Reports

Mariner 10 Mercury Encounter

Abstract. *Mariner 10's closest approach to Mercury on 29 March 1974 occurred on the dark side of the planet at a range of approximately 700 kilometers. The spacecraft trajectory passed through the shadows of both the sun and Earth. Experiments conducted included magnetic fields, plasma and charged particle studies of the solar wind interaction region, television photography, extreme ultraviolet spectroscopy of the atmosphere, the detection of infrared thermal radiation from the surface, and a dual-frequency radio occultation in search of an ionosphere.*

Mariner 10 encountered Mercury on 29 March 1974 after a flight of 146 days (Fig. 1). The exploration of Mercury was the primary objective of the mission and the basis for the selection of the Mariner 10 experiment complement. It was desired to grossly characterize several of the important properties of this little-known planet, particularly to determine the nature of its surface morphology; whether an atmosphere is present, and, if so, the constituents; its interaction with the solar wind; and a refinement of its mass and radius. In recognition of the important information it contains concerning a planet's bulk properties, the study of the interaction between Mercury and the solar wind was given a high scientific priority, with the result that a dark-side passage was selected for the flyby. An aim point within the solar occulation zone also made possible a sensitive search for a tenuous neutral atmosphere by observation of the extinction of solar extreme ultraviolet radiation and a favorable groundtrack for studying the infrared thermal emission of the surface from midafternoon to midmorning, local time. Passage through the region wherein Earth is occulted by Mercury as viewed from the spacecraft was desired for the conduct of a dual-frequency (X- and S-band) radio occultation probe in search of an ionosphere and for the radius measurement. The flyby trajectory was not optimal for the classic tool of the exploratory spacecraft, imaging, but the provision of two telescopes (focal length, 1.5 m) capable of 100-m resolution at a range of 5000 km resulted in a very satisfactory television experiment. A second extreme ultraviolet spectrometer, designed to detect resonance scattering emissions of H, He, O, C, Ne, and Ar, was mounted on the scan platform, sharing its positioning control with the television experiment.

The Mariner 10 spacecraft and its flight through Venus encounter has been described by Dunne (*1*). After the Venus encounter operations, spacecraft activity lapsed into a normal cruise mode with continuous collection of data on magnetic fields, plasma, and charged particles at 2450 bits per second. On 16 March 1974 at 1155 G.M.T., a third trajectory correction maneuver (TCM) was carried out, moving the flyby point at Mercury from a miss distance of some 10^4 km on the bright side to the desired dual occultation target point. The Mercury flyby geometry is shown in Figs. 2 and 3.

The closest approach occurred at 2046 G.M.T. on 29 March; the closest approach distance was 703 km relative to the surface, based on a Mercury radius of 2439 km. The spacecraft velocity relative to Mercury was 11.13 km sec^{-1}, and the distances to Earth and the sun were 148.6×10^6 and 69.7×10^6 km, respectively. Solar occultation entry and exit times were 2042 and 2049 G.M.T., respectively. Corresponding times for Earth occultation were 2048 and 2059 G.M.T. The sun-Earth-probe angle at closest approach was 27°.

