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PROJECT: MARINER MARS 1964

SCHEDULED LAUNCH:

Mariner C: No earlier than Nov. 4
Mariner D: Two days to one month later

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MARINER MARS 1964
MISSIONS SCHEDULED
FOR EARLY NOVEMBER

The United States will soon undertake the most difficult mission yet in its program of unmanned space exploration.

Two identical Mariner spacecraft will be launched from Cape Kennedy, Fla., toward the planet Mars by the National Aeronautics and Space Administration within a month-long period beginning no earlier than Nov. 4.

The mission is unprecedented:

- The flight distance to Mars is some 350 million miles compared with 180 million miles for the 1962 Mariner II flight past Venus.

- The Mars flight time is about eight-and-one-half months compared with the three-and-one-half months for Mariner II.

- A communications distance of 150 million miles for this mission compares with the record 53.9 million miles established 20 days after Mariner II flew past Venus.

- Some 138,000 components in each Mars Mariner will have to function some 6,500 hours in space.

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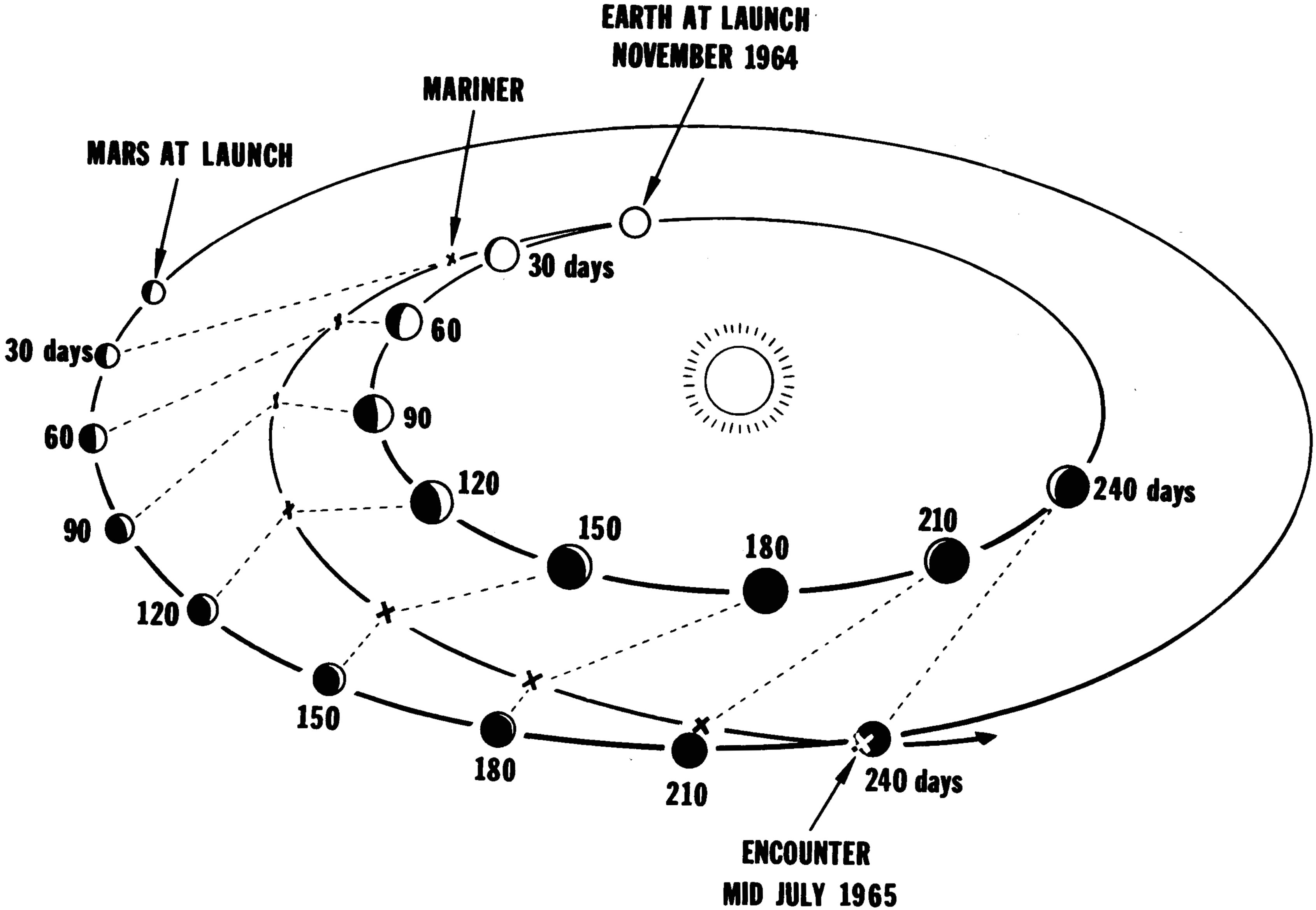
- Extreme demands will be placed on the accuracy and performance of the Atlas-Agena D launch vehicle. This will be the first NASA use of the improved Agena D second stage on an Atlas D booster.

Because of the difficulty of the mission, new engineering applications required for this mission include use of an improved propellant system for the Agena D launch vehicle second stage, a new spacecraft radio system, the first use of the star Canopus for spacecraft attitude reference, and a midcourse motor capable of firing twice.

Despite their complexity, these missions are being undertaken because Mars is of physical and geological interest and offers the best opportunity in our solar system for shedding light on the possibility of extraterrestrial life. These first, pioneering missions, however, are not designed to provide answers to the question of life on Mars.

The Mariners will be mated to the Atlas-Agenas on Launch Complexes 12 and 13 at Cape Kennedy. A third back-up flight spacecraft has been checked out and could be substituted if required. The first Mariner launched will be designated Mariner C. The second, which will be launched no earlier than two days but within four weeks of the first, will be Mariner D.

MARINER TRAJECTORY TO MARS



If launched successfully, they will be designated Mariner III and Mariner IV. Because of their trajectories, the two spacecraft will arrive at Mars about two to four days apart in mid-July of next year.

Mission objectives are to provide engineering experience on the operation of spacecraft during long-duration flights away from the Sun and to perform scientific measurements in interplanetary space between the orbits of Earth and Mars and in the vicinity of Mars.

Eight scientific investigations can be performed by each spacecraft.

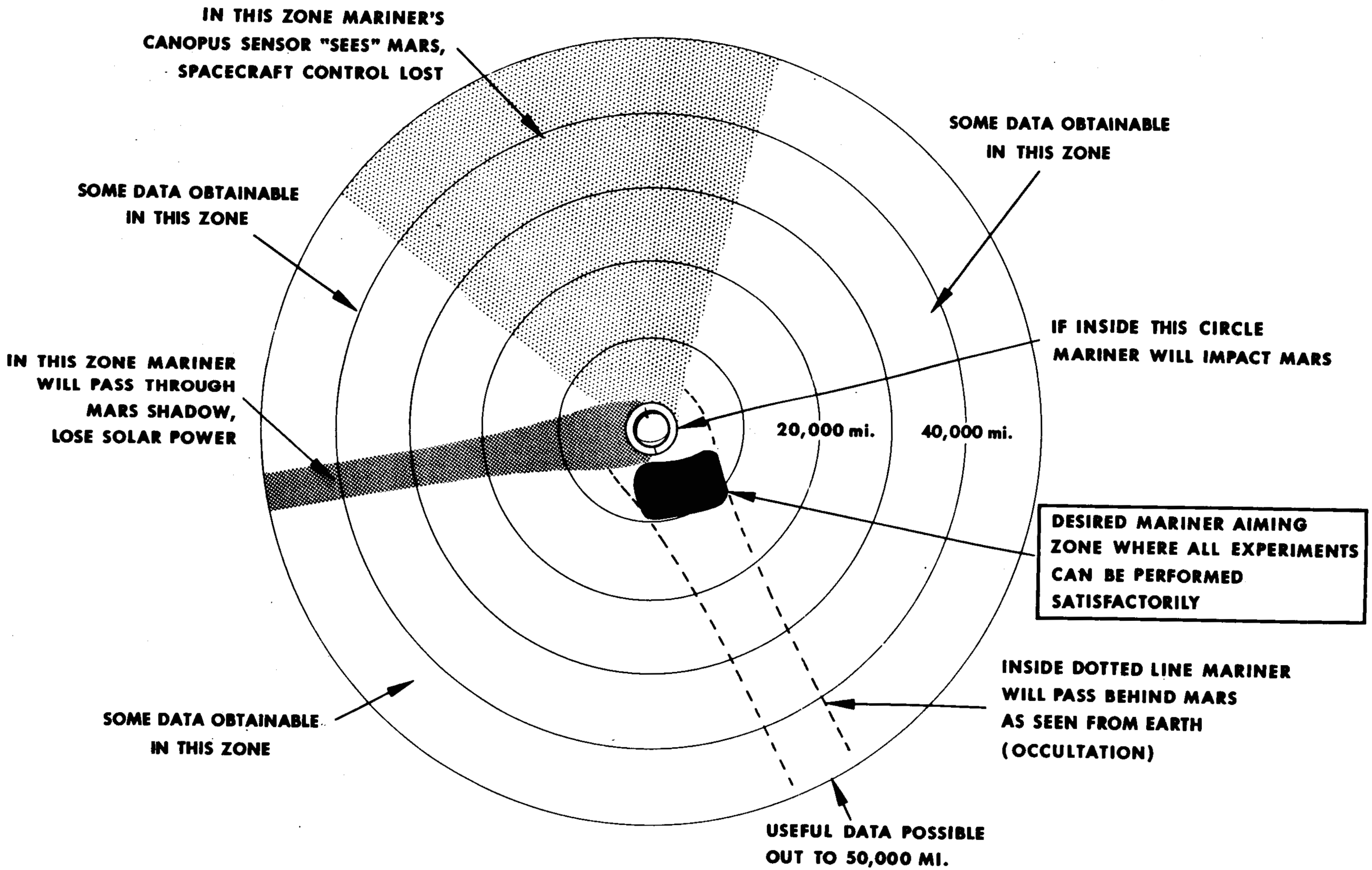
Six are designed to measure radiation, magnetic fields and micrometeorites in interplanetary space and near Mars.

If all goes well, two additional experiments could be conducted by each Mariner in the vicinity of Mars. A single television camera could take up to 22 still photographs of Mars, and an occultation experiment to determine characteristics of the Martian atmospheric pressure is planned.

The resolution of the television pictures of Mars and the area of the planet they will cover are difficult to predict because they depend on the fly-by distance from the planet.

MARINER AIMING ZONE

TARGET PLANE PASSES THROUGH CENTER OF MARS,
IS PERPENDICULAR TO INCOMING MARINER TRAJECTORY



If planned trajectories are achieved, however, the pictures should be comparable in detail with photographs of the Moon taken by the best Earth-based telescopes.

If desired accuracies are obtained at launch and during midcourse maneuver, the spacecraft will fly by Mars inside a roughly oblong zone some 7,000 miles wide and 10,000 miles long centered 8,600 miles from the Martian surface. If on the desired trajectory, the spacecraft will pass Mars between the Martian equator and the South Pole on the trailing edge of the planet as viewed from Earth.

Useful planetary data could be obtained, however, within 54,000 miles of the planet.

Physically, the Mars Mariner spacecraft have evolved from the familiar Mariner II. Each will weigh 575 pounds including about 60 pounds of scientific instruments with a Data Automation System. Because the spacecraft will be traveling away from the Sun, each will have four solar panels instead of the two carried by Mariner II.

The Mariner program is directed by NASA's Office of Space Science and Applications. It has assigned project management to the Jet Propulsion Laboratory, Pasadena, Calif., operated by the California Institute of Technology. JPL designed, built and tested the Mariner spacecraft. NASA's Lewis Research Center, Cleveland, is responsible for the Atlas-Agena launch vehicle and Goddard Space Flight Center's Launch Operations will supervise the launch at Cape Kennedy.

