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Tracking and Data Acquisition Support for the Mariner Venus 1962 Mission

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This report has been prepared from many internal JPL documents relating to the preparation of the Deep Space Instrumentation Facility, operational readiness tests, the tracking operations, and post-flight analyses. Significant contributions were made by engineers and technicians at the Deep Space Communication Stations at Goldstone, California; Woomera, Australia; Johannesburg, South Africa; and at the Jet Propulsion Laboratory, Pasadena, California. Special acknowledgement is made of contributions by Messrs. J. R. Hall, W. D. Chaney, W. E. Larkin, D. Hogg, W. Mettyear, C. A. Holritz, A. T. Burke, and J. Orbison. Mr. L. Wood assisted the author in organizing the material and preparing the final draft.

The descriptions of the *Mariner II* spacecraft and its scientific experiments, flight plans, and mission synopsis are taken from published material on the *Mariner* Project and are presented in this Memorandum to provide a better understanding of the Deep Space Instrumentation Facility Operations. The author is indebted to W. A. Collier, *Mariner* Assistant Project Manager, for a careful review of this report.

ABSTRACT

This Document summarizes the technical activities of the Deep Space Instrumentation Facility in support of the *Mariner II* mission. The narrative includes a synopsis of the mission, a comprehensive account of the tracking operations, and a performance evaluation. The tracking and data acquisition support are also delineated, and a complete list of reference material is given.

I. INTRODUCTION

The purpose of this Memorandum is to:

1. Summarize the technical activities of the Deep Space Instrumentation Facility (DSIF) in support of the *Mariner II* mission.
2. Present, in one document, the important technical material associated with these activities.
3. Provide an historical account of the DSIF organization, equipment configurations, interstation communication networks, and tracking operations.

A brief description of spacecraft and launch vehicle flight performance is included, as required, to convey an understanding of the DSIF activities.

In July of 1960, the National Aeronautics and Space Administration (NASA), through its Office of Space Science, approved the proposal of the California Institute of Technology's Jet Propulsion Laboratory (JPL) to send a spacecraft to Venus in the Summer of 1962. The project objectives were to develop the technology of spacecraft for lunar, planetary, and interplanetary exploration; to acquire information about interplanetary space and Venus; and to gather data which could be useful in planning manned flights to the Moon and the planets.

Through its Office of Space Flight Operations, NASA established the Deep Space Network in 1958–59 and gave to the Jet Propulsion Laboratory the responsibility for designing, developing, engineering, installing, and operating the Network. In addition, JPL was to provide the supporting research and development necessary to maintain the Network at the state of the art in space communications.

Figure 1 shows the organization comprising the Office of Space Flight Operations and the personnel involved in implementing the Deep Space Network during the *Mariner II* mission. Similarly, Fig. 2 shows an organizational breakdown of JPL during the *Mariner II* mission; the DSIF organization is shown in Fig. 3.

This Memorandum presents the following subject matter of the *Mariner II* mission:

1. *Mission Synopsis.* A recapitulation of significant events occurring throughout the mission.
2. *Mission Objectives.* The scientific experiments conducted, and DSIF objectives throughout the mission.

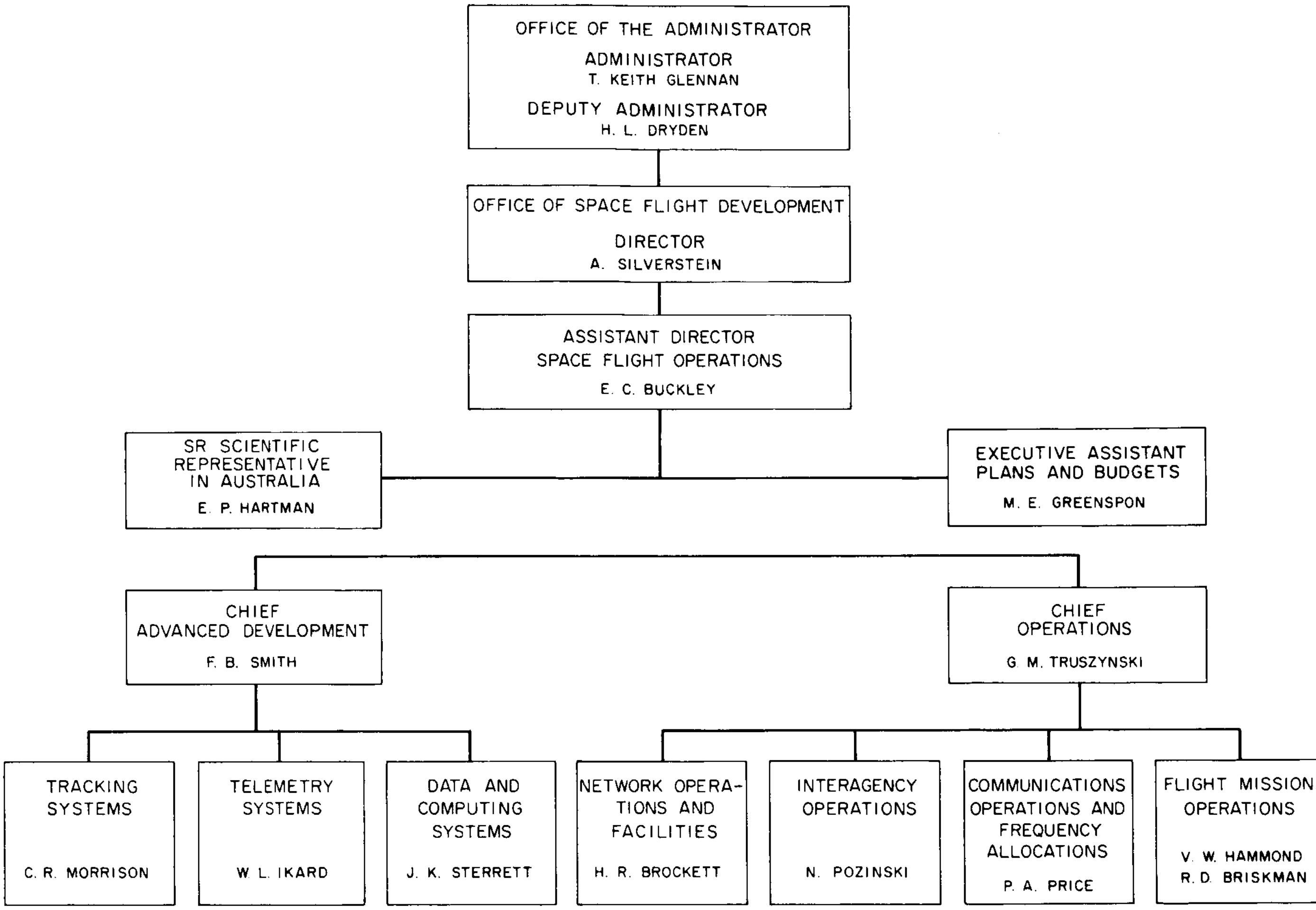


Fig. 1. NASA organization of Office of Space Flight Operations

3. *DSIF Preparation for Mission.* A discussion of requirements, problems and solutions, planning personnel, and Network configuration for the mission.

4. *Flight Plan.* The plan for conducting flight operations and the expected achievements.

5. *Test Analysis.* Evaluation of the operational readiness and Network integration tests.

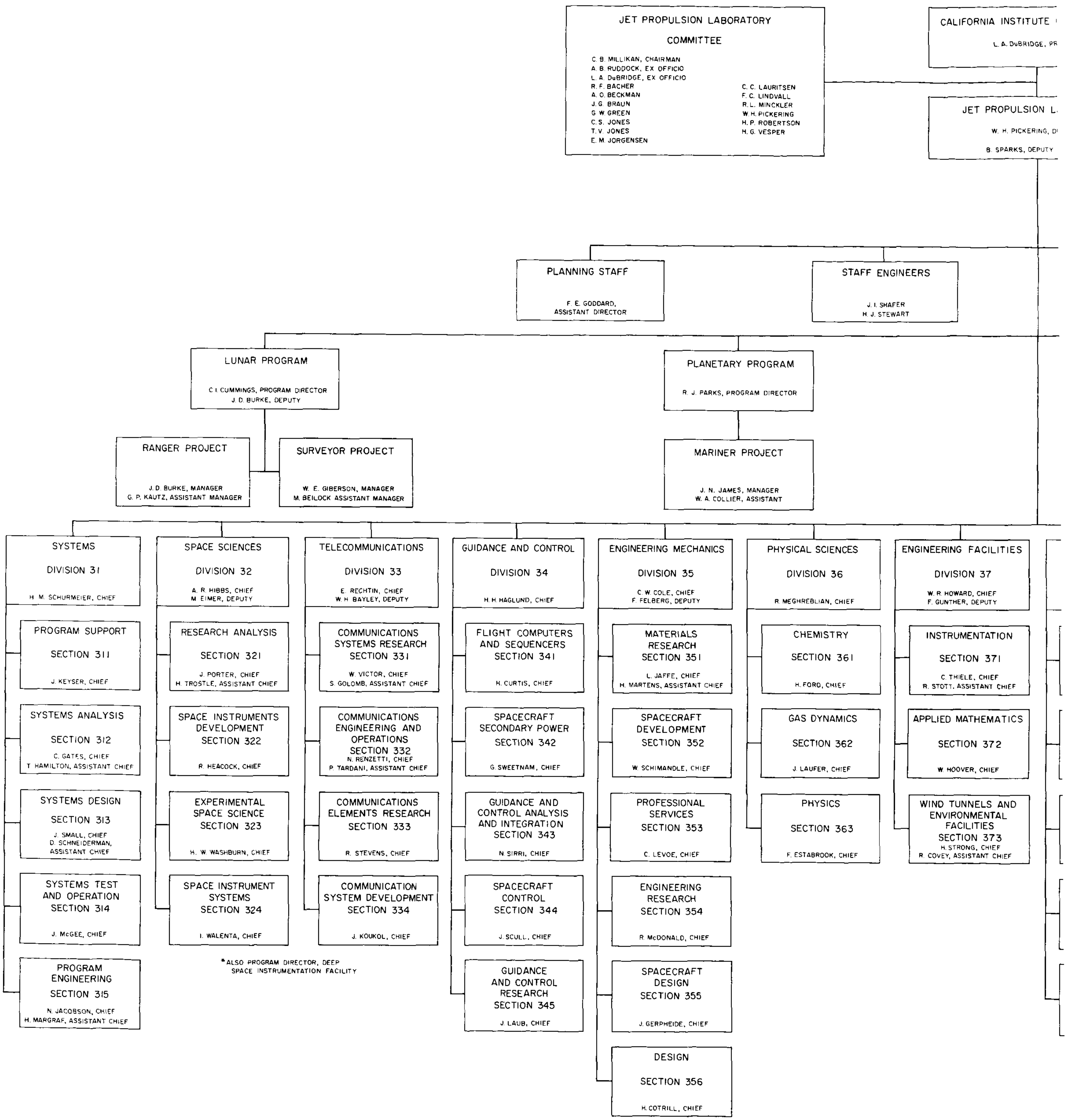
6. *Tracking Operations.* A chronology of DSIF operations during the mission.

7. *Post-Mission Performance Evaluation.* A discussion of accomplishments and remedial action taken on malfunctioning equipment.

8. *Participation of Non-DSIF Agencies.* The role of participants such as the Atlantic Missile Range (AMR) sites and the Space Flight Operations Center.

In addition, station organizational charts and summaries of tracking operations (in the form of edited station logs) are included in the Tracking Operations Section of this Memorandum as supplementary information for *Mariner II.*

At the time of the *Mariner II* mission, the DSIF consisted of four permanent stations, one mobile tracking station, and a spacecraft monitoring station. The four permanent stations were located at three installations approximately 120 deg apart in longitude around the Earth. These permanent stations, which had 85-ft steerable paraboloidal antennas and associated electronics, were located at Goldstone, California; Woomera, Australia; and Johannesburg, Republic of South Africa. The Mobile Spacecraft Monitoring Station (used for prelaunch checkout of the spacecraft system, to obtain spacecraft radio transmitter frequency after liftoff, and to record spacecraft telemetry during the early part of the



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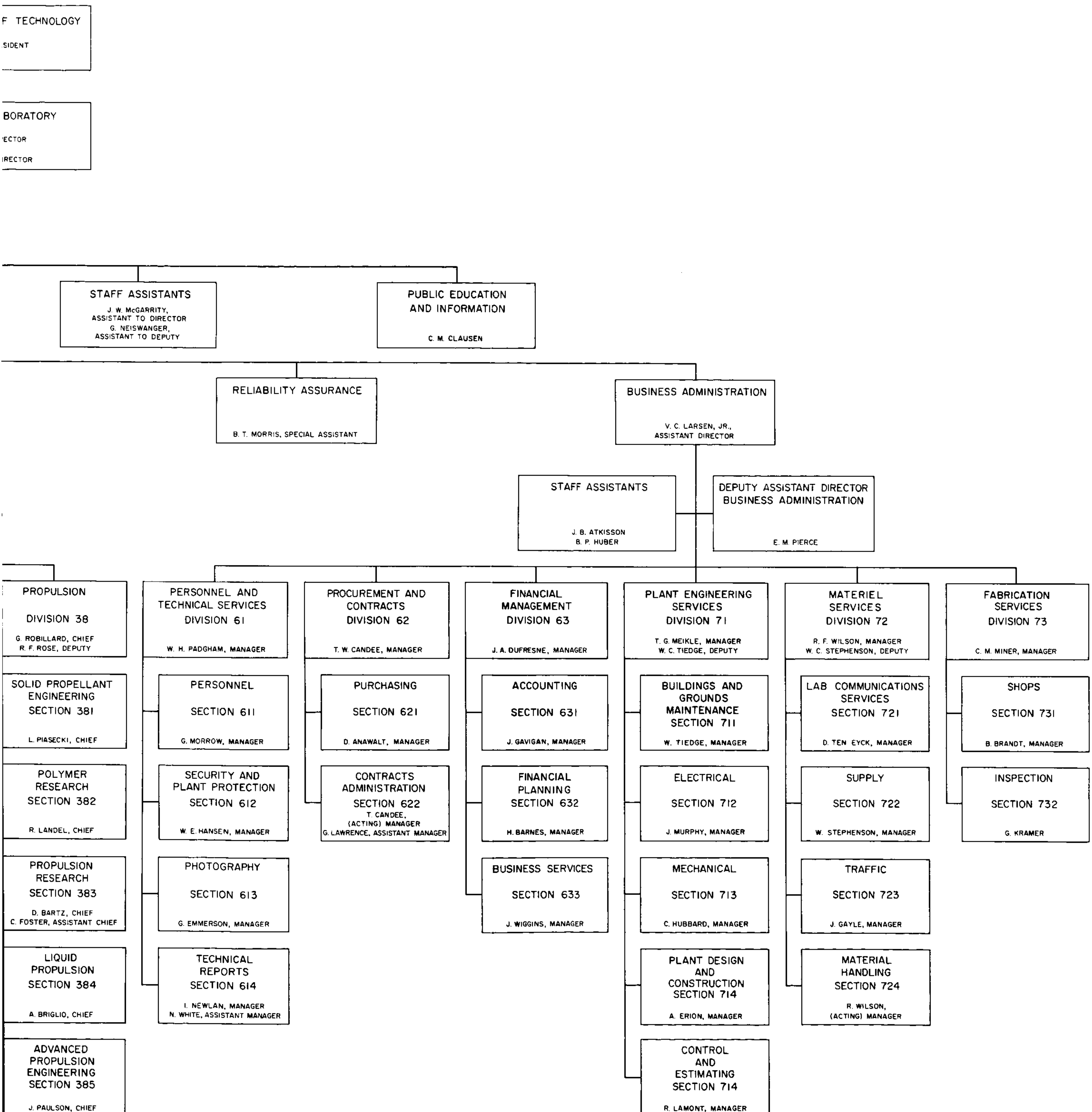


Fig. 2. JPL organization during *Mariner II* mission

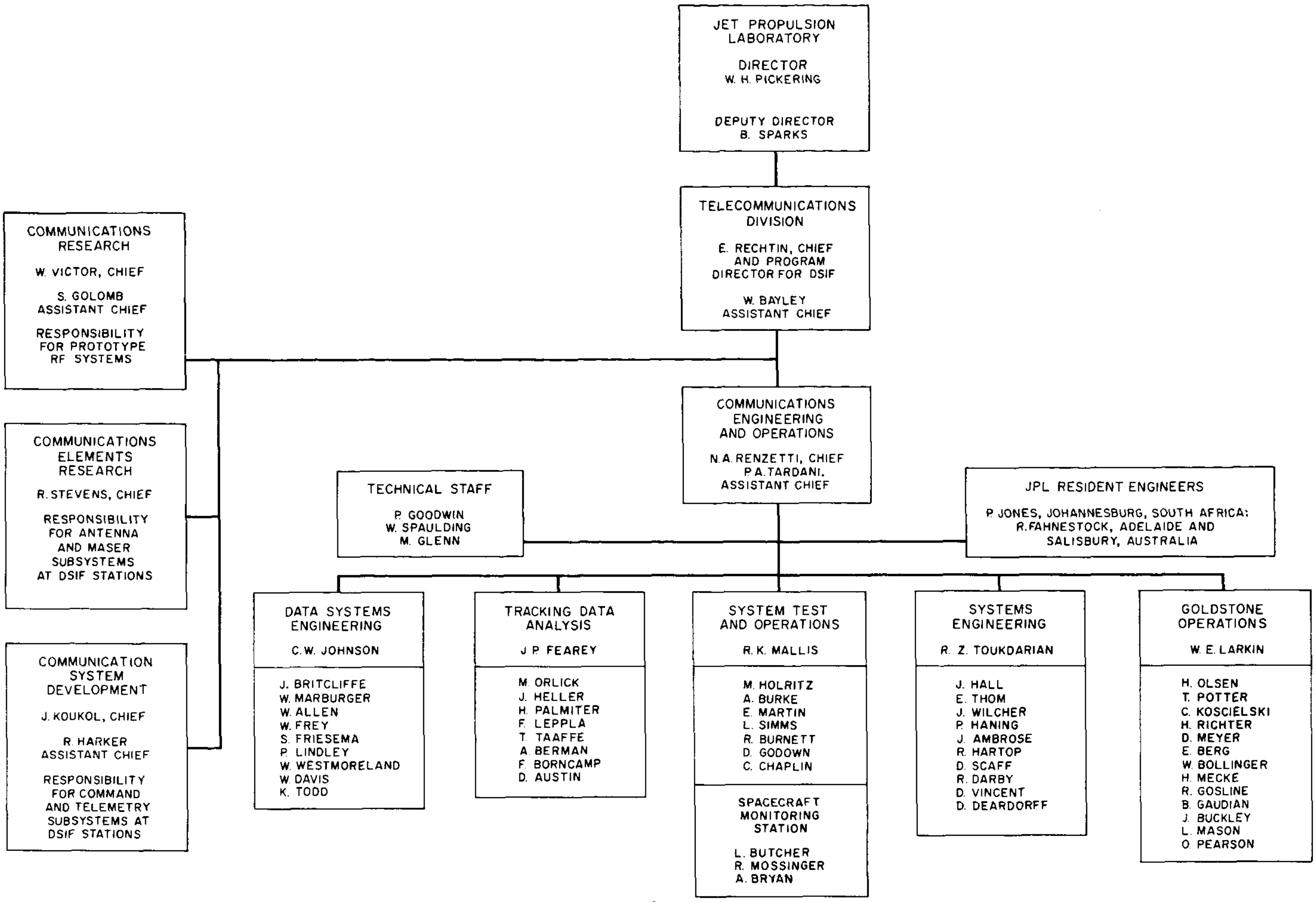


Fig. 3. DSIF organization for *Mariner II* mission

flight) was located at Cape Canaveral. The Mobile Tracking Station, used to provide immediate post-injection tracking and telemetry reception and acquisition information for the permanent stations, was located at Johannesburg, South Africa. Stations and their identifications at the time of *Mariner II* launch, are given in Table 1.

Table 1. Station identifications

DSIF	Station and location
0	Mobile Spacecraft Monitoring Station, Cape Canaveral, Florida
1	Mobile Tracking Station, Johannesburg, South Africa
2	Pioneer Station, Goldstone, California
3	Echo Station, Goldstone, California
4	Woomera Tracking Station, Island Lagoon, Australia
5	Johannesburg Tracking Station, Johannesburg, South Africa

The DSIF Stations obtained angular position, doppler, and telemetry data during the post-injection phases of the trajectory, and transmitted ground-computed commands to the spacecraft. Tracking operations were carried on by the DSIF on a 24-hr/day schedule during virtually the entire mission. Because of overlap in coverage near the horizon, two stations were often in contact with the spacecraft simultaneously, a condition that proved to be quite useful in transferring contact from one station to the next. The Space Flight Operations Center (SFOC), through its Central Computing Facility, provided angle and frequency acquisition information for each of the DSIF Stations in time for their respective tracking periods. The DSIF Stations transmitted telemetry data to the SFOC in near-real-time throughout the mission. The tracking data were transmitted in near-real-time during the launch, midcourse, and encounter periods, and also 1 day/wk when precision tracking data were obtained. During the remainder of the period, tracking data were forwarded in non-real-time. Tracking summaries were supplied to the SFOC on a daily and weekly basis, so that tracking and station conditions could be included in the data analysis.

The DSIF operating schedule for support of *Mariner II* was planned to provide complete 24-hr/day coverage during the critical parts of the mission (launch, midcourse, terminal maneuver, etc.) and 10-hr/day coverage during the cruise mode. However, during the entire mission, each station actually tracked the spacecraft for the full duration of its own view period.

In its initial configuration for the *Mariner II* mission, the DSIF was to provide:

1. *Tracking Data.* Two angles, either hour angle (HA) and declination (Dec) or azimuth (Az) and elevation (El), and one-way or two-way doppler.

2. *Commands.* Transmission to spacecraft of commands required for midcourse, backup commands for certain on-board spacecraft sequenced functions (such as on or off of cruise science), start of encounter sequence, etc.

3. *Telemetry Data.* Scientific and engineering telemetry reception, recording, and transmission of data to JPL in Pasadena.

Tracking data from the *Mariner II* flight demonstrated the inherent accuracy of the DSIF unified L-band system, and the feasibility of precise radio guidance into deep space. Throughout the mission, the DSIF accomplished all tracking and data acquisition objectives and experienced no failures of consequence. By tracking on a 24-hr/day basis, numerous spacecraft problems were detected early enough so that preventive or remedial action could be taken to avoid any unnecessary loss of data. Even more proficiency could have been exercised had the tracking stations been equipped for data monitoring.

The *Mariner II* flight also proved the soundness of an internationally managed network in which each country provided the local station management and staff under the overall technical direction of JPL/NASA. This approach produced excellent station performance, superior station morale, and minimum operating cost. The two overseas agencies cooperating in this project were the Weapons Research Establishment of the Department of Supply of the Commonwealth of Australia and the National Institute of Telecommunications Research of the Council for Scientific and Industrial Research of the Republic of South Africa.

The spectacular success of *Mariner II* was possible only through the spacecraft technology and the crystallizing of deep space communication and tracking techniques developed through previous missions.

II. *MARINER II* MISSION

A. Mission Synopsis

On December 14, 1962, the *Mariner II* spacecraft completed the first successful interplanetary voyage when it passed within 22,000 mi of the planet Venus. At its historic rendezvous, *Mariner II* was 36,000,000 mi from the Earth, having traversed 180,200,000 mi of space in 109 days. During that time the DSIF Stations maintained constant communication with the 447-lb vehicle, transmitting commands and recording a huge volume of information about the spacecraft, interplanetary space, and Venus. *Mariner II* proved that a spacecraft can be tracked with impressive accuracy on a microwave channel using only 3 w of power and can be guided from the Earth across tens of millions of miles.

The choice of Venus as the destination for the first NASA venture in "deep" space was a conservative one, for the other planets are even more difficult to reach. During its nearly circular orbit, Venus comes within 26,300,000 mi of the Earth at closest approach, or inferior

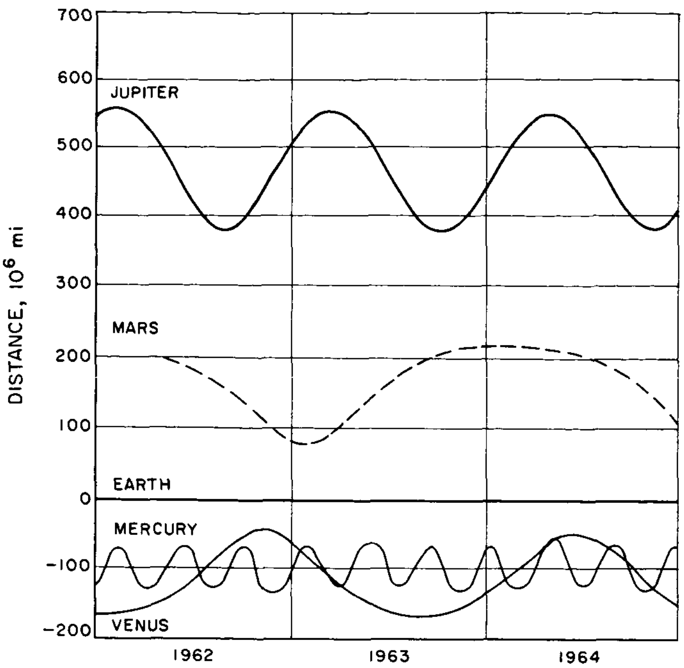


Fig. 4. Planetary distances

conjunction, every 19 months, thus providing a launch opportunity for Earth-based space probes (Fig. 4). In the Summer of 1960, it was not possible to schedule a flight for the next launch opportunity in January and February 1961. The choice of the opportunity after that (in July and August 1962) allowed 2 yr for preparation.

In July 1960, it appeared that the *Atlas–Centaur* would be developed in time to serve as the launch vehicle. This new combination, with a *Centaur* second-stage rocket fueled by hydrogen and oxygen, made it possible to think in terms of a half-ton spacecraft. By the Fall of 1960, design was well underway on an 1100-lb spacecraft. The program called for the fabrication of three identical craft and for the detailed planning and engineering of two launchings in the Summer of 1962. The extreme technological challenges made it unlikely that success could be achieved on both tries. Assuming that the delicate instruments and complex spacecraft mechanisms survived the accelerations, vibrations, and changing atmospheric pressure of the ascent into space, they would have to spend 3 or 4 months, unattended except for a few remote commands by radio, in a hostile environment both of extreme vacuum and cold, and of heat and high-energy radiation from the Sun and cosmic sources. Not all the hazards could be anticipated, and those that were could not all be simulated in the laboratory in time to meet the operational deadlines.

In the Spring of 1961, the parallel development of the *Centaur* began to falter, and in August it became certain that this second-stage rocket would not be ready in time. The 1110-lb spacecraft design had to be shelved; thus, design of a much smaller spacecraft began—one that might be launched by the *Atlas* in combination with an *Agena* second-stage rocket. The designers and fabricators of the *Atlas–Agena* were able to strip 110 lb from the *Agena*, thus providing additional geocentric energy for launching.

In the 3 wk prior to September 1, 1961, using designs from the *Ranger* and 1100-lb *Mariner*, a 447-lb *Mariner* was projected. This left 9 months to design, build, and deliver the spacecraft and its launching vehicle.

With all aspects considered, theoretically there existed a 51-day period from July 22 through September 10 during which a launch could be effected (Fig. 5). This would give barely enough time for two attempts, for a minimum of 24 days was required to ready the pad between launchings, and the possibility of delays could easily account for the remaining 27 days.

Three complete *Mariners* were built: two for launching and one to serve as a spare; all came within 3 lb of the design weight. With its hinged parts folded for stowage in the protective cone, *Mariner* measured 5 ft in diameter at its base and 10 ft in height. Unfolded for space flight,

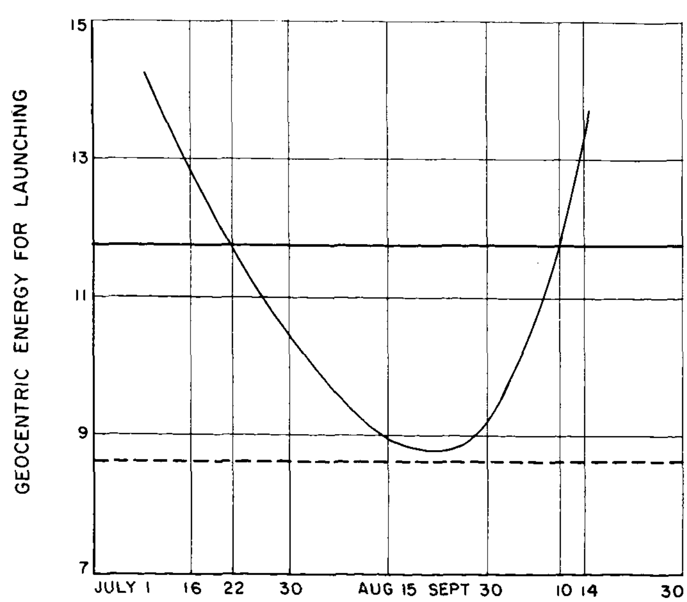


Fig. 5. Venus launch constraints

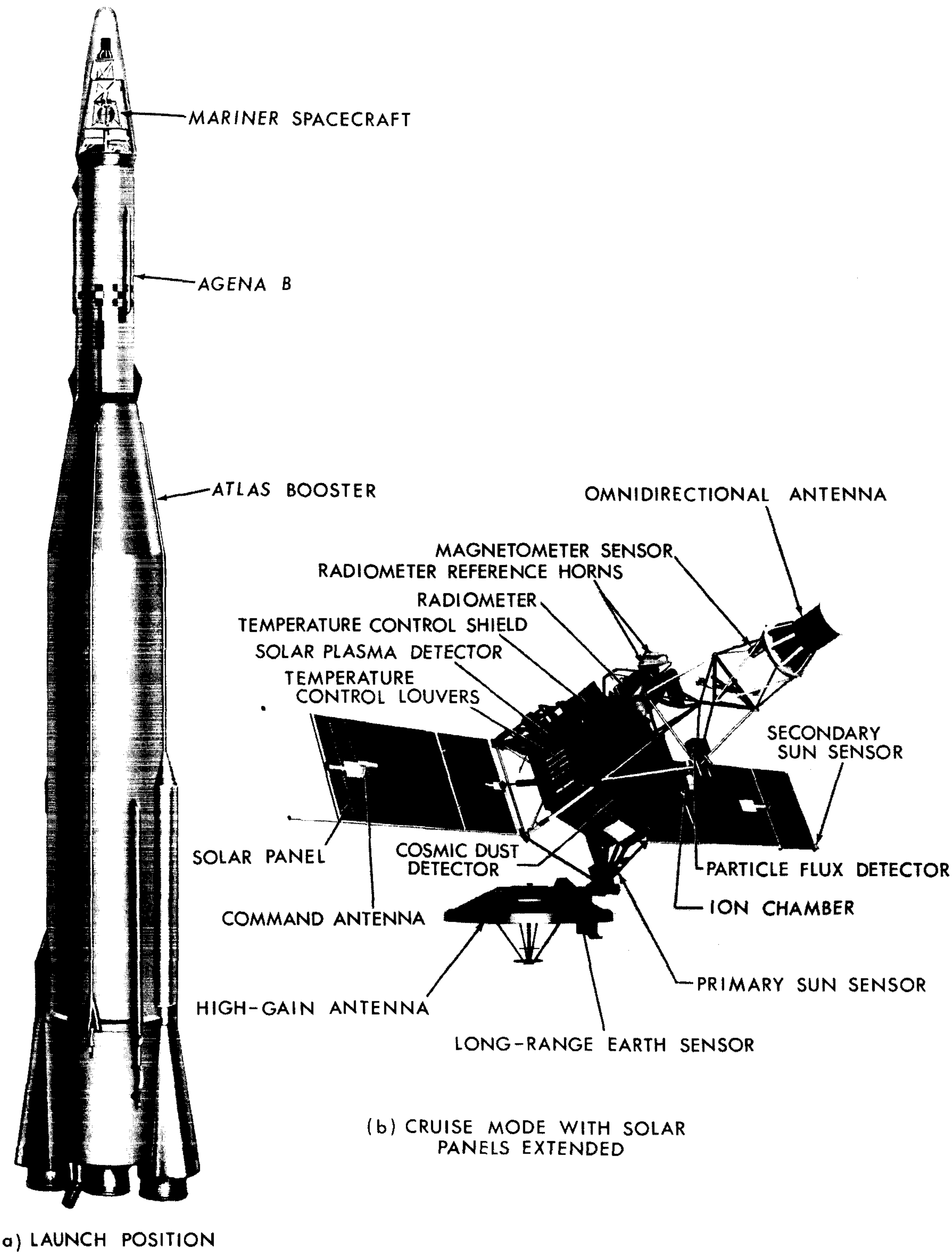


Fig. 6. *Mariner* spacecraft: (a) launch position and (b) cruise mode with solar panels extended

the spacecraft gained 2 ft in height and an ungainly "wing-spread" of 16.5 ft. (The "wings" were the two solar-cell panels bearing a total of 9800 cells; see Fig. 6.)

In the first week of June 1962, three *Mariner* spacecraft, two *Atlas*, and two *Agenas* were shipped to Cape Canaveral. The *Atlas–Agena–Mariner* was set up by mid-July for a launch attempt on July 19, 3 days early, in order to stretch the theoretical launching period. Difficulties discovered during countdowns postponed the launching until 09:21:20 GMT on July 22, 1964. The launching failed, however, due to a defective signal from the *Atlas* and the omission of a single symbol from the program equations of the ground-based computer guiding the flight. *Mariner I* sent signals continuously until it hit the Atlantic Ocean 357 sec after liftoff.

