NASA SP-424

The Voyage of Mariner 10

Mission to Venus and Mercury

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Prepared by
Jet Propulsion Laboratory
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NASA Scientific and Technical Information Office 1978
National Aeronautics and Space Administration
Washington, DC

Introduction

RARELY IN THE LIFETIME of an individual is he privileged to witness and be part of an historic first for mankind. Such has been my privilege. Even more rarely is one privileged to be part of such a dedicated, competent, and professional group as comprised the Mariner Venus/Mercury Project Team. It was a moderately small group of diverse talents, dedicated to accomplishing an historic scientific voyage to Mercury by way of Venus, and to do it within tight schedule and cost constraints.

These people met and exceeded the challenges and further distinguished themselves several times during the flight of Mariner 10 when emergencies were encountered which threatened the success of the mission. Their professional response to these emergencies proved the competence of this truly remarkable team of NASA, Boeing, Philco-Ford, Planning Research Corporation, university, and Jet Propulsion Laboratory people. Without this team the exciting discoveries made on the Mariner 10 flight to Venus and Mercury would not have been possible.

W. Eugene Giberson
Mariner Venus/Mercury Project Manager
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Chapter 2

Mariner Venus-Mercury Mission

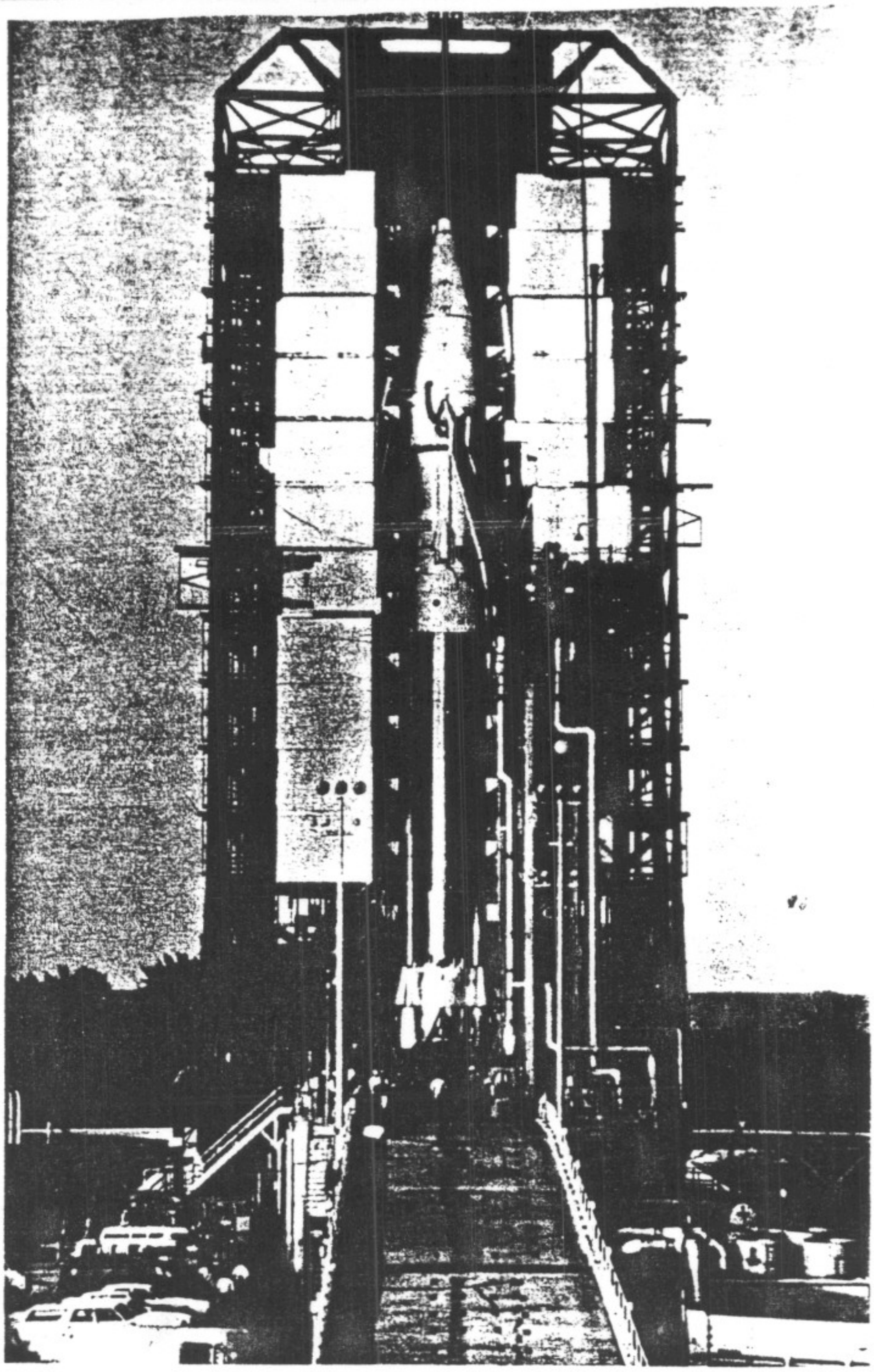
THE GRAVITY-ASSIST trajectory technique which was needed to obtain an economically acceptable mission to Mercury resulted from over 20 years of speculation, scientific research, and engineering development. The technique allows a spacecraft to change both its direction and speed without expenditure of propellant, thereby saving time and increasing scientific payload on interplanetary missions. By its use an acceptable payload could be launched to Mercury by an Atlas/Centaur. The much larger and more costly Titan III C/Centaur would be required for a direct flight to the innermost planet.