Tracking and communication with the Mars Mariners will be by the NASA/JPL Deep Space Network (DSN). In addition to permanent DSN stations at Goldstone, Calif.; Woomera, Australia; and Johannesburg, South Africa, two new stations at Madrid, Spain; and Canberra, Australia, are under construction and may be activated during this mission. All data will flow from DSN stations to JPL's Space Flight Operations Facility in Pasadena which will control the mission.

Scientific investigations aboard the Mariners are provided by scientists representing eight universities and two NASA laboratories.

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MARINER MARS 1964 TECHNICAL BACKGROUND

An opportunity for a mission to Mars comes only once every 25 months. Because opportunities are rare and the mission is difficult, it was determined to launch two identical Mariner spacecraft to Mars during the 1964 opportunity.

The following spacecraft and mission description is equally applicable to Mariner C or Mariner D.

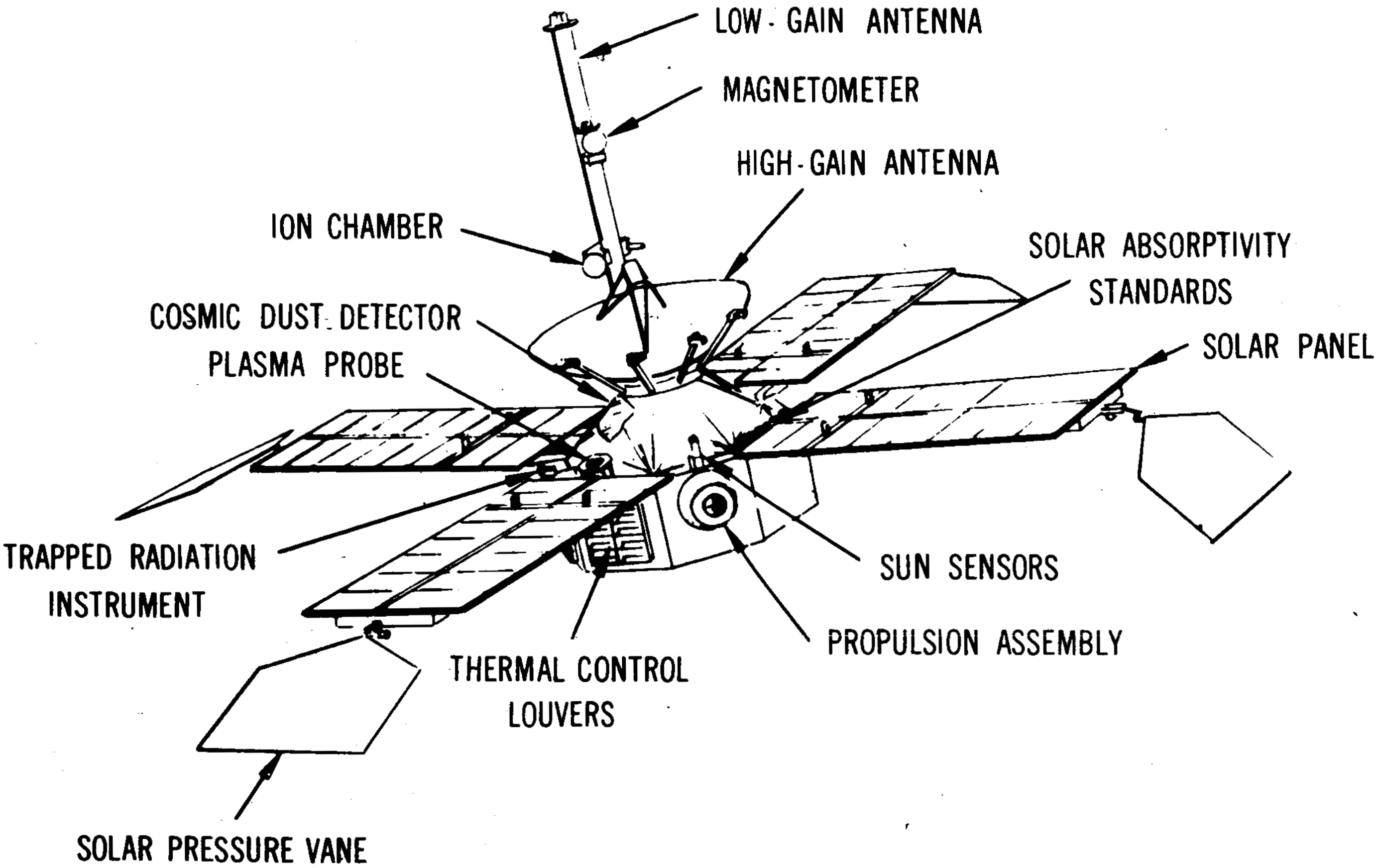
MARINER DESCRIPTION

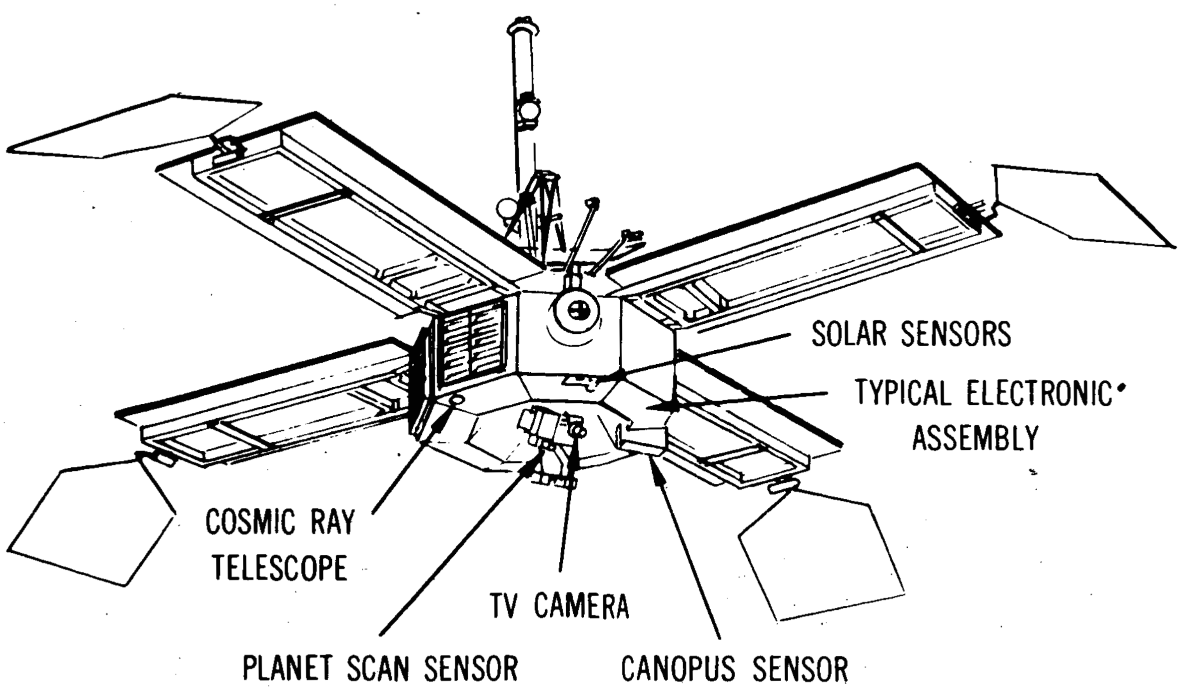
The Mariner Mars fly-by spacecraft were designed and built by the Jet Propulsion Laboratory in Pasadena, Calif. Industrial contractors provided subsystems and components.

Mariner's basic structure is a 30-pound eight-sided magnesium frame-work with seven electronics compartments. The midcourse rocket propulsion system takes up the eighth compartment. The compartments themselves provide structural support to the spacecraft.

Four solar panels, each 71½ inches long and 35½ inches wide, are attached to the top or sunward side of the octagon. Solar pressure vanes which will act as an auxiliary attitude control system during Mariner's flight, are located at the ends of each panel.

MARINER/MARS SPACECRAFT





The interior of the octagon contains gas bottles and regulators for Mariner's dual attitude control gas system. Propellant tank for the liquid-fuel midcourse motor is supported by a cantilever arrangement inside the octagonal cavity, with the rocket nozzle protruding through one of the eight sides of the spacecraft.

Two sets of attitude control jets consisting of six jets each, which control the spacecraft on three axes, are mounted on the ends of the solar panels near the pressure vane actuators.

The high-gain antenna is attached to the spacecraft by an eight-legged superstructure atop the octagon. Its honeycomb dish reflector is an ellipse, 46 inches by 21 inches, and is parabolic in cross-section. The antenna, which weighs only 4 1/2 pounds, is in a fixed position so that it will be pointed toward the Earth during the latter half of the Mariner flight including planet encounter and post-encounter phases.

The low-gain omni antenna is mounted on the end of a circular aluminum tube, 3.88 inches in diameter and extending 88 inches from the top of the octagonal structure. The tube acts as a waveguide for the low-gain antenna.

The Canopus star tracker assembly is located in the shade of the spacecraft on the lower ring structure of the octagon for a clear field of view. Sun sensors are located on both the top and bottom surfaces of the spacecraft body in order to provide spherical coverage.

The eight compartments girdling the spacecraft house the following: Bay 1, power supply and synchronizer, battery charger and squib firing assembly; Bay 2, midcourse maneuver rocket engine; Bay 3, science equipment and Data Automation System; Bay 4, data encoder (telemetry) and command subsystems; Bays 5 and 6, radio receiver, transmitters and video tape recorder; Bay 7, Central Computer and Sequencer and attitude control subsystem; Bay 8, power booster regulator and spacecraft battery.

Six of the electronics compartments are temperature controlled by light-weight louver assemblies on the outer surfaces. The octagon's interior is insulated by multi-layer fabric thermal shields at both top and bottom of the structure.

The Mariners will carry scientific instrumentation for seven interplanetary and planetary experiments. The eighth experiment, occultation, requires only the spacecraft communications system. The ion chamber and helium vapor magnetometer are mounted on the low-gain antenna support boom above the spacecraft. The trapped radiation detector and plasma probe are attached to the upper octagonal ring. The cosmic ray telescope looks through the lower ring of the octagon from one of the compartments. The cosmic dust detector is attached to the superstructure holding the high-gain antenna. The television camera and two planetary sensors are mounted on a scan platform below and to the center of the octagon.

Each Mariner weighs 575 pounds and measures 9 1/2 feet to the top of the low-gain antenna. With solar panels extended and solar pressure vanes in up position, the spacecraft spans 22 feet, 7 1/2 inches across. The octagonal structure is 50 inches across.

Power

Primary power source for the Mariner spacecraft is an arrangement of 28,224 photovoltaic solar cells mounted on four panels which will face the Sun during most of the flight to Mars. The cells, covering 70 square feet, will collect energy from the Sun and convert it into electrical power.

A rechargeable silver-zinc battery will provide spacecraft power during launch, midcourse maneuver and whenever the panels are turned away from the Sun. The battery will be kept in a state of full charge and will be available during planet encounter as an emergency power backup source.

Two power regulators will divide the power load and provide redundancy. In the event of a failure in one, it will be removed automatically from the line and the second will be switched in to assume the full load.

The solar panels will be folded in a near vertical position above the spacecraft during launch and will be deployed after separation from the launch vehicle. Each panel weighs 18.7 pounds, including the weight of 7056 solar cells and protective glass filters that reduce the amount of solar heat absorbed without interfering with the energy conversion. Lightweight panel structures that support the cells are made of thin-gauge aluminum approximating the thickness of kitchen foil. Panels are constructed of .0035-inch aluminum sheet formed into a corrugation that is bonded to the cell-mounting surface made of .005-inch sheet.

Nominal power from the panels is expected to be 640 watts at maximum power voltage for cruise conditions in space near Earth. This power capability decreases to about 310 watts at Mars encounter. Total power demands during the mission range from about 140 watts during post-encounter playback of television data to 255 watts during a midcourse maneuver.

The battery is a sealed unit containing 18 silver-zinc cells. Its minimum capacity ranges from 1200 watt hours at launch to about 900 watt hours at planet encounter. Load requirement on the battery may vary between zero amps and 9.5 amps with battery voltages expected to vary from 25.8 and 33.3 volts. The battery weighs 33 pounds.