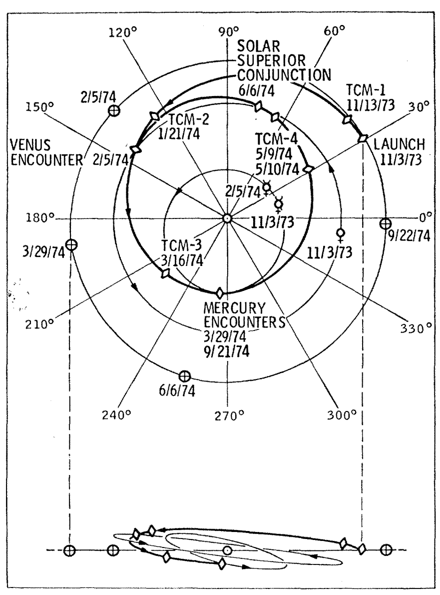
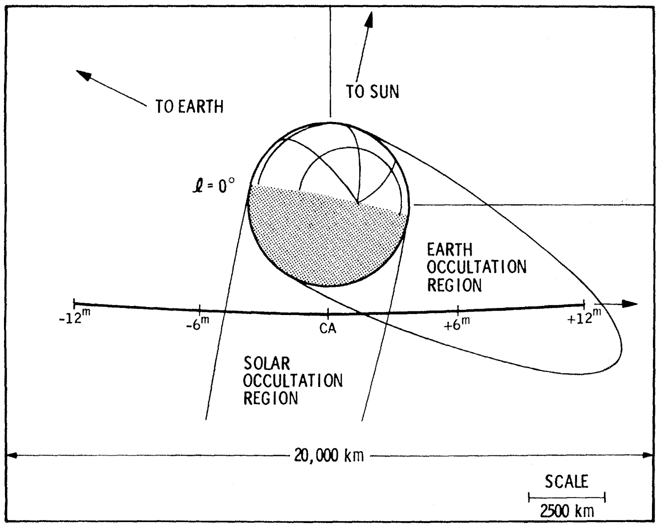


Fig. 1. Overview of the trajectory of the Mariner 10 mission, showing the relative position of the spacecraft, Earth, Venus, and Mercury at the times of significant events. Verticle exaggeration is approximately 3 to 1 in the lower view.

The Mercury encounter sequence extended from 23 March, when the first television pictures were obtained at a range of some 5.3×10^6 km, to 2 April, approximately 4 days after closest approach (CA). During the early phases of the encounter sequence, operations were confined to about an hour of picture-taking per day, using the spacecraft tape recorder, with interleaved extreme ultraviolet airglow spectrometer scans and spacecraft motion-driven drifts through the planet's atmosphere. This cyclic pattern was accelerated as the spacecraft closed rapidly with the planet, becoming a 1½-hour cycle starting at a range of about 750,000 km (16 hours prior to CA). From this time until some 16 hours past encounter, all science sequence commands were issued by the spacecraft's central computer and sequencer (CC & S), which had been programmed to do so before the start of the ground-commanded far encounter sequence on 23 March. The transmission of full-resolution pictures at 117.6 kilobits per second started 3 hours, 33 minutes, prior to encounter, continuing until 4 hours, 15 minutes, past CA. This high data rate, which increased high-resolution (<2.7 km) coverage by approximately a factor of 4, was made possible by the installation of special low-noise masers (*2*) on the 64-m antennas at Deep Space Station (DSS) 14 (Goldstone, California) and DSS 43 (Tidbinbilla, Australia). Near CA, from 28 minutes before until 8 minutes after, imaging was interrupted, and high-resolution extreme ultraviolet airglow spectrometer scans were obtained in search of Ar, the heaviest of the gases for which the experiment was designed and therefore the smallest in scale height.

During this interval, a range point was obtained at X-band for the celestial mechanics experiment. This was accomplished by means of a rapid uplink transfer between Goldstone DSS 12



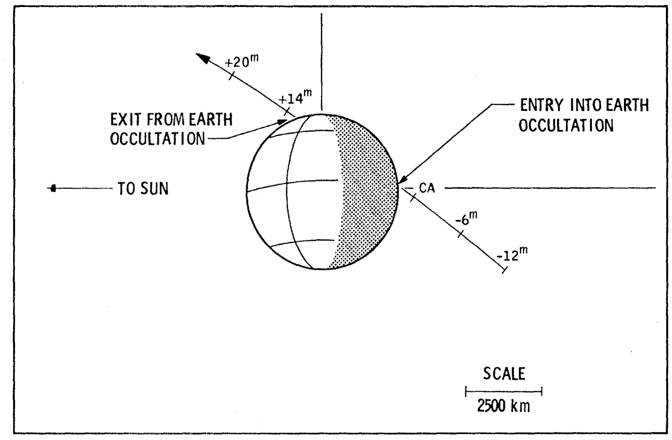


Fig. 2 (left). Mercury close flyby geometry, viewed from the trajectory north pole. Fig. 3 (right). Mercury encounter as viewed from Earth, showing Earth occultation immersion and emersion.