The schedule now called for launching *Mariner II* 24 days later, on August 14. The failure analysis of *Mariner I* and subsequent corrective action on *Mariner II* caused several postponements, and the launching was not effected until August 27. The huge *Atlas* fired at 06:53:17 GMT and soared to an altitude of 100 mi. The nose cone protecting *Mariner* was ejected and the *Atlas* separated from the *Agena*. The *Agena–Mariner* pitched over almost to the horizon when the *Agena* fired for the first time, burning for 147 sec, thus achieving a "parking" orbit at an altitude of 115 mi. There it coasted until 24 min after launch, when it reached the optimum location for takeoff for Venus.

The *Agena* now fired again achieving the velocity necessary to escape the Earth's gravitational field. Explosive charges and springs separated the *Agena* from the *Mariner*; small nozzles expelled residual gases to turn the spent *Agena* aside and slow it down so the rocket carcass would not interfere with the optical sensors, nor impact Venus. Within 1 hr after liftoff, the central computer and sequencer (CC&S) on board caused the solar panels to open; it then instructed the gyros and Sun sensors to activate the nitrogen jets and point the long axis of the spacecraft toward the Sun.

As soon as *Mariner II* began its interplanetary trajectory, a computer at JPL was calculating its exact course. The angle at which the DSIF antennas picked up the spacecraft's signal most strongly located its position with respect to Earth. Measurement of the doppler shift (change in frequency) of the signal from the frequency at which it was transmitted yielded a correspondingly precise plot of the spacecraft's radial velocity (speed away from the Earth). For 10 hr after launch, the computer had calculated that *Mariner II* would miss Venus by 233,000 mi. The necessary correction lay within the capability of the midcourse propulsion system of the spacecraft.

On September 5, 9 days after launching, punched tapes containing the calculated midcourse maneuver commands were fed into an encoder at Goldstone. These commands were then transmitted to *Mariner II* for storage in its computer. At 22:49 GMT with the spacecraft 1,492,500 mi away, the command for execution of the midcourse maneuver was given. This maneuver, which is very delicate, required 3.75 hr for execution (Fig. 7).

Within the next few days, tracking data established that the maneuver was a success even though *Mariner II* was traveling 2 mi/hr faster than had been planned. Instead of passing Venus at the hoped-for distance of 10,000 mi, it would pass the planet at a distance of 21,648 mi. This was still well within the 40,000-mi probe capabilities of the on-board planetary experiments.

On the 12th day of the flight, *Mariner II* lost lock on the Earth and the Sun; it recovered, however, within 3 min. As the spacecraft fell toward the Sun, it was picking up orbital speed, and on the 64th day after launch it overtook and passed the Earth. The next day a short circuit occurred in one of the solar-cell panels. The short circuit corrected itself and then recurred a few days later. Fortunately, the spacecraft was now close enough to the Sun for the other panel alone to supply more than enough power.

On the 91st day, with *Mariner II* 22,500,000 mi from Earth, the DSIF set a new distance record for communications. This record was to be exceeded continuously for the rest of the trip.

By the 100th day of the flight, with Venus 9 days away, the temperature of some of the subsystems of *Mariner II* had risen alarmingly, averaging 40°F more than expected. Most of the subsystems could still function, but were approaching their temperature design limits. Even though the battery had reached its upper limit, and the Earth sensor had passed its limit, both were still functioning.

On the 107th day, a portion of the spacecraft's CC&S failed. The CC&S now could not be relied upon to initiate the operations programmed for Venus encounter 2 days later. The possibility of a computer failure had

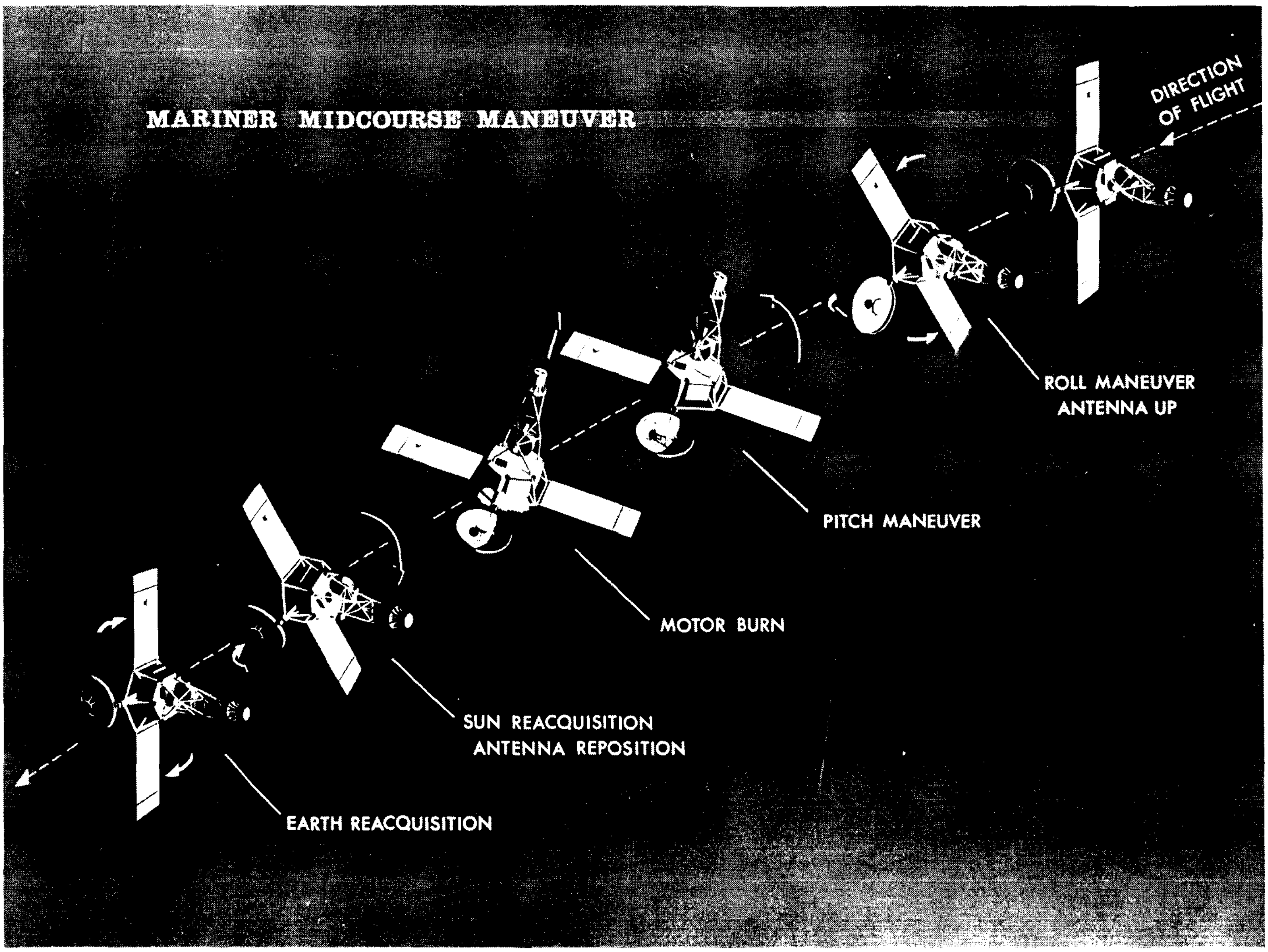


Fig. 7. Midcourse maneuver sequence

been foreseen, and the "system" had been designed to accept a "backup" command from Earth that would set the scanning program in motion.

Early on December 14, at approximately 6 hr before encounter, it became apparent that the CC&S aboard *Mariner II* had failed to start the operations scheduled for the encounter. With the spacecraft 36,000,000 mi away, Goldstone transmitted the "backup" command to start these operations. It took 6.5 min for the signal, traveling at the speed of light, to reach the spacecraft and make the return trip to Earth, verifying that the attachments had gone into operation for the microwave and infrared scans of Venus.

As the spacecraft reached the scan zone, it proceeded to scan the disk of the planet, which was 16 deg in diameter at this close range. Altogether it made three passes across the disk "up and down," while the orbit of the spacecraft provided the lateral motion. The radiometer sent 18 readings: 5 from the night side of Venus, 8 from the terminator (the shadow line between the dark and light sides), and 5 from the day side (Fig. 8). The experiments and their findings are discussed in detail in "Scientific Experiments," which follows this Mission Synopsis.

After making its nearest approach to Venus on December 14, 1962, *Mariner II* continued in its now eternal orbit around the Sun. The "year" of this new solar satellite has a duration of 345.9 terrestrial days. It made its closest approach to the Sun at 65,500,000 mi on December 27, and on the 129th day, January 2, 1963, ceased to transmit information to the Earth. At that time it was 54,000,000 mi from the Earth, 5,700,000 mi from

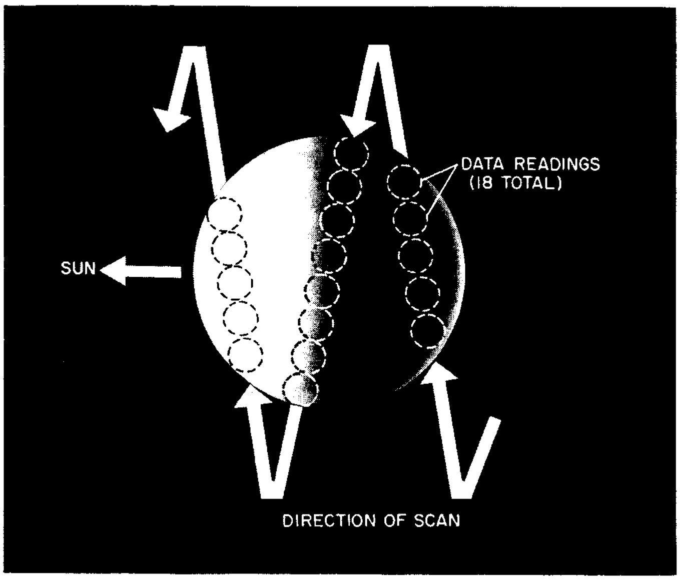


Fig. 8. *Mariner II* radiometer scans of Venus

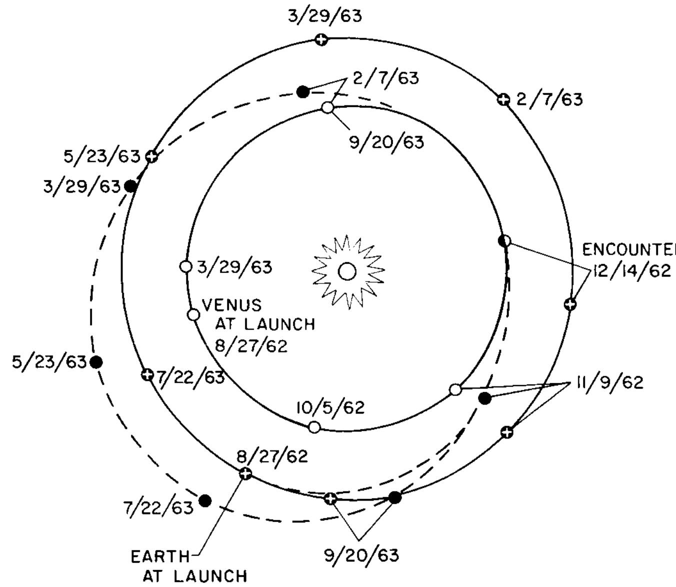


Fig. 9. Solar orbit of *Mariner II*

Venus, and had traveled 223,700,000 mi through the solar system in 129 days (Fig. 9). Scientists and engineers will spend years studying the 11,000,000 measurements *Mariner II* sent back, all now recorded on magnetic tapes and stored in vaults.

B. Scientific Experiments

Scientific instruments were able to produce unprecedented quantities of data about interplanetary space and Venus. They produced data about the magnetic fields of the solar system, cosmic rays, and the solar wind (the streams of protons and electrons that issue from the Sun). At the rendezvous with Venus, the instruments observed the planet with a resolution impossible from the Earth. The experiments performed, and the experimenters, are listed in Table 2.

Venus, it can now be said, is covered by cold, dense clouds, but has a surface temperature of approximately 800°F on both its dark and its sunlit side. The planet

Table 2. *Mariner II* experiments

Experiment	Purpose	Experimenters
Microwave radiometer	Determine the temperature of the planet surface and details concerning its atmosphere	Dr. A. H. Barrett, Massachusetts Institute of Technology; D. E. Jones, JPL; Dr. J. Copeland, Army Ordnance Missile Command and Ewen-Knight Corp.; and Dr. A. E. Lilley, Harvard College Observatory
Infrared radiometer	Determine the structure of the cloud layer and temperature distributions at cloud altitudes	Dr. L. D. Kaplan, JPL and University of Nevada; Dr. G. Neugebauer, JPL; and Dr. C. Sagan, University of California, Berkeley, and Harvard College Observatory
Magnetometer	Measure planetary and interplanetary magnetic fields	P. J. Coleman, NASA; Dr. L. Davis, Caltech; Dr. E. J. Smith, JPL; and Dr. C. P. Sonett, NASA
Ion chamber and matched Geiger—Mueller tubes	Measure high-energy cosmic radiation	Dr. H. R. Anderson, JPL; and Dr. H. V. Neher, Caltech
Anton special-purpose tube	Measure lower radiation (especially near Venus)	Dr. J. Van Allen and L. Frank, State University of Iowa
Cosmic dust detector	Measure the flux of cosmic dust	W. M. Alexander, Goddard Space Flight Center, NASA
Solar plasma spectrometer	Measure the intensity of low-energy, positively charged particles from the Sun	M. Neugebauer and Dr. C. W. Snyder, JPL

seems to have little or no magnetic field, and hence no belts of trapped radiation analagous to the Van Allen belts of the Earth, and to be rotating very slowly or not at all. From the tracking of the spacecraft, it was possible to calculate the Astronomical Unit (AU) (mean distance from the Earth to the Sun) with greater accuracy than ever before, to figure the mass of Venus and the Moon with far more precision than that previously attained, and even to locate certain points on the Earth more accurately.

1. Microwave Radiometer

The microwave radiometer scanned the surface of Venus at two wavelengths, detecting emissions from Venus at 13.5 and 19 mm. In the electromagnetic spectrum, 13.5 mm is the location of a microwave water absorption band. The 13.5-mm readings would establish the presence of water in the atmosphere of Venus above certain minimal levels. The 19-mm wavelength, however, is not affected by water vapor and is capable of penetrating the cloud cover and deeper atmosphere down to the surface or very close to the surface. Thus, the larger the temperature differences between the two radiometer measurements, the more water vapor present in the atmosphere. In addition, the 19-mm wavelength was able to test two of the theories ("limb brightening" and "limb darkening") concerning the atmosphere of Venus.

The "limb brightening" theory postulated that Venus has an ionosphere with an electron density thousands of times that of Earth. If this were true, it could easily have misled scientists attempting to compute Venusian temperatures from Earth-based radio measurements.

As the radiometer scanned the planet, it looked through the least amount of atmosphere when it was pointed straight down in relation to the planet, and the most amount when it pointed at the limb, or edge, of the planet. If a high electron-density ionosphere, such as a radio "mist," had existed around Venus, the radiometer would have detected the condition called limb brightening as it looked through the thicker concentration of electrons in the atmosphere at the edge of the planet.

The other theory, the one which had been assumed by most scientists before the *Mariner* measurements, is that Earth-based radio measurements are indeed explained by a hot surface on the planet, and that the heat of solar radiation is trapped under the planet's thick clouds. According to this theory, the atmosphere above the surface gets colder and colder with height, and there is not a high-electron density ionosphere around Venus. Looking straight down at the planet from space then, one would see the hot surface, but looking toward the edge one would be looking through a thicker concentration of the cooler clouds, and consequently the edge (or limb) would appear darker. It was this condition, limb darkening, which was detected for the first time as *Mariner II* flew by Venus.

Analysis of the radiometer scans shows that the surface of Venus, where the 19-mm radiation originates, appears to have a temperature of about 800°F (Fig. 10). Apparently, there is also very little water vapor in the atmosphere, less than a thousandth of that of the Earth's atmosphere.

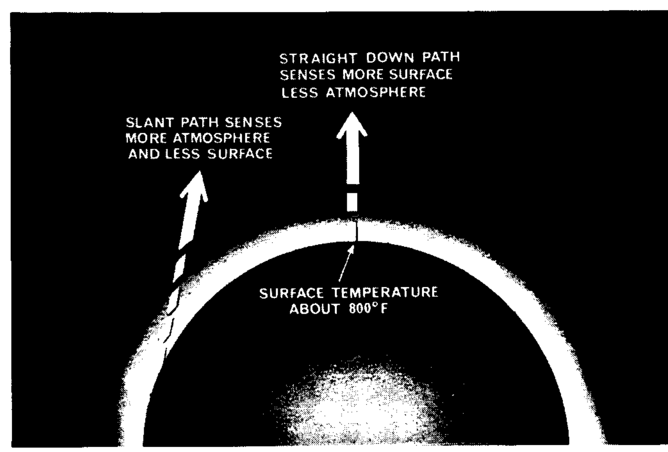


Fig. 10. Microwave temperature study of Venusian atmosphere and surface

2. Infrared Radiometer

The infrared (IR) radiometer was a companion experiment to the microwave radiometer, and the data obtained correlated with the microwave radiometer data. The IR radiometer was rigidly attached to the microwave antenna so that both systems scanned the same areas of Venus.

The IR radiometer was designed to detect emissions from Venus at 8.4- and 10.4-μ wavelengths of the spectrum. Measurements from Earth taken at these two wavelengths indicated temperatures below zero, but it was not clear from the data whether all of this radiation came from the cloud tops, or whether some of it emanated from the atmosphere, or from the surface through cloud breaks. If there were appreciable breaks in the clouds, a substantial difference would be detected between measurements at the two wavelengths because, in the 8-μ region, the atmosphere is transparent except for clouds; in the 10-μ region, the lower atmosphere is hidden by the presence of carbon dioxide. Through a cloud break, the 8-μ emission would penetrate to a much lower point in the atmosphere.

Analysis of the data from both wavelengths of the IR radiometer gives approximately the same temperature at all points. This indicates that both channels saw down to the same depth in the Venusian clouds, and that both channels were looking at a thick, dense cloud layer opaque to infrared radiation. If there had been breaks in this cloud mass, the 8-μ channel would have seen down to a deeper, hotter region, but the view of the 10-μ detector would have been stopped at a higher altitude by the carbon dioxide in the Venusian atmosphere. From Earth-based measurements, it is known that carbon dioxide is an important constituent of the Venusian atmosphere. The amount of carbon dioxide above this cloud layer, which was opaque to the infrared channels, was too small to be detected by the *Mariner* instruments.

The IR instruments observed limb darkening, as did the microwave radiometer. This observation indicates that the cloud layer is thick and somewhat translucent to infrared, as a thin fog is translucent to light. In that part of the scan in which the IR radiometer looked down at the center of the planet, it could see a deeper, hotter, and brighter part of the cloud layer; but at the limb of the planet, the sensors were looking edgewise through the cloud and could not see so deep. Only the upper, cooler and darker, portion of the cloud layer was visible (Fig. 11).

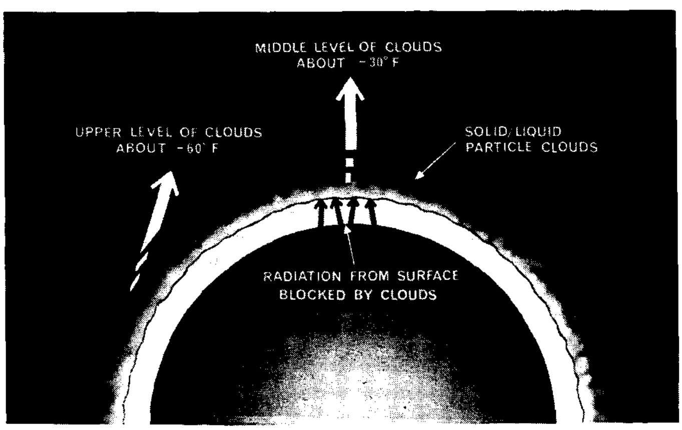


Fig. 11. Infrared temperature study of Venusian clouds

The IR measurements produced a curious result. Toward the south end of the terminator, the temperatures on both channels showed a cold spot on Venus, about 20°F cooler than the rest of the cloud layer. This means that clouds in this region are higher, or more opaque, or both. An interesting possibility is that this cooler section of the cloud layer is associated with some hidden surface feature, such as a high mountain. This cold spot was the only anomaly observed.

Temperatures in the cloud layer were the same on the dark side as on the light side. At the center of the planet, the temperature was measured at approximately −30°F.

3. Fields and Particles

The eight fields and particles sensors, which were carried on *Mariner II*, have produced an unprecedented quantity of high-quality data on the nature of the interplanetary medium. The *Mariner* data, for example, indicating that solar gas continuously flows out from the Sun at great speeds, appear to settle a 30-yr old scientific controversy. During the 129 days between launching and the final loss of radio contact with the spacecraft, fields and particles data were actually recorded by the tracking stations for approximately 104.1 days.

Data were recorded without interruption for one period of 38.3 days and for three other periods of greater than 9 days. Nothing approaching this continuous long-term coverage of a distant space probe has ever been achieved before, and such coverage is of great value in discovering the temporal and spatial variations in interplanetary phenomena.

The eight fields and particles sensors included: three to measure magnetic field components, three to count cosmic-ray particles, one to measure the ionization produced by cosmic rays, and one to measure the energy and quantity of solar plasma (positive-charged atomic particles with very low velocities).

The cosmic radiation of both solar and galactic origin was monitored by three omnidirectional detectors and one unidirectional detector. The omnidirectional detectors were an ionization chamber and two Geiger counters. The unidirectional detector was a small Geiger counter of a type which has been used extensively in the exploration of the Van Allen belts of trapped radiation around the Earth. Two of the Geiger counters sampled the particle flux every 7.4 min, thus making more than 10,000 measurements during the mission; the third one operated at twice this sampling rate. The ionization chamber was in continuous operation and gave an integrated reading approximately every 6.3 min.

The solar plasma experiment made successive measurements of the plasma flux at ten different energy intervals. It required 3.7 min to acquire a complete energy spectrum of the plasma; approximately 40,000 such spectra were obtained.

During the encounter with Venus, the fields and particles experiments collectively were designed to investigate the extent and nature of the magnetosphere of the planet on its sunward side. The magnetosphere of the Earth is the region within which the geomagnetic field is confined, and where magnetically trapped radiation is found. It has been investigated by various instrumented satellites and space probes to the extent that its general features are known, making it possible to predict what *Mariner* might see if it penetrated the magnetosphere of Venus. Near the boundary of the magnetosphere, the magnetic field should change rather drastically in direction and magnitude from its interplanetary values, and rather large fluctuations in the fields would be expected for considerable distances outside the boundary. The cosmic-ray instruments would detect trapped radiation inside, but should see only the interplanetary cosmic-ray background outside. Also, the solar plasma should disappear as the spacecraft passed inward through the boundary.

The Earth's magnetosphere on the sunward side usually extends about 40,000 mi out and would be clearly detectable by the *Mariner* instruments. If the Venusian magnetic field were similar to that of Earth, at an altitude of 21,600 mi (the closest approach of *Mariner* to Venus), the magnetic field would be 100 to 200 gammas, the counting rates of the cosmic-ray instruments would be large (up to about 3,000/sec for the unidirectional counter near the equator), and no solar plasma would be seen.

In sharp contrast, however, all the fields and particles instruments continued to produce their interplanetary readings as *Mariner* coasted by Venus. The magnetometer saw no unusual changes in the field which exceeded its 5-gamma limit of sensitivity. The unidirectional Geiger counter continued to register 2 counts/second, and the other radiation detectors also saw no change. The solar plasma velocity increased very slightly as the planet was passed, but showed no unusual behavior.

These results confirm qualitatively some of the theoretical ideas which are generally accepted regarding the source of planetary magnetic fields and the nature of field–plasma interactions. The strength of a planetary field is believed to be closely related to the rate of rotation. Other experiments have shown that Venus appears to rotate very slowly, and thus would be expected to have a small field. The size of a planet's magnetosphere is determined by the equilibrium between the pressure of the solar plasma pushing inward and the expansive pressure of the magnetic field of the planet. At Venus, the plasma pressure must be somewhat greater than at the Earth because of the closer proximity to the Sun. This fact, coupled with a smaller magnetic field, would indicate that the magnetosphere of Venus might be considerably smaller than the Earth.

Perhaps the most interesting new information is the demonstration that solar plasma flowing radially out from the Sun was detectable in every one of the 40,000 spectra obtained in the 4-month mission, and hence, presumably, is always present. The existence of this plasma flow, sometimes called the "solar wind," had been suspected for some time, having been postulated to explain the motion of certain comet tails and the occurrence of geomagnetic storms. It had been measured for short periods by the American space probe, *Explorer X*, and by several Russian probes. The *Mariner II* measurements are more detailed and vastly more extensive than previous measurements.

The solar wind had been explained theoretically as a continuous expansion of the solar corona—the tenuous, extremely hot, outer atmosphere of the Sun. The *Mariner* results show that the velocity of this expansion (if such is the mechanism) undergoes frequent fluctuations, which probably reflect the inhomogeneity of the solar surface. Approximately 20 occasions were seen when the velocity increased within a day or two by amounts from 20 to 100%. The fluctuations correlate well with the amount of magnetic disturbance observed on the Earth; in several cases, sudden and sharp increases in the density, velocity, and temperature of the plasma preceded the onset of sudden magnetic storms. The time delay corresponds to the fact that *Mariner* was, at all times, inside the Earth orbit, so that the outward-moving plasma cloud would generally reach the spacecraft first.

The velocity of the observed solar wind varies from approximately 200 to 500 mi/sec, and its temperature is in the neighborhood of 1,000,000°F. Thus, it resembles the blast out of a rocket nozzle more than it resembles a wind. It is similar to a rocket blast also in that its velocity is greater than that of typical wave motion in a plasma (called an Alfvén wave), so that its flow is, in this sense, "supersonic." On the other hand, its tenuosity is almost beyond comprehension, there being normally only about 10 to 20 protons (hydrogen nuclei) and electrons per cubic inch.

The presence of the solar wind drastically alters the configuration of the exterior magnetic field of the Sun. The solar plasma carries along with it lines of magnetic force which originate in the corona. The frequent variations in plasma velocity result in the deformation of these field lines, so that it is difficult to deduce what the general undisturbed configuration of the solar field would be from the point-by-point measurement of the magnetic field. *Mariner II* showed that the field transverse to the radial direction from the Sun is typically from 2 to 5 gammas at quiet times, and shows some tendency to have its direction approximately parallel to the plane of the Earth's orbit. An appreciable component perpendicular to the orbit exists much of the time, and fluctuations of 10 to 20 gammas or even more are not uncommon. Such large fluctuations usually correlate with changes in the plasma flow. (For comparison, the Earth's magnetic field is approximately 30,000 gammas at the equator and 50,000 gammas at the poles.)

The omnidirectional cosmic-ray detectors measured a fairly constant flux throughout most of the flight, indicating that they were detecting galactic cosmic rays. The fact that the flux encountered by the spacecraft did not change, even with a 30% decrease in the distance between *Mariner* and the Sun, is of considerable theoretical interest in connection with the understanding of the spatial and temporal variations of the cosmic rays.

The walls of the omnidirectional detectors were equivalent to 0.01 in. of steel, so that they responded to protons with energies above 10,000,000 electron volts (mev) and electrons above about 0.5 mev. Results from *Mariner*, compared with those obtained from balloon-borne instruments, are of interest. Measurements made in the *Mariner* ionization chamber alone tell nothing about the distribution of energies of particles that do penetrate the wall. The following may be deduced by comparing *Mariner* with Thule, Greenland, and balloon flights. Balloon measurements showed a scarcity of primary protons below about 800 mev of energy at this phase of the solar cycle. The fact that cosmic rays in space are even less than that deduced from measurements at the poles confirms this scarcity of particles at distances far from the Earth. In fact, one may draw the conclusion that, at the time *Mariner* was collecting data, there were very few, if any, particles, except for one burst of particles ejected from the Sun, in the energy range 10 to about 800 mev for protons. Solar cosmic rays were detected clearly on only one occasion, October 23 and 24, when the number of particles detected in each sampling interval increased for a time by more than a factor of 5. A comparison of the response of the three detectors indicates that the particles in the stream were primarily protons with energies near 25 mev. Thus, a very modest increase in the wall thickness of detectors would have excluded the particles almost entirely.

This event was a comparatively minor one as solar-proton events go. The total radiation dose inside the ionization chamber amounted to only about 0.25 roentgen. During the entire mission, the dose was only about 3 roentgens, predominantly from very penetrating particles. Since an astronaut could almost certainly accept doses of 30 to 50 or perhaps even 100 times this amount over a 4-month period without serious effects, it appears that space posed no radiation hazard to any space travelers that may have been aboard.

In contrast to the omnidirectional detectors, the Iowa unidirectional counter saw not only the October 23 event, but at least seven other smaller bursts of radiation during September and October. The nature of the radiation has not been positively identified from the information at hand but, since it was not seen by the thicker-walled omnidirectional detectors, it may consist of protons between 0.5 and 10 mev or electrons between 0.04 and 0.05 mev.

In summary, here is a picture of ionized particles in interplanetary space. From a few hundred to 1000 ev, particles are numerous. Something like 100,000,000/sec strike a square centimeter. In the range, 0.5 to 10 mev for protons, very few exist at times, but at other times their flux may be a number of times that of cosmic rays. In the range of energies, 10 to 800 mev for protons, there is normally an almost complete absence of particles. During a solar burst, the number of particles in this energy range may be very large. Above 800 mev, galactic cosmic rays enter interplanetary space; these decrease in number quite rapidly as the energy increases. The total number of such particles is about 3 cm/sec, an energy range not investigated at all but which may be important.

During a 30-day period during November and early December, the unidirectional counter detected only two very small increases in the radiation intensity. It is interesting that during this period the mean velocity of the solar wind was considerably lower than it had been during September and October, when the counter was detecting frequent bursts of radiation. This fact suggests that the sources of high-velocity plasma clouds and the low-energy solar cosmic rays may be identical or related in some way.

4. Cosmic Dust

The cosmic dust experiment on *Mariner II* was designed to measure the flux of interplanetary dust particles between the Earth and Venus. The system was capable of detecting dust particles with masses as low as 1.3×10^{-10} g (about one trillionth of a pound). Over 1700 hr of reduced data have been received. During this time, two dust-particle impacts on the sensor plate were recorded. The dust-particle flux indicated by this measurement is approximately 4 orders of magnitude less than that observed near the Earth from similar experiments on satellites. Both of these events occurred in deep space, and no impacts were recorded in the vicinity of Venus.

5. Radio Tracking

Precise two-way doppler tracking of *Mariner II* during its 130-day flight to Venus and beyond has provided scientists with basic information that has further refined physical constants that are important in understanding the solar system and the Earth. Using the data obtained, the scientists were able to apply themselves to obtaining, with more certainty than previously available, such information as:

1. The mass of Venus.
2. The precise location of tracking stations on the Earth.
3. The value of the Astronomical Unit (the mean distance from the Earth to the Sun).
4. The mass of the Earth's Moon.

The high accuracy and great volume of *Mariner* tracking data have served as a stimulus to workers in celestial mechanics to combine radio tracking data, radar astronomy data, and optical data. The long-term results of such a combination will resolve existing incompatibilities in experimental results and dramatically advance our ability to describe the mechanics of the solar system. This clearly is needed for accurate navigation and guidance for more advanced missions.

Before the *Mariner* mission, it was suspected that uncertainties in some of the solar system physical constants—such as the AU—would make it difficult, if not impossible, to use ground-based radio guidance techniques to command a spacecraft to hit a planet. It was suspected that it would be necessary to use some sort of "homing" device on the spacecraft so that it could "sense" the planet and home in on it. Now it appears that simpler Earth-based radio guidance techniques will remain competitive to on-board guidance measurements and computation techniques until extremely precise target-error control is desired. For example, on December 7, 1 wk before the *Mariner* encounter with Venus, the position of the spacecraft with respect to Venus was uncertain to only 800 mi—primarily due to the positional uncertainty of Venus with respect to the Earth. Now, as the precise tracking data have been analyzed, it is possible to reconstruct the position of the spacecraft with respect to Venus to within 10 mi at encounter. Closest approach of *Mariner* with respect to Venus was 21,648 mi.

More than 22,000 two-way doppler data points were taken during the 130-day *Mariner* mission, and it is the volume and precision of these data points that have proved so useful in refining the trajectory. Two-way doppler is a precise method of measuring radial velocity of a spacecraft by using the well-known doppler shift in frequency in a radio signal between two moving objects. This effect is what causes the sound of a train whistle to rise in pitch as the train approaches and drop in pitch as it passes. Two-way doppler is an extremely precise method of determining shift in the radio signal frequency.

In the *Mariner* mission, the Goldstone Tracking Station of the Deep Space Instrumentation Facility transmitted a signal to *Mariner*. The signal, received at the spacecraft, was shifted in frequency by the doppler effect, and then was retransmitted by the spacecraft to Goldstone. The signal received at Goldstone was further shifted by the velocity of the spacecraft in relation to the station. Velocity changes, so precise as to be on the order of 0.1 in./sec, were measured by this two-way doppler tracking. Using these data, it was possible to calculate exactly how the *Mariner* trajectory was perturbed by the Venusian gravity as *Mariner* flew by Venus.

The size of this perturbation and the accuracy of its determination, then, were extremely useful in determining the mass of Venus. Classical astronomers, using data on the perturbation of the orbits of other celestial bodies caused by Venus and collected over several decades, have calculated the mass of Venus to be 0.8148 that of the Earth. The probable error is 0.5%. The *Mariner* data—collected over 2 wk, 1 wk before and 1 wk after encounter—have determined the Venus mass with a probable error of 0.005%.