The battery will be capable of delivering its required capacity and meeting all electrical requirements within an operational temperature range of 50° to 120° F. At temperatures beyond these limits, it will still function although its capability will be reduced.

To ensure maximum reliability, the power subsystem was designed to limit the need for battery power after initial Sun acquisition. Except during maneuvers, the battery will remain idle and fully charged.

Under normal flight conditions the primary power booster-regulator will handle all cruise and encounter loads. A second regulator will support power loads during maneuvers. Should an out-of-tolerance voltage condition exist in the cruise regulator for 3.5 seconds or longer, the maneuver regulator will take its place on the line.

Primary form of power distributed to other spacecraft systems is 2400 cycles-per-second square wave. The gyro motors use 400 cps three-phase current and the video tape recorder motor and science scan motor are supplied with 400 cps single-phase current.

Telemetry measurements have been selected to provide the necessary information for the management of spacecraft power loads by ground command if necessary.

The battery, regulators and power distribution equipment are housed in two adjacent electronics compartments on Mariner's octagonal base.

Communications

Two-way communications with the Mariner will be accomplished with a radio link between Earth tracking stations and a dual transmitter-single receiver radio system aboard the spacecraft.

The on-board communications system also includes a telemetry subsystem, command subsystem, video tape recorder and high and low-gain antennas.

Communications will be in digital form. Radio command signals transmitted to Mariner will be decoded -- translated from a binary form into electrical impulses -- in the command subsystem and routed to their proper destination. Mariner is capable of accepting 29 direct commands and one stored command. The latter is a three-segment command for midcourse trajectory correction and is held in the Central Computer and Sequencer until required.

Data telemetered from the spacecraft will consist of engineering and scientific measurements prepared for transmission by the data encoder. The encoded information will indicate voltages, pressures, temperatures, louver and solar pressure vane positions and other values measured by the spacecraft telemetry sensors and scientific instruments.

The 100-channel telemetry subsystem is capable of sampling 90 engineering and science measurements and can operate in four sequences in which the data transmitted are (1) engineering only during maneuvers; (2) a mix of science data and engineering during cruise; (3) science data and television engineering data at planet encounter; and (4) stored science data from the video tape recorder after Mars encounter with occasional insertions of engineering measurements.

All engineering data and all science data, except TV pictures, will be transmitted in real time. Science data transmitted in real-time at encounter are also recorded with the pictures on tape to be re-transmitted with pictures.

The purpose of the four-sequence operation of Mariner's telemetry system is to obtain the maximum available sampling rate on measurements required during a particular phase of the mission by not transmitting less useful information during that period.

Mariner can transmit information to Earth at two rates -- 9 1/3 bits per second and 33 1/3 bits per second. The greater rate will be used for as long as the signal level from the spacecraft is high enough to allow good data recovery. As communication distance increases, a decision will be made to command the data encoder to operate at the lesser rate. The on-board Central Computer and Sequencer will back up the data rate switchover by ground command, which probably will occur sometime after the first 10 per cent of the mission is completed.

Synchronizing pulses will be spaced at regular intervals between the data signals from Mariner. Ground-based receiving equipment will generate identical pulses and match them with the pulses from the spacecraft. This will provide a reference to determine the location of the data signals, allowing receiving equipment to separate data signals from noise.

The spacecraft S-band receiver will operate continuously during the mission at 2113 megacycles. It will receive Earth commands through either the low-gain antenna or the fixed high-gain antenna.

The low-gain antenna, providing essentially uniform coverage in the forward hemisphere of the spacecraft, will provide the primary path for the Earth-to-spacecraft link. Switchover to the high-gain antenna and back to the low-gain, if desired, may be commanded from Earth.

The transmitting subsystem consists of two redundant radio frequency power amplifiers and two redundant radio frequency exciters of which any combination is possible. Only one exciter-amplifier combination will operate at any one time. Selection of the combination will be by on-board logic with ground command backup.

Both power amplifiers will operate at a nominal output of 10 watts. Transmitter frequenfy is 2295 megacycles.

The operating transmitter can be connected to either antenna. Switchover will occur on command from the Central Computer and Sequencer with ground command backup. Transmission via the high-gain antenna will be required for approximately the last half of the mission. Attitude of the spacecraft will be such that the high-gain antenna is pointed at Earth during this portion of the mission.

Weight of Mariner's radio subsystem, including receiver, both transmitters, cabling and both antennas, is 42.5 pounds.

Midcourse Motor

Mariner's midcourse rocket motor is a liquid monopropellant engine capable of firing twice during the Mars mission. Its function is to compensate for divergences from the planned launch injection conditions. The engine burns anhydrous hydrazine fuel and uses nitrogen tetroxide as the starting fluid.

The rocket nozzle protrudes from one of the eight sides of Mariner's octagonal base below and between two of the solar panels. The engine's direction of thrust is nearly parallel to the panels, hence perpendicular to the longitudinal or roll axis of the spacecraft.

Hydrazine is held in a rubber bladder contained inside a spherical pressure vessel. The fuel is forced into the combustion chamber by means of a pressurized cartridge. Burning is maintained by a catalyst stored in the chamber.

Firing of the engine is controlled by the Central Computer and Sequencer, which receives the time, direction and duration of firing through the ground-to-spacecraft oommunication link. At the command signal from the CC&S, explosively-actuated valves allow pressure-regulated nitrogen gas to enter the fuel tank.

A timer shutoff mechanism in the CC&S actuates another set of valves which stops propellant flow and fuel tank pressurization. During rocket engine firing, spacecraft attitude is maintained by autopilot-controlled jet vanes positioned in the rocket exhaust.

Re-start capability and redundancy are provided by second sets of explosive start and shutoff valves. The second midcourse maneuver may or may not be required.

The midcourse motor can burn for as little as 50 milliseconds and can alter velocity in any direction from less than 1/8 mile per hour to 188 miles per hour. Maximum burn time is 100 seconds. Thrust is continuous at 50.7 pounds.

Weight of the midcourse propulsion system, including fuel and gas pressurization system, is 47.5 pounds.

Attitude Control

Stabilization of the spacecraft during the cruise and encounter portions of the Mariner Mars mission is provided by 12 cold gas jets mounted at the outer ends of the four solar panels. They are fed by two bottles made of titanium each holding 2.5 pounds of nitrogen gas pressurized at 2470 pounds per square inch.

The jets are linked by logic circuitry to three gyroscopes, to the Canopus star sensor and to the primary and secondary Sun sensors.

There are two identical sets of six jets and one bottle in each set. Normally both sets will operate during the mission. Either system can handle the entire mission in the event the other fails.

The primary Sun sensor is mounted atop Mariner's octagonal structure on the Sunlit side and the secondary sensors are located in the shade of the spacecraft. These are light-sensitive diodes which inform the attitude control system when they see the Sun. The attitude control system responds to these signals by turning the spacecraft and pointing the solar panels toward the Sun. The nitrogen gas escapes through the appropriate jet nozzle, imparting a reaction to the spacecraft to correct its angular position.

It is planned to use the star Canopus for pointing the high-gain antenna back to Earth and to provide a celestial reference upon which to base the midcourse maneuver. The Canopus sensor will activate the gas jets to roll the spacecraft about the already fixed longitudinal or roll axis until it is "locked" in cruise position. Brightness of the Canopus sensor's target will be telemetered to the ground to verify the correct star has been acquired. An Earth detector aboard the Mariner also will provide engineers with verification of Canopus acquisition. This detector cannot see Earth if Canopus has not been acquired and is effective only near Earth.

During firing of the midcourse motor, stabilization will be affected by the use of rudder-like deflecting vanes in the rocket engine's exhaust stream. The Mariner's autopilot controls spacecraft attitude during engine firing by using the three gyros to sense motion about Mariner's three axes for positioning the jet vanes.

An auxiliary attitude control system will position sail-like vanes at the ends of the four solar panels to correct solar pressure unbalance and provide control about the pitch and yaw axes within the limit cycle of the gas jet system.

Each vane consists of seven square feet of aluminized Mylar sheet stretched over an aluminum framework. The vanes are latched in a furled position against the backs of the solar panels during launch. As the panels deploy, the vane is released and unfolds like an Oriental fan. Electromechanical and thermomechanical actuators control the vane positions. Weight of each solar vane, its deployment mechanism, latch, cable and actuator, is less than 1½ pounds.

Total weight of the attitude control system including autopilot is about 62½ pounds.

Central Computer and Sequencer

The Central Computer and Sequencer performs the timing, sequencing and computations for other subsystems aboard the Mariner spacecraft. The CC&S initiates spacecraft events in three different mission sequences -- launch, midcourse and cruise/encounter.

The launch sequence includes spacecraft events from launch until the cruise mode is established, a maximum of 16 2/3 hours after liftoff. These events include deployment of solar panels and activation of the attitude control subsystem, solar pressure vanes and Canopus sensor.

The midcourse maneuver sequence controls the events necessary to perform the midcourse maneuver in trajectory. Three of these are commands radioed from Earth and stored in the CC&S prior to initiation of the maneuver. They tell the spacecraft how far and in which direction to turn on its pitch and roll axes and how long the midcourse rocket engine must fire.

The master timer sequence controls those events that occur during the cruising portion of flight and planet encounter. CC&S commands during this sequence switch the spacecraft telemetry transmission to a slower bit rate; switch the transmitter to the high-gain antenna; set the Canopus sensor at various cone angles relative to the predicted encounter time; turn on planetary science equipment prior to encounter for the 14-hour encounter sequence; and switch to the post-encounter telemetry mode for transmission of recorded video data.

The CC&S weighs about $11\frac{1}{2}$ pounds.

Temperature Control

If dependent solely upon direct sunlight for heat, an object in space would be approximately 125° F. colder at Mars than at Earth.

For a spacecraft traveling to Mars, away from Earth and from the Sun, the primary temperature control problem, then, is maintaining temperatures within allowable limits despite the decreasing solar intensity as the mission progresses. In airless space, the temperature differential between the sunlit side and the shaded side of an object can be several hundred degrees.

Heating by direct sunlight on the Mariner spacecraft is minimized by the use of a thermal shield on its Sun side. The side away from the Sun is covered with a thermal shield to prevent rapid loss of heat to the cold of space.

The top of Mariner's basic octagon is insulated from the Sun by a shield of 30 layers of aluminized Mylar mounted to the high-gain antenna support structure. The Mylar is sandwiched between a layer of Teflon on the bottom and black Dacron on top. The entire assembly is sewn together to form a space "blanket." The bottom is enclosed by a similar shield to retain heat generated by power consumption within the spacecraft.

Temperature control of six of the electronics compartments is provided by polished metal louvers actuated by coiled bimetallic strips. The strips act as spiral-wound springs that expand and contract as they heat and cool. This mechanical action, which opens and closes the louvers is calibrated to provide an operating range from fully closed at 55°F. to fully open at 85° F. A louver assembly consists of 22 horizontal louvers driven in pairs by 11 actuators. Each pair operates independently on its own local temperature determined by internal power dissipation.

Paint patterns and polished metal surfaces are used on the Mariner for passive control of temperatures outside of the protected octagon. These surfaces control both the amount of heat dissipated into space and the amount of solar heat absorbed or reflected away, allowing the establishment of temperature limits. The patterns were determined from testing a Temperature

Control Model (TCM) of the spacecraft. The TCM was subjected to the variations of temperature anticipated in the Mars mission in a space simulation chamber at JPL.

The high-gain antenna dish, which is dependent upon the Sun for its surface heat, is painted green to keep it at near room temperature during planet enoounter but within its upper thermal limit earlier in the mission.

SCIENTIFIC EXPERIMENTS

Data Automation System

Seven of the eight scientific experiments aboard Mariner are controlled and synchronized by the Data Automation System (DAS) and the data recorded by the instruments are converted by the DAS into a suitable digital form for transmittal to Earth.

During the mission, the DAS accumulates scientific data, reduces the data from each experiment (except the occultation experiment) to a common digital form and common rate and then feeds the data to the radio transmitter telemetry channel at proper intervals.

