# MARINER II

*A progress report on the spacecraft now heading for Venus*

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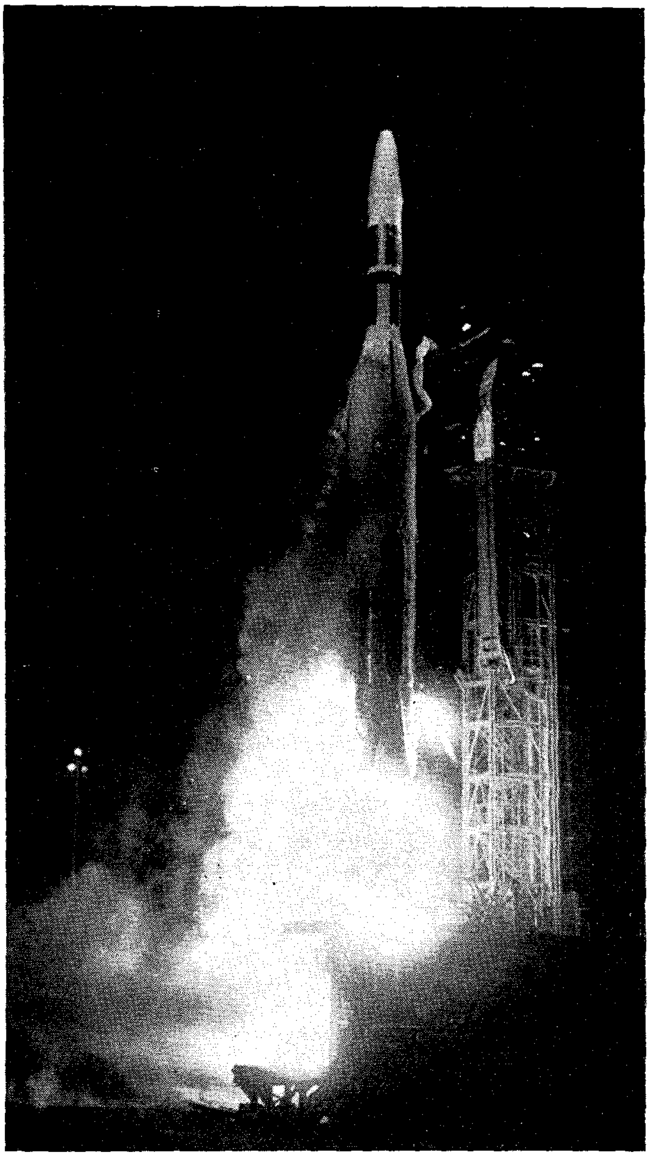


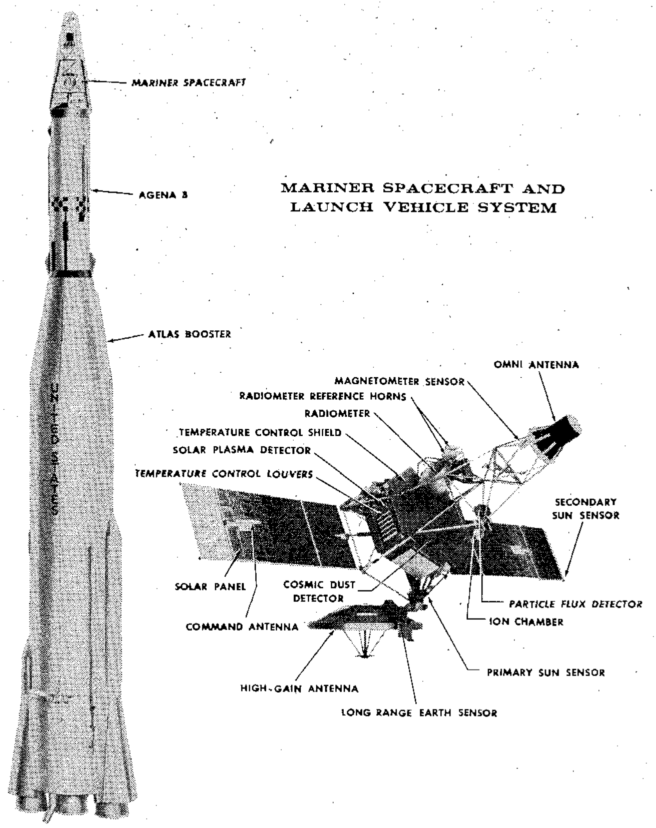
Mariner II was launched from Cape Canaveral on August 26, 1962. On December 14 the spacecraft will rendezvous with the plant Venus, and, if all equipment continues to operate, will report on actual measurements of the planet.