Another significant result obtained was the absolute location of the Goldstone Station. Before the *Mariner* mission, the exact location of the Goldstone Station had been known to within 100 yd. After *Mariner's* data were analyzed, it was known to within 20 yd.

The way the station location is determined from the doppler data may be understood by supposing the spacecraft to be fixed in space with respect to the center of the Earth. The only doppler tone observed would be caused by the station's rotational velocity component along the direction to the spacecraft. The observed doppler tone at the station depends, then, on the latitude, longitude, and radius from the center of the Earth. Since many measurements were obtained during many passes at the DSIF Stations, it was possible to deduce the proper combination of station location errors to match the data.

The mass of the Moon was determined by similar reasoning from the data. In this case, the variation in doppler tone is due to the movement of the Earth around the Earth–Moon system's center of mass, or barycenter. The Earth makes one revolution around this barycenter every 28 days at a speed of 27 mph.

Of the three items that influence this motion (the Earth's mass, the Moon's mass, and the Earth–Moon distance) the Moon's mass is the least well known. The Moon's mass, prior to *Mariner II*, was known to a certainty of 0.1%. The scientists, by analyzing the data, were able to reduce this to an even smaller figure.

The Astronomical Unit (AU) is used as the yardstick of the solar system. Data from classical astronomical observations have derived a value of the AU which is 50,000 mi different from the value derived by Venus radar bounces in 1961. The radar-established AU is 92,956,200 ± 310 mi. The optical AU is 50,000 mi smaller.

A similar Venus radar bounce, conducted by the Venus Station at Goldstone during the *Mariner* mission, produced the same result as the 1961 bounce, also conducted at Goldstone. The *Mariner* tracking data now provide an additional radio determination which has helped resolve the conflict between the radar-established AU and that calculated by optical measurements.

6. Deep Space Telecommunications

Two major telecommunication activities were in process during the Venus encounter of 1962. The first, and by far the largest, activity involved the two-way communications and tracking of the *Mariner* spacecraft from the DSIF Stations on the Earth. The second activity involved an Earth-based radar which reflected signals off the planet Venus during the same month that the *Mariner* spacecraft was traveling toward the planet.

Communications between *Mariner* and the DSIF have resolved several questions of considerable importance for future deep space exploration. It was demonstrated that reliable deep space communication to and from the spacecraft was possible within the solar system, certainly to distances of 53,000,000 mi, without significant disturbing effects from space itself. We also know that extremely precise tracking is practical in deep space, particularly of the radial velocity of the spacecraft from the Earth. It was demonstrated that on the order of 0.1 in./sec in radial velocity can be measured to distances of at least 53,000,000 mi.

By the technique of using directional antennas on fully stabilized spacecraft and extremely sensitive equipment on the Earth, it has been proved possible to acquire great quantities of data during the long deep space flights. The *Mariner II* flight resulted in the accumulation of some 65,000,000 bits of information with an accuracy of at least 1% and yet with the use of only 3 w of radio frequency power. A new technique for precision synchronization of telemetry and communication channels using pseudorandom codes successfully demonstrated that precise synchronization is possible using only very low powers.

The *Mariner* flight also demonstrated the utility of the basic design of the DSIF as a world-wide network of cooperating stations which can keep continuous, 24-hr/day contact with the spacecraft, transmit the data to California, and have it available to experimenters in a relatively short time. Some 85% of the data transmitted from the spacecraft was available to the experimenters within 1 hr of reception at the Earth, and approximately 98% of the data was accurately recorded for future use.

III. PRE-MISSION

A. Planning

The tracking and data acquisition for *Mariner II* was by far the most challenging of all DSIF assignments. Not only did this mission require signal transmission at unprecedented distances, but the quantity of data for the extended flight was tremendous. The mission required ground support equipment capable of providing near-optimum communication and tracking capabilities. The received radio-signal frequency and spacecraft angle-tracking data are required for the measurement of spacecraft velocity and position, and radio communication is required for the transmission of telemetering data and commands. The accuracy and precision of the tracking and communications equipment determine, to a large extent, the validity of the experimental data obtained.

1. DSIF Requirements

The function of the DSIF was to obtain angular position, doppler, and telemetry data from the *Mariner II* spacecraft during the post-injection phase of the trajectory. Additionally, the DSIF was obligated to send ground-computed commands to the spacecraft for midcourse trajectory corrections, and for the various spacecraft operational mode changes. Tables 3 and 4 outline the command functions and planned command sequence.

Data obtained at the DSIF Stations were to be transmitted to JPL in real-time or near-real-time by teletype. Original copies of these data were also to be dispatched to JPL by the fastest possible means.

The DSIF was initially committed to 24-hr/day coverage during the critical periods, and 10-hr/day coverage during the cruise phase of the flight. The critical periods were from launch through midcourse maneuver plus 2 days, or a maximum of 10 days, and 24 hr before and after encounter. The cruise phase consisted of the period after midcourse maneuver to encounter and the period after encounter to the end of the mission. During the period midcourse maneuver to encounter, DSIF 2 and 3 were to track for one 10-hr period every 4 to 10 days, averaging one period per 7 days. Coverage for 24 hr/day was to be provided upon a 6- to 12-hr notice during scientific and engineering alarms, as required. Conflicting requirements between *Mariner II* and *Ranger V*, which was launched during the *Mariner II* mission, were to be resolved at the time of occurrence.

2. Tracking and Data Acquisition

The primary tracking function of the DSIF was to keep the antenna pointed toward the space probe, so that continuous RF communications could be maintained. Acquisition of the target was accomplished either by pointing the antenna according to the pre-calculated ephemeris or, if desired, by using a search pattern. Two search patterns were available at hour angle–declination antenna installations:

1. Spiral scan, which causes the antenna to spiral outward from some initial pre-set angle coordinates (not used for *Mariner* mission).

2. Sawtooth scan, which causes the antenna to sweep back and forth across a rectangular area (used only for acquisition when probe came over horizon).

Once the probe had been "acquired," the antenna tracked it automatically using a phase-locked, simultaneously lobing system. The angle of the antenna, with respect to the signal source, was determined by each of the four overlapping lobes of the antenna pattern. The sum and difference signals were compared in both amplitude and phase, and the resulting signals were introduced into the three-channel tracking receiver.

The DSIF Stations incorporated a highly stable, narrow-band, double-conversion receiver, which was phase-locked to the spacecraft transmitter frequency. The receiver provided the information necessary for precise measurement of signal frequencies, for angular tracking of the signal source, and for detection of the phase-modulated telemetered data. (The receiver contains three channels: one reference channel and two angle-error channels. The reference signal is used to obtain doppler, telemetry, and signal characteristics for recording. It contains the phase-locked loops for frequency mixing and the phase reference and AGC control for all three channels. The two angle-error channels produce signals which are proportional to the error of the antenna-pointing angle. These error signals are fed to the servo-control system and position the antenna for automatic tracking of a received signal. A semi-automatic acquisition-control assembly is incorporated in the receiver to facilitate synchronization of the receiver frequency to that of the spacecraft transmitter.)

Since all of the DSIF Stations are utilized on a space-probe mission, a Teletype Communications Network has been established between the stations and JPL. The Communications Network is required for the coordination of effort necessary for the conduct of each mission, and provides a means for transmitting technical data. The Teletype Network is also used to transmit tracking, scientific, and engineering data to a Central Computing Facility, located at JPL. Computation of the ephemerides and prediction data and mid-course maneuver requirements for the spacecraft, as well as processing of scientific and engineering data from the stations, is done at this Facility.

The doppler-tracking data provided by the DSIF were of two general types: a one-way doppler measurement, in which the signal from the spacecraft is derived from the oscillator in the spacecraft; and a two-way measurement, in which the spacecraft signal is a coherent multiplication of the transmission from a ground station. For the *Mariner II* mission, the Goldstone and Johannesburg Stations had two-way doppler capabilities. At Woomera, only one-way doppler data were available.

The two-way communication systems installed at Goldstone and Johannesburg employed two separate frequencies: one for transmission to the spacecraft and one for reception from the spacecraft. The use of two frequencies is necessary because two-way doppler cannot be obtained using a single frequency. The actual selection of the frequencies, however, is governed by diplexer and antenna considerations. If the frequencies differ by less than 6%, the diplexer cannot separate the transmitted and received frequencies; and if they differ by more than 10%, the use of a single antenna for both frequencies is difficult. The DSIF transmits 890 Mc to the space vehicle. The spacecraft transponder receives this signal, multiplies it by 96/89, and retransmits 960 Mc back to Earth.

The primary advantage of a two-way system is the increase in the accuracy of frequency measurements for doppler detection. The DSIF doppler-detection system references the measured frequency of the received signal to the transmitted frequency in the case of two-way doppler and to a standard reference frequency in the case of one-way doppler. In the one-way system, where the spacecraft generates and transmits a carrier signal to Earth, the drift in frequency of the spacecraft oscillator is unknown. Consequently, the received frequency would not reflect the true doppler shift.

In the two-way system, any drift of the transmitter-oscillator can be measured precisely, and the doppler measurement can be adjusted accordingly. Also, in the two-way system, the doppler-frequency shift is approximately doubled, since the carrier signal must travel to the space vehicle and back again. Therefore, the precision with which the radial velocity can be measured is increased, inasmuch as a specific velocity is represented by a larger frequency shift than in the one-way system. The doppler frequency shift is measured by the DSIF at nominally 30 Mc, except at the Goldstone Stations, where, for greater precision, the frequency is multiplied by 30 to obtain the shift at the carrier frequency.

During those periods when the space probe was "visible" to both the Woomera Station and the Goldstone or Johannesburg Stations, the signal received by Woomera was the Goldstone or Johannesburg carrier as retransmitted by the spacecraft transponder. The data so received by the Woomera Station were then correlated with the Goldstone or Johannesburg transmission data, and a pseudo two-way doppler measurement achieved. Similarly, the accuracy of the one-way system was improved when two stations, in the one-way mode, were "viewing" the spacecraft. By correlating the recorded data from each station, the spacecraft-oscillator drift was calculated and the data measurements improved.

The nominal duration for the *Mariner II* mission was 150 days, and for the majority of the time the DSIF was to provide tracking coverage of from 16 to 20 hr/day, using two stations each day. However, each of the three permanent DSIF Stations operated on a 24-hr/day basis. The DSIF provided tracking information and raw telemetry information; in addition, the Goldstone and Johannesburg Tracking Stations had the capability of transmitting commands to the spacecraft when required.

3. Command Procedures

During the *Mariner II* mission, two types of commands were transmitted to the spacecraft from the DSIF. One type of command, a real-time command, initiated pre-programmed events in the spacecraft. The other type of command, a stored command, was used to program the spacecraft actions for the mid-course maneuver. (See Table 3 for an explanation of the command functions.) These commands, both real-time and stored, were punched on paper teletype tape and fed into the tape reader of the Read–Write–Verify (RWV) System, which modulates the transmitter. The real-time command tapes were available at the DSIF Stations prior to the mission. The

Table 3. Command functions

Command	Function
RTC-1	*Roll override.* Used in case Earth acquisition is lost. Earth sensors are switched out; spacecraft will roll until Earth sensor detects an illuminated object
RTC-2	*Clockwise hinge override.* Changes hinge angle of Earth-oriented, high-gain antenna. Each command causes hinge angle to change in an increment of 2 deg
RTC-3	*Counterclockwise hinge override.* Same as RTC-2, except that hinge angle is changed in opposite direction
RTC-4	*L-band to omnidirectional antenna.* Switches transponder output from Earth-oriented, high-gain antenna to omnidirectional antenna
RTC-5	*L-band to high-gain antenna.* Switches transponder output to Earth-oriented, high-gain antenna
RTC-6	*Initiate midcourse maneuver.* Switches spacecraft attitude control to gyro control; spacecraft turns are initiated according to stored command values. Midcourse motor burn is initiated. After completion of motor burn, spacecraft is reoriented and solar and Earth acquisition procedures are initiated
RTC-7	*Command encounter mode.* Turns the planet science on. Engineering telemetry is switched out; radiometer scan begins
RTC-8	*Command planet science off.* Returns spacecraft to cruise mode. Radiometer is turned off; engineering telemetry is switched into telemetry system. Countermands RTC-10
RTC-9	*Command Sun acquisition.* Unlatches solar panels and removes solar acquisition inhibit
RTC-10	*Command cruise science off.* Switches science telemetry off; engineering telemetry only transmitted
RTC-11	*Spare*
RTC-12	*Command Earth acquisition.* Removes Earth acquisition inhibit; spacecraft starts roll search. When spacecraft Earth sensor acquires and nulls an object, telemetry data rate is automatically switched to 8.3 bits/sec
SC-1	*Midcourse roll duration.* Contains time duration of midcourse roll maneuver
SC-2	*Midcourse pitch duration.* Contains time duration of midcourse pitch maneuver
SC-3	*Midcourse velocity increment.* Contains velocity incremental change required for midcourse motor burn

stored command tapes were determined by the Central Computing Facility (CCF) during the mission, and transmitted to the DSIF Stations via DSIF Network Control. A command verification procedure was followed to ensure that accurate command transmission and compliance were obtained.

a. Transmission of commands to DSIF Stations. Teletype messages were used to transmit the command information from Network Control to a DSIF Station. In the case of the midcourse maneuver, these command information messages gave:

1. The three required stored commands, each repeated three times.
2. The times, each repeated three times, at which the real-time command for the maneuver initiation should be transmitted.

b. Verification of commands prior to transmission to the spacecraft. After the command information message was received at a DSIF Station, a series of verification procedures was initiated to ensure accurate command transmission. The Station Manager acknowledged verbally via teletype or by telephone:

1. Receipt of the message.
2. Command numbers (octal presentation).
3. Command execution time.

In the case of messages containing stored commands to be transmitted to the spacecraft, a duplicate of the command message was made on the teletype reperforator and was then transmitted to Network Control for verification. Network Control verbally informed the DSIF Station of verification.

In the case of real-time commands, which were available at the DSIF Station on pre-punched tapes, only the acknowledgment and confirmation of the Station Manager's verbal report were required prior to transmission to the spacecraft. In the case of stored commands, additional verification procedures were performed. After being thoroughly checked, the Read–Write–Verify (RWV) System was used to verify the stored commands to be transmitted to the spacecraft. The RWV System was also used to modulate the transmitter when commands were transmitted to the spacecraft.

When the proper operation of the RWV System had been ascertained, each group of three identical commands was read into the RWV System, verified, and a command tape "cut." The RWV System provided a display of the octal interpretation of each command and, for each group of identical commands, these displays were checked for agreement among themselves and with the octal interpretation received from Network Control. These octal displays were also verbally reported to Network Control.

As each group of identical command words was verified, the octal command interpretation was set on the RWV System thumbwheels, and the command word punched on a paper tape. At the conclusion of the verification of the teletyped command words, this paper tape then contained sequentially one of each of the stored commands which were verified (Table 4). This tape was then read into the RWV System, and the octal interpretation of each command word checked.

c. Transmission of commands by the DSIF. The same procedure was used in transmitting real-time and stored commands. The command tape, either the pre-punched real-time command or the verified stored command tape from the RWV unit, was fed into the RWV System. At the proper time, the command was initiated and started its transmit cycle which also includes a verify mode. If the RWV System detected loss of spacecraft synchronization or some error, either in the command or the RWV circuitry, the command transmission was inhibited. There was an emergency mode which could be used, however, if it was desired or necessary to transmit a command without using the verify mode of the transmit cycle.

After successful command transmission, the Station Manager would notify Network Control via telephone of the command transmitted and the transmission time. Additionally, DSIF 5 would send a transmission verification message to the SFOC. The Station Manager also included this information in the next teletype station report.

4. Tracking Data Analysis Group

In preparation for the *Mariner II* mission, precalibration testing was performed at all DSIF Stations, including star tracks and boresight versus polarization tests. The calibration data obtained from these tests contained angle systematic-error corrections and boresight-shift information.

The monitoring of raw data assumed major importance on several occasions when the DSIF was suspected of generating erroneous data. Because monitoring procedures, as conceived before the flight, proved to be inadequate in providing the sensitivity and speed of monitoring

Table 4. Command sequence

Command midcourse maneuver sequence (L + 8 days)
Transmit SC-1, SC-2, SC-3 and RTC-4 to spacecraft (roll, pitch, velocity and antenna changeover)
Transmit midcourse execute command, RTC-6 (L + 8.1 days)
Spacecraft starts propulsion sequence
(1) Turn on accelerometer
(2) Turn on gyro
(3) Turn off cruise science (data rate remains at 8.3 bits/sec, but only engineering telemetry is transmitted)
RTC-6 + 60 min
(1) Turn off Earth sensor power
(2) Inhibit Earth acquisition
(3) Connect roll gyro capacitor
(4) Set roll turn polarity
(5) Deploy high-gain antenna
(6) Start roll turn
Stop roll turn (latest time RTC-6 + 68.7 min)
RTC-6 + 72 min
(1) Turn on autopilot
(2) Switch out Sun sensor pitch and yaw errors
(3) Connect pitch and yaw gyro capacitors
(4) Set pitch turn polarity
(5) Start pitch turn
Stop pitch turn (latest time 16.7 min after start)
RTC-6 + 94 min
(1) Start accelerometer integration
(2) Command motor ignition
Command motor shut off (latest time 2.5 min after start)
Turn off autopilot (RTC-6 + 98 min)
(1) Switch out gyro capacitors
(2) Command high-gain antenna to reacquisition position
(3) Relinquish CC&S control of gyro power and accelerometer
(4) Commence automatic Sun acquisition
(5) Switch in Sun sensor error signal
Sun acquisition complete (RTC-6 + 98 to 128 min)
(1) Turn off gyros
(2) Turn on cruise science (telemetry remains at 8.3 bits/sec)
Remove inhibit on Earth acquisition (RTC-6 + 200 min)
(1) Turn on Earth sensor power
(2) Turn on gyros
(3) Initiate roll search
(4) Turn off cruise science
Earth acquisition complete (RTC-6 + 200 to + 3 min)
(1) Switch transmitter to high-gain antenna
(2) Turn off gyros
(3) Turn on cruise science

required, the IBM 1620 computer at the Goldstone Tracking Station was utilized to provide such monitoring in near-real-time. This form of monitoring became a standard procedure when DSIF 3 was taking precision two-way doppler data every 8 days, and provided invaluable assistance to both the Tracking Data Analysis Group and the Orbit Determination Group.

Monitoring of reduced data proceeded according to pre-flight planning, except that somewhat closer teamwork than had been envisioned proved necessary between the Tracking Data Analysis Group and the Orbit Determination Group in the interpretation of tracking-data residuals. This need resulted, in large measure, from the complexity of the Orbit Determination Program and to the variety of options available within the program. Correlation of supplementary data, including VCO frequencies, transmitter on-times, etc., was quickly recognized as a full-time responsibility for one individual. Hence, one member of the Group was assigned to this work for the duration of the mission.

5. Planning Personnel

a. National Aeronautics and Space Administration (NASA). The National Aeronautics and Space Administration, created by the Space Act of 1958, was given the responsibility for creating and providing a broad capability of launching large loads into space, of surviving there, of taking new knowledge of nature from the more unobstructed view of the universe, and of operating in space as required by the national interest. Military space activities peculiar to the defense of the United States were left with the Department of Defense.

The responsibility for the *Mariner* Venus 1962 Project at National Aeronautics and Space Administration Headquarters was assigned to the Office of the Director of Lunar and Planetary Programs, under the over-all direction of the Office of Space Sciences. The organization chart shown in Fig. 1 indicates the relationship of these offices.

b. Jet Propulsion Laboratory (JPL). The Jet Propulsion Laboratory was assigned Project Management responsibility for the *Mariner* Venus 1962 Project. JPL was also assigned system management responsibility for the *Mariner II* spacecraft system, including the associated complex for post-injection space flight operations. An organization chart of JPL during the period of the *Mariner* Project is shown in Fig. 2. A summary of the responsibilities under the Project Manager structure is given in Sect. III-6 of this Technical Memorandum.

c. Marshall Space Flight Center (MSFC). The George C. Marshall Space Flight Center was assigned responsibility for the over-all management and conduct of the launch vehicle portion of the *Mariner* Venus Project. In particular, this assignment included administrative and technical responsibility from vehicle procurement through launch and tracking to spacecraft injection.

Vehicle System Responsibility. The Director, MSFC, in order to assume management cognizance of the *Agena B* and *Centaur* Projects, established as his principal agent a Light and Medium Vehicle Office. This Office was responsible for assuring proper vehicle support to the several space projects (including *Mariner II*) which utilize these vehicles along with procurement and coordination with the Air Force *Atlas* boost vehicle. In order to support the *Mariner* Venus Project, as well as others utilizing the *Agena B* vehicle, an *Agena B* Systems Manager was appointed within this organization. He was responsible for the planning and execution of the approved *Agena B* Vehicle Projects, including procurement modification; ground support equipment; planning and implementation of launch-to-injection, tracking and instrumentation; and certification of performance and reliability analysis. The assigned responsibility included ensuring the integrity and performance of the launch vehicle and spacecraft for proper mating of these systems for the successful injection of the spacecraft. This effort included facilities and ground support equipment for the various phases of manufacturing, testing, and launch preparation. In view of the contractual arrangements for launch vehicles, the activities of the prime contractors and subcontractors were directed by the Manager through the Air Force Space Systems Division.

Launch Operations Responsibility. Within Marshall Space Flight Center, a Launch Operations Directorate (LOD) was assigned responsibility for NASA launches in accordance with the Marshall Manual. For the project assigned to the Light and Medium Vehicle Office, LOD was to perform the launch operations in response to program requirements and objectives as specified by the *Agena B* Systems Manager. On July 1, 1962, LOD was redesignated as the Launch Operations Center. There was no need, however, to renegotiate agreements reached earlier with LOD relating to the *Mariner* Venus Project.

Air Force Space Systems Division (AFSSD). Responsibility for procurement of launch vehicles, together with logistic and management support to meet NASA *Agena* launch schedules, was assigned to the United States Air Force. The AFSSD was responsible for operational, administrative, and technical support for NASA *Agena* launch vehicles. This assignment included personnel and facilities in support of launch operations. AFSSD acted as agent for MSFC in contract procurement of launch vehicles in accordance with U. S. Air Force procedures, except as modified by NASA regulations and policy or by law. The SSD Director for NASA *Agena* Projects was the normal USAF contact for SSD operations associated with the NASA *Agena* Project.

6. Major Contractor Support

a. Lockheed Missiles and Space Company (LMSC). Within LMSC, the NASA *Agena* Project was managed by a Program Office. The MSFC representative's office and a portion of the LMSC staff active on the project were located in close proximity for ease of communications. In 1960, LMSC "projectized" its organization to increase the responsiveness of the various technical groups contributing to the program.

b. General Dynamics/Astronautics (GD/A). The *Atlas* launch booster for the *Mariner* Venus Project was procured for NASA by the United States Air Force from GD/A. The GD/A organization consisted of a Program Office whose personnel reported directly to the *Atlas D* Project Engineer, who in turn reported to the Vice President and Program Director of Space Launch Vehicles.

c. Permanent Project-Wide Bodies. In order to utilize the relationships developed on *Ranger/Agena* to the maximum, the same Board and Panels that existed in the *Ranger* Project were used for *Mariner II*, serving as technical advisers to the Project and System Managers.

d. Agena B Coordination Board. This Board was appointed at the beginning of the *Ranger* Project to coordinate the vehicle requirements of the various users of the *Agena B* vehicle and to provide a mechanism for the settlement of inter-agency problems.

e. Vehicle Integration Panel. This Panel continually monitored, compiled, and evaluated the structural, network, and configurational problems as they related to the interface between the spacecraft and vehicle with shroud. The Panel was also responsible for the interface aspects of the launch checkout procedure.

f. Performance Control Panel. This Panel continually monitored, compiled, evaluated, and coordinated data relating to performance, trajectories, guidance and control, and flight dynamics as they interacted with the vehicle, the shroud, and the spacecraft interface.

g. Tracking, Communication, In-Flight Measurements and Telemetry Panel. This Panel continually monitored, compiled, evaluated, and coordinated data relating to tracking, communications, inflight measurements and telemetry as these items interacted with the vehicle, the shroud, and the spacecraft.

h. Atlas–Agena B Flight Test Working Sub-Group. This Group acted as the prime mechanism for coordinating flight preparations. Members participated in vehicle and range readiness meetings, culminating $T - 1$ day, at which time the Launch Operations and Test Director assumed overall control with AFSSD assistance.

i. Launch Vehicle Relations. A major concern of the *Mariner* Venus Project management was to control, coordinate, and remain aware of the many activities of the project, since five separate organizations had areas of prime technical cognizance. In order to assist in the resolution of problems, to keep channels of communications open, and to inform and unite the different organizations for achieving the objectives of the *Mariner R* Project, considerable person-to-person contacts were made.

To facilitate coordination, a series of status reviews was held. At these reviews, project policies and orientation were presented and all agencies involved in the project were represented. Consensus was that the status meetings promoted better understanding of organizational interfaces within the project.

7. JPL Activities

In addition to project management responsibility for the *Mariner* Venus Project, JPL was responsible for: (1) the design, fabrication, and testing of the spacecraft and its associated ground support equipment; (2) the space flight operations of the spacecraft from injection to planetary encounter; and (3) the Deep Space Instrumentation Facility tracking operations. To implement these responsibilities, the following techniques were developed by the project.

a. Project Policy and Requirements Document. This Document specified the project policy and requirements for the *Mariner II* (1962) mission. It established the operational procedures for the project in that it stated mission objectives, system requirements, milestones, and an over-all guideline schedule.

b. Weekly Project Meeting. Weekly project meetings were held with representatives from each of the JPL operating divisions. These meetings established the hard core of individuals who had a continuity with the over-all aspects of the project. They were assigned from each technical area and formed an organizational matrix to aid in the exchange of information, to monitor progress, and to function as the hub of all Project action.

c. Design Freeze. Since *Mariner II* was a crash project, requiring shipping of equipment to AMR 9½ months after the go-ahead, it was necessary to freeze the design without inhibiting necessary design action. The problem of when and how to freeze the design was complicated by a natural tendency by hardware-producing divisions to set the cut-off date as late as possible, while wishing other areas to freeze as early as possible.

An initial survey of the subsystems was conducted to determine when to freeze and in what order. Major interfaces were scheduled first. Thereafter, any individuals who desired to freeze their particular subsystems, in whole or in part, could do so by referencing the appropriate control documents on the freeze list. A list ("*Mariner II* Change Freeze") was published periodically; any changes to those drawings and specifications listed required an Engineering Change Requirement (ECR).

Thus, the *Mariner* Venus Project was able to institute a continuing freeze concept while maintaining flexibility of operation by scheduling major interface freezes and allowing other areas to be frozen at will for defensive reasons. A complete freeze requiring ECR action was instituted January 15, 1962.

d. Scheduling. The evolution of schedules continued during the Project so that two agencies, JPL and MSFC, were providing a continuous flow of detailed functional schedules.

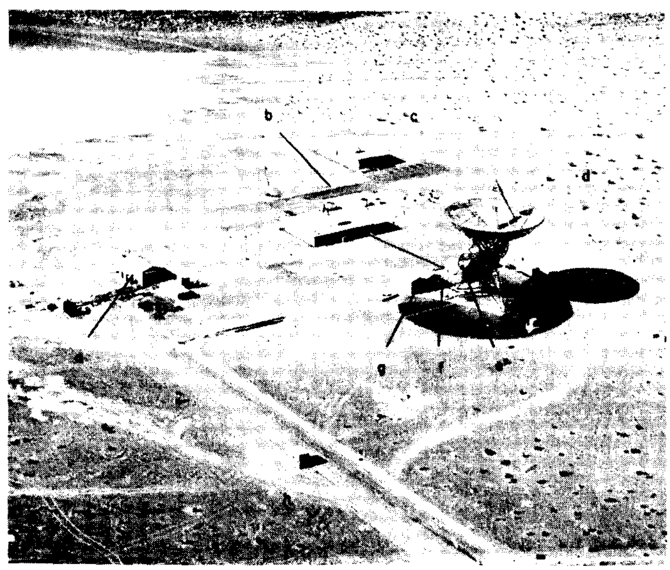
It was project policy to accept the schedules as being at all times dynamic in nature and, therefore, subject to change. However, it was also project policy to insist that all phases of the Project be scheduled with the best available information, and to use the schedules as a measurement of planning efficiency.

From the schedules, Project Management Plan (PMP) reports were prepared, and reporting of PMP milestones to NASA Headquarters was accomplished.

e. Mariner III. The original plans for the *Mariner* Project stated a requirement for two flight-ready spacecraft and one set of unassembled spares. When the delivery of the three sets of spacecraft parts was complete, it was decided that the incorporation of the set of spares into an assembled and tested spacecraft would be beneficial and useful to the project. Subsequent events showed this decision to be wise. The resulting *Mariner III* spacecraft was used for problem detection at AMR while *Mariner II* was in launch condition.

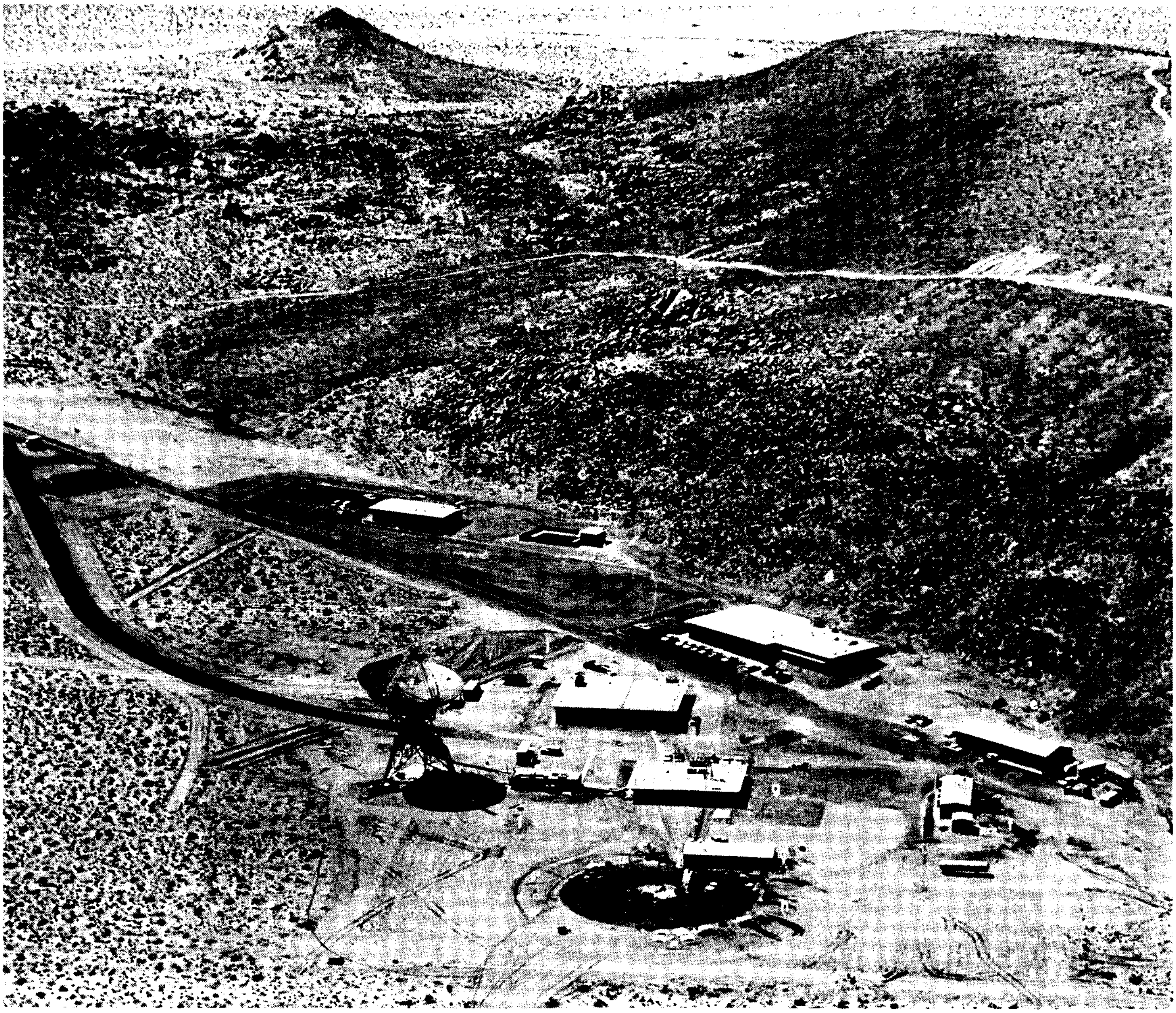
8. DSIF Station Geometry and Coverage

The locations of the Deep Space Stations are shown in Table 1. Pictures of the Deep Space Stations, the Launch, and the Mobile Stations are shown in Figs. 12 through 17.