The concept of gravity-assist interplanetary missions first received serious attention in the literature of the 1950's, though multiple-planet orbits had been considered during the 1920's and 30's.

In the following years the concept was utilized mainly in studies of round-trip interplanetary flights in which the spacecraft leaves the Earth, flies by several planets, and returns to Earth. The first systematic development of the gravity-assist technique was performed at the Jet Propulsion Laboratory, Pasadena, California, in the early 1960's. Previously, such multiple-planet trajectories had been sought by inspecting computer-generated listings of parts of flight paths, such as the Earth–Venus and Venus–Earth components, and matching them in regard to velocities and time. An Earth–Venus–Earth round trip had been discovered by this method, and JPL trajectory designers next developed a mathematical technique for searching out gravity-assist trajectories so that they were able to program the equations for processing on a digital computer. They soon discovered the existence of Earth–Venus–Mercury trajectory opportunities for 1970 and 1973, but found that the gravity-assist trajectory was extremely sensitive to errors in aiming the spacecraft toward the first planet, suggesting that a new kind of guidance might be necessary to make the technique practicable. Further analysis revealed, however, that there were actually no barriers in contemporary guidance technology to prevent a multiple-planet mission. As a result, detailed plans and a navigation strategy for the 1970 Venus–Mercury opportunity were prepared, establishing its practical feasibility as a space mission.

Early in 1970, Guiseppe Colombo of the Institute of Applied Mechanics in Padua, Italy, who had been invited to JPL to participate in a conference on the Earth–Venus–Mercury mission, noted that in the 1973 mission the period of the spacecraft's orbit, after it flew by Mercury, would be very close to twice the period of Mercury itself. He suggested that a second encounter with Mercury could be achieved. An analytical study conducted by JPL confirmed Colombo's suggestion and showed that by careful choice of the Mercury flyby point, a gravity turn could be made that would return the spacecraft to Mercury six months later.

Fig. 2-1. The Atlas/Centaur provided the necessary launch capability for the Venus swingby to Mercury.



In June 1968, the Space Science Board of the National Academy of Science completed a planetary exploration study in which the mission to Mercury via Venus was endorsed. The Board recommended that a 1973 launch opportunity be aimed for and suggested some of the scientific experiments that might be carried out on the mission.

Approved by NASA in 1969, the mission which resulted from this recommendation involved the scientific community early enough for scientists to contribute to decisions concerning design of the spacecraft and selection of its subsystems. The possibility of later conflict between mission constraints and science needs would thereby be reduced.

The National Aeronautics and Space Administration selected a group of scientists to represent the several disciplines that would be involved in the science payload of a mission to Mercury via

Venus, and a Science Steering Group was officially formed in September 1969. Its purpose was to recommend objectives for and plan a good science mission within tight monetary constraints, coordinating the requirements of teams for the individual instruments and participating in project design and tradeoff studies relevant to mission, spacecraft, and flight operations.

In January 1970, a Mariner Venus/Mercury project office was established at JPL, under the direction of Project Manager Walker E. Giberson. Experiments were selected by July 1970, and by July 1971 a contract was negotiated with the Boeing Company, Kent, Washington, for design and fabrication of two spacecraft: a flight spacecraft and a test spacecraft.

Overview of the Mission

The mission plan called for launching the spacecraft with an Atlas SLV-3D/Centaur D-1A launch vehicle (Fig. 2-1) between October 16 and November 21, 1973. From such a launch window the spacecraft could encounter Venus between February 4 and 6 and Mercury between March 27 and 31, 1974.