(26-m antenna, 10-kw transmitter) and Goldstone DSS 14; DSS 12 had been maintaining uplink for command purposes in order that DSS 14 could be operated in a "listen only" mode to receive the high rate imaging. The 100-km DSS 14 transmitter was required to provide an adequate signal-to-noise ratio in the received spacecraft carrier and its superimposed range code. The forward beam of the infrared radiometer (IRR) intersected Mercury's surface at 2022 G.M.T., leaving at 2044 G.M.T. The IRR mode-2 command (aft beam, planet; forward beam, reference) was sent by the CC & S at that time; 1 minute later, the aft beam intersected the surface, continuing measurement until crossing the far limb at 2057 G.M.T.

Data obtained during passage through Earth occultation was recorded on the spacecraft tape recorder and played back several times starting at 16 hours after encounter. With the exception of this playback, the outgoing sequence mirrored the incoming one but was terminated after an imaging search for a Mercury satellite conducted at encounter plus 4 days.

After Mercury encounter operations, the spacecraft was returned to its cruise state for the long voyage around the sun and back to Mercury. A TCM was conducted on 9–10 May to allow a re-encounter with Mercury on 21 September 1974 between 2100 and 2200 G.M.T.

The scientific results obtained at Mercury are of significant planetological interest. The distinctly nonlunar solar wind interaction region characterized by the existence of a planetary magnetic field and structured streams of accelerated electrons and protons is as exciting as it was unexpected. Whether that field is induced or intrinsic, its implications with respect to the internal constitution of the planet may be profound. The existence of extensive areas of terrain morphologically similar to the lunar mare material, combined with the planet's high density and the apparently primordial character of the surface in general, leads to important speculations concerning the nature of processes which occurred early in Mercury's history, the understanding of which may lead to modifications in theories dealing with the formation and subsequent evolution of the terrestrial planets. It should be remembered, however, that Mariner 10 has given us but a brief glimpse of Mercury, raising, as do most initial ventures in planetary exploration, many more questions than it has answered. But the questions now have a sharper focus, and their answers a clearer place in the hierarchy of solar system studies.

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References and Notes

1. J. A. Dunne, *Science* **183**, 1289 (1973). The Mariner 10 launch time which was reported to be 0245 on 2 November 1973 was in fact 0545 on 3 November.
2. R. C. Clauss and E. R. Wiebe, *Jet Propulsion Lab. Tech. Rep. 32-1516 XIX* (1974), p. 93.
3. I thank J. Y. Pedigo of the Jet Propulsion Laboratory (JPL) for assistance in the preparation of figures and manuscript and D. G. Rea and J. B. Jones of JPL for critical review and comment. This report represents one aspect of research carried out by JPL under NASA contract NAS 7-100.

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Preliminary Infrared Radiometry of the Night Side of Mercury from Mariner 10

Abstract. *The infrared radiometer on Mariner 10 measured the thermal emission from the planet with a spatial resolution element as small as 40 kilometers in a broad wavelength band centered at 45 micrometers. The minimum brightness temperature (near local midnight) in these near-equatorial scans was 100°K. Along the track observed, the temperature declined steadily from local sunset to near midnight, behaving as would be expected for a homogeneous, porous material with a thermal inertia of 0.0017 cal* cm^{-2} $sec^{-1/2}$ $°K^{-1}$*, a value only slightly larger than that of the moon. From near midnight to dawn, however, the temperature fluctuated over a range of about 10°K, implying the presence of regions having thermal inertia as high as 0.003 cal* cm^{-2} $sec^{-1/2}$ $°K^{-1}$.

The average thermophysical properties of the upper few centimeters of the Mercurian soil can be inferred from measurements of the cooling curve of the surface during the night. The night temperatures are sensitive primarily to a single parameter, the thermal inertia $(K\rho c)^{1/2}$ of the soil (*1*), which in turn depends primarily on the porosity of the soil. Temperature fluctuations