The telemetry channel alternately carries 280 bits of scientific data and 140 bits of engineering data except during Mars encounter when the 140 bits provide additional science data and information on performance of the scientific instruments.

Data from the interplanetary instruments are transmitted as soon as received and conditioned by the DAS. The television data, however, is recorded on a tape machine controlled by the DAS for transmission to Earth at a later time. This is required because the television pictures are recorded at a much higher rate than it is possible to transmit this data. All science data during encounter are reoorded on the tape as a back-up to the same science data being transmitted in real-time.

Performance data on the television subsystem -- filter position, signal level, shutter time, etc. -- are continually transmitted during the encounter sequence.

The DAS is composed of four units: real-time unit, non-real time unit, buffer memory and power converter. The total weight is about 12 pounds. During cruise the power requirement is 1.35 watts ; during Mars encounter, 3.06 watts.

Television

As the Mariner spacecraft passes Mars a single television camera viewing Mars through a reflecting telescope will take as many as 22 black and white, photographs of the Martian surface. The photographs will be stored on magnetic tape in digital form to be played back for transmission to Earth after Mariner passes Mars.

It is required to store the photographs on tape for later playback because the radio transmission rate from the Mars distance is 8.33 bits per second and the photographs are recorded at a rate of 10,700 bits per second.

Each photograph will consist of approximately 250,000 bits. It will take 8 1/3 hours to play back each picture. If the communication distance has not been exceeded after one playback of all pictures, each photograph will be transmitted again to provide a comparison for detection of errors in the transmission. Playback will begin about 13 to 15 hours after the last picture is taken. About 1 1/2 hours of engineering data will be transmitted between each picture. All data from the other scientific instruments will be recorded with the pictures as a back-up to the real-time transmission of science data.

The camera head and two planet sensing devices are mounted on a movable platform. This planetary scan platform will sweep through 180 degrees until a Wide Angle Planet Sensor (50° field of view) gives a planet-in-view signal. The platform will then stop its sweeping motion and center the planet in the sensor's field of view.

Picture recording begins when Mars enters the field of view of a Narrow Angle Mars Gate sensor (1 $1/2^{\circ}$ field of view) and the device generates a signal that is translated by the Data Automation System into a command that turns on the tape recorder.

Photographs will be taken in groups of two with a small gap between in each pair. Depending on camera distance from the planet, each pair of pictures may cover somewhat overlapping areas on the Martian surface. The number of pictures recorded will be determined by the time required at encounter to synchronize tape recorder and camera for the first picture and by lighting conditions on Mars.

The recorder will be turned off after recording each picture and then turned on again to record the next.

The tape is a continuous loop 330 feet long. Data will be recorded on two tracks.

Although the camera system will be turned on six to 10 hours prior to closest approach, pictures will not be recorded until the command from the Narrow Angle Mars Gate turns on the tape recorder. The camera itself will function as a backup to the Mars Gate. When the vidicon senses the increased illumination of Mars, a signal will be generated to order the tape recorder turned on.

It is anticipated that the camera system will sweep through a large illumination range on Mars which will include photographs near the shadow line or terminator. The camera system is equipped to increase or decrease its sensitivity to light to compensate for the changing lighting conditions. This is accomplished by a sampling circuit that detects changes in the strength of the video signal, which directly relates to the amount of light detected by the vidicon, and orders an increase or decrease in the amount of amplification in the television system's amplifier chain.

A picture is formed on the vidicon target in 1/5th of a second every 48 seconds. The scanning or readout of the 200 line picture requires 24 seconds and erasure of the image and preparation for the next requires 24 seconds.

The exposure time or shutter speed will be one-fifth of a second. If illumination levels are higher than expected at Mars the exposure time will be shortened to 2/25 of a second by an automatic switching device.

The shutter consists of a single rotating disc containing four openings for alternating filters. Two filters will be blue-green and two will be orange-red.

The filters will provide high contrast in the black and white photographs received on Earth and emphasize the difference in colors seen from Earth on Mars.

The telescope associated with the camera system is an f/8 Cassegrainian system of 12 inches equivalent focal length. The beryllium primary mirror has a diameter of 1.62 inches and an f-ratio of 2.47. The beryllium secondary mirror provides an amplification of 3.0.

The television system is divided into two parts. The camera head and a small portion of the electronic circuitry is located on the scan platform. The balance of the electronic equipment required for the television system is located in a compartment on the spacecraft bus.

A removable lens cover will protect the camera optics during the mission from micrometeorite damage.

Investigators are Professor R. B. Leighton, Prof. B. C. Murray and Prof. R. P. Sharp, of the California Institute of Technology.

Occultation Experiment

The purpose of the occultation experiment is to determine some characteristics of the atmosphere of Mars by transmitting radio signals from the Mariner spacecraft through the Martian atmosphere.

Performing this experiment does not require additional weight or power on the spacecraft. It does require, however, designing a trajectory for the spacecraft that will pass behind Mars.

As the spacecraft flies behind Mars, its radio signal will be bent by the Martian atmospphere and will change in frequency and strength. This is due to refraction and diffraction in the atmosphere whose effects on the Doppler (phase shift) signal are predictable. The strength of the telemetry carrier will also fluctuate and will provide informative data.

Current estimates on the surface pressure vary over a wide range and the scale height, or how the density varies with altitude, is unknown. The surface pressure on Mars is variously estimated to be between 10 and 100 millibars (about one to 10 percent of the barometric pressure on the Earth's surface) with 25 millibars accepted by some investigators.

It is essential for landing a capsule on Mars to determine these physical characteristics. Design of an entry capsule requires knowing the rate it will be slowed by atmospheric drag and whether or not a parachute system is sufficient or if some other means of slowing the capsule is required.

The scale height is also critical. This factor is of importance in the design of a capsule's heat shielding and entry shape.

The detection of the changes in the radio signal will provide a severe test of the capabilities of the Deep Space Network (DSN). The capability to accurately detect minute changes in a radio signal has been developed by the DSN in earlier missions, the Mariner II Venus mission and the Ranger VI and VII lunar flights, and by successful radar bounce experiments on the Moon, Venus, Mars and Mercury. These accuracies have been developed to a point that has made the occultation experiment feasible.

Investigators are Dr. Arvydas J. Kliore, Dan L. Cain and Gerald S. Levy of JPL, Prof. Von R. Eshelman of Stanford Electronics Laboratory, and Prof. Frank Drake of Cornell University.

Solar Plasma Probe

The solar plasma probe will measure the density, velocities, temperatures and direction of low energy (30 electron volts to 10,000 electron volts) protons that stream outward from the Sun at supersonic speeds to form what has been termed the solar wind.

Solar plasma emitted from the Sun is a boiling off of the Sun's atmosphere. It takes three forms. The solar wind, which appears to be emitted continuously in all directions; solar streams which originate in relatively small regions of the Sun; and the solar shell which is defined as bursts of solar plasma from solar flares.

The plasma itself is a thin, high velocity, high temperature gas. It is composed of the same material as the Sun, nuclei of helium and hydrogen atoms, with hydrogen nuclei (protons) being the main constituent. The atoms in the solar plasma are ionized (have lost their electrons) because of the very high temperature of the outer atmosphere (corona) of the Sun.

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The study of solar plasma is important to scientists because it is the predominant and controlling factor in interplanetary space in that it can affect magnetic fields and cosmic rays. To understand the nature of interplanetary space, it is essential to comprehend the nature of solar plasma.

Earlier solar plasma experiments in space -- Mariner II, Explorer XVIII, Explorer X -- have provided about eight months of total study time. The Mariner Mars mission will more than double this amount. However, the changing characteristics of the solar plasma are related to a cycle of solar activity that spans 11 years. Only a fraction of the desired information has been obtained.

The solar plasma probe is composed of three major parts; a collector cup, a high voltage power supply and circuitry to provide an output signal to the data automation system that conditions the data for transmission to Earth.

A mesh of fine tungsten wire in front of the collector is given a negative voltage that alternates rapidly between two limits. Thus, protons having a range of energies corresponding to these limits are alternately repelled and passed through to the collector, producing an intermittent current that is detected.

Low energy protons are repelled continuously. Higher energy protons pass through continuously but their continuous current is not detected.

The voltage limits on the mesh are repeatedly cycled through 32 voltage levels to allow detection of protons at 32 energy bands within a range of 30 to 10,000 electron volts.

From the measurement of current collected in each of the 32 energy ranges, the density, velocity, and temperature of the plasma can be deduced.

Improvements in this probe over those flown on Mariner II and on Explorer X are the greater energy range that can be detected and detection of the direction of motion of a proton in the solar plasma. The direction of motion is obtained by dividing the collector into three pie-shaped sectors. If the solar plasma enters the probe and impinges on the current collecting plates at an angle, the sectors will not receive equal currents. One of the sectors will receive the most current which will determine the direction of the plasma's motion.

The plasma probe is mounted on top of the spacecraft bus at an angle 10 degrees off the spacecraft-Sun line. It weighs 6.4 lbs. and utilizes three watts of power.

The investigators for the plasma probe are Prof. Herbert L. Bridge, Dr. Alan Lazarus of the Massachusetts Institute of Technology and Dr. Conway W. Snyder, JPL.

Ionization Chamber Experiment

This experiment includes an ionization chamber and Geiger-Mueller tube to measure radiation, principally galactic cosmic rays, in an energy range above 10 million electron volts for protons, 1/2 million electron volts for electrons and 40 million electron volts for alpha particles.

The ionization chamber will yield a measurement related to the average energy and amount of radiation at these levels and the Geiger-Mueller tube will count individual particles. Results from the two instruments will be correlated to yield data on the density of cosmic rays and their energy levels in interplanetary space between Earth and Mars and in the vicinity of Mars.

The ionization chamber is a five-inch stainless steel sphere with a wall thickness of 1/100th of an inch. The metal serves as a shielding that will only allow radiation above a given level to penetrate.

The sphere is filled with argon gas. Particles that penetrate the sphere leave a trail of ions in the gas. The ions are detected and an electric pulse is produced that is proportional to the rate of ionization in the argon gas. This pulse is processed and telemetered to Earth.

The Geiger-Mueller tube is also shielded to allow penetration by particles in the same range as detected by the chamber. The tube consists of an enclosed volume of gas with two electrodes. at a different electrical potential.

The tube generates a current pulse each time a charged particle passes through the tube. The tube can count particles at a maximum rate of 50,000 per second.

This experiment weighs 2.9 lbs. and is located on the spacecraft's mast.

The investigators are Prof. H. Victor Neher of the California Institute of Technology and Dr. Hugh R. Anderson, JPL.

Trapped Radiation Detector

The purpose of this experiment is to search for magnetically trapped radiation in the vicinity of Mars that, if it exists, might be similar to the Earth's Van Allen belts of trapped radiation.

The experiment consists of four detectors, three Geiger-Mueller tubes and one solid state detector, a silicon diode covered with thin nickel foil to exclude light.

The three GM tubes are shielded so that low energy particles can only enter by passing through a window at the end of each tube. Tubes A and B will detect protons greater than 500 thousand electron volts and electrons greater than 40 thousand electron volts. Tube C will detect protons greater than 900 thousand electron volts and electrons greater than 70 thousand electron volts. The solid state detector will measure protons in two ranges: from 500 thousand electron volts to 8 million electron volts and from 900 thousand electron volts to 5.5 million electron volts.

During the cruise portion of the mission the trapped radiation detector will measure cosmic rays and electrons.

The experiment is located on the top of the spacecraft bus and weighs about 2¼ pounds.

Investigators are Dr. James A. Van Allen, Dr. Louis A. Frank and Stamatios M. Krimigas, of the State University of Iowa.

Helium Vector Magnetometer

The scientific objectives of the magnetometer experiment are to determine if Mars has a magnetic field and, if so, to map its characteristics; to investigate the interaction between planetary and interplanetary magnetic fields and measure the magnitude and direction of the interplanetary magnetic field and determine its variations.

