NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

THE NOW FRONTIER

LINKING EARTH AND PLANETS

(NASA-CR-142828) MISSION TO THE INNER PLANETS (Jet Propulsion Lab.) 4 p HC $3.25 CSCL 22A

Mission to the Inner Planets

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CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

N75-24629

ISSUE NUMBER THREE
PUBLIC EDUCATIONAL SERVICES OFFICE

Unclas
G3/91 21873

THE MARINER 10 MISSION

Mariner 10 arrives at Venus on February 5, 1974, after a 3-month, 150 million mile trip halfway around the Sun. The gravity of Venus changes the speed of the spacecraft to plunge it deeper into the gravitational field of the Sun to reach the orbit of Mercury and rendezvous with this innermost planet on March 29, 1974.

Mariner 10 sped from Cape Canaveral, Florida, November 2, 1973, atop an Atlas/Centaur multistage rocket launch vehicle. And, in contrast with earlier planetary spacecraft, it tried out its instruments on the Earth and Moon as it sped at 25,255 miles per hour on its way to Venus. The day following launch, scientists directed Mariner's two television cameras to produce four mosaics of 88 pictures each of Earth and Moon. Since Earth is cloud-covered like Venus, and the Moon airless and optically similar to Mercury, these picture series gave valuable early information on how the cameras might return information about the two target planets. Thus the instruments were calibrated. Other instruments too were tested on the Earth and Moon.

Experimenters were delighted at the clarity of the returned pictures. The Earth photographs revealed clear details of clouds; some provided three-dimensional views. And the pictures of the Moon showed north polar regions not seen by astronauts, photographs that recorded objects only 2 miles across.

Later the cameras photographed star fields and further confirmed the high quality of the images being returned over the radio link to Earth.

THE SPACECRAFT AND ITS PATH

Mariner 10 is the first complex spacecraft to be designed to travel into the inner reaches of the solar system as close to the Sun as 43 million miles. Developed from earlier spacecraft in the Mariner series that flew by Venus and Mars and orbited Mars, Mariner 10 faces new challenges of the interplanetary environment.

Cover: Mariner 10 on its path from Earth (in the upper left part of the picture, with the Moon close by). The spacecraft has just passed Venus and is on its way to Mercury.

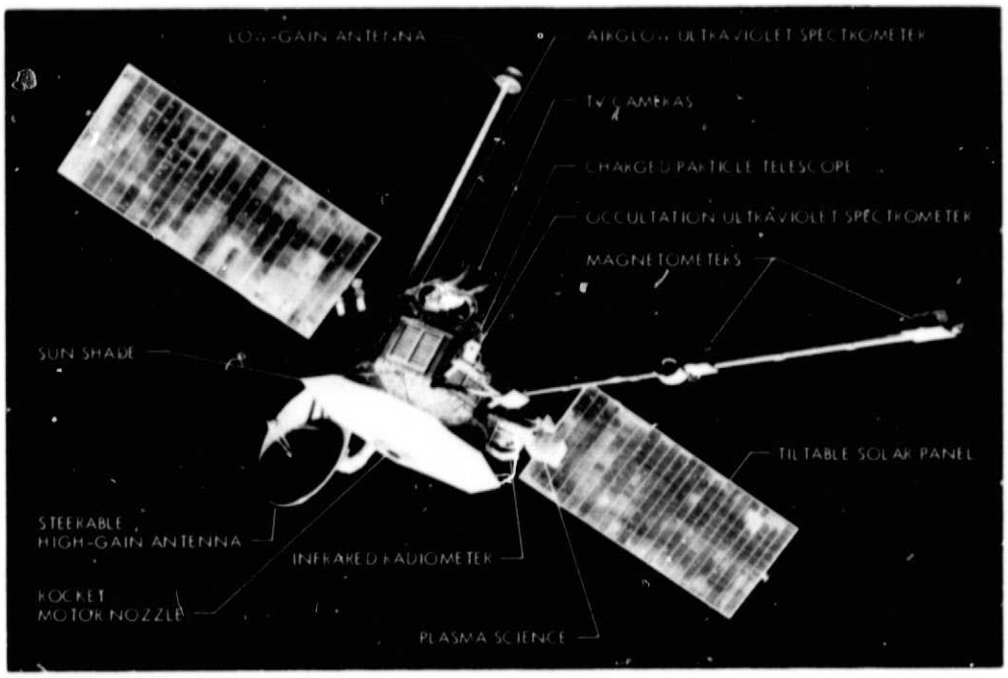

Figure 1. The Mariner 10 spacecraft.