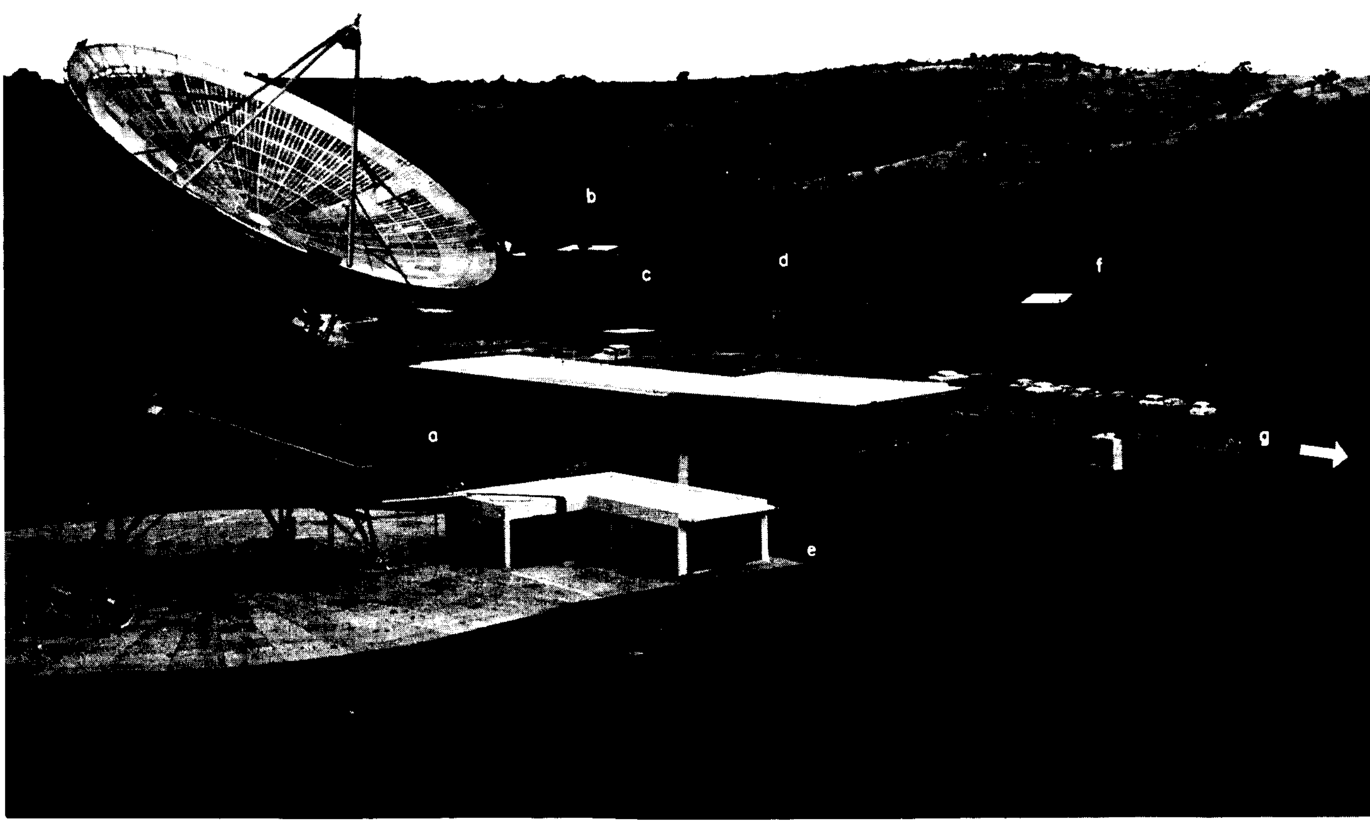
a. GENERATOR BLDG
b. CONTROL BLDG
c. LABORATORY BLDG
d. ANTENNA
e. HYDRO-MECHANICAL BLDG
f. MASER AND PARAMETRIC AMPLIFIER BLDG
g. ANTENNA FEED STORAGE BLDG
h. GUARD HOUSE

Fig. 12. Goldstone Pioneer Station, 85-ft-diameter polar mount antenna



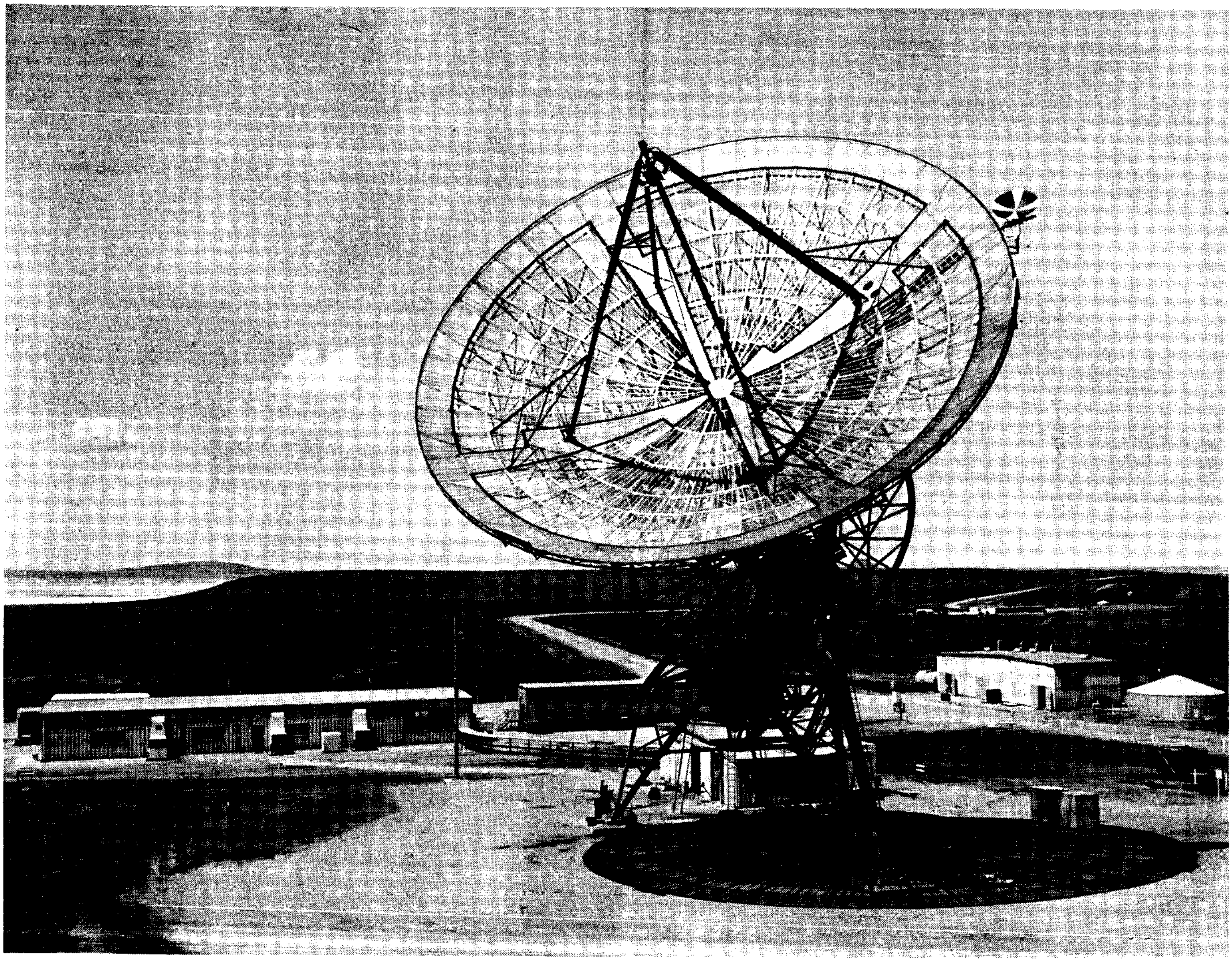
a. GUARD HOUSE
b. DORMITORY
c. WATER STORAGE TANK
d. SYSTEM ENGINEERING, ADMINISTRATION AND CAFETERIA BLDG
e. TRANSPORTATION BLDG
f. GENERATOR BLDG
g. CONTROL BLDG
h. STORAGE BLDG AND FUTURE MACHINE SHOP
i. HYDRO-MECHANICAL BLDG
j. COMMUNICATIONS AND OPERATIONS BLDG

Fig. 13. Goldstone Echo Station, 85-ft-diameter polar mount antenna



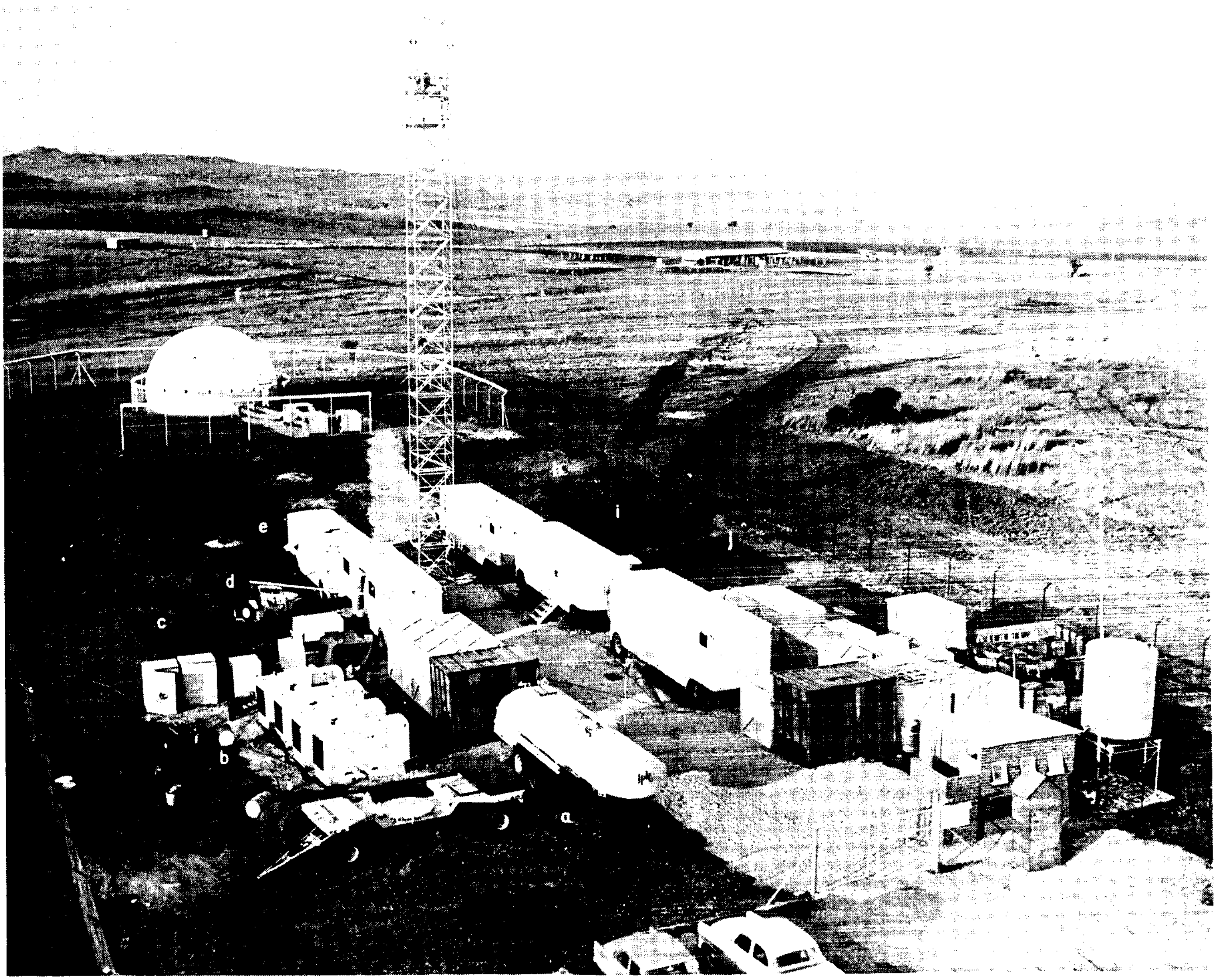
a. CONTROL BUILDING
b. STATION PERSONNEL HOUSING
c. GUARD HOUSE
d. MESS AND RECREATION BUILDING
e. HYDRO-MECHANICAL BUILDING
f. DORMITORY
g. TO TRANSPORT AND GENERATOR BUILDING

Fig. 14. Johannesburg Station, South Africa, 85-ft-diameter polar mount antenna



a. CONTROL BUILDING
b. TRAILER SHED
c. HYDRO-MECHANICAL BUILDING
d. GENERATOR BUILDING
e. WATER TANK

Fig. 15. Woomera Station, Australia, 85-ft-diameter polar mount antenna



a. FUEL TANKER
b. GENERATORS
c. STORAGE AREA
d. COMMUNICATIONS AND OFFICE VAN
e. PARTS VAN
f. ANTENNA IN RADOME
g. COLLIMATION TOWER
h. RADIO VAN
i. DATA HANDLING VAN
j. TELEMETRY VAN
k. STORAGE AREA

Fig. 16. Mobile Tracking Station, Johannesburg, South Africa

a. RECEIVING AND TRANSMITTING ANTENNA

b. TRANSMITTER AND RECEIVER TRAILER

c. CHECKOUT ANTENNA (COLLIMATION)

d. TELEMETRY TRAILER

Fig. 17. Launch Station, Cape Canaveral, Florida

Maps of the Goldstone, Johannesburg, and Woomera Stations are shown in Figs. 18 through 22.

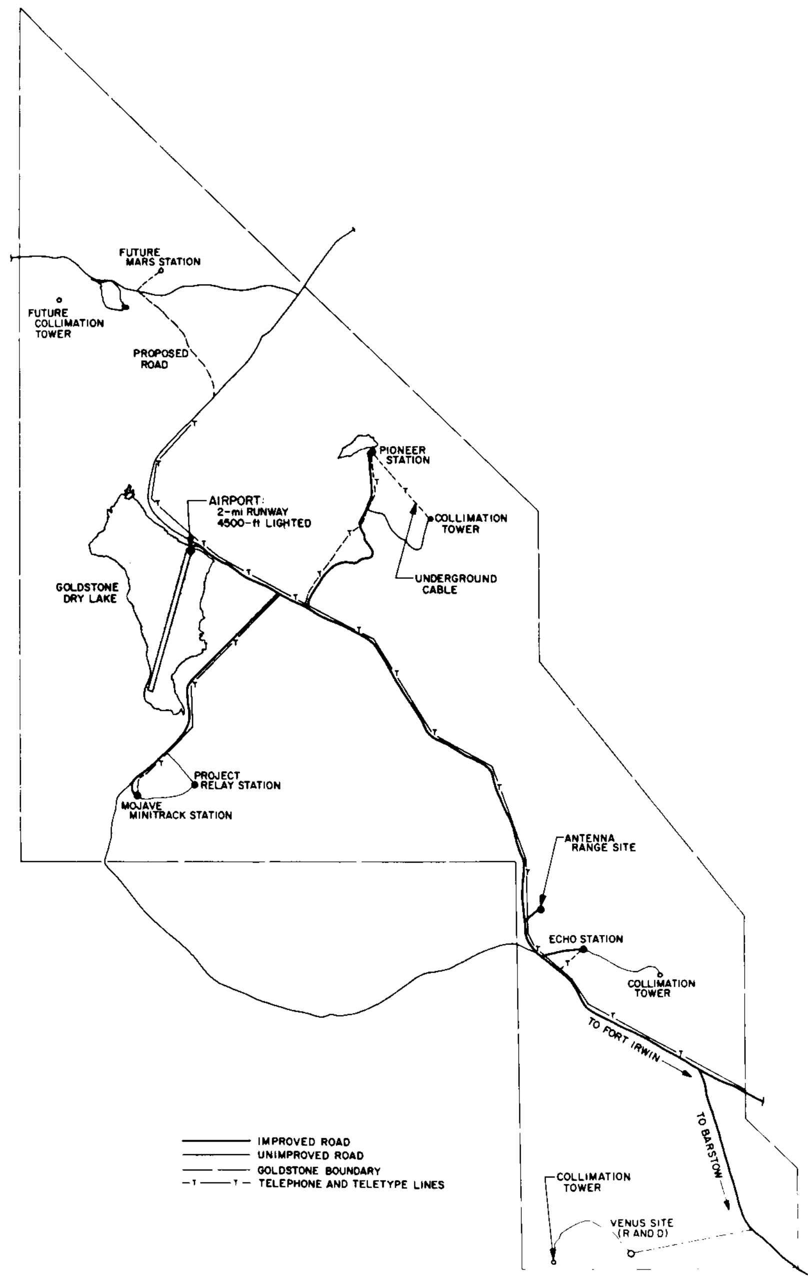


Fig. 18. Map of Goldstone Space Communication Stations

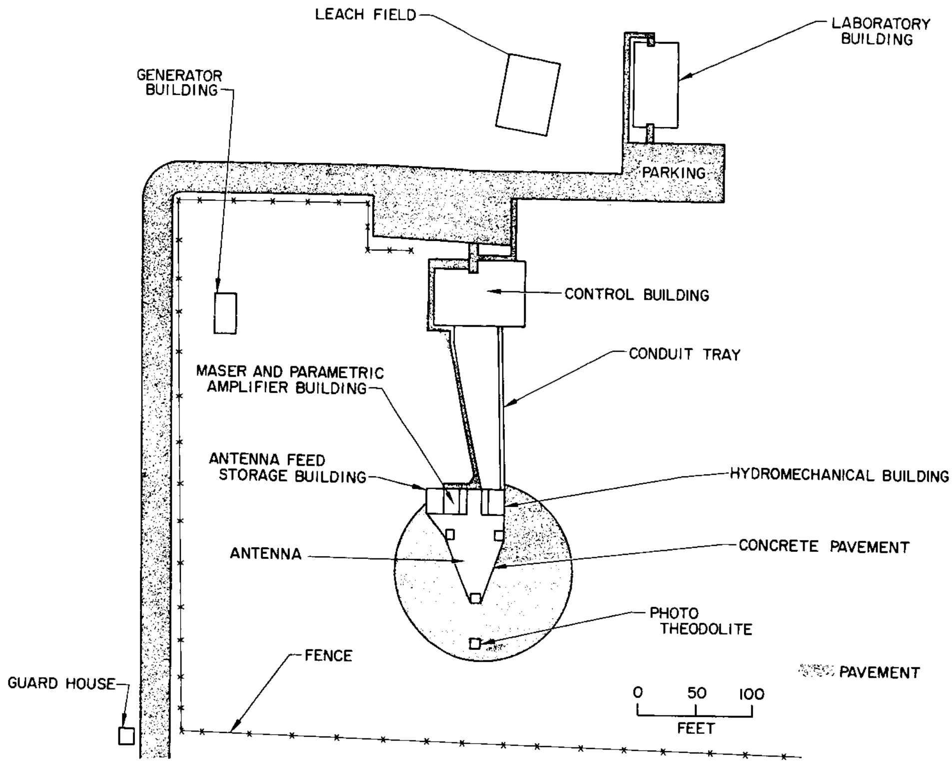


Fig. 19. Goldstone Pioneer Station layout

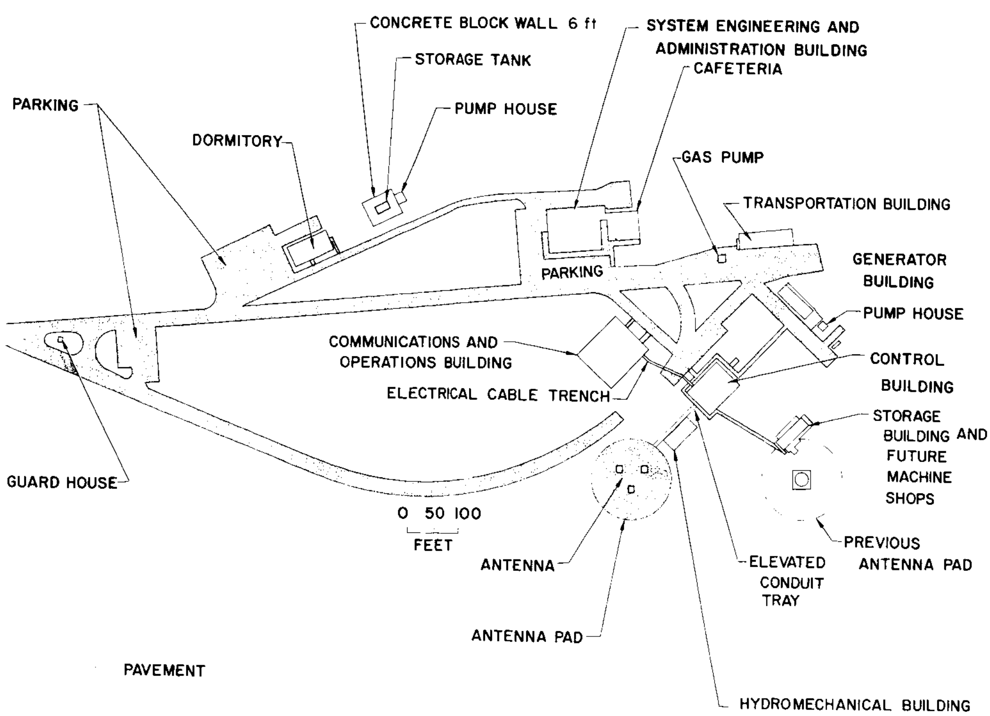


Fig. 20. Goldstone Echo Station layout

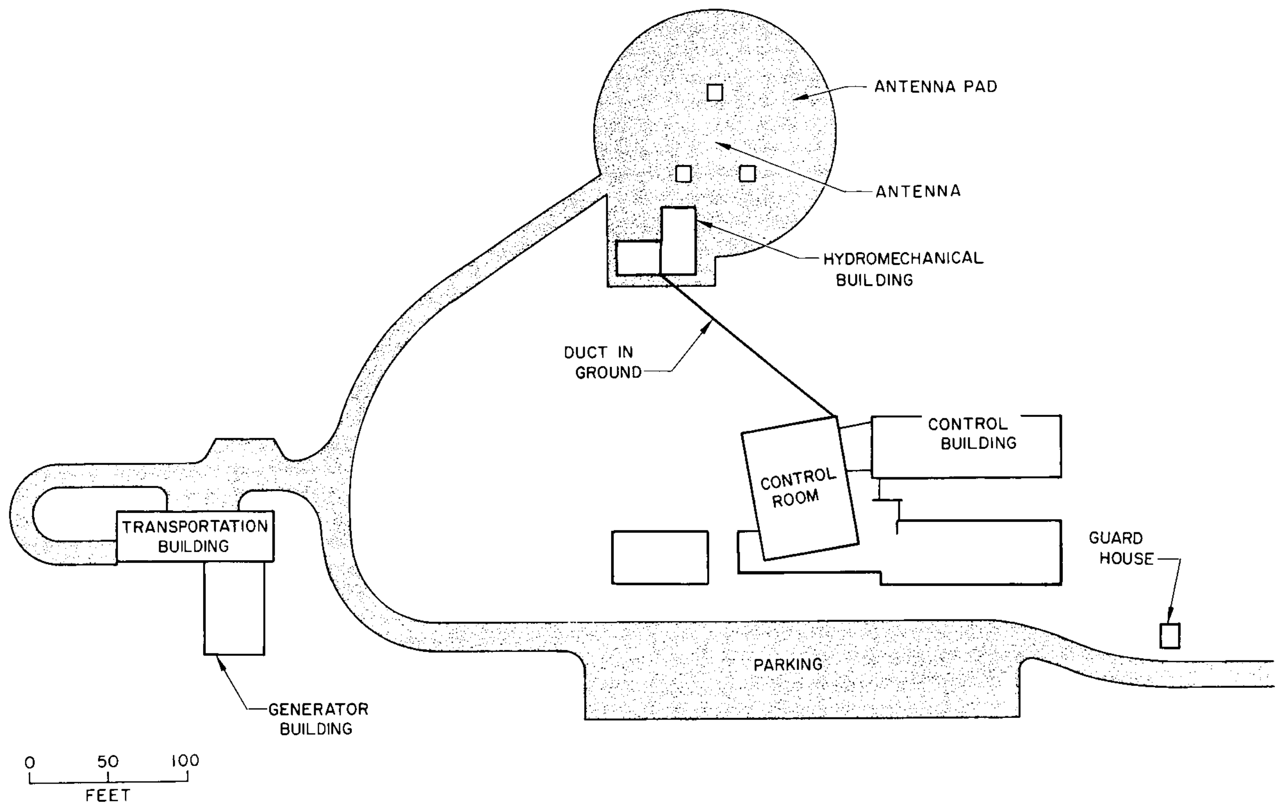


Fig. 21. Layout of Johannesburg Station, South Africa

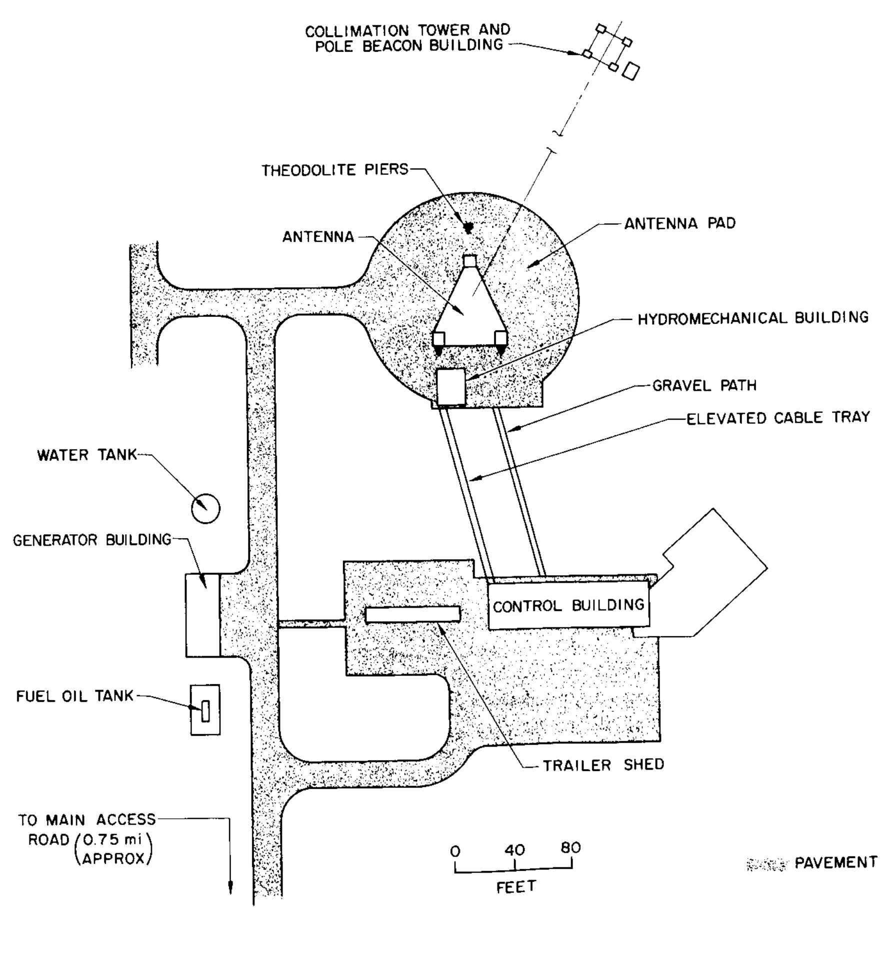


Fig. 22. Layout of Woomera Station, Australia

The loci of sub-vehicle points for the three major Deep Space Stations are shown in Fig. 23. This figure shows the field of view of each polar mount Deep Space Station as a function of spacecraft altitude, as well as the region of overlapping coverage.

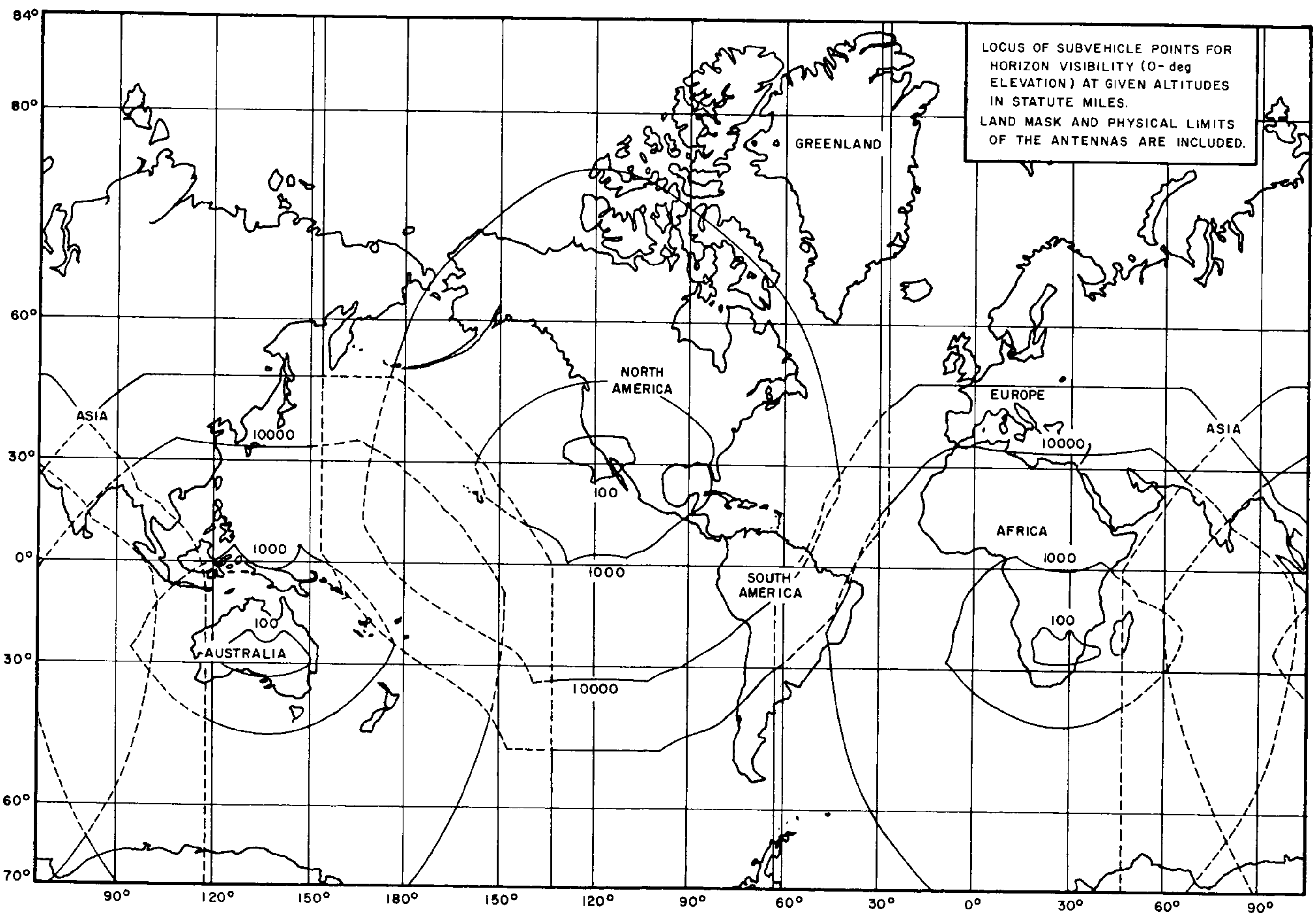


Fig. 23. Station coverage for 85-ft polar mount antennas at Goldstone, Johannesburg, and Woomera

Stereographic projection charts of the three Deep Space Stations are shown in Figs. 24 through 26. These charts show the relative azimuth–elevation and hour angle–declination angle coordinates for each site, as well as the antenna limits and the local horizon masks. Ephemeris data may be plotted directly on these charts.