The proposed trajectory relied upon Venus's gravitational field to alter the spacecraft's flight path and speed relative to the Sun, such that the reduction in velocity would cause the spacecraft to fall closer to the Sun and therefore to cross Mercury's orbit at the exact time needed to encounter the planet (Fig. 2-2). Closest-approach altitudes at Venus and Mercury would be 5000 and 1000 km (3100 and 620 mi), respectively.

To meet the demands of the gravity-assist technique, Mariner Venus/Mercury had to be launched on an orbit around the Sun that would intercept the planet Venus with high precision. The spacecraft could not carry sufficient propellant for very large maneuvers after the encounter with Venus, and the trajectory to Venus demanded new levels of accuracy. At least two maneuvers to correct the trajectory would be needed between Earth and Venus and two more between Venus and Mercury. Flyby of Venus had

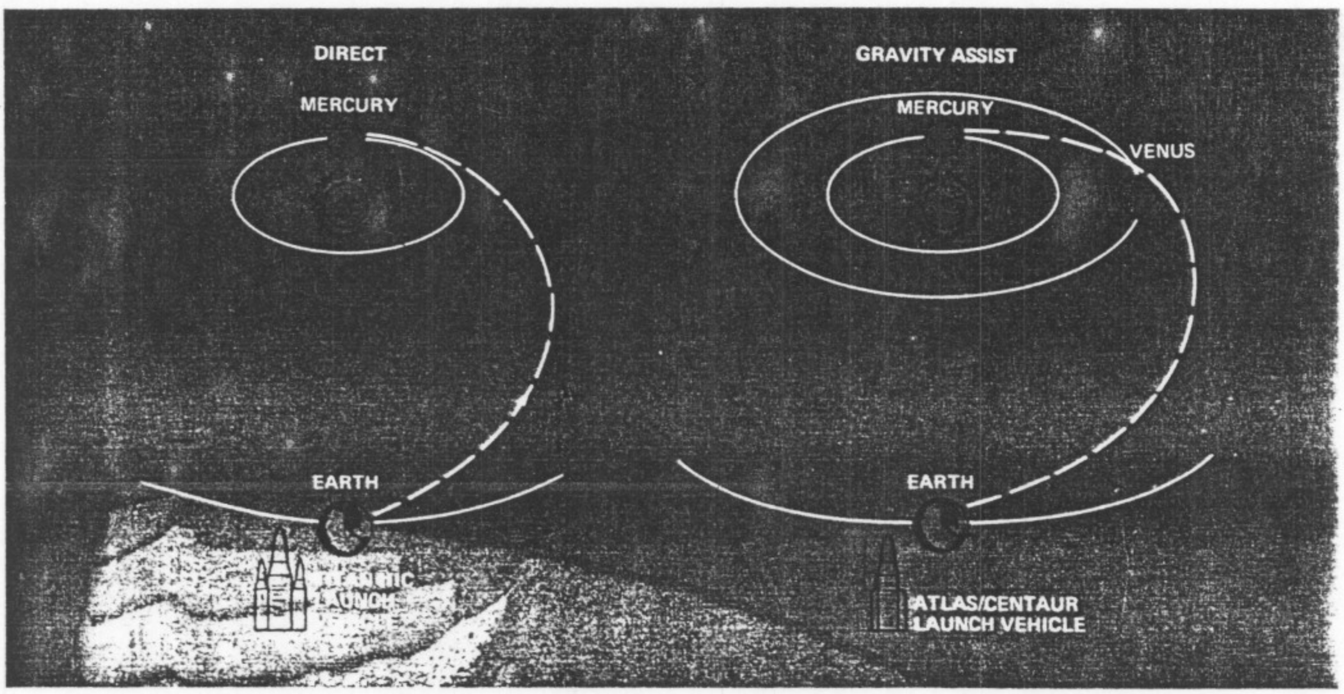


Fig. 2-2. The gravity-assist trajectory to Mercury uses the gravity and orbital motion of Venus to provide a slingshot that hurls a spacecraft into the inner Solar System without further use of propellants except for minor corrections to the trajectory. A direct flight to Mercury would require a much larger launch vehicle to deliver the same payload of scientific instruments without this Venus assist.