This is the first in what is planned to be an extended series of planetary exploration launches. The present primary objective of the Planetary Program is to conduct the initial unmanned spacecraft exploration of the planets and interplanetary space. An important secondary objective, however, is to develop the base for the eventual manned exploration phase.

Scientifically, our objective is to contribute information which will assist in answering two broad questions:

1) What, if any, life forms exist on the planets?
2) How was the solar system formed?

For two good reasons, we intended to concentrate at first on our two closest neighbors, Venus and Mars, and on the interplanetary space roughly within the ecliptic plane and between these two planets. Venus and Mars are probably most like the earth of any of the planets and therefore offer perhaps the most exciting fairly immediate rewards in terms of new information, and they are also the easiest to reach and explore.



MARINER SPACECRAFT AND LAUNCH VEHICLE SYSTEM

We have indications from earth measurements that these two planets have some characteristics quite different from earth. Venus, for example, being about the same size as the earth, would appear to have a much denser atmosphere — perhaps ten times as dense at the surface — to have very little oxygen or water vapor in its atmosphere, and to have a surface temperature perhaps as hot as 600° to 800° Fahrenheit. It has a cloud layer that precludes visual observation of the surface and, therefore, a visual measure of its rotation speed or axis. Radio reflection measurements would indicate that it has a relatively low rotation rate, perhaps keeping one face toward the sun.

Mars, on the other hand, not only is smaller than the earth, but has a much less dense atmosphere. It, too, would appear to have very little oxygen or water vapor in its atmosphere. Its surface can be seen, and it has a rotation rate close to that of the earth. Changes of surface characteristics, some of them cyclic with the Mars seasons, have been noted. These surface changes and infrared earth-based measurements both indicate the possibility that some sort of life forms do, in fact, exist on Mars.

Despite — or even, perhaps, because of — these differences, there has been over the years a great deal of curiosity, scientific and otherwise, about these planets. A great deal of new and valuable information can be obtained through closer observation by spacecraft to be launched to the vicinity of these two planets.

For any reasonable or efficient use of launch vehicle capability, launchings to the planets can be made only infrequently, of course. For Venus, opportunities occur approximately once every 19 months, and for Mars, once every 25 months. The period of these opportunities last for about three months or less, depending upon how much of the maximum launch vehicle performance capability one is willing to sacrifice. The travel time is about 3 to 4 months to Venus and 6 to 7 months to Mars. Incidentally, these laws of physics apply in Russia as they do in the United States.

On the average, a given launch vehicle can launch about the same payload to both Venus and Mars. The reason the travel time to Mars is about twice that to Venus is due largely to the fact that the spacecraft slows down if it moves away from the sun and speeds up if it moves toward the sun, due to its change in potential energy. From opportunity to opportunity at each of the planets, however, the energy requirements to reach the planet can vary by almost a factor of two. Depending on a number of factors involved, the payload capability could vary much more than this factor of two. This variation in energy requirements is approximately cyclic, with a period of about 8 years for Venus and 15 years for Mars.

## *The choice of Venus*

The choice of Venus as opposed to Mars for the first mission resulted primarily from (1) the shorter flight times involved, (2) the shorter communication distances involved, and (3) the easier solar power collection problem at Venus-distance from the sun. (It requires about 2½ times as much solar panel area at Mars as at Venus). The Venus mission was therefore relatively more inexpensive and reliable.

Summers have been very significant in the history of the Mariner Project to date. In summer 1960, authorization was received for preparing a 1000-lb. spacecraft for launching in 1962. In summer 1961, it became necessary to redesign the spacecraft to a weight of 450 pounds within the capability of the Atlas-Agena launch vehicle. Summer 1962 was, of course, the launch period.

The extensive redesign about one year before launch required certain corners to be cut from the normal and otherwise desirable design and testing cycles. This rather remarkable feat would not have been possible without the extensive efforts and experience that was available from the Ranger Project as well as the early Mariner activities. Hardware from both activities was used, with some modifications.

The Mariner weighs 447 pounds and, in the launch position, is 5 feet in diameter at the base and 9 feet, 11 inches high. In the cruise position, with solar panels and high-gain antenna extended, it is 16.5 feet across in span and 11 feet, 11 inches high.

The design is a variation of the hexagonal concept used for the Ranger series. The hexagon framework base houses a liquid fuel rocket motor, for trajectory correction, and six modules containing the attitude control system, electronic circuitry for the scientific experiments, power supply, battery and charger, data encoder and command subsystem, digital computer and sequencer, and radio transmitter and receiver. Sun sensors and attitude control jets are mounted on the exterior of the base hexagon.

