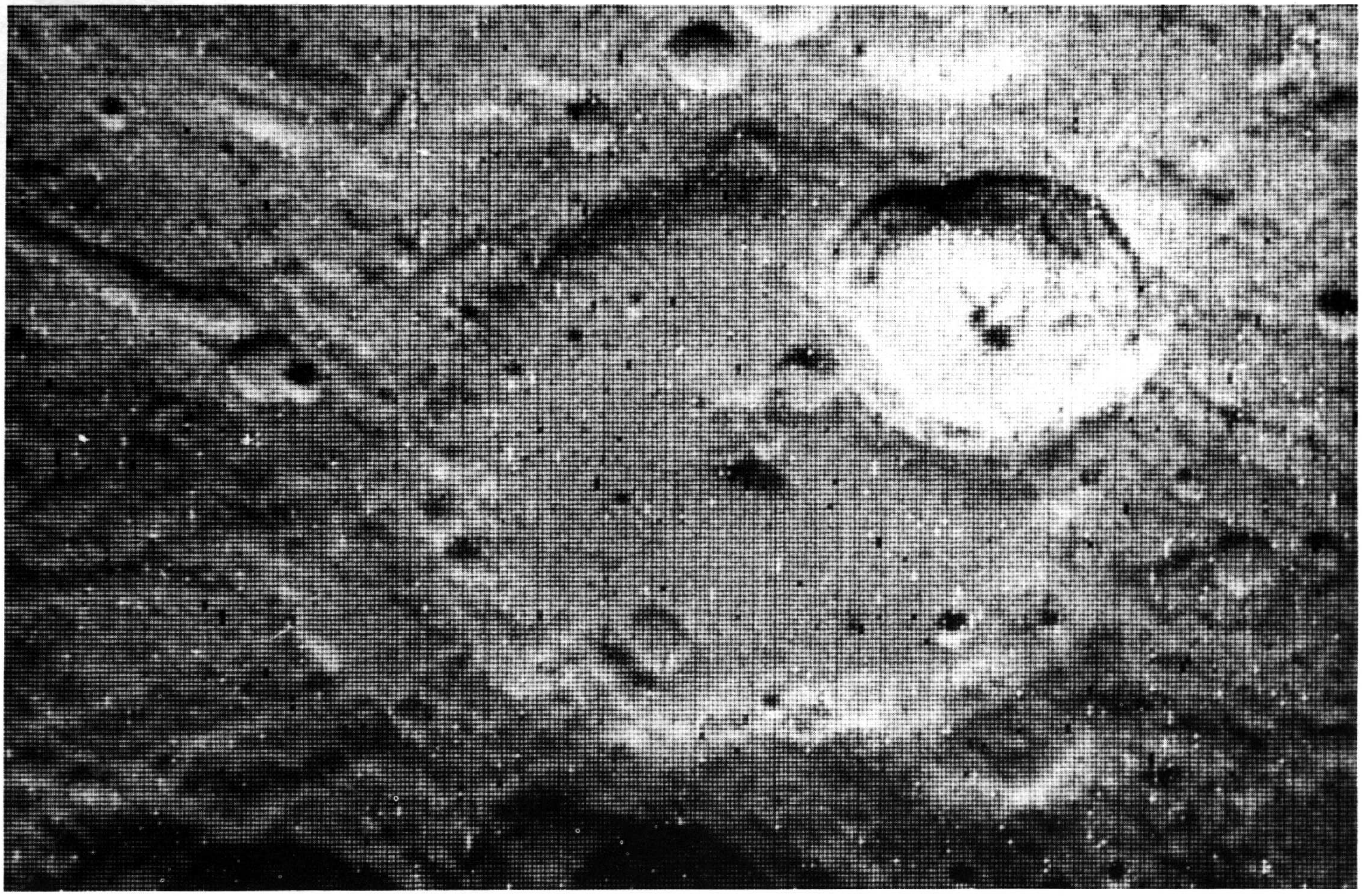


DOPPLER VARIATION DURING MERCURY ENCOUNTER



MERCURY MASS DETERMINATION





The Mariner 10 television-Science Team has proposed the name "Kuiper" for this very conspicuous bright Mercury crater (top center) on the rim of a larger older crater. Prof. Gerard P. Kuiper, a pioneer in planetary astronomy and a member of the Mariner 10 TV team, died December 23, 1973, while the spacecraft was enroute to Venus and Mercury. Mariner took this picture from 88,450 kilometers (55,000 miles) some 2-1/2 hours before it passed Mercury on March 29. The bright-floored crater, 41 kilometers (25 miles) in diameter, is the center of a very large bright area which could be seen in pictures sent from Mariner 10 while Mercury was still more than two million miles distant. The larger crater is 80 kilometers (50 miles) across.

At the Press Conference to reveal preliminary science results of the Mariner 10 Mercury Encounter, Mr. N. W. (Bill) Cunningham, Mariner Venus/Mercury Program Manager of NASA Headquarters made the following proposal to name a Mercury feature for Dr. Gerard Kuiper.

On July 31, 1964, Dr. Gerard Kuiper, standing on this same stage, presented the preliminary results of the Ranger 7 mission which had just returned the first close-up photographs of the lunar surface. Dr. Kuiper was the principal investigator of the Ranger Television Team and that mission initiated the exploration of the terrestrial planets. Mariner 10 has now completed this cycle. Perhaps you remember his opening remarks on that occasion: "This is a great day for science, this is a great day for the United States".

Dr. Kuiper was also a member of this Mariner 10 TV team. His fellow team members have proposed that a prominent surface feature in the Mercury photographs be named in his honor. NASA endorses this suggestion and will recommend to the appropriate commission of the International Astronomical Union that the very bright crater first seen in the photographs of Mercury and which Dr. Bruce Murray has already pointed out, be named Kuiper.

I'm pleased that Mrs. Kuiper, who is seated in the audience, is able to be with us today on this occasion .

I would like to also add that I am personally very pleased that this particular feature will carry Dr. Kuiper's name. It is a fitting tribute to a tremendous person, a great scientist, and a good friend. Thank you.