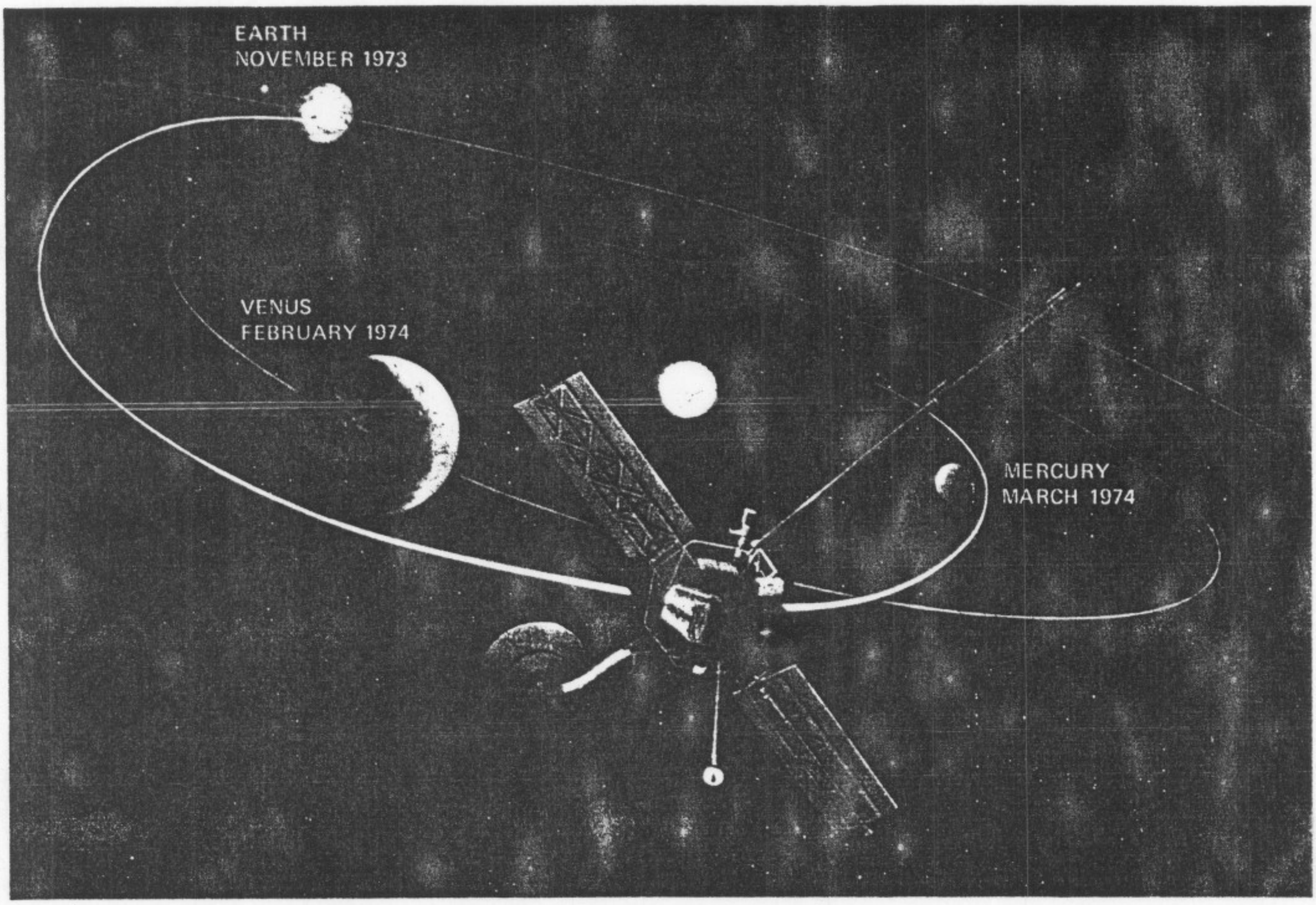


Fig. 2-3. Times of launch and arrival at the planets were clearly defined.

to be controlled within 400 km (250 mi), otherwise no Mercury encounter could take place.

In overview (Fig. 2-3), the mission would start with liftoff from Kennedy Space Center, the Centaur engine cutting off shortly thereafter, placing the spacecraft in a parking orbit which would carry it partway around the Earth for 25 min.

The Centaur then would burn a second time, thrusting Mariner in a direction opposite to the Earth's orbital motion. This direction was required to provide the spacecraft with a lower velocity relative to the Sun than Earth's orbital velocity, allowing the spacecraft to be drawn inwards in the Sun's gravitational field to achieve its encounter with Venus.

A few months later the Mariner spacecraft would approach Venus from the planet's dark side, passing over the sunlit side and, slowed by Venus, falling closer to the Sun to rendezvous with Mercury.

The Mariner 10 Spacecraft

More than a decade of evolution of Mariner technology was continued by the Mariner Venus/Mercury 1973 spacecraft, which was the sixth of a series that began with Mariner Venus in 1962 and included Mariner Mars 1964, Mariner Venus 1967, Mariner Mars 1969 and Mariner Mars Orbiter 1971 (Figure 2-4). In common with

Fig. 2-4. Mariner Venus/Mercury continued a line of successful Mariner spacecraft that had previously explored Venus and Mars.

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