A tubular superstructure extends upward from the base hexagon. Scientific experiments are attached to this framework. An omnidirectional antenna is mounted at the peak of the superstructure. A parabolic, high-gain antenna is hinge-mounted below the base hexagon. Two solar panels are also hinged to the base hexagon. They fold up alongside the spacecraft during launch, parking orbit, and injection and are folded down, like butterfly wings, when the craft is in space. A command antenna for receiving transmissions from earth is mounted on one of the panels.

The solar panels contain 9800 solar cells in 27 square feet of area. They will collect energy from the sun and convert it into electrical power at a minimum of 148 watts and a maximum of 222 watts. The amount of power available from the panels is expected to increase slightly during the mission, due to the increased intensity of the sun. Each solar cell has a protective glass filter that reduces the amount of heat absorbed from the sun, but does not interfere with the energy conversion process. The glass covers filter out the sun's ultraviolet and infrared radiation that would produce heat but not electrical energy.

Prior to the time that the solar panels were pointed toward the sun, power was supplied by a 33.3-pound silver-zinc rechargable battery with a capacity of 1000 watt hours. The recharge capability is used to meet the long-term power requirements of the Venus Mission. The battery supplies power directly for switching and possibly sharing peak-loads with the solar panels and also during trajectory correction when the panels are not directed at the sun.

The power subsystem converts electricity from the solar panels and battery to 50 volt, 2400 cycles per second; 26 volt, 400 cps; and 25.8 to 33.3 volt DC.

## *Two-way communication*

Two-way communication aboard the Mariner is supplied by the receiver/transmitter, two transmitting antennas – the omnidirectional and high-gain antenna, and the command antenna for receiving instructions from earth. Transmitting power is 3 watts.

The high-gain antenna is hinged and equipped with a drive mechanism allowing it to be pointed at the earth on command. An earth sensor is mounted on the antenna yoke near the rim of the high-gain dish-shaped antenna to search for and keep the antenna pointed at the earth.

Stabilization of the spacecraft for yaw, pitch, and roll, is provided by ten cold gas jets, mounted in four locations (3, 3, 2, 2,), fed by two titanium bottles containing 4.3 pounds of nitrogen gas pressurized to 3500 pounds per square inch. The jets are linked by logic circuitry to three gyros in the attitude control subsystem, to the earth sensor on the parabolic antenna, and to six sun sensors mounted on the spacecraft frame and on the back of the two solar panels.

The four primary sun sensors are mounted on four of the six legs of the hexagon, and the two secondary sensors on the backs of the solar panels. These are light-sensitive diodes which inform the attitude control system – gas jets and gyros – when they see the sun. The attitude control system responds to these signals by turning the spacecraft and pointing the longitudinal or roll axis toward the sun. Torquing of the spacecraft for these maneuvers is provided by the cold gas jets fed by the nitrogen gas regulated to 15 pounds per square inch pressure. There is calculated to be enough nitrogen to operate the gas jets to maintain attitude control for a minimum of 200 days.

## *Central Computer and Sequencer*

Computation for the subsystems and the issuance of commands is a function of the digital Central Computer and Sequencer (CC&S). All events of the spacecraft and contained in three CC&S sequences. The launch sequence controls events from launch through the cruise mode. The midcourse propulsion sequence controls the midcourse trajectory correction maneuver. The encounter sequence provides required commands for data collection in the vicinity of Venus.

The CC&S provides the basic timing for the spacecraft subsystems. This time base is supplied by a crystal control oscillator in the CC&S operating at 307.2 kilocycles (kc). This is divided down to 38.4 kc for timing in the power subsystem and divided down again to 2400 and 400 cps for use by various subsystems. The control oscillator provides the basic "counting" rate for the CC&S to determine issuance of commands at the right time in the three CC&S sequences.

The subsystems clustered around the base of the spacecraft are insulated from the sun's heat by a shield covered with layers of aluminum-coated plastic film. At the bottom of the spacecraft, just below the subsystem modules, is a second temperature control shield. It prevents too rapid loss of heat into space, which would make the establishment of required temperatures difficult to maintain. The two shields form a sandwich that helps to minimize the heat control problem.

Temperature control of the attitude control subsystem is provided by louvers actuated by coiled bimetallic strips. The strips act as coil springs that expand and contract as they heat and cool. This mechanical action opens and closes the louvers. The louvers are vertical on the face of the attitude control box and regulate the amount of heat flowing into space. This is a critical area as some of the equipment may not function properly above 130°F.

Paint patterns, aluminum sheet, thin gold plate, and polished aluminum surfaces are used on the Mariner for passive control of internal temperatures. These surfaces control both the amount of internal heat dissipated into space and the amount of solar heat reflected away, allowing the establishment of temperature limits. The patterns were determined from testing of a Temperature Control Model (TCM).