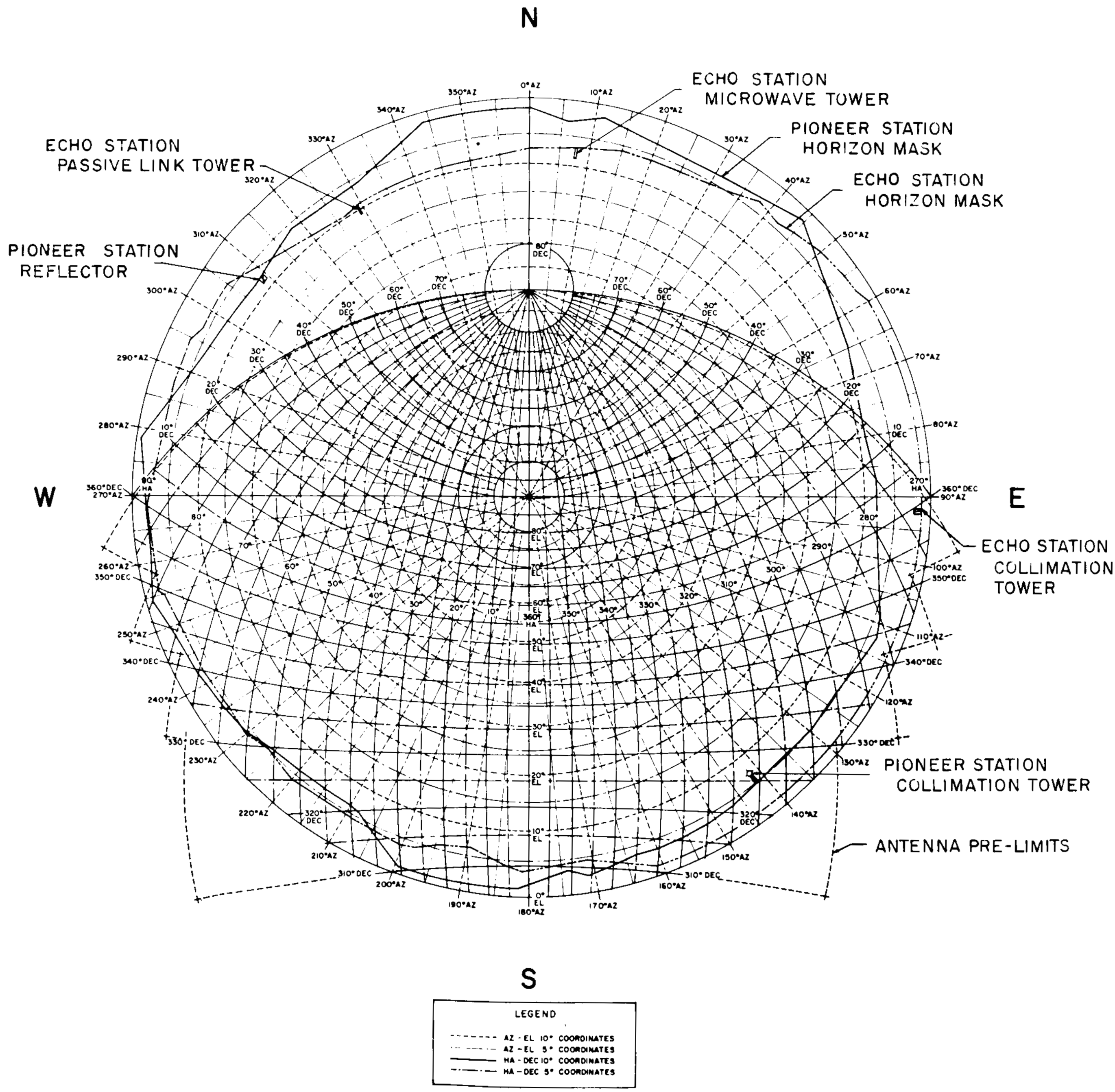


Fig. 24. Goldstone Echo and Pioneer Station coordinates, stereographic projection for 85-ft-diameter polar mount antenna

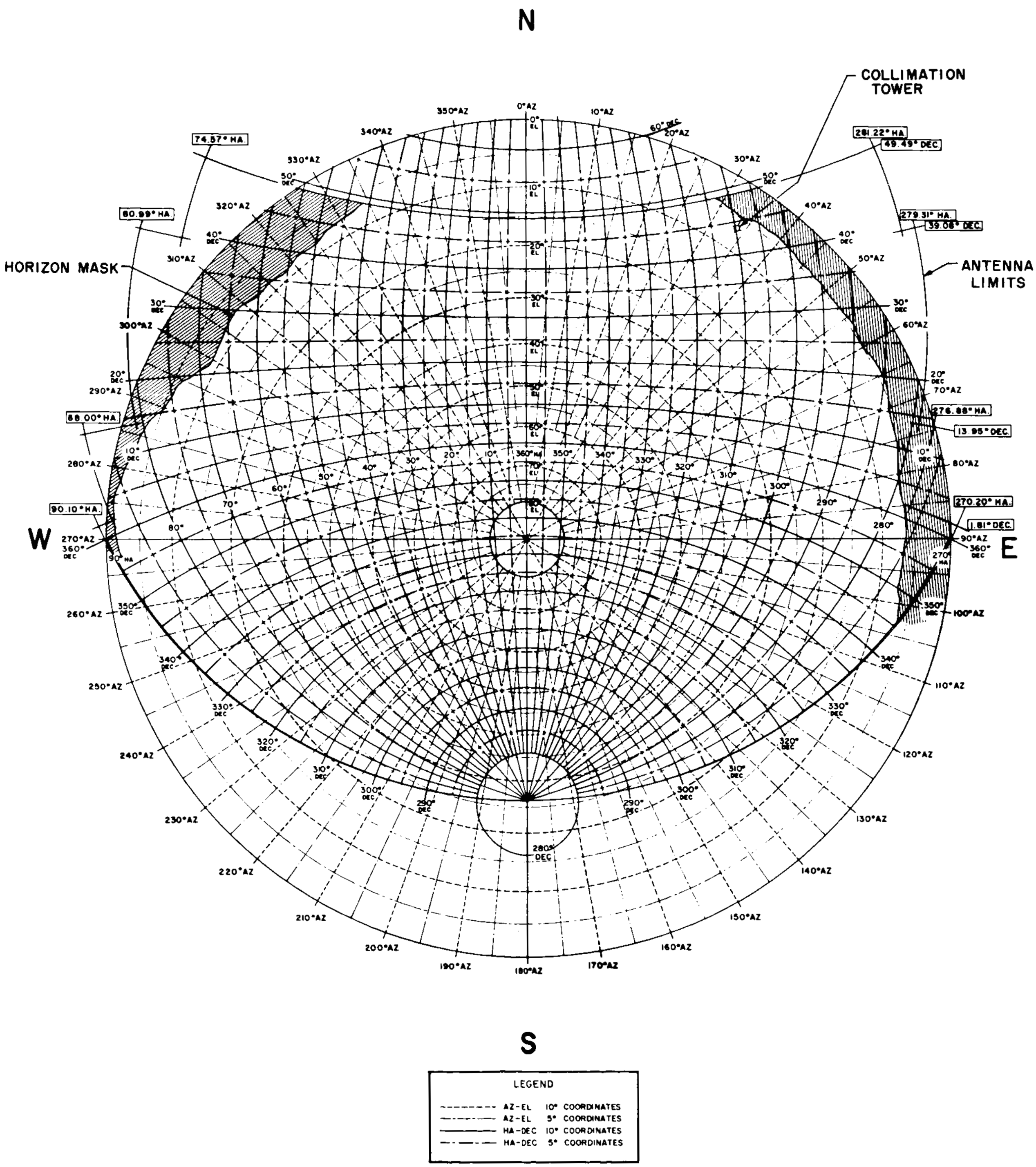


Fig. 25. Johannesburg Station coordinates, stereographic projection for 85-ft-diameter polar mount antenna

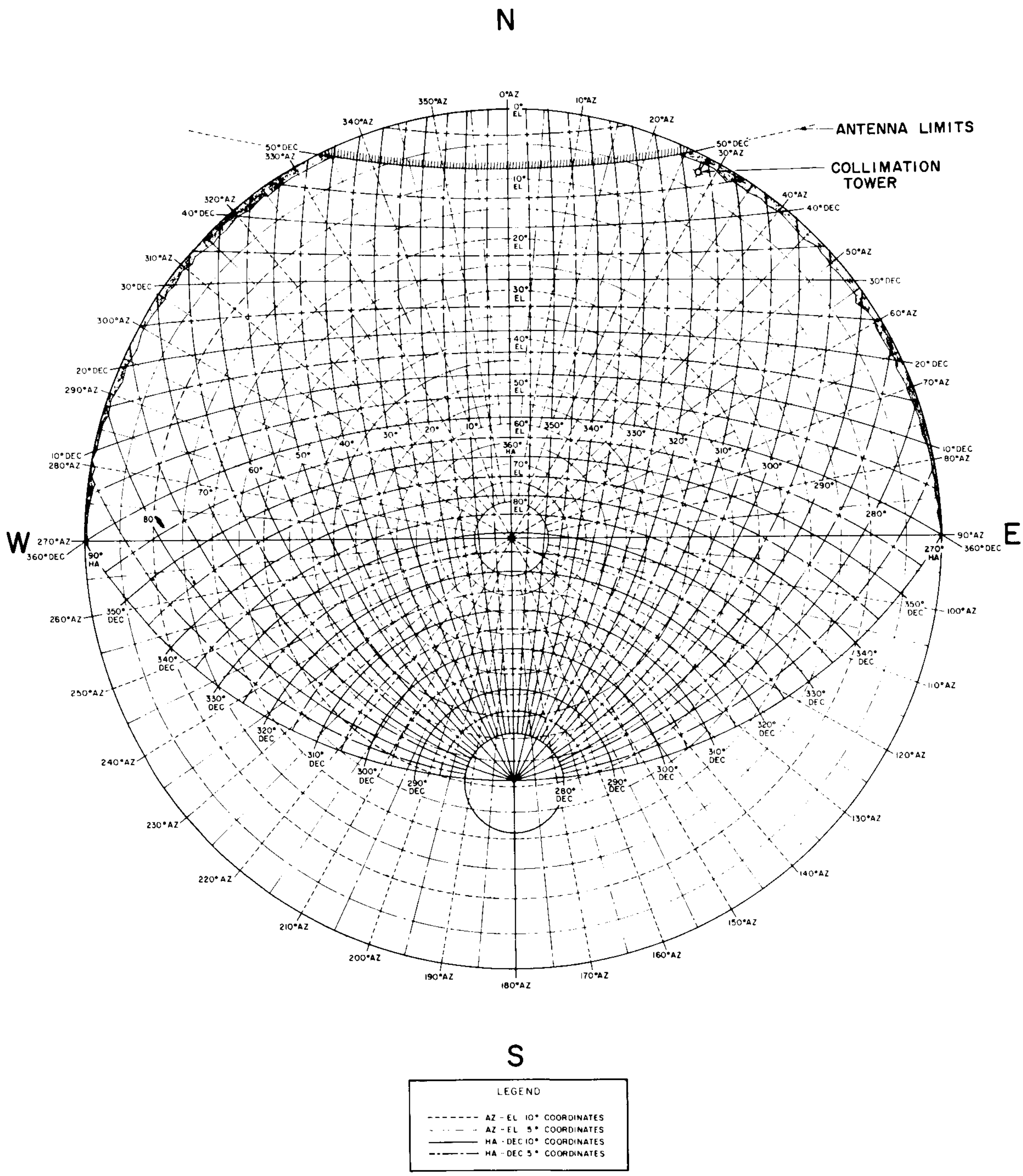


Fig. 26. Woomera Station coordinates, stereographic projection for 85-ft-diameter polar mount antenna

Table 5. DSIF capabilities for *Mariner II*

Station	Antenna size, ft	Maximum angular rate, deg/sec	Antenna gain (960 Mc), db		Receiver noise figure, db	Transmitter power, w	Command capability	Data transmission		Recorded telemetry	Air mail time to JPL, days
			Track	Listen				Angles, doppler	Telemetry		
Mobile Tracking	10 (Az–El)	10	22.2	—	6.3	25	No	Real-time	None	Yes	7
Goldstone Pioneer	85 (HA–Dec)	0.7 (both axes)	43.5	45.5	0.6	—	No	Real-time (doppler only)	Real-time	Yes	1
Goldstone Echo	85 (HA–Dec)	0.7 (both axes)	43.5	46.0	NA	200/ 10 kw	Yes	NA	NA	Yes	1
Woomera	85 (HA–Dec)	0.7 (both axes)	43.5	46.0	1.8	50	No	Real-time	Near-real-time	Yes	7
Johannesburg	85 (HA–Dec)	0.7 (both axes)	43.5	46.0	1.8	200/ 10 kw	Yes	Real-time	Near-real-time	Yes	7

9. Equipment

The following paragraphs describe the equipment throughout the DSIF for the *Mariner* mission. Table 5 outlines the DSIF capabilities for the mission, while Figs. 27 through 30 illustrate the over-all equipment configuration for each station. A view of the control room of a Deep Space Station is shown in Fig. 31; Fig. 32 shows associated equipment.

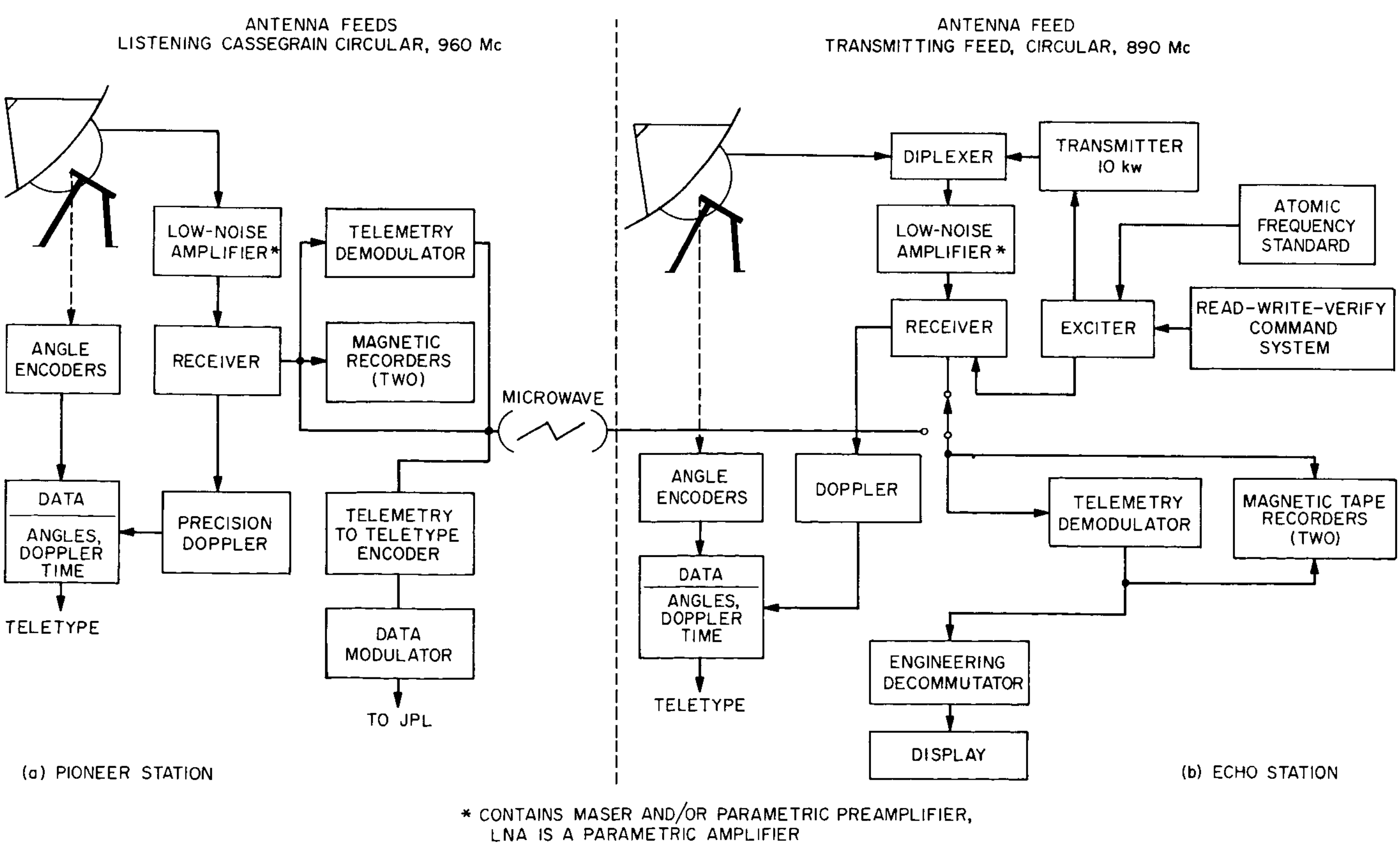


Fig. 27. Goldstone Stations: (a) Pioneer and (b) Echo

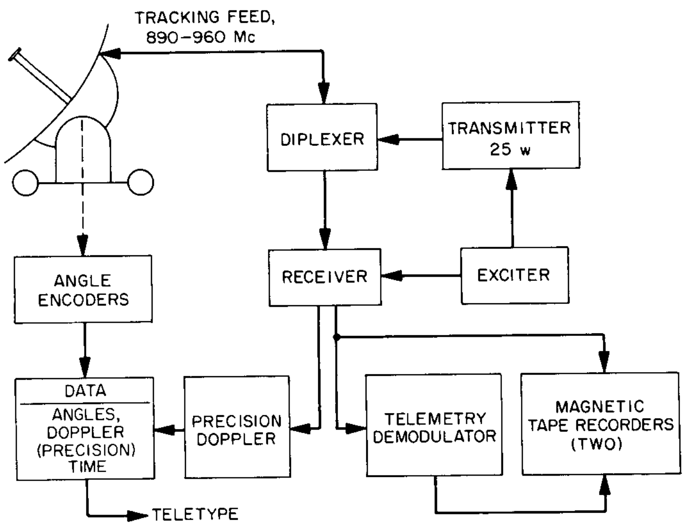


Fig. 28. Mobile Tracking Station

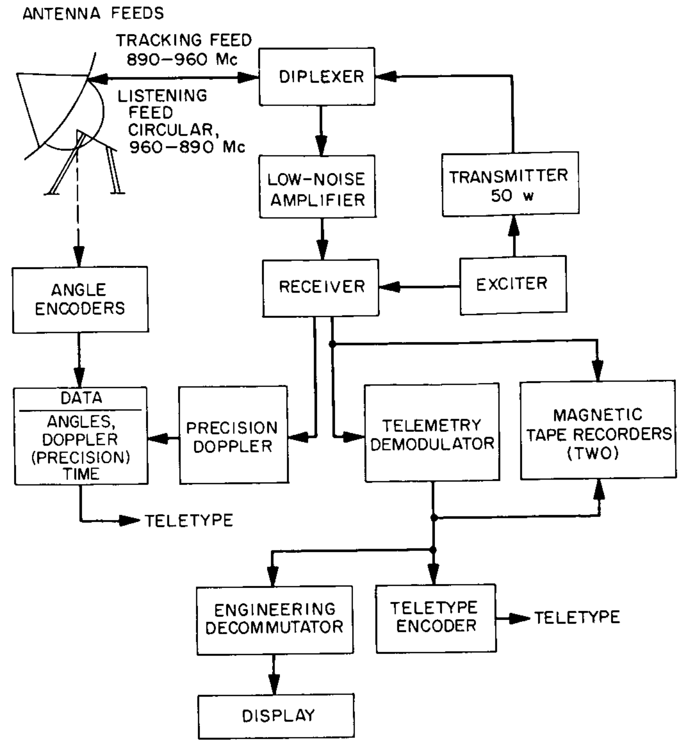


Fig. 30. Woomera Tracking Station

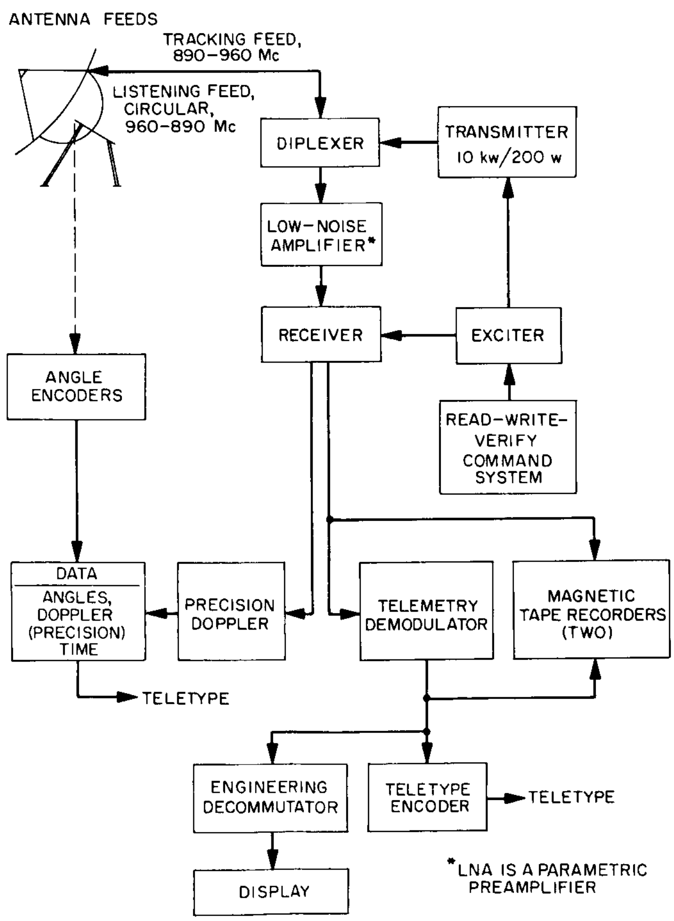


Fig. 29. Johannesburg Tracking Station

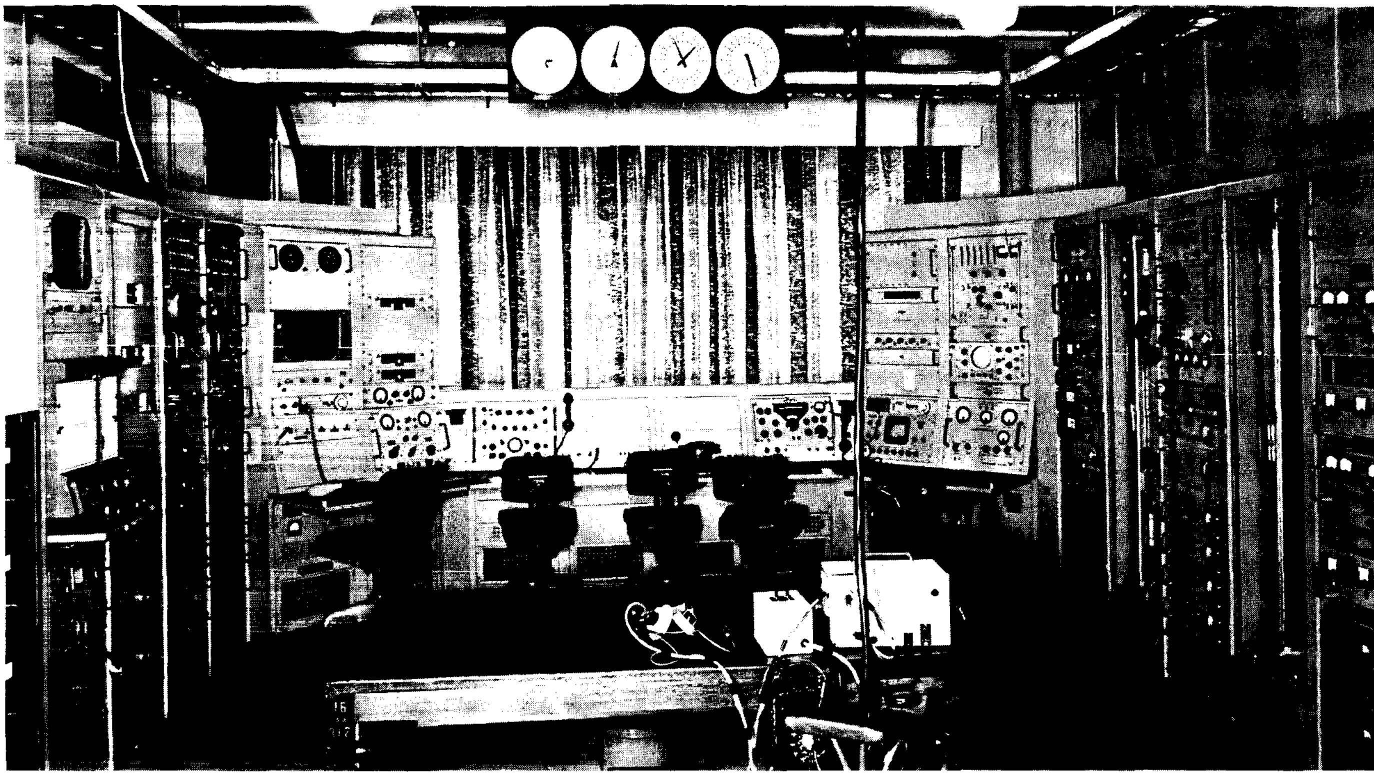


Fig. 31. Deep Space Station control room

a. DSIF Communications Stations: Echo and Pioneer. The Echo and Pioneer Stations were both equipped with a steerable 85-ft-diameter paraboloidal reflector antenna, each with its associated drive system, radio tracking, transmitting and receiving, and data-recording and transmission system. The antennas are polar-mounted (moving parallel in hour-angle and perpendicular in declination to the Earth's equatorial plane) and have a pointing accuracy of better than 0.02 deg. The tracking system at the Echo Station consisted of an antenna feed system, a maser parametric amplifier system, a phase-coherent receiving system, and an electrohydraulic servosystem. The receiver system detected a signal transmitted from the *Mariner* spacecraft and, from a combination of the antenna feed signals, provided a pointing error signal which was used by the servosystem to position the antenna. The Echo Station had the added capability of tracking with a precision two-way doppler system, and of transmitting commands to space vehicles. An increased signal detection capability could be obtained with the substitution of a Cassegrain antenna feed for the tracking feed.

Receiver. The Echo and Pioneer Stations at Goldstone were both equipped with a three-channel, 960-Mc superheterodyne receiver designed for reception of a continuous wave signal in a narrow frequency band in the 960-Mc range. These receivers used phase-lock techniques to achieve a very narrow noise bandwidth and to track a signal over the narrow frequency band for which they were designed. The inputs to the receiver channels consisted of three signals from the antenna feed: a sum or reference signal and two angular error signals. The sum channel, using a supplementary wide-band telemetry channel having an information bandwidth of 3.5 kc provided telemetered spacecraft information for recording. The angular error channels provided the DC error signals for the servosystem. The receiver, parametric amplifier, and maser amplifier and control equipment are shown in Fig. 33. Tables 6 through 8 show the characteristics for these equipments.

Transmitter. The transmitter at the Echo Station was a 10-kw, 890-Mc unit which could be used with a diplexer to allow simultaneous operation of both the transmitter and the receiver. Simultaneous operation of the receiver and transmitter and the use of a spacecraft transponder (communication equipment that receives a transmitted signal, multiplies it, and retransmits it at

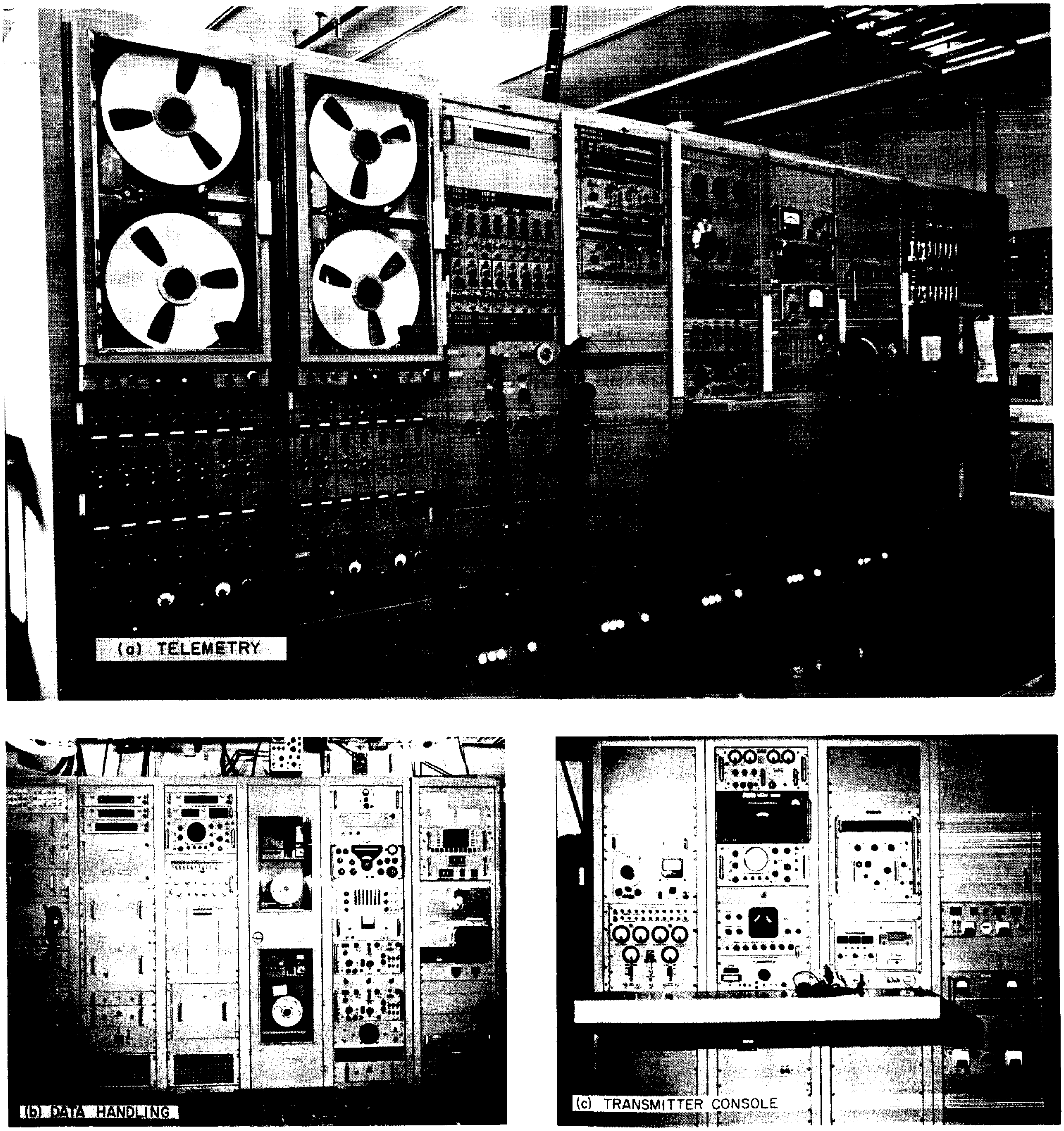


Fig. 32. Associated equipment: (a) telemetry, (b) data handling, and (c) transmitter control

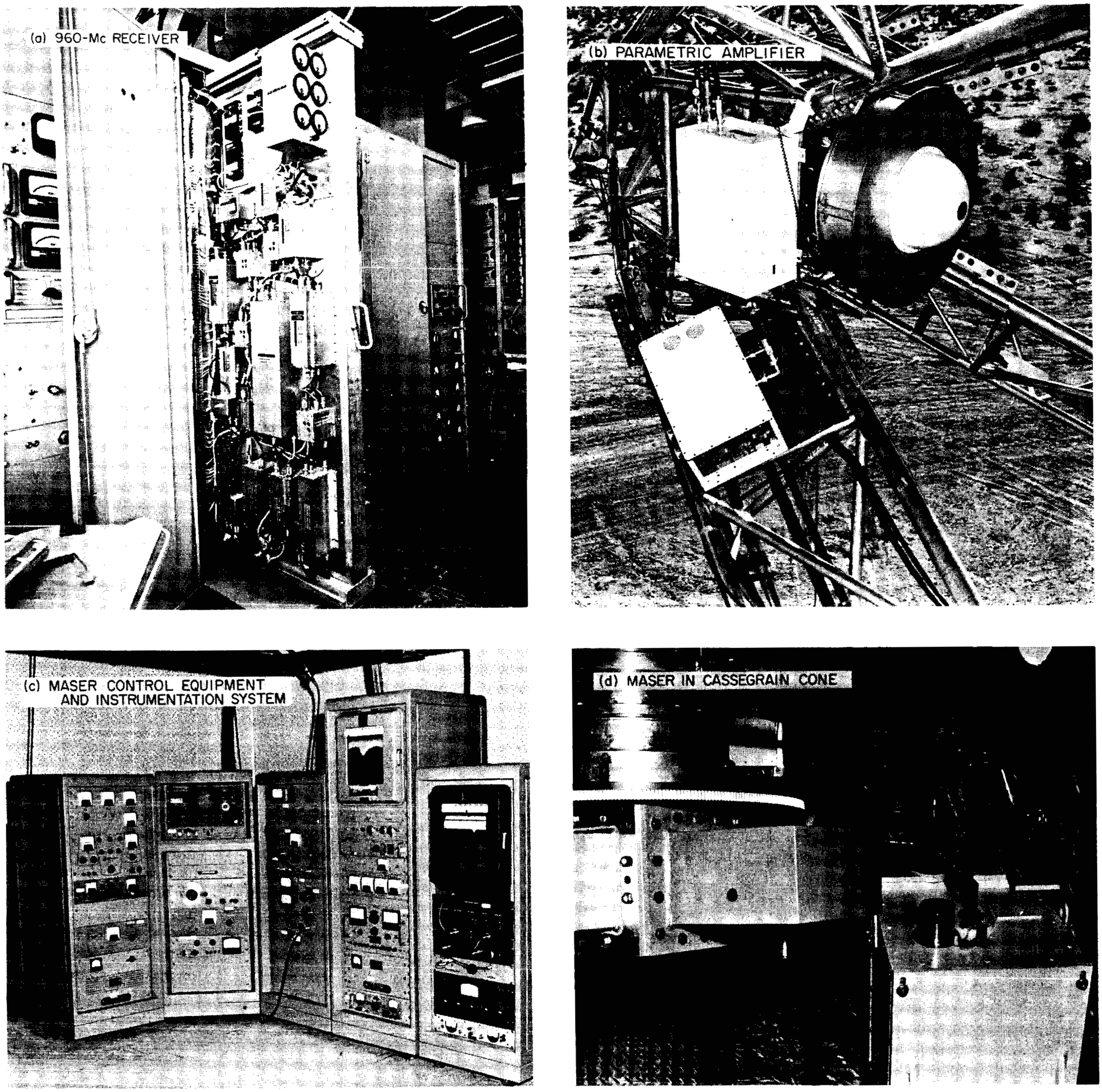


Fig. 33. Equipment installed: (a) 960-Mc receiver, (b) parametric amplifier, (c) maser control equipment and instrumentation system, and (d) maser in Cassegrain cone

a different frequency) enabled accurate doppler (radial velocity) measurements to be made, since the transmitter frequency was accurately known. The transmitter also provided command transmission capability for the Station. A typical 10-kw transmitter is shown in Fig. 34.