If a magnetic field around Mars is similar to Earth's, the magnetometer should detect the transition from the interplanetary field to that of planetary field by measuring disturbances caused by the interaction of the solar wind and the planetary field. This interaction causes instabilities in the magnetic fields embedded in the solar wind and these disturbances are detectable at considerable distances.

The magnetometer will detect a general magnetic field around Mars if the spacecraft trajectory lies within the hydromagnetic cavity formed by the solar wind around a planet. In this area a planetary field is relatively undisturbed by the solar wind.

The Mariner Mars mission will provide the first scientific opportunity to measure magnetic fields in interplanetary space at distances from the Sun greater than Earth's orbit.

Knowledge of the interplanetary field is important in understanding the nature of solar cosmic rays, solar flares, galactic cosmic rays, origin of the solar wind near the Sun, solar magnetic fields and the interaction of the solar wind with the Earth and Moon.

A new type of magnetometer, developed specifically for use on planetary missions, will be flown for the first time on the Mars mission. The instrument is a low field vector helium magnetometer that measures not only the magnitude of the magnetic field but its direction as well.

A helium magnetometer is based on the principle that the amount of light that can pass through helium gas, that has been excited to a higher than normal energy level, is dependent on the angle between the light axis and the direction of the surrounding magnetic field. Measuring the amount of light passed through the helium gives a measurement of the magnetic field in magnitude and direction.

The light source is a helium lamp in the magnetometer. The light, collimated and circularly polarized, passes through a cell containing the excited helium gas and then impinges on an infrared detector that measures the amount of light passed through the helium gas.

The magnetometer is located on the low gain antenna mast to minimize the effect of the spacecraft's magnetic fields. Electronics supporting the experiment are located in a compartment on the spacecraft. The magnetometer weighs 1.25 pounds. The electronics weighs six pounds. Its sensitivity is 1/2 gamma per axis and the dynamic range is ± 360 gamma per axis. The experiment operates on seven watts of power.

The investigators are Dr. Edward J. Smith, JPL, Paul J. Coleman, Jr., University of California at Los Angeles, Prof. Leverett Davis, Jr., California Institute of Technology and Dr. Douglas E. Jones, Brigham Young University and JPL.

Cosmic Ray Telescope (CRT)

This experiment will detect and measure cosmic rays by type, energy levels and direction of motion. The experiment will produce a detailed analysis of portions of the energy range covered by the ionization chamber experiment and in addition, will sense particles with lower energies.

The CRT will discriminate between protons in three energy groups: .80 million to 15 million electron volts; 15 million to 80 million electron volts; and 80 million to 190 million electron volts. It will discriminate between alpha particles from 2 million to 60 million electron volts; 60 million to 320 million electron volts and 320 million to infinite million electron volts.

The CRT has three coaxial gold-silicon solid state detectors with intermediate absorbers arranged in similar fashion to a series of lenses in a telescope. Dependent upon their energy and direction, particles will pass through detector 1 only or through 1 and 2 or through detectors 1, 2 and 3. Detector 1 yields a pulse proportional to the amount of energy lost as a particle penetrates. The type of particle is determined by the pulse height that is recorded and evidence of coincidental pulses in the other detectors.

The CRT is located on the underside of an electronics compartment in the spacecraft bus and weighs 2.5 lbs.

Investigators are Dr. John A. Simpson and Joseph O'Gallagher of the University of Chicago.

Cosmic Dust Detector

The objectives of this experiment are to make direct measurements of the dust particle momentum and distribution near Earth, in interplanetary space and in the vicinity of Mars.

The experiment is composed of two sensors that measure strikes by direct penetration and by microphonic techniques.

A square aluminum plate yields a microphone signal when struck by a dust particle. Bonded to both sides of the plate are layers of non-conducting material covered with a layer of evaporated aluminum, forming penetration sensors. The penetration sensors will specify which side of the microphone plate was struck. The strength of the signal derived from the microphone plate will yield data on the momentum of the particle.

The flight paths of the two Mariner spacecraft will pass close to the orbits of four meteor streams generally believed to be composed of particles once contained in the nuclei of a comet. It is expected to require several days to pass through each stream.

The streams are the Leonid, Geminid, Jrsids and the Tuttle-Giacobini-Kresak. The Leonid meteor stream will be in a period of peak activity, which occurs approximately every 33 years, near the time the Mariner spacecraft will encounter the stream.

The Mariner cosmic dust detector weighs two pounds and is mounted on the upper side of the spacecraft. The plate is approximately perpendicular to the direction the spacecraft is moving.

Investigators are W. M. Alexander, O. E. Berg, C. W. McCracken and L. Secretan, of Goddard Space Flight Center, Greenbelt, Md., and J. L. Bohn and O. P. Fuchs of Temple University, Philadelphia.

LAUNCH VEHICLE

Mariner Mars 64 is the first NASA mission to use the improved Agena-D upper stage vehicle and places maximum performance demands on the Agena and its Atlas D booster. It is also the first U.S. space mission to require a second burn of the newest model Agena-D.

Under some circumstances, it might be desirable to launch the second Mariner two days after the first so a special 36-hour data return plan has been developed. Experienced Lewis engineers will be located at a downrange tracking station during the launch. They will perform a preliminary analysis of Agena tracking and telemetry data and report the results to Cape Kennedy.

Thus project officials would be able to pinpoint a problem in the first flight in time to provide a greater margin of success for the second launch.

This model of the Agena-D -- the SS-OIB -- is an improved performance vehicle and can carry a heavier payload than its predecessors. Payload capability is increased by about 80 pounds.

This capability is gained by the use of lighter weight parts and by an improved propellant utilization system which leaves less residual propellant at Agena mission completion.

The launch sequence of the Atlas-Agena D is described at the beginning of the next section, "The Mission."

LAUNCH VEHICLE STATISTICS

Total lift-off weight: 280,000 pounds
Total lift-off height: 104 feet

	Atlas-D Booster	Agena-D Upper Stage
Weight	260,000 pounds	15,500 pounds
Height	67 feet	24 feet
Thrust	about 370,000 pounds at sea level	16,000 pounds at altitude
Propellants	liquid oxygen and RP-1, a kerosene-type fuel	unsymmetrical dimethyl-hydrazine (UDMH) and inhibited red fuming nitric acid (IRFNA)
Propulsion	two booster engines, one sustainer engine and two vernier attitude and roll control engines built by Rocketdyne Division, North American Aviation, Inc.	one engine built by Bell Aerosystems Company
Speed	about 13,000 mph at apogee for Mariner flight	about 17,500 mph after first burn, about 25,600 mph at spacecraft injection
Guidance	General Electric radio command guidance equipment; Burroughs ground guidance computer	Honeywell, Inc., inertial guidance and Barnes horizon sensors
Contractor	General Dynamics/Astronautics, San Diego, California	Lockheed Missiles and Space Company, Sunnyvale, California

Countdown Milestones

T-395 minutes	Deliver pyrotechniques to launch complex
T-155 minutes	Start Agena UDMH tanking
T-135 minutes	Complete UDMH tanking
T-130 minutes	Remove gantry
T- 90 minutes	Start IRFNA tanking
T- 65 minutes	Complete IRFNA tanking
T- 60 minutes	Scheduled hold to meet launch window
T- 40 minutes	Start Atlas LOX tanking
T- 7 minutes	Scheduled hold to meet launch window
T- 2 minutes	Secure LOX tanking
T- 19 seconds	Momentary hold
T- 2 seconds	Engines full thrust
T- 0 seconds	Release/lift-off

-more-

THE MISSION

The Mariner spacecraft will be boosted into a parking orbit at an altitude of 115 miles and a velocity of 17,500 miles an hour by the Atlas-Agena prior to its injection on a Mars trajectory.

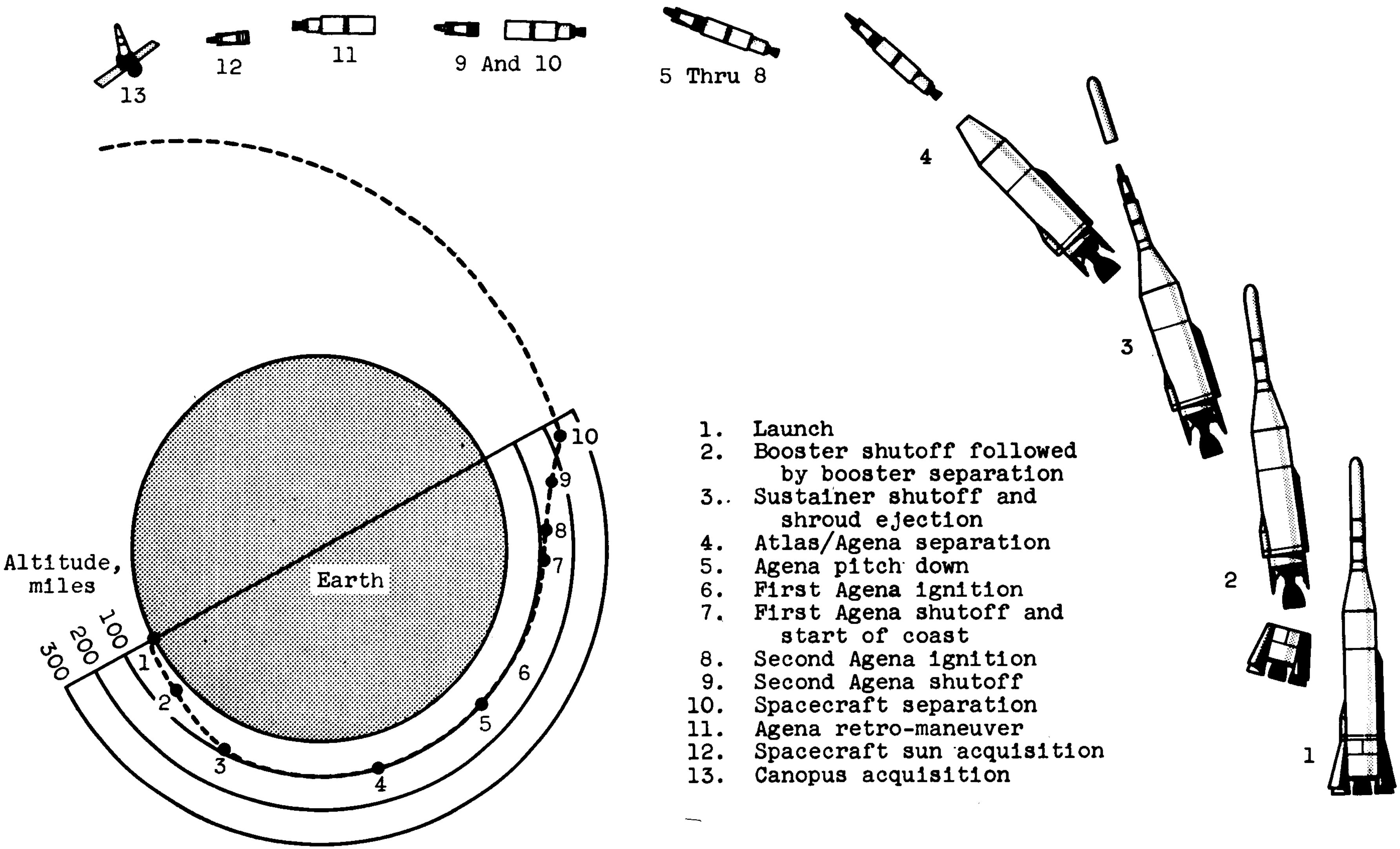
After lift-off, the Atlas vehicle is controlled by a combination of on-board autopilot and ground-based radio commands. For the first few minutes of flight, the vehicle attitude is controlled by gimballing the booster engine thrust nozzles.

About two minutes after launch, a radio command is transmitted which shuts down the booster engine (BECO or booster engine cut off). This event is followed by staging or release of the booster engine section. Vehicle attitude control is then determined by the sustainer engine until the transmission of the SECO command about five minutes after launch. At SECO, the vernier engines which had provided roll control during sustainer phase are activated to provide total vehicle attitude control. This continues until transmission of the VECO command less than a minute after SECO transmission.