For example, at Mariner's closest approach to the Sun, it receives five times as much light and heat as it does on leaving Earth. This requires that the solar radiation must be screened from the spacecraft and its scientific instruments to prevent them from overheating. A sunshade of beta cloth—the material used for astronauts' suits—is extended as the spacecraft leaves Earth.

The solar panels, too, which extend into sunlight to collect and convert solar radiation into electrical energy for the spacecraft's instruments and controls, are designed to be tilted more and more from the sunlight as Mariner 10 approaches closer and closer to the Sun.

Figure 1 shows the main features of the Mariner spacecraft. There is a basic eight-sided framework which encloses eight bays of electronics. This structure is 54½ inches across and 18 inches deep. Its center cavity is almost filled by a spherical tank of rocket propellant and a rocket motor used to maneuver the spacecraft. The nozzle of this rocket projects through the base of the structure, which is on the sunwards side during the flight. Below this structure is the heat shade, through a hole in which the rocket nozzle projects.

Two solar panels extend on either side of the basic structure for almost 9 feet. There are also two antennas for communicating with Earth. A low-gain antenna projects almost 10 feet from the top of the basic structure. A high-gain parabolic antenna, 54 inches across, extends to one side and is motor-driven to point towards Earth.

There are also sensors to track the star Canopus and the Sun, and a battery of scientific instruments. Two identical television cameras peer like twin eyes from the top of the structure. Together with an ultraviolet spectrometer, they can be pointed by Earth command. Other instruments are affixed directly to the basic structure and are fixed relative to the spacecraft. Also, booms extend from the basic structure, carrying instruments to measure magnetic fields and the interplanetary plasma of charged particles.

Mariner 10 carries reliable communication radio systems to accept commands from Earth and return scientific and engineering information. The spacecraft also carries a computer so that commands can be accepted by Mariner that will trigger a whole sequence of events, as well as direct commands to perform specific tasks, such as switching on a piece of apparatus.

Some information collected by the spacecraft can be stored on magnetic tape within it and transmitted later. This permits the spacecraft to collect data when it is hidden from Earth behind a planet and later to send this data when it emerges.

The Mariner 10 spacecraft weighed 1042 pounds at launch, including 64 pounds of rocket fuel and nitrogen gas.

A requirement for this new spacecraft is to transmit much more information back to Earth than earlier flyby spacecraft during the brief periods of encounter with the two target planets. So the rate at which information is transmitted over the radio links has been increased. This is like talking faster on the telephone if you want to describe as much as possible about an event as it actually happens.

This higher data rate, as it is termed, permits Mariner to send back more live pictures of the planets as it flies past them.

Another requirement for the mission was to ensure very accurate flight. Because the spacecraft uses the gravity of Venus to swing it on a path to Mercury, small errors in its approach to Venus would be magnified a thousand times at Mercury unless corrected by the rocket engine of the spacecraft. But since project scientists want to conserve as much fuel as possible so that they can command the spacecraft into other maneuvers after it passes Mercury, the spacecraft has to be aimed as accurately as possible in the early stages of flight. Even so, four corrective thrust periods are planned: the first just after leaving Earth and Moon, the second just before arrival at Venus, the third after flying by Venus, and the fourth before arrival at Mercury.

Three further maneuvers are needed to bring the spacecraft back to Mercury again (September 1974) 6 months after the first pass. And if there is propellant left, a third pass by Mercury could be attempted 6 months later (March 1975).

The success of all these maneuvers relies upon controllers having accurate knowledge about the speed of the spacecraft and its position along its path, as well as the direction of its path. Such information is obtained by tracking the spacecraft from ground stations at Goldstone, in the Mojave Desert, California; in Spain; and in Australia. The three tracking stations pass information to a control center at the Jet Propulsion Laboratory in California where navigation specialists, aided by powerful computers, determine the exact position and speed of the spacecraft. Computers predict where the spacecraft is headed. Navigators decide on changes, and mission controllers send commands to the spacecraft to make the necessary changes in its path.