Instrumentation and Data Handling. Instrumentation and data-handling systems at the Echo and Pioneer Stations recorded tracking data for computer analysis to determine accurate *Mariner* position and to record spacecraft telemetry. The data handling system recorded the

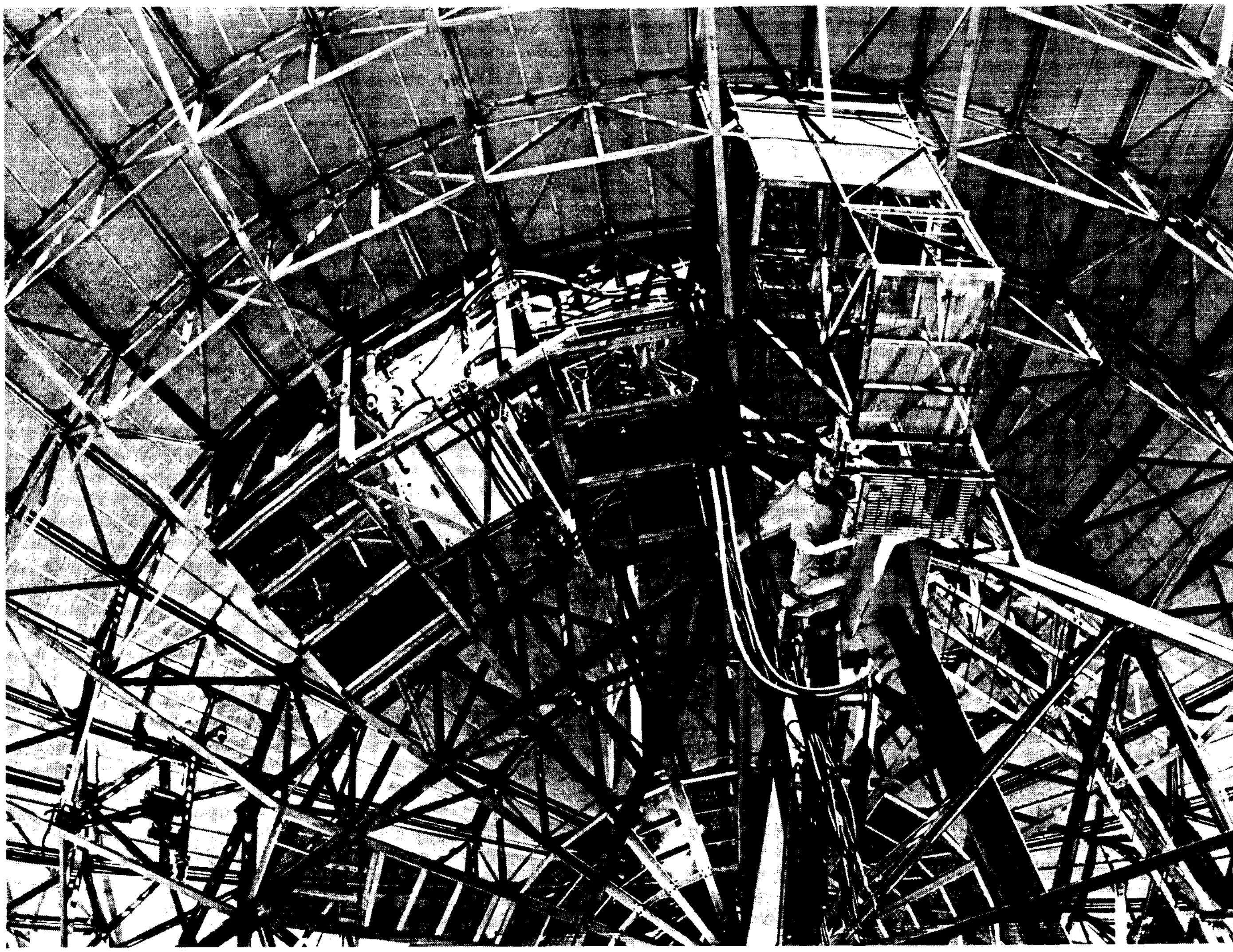


Fig. 34. 10-kw transmitter

Table 6. Receiver characteristics

Number of channels	One reference and two angle
Frequency range	960.05 Mc ± 30,000 cps with one set of crystals. Sets of crystals are available to set the center frequency between 955 and 965 Mc
Phase-lock loop bandwidth	20 cps or 60 cps, nominal
Threshold	20-cps position: −151.7 dbm ± 1.5 db 60-cps position: −147.0 ± 1.5 db
Noise temperature (each channel)	1350°K
First IF amplifier	30 Mc; bandwidth = 1 to 2 Mc
Second IF amplifier (narrow-band)	455 kc; information bandwidth = 1600 cps
Second IF amplifier (wide-band)	455 kc; information bandwidth = 5000 cps
Carrier loop noise bandwidth	20 to 250 cps

time-labeled tracking data–antenna pointing angles, doppler data, and a quality code on paper tape in teletype code. The tracking data were then transmitted via teletype to the Central Computing Facility at the Jet Propulsion Laboratory. The instrumentation system at each station consisted of the phase-locked discriminators and the recording equipment necessary to record the telemetry signal from the receiver supplementary wide-band telemetry channel. At each station, the recording equipment consisted of two seven-track magnetic-tape recorders, an ultraviolet oscillograph, and a hot-stylus recorder. These recorders also recorded station performance information. The magnetic-tape records were used for subsequent detailed analysis of the data, while the oscillograph records provided data for quick-look analysis.

Table 7. Parametric amplifier characteristics

Characteristics	Frequency	
	960 Mc	2295 Mc
Gain, db	20	20
Bandwidth (minimum), Mc	10	10
Noise temperature, °K	150[a]	190[a]
System temperature, °K	200[b]	
Pump frequency, Gc	17.4	17.4
Ambient temperature range, °C	−23 to 55	−23 to 55
Ambient humidity range, %	0 to 100	0 to 100
Ambient altitude range, ft	0 to 10,000	0 to 10,000

[a] Includes approximately 15°K noise temperature contributed by receiver input mixer.

[b] Includes antenna, diplexer, parametric amplifier, microwave bridge, receiver mixer, and connections with the antenna pointed to the zenith.

Table 8. Maser amplifier characteristics

Frequency, Mc	960
Gain, db	20
Noise temperature, °K	25
System temperature, °K	52 (approx)[a]
Gain stability with orientation, db	± 0.3

[a] Includes antenna, parametric amplifier, microwave bridge, receiver mixer, and connections as mounted with a Cassegrain feed, and with the antenna pointed to the zenith.

Table 9. Station recording equipment

Equipment	Goldstone		Woomera	South Africa	Mobile	Launch
	Echo	Pioneer				
Direct writing 8-channel						
Sanborn Model 358	1					
Sanborn Model 158		1			1	
Photographic oscillograph						
Midwest 621, 14-channel		1	1	1		
Photographic oscillograph						
Midwest 603, 36-channel	1	1	1	1	1	1
Tape recorder						
CEC 752A; ½-in. tape			2	2		
Tape recorder						
Ampex FR107; ½-in. tape	1	1				2
Tape recorder						
Ampex FR607; ½-in. tape	1	1				
Printer						
H-P 560A	1	1	1	1	1	

Table 10. Typical magnetic tape recorder[a] track assignments

Track	Assignment	Signal range
1	Station instrumentation	—
	VCO IRIG Channel 4 acquisition relay signal	—
	VCO IRIG Channel 5 static phase error	± 3 v
	VCO IRIG Channel 6 receiver signal strength	−90 to −153 dbm
	VCO IRIG Channel 7 amplitude modulation and acquisition relay signal	± 3 db
	VCO IRIG Channel 8 reference channel dynamic phase error	± 90 deg
2	Command modulation tones	1 v rms
3	Raw telemetry data	50 cps to 5 kc
4	Timing mixer	
	(1) Wow and flutter tones	6.25 kc
	(2) 100-pps NASA time code on 1,000-cps carrier	1000 cps
	(3) 2-pps NASA time code on 100-cps carrier	100 cps
5	Raw telemetry data	50 cps to 5 kc
6	Voice-station command line and voice label	3 kc
7	Tracking filter mixer (mixed VCO frequencies of all discriminators)	—

[a]Normal speed: 3¾ in./sec.

Table 9 lists the available recording equipment, and Tables 10 and 11 show magnetic tape and oscillograph track assignments.

Servosystem. At the Echo and Pioneer Stations, the antenna was positioned by an electrohydraulic servosystem which used the error signals from the receiver to position the antenna so that the error signals were nulled. Hydraulic drive systems were used because they produced no electrical interference and had a high static stiffness. Two-speed drive systems were employed at each station to provide the speed capability required for tracking spacecraft or an orbiting satellite. The low-speed antenna rates were 0.001 to 0.030 deg/sec for both axes. The high-speed rates ranged from 0.020 to 1 deg/sec for hour-angle and from 0.20 to 0.8 deg/sec for declination.

Table 11. Typical 36-channel photographic-oscillograph channel assignments

Channel	Function	Signal range
1	Static reference	—
2	One readout per minute time code	—
3	Receiver acquisition relay	0 to + 6 v
4	Acquisition switch position	0 to + 6 v
5	Antenna mode switch	0 to 28 v (stairstep)
6	Transmitter reverse power	—
7	Analog discriminator, Channel 1	—
8		
9	Static phase error	± 3 v
10		
11	RF hour-angle error	± 0.1 deg
12	Analog discriminator, Channel 2	—
13	RF declination-angle error	± 0.1 deg
14	Analog discriminator, Channel 3	—
15	Static reference	—
16	Analog discriminator, Channel 4	—
17	Signal strength	−90 to −160 dbm
18	Analog discriminator, Channel 5	—
19	Analog discriminator, Channel 6	—
20	Amplitude modulation	± 3 db
21	Analog discriminator, Channel 8	—
22	Analog discriminator, Channel B-2	—
23		
24	Dynamic phase error	± 90 deg
25		
26	Analog discriminator, Channel B-19	—
27		
28	Analog discriminator, Channel B-20	—
29		
30		
31	Digital azimuth error	+ 0.16 deg
32	Transmitter forward power	0 to 200 w
33	Digital elevation error	± 0.16 deg
34		
35		
36	Static reference	—

The antennas can be operated in winds up to 45 mph and can be driven to the stowed (minimum wind load) position in winds up to 60 mph. In the stowed position, the antennas can withstand winds of 120 mph.

b. Deep Space Communications Station: Woomera. The Woomera Deep Space Station, Woomera, Australia, operated by the Australian Department of Supply, is also sponsored by NASA and JPL as part of a permanent Deep Space Instrumentation Facility capable of tracking, commanding, and receiving telemetry from space vehicles.

The Australian Station is located 15 mi from Woomera village. Its facilities included a steerable, 85-ft-diameter, parabolic reflector antenna and associated drive system, radio-tracking and receiving equipment, and data recording and transmitting equipment. The antenna-reflector surface was polar mounted (moving parallel in hour-angle and perpendicular in declination to the Earth's equatorial plane) and had a pointing accuracy of better than 0.1 deg. The tracking system was comprised of a simultaneous lobing antenna feed supported at the focus of the reflector by a quadripod, a parametric low-noise amplifier, a phase-coherent receiving system, and an electrohydraulic servosystem. The receiver system detected a signal transmitted from the spacecraft and, from a combination of the antenna feed signals, provided a pointing error signal which was used by the servosystem to position the antenna. The station provided angle and two-way doppler data readouts on *Mariner II* for real-time transmission to JPL by teletype. The telemetry demodulator output was encoded in a suitable format and transmitted to JPL in near-real-time.

c. Deep Space Communications Station: Johannesburg. The Johannesburg, South Africa, Deep Space Station was staffed by personnel from the National Institute of Telecommunications Research (NITR) of the South African Council for Scientific and Industrial Research and was sponsored by NASA and JPL as part of a permanent Deep Space Instrumentation Facility.

The South African Station is located in a bowl-shaped valley, approximately 40 mi northwest of Johannesburg. This station had a standard, phase-locked, 960-Mc receiver diplexed with a 10-kw, 890-Mc transmitter to provide both precision two-way doppler and spacecraft command capability. A Read–Write–Verify unit was incorporated in the command system and allowed readback and confirmation of transmitted commands. The primary function of this station during the *Mariner II* mission was to track the spacecraft and to obtain precision doppler, engineering and scientific telemetry and tracking data. The station provided angle and precision doppler data readouts on *Mariner II* for real-time data transmission to JPL by teletype. The telemetry demodulator output was encoded in a suitable teletype format, and the data were transmitted by teletype to JPL in near-real-time.

d. Mobile Tracking Station. During the *Mariner* mission, the Mobile Station was located approximately 1 mi east of the DSIF Station at Johannesburg, South Africa. The Mobile Tracking Station was used primarily to obtain data at or near the *Mariner II* injection point. The station had a 10-ft parabolic antenna reflector that was capable of tracking 10 deg/sec. A circular polarized tracking antenna feed was mounted at the antenna reflector focal point. In addition to the standard receiving equipment, a 25-w, 890-Mc transmitter was diplexed on the antenna for the purpose of obtaining precision two-way doppler data. Angle and precision doppler data were transmitted to JPL by teletype in real-time.

Adequate support equipment is an important logistic factor in maintaining the Mobile Tracking Station in remote areas. An office van provided administrative space and also a central location for station documentation. Master patch panels were located in this van for the tactical inter-van intercom system, a paging system, a five-key telephone system, and a full duplex teletype terminal. Backup communications equipment consisted of a teletype converter and an S-line communications receiver and 2-kw transmitter. Power for the MTS was provided by four 75-kw diesel-driven generators and two 400-cps converters. Magnetic switches allowed for instantaneous transfer of load in the event of failure of either generators or converters. Diesel fuel was stored in a 4,000-gal fuel tanker. The rear of this tanker held spares for the air conditioning equipment (provided for each van) and for power generation equipment. A spare-parts van held spare modules, test equipment, and miscellaneous hardware and tools.

e. Spacecraft Monitoring Station. The Spacecraft Monitoring Station was located at Cape Canaveral, Florida, near Launch Complex 12. The station had two trailers: one for the transmitter and receiver and the other for test equipment, recording equipment, and equipment for processing portions of the received signal for real-time display on strip charts; a 6-ft-diameter dish antenna for

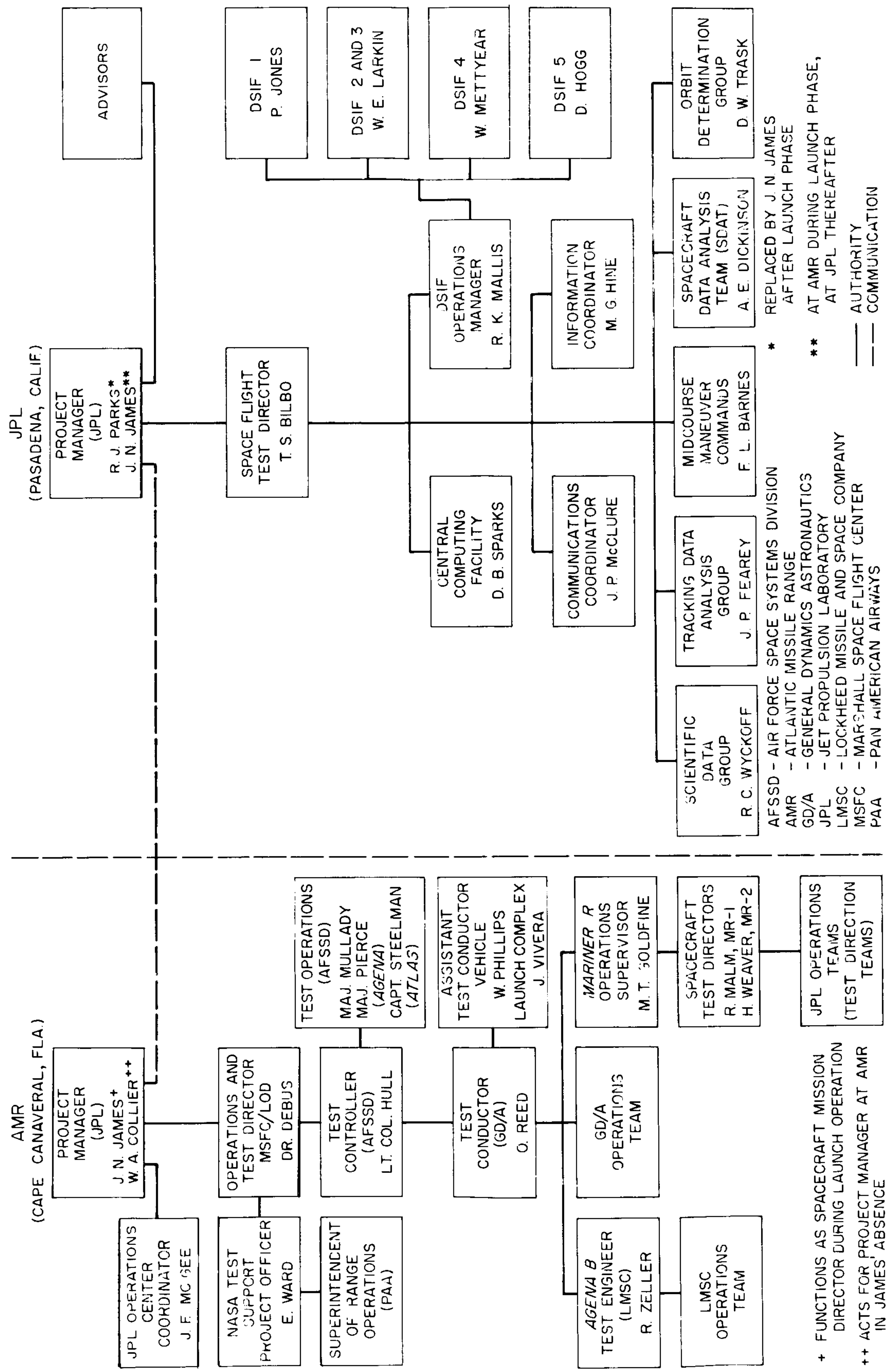


Fig. 35. Over-all *Mariner II* Project organization

receiving and transmitting; and a collimation tower for calibrating and checking station equipment. The tower simulated the spacecraft for checkout procedures, transmitting on the same frequencies used by *Mariner.*

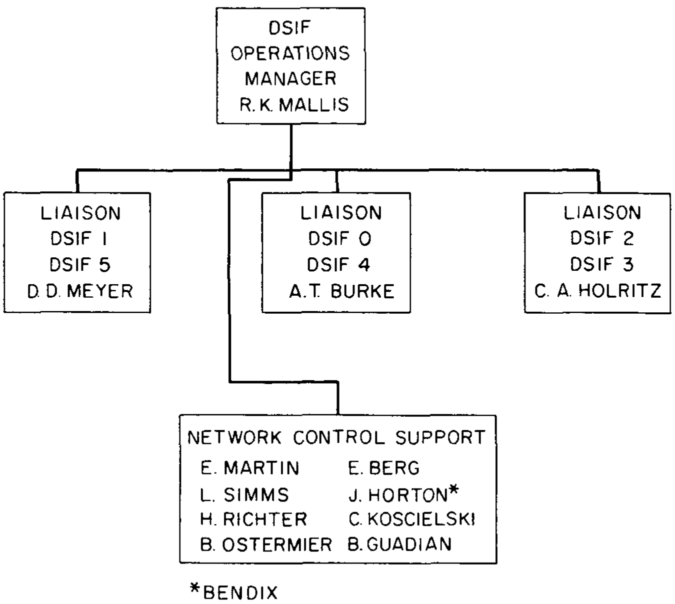


Fig. 36. Network Control organization

10. Space Flight Operations Organization

The following statement of responsibility is supplemented by organizational charts which depict the *Mariner* mission management. The charts include the over-all Project organization (Fig. 35), the Network Control organization (Fig. 36), the DSIF Operations organization (Fig. 37), and the organization of each DSIF Tracking Station (Figs. 38–43).

a. Project Manager, J. N. James. The Project Manager had the responsibility and authority for the execution to completion for the development and operation of the *Mariner II* mission.

b. Space Flight Test Director, T. S. Bilbo. It was the responsibility of the Space Flight Test Director to:

1. Interpret the standard operating procedure and place requirements consistent with the Space Flight Operations Plan (SFOP) on the various operating groups.
2. Resolve any ambiguities directly associated with the SFOP arising during its execution.
3. Make appropriate decisions requiring emergency action to assure success of the mission if the Project Manager could not be contacted.

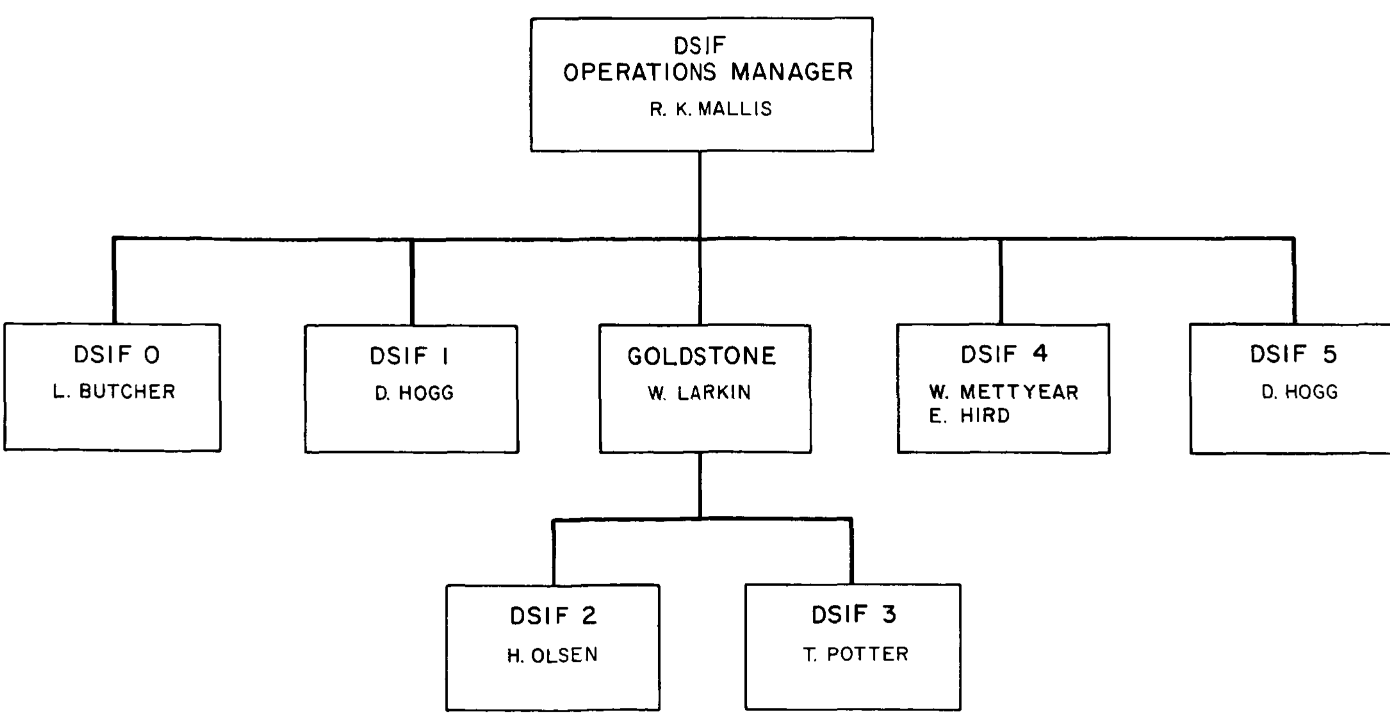


Fig. 37. DSIF organization

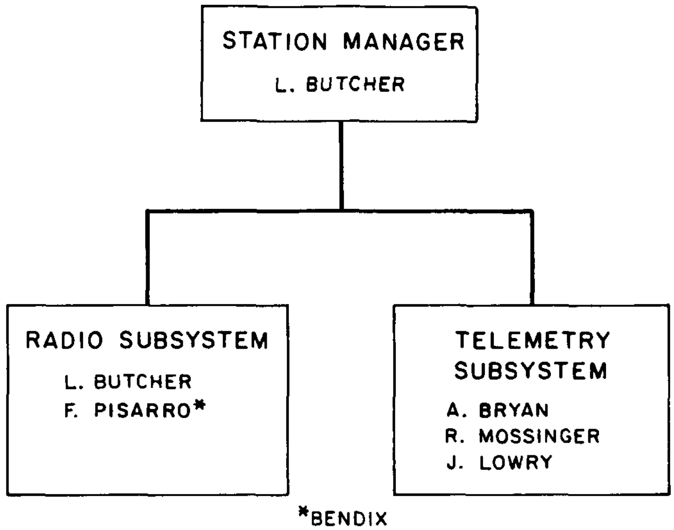


Fig. 38. Launch Station organization

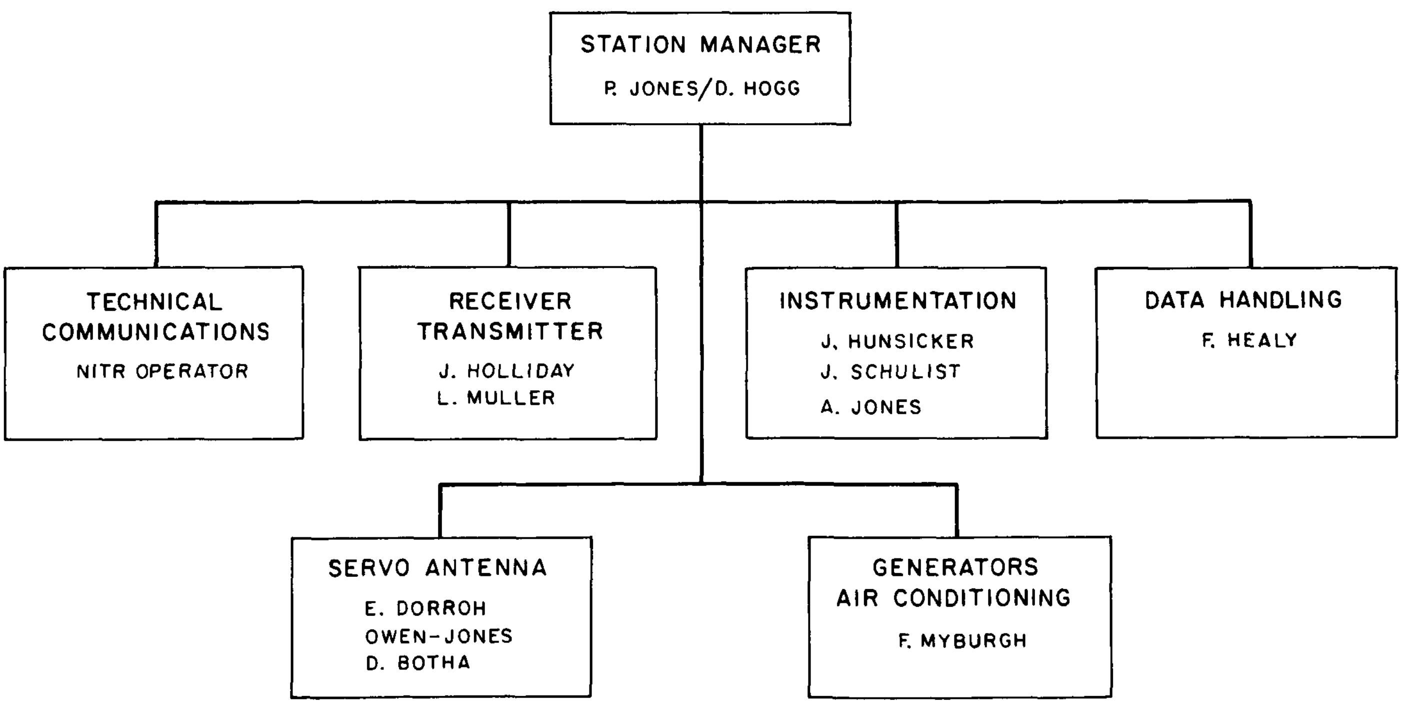


Fig. 39. Mobile Tracking Station organization

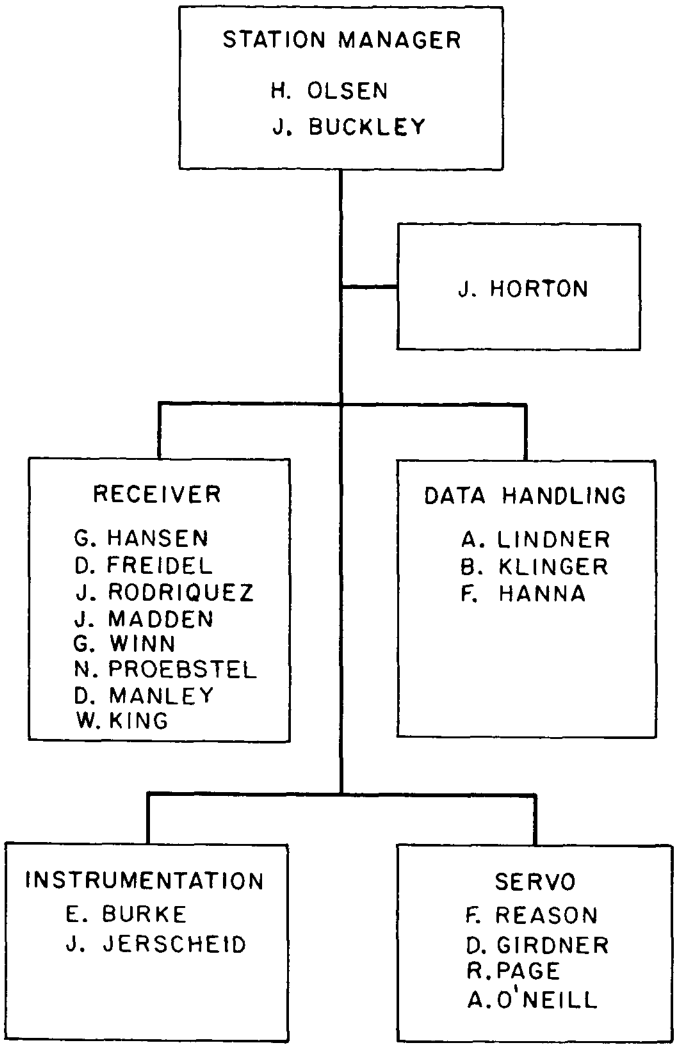


Fig. 40. Pioneer Station organization

In the fulfillment of his responsibility, the Space Flight Test Director was accountable to the Project Manager and was delegated the same authority as the Project Manager for placement of requirements on operating groups in accordance with the SFOP.

c. JPL/AMR Operation Center Coordinator, J. F. McGee. The JPL/AMR Operation Center Coordinator was responsible for systematically conducting all activity of the Operation Center during countdown and immediately after launch. He supervised the communication control system at AMR and provided coordinated use of cross-country leased voice circuits.

d. Advisors. It was the responsibility of the advisors to be aware of the performance of the spacecraft system, instrumentation subsystem, and DSIF during flight and supply judgment to the Project Manager as to possible future courses of action in the event of nonstandard behavior of the spacecraft.

e. DSIF Operations Manager, R. K. Mallis. It was the responsibility of the Operations Manager to direct the operation of the Deep Space Instrumentation Facility, including the transmission of data and commands between the spacecraft and the Central Computing Facility, so as to meet the requirements placed by the Space Flight Test Director in accordance with the SFOP.

f. Central Computing Facility, D. B. Sparks. It was the responsibility of the Central Computing Facility personnel to program and operate the computers and peripheral equipment (Sect. II) in accordance with the procedure outlined.

g. Scientific Data Group, R. C. Wyckoff. It was the responsibility of this Group to control the flow of, and mathematical operations on the data related to scientific experiments during the interval between its receipt from the DSIF and its transmission to the appropriate scientists. Any analysis or inflight evaluation of the scientific data was supplied by this Group.

h. Tracking Data Analysis Group, J. P. Fearey. It was the responsibility of this Group to evaluate the tracking data to be utilized in the orbit determination process and to evaluate the operation of the DSIF equipment used to generate those data.

i. Spacecraft Data Analysis Team (SDAT), A. E. Dickinson. It was the responsibility of this Group to evaluate spacecraft performance, to recommend to the Space Flight Test Director that commands be transmitted to the spacecraft as required, and to inform the Test Director of the results of these transmissions.

j. Orbit Determination Group, D. Trask. It was the responsibility of this Group to use the tracking and pertinent telemetry data to obtain the best estimate of the actual trajectory of the spacecraft according to the procedure outlined in Sect. VII. Acquisition and prediction information were supplied to the DSIF by this Group.

k. Midcourse Maneuver Commands, F. L. Barnes. The commands required for the midcourse maneuver were generated by F. L. Barnes in accordance with the procedure outlined.

l. Communications Coordinator, J. P. McClure. It was the responsibility of the Communications Coordinator to establish such operational voice and teletype circuits between JPL, AMR, and the DSIF Stations as were necessary to conduct the operations and maintain the operational communication networks used to coordinate the activities of the Space Flight Operations Complex at JPL. These responsibilities were discharged in accordance with the procedure outlined.

m. Information Coordinator, M. G. Hine. It was the responsibility of the Information Coordinator to obtain