Atlas-Agena Separation

Another series of radio commands is transmitted which turns on the Agena timer, activates the Agena guidance and control

TYPICAL MARINER 64 FLIGHT SEQUENCE



system, initiates separation of the Agena from the Atlas and fires retrorockets which retard the forward motion of the Atlas.

The Agena engine ignites for the first time about six minutes after launch on command of the Agena timer. This first burn lasts for about two minutes and is terminated when the Agena velocity meter determines that the correct increase in velocity has been achieved.

Coast Period

The Agena-Mariner coasts at an altitude around 115 miles before second burn ignition. The vehicle remains in parking orbit for a period of time determined by the final injection point -- a point determined by the relative position of the planet Mars at the time and date of launch.

At the proper point in the parking orbit to ensure attaining the interplanetary trajectory, the Agena engine is started for the second time. Engine shutdown is again determined by the velocity meter. The required velocity is about 25,600 miles an hour.

On command from the Agena timer the spacecraft separation system is activated. After the Mariner spacecraft leaves the Agena, the vehicle performs a 180 degree turning maneuver followed by firing of the retro-rocket.

The launch vehicle has completed its part of the mission when the spacecraft is separated from the Agena. With Agena retrofire, the second stage decelerates and enters a solar orbit. Agena retro-fire assures that the vehicle will not hit Mars and that Agena's reflection will not confuse spacecraft sensors.

First Spacecraft Events

As the Mariner is separated from the Agena, a series of spacecraft events are initiated by the separation connector:

1. Full power is applied to the spacecraft transmitter. Until this point the transmitter power has been held at low power to prevent high voltage arcing that could damage equipment in the critical area between 150,000 to 250,000 feet.

2. The cruise scientific experiments are turned on.

3. The CC&S is fully activated. Up to this point it has been inhibited from inadvertantly giving commands.

4. The tape recorder used to record television pictures at Mars encounter is turned off. The tape recorder runs during the launch phase to apply tension on the tape to prevent unwinding and snarling.

5. The attitude control system is turned on and Sun acquisition is initiated. The attitude control system initiates a spacecraft roll for calibration of the magnetometer.

6. Pyrotechnic devices are armed. A hydraulic timing device is activated which will give a back-up signal for arming the pyrotechnics and a signal for deployment of the solar panels and to unlatch the scan platform. These signals are given within a minute and 20 seconds after separation.

The Central Computer and Sequencer (CC&S) gives a back-up command, for deployment of solar panels and solar pressure vanes and for unlatching the scan platform, at liftoff plus 53 minutes. The initial commands from the hydraulic timing device occur 30 to 50 minutes from liftoff depending on the length of the parking orbit which is determined by the day and time of launch.

Sun-Canopus Acquisition

Sun acquisition will be completed in approximately 20 minutes after the first command. The time is dependent on the attitude of the spacecraft when the process begins. Any tumbling motion imparted to the spacecraft at separation is cancelled out during the acquisition process.

Sun sensors, two primary and two secondary, are mounted on the bus and will provide signals to the cold gas jets to cancel out the tumbling motion and maneuver the spacecraft until its four solar panels are pointed at the Sun. The spacecraft will now begin drawing power from the panels as they convert sunlight to electricity. The batteries, which have supplied power up until now, will only be used during the midcourse maneuver and in the event that, during the mission or at encounter, the spacecraft power demands should exceed the panels' output.

The next spacecraft event, and the next order from the CC&S, occurs at 16 1/2 hours after launch. The Canopus Star Sensor is activated and the spacecraft begins a roll search, at a different roll rate than the magnetometer calibration roll, to allow the sensor to fix on Canopus and thus orient the spacecraft in the roll axis.

Again, the time required for this acquisition depends on the position of the sensor relative to the star at the time acquisition begins. Maximum time for completion of Canopus acquisition is 75 minutes.

It will be required during the mission to command the Canopus sensor by CC&S or Earth command to change the angle of its field of view to allow for the changing geometrical relationship of the spacecraft's roll axis and the star Canopus. This change will occur four times.

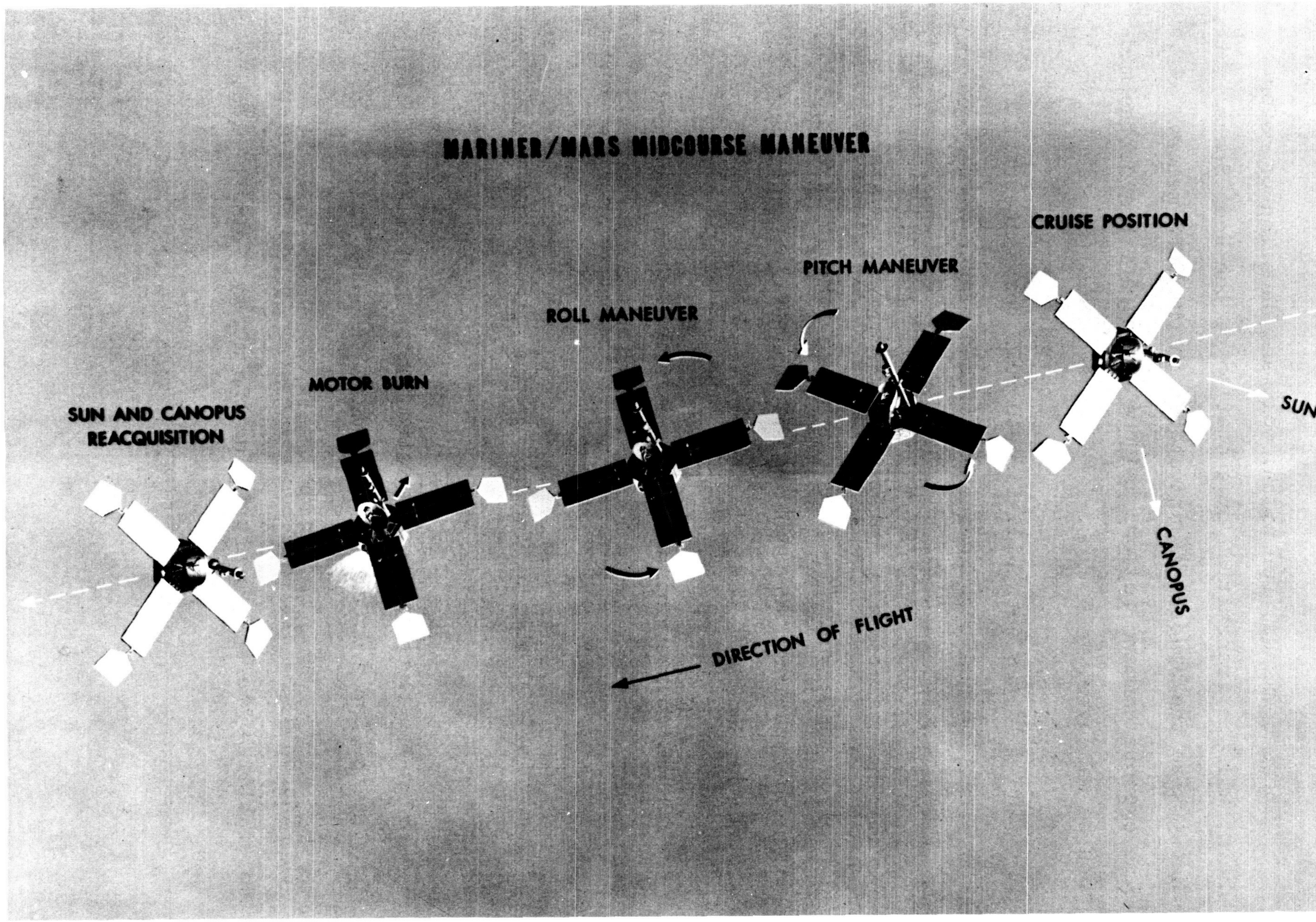
During the cruise portion of the mission, signals from the primary Sun sensor and the Canopus sensor to the attitude control system will fire the cold gas jets to maintain the spacecraft attitude -- solar panels pointed at the Sun and star sensor pointed at Canopus.

At the time of Canopus acquisition, a solid state sensing device will signal that it is viewing Earth. The device cannot view Earth if the Canopus sensor is not locked onto Canopus. This will provide a check on data from the star sensor indicating it has Canopus in view. It is possible that the star sensor could lock-on to some other celestial body. The solid state sensing device is effective only near Earth.

Midcourse Maneuver

The spacecraft is now in its cruise mode which will continue until the midoourse maneuver is commanded. This probably will occur two to 10 days after launch. The midcourse maneuver will alter the spacecraft's solar orbit by changing its velocity.

Trajectory calculations at JPL's Space Flight Operations Facility will establish the actual flight path of the spacecraft for comparison with the flight path required for a Mars fly-by. Commands will be calculated for transmission to the spacecraft to alter Mariner's flight path.


MARINER/MARS MIDCOURSE MANEUVER
CRUISE POSITION
PITCH MANEUVER
ROLL MANEUVER
MOTOR BURN
SUN AND CANOPUS
REACQUISITION
SUN
CANOPUS
DIRECTION OF FLIGHT

These commands, for pitch, roll and duration of motor burn, will be transmitted by a station of the Deep Space Network to the spacecraft and stored in the CC&S memory. The execute command follows and the spacecraft begins the mid-oourse maneuver.

The cold gas jets will fire to roll the spacecraft in the direction and through the prescribed number of degrees as commanded by the CC&S. The pitch turn is followed by a roll turn. The spacecraft's midcourse motor is now pointing in a direction that, when fired for the proper amount of time, will alter the spacecraft's velocity and thus its flight path around the Sun.

The midcourse maneuver is a precision event. An error in the duration of the motor firing that would make a difference in the final velocity of the spacecraft of one mile per hour will make a 9000 mile difference in the flight path at the Mars fly-by.

When the maneuver is completed the spacecraft will again acquire the Sun and Canopus on command from the CC&S.

The cold gas attitude control system is not sufficient to stabilize the spacecraft during the motor firing period.

Movable jet vanes in the motor exhaust perform the stabilization function at this time. They are controlled by an autopilot that is turned on for the midcourse maneuver and used only at this time. The autopilot accepts signals from gyros to keep the motor thrust pointed in the right direction.

From execute command to reacquisition of Canopus, the maneuver will take approximately four hours. Although the telemetry will give some indication that the maneuver has been performed accurately, it will require a long period of tracking to calculate the spacecraft's new flight path.

During the midcourse maneuver the spacecraft transmits only engineering data to Earth. At completion of the maneuver the telemetry format will revert to the cruise mode of one-third engineering data and two-thirds science data.

If required, a second midcourse maneuver can be performed by the Mariner. This is the first spacecraft to have this capability.

Mariner is again in its cruise mode and with two exceptions, will continue in this mode until encounter with Mars.

The two exceptions are concerned with communications. As the distance from spacecraft to Earth increases it will be necessary to slow the transmission bit rate from 33 1/3 bits per second to 8 1/3 bits per second. This will occur, on command from the CC&S with a back-up command from Earth, at approximately nine weeks after launch.

Later in the mission, about 12 weeks after launch, the spacecraft's transmitters will be switched from the omni-directional antenna to the high gain antenna. This is a CC&S command backed-up from Earth and will be performed at the time the omni-directional antenna nears the limits of its transmission distance capability.

The high gain antenna is rigidly fixed on the spacecraft, unlike the Rangers or Mariner II which had movable high gain antennas, because after the switchover point, Earth will be continually in the antenna's view.

The next mission event will be Mars encounter.

Encounter

The encounter sequence will begin from six to 10 hours before the spacecraft makes its closest approach to the planet. At this time the CC&S, with Earth command back-up, will turn on the television system, that portion of the Data Automation System that functions at encounter, the scan platform, the two Mars sensors and the tape recorder electronics. Although receiving power, the tape recorder is not running and will not record pictures until later.

A cover shielding the optics of the vidicon and the two planet sensors is removed at this point by the encounter command from the CC&S to a pyrotechnic device. The battery charger is also turned off at this time.