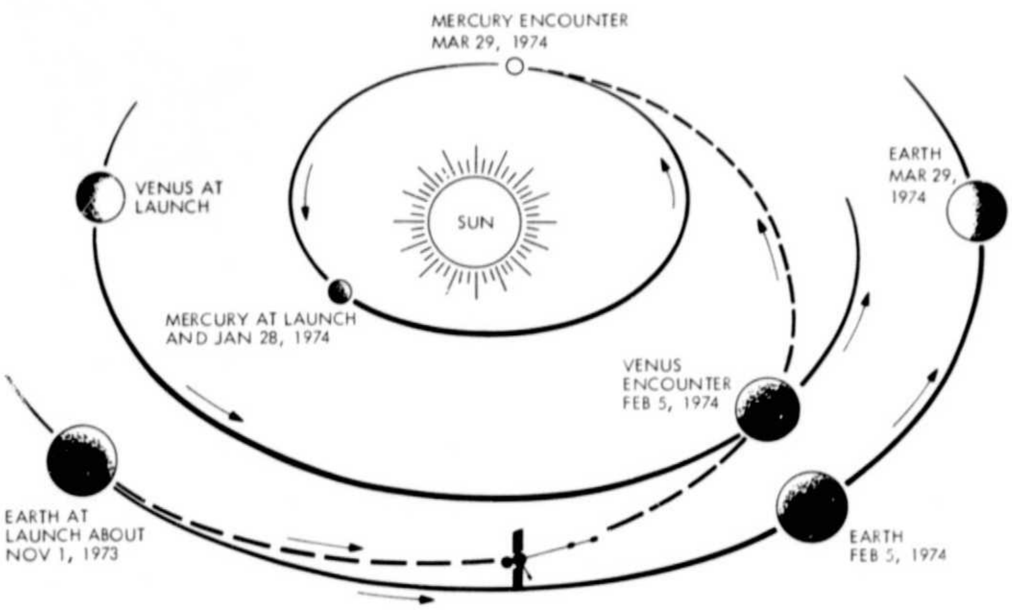

Figure 2. The Mariner 10 flight path to Venus and Mercury.

Arrival times and distances have to be arranged precisely so that instruments can not only photograph the target planets at required angles and covering specified areas, but also look at the planets at infrared and ultraviolet wavelengths and make other experiments.

For all these tasks, timing is extremely critical because of the short time that the spacecraft is near the planet.

Mariner 10 follows a curved path to Venus (Figure 2), going about one-quarter of the way around the Sun before it meets with the planet. When this path is bent by the gravity of Venus, it curves more steeply towards the Sun. The spacecraft then follows the new path for about another quarter of the way around the Sun until it meets with Mercury.

If the spacecraft were not slowed by the gravity of Venus—by the way in which it is directed to fly past that planet—its speed would be too high to allow the gravitational field of the Sun to pull Mariner to the orbit of Mercury. Without the aid from the gravity of Venus, the path of Mariner would dip only slightly inside the orbit of Venus, and to reach Mercury by a direct launch without a gravity assist from Venus would require a larger, more expensive launch vehicle or a lighter payload that could include only a few scientific experiments.

After encounter with Mercury, Mariner 10 zooms outwards again and crosses the orbit of Venus, but Venus is far away on its orbit. Later, Mariner 10 moves back to Mercury's orbit and now it is lucky. Mercury has made two circuits of the Sun while the spacecraft made one. Mariner meets Mercury for the second time. And if sufficient propellant remains in the spacecraft, a third rendezvous can be made with Mercury the next time around the spacecraft's orbit.

WHAT THE SPACECRAFT DOES

Mariner 10 is designed to investigate Mercury and Venus in several ways:

(1) Measure particles, fields, and radiation from the planets and their environs.
(2) Televise pictures of the planets with great detail to show cloud structure on Venus and the surface structure of Mercury (Figure 3).

(3) By ground-based observations of the path of the spacecraft, measure the gravity field of Venus and Mercury, their sizes, and their masses.

(4) By observations of the radio signals coming from the spacecraft as it goes behind Venus and Mercury as seen from Earth, determine the structure of the Venus atmosphere and check whether Mercury has a tenuous atmosphere of any kind.

In addition, the spacecraft also provides information on the interplanetary space from Earth's to Mercury's orbit, and on how the planets interact with this interplanetary environment.

To perform these tasks, Mariner 10 uses a battery of scientific instruments. A magnetometer measures magnetic fields, a plasma analyzer measures the ions and electrons flowing through space from the Sun (the solar wind), cosmic ray telescopes study solar and galactic cosmic rays. The main objective of all of these instruments is to learn about the planets by studying their effects on the interplanetary environment, such as magnetic tails and bow shocks connected with them.