The TCM was subjected to the variations of temperature anticipated in the Venus Mission in a space simulation chamber at JPL.

Communication with the spacecraft is in digital form. The command subsystem aboard the Mariner decodes incoming digital commands and sends them to the designated subsystems. Data from engineering and scientific sources are encoded to digital form for transmission to earth.

Synchronizing pulses are spaced at regular intervals between the data signals from Mariner. Ground-based receiving equipment generates identical pulses and matches them with the pulses from the spacecraft. This provides a reference to determine the location of the data signals allowing receiving equipment to separate data signals from noise.

Six scientific experiments are carried aboard the Mariner. Four of these are designed to collect information in space and in the vicinity of Venus. The other two will provide information solely on Venus and will operate only as Mariner passes the planet.

The experiments are:

1) Microwave radiometer experiment to measure temperature distribution on the planet's surface.

2) Infrared radiometer experiment to provide information on the distribution of thermal energy in the planet's atmosphere.

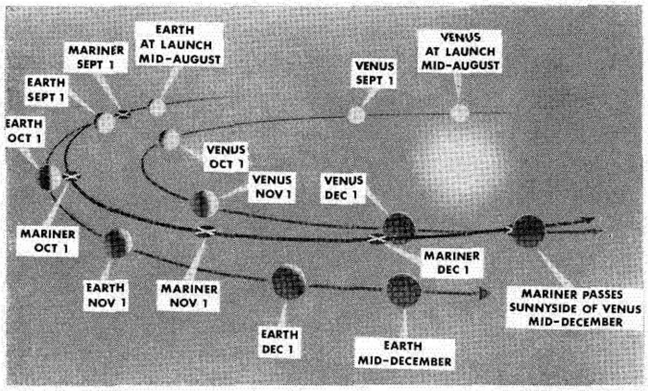
3) Magnetometer experiment to determine the three mutually perpendicular components of the magnetic field in the interplanetary space between earth and Venus, and in the vicinity of Venus at planetary encounter.

4) Charged particle experiment to detect the distribution, variations, and energies of electrically charged particles in space and in the vicinity of Venus, and the rate at which charged particles lose energy.

5) Plasma experiment to obtain information on the extent of, variations in, and mechanism of the solar corona.

6) Micrometeorite experiment to measure the density of cosmic dust particles which exist in interplanetary space and in the vicinity of Venus.

The microwave radiometer is mechanized so it can scan Venus during the fly-by. Initially, it is designed to go into a fast scan search. When it detects the planet, the radiometer will adopt a slow scan mode. The infrared experiment is attached to the rim of the dish-shaped microwave device and will scan with the larger instrument.



*Mariner II trajectory. When the spacecraft encounters Venus in mid-December, the distance between the earth and Venus will be about 36 million miles.*

## *Launching Mariner II*

Mariner II was launched at 11:53 p.m. PDT on August 26, 1962, after several delays. The launch vehicle injected the spacecraft properly into a trajectory that was within the expected accuracy of the launch vehicle and within the correction capability of the trajectory correction maneuver built into the spacecraft.

Spacecraft telemetry and tracking data is received at the three Deep Space Instrumentation Facility (DSIF) sites located in California, South Africa, and Australia. This information is relayed in near real time by teletype lines to the Jet Propulsion Laboratory. The spacecraft was first picked up by the South Africa station and then shortly thereafter by the Australian station.

It was with considerable satisfaction that we received the report from the JPL specialists assigned to monitor the telemetry data – not long after the events actually occurred – that the solar panels had opened, that the spacecraft had acquired the sun, that the gyros which are used only for acquisition and maneuvers had turned off, and that the battery was being charged by the energy from the solar panels.

Approximately 57 hours after launch, when it was established that the spacecraft was performing in a completely satisfactory fashion, the cruise (interplanetary) science experiments were turned on by ground command from the South Africa DSIF site. All experiments did turn on, are working properly, and have been collecting valuable data almost continuously except for the trajectory correction maneuver period.

During the first week of flight, the roll axis control system was purposely not turned on. During this period, the spacecraft was too close to the earth for the earth sensor to operate properly. About seven days out, the on-board programmer caused the roll control system to be activated and the high-gain antenna to be pointed toward the earth.

There was some question at first whether the earth sensor had acquired the earth or the moon, since either one would have caused the high-gain antenna coverage to include the earth. The correction maneuver could be made regardless of which had been acquired, but it was desirable to know which body had been acquired. Therefore, the maneuver was postponed for one day to see how signals varied during that period, and thus determine which object had been acquired. After the extra day, it was determined that the earth had been acquired, and we were ready to proceed with the maneuver.