The scan platform is now sweeping through 180 degrees nearly vertical to the direction of motion of the spacecraft. The television system is functioning but pictures are not recorded at this point. Pictures will not be recorded until a signal is sent from the narrow angle Mars sensor through the DAS to the recorder that the vidicon camera is seeing the planet.

As Mariner approaches Mars the wide angle sensor will detect the planet, and send a signal that stops the 180 degree sweep of the scan platform. The scan platform will not track the planet.

Telemetry is now switched from a combination of engineering data and science data to all science, with the exception of engineering data on the TV system.

The next event is the acquisition of Mars by the narrow angle sensor. The scan platform is now locked in place and recording of pictures begins. Starting of the tape machine is synchronized with the sequencing of the television camera.

The spacecraft will sweep past Mars recording pictures and transmitting other scientific data to Earth. All science data will also be recorded on the tape. The signal being transmitted to Earth, telemetry carrier and the Doppler signal, will be transmitted through the Martian atmosphere as the Mariner crosses behind the planet to perform the occultation experiment.

Transmission from the spacecraft will not be received on Earth as Mariner passes behind Mars. When it reappears the tracking station will begin a search to reacquire the spacecraft.

About 14 hours after the CC&S or Earth command was given to begin the encounter sequence, the CC&S will command the encounter instruments turned off. Six hours later it will order the tape recorder to begin the playback of the pictures recorded.

Each picture will require approximately 8 1/3 hours to transmit to Earth. Between each picture the spacecraft will transmit 1 1/2 hours of engineering data. The entire tape will be played back twice if the spacecraft has not exceeded the communication range after the first playback.

After the picture data has been transmitted and if the Mariner is still within communication range, the scientific instruments will be turned back and the telemetry format switched to one-third engineering data, two-thirds science data. The spacecraft is again in cruise mode and this will continue until Mariner exceeds the communication range. At that point the mission will end but the Mariner will continue to circle the Sun in a perpetual solar orbit.

Trajectory

The Mariners will be launched from Cape Kennedy at a sufficient velocity to escape Earth plus the additional velocity required to provide an encounter with Mars.

Escape velocity, 25,200 mph, would only be sufficient to place a Mariner in a solar orbit that would be near Earth's orbit. The additional velocity is carefully calculated to yield a solar orbit that will cross the path of Mars on a given date with the spacecraft properly oriented to Mars, Earth and Sun to perform its scientific experiments, communicate with Earth and receive power from the Sun.

The total required velocity is imparted to the spacecraft at the point of injection by the Agena-D second stage. The final velocity and the injection point varies from day to day throughout the launch period as the relationship between the position of Earth and Mars changes.

A typical injection velocity is 25,663 miles per hour, relative to Earth. At encounter a typical spacecraft velocity would be 11,405 mph, relative to Mars. It is required to state velocities in the relative sense because the velocity of a body in the solar system is based on the position of the observer.

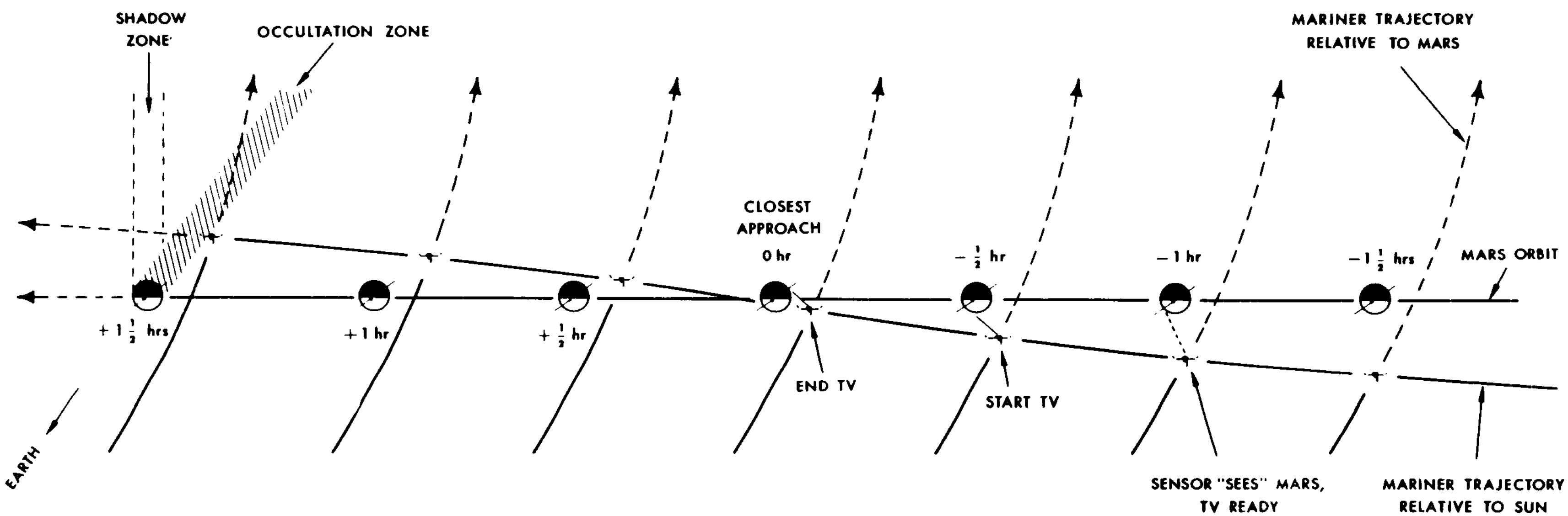
To an observer on Earth the velocity of Mariner at injection would be as stated, 25,663 mph. To an observer on the Sun the velocity of the spacecraft at injection would be 87,185 mph. This is because the Earth itself is orbiting the Sun at a speed in excess of 60,000 miles per hour and this velocity plus the injection velocity is imparted to the spacecraft at injection.

The velocity of the spacecraft relative to Earth at injection will slowly diminish as Mariner heads outward from Earth and the Earth's gravitational field pulls on the spacecraft. As Mariner approaches Mars the velocity of Mariner will increase under the attraction of the planet.

At launch Mars will be ahead of Earth. At encounter Mars will be trailing Earth by approximately 150,000,000 miles.

The spacecraft will follow a long curving path around the Sun after injection. It will pass Mars prior to encounter and, as its velocity is still decreasing, Mars will catch up with the Mariner and pass it. After this pass occurs, Mariner's

TYPICAL MARINER TRAJECTORIES NEAR MARS



direction of flight will carry it behind Mars to allow the occultation experiment. It will be behind Mars for approximately one hour.

Mariner's trajectory is planned to pass behind Mars on a line between the equator and the South Pole.

In designing trajectories for the Mars mission the trajectory engineer must satisfy numerous restrictions or constraints that influence the final trajectory. For example, the flight time must not exceed certain limits imposed by the lifetime of the spacecraft; injection velocities are prescribed by the capability of the boost vehicle, thus affecting the transit time; for power considerations the spacecraft must always be within 162 million miles of the Sun; neither Mars nor its two moons can be allowed to infringe on the field of veiw of the Canopus sensor nor shadow the spacecraft from the Sun; and encounter must occur during the viewing period of Goldstone, the Mojave Desert, Calif., station of the Deep Space Network.

Other factors influencing the trajectory include the effect of solar wind pressure on the flight path; the gravitational attraction of Sun, Earth, Mars, Mercury, Venus and Jupiter; and a requirement that the encounter velocity be kept as low as possible.

In selecting an aiming zone that will determine the path of the spacecraft as it passes Mars, the trajectory engineer is required to assure that the Mariner will not impact Mars, in order to prevent contamination of the planet by Earth microorganisms. The aiming zone must also satisfy the requirements of the scientific experiments aboard the spacecraft, for example, be designed to yield satisfactory television pictures.

The accuracy of the encounter with Mars will be influenced by launch accuracy and the midcourse correction accuracy.

Calculations after launch will determine if the flight path of the spacecraft is within the correction capability of the midcourse motor. Mariner has the capability of performing two midcourse corrections in the event the first does not yield the desired accuracy for encounter.

The accuracies demanded by the launch vehicle and by the midcourse motor can be illustrated by the following numbers. The injection velocity can vary only by plus or minus 30 miles per hour or the resulting trajectory will not be within the correction capability of the midcourse motor. At midcourse maneuver, an error of one mile per hour will result in moving the spacecraft at Mars by 9,000 miles.

DEEP SPACE NETWORK

The Deep Space Network (DSN) consists of four permanent space communications stations, a launch tracking station at Cape Kennedy, the Space Flight Operations Facility (SFOF) in Pasadena, Calif., and a ground communications system linking all locations.

The four permanent stations, located approximately 120 degrees apart around the Earth, are at Woomera, Australia; Johannesburg, South Africa; and two at Goldstone, Calif.

Two new stations -- near Canberra, Australia, and Madrid, Spain -- are under construction. The Canberra station will be operational early in 1965. The Madrid station will go on the air later in the year.

The DSN is under the technical direction of the Jet Propulsion Laboratory for the National Aeronautics and Space Administration. Its mission is to track, receive telemetry from and send commands to unmanned lunar and planetary spacecraft from the time they are injected into orbit until they complete their missions.

Dr. Eberhardt Rechtin is JPL's Assistant Director for Tracking and Data Acquisition. Dr. N. A. Renzetti is DSN Systems Manager.

The Goldstone DSN stations are operated by JPL with the assistance of the Bendix Field Engineering Corp. Walter E. Larkin is JPL's Engineer in Charge.

The Woomera and Canberra stations are operated by the Australian Department of Supply, Weapons Research Establishment. Station Manager at Woomera is William Mettyear, and JPL's DSN resident is Richard Fahnestock. Canberra station Manager and JPL DSN resident are Robert A. Leslie and Merideth S. Glenn, respectively.

The Johannesburg station is operated by the South African government through the National Institute for Telecommunications Research. Doug Hogg is station Manager and Paul Jones is DSN resident in Johannesburg.

At Madrid, JPL will operate the newest DSN station under an agreement with the Spanish government. Donald Meyer of JPL is station Manager, and Phil Tardani, also of JPL, is DSN resident in Madrid.

The 1964 Mariner mission to Mars will span a time period of about nine months. The Deep Space Net will monitor the Mariner spacecraft continuously. The permanent stations provide 360 degrees coverage around the Earth so that one or more of their 85-foot antennas can always point toward the spacecraft.

Nerve center of the Net is the Space Flight Operations Facility at JPL Headquarters in Pasadena. The overseas stations and Goldstone are linked to the SFOF by a communications network, allowing tracking and telemetry information to be sent there for analysis.

All of the Deep Space stations of the DSN are equipped with 85-foot diameter antennas, transmitting, receiving, data handling, and interstation communication equipment. Microwave frequencies (S-band) will be used in all communications with the Mariner spacecraft.

The Pioneer station at Goldstone, along with Canberra, Woomera and Johannesburg, will be primary stations for the mission. Each has a 10,000 watt transmitter. The Venus research and development station at Goldstone, with a 100,000 watt transmitter, will provide command backup capability should more power be required late in the mission. Another Goldstone station -- Echo -- will be used for Ranger lunar missions which may occur during Mariner transit to Mars.

The Madrid and Echo stations will probably assist in monitoring the Mariner spacecraft during planet fly-by.

Tracking data obtained early during launch will be computed both at Cape Kennedy and at the Central Computing Facility in the SFOF so that accurate predictions can be sent to the DSN stations giving the location of Mariner in the sky when it appears on the horizon.

Scientific and engineering measurements and tracking data radioed from a spacecraft are received at one of the stations, recorded on tape and simultaneously transmitted to the SFOF via high speed data lines, teletype or microwave radio. Incoming information is again recorded on magnetic tape and entered into the SFOF's computer system for processing.

At approximately halfway to Mars, the two Mariner spacecraft will both be in view of the same DSN antenna at the same time. The station viewing both spacecraft will simultaneously transmit to the SFOF real-time telemetry data from one spacecraft and record and store telemetry data from the other for later transmission or transportation to JPL.

Scientists and engineers seated at consoles in the SFOF have pushbutton control of the displayed information they require either on TV screens in the consoles or on projection screens and automatic plotters and printers. The processed information also is stored in the computer system disc file and is available on command.