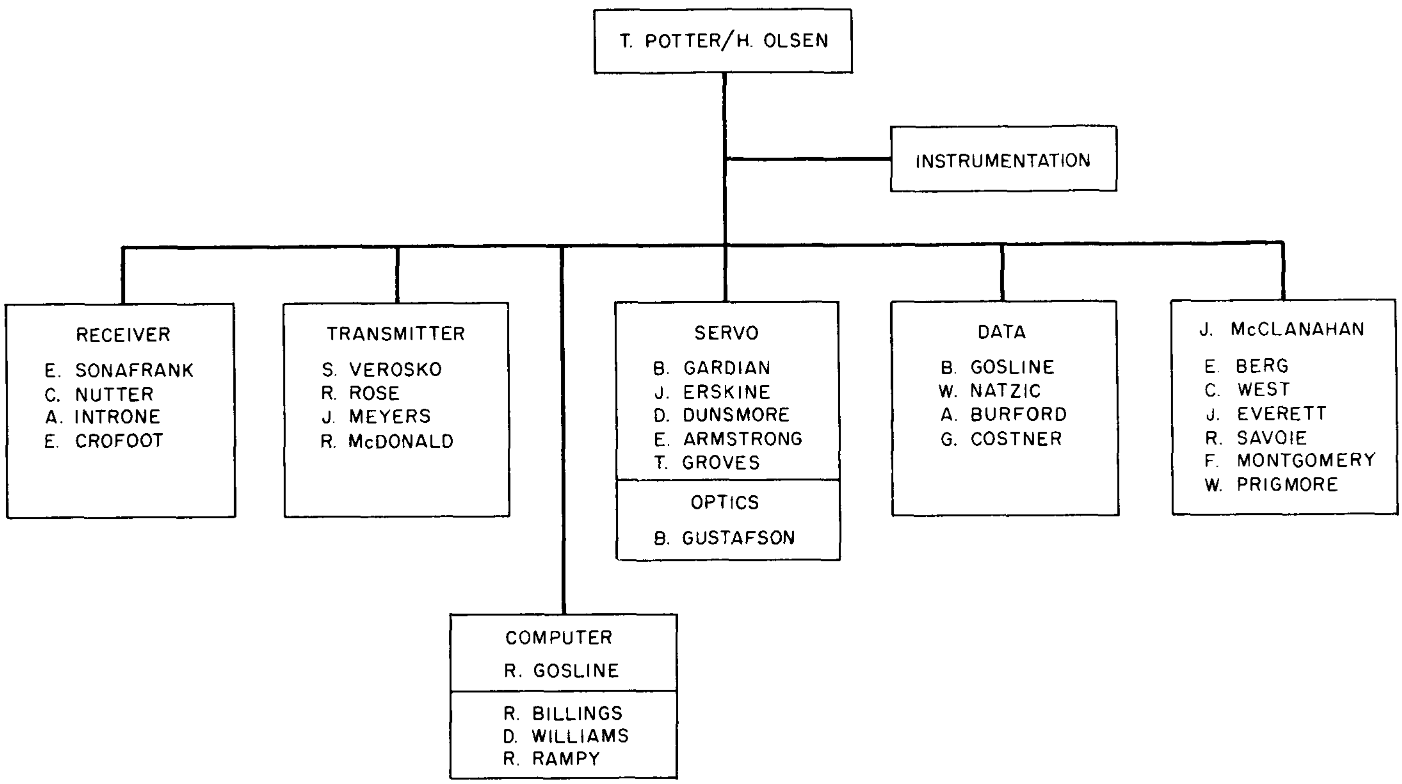


Fig. 41. Echo Station organization

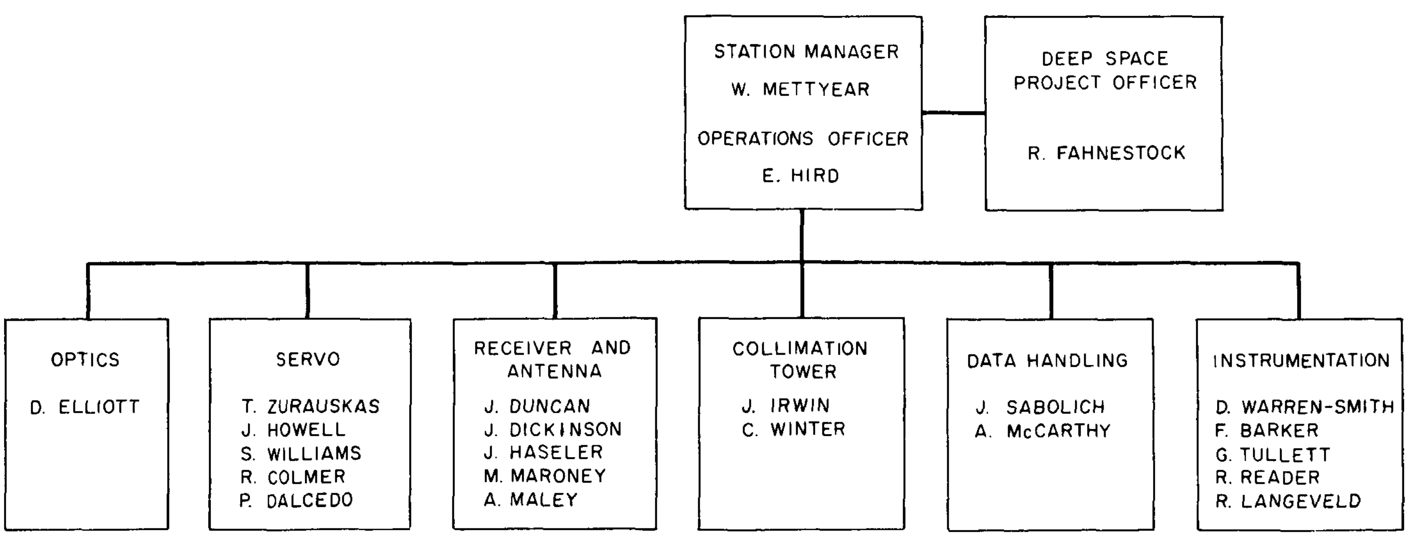


Fig. 42. Woomera Station organization

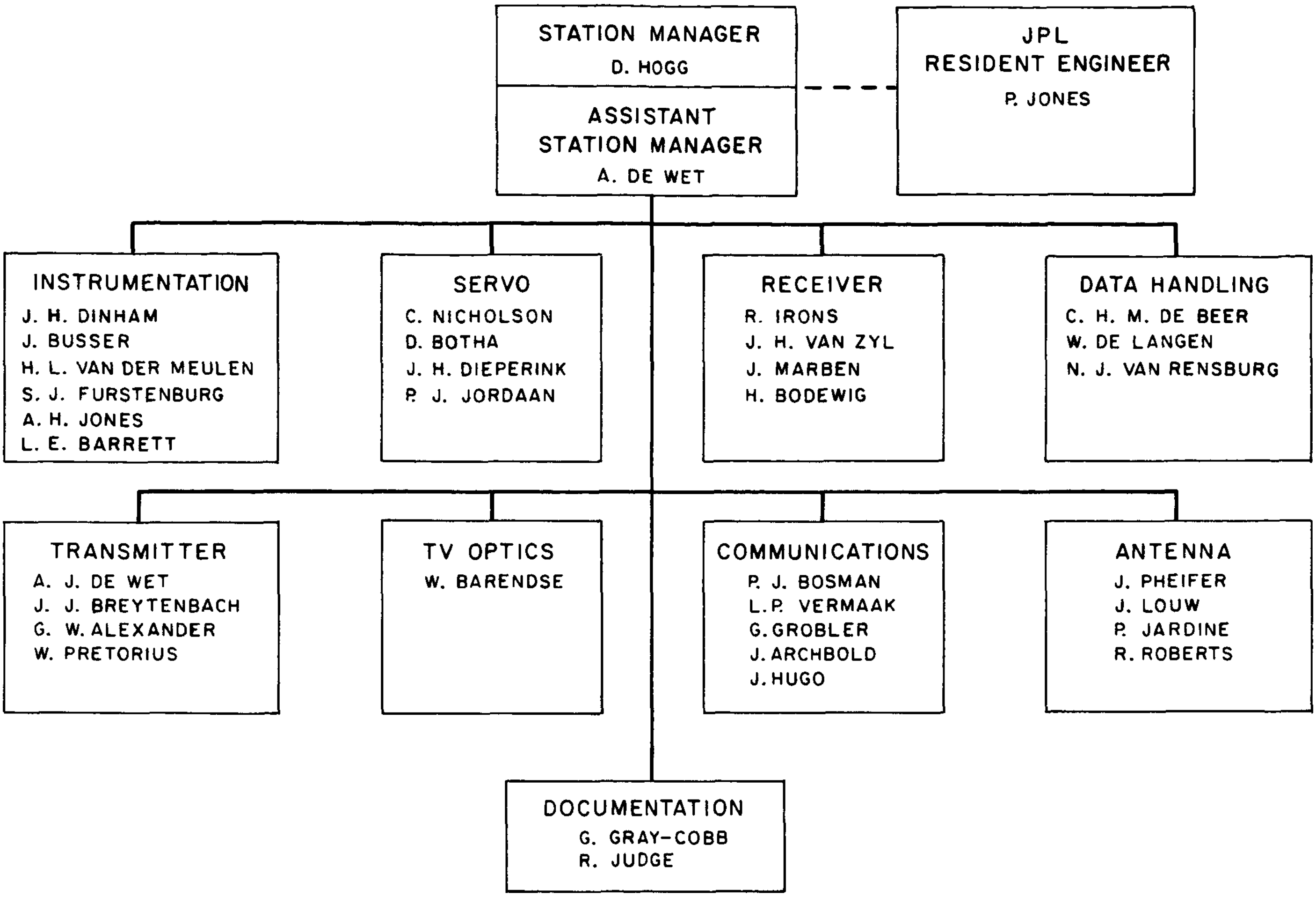


Fig. 43. Johannesburg Station organization

status information from all elements of the Space Flight Operations Complex on a timely basis, maintain the status boards in the Operations Center, and prepare status reports for the Project Manager and Test Director in accordance with the procedure outlined.

B. Flight Plan

Mariner II was the second of two flights, during the launch opportunity of 1962, aimed at Venus encounter. The primary objectives of the *Mariner* mission were to develop and launch two spacecraft to the near vicinity of the planet Venus in 1962. The primary objectives of the mission were to receive communications from the spacecraft in the vicinity of Venus and to perform a radiometric temperature measurement of the planet. A secondary objective of the mission was to make measurements of the interplanetary magnetic field and/or particle measurements in transit and in the vicinity of the planet.

A Venus "flyby" trajectory was chosen to maximize the amount of scientific data return. The closest approach was selected to be small enough to allow meaningful measurements to be made and big enough to ensure very low probability of impact with Venus.

In order to meet these objectives, the capability of obtaining precise interplanetary orbits with a spacecraft which could be stabilized, attitude-controlled, and guided had to be demonstrated by a thorough pre-flight analysis. In addition, there was needed an operational capability of determining the orbit from Earth-tracking data and commanding the execution of a precision midcourse correction (Table 4).

In short, analysis of the *Mariner II* mission entailed the following steps:

1. Designing the trajectory to satisfy strict objectives and constraints.

2. Determining a statistical description of injection errors and the midcourse-correction capability needed to correct these errors.
3. Analyzing the effect of the midcourse maneuver on the trajectory errors at Venus.
4. Developing the operational capability of tracking and executing the midcourse correction to maximize data return.

1. Trajectory

Consideration of a single trajectory for engineering design, as representing the Cytherean mission, is inappropriate. One should think of the mission as being represented by a set of standard trajectories and dispersions.

A maximum firing period for the two Venus launchings was restricted by the maximum velocity or geocentric energy which the *Mariner* spacecraft could achieve by utilizing the *Atlas–Agena* vehicle. In order to include all possible *Mariner* launch days, a firing period of 67 days was utilized in the trajectory design.

On any given day, the capability exists for launching over a period of time. Unless compensated for, a delay in the launch time causes an error at Venus encounter. This error increases as the delay becomes longer. The method used for compensation of the delay involves simultaneously altering the launch azimuth and the parking orbit coast time between the *Agena* burn periods. The Air Force Eastern Test Range is instrumented to cover southeast launches from 90 deg to 114 deg east of north. Further, trajectories in this corridor provide spacecraft injections near South Africa or between South Africa and Australia, so that either Johannesburg or Woomera acquires soon after injection. Mission design requirements for the launch opportunity on any given day for space vehicles of this complexity usually yield a minimum of 30 days of firing window.

Launch azimuths from 90 to 114 deg east of north were considered for the mission, and yield a 2.5- to 3.0-hr firing window.

The time of launch and the time from launch to geocentric injection varies with launch azimuth at launch date. For a launch azimuth of 90 deg east of north, the longest time from launch to injection is approximately 35 min, taking into account all possible launch days. For a launch azimuth of 114 deg east of north, the shortest time from launch to injection is approximately 21 min.

Approximately 8 to 10 days after launch, heliocentric injection occurs. At this time the probe begins to move primarily under the influence of the Sun in a near-elliptical orbit before aphelion. For the first 38 days of the firing period, the probe enters into its near elliptical orbit before aphelion; for the remainder of the firing period, heliocentric injection occurs after aphelion. If the Earth–Probe–Sun angle is less than 90 deg, the probe is outside the Earth's orbit, and a heliocentric injection time before aphelion is implied. If the angle is greater than 90 deg, the probe is within the Earth's orbit and a heliocentric injection time after aphelion is implied. The maximum Earth–Probe–Sun angle occurs some 25 to 35 days before Venus encounter. The Earth–Probe distance at this time varies from 16,000,000 to 28,000,000 km depending on the launch date. As the launch is delayed from the earliest to the latest launch date, flight time from launch to Venus encounter varies from 150 to 93 days, respectively. Thus, the mission was designed such that the two spacecraft could be launched during the 67-day firing window.

Mariner I was launched early in the window, thereby requiring a longer flight; *Mariner II* followed at a later date utilizing a shorter trajectory. The major constraint between the two was the time necessary on the launching pad to prepare *Mariner II* for the mission. The Earth–Venus communication distance at arrival also varies with date, as several arrival dates were utilized.

The near-Venus trajectory is approximately a hyperbola with respect to the target planet. The hyperbolic excess velocity varies from 5.5 to 6.0 km/sec depending on launch date. The probe approaches Venus from above the ecliptic plane and from behind (i.e., catching up with Venus in its orbit around the Sun). It was desired that the trajectory pass through a point which lies on the line of intersection of Venus' orbital plane and a plane normal to the Venus–Sun line containing the center of Venus. This nominal aiming point corresponds to a range of closest approach distance of 20,000 to 30,000 km dependent on launch date. Because of midcourse guidance errors, actual trajectories could miss the nominal aiming point by 15,000 to 20,000 km. The mission was such that the arrival dates at Venus encounter for the two spacecraft would not be separated by more than 14 days or less than 3 days. Thus, at Cytherean distances, the DSIF would have two spacecraft in view simultaneously. The trajectory was designed so that the probability that the unsterilized spacecraft would impact the planet Venus was less than 0.001%.

C. *Test Analysis*

1. Pre-Flight Calibration

In order to improve the quality of the primary angular data used in the Orbit Determination Program (ODP), it is first corrected for the antenna Optical Pointing Error (OPE). For the angle data Stations DSIF 4 and 5, this error was determined from a series of independent, horizon-to-horizon, star tracks conducted in 1961 and 62. A polynomial curve fit by the method of least squares was made to the differences between the refraction corrected Ephemeris values and the observed values read from the angle encoders. The OPE is then represented by the coefficients of the resulting polynomial. In general, the pre-flight calibration star tracks are required for two purposes: (1) to detect gross system errors, and (2) to test the validity of the correction polynomial. The coefficients describing the OPE for the *Mariner II* mission may be seen in Tables 12 and 13, which contain the results of pre-flight calibration tests conducted by DSIF 1, 4, and 5. These tables represent the evaluation of pertinent DSIF observables.

Table 12. Boresight versus polarization angle test results

DSIF	Signal strgth, dbm	Azimuth, deg		Elevation, deg		Hour angle, deg		Declination, deg	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
1	−120	0.229	0.224	−0.070	−0.096	—	—	—	—
	−130	—	—	—	—	—	—	—	—
	−140	0.205	0.165	0.080	0.124	—	—	—	—
4	−120	—	—	—	—	0.052	0.010	0.046	0.004
	−130	—	—	—	—	0.016	0.035	0.068	0.025
	−140	—	—	—	—	0.046	0.045	0.047	0.028
5	−120	—	—	—	—	−0.024	0.016	−0.003	0.005
	−130	—	—	—	—	−0.028	0.016	−0.006	0.004
	−140	—	—	—	—	−0.033	0.017	−0.033	0.006

Table 13. Angular error coefficient characteristics

DSIF 4	
$A_{00} = 8.55001840 \times 10^{-3}$	$B_{00} = 1.34309100 \times 10^{-2}$
$A_{01} = 5.45289422 \times 10^{-4}$	$B_{01} = 1.34214922 \times 10^{-4}$
$A_{02} = 2.48239589 \times 10^{-6}$	$B_{02} = -1.41108901 \times 10^{-5}$
$A_{03} = 2.24566914 \times 10^{-7}$	$B_{03} = 0.0$
$A_{10} = 4.27133878 \times 10^{-4}$	$B_{10} = -4.31028233 \times 10^{-4}$
$A_{11} = 8.69584098 \times 10^{-6}$	$B_{11} = 3.34771543 \times 10^{-6}$
$A_{12} = -6.52074417 \times 10^{-7}$	$B_{12} = 1.01895206 \times 10^{-7}$
$A_{13} = -1.59490382 \times 10^{-8}$	$B_{13} = 0.0$
$A_{20} = 2.53268802 \times 10^{-6}$	$B_{20} = -9.56363999 \times 10^{-6}$
$A_{21} = -7.04116079 \times 10^{-9}$	$B_{21} = 4.53942058 \times 10^{-9}$
$A_{22} = -7.04116079 \times 10^{-9}$	$B_{22} = 2.09578021 \times 10^{-9}$
$A_{23} = -1.23595449 \times 10^{-10}$	$B_{23} = 0.0$
$A_{30} = -8.38262784 \times 10^{-8}$	$B_{30} = 0.0$
$A_{31} = 1.90513748 \times 10^{-9}$	$B_{31} = 0.0$
$A_{32} = 3.95248319 \times 10^{-10}$	$B_{32} = 0.0$
$A_{33} = 9.57751208 \times 10^{-12}$	$B_{33} = 0.0$
DSIF 5	
$A_{00} = 9.14878200 \times 10^{-3}$	$B_{00} = 2.98696570 \times 10^{-2}$
$A_{01} = 1.58528433 \times 10^{-4}$	$B_{01} = 1.04434590 \times 10^{-4}$
$A_{02} = 6.24530962 \times 10^{-6}$	$B_{02} = -3.64955790 \times 10^{-6}$
$A_{03} = 3.43842729 \times 10^{-7}$	$B_{03} = 2.01838829 \times 10^{-7}$
$A_{10} = 3.95889511 \times 10^{-4}$	$B_{10} = -7.39376711 \times 10^{-5}$
$A_{11} = 9.36369950 \times 10^{-6}$	$B_{11} = 4.55037975 \times 10^{-6}$
$A_{12} = -3.41913978 \times 10^{-7}$	$B_{12} = -9.45727640 \times 10^{-8}$
$A_{13} = -3.76659061 \times 10^{-9}$	$B_{13} = -7.12650861 \times 10^{-9}$
$A_{20} = 4.31922333 \times 10^{-6}$	$B_{20} = -9.21918567 \times 10^{-6}$
$A_{21} = -1.03537453 \times 10^{-8}$	$B_{21} = 5.89778738 \times 10^{-8}$
$A_{22} = -3.04187273 \times 10^{-9}$	$B_{22} = 3.62801844 \times 10^{-9}$
$A_{23} = -1.52368379 \times 10^{-11}$	$B_{23} = -5.16572982 \times 10^{-11}$
$A_{30} = -4.82682978 \times 10^{-8}$	$B_{30} = 0.0$
$A_{31} = 6.22450846 \times 10^{-10}$	$B_{31} = 0.0$
$A_{32} = 1.79924034 \times 10^{-10}$	$B_{32} = 0.0$
$A_{33} = 3.31402952 \times 10^{-10}$	$B_{33} = 0.0$

Results of the boresight versus polarization angle tests are listed in Table 12. The mean error and standard deviation in degrees were computed for all polarization angles at each signal strength.

The angular error coefficients determined from star tracks conducted during 1961 and 1962 at DSIF 4 and 5 are presented in Table 13. These angular error coefficients represent the best estimate of optical pointing error and were preliminarily used to correct *Mariner II* angular data used by the Orbit Determination Program.

The RF boresight versus polarization angle test was an attempt to study the RF errors. The test was designed to correlate the optical and RF errors observed at the collimation tower over a range of signal levels and polarization angles. Experience has shown that the results of the test cannot be applied to the inflight data in a meaningful manner. Hence, for the purpose of describing the RF pointing error, the test is inadequate, and a new method for determining the RF antenna calibration is required. However, the tests are required to add to the composite statistical data, and they are an excellent indication of RF system status and autotrack capabilities.

a. DSIF 1. A boresight versus polarization angle test, originally conducted for *Mariner I* and considered adequate for *Mariner II*, was conducted on July 15, 1962.

The test was conducted at polarization angles of 0, 180, and 240 deg for signal strengths of -120 and -140 dbm. The mean error in azimuth exceeded *Rangers III* and *IV* by a factor of 2; the angle tracking jitter exceeded *Rangers III* and *IV* by a factor of 4. Since angular data from DSIF 1 are not primary data, the boresight/polarization test was considered satisfactory for the *Mariner II* mission. Star tracks were not conducted by DSIF 1 because angular data are not considered primary data.

b. DSIF 2. A star track of Alpha Aquilae (Altair) was conducted on August 3, 1962. Hour angle and declination residuals (observed minus computed) compared favorably with previous star tracks. Angular correction coefficients were not determined for DSIF 2, since the station would be in slave mode only for the *Mariner II* mission. Boresight versus polarization angle tests were not required for *Mariner II*.

c. DSIF 3. A star track of Alpha Aquilae (Altair) was conducted on August 8, 1962. Hour angle and declination residuals (observed minus computed) compared favorably with previous star tracks. Angular correction coefficients were not determined for DSIF 3, since the station would be acting as transmitter only for the *Mariner II* mission. Boresight versus polarization angle tests were not required for *Mariner II*.

d. DSIF 4. A star track of Alpha Aquilae (Altair) was conducted on August 16, 1962. A curve generated from a polynomial using the angular correction coefficients compared very favorably with the hour angle and declination residuals (observed minus computed) from the star track. Based on the August 16 star track, the angular correction coefficients determined from the 1961–1962 star tracks were considered to be the best estimate of OPE.

A boresight versus polarization angle test was conducted on July 12, 1962 at signal strengths of -120, -130 and -140 dbm. Results compared favorably with previous tests.

e. DSIF 5. A star track of Alpha Aquilae (Altair) was conducted on August 2, 1962. A curve generated from a polynomial using the angular correction coefficients determined from 1961–1962 star tracks compared very favorably with the hour angle residuals; however, the declination residuals were biased approximately -0.01 deg for the entire star track. A second star track of Alpha Aquilae (Altair) was conducted on August 17, 1962. The hour angle residuals from this star track again agreed favorably with the curve generated from the polynomial using the angular correction coefficients. Declination residuals for -30 HA 30 agreed with the polynomial. Film data were not taken to verify that the star was centered during these tracks. It was decided to use the angular correction coefficients from the 1961–1962 star tracks for the *Mariner II* mission.

IV. TRACKING OPERATIONS

A. Pre-Launch Phase

During the period prior to launch of *Mariner I*, all DSIF Stations were engaged in a thorough checkout of both system and subsystem configurations. Installation of new equipment, star tracking operations, and practice countdown tests ensured the optimum performance capability of all stations. DSIF Network integration tests were performed on July 16 and 19, 1962. All stations were ready before the initial, cancelled launch attempt on July 21.

On July 22, DSIF 0, the Spacecraft Monitoring Station, was locked to the spacecraft transponder at 08:18 GMT, about 1 hr prior to launch. The countdown proceeded smoothly from this point until launch, which occurred at 09:21.20 GMT. The receiver signal level at this time was −88 dbm. The station had a good track until 09:26.17 GMT, when the missile was destroyed by the Range Safety Officer because of a deviation from the planned flight path. The receiver dropped lock momentarily and then stayed in lock until 09:27.20 GMT, at which time the mission was concluded. During the launch phase, all data

Table 14. Schedule of DSIF Station pre-launch tests

Station	Location	Date (1962)	Test	Station	Location	Date (1962)	Test
Launch (DSIF 0)	Cape Canaveral, Florida	August 1	Dummy Run No. 1	Woomera (DSIF 4)	Island Lagoon, Australia	July 31	Star track
		August 3	J-FACT			August 3	Star track
		August 8	Final system			August 13	Aircraft track for collimation of acquisition aid antenna and acquisition training
		August 13	Operational readiness				Operational readiness
		August 24	Operational readiness			August 16	Star track
Mobile Tracking (DSIF 1)	Johannesburg, South Africa	August 13	Operational readiness			August 22	Aircraft track for acquisition training
		August 24	Operational readiness			August 24	Operational readiness
Pioneer (DSIF 2)	Goldstone, California	August 2	Star track	Johannesburg (DSIF 5)	Johannesburg, South Africa	August 2	Star track
		August 13	Operational readiness			August 13	Aircraft track for collimation of acquisition aid antenna and acquisition training
		August 24	Operational readiness				Operational readiness
Echo (DSIF 3)	Goldstone, California	August 9	Star track			August 17	Star track
		August 13	Operational readiness			August 21	Aircraft check to check acquisition antenna and provide acquisition practice
		August 16	Star track				
		August 24	Operational readiness				

Note: All systems operated satisfactorily.

from the spacecraft were good, and the demodulator stayed in lock until 09:26.17 GMT. Since the vehicle was destroyed a few minutes after launch, DSIF 0 was the only station to obtain data.

Measures were taken to correct the difficulty experienced in the *Mariner I* launch, including a more rigorous checkout of the *Atlas* rate beacon and revision of the data-editing equation. The data-editing equation is designed as a guard against acceptance of faulty data by the ground guidance equipment. The DSIF maintained an operational readiness during the period prior to the *Mariner II* launch. Preparation of the individual DSIF Stations was conducted as given in Table 14. All DSIF Stations were in an operational readiness state awaiting mission initiation.

Tables 15 through 18 outline, in chronological sequence, the major features of the DSIF operation during the *Mariner II* flight. Figure 44 shows the Earth track of *Mariner II* by DSIF installations throughout the world. The ground and spacecraft modes are given in Table 19; command functions for *Mariner II* are shown in Table 4.

Table 15. Operations log for Launch Countdown 2[a]

Time, GMT	Countdown time	Event
23:32	$T - 300$ min	Communications with Pasadena established
23:37	$T - 295$ min	Range count started
		Range status: All *green* with following exceptions:
		Computer on Twin Falls Victory Ship (TFV) is again inoperative. Uncorrected data expected from TFV
		No data from Station 92 because of communication problem between Stations 92 and 7
00:32	$T - 240$ min	Range Safety Command (RSC) checks started
00:45	$T - 227$ min	RSC checks satisfactorily completed
00:56	$T - 216$ min	No-voltage checks satisfactorily completed
01:07	$T - 205$ min	Count picked up with spacecraft
		Antenna reference hinge angle: 73.3 deg
		Encounter parameter: 1215 counts
01:12	$T - 200$ min	Spacecraft power on: 38 v, 4.9 amp
01:44	$T - 168$ min	AZUSA tracking system checks satisfactorily completed
02:05	$T - 147$ min	Correct light indication not received when *Atlas* main-battery activation initiated. Battery believed to be satisfactory, but will be replaced to gain additional assurance
02:15	$T - 137$ min	SRO report: Station 92 now in *green* condition
02:42	$T - 110$ min	Spacecraft report:
		Frequencies:
		960.036718 at 02:25 GMT
		890.037750 at 02:35 GMT
		960.040722 at 02:38 GMT
		Case II temperature: 93°F
		D-deck sync: 0241:09

[a]AMR Test No. 3731, August 26–27, 1962.

Table 15. Operations log for Launch Countdown 2 (cont'd)

Time, GMT	Countdown time	Event
02:52	$T - 100$ min	*Hold* for *Atlas* main-battery replacement, expected 30-min duration
03:01	$T - 100$ min	$T - 12$-hr weather report: go Bending moment: 24.5% Usable control: 18.4% Total effect: 52.5% $T - 6$-hr weather report: go Bending moment: 25.0% Usable control: 22.8% Total effect: 53.0%
03:02	$T - 100$ min	Decision made to change *Atlas* telemetry "can" because of unsatisfactory Channel 11 subcarrier
03:09	$T - 100$ min	*Atlas* main battery replaced and activated. Proper indication received
03:20	$T - 100$ min	*Hold* extended 15 min to complete installation of TV cameras on service tower (cameras required to monitor *Agena* acid tanking)
03:32	$T - 100$ min	Count resumed
03:35	$T - 97$ min	DSIF in *green* condition with exception of voice communications with DSIF 4 and 5, not yet established
03:37	$T - 95$ min	All spacecraft systems *go*
03:49	$T - 83$ min	Difficulties experienced with Pasadena end of circuit GT131-69
03:50	$T - 82$ min	100% acid tanking started
04:02	$T - 70$ min	All spacecraft systems *go*
04:03	$T - 69$ min	100% acid tanking completed
04:04	$T - 68$ min	Report received from Hangar AE Communications Center: circuit 69 checks out with CB toll office
04:12	$T - 60$ min	Built-in hold (BIH) started, expected duration 30 min Intermittent trouble reported with data links between Communications Center and 7090 computer at IPP (may prevent transmission of acquisition message to Stations 12, 13, and TFV)
04:42	$T - 60$ min	*Hold* extended by Mission Director to obtain verification of spacecraft battery life
04:43	$T - 60$ min	Count resumed
04:48	$T - 55$ min	DSIF *green* with exception of voice communication with DSIF 5. Trouble on voice line between London and Pretoria Spacecraft, vehicle, and range all in *green* condition
04:52	$T - 51$ min	Radar 1.16 (Cape FPS-16) reported inoperative

Table 15. Operations log for Launch Countdown 2 (cont'd)

Time, GMT	Countdown time	Event
05:03	$T - 40$ min	Spacecraft report:
		Frequencies:
		960.036751 at 04:45 GMT
		890.037600 at 04:51 GMT
		960.040537 at 04:53 GMT
		890.037750 at 04:49 GMT
		Minus 20 mv
		Case II temperature: 93°F
		D-deck sync: 0501:09
05:08	$T - 35$ min	Loop test satisfactorily completed
05:13	$T - 30$ min	Radar 1.16 now reported *green*
05:18	$T - 25$ min	T − 2-hr weather report: go
		Bending moment: 20%
		Usable control: 16%
		Total effect: 49.7%
05:24	$T - 19$ min	Voice communications with DSIF 5 now *green*
05:31	$T - 12$ min	Spacecraft report:
		Case II temperature: 93°F
		Encounter parameter: 1215 counts
05:36	$T - 7$ min	Spacecraft station: all systems *go*
05:38	$T - 5$ min	BIH started, expected duration 4 min
		Launch plan: 27D
		Ready reports:
		Vehicle: *go*
		Spacecraft: *go*
		Range: *no-go*
		GE guidance primary power lost. *Hold* extended for estimated 10 min
05:45	$T - 5$ min	*Hold* extended for additional 5 min
06:00	$T - 5$ min	Launch plan: 27F
		Ready reports:
		Vehicle: *go*
		Spacecraft: *go*
		Range: *go*
06:06	$T - 5$ min	Count resumed
06:10	$T - 60$ sec	*Hold:* GE guidance experiencing fluctuations on return signal. Recycled to $T - 5$ min

Table 15. Operations log for Launch Countdown 2 (cont'd)

Time, GMT	Countdown time	Event
06:22	$T - 5$ min	Launch plan: 27H Ready reports: Vehicle: go Spacecraft: go Range: go
06:26	$T - 5$ min	Count resumed
06:30	$T - 50$ sec	*Hold:* GE guidance experiencing fluctuations on return signal. Recycled to $T - 5$ min
06:34	$T - 5$ min	Voice communications with DSIF 5 out. RA-54 teletype line to DSIF 5 out
06:41	$T - 5$ min	Voice communications with DSIF 5 reinstated
06:43	$T - 5$ min	Remaining life (before launch) on *Atlas* main battery down to 3 min. When count resumed for next attempt, switch-over to internal power to be delayed until $T - 60$ sec to help conserve battery life
06:44	$T - 5$ min	Launch plan: 27K Ready reports: Vehicle: go Spacecraft: go Range: go
06:48	$T - 5$ min	Count resumed
06:53	$T - 0$	*Liftoff:* 06:53:13.927 GMT DSIF 0 in one-way lock at liftoff. Lock maintained, with momentary dropouts during booster staging, until final loss of signal at $L + 463$ sec. Signal level at launch: -85 dbm, gradually decreasing to -120 dbm just prior to dropout Normal operation indicated in preliminary evaluation of spacecraft data Event register reading subsequent to launch: 0-0-1-0 AMR inflight data transmission and computational operations all performing close to nominal times Following general evaluations yielded by real-time monitoring of AMR data: Station 91: Approximately 30% of data badly garbled. Corrected when Station 91 switched frequencies Station 12: Data generally of good quality TFV: All yaw data uncorrected on board ship because of inoperative computer. Real-time utilization of data prevented by data-handling problem at AMR Station 13: Data not time-labeled, preventing real-time utilization of information
07:24	$L + 1865$ sec	Spacecraft acquired by DSIF 1 at signal level of -100 dbm
07:32	$L + 2325$ sec	Reports received that DSIF 5 acquired spacecraft at 07:24 GMT
08:28	$L + 95$ min	Sun acquisition at 07:58:54 GMT confirmed by evaluation of spacecraft telemetry data at Hangar AE

Table 16. Summary of DSIF operations, launch to midcourse

Station	Pass	Date (1962)	Time of acquisition, GMT	Time of loss, GMT	Maximum received-signal strength, dbm	Remarks
Mobile Tracking	1	August 27	07:21:37	21:08:46	−100	Two-way lock at 07:30:38. Trouble in maintaining two-way lock. Also, trouble in data system, resulting in loss of approximately 2 hr of data
Johannesburg	1		07:31:45	21:04:35	−82	Initial attempts to obtain two-way lock not successful. Two-way lock acquired at 10:02
Woomera	1		07:37:30	13:18:00	−110	Two-way lock at 08:44:43. Receiver in- and out-of-lock between 08:14 and 08:44 while Johannesburg Station was attempting two-way lock
Pioneer	1		19:34:05	03:31:20	−122	Variations of 12 db in received signal noted, caused by maser and parametric amplifier drift. Two-way lock at 20:12
Echo	1		20:12:15	03:31:20		Transmitter power, 7 kw
Woomera	2	August 28	01:48:00	13:52:00	−128	Two-way lock at 03:01:13
Johannesburg	2		09:35:48	21:10:35	−132.5	No telemetry data sent by teletype until 11:27 because of telemetry demodulator difficulties
Pioneer	2		19:37:30	06:09:00	−132	Maser bypassed for this tracking period. Two-way lock at 20:26:23
Echo	2		20:00:35	06:09:00		
Woomera	3	August 29	01:51:10	13:58:00	−134.5	Two-way lock at 06:10
Johannesburg	3		09:34:34	21:06:40	−126	Two-way lock from 11:51 to 20:18. RTC 8 transmitted at 16:13:00
Pioneer	3		19:41:00	06:25:45	−138.2	Two-way lock at 20:01:49
Echo	3		20:01:49	05:48:00		
Woomera	4	August 30	01:51:30	13:57:00	−138	Two-way lock at 05:53
Johannesburg	4		09:40:20	21:02:20	−142	Two-way lock at 13:20:50
Pioneer	4		19:32:00	06:27:48	−137	Two-way lock at 21:05:45; maser back in operation
Echo	4		20:05:00	06:27:00		

Table 16. Summary of DSIF operations, launch to midcourse (cont'd)

Station	Pass	Date (1962)	Time of acquisition, GMT	Time of loss, GMT	Maximum received-signal strength, dbm	Remarks
Woomera	5	August 31	01:46:00	13:53:06	−140	50-w transmitter at Woomera not used after August 30
Johannesburg	5		09:32:05	21:01:01	−140.5	Two-way lock at 09:33:15. Scheduled transmitter-power decrease from 400 to 20 w to determine transponder threshold
Pioneer	5		19:28:15	06:21:40	−138	Two-way lock at 19:30:25
Echo	5		19:20:00	06:20:00		
Woomera	6	September 1	01:53:00	13:50:00	−142.5	
Johannesburg	6		09:30:00	20:56:35	−142	Listening feed installed before this track
Pioneer	6		19:23:00	06:20:21	−142	Considerable variation in received-signal level because of maser and parametric amplifier gain variation
Echo	6		19:25:00	06:20:00		
Woomera	7	September 2	01:44:00	13:41:00	−144	
Johannesburg	7		11:58:15	19:56:00		Attempt for two-way lock prevented by noise problem in transmitter
Pioneer	7		19:20:30	06:16:00	−128	Received-signal level, −145 dbm before Earth acquisition. Two-way lock at 19:20:30
Echo	7		19:20:00	06:15:00		
Woomera	8	September 3	01:41:00	13:38:00	−124	Decrease in received-signal level to −161 dbm and lock-drop by receiver before Earth acquisition
Johannesburg	8		13:45:00	20:51:34	−125	
Pioneer	8		19:15:50	06:14:00		Two-way lock at 19:27:00
Echo	8		19:27:00	06:15:00		
Woomera	9	September 4	01:40:00	13:42:00	−125	
Johannesburg	9		09:15:62	20:47:40		Two-way lock at 09:18:27
Pioneer	9		19:09:00	06:00:29	−129	Decrease in signal level to −156 dbm during midcourse maneuver
Echo	9		19:09:00	06:00:00		Commands transmitted for midcourse maneuver

Table 17. Midcourse maneuver command sequence

Command	Time initiated, GMT	Time transmitted, GMT	Time verified, GMT
SC-1	21:30:00	21:30:32	21:30:57
SC-2	21:32:00	21:32:31	Inhibited[a]
SC-2	21:35:00	21:35:30	21:35:57
SC-3	21:37:00	21:37:28	Inhibited[a]
SC-3	22:23:00	22:23:28	22:23:56
RTC-4	22:39:00	22:39:31	22:39:58
RTC-6	22:49:00	22:49:29	22:49:57

[a]When SC-2 was inhibited, the cause was assumed to be a momentary loss of sync between the read–write–verify (RWV) modulator and detector. When SC-3 was inhibited, a thorough investigation showed the temperature in the modulator compartment of the RWV system to be much lower than normal. The compartment was left open, allowing the temperature to rise, and the system then functioned normally throughout the remainder of the command sequence.