The three quantitative numbers needed for the command, the roll turn, the pitch turn, and the velocity increment had been calculated on the computer at JPL from previous tracking data and from considerations of the desired target point. These commands had been relayed to the DSIF station at Goldstone, California, in the form of command tapes. These tapes were duly used to transmit this information to the spacecraft some 1.5 million miles out in space. After assurance that these quantitative commands had been properly transmitted, the execute command was initiated.

The gyros were turned on and warmed up for an hour. The spacecraft rolled and then pitched as commanded. During the course of this maneuver, the spacecraft went through a deep null in the low-gain antenna pattern and, for a short period, the signals went below the receiver threshold. By completion of the maneuver, the signal strength was back up and the receivers were back in lock.

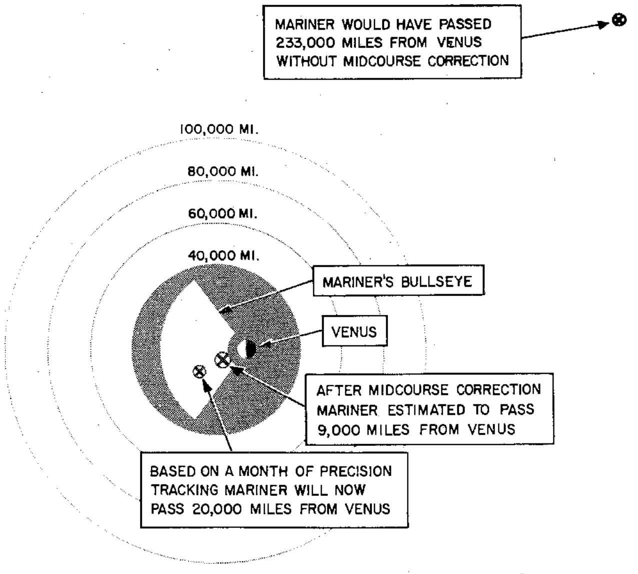
At the precise instant that the rocket motor was programmed to fire, the Goldstone tracking station noted a change in Doppler frequency, indicating that the motor had indeed fired. This Doppler shift lasted burn and then ceased. The spacecraft then proceeded burn and then ceased. The spacecraft then proceeded as planned to reacquire the sun and, some time later, the earth.

### *Hitting the bull's eye*

This midcourse correction maneuver was designed to correct a trajectory that would have taken the spacecraft some 233,000 miles from Venus.

Shortly after the maneuver, it was predicted that Mariner II would pass about 9,000 miles from the surface of the planet. After almost five weeks of more precise tracking, however, it was determined that the small midcourse correction rocket had given the spacecraft slightly more velocity than planned. The velocity change required was an addition of 45 miles an hour to the 60,117 miles an hour the spacecraft was traveling in relation to the sun. Instead (for reasons not yet determined) the small rocket imparted an additional velocity of 47 miles an hour.

At interplanetary distances, this overcorrection of two miles an hour was enough to alter the course of the spacecraft by more than 10,000 miles. The latest estimated miss distance, therefore, is 20,900 miles—which may be off by as much as 3,000 miles. This is because of uncertainty about the exact location of tracking stations on earth, the distance of the astronomical unit (the distance between the earth and sun), and uncertainty about how the pressure of sunlight may affect the spacecraft.



*Mariner II is now scheduled to pass within 20,900 miles of Venus — still in the bull's eye it is aiming for.*

Even with the wider miss, Mariner II will still pass within the planned bull's eye — a pie-shaped target area extending from about 4,000 to 40,000 miles above Venus on the sunlit side of the planet—in which scientific planetary experiments will still be effective.

Mariner II has already discovered a steady wind of charged particles blowing off the boiling surface of the sun into interplanetary space. The existence of this solar wind provides a new insight into interplanetary weather and the manner in which some solar energy is transported to earth.

Apparently the solar plasma takes the form of a continuous wind, which at times reaches hurricane force with outbursts, such as solar flares, on the sun. Even though this gas is exceedingly tenuous under any terrestrial scale, it is definitely dense enough, and is moving fast enough, to be able to push the interplanetary magnetic field around as it sees fit.

Another finding made by Mariner II is that the density of cosmic dust — microscopic particles weighing as little as five one-trillionths of a pound — was only a thousandth of that observed by satellites in the environs of the earth. Through some mechanism not yet understood, the earth apparently traps the dust in its vicinity.

From an accumulation of such scientific data as this, we hope to develop a base for the eventual manned exploration of space.