This major command center, designed for 24-hour-a-day functioning and equipped to handle two spaceflight missions concurrently while monitoring a third, is manned by some 250 personnel during critical events -- launch, midcourse maneuver, planet encounter -- of a Mariner mission.

In the SFOF's mission control area, stations are set up for the project manager, operations director in charge of the mission, operations manager responsible for physical operation of the SFOF, information coordinator and for representatives from the supporting technical teams.

Mission control personnel are supported by three technical teams. Space Science Analysis is responsible for evaluation of data from the scientific experiments aboard the spacecraft and for generation of commands controlling the experiments.

Flight Path Analysis is responsible for evaluation of tracking data determination of flight path and generation of commands affecting the trajectory of the spacecraft.

Spacecraft Performance Analysis evaluates the condition of the spacecraft from engineering data radioed to Earth and generates commands to the spacecraft affecting its performance.

MARINER PROJECT TEAM

The National Aeronautics and Space Administration's programs for unmanned investigation of space are directed by Dr. Homer E. Newell, Associate Administrator for Space Science and Applications. Oran W. Nicks is the Director of OSSA's Lunar and Planetary Programs and Glenn A. Reiff is the Mariner Program Manager. Andrew Edwards is NASA's Mariner program engineer and James Weldon is program scientist. Joseph B. Mahon is Agena Program Manager for OSSA's Launch Vehicle and Propulsion Programs.

NASA has assigned Mariner project management to the Jet Propulsion Laboratory, Pasadena, Calif., which is operated by the California Institute of Technology. Dr. William H. Pickering is the Director of JPL and Assistant Director Robert J. Parks heads JPL's lunar and planetary projects.

Jack N. James is Mariner Project Manager. His two assistant project managers are Wilbur A. Collier and Theodore H. Parker. In a staff capacity, Norman R. Haynes is in charge of mission analysis and planning, and John S. Reuyl, launch constraints.

Richard K. Sloan is the Mariner Project Scientist.

The project is divided into four systems:

Spacecraft

Spaceflight Operations

Deep Space Network

Launch Vehicle

The first three systems are assigned to the Jet Propulsion Laboratory. The fourth is assigned to NASA's Lewis Research Center, Cleveland, for the Atlas-Agena launch vehicle. Dr. Abe Silverstein is the Director of Lewis Research Center. Launch operations for Lewis are directed by Goddard Space Flight Center Launch Operations at Cape Kennedy.

A few of the many key personnel in each of the systems are listed.

Dan Schneiderman Spacecraft System Manager

John R. Casani - Spacecraft Project Engineer

Milton T. Goldfine - Spacecraft Operations Manager

James Maclay - Environmental Requirements Engineer

Richard A. Welnick - Quality Assurance Engineer

David E. Shaw - Spacecraft Program Engineer

A. Nash Williams - Spacecraft Launch Vehicle Integration

Herbert G. Trostle - Space Science

James N. Bryden - Spacecraft Telecommunications

James D. Acord - Spacecraft Guidance and Control

James H. Wilson - Spacecraft Engineering Mechanical

Douglas S. Hess - Spacecraft Test Facilities

Bruce Schmitz - Post-injection propulsion and pyrotechnics

Wade G. Earle - Test Conductor, First flight spacecraft

Max E. Goble - Test Conductor, Second flight spacecraft

H. Holmes Weaver - Test Conductor, Test model spacecraft

Thomas S. Bilbo — Spaceflight Operations Systems Manager

David W. Douglas - Spaceflight Operation Director

Don B. Sparks - Facility Operations Manager

Frank G. Curl - Data Processing Project Engineer

Jay F. Helms - Communications

Dr. Nichola A. Renzetti — Deep Space Network System Manager

Arthur T. Burke - Project Engineer

Clarence A. Holritz - DSN Operations Manager

Dr. S. Himmel — Launch Vehicle System Manager

C. Conger - Assistant Launch Vehicle System Manager

R. Gedney - Project Engineer

D. E. Forney - Chief of Agena Field Engineering Branch

Robert H. Gray - Chief of Goddard Launch Operations

Harold Zweigbaum - Manager of Atlas-Agena Launch Operations

CONTRACTORS

The Atlas, designed and built by General Dynamics/Astronautics (GD/A), San Diego, Calif., is purchased through the Space Systems Division of the U.S. Air Force Systems Command and Rocketdyne Division of North American Aviation, Inc., of Canoga Park, Calif., builds the propulsion system. Radio command guidance is by Defense Division of General Electric Co. and ground guidance computer by the Burroughs Corp.

Some of the key General Dynamics personnel are Charles S. Ames, vice president and project director for space launch vehicles; Jim Von Der Wische, project engineer for Mariner; Tom O'Malley, GD/A launch operations; Cal Fowler, launch conductor on Complex 13; and Orion Reed, launch conductor on Complex 12.

The Agena D stage and its mission modifications are purchased directly by the Lewis Center from Lockheed Missiles and Space Co. (LMSC) Sunnyvale, Calif. Bell Aerosystems Co. Buffalo, N.Y., provides the propulsion system. Jack L. Shoenhair is manager of medium space vehicles for LMSC, Peter J. Ward is Mariner program manager, Malcom E. Avery is Mariner project engineer and Bud Zeller is Mariner operations test director.

Many contractors provided components, assemblies and personnel to the project. A list of some 61 key subcontractors to the Jet Propulsion Laboratory who provided instruments and hardware for Mariner Mars 64 follows. Their contracts amounted to $21.1 million.

SUBCONTRACTORS

Advanced Structures Division Whittaker Corp. Las Mesa, Calif.	spacecraft hi-gain antennas
Airrite Products Division of Electrada Corp. Los Angeles, Calif.	midcourse propulsion fuel tanks, nitrogen tanks
Alpha-Tronics Corp. Monrovia, Calif.	data automation system analog-to-pulse width converters
Anadite Co. Los Angeles, Calif.	surface treatment of structural elements and chassis
Anchor Plating Co. El Monte, Calif.	Gold plating
Applied Development Corp. Monterey Park, Calif.	ground telemetry decommutators, printer programmers
Astrodata Inc. Anaheim, Calif.	time code generator/translators, ground command read-write-verify equipment, encoder simulator, and spacecraft system test data system
Barnes Engineering Co. Stamford, Conn.	Canopus star tracker electronics
Bendix Corp. Scintilla Division Santa Ana, Calif.	connectors
Bergman Manufacturing Co. San Rafael, Calif.	chassis forgings
Cannon Electric Co. Los Angeles, Calif.	connectors
CBS Laboratories Division of Columbia Broadcasting System, Inc. Stamford, Conn.	image dissector tubes for Canopus star trackers

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Computer Control Co., Inc. Framingham, Mass.	real time data automation system logic cards for scientific instruments, operational support equipment, DAS voltage-to-pulse width converters
Correlated Data Systems Corp. Glendale, Calif.	spacecraft external power source and solar panel simulators, voltage controlled oscillators
Data-Tronix Corp. King of Prussia, Pa.	voltage controlled oscillators
Delco Radio Division General Motors Corp. Kokomo, Ind.	telemetry format simulators
Digital Equipment Corp. Los Angeles, Calif.	data automation system operational support data system
Dunlap and Whitehead Manufacturing Co. Van Nuys, Calif.	midcourse propulsion and structural elements
Dynamics Instrumentation Co. Monterey Park, Calif.	ground telemetry consoles, assembly of planetary scan subsystem electronics
The Electric Storage Battery Co. Raleigh, N.C.	spacecraft batteries
Electro-Optical Systems, Inc. Pasadena, Calif.	ion chamber assemblies, assembly and test of spacecraft solar panels, modification and test of spacecraft power system, spacecraft assembly cables
Electronic Memories, Inc. Los Angeles, Calif.	magnetic counter assemblies for spacecraft central computer and sequencer
Engineered Electronics Co. Santa Ana, Calif.	non-real time data automation system
Fargo Rubber Corp. Los Angeles, Calif.	midcourse propulsion fuel tank bladders

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Farrand Optical New York, N.Y.	television optical systems
Franklin Electronics, Inc. Bridgeport, Pa.	ground telemetry high speed digital printers
General Dynamics Corp. General Dynamics/Electronics San Diego, Calif.	assembly of television subsystems
General Electrodynamics Corp. Garland, Texas	vidicons and television tube test set
Grindley Manufacturing Co. Los Angeles, Calif.	midcourse propulsion jet vanes, fuel manifolds, oxidizer tank shell, and supports
Hi-Shear Corp. Torrance, Calif.	squibs
Hughes Aircraft Co. Microwave Tube Division Los Angeles, Calif.	traveling wave tubes
IMC Magnetics Corp. Westbury, N.Y.	solar vane actuators
International Data Systems, Inc. Dallas, Texas	ground command modulation checker, telemetry power supplies
Kearfott Division General Precision, Inc. Los Angeles, Calif.	gyroscopes, jet vane actuators
Lawrence Industries, Inc. Burbank, Calif.	printed circuits
Lockheed Electronics Co. Division Lockheed Aircraft Corp. Los Angeles, Calif.	solar cell modules and magnetic shift register for central computer and sequencer
Lockheed Aircraft Service Co. Division Lockheed Aircraft Corp. Ontario, Calif.	spacecraft low-level positioners
Magnamill Los Angeles, Calif.	structural elements and chassis
Massachusetts Institute of Tech. Division of Sponsored Research Cambridge, Mass.	Plasma probes

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Metal Bellows Corp. Chatsworth, Calif.	midcourse propulsion oxidizer bellows assembly
Milbore Co. Glendale, Calif.	midcourse propulsion engine components
Mincom Division Minnesota Mining and Manufacturing Co. Camarillo, Calif.	ground telemetry tape recorders
Motorola, Inc. Military Electronics Division Scottsdale, Arizona	spacecraft transponders, command systems and associated operational support equipment, and DSIF equivalent operational support equipment
Nortonics A Division of Northrop Corp. Palos Verdes Estates, Calif.	Development and support of attitude control electronics
Philco Corp. Palo Alto, Calif.	integrated circuit sequence generator system, spacecraft antenna feeds and spacecraft antenna subsystem tests
Proto Spec Pasadena, Calif.	chassis and subchassis
Pyronetics, Inc. Santa Fe Springs, Calif.	midcourse propulsion system explosive actuated valves
Rantec Corp. Calabasas, Calif.	S-Band circulator switches, pre-selection and band rejection filters
Raymond Engineering Laboratory, Inc.	spacecraft video storage tape recorder
Ryan Aeronautical Co. Aerospace Division San Diego, Calif.	spacecraft solar panel structure
Siemens and Halske AG Munich, West Germany	RF amplifier tubes
Space Technology Laboratories El Segundo, Calif.	spacecraft central computer and sequencer and associated operational support equipment

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Sperry Utah Co. A Division of Sperry Rand Corp. Salt Lake City, Utah	magnetometer mapping fixture
State University of Iowa Iowa City, Iowa	trapped radiation detectors
Sterer Engineering and Manufacturing Co. North Hollywood, Calif.	valves and regulators for attitude control gas system
Texas Instruments, Inc. Apparatus Division Dallas, Texas	spacecraft video storage subsystem electronics, spacecraft data encloders and associated operational support equipment, helium magnetometers, attitude control gyro electronics assemblies data demodulators
Textron Electronics, Inc. Heliotek Division Sylmar, Calif.	silicon photovoltaic solar cells
Thompson Ramo Wooldridge, Inc. Redondo Beach, Calif.	thermal control louvers and power converters
Univac Division of Sperry Rand Corp. St. Paul, Minn.	spacecraft data automation system buffer memory
The University of Chicago Chicago, Ill.	spacecraft cosmic ray telescopes
Wems, Inc. Hawthorne, Calif.	spacecraft television electronics modules, spacecraft attitude control electronic modules
Wyman Gordon Corp. Los Angeles, Calif.	spacecraft structural forgings

In addition to these subcontractors, there were over 1,000 individual firms contributing to Mariner. These procurements amounted to over $19 million.

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