An infrared radiometer (heat measurer) measures temperatures of the clouds of Venus and the surface of Mercury. Two independent ultraviolet instruments (measuring light beyond the violet of the spectrum) analyze the planetary atmospheres. One instrument is fixed to the body of the spacecraft and is used at Mercury to search for traces of atmosphere along the edge of the planet's disc. A scanning instrument can be pointed on command. This is used to scan the entire discs of the planets, searching for evidence of hydrogen, helium, argon, neon, oxygen, and carbon. Close to Earth, this same instrument measured the hydrogen corona of the Earth and the reflective properties of the Moon. At Venus both instruments search for specific gases, and during the cruise phase they look for sources of radiation coming from hot stars and nebula (or gas clouds) in the galaxy.

A complex of two television cameras with eight filters, capable of taking both narrow and wide angle pictures, photographs Earth and Moon (for comparison purposes) and Venus and Mercury. Mounted on a platform, the complex is directed by command from Earth. As well as taking pictures in different colors of light, these cameras also reveal how the light is vibrating (its polarization). Such observations reveal information on the composition of the clouds of Venus and the surface of Mercury.

A radio experiment uses the signals transmitted from the spacecraft to Earth. By tracking the spacecraft's signals, experimenters determine how the spacecraft is affected by the gravitational fields of the planets. From this information they may determine the shape of each planet and determine whether there are any concentrations of mass that distort the gravitational field, like the mascons (mass concentrations) discovered beneath the maria of the Moon. By analysis of what happens to the radio signals as they pass close to the edge of the planet when the spacecraft goes behind the planet as seen from Earth, experimenters probe the atmosphere of Venus to determine its characteristics and constituents and to check for any tenuous atmosphere of Mercury. If one is detected, its characteristics will also be determined.

To take full advantage of the Venus occultation, which will bend the radio signals appreciably, an antenna on the spacecraft is steered so as to partially compensate for the bending. In this manner, information can be obtained to much deeper levels of the Venusian atmosphere.

A project of NASA's Office of Space Science, the Mariner 10 project is managed by the Jet Propulsion Laboratory of the California Institute of Technology, Pasadena, California. The spacecraft was built by The Boeing Company, Seattle, Washington. Tracking is by NASA's Deep Space Network, operated by the Jet Propulsion Laboratory. The scientific instruments are supplied by NASA centers, universities, and private industry.

STUDENT INVOLVEMENT

Student Project One

On the map of the solar system, made as a project for leaflet No. 1 of this series, draw the path of Mariner 10. Work backwards from the encounter with Mercury and Venus on March 29 and February 5 respectively, using Figure 2 as a guide to find the position of the Earth at launch. Remember Earth goes around the Sun in 365¼ days, Venus in 225 days, and Mercury in 88 days. Mark positions on all orbits at 10-day intervals. Allow for the fact that Mercury moves slightly faster when on the parts of its orbit closer to the Sun than when most distant from the Sun. The most distant part of Mercury's orbit is approximately where Mariner encounters the planet. Venus' speed is almost constant, and so is the Earth's, since both move on almost circular orbits.

Student Project Two

In an earlier pamphlet it was stated that an observer on Venus would appear to be standing in a huge bowl as though in a hollow planet with clouds in the center. Use your imagination and produce an illustration, a drawing or painting, of what it would be like if you could stand on Venus in some kind of space suit that would protect you from the enormous pressure at the bottom of the carbon dioxide atmosphere. Radar indicates that the surface is gently undulating in parts with some rough surface and some large shallow craters.

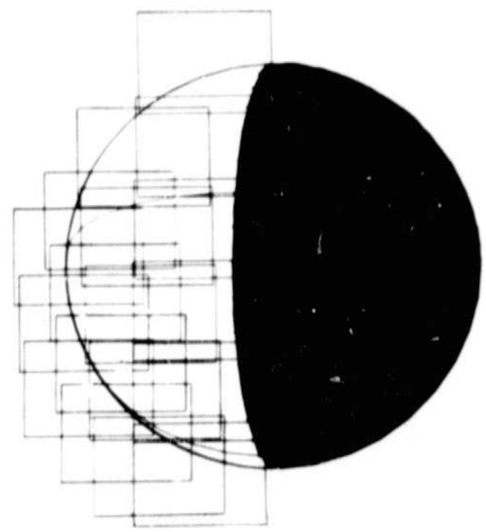

Figure 3. A photographic mosaic of Mercury is expected to be obtained from overlapping photographs of the planet.

READING LIST

J. H. Wilson, *Mariner Venus Mercury 1973*, Technical Memorandum 33-657, Jet Propulsion Laboratory, Pasadena, California, October 15, 1973.

P73-219 JPL 654 4.5M 1-74 PRINTED IN U.S.A.