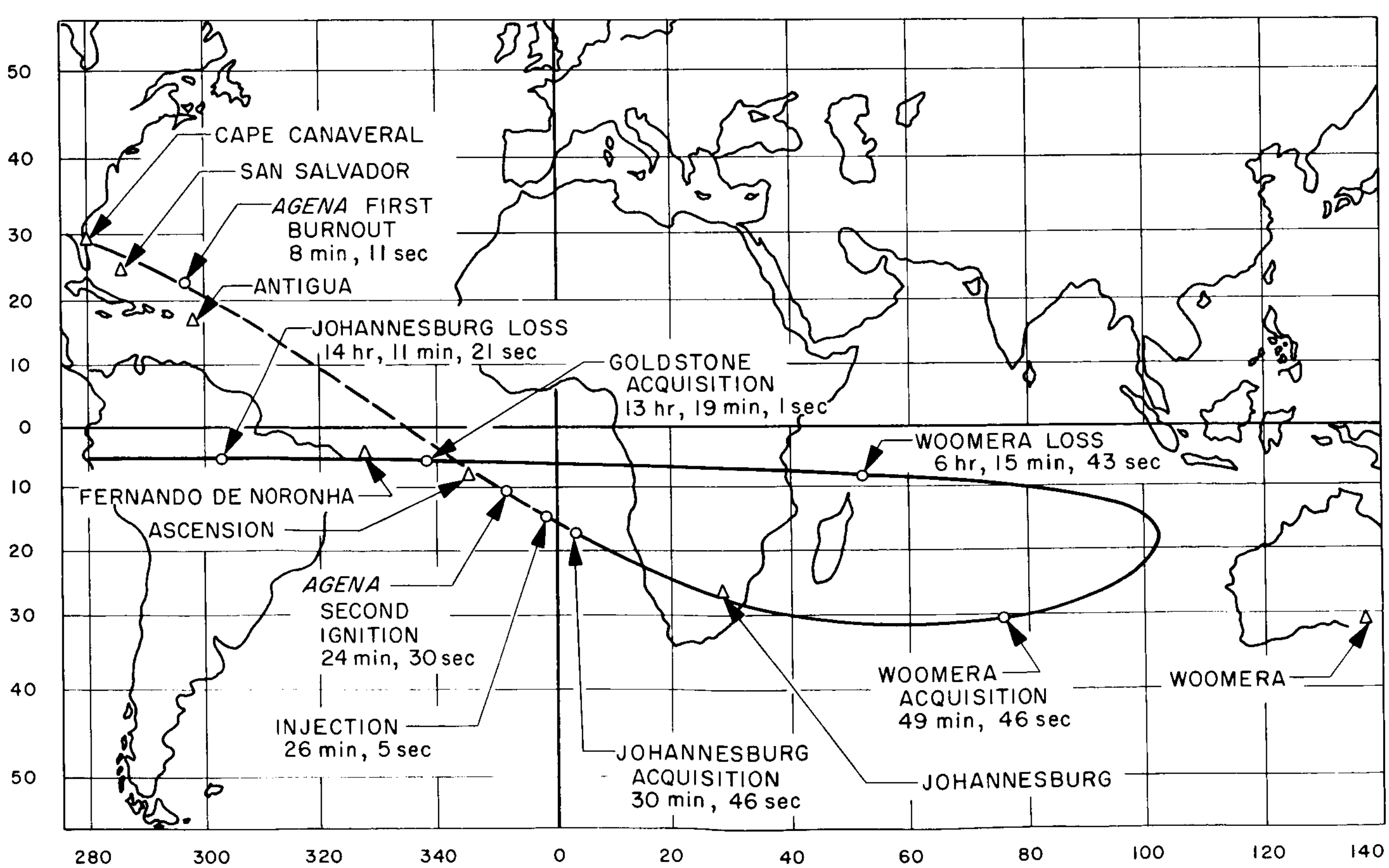


Fig. 44. Earth track of *Mariner II*

Table 18. Summary of DSIF operations, midcourse to end of mission

Station	Pass	Date (1962)	Time of acquisition, GMT	Time of loss, GMT	Maximum received-signal strength, dbm	Remarks
Woomera	10	September 5	01:30	13:31	−125	—
Johannesburg	10		09:19	20:43	−126	Two-way lock from 09:56–18:50
Pioneer	10		19:04	06:00	−127	Two-way lock at 19:15
Echo	10		19:15	06:00		
Woomera	11	September 6	01:40	13:34	−128	—
Johannesburg	11		09:07	19:14	−125.5	Two-way lock from 09:22–18:50
Pioneer	11		19:00	06:10	−127	Two-way lock at 19:40
Echo	11					
Woomera	12	September 7	01:20	13:31	−127.5	—
Johannesburg	12		09:00	20:36	−126.5	Two-way lock from 09:36–18:50
Pioneer	12		18:57	06:05	−128.5	Two-way lock at 18:59
Echo	12		18:59	06:00		
Woomera	13	September 8	01:15	13:27	−126	—
Johannesburg	13		09:02	19:50	−127.5	Two-way lock from 09:28–18:45
Pioneer	13		18:53	06:01	−130	Two-way lock at 18:53
Echo	13		18:53	06:00		
Woomera	14	September 9	03:52	10:00	−128	—
Johannesburg	14		08:54	20:28	−128.5	One-way lock
Pioneer	14		18:48	05:55	−126.5	One-way lock
Echo	14					Not scheduled
Woomera	15	September 10				Not scheduled
Johannesburg	15		08:50	20:20	−129.5	One-way lock
Pioneer	15		18:39	05:48	−131	One-way lock
Echo	15					Not scheduled
Woomera	16	September 11	01:04	13:15	−130	—
Johannesburg	16					Not scheduled
Pioneer	16					Not scheduled
Echo	16					Not scheduled
Woomera	17	September 12				Not scheduled
Johannesburg	17		09:01	20:13	−132	One-way lock
Pioneer	17					Not scheduled
Echo	17					Not scheduled
Woomera	18	September 13	00:55	13:05	−132.5	
Johannesburg	18		00:	00:		Not scheduled
Pioneer	18		18:31	05:40	−133	One-way lock
Echo	18					Not scheduled
Woomera	19	September 14				Not scheduled
Johannesburg	19		08:48	20:06	−131.5	
Pioneer	19		18:28	05:27	−132	Two-way lock at 18:38
Echo	19		18:37	05:20		
Woomera	20	September 15	00:55	09:00	−131	
Johannesburg	20		08:29	20:01	−132.5	
Pioneer	20					Not scheduled
Echo	20					Not scheduled
Woomera	21	September 16	00:42	12:52	−131.5	
Johannesburg	21					Not scheduled
Pioneer	21		18:20	03:15	−132	One-way lock
Echo	21					Not scheduled

Table 18. Summary of DSIF operations, midcourse to end of mission (cont'd)

Station	Pass	Date (1962)	Time of acquisition, GMT	Time of loss, GMT	Maximum received-signal strength, dbm	Remarks
Woomera	22	September 17	02:38	11:00	−131.5	
Johannesburg	22		10:30	19:15	−132	
Pioneer	22		18:30	04:00	−132	One-way lock
Echo	22					Not scheduled
Woomera	23	September 18	03:20	12:30	−131.5	
Johannesburg	23		11:45	19:00	−132	
Pioneer	23		18:30	03:00	−132.5	One-way lock
Echo	23					Not scheduled
Woomera	24	September 19	02:26	11:00	−134	
Johannesburg	24		10:33	19:00	−132.5	
Pioneer	24		18:30	03:00	−132.5	One-way lock
Echo	24					Not scheduled
Woomera	25	September 20	02:13	11:00	−134.5	
Johannesburg	25		10:30	18:45	−133.5	
Pioneer	25		18:15	02:45	−134	One-way lock
Echo	25					Not scheduled
Woomera	26	September 21	02:11	10:45	−134.7	
Johannesburg	26		10:08	18:46	−133	
Pioneer	26		18:15	02:45	−130	One-way lock
Woomera	27	September 22	02:05	10:45	−133.8	
Johannesburg	27		10:15	18:45	−134	
Pioneer	27		18:08	04:45	−135	Two-way lock at 18:08
Echo	27		17:58	04:45		
Woomera	28	September 23	02:08	10:45	−134	
Johannesburg	28		10:12	18:57	−133.5	
Pioneer	28		17:47	04:33	−135	Two-way lock at 17:57
Echo	28		17:52	04:30		
Woomera	29	September 24	01:45	10:30	−135	
Johannesburg	29		09:31	18:30	−134	
Pioneer	29		18:00	02:30	−134	One-way lock
Woomera	30	September 25	01:57	10:30	−135	
Johannesburg	30		09:45	18:30	−134	
Pioneer	30		17:40	03:00	−137	One-way lock
Woomera	31	September 26	01:54	10:30	−135.4	
Johannesburg	31		10:02	18:30	−134.5	
Pioneer	31		17:38	04:35	−135.5	One-way lock
Woomera	32	September 27	01:52	10:30	−136	
Johannesburg	32		09:46	18:15	−135	
Pioneer	32		17:29	03:00	−135.5	One-way lock
Woomera	33	September 28	01:46	10:15	−136.3	
Johannesburg	33		09:45	18:15	−135	
Pioneer	33		18:07	02:45	−134.5	
Woomera	34	September 29	01:39	10:15	−135.7	
Johannesburg	34		09:44	18:45	−135.1	
Pioneer	34		17:19	04:01	−136.3	Two-way lock at 17:19
Echo	34		17:04	04:00		
Woomera	35		23:51	10:00	−137.4	
Johannesburg	35	September 30	09:28	18:00	−136.1	
Pioneer	35		17:24	02:30	−136.5	One-way lock
Woomera	36	October 1	01:25	11:00	−137.9	
Johannesburg	36		09:30	18:00	−136.3	

Table 18. Summary of DSIF operations, midcourse to end of mission (cont'd)

Station	Pass	Date (1962)	Time of acquisition, GMT	Time of loss, GMT	Maximum received-signal strength, dbm	Remarks
Pioneer	36		17:08	02:30	−136.2	One-way lock
Woomera	37	October 2	01:15	09:45	−137.8	
Johannesburg	37		09:07	17:45	−136.4	
Pioneer	37		17:04	02:15	−136.5	One-way lock
Woomera	38	October 3	01:11	09:45	−136.5	
Johannesburg	38		09:06	17:45	−136	
Pioneer	38		16:58	02:15	−137.5	One-way lock
Woomera	39	October 4	01:15	09:45	−138	
Johannesburg	39		09:09	17:30	−136	
Pioneer	39		17:13	02:00	−137.5	One-way lock
Woomera	40	October 5	01:00	09:30	−138.2	
Johannesburg	40		08:58	17:30	−136.8	
Pioneer	40		16:51	02:00	−136.4	One-way lock
Woomera	41	October 6	01:03	09:30	−138.1	
Johannesburg	41		08:52	17:30	−137.7	
Pioneer	41		16:43	03:30	−136.4	One-way lock
Woomera	42	October 7	00:42	09:15	−138.4	
Johannesburg	42		08:45	17:15	−136	
Pioneer	42		16:50	02:00	−137.5	One-way lock
Woomera	43	October 8	00:42	09:15	−139.1	
Johannesburg	43		08:26	17:00	−137.7	
Pioneer	43		16:35	01:45	−139	One-way lock
Woomera	44	October 9	00:26	09:00	−139.1	
Johannesburg	44		08:51	17:00	−138.4	
Pioneer	44		16:25	01:45	−141.5	One-way lock
Woomera	45	October 10	00:33	09:00		No signal strength due to AGC trouble
Johannesburg	45		09:01	16:15	−138.3	
Pioneer	45		16:28	23:15	−139.5	One-way lock
Woomera	46		23:00	08:15	−143.4	
Johannesburg	46	October 11	08:07	17:00	−134	
Pioneer	46		16:26	01:30	−139.2	One-way lock
Woomera	47	October 12	00:23	09:00	−143.6	
Johannesburg	47		08:11	17:02	−140.1	
Pioneer	47		16:17	01:30	−139	One-way lock
Woomera	48	October 13	00:12	08:45	−143.4	
Johannesburg	48		08:19	16:15	−139	
Pioneer	48		16:06	23:12	−139	
Woomera	49		22:38	08:30	−149.9	
Johannesburg	49	October 14	08:09	17:15	−139.4	
Pioneer	49		16:16	03:00	−139.2	Two-way lock at 16:16
Echo	49		15:30	02:50		
Woomera	50		22:20	08:30	−144.6	
Johannesburg	50	October 15	07:59	16:50	−139.3	
Pioneer	50		15:54	01:30	−138.5	One-way lock
Woomera	51	October 16	00:28	08:32	−139.4	
Johannesburg	51		08:26	16:45	−139.4	
Pioneer	51		15:50	01:30	−139.5	One-way lock
Woomera	52	October 17	00:45	09:00	−140	

Table 18. Summary of DSIF operations, midcourse to end of mission (cont'd)

Station	Pass	Date (1962)	Time of acquisition, GMT	Time of loss, GMT	Maximum received-signal strength, dbm	Remarks
Johannesburg	52		08:00	16:30	−139.3	
Pioneer	52		16:03	01:17	−141	One-way lock
Woomera	53	October 18	00:15	00:45	−140.5	
Johannesburg	53		08:12	15:30	−142.1	
Pioneer	53		15:38	02:40	−140.3	One-way lock
Woomera	54	October 19	04:35	09:58	−141	Late acquisition due to *Ranger V* tracking
Johannesburg	54		11:20	15:36	−141	
Pioneer	54		16:33	02:34	−140	One-way lock
Woomera	55	October 20	03:46	09:52	−141.1	Late acquisition due to *Ranger V* tracking
Johannesburg	55		11:09	17:03	−141.1	
Pioneer	55		16:07	02:33	−141	One-way lock
Woomera	56	October 21	03:46	00:48	−138.2	Late acquisition due to *Ranger V* tracking
Johannesburg	56		11:02	16:59	−141	
Pioneer	56		20:54	02:26	−142.5	One-way lock
Woomera	57	October 22	03:42	09:41	−140.8	Late acquisition due to *Ranger V* tracking
Johannesburg	57		08:26	16:54	−143.1	
Pioneer	57		15:26	01:00	−142.5	One-way lock
Woomera	58		23:59	08:30	−139	
Johannesburg	58	October 23	08:00	16:30	−141.5	
Pioneer	58		15:21	01:00	−141.9	One-way lock
Woomera	59		23:38	08:15	−137.6	
Johannesburg	59	October 24	07:45	16:42	−141.7	
Pioneer	59		14:31	01:50	−141.5	Two-way lock at 14:38
Echo	59		14:38	01:50		
Woomera	60		22:42	08:11	−142.1	
Johannesburg	60	October 25	06:53	16:00	−142.5	
Pioneer	60		14:59	00:27	−141	One-way lock
Woomera	61		23:21	07:45		No signal level recorded because of parametric amplifier trouble
Johannesburg	61	October 26	06:49	15:45		No AGC calibration
Pioneer	61		14:56	00:15	−142	One-way lock
Woomera	62		23:16	07:45	−145.6	
Johannesburg	62	October 27	06:49	16:15	−142	
Pioneer	62		14:52	01:32	−142.5	Two-way lock at 15:37
Echo	62		14:52	01:32		
Woomera	63		22:25	07:30	−146.8	
Johannesburg	63	October 28	06:22	15:30	−143.9	
Pioneer	63		14:47	23:10	−142.1	One-way lock
Woomera	64		22:45	07:30	−145.9	
Johannesburg	64	October 29	06:27	15:30	−142	
Pioneer	64		14:41	23:51	−142.4	One-way lock
Woomera	65		22:57	07:30	−145.6	

Table 18. Summary of DSIF operations, midcourse to end of mission (cont'd)

Station	Pass	Date (1962)	Time of acquisition, GMT	Time of loss, GMT	Maximum received-signal strength, dbm	Remarks
Johannesburg	65	October 30	06:30	15:30	−142.2	
Pioneer	65		14:35	00:00	−143.8	One-way lock
Woomera	66		22:59	07:30	−146.7	
Johannesburg	66	October 31	06:20	15:30	−144.5	Horn feed installed after this tracking period
Pioneer	66		14:47	23:45	−145	Two-way lock 20:00 to 20:42
Echo	66		19:57	20:42		RTC-10 initiated at 20:25:30 and verified at 20:26:27
Woomera	67		22:30	07:15	−147.1	
Johannesburg	67	November 1	06:20	15:15	−142.4	
Pioneer	67		14:34	23:45	−143	One-way lock
Woomera	68		22:41	06:53	−147.1	
Johannesburg	68	November 2	06:19	15:15	−142.4	
Pioneer	68		14:23	01:13	−146	One-way lock
Woomera	69	November 3	00:26	07:15	−147.4	
Johannesburg	69		06:10	15:15	−143.6	
Pioneer	69		14:17	01:08	−143.5	One-way lock
Woomera	70	November 4	01:12	07:00	−144.4	
Johannesburg	70		06:07	15:00	−143.4	
Pioneer	70		14:12	23:30	−143.5	One-way lock
Woomera	71		21:45	07:00	−145.5	
Johannesburg	71	November 5	06:04	15:30	−143	
Pioneer	71		14:07	00:32	−143.5	Two-way lock at 14:07
Echo	71		00:30	13:55		
Woomera	72		21:15	07:32	−144.2	
Johannesburg	72	November 6	05:39	14:45	−144.7	
Pioneer	72		14:03	23:15	−144	One-way lock
Woomera	73		21:59	06:45	−144.9	
Johannesburg	73	November 7	05:39	14:45	−144	
Pioneer	73		13:58	23:00	−144.5	One-way lock
Woomera	74		21:36	06:30	−145.4	
Johannesburg	74	November 8	05:22	14:30	−143.2	
Pioneer	74		13:54	23:00	−144.7	Two-way lock at 20:46–22:32
Echo	74		20:45	22:32		RTC-8 initiated at 21:25:00 and verified at 21:26:00
Woomera	75		21:42	06:30	−145.1	
Johannesburg	75	November 9	05:30	15:20	−143.7	
Pioneer	75		13:50	22:08	−144	One-way lock
Woomera	76		21:17	06:30	−147.3	
Johannesburg	76	November 10	05:28	15:30	−144	
Pioneer	76		13:45	00:32	−145.5	Two-way lock at 13:45
Echo	76		13:43	00:35		
Woomera	77		20:24	06:15	−146.8	
Johannesburg	77	November 11	05:14	14:15	−143.4	

Table 18. Summary of DSIF operations, midcourse to end of mission (cont'd)

Station	Pass	Date (1962)	Time of acquisition, GMT	Time of loss, GMT	Maximum received-signal strength, dbm	Remarks
Pioneer	77		13:40	22:45	−146	One-way lock
Woomera	78		21:22	06:00	−145.6	
Johannesburg	78	November 12	05:10	14:15	−145.3	
Pioneer	78		13:36	23:30	−145.5	One-way lock
Woomera	79		21:05	06:00	−146.8	
Johannesburg	79	November 13	04:59	14:00	−145	
Pioneer	79		13:33	22:30	−145	One-way lock
Woomera	80		21:06	06:00	−146.7	
Johannesburg	80	November 14	05:02	14:00	−146	
Pioneer	80		13:28	22:30	−145	One-way lock
Woomera	81		21:15	06:00	−147.2	
Johannesburg	81	November 15	04:54	14:00	−145.2	
Pioneer	81		13:24	22:30	−145.5	One-way lock
Woomera	82		21:19	06:59	−146	
Johannesburg	82	November 16	05:48	14:00	−147.1	
Pioneer	82		13:22	21:55	−146	One-way lock
Woomera	83		21:16	06:00	−146.2	
Johannesburg	83	November 17	05:00	14:40	−146	
Pioneer	83		13:20	23:58	−146	Two-way lock at 13:20
Echo	83		13:13	24:00		
Woomera	84		21:01	05:45	−148.2	
Johannesburg	84	November 18	04:52	13:45	−146.6	
Pioneer	84		13:14	22:15	−146	One-way lock
Woomera	85		20:56	05:46	−146.9	
Johannesburg	85	November 19	04:51	13:45	−147.1	
Pioneer	85		13:15	22:15	−146	One-way lock
Woomera	86		21:14	05:45	−148.8	
Johannesburg	86	November 20	04:46	13:45	−146.4	
Pioneer	86		13:13	22:00	−146.5	One-way lock
Woomera	87		20:43	05:30	−148.7	
Johannesburg	87	November 21	04:36	13:30	−146.7	
Pioneer	87		13:05	22:00	−146	One-way lock
Woomera	88		20:37	06:56	−148.7	
Johannesburg	88	November 22	04:44	14:00	−148.3	Very little telemetry data by teletype because of demodulator trouble
Pioneer	88		12:57	22:00	−146.5	One-way lock
Woomera	89		20:44	05:30	−149.1	
Johannesburg	89	November 23	04:34	13:30	−148.2	
Pioneer	89		12:57	21:45	−146.5	One-way lock
Woomera	90		20:30	05:15	−148.7	
Johannesburg	90	November 24	04:15	13:15	−149	
Pioneer	90		12:56	21:45	−146.5	One-way lock
Woomera	91		20:27	05:15	−149.2	
Johannesburg	91	November 25	04:01	13:15	−149.3	
Pioneer	91		12:54	21:45	−147.5	One-way lock
Woomera	92		20:16	05:15	−148.2	
Johannesburg	92	November 26	04:17	14:00	−148.6	
Pioneer	92		12:46	23:11	−147.5	Two-way lock at 13:13

Table 18. Summary of DSIF operations, midcourse to end of mission (cont'd)

Station	Pass	Date (1962)	Time of acquisition, GMT	Time of loss, GMT	Maximum received-signal strength, dbm	Remarks
Echo	92		13:13	23:15		
Woomera	93		20:31	05:15	−148.8	
Johannesburg	93	November 27	04:09	13:15	−148.8	
Pioneer	93		12:45	21:45	−147.5	One-way lock
Woomera	94		20:13	05:15	−149.3	
Johannesburg	94	November 28	04:02	13:15	−149	
Pioneer	94					Not scheduled
Echo	94		12:57	21:45	−148	Functional as *receive only* station
Woomera	95		20:39	06:15	−150	
Johannesburg	95	November 29	05:49	13:15	−151.9	Parametric amplifier trouble during most of this period
Pioneer	95					Not scheduled
Echo	95		12:12	21:46	−148.4	*Receive only*
Woomera	96		20:27	05:15	−148.4	
Johannesburg	96	November 30	04:11	13:15	−148.5	
Pioneer	96					Not scheduled
Echo	96		12:08	21:40	−148.3	
Woomera	97		20:39	05:15	−150.6	
Johannesburg	97	December 1	04:21	13:45	−150.5	
Pioneer	97		12:35	20:55	−147.8	Two-way lock at 12:35
Echo	97		12:25	21:45		*Transmit only*
Woomera	98		20:15	06:43	−150.5	
Johannesburg	98	December 2	05:27	13:00	−148.7	
Pioneer	98		12:36	21:30	−148.8	One-way lock
Woomera	99		19:57	05:00	−150.9	
Johannesburg	99	December 3	03:56	13:00	−150.3	
Pioneer	99		12:30	21:30	−149.2	One-way lock
Woomera	100		20:30	05:30	−149.7	
Johannesburg	100	December 4	03:56	13:00	−150.3	
Pioneer	100		12:27	21:30	−148	One-way lock
Woomera	101		19:53	05:30	−151.5	
Johannesburg	101	December 5	03:55	13:00	−150.1	
Pioneer	101		12:41	21:30	−148.1	One-way lock
Woomera	102		20:01	05:00	−151	
Johannesburg	102	December 6	03:49	13:00	−146.1	Sudden gain change during calibrations
Pioneer	102		12:23	21:30	−149.4	One-way lock
Woomera	103		20:17	05:00	−150.6	
Johannesburg	103	December 7	03:48	13:00	−152.3	
Pioneer	103		12:24	21:30	−148.7	Two-way lock at 12:24
Echo	103		12:14	21:30		
Woomera	104		20:08	05:30	−151.1	
Johannesburg	104	December 8	04:44	13:00	−150	
Pioneer	104		12:24	22:30	−149.5	Two-way lock at 12:24
Echo	104		12:12	22:30		Command-modulation tests conducted during this period
Woomera	105		19:44	05:10	−150.4	

Table 18. Summary of DSIF operations, midcourse to end of mission (cont'd)

Station	Pass	Date (1962)	Time of acquisition, GMT	Time of loss, GMT	Maximum received-signal strength, dbm	Remarks
Johannesburg	105	December 9	03:50	13:00	−150	
Pioneer	105		12:20	21:30	−149.2	One-way lock
Echo	105		14:01	21:30	−151	*Receive only*
Woomera	106		19:38	05:00	−150.5	
Johannesburg	106	December 10	03:47	13:01	−150.8	
Pioneer	106		12:18	22:30	−149.2	One-way lock
Echo	106		13:03	20:15	−152.5	*Receive only*. Tests conducted to determine telemetry threshold
Woomera	107		22:16	04:45	−149.7	Listening feed installed before this period
Johannesburg	107	December 11	03:45	12:45	−152.1	
Pioneer	107		12:17	22:26	−149	Two-way lock at 12:17
Echo	107		12:08	22:20		*Transmit only*
Woomera	108		18:28	05:00	−148	
Johannesburg	108		03:45	13:28	−151.9	
Pioneer	108	December 12	12:20	22:23	−150.5	Two-way lock at 12:31
Echo	108		12:31	22:20		*Transmit only*
Woomera	109		18:32	05:00	−149.3	
Johannesburg	109	December 13	03:49	13:31	−151.5	
Pioneer	109		12:13	22:20	−150.6	Two-way lock from 12:13–13:06, 17:06–17:43, 19:30–22:10
Echo	109		12:04	22:10		Command-loop tests conducted
Woomera	110		18:15	05:00	−149.5	
Johannesburg	110	December 14	01:36	13:31	−152.3	
Pioneer	110		12:16	22:16	−150.6	Two-way lock at 12:27. Routine Venus encounter
Echo	110		12:24			RTC-7 initiated at 13:35 and verified at 13:35:57. RTC-8 initiated at 20:32:00 and verified at 20:32:57
Woomera	111		18:10	05:00	−149.7	
Johannesburg	111	December 15	01:37	13:27	−152	
Pioneer	111		12:17	22:12	−151.4	Two-way lock at 12:17. Tests conducted on telemetry demodulator threshold
Echo	111		12:07	22:10		RTC-2 initiated at 13:25 and verified at 13:25:56; again initiated at 13:40 and verified at 13:40:56. Between 13:50 and 22:06:30, a total of 165 RTC-0 commands transmitted

Table 18. Summary of DSIF operations, midcourse to end of mission (cont'd)

Station	Pass	Date (1962)	Time of acquisition, GMT	Time of loss, GMT	Maximum received-signal strength, dbm	Remarks
Woomera	112		18:29	04:30	−149.1	
Johannesburg	112	December 16	03:00	13:26	−152.2	
Pioneer	112		12:12	22:15	−151	Two-way lock at 12:34
Echo	112		12:34	21:50		Between 13:08 and 13:50, a total of 25 RTC-0 commands transmitted
Woomera	113		18:31	04:00	−150.6	
Johannesburg	113	December 17				Not scheduled
Pioneer	113		12:08	22:08	−151	Two-way lock at 12:34
Echo	113		12:02	21:55		
Woomera	114					Not scheduled
Johannesburg	114	December 18				
Pioneer	114		13:20	22:06	−151.5	Two-way lock at 17:39. Acquisition delayed because of water in feed line
Echo	114		17:39	21:55		Total of seven RTC-0 commands transmitted between 21:02 and 21:08. Spacecraft transponder-threshold tests conducted
Woomera	115					Not scheduled
Johannesburg	115	December 19				Not scheduled
Pioneer	115		12:07	22:05	−150.6	Two-way lock at 12:07
Echo	115		11:59	21:45		
Woomera	116					Not scheduled
Johannesburg	116	December 20				Not scheduled
Pioneer	116		12:27	22:01	−152.4	Two-way lock at 12:27
Echo	116		11:58	21:50		Total of six RTC-2 commands transmitted between 16:05 and 17:20
Woomera	117					Not scheduled
Johannesburg	117	December 21	02:09	12:00	−154.2	
Pioneer	117					Not scheduled
Woomera	118					Not scheduled
Johannesburg	118	December 22	02:06	12:00	−156	
Pioneer	118					Not scheduled
Woomera	119		19:00	05:00	−153.8	
Johannesburg	119	December 23				Not scheduled
Pioneer	119					Not scheduled
Woomera	120		18:58	05:00	−153.7	
Johannesburg	120	December 24				Not scheduled
Pioneer	120					Not scheduled
Woomera	121					Not scheduled
Johannesburg	121	December 25				Not scheduled
Pioneer	121					Not scheduled
Woomera	122					Not scheduled

Table 18. Summary of DSIF operations, midcourse to end of mission (cont'd)

Station	Pass	Date (1962)	Time of acquisition, GMT	Time of loss, GMT	Maximum received-signal strength, dbm	Remarks
Johannesburg	122	December 26	01:54	12:00	−154.5	
Pioneer	122					Not scheduled
Woomera	123		18:48	05:00	−153.9	
Johannesburg	123	December 27				Not scheduled
Pioneer	123					Not scheduled
Woomera	124		18:53	05:30	−155	
Johannesburg	124	December 28				Not scheduled
Pioneer	124		12:00	21:30	−154.2	Two-way lock at 12:10
Echo	124		12:10	21:30		In and out of two-way lock several times because of synthesizer. Unable to obtain vehicle sync for transmission of RTC-2
Woomera	125	December 29				Not scheduled
Johannesburg	125		04:41	08:22	−156	
Pioneer	125					Not scheduled
Woomera	126		17:52	02:00	−155.3	
Johannesburg	126	December 30				Not scheduled
Pioneer	126		12:01	21:35	−155.5	Two-way lock at 12:30
Echo	126		12:30	21:35		Demodulator and decommutator continuously dropping lock; determination made that spacecraft flip-flops had dropped by 13 cps
Woomera	127					Not scheduled
Johannesburg	127	December 31	02:45	12:00	−156.6	
Pioneer	127					Not scheduled
Woomera	128		23:15	02:00	−157.1	
Johannesburg	128	January 1 (1963)				Not scheduled
Pioneer	128		19:10	20:00		One-way lock
Woomera	129					Not scheduled
Johannesburg	129	January 2	09:51	13:02	−156.4	
Pioneer	129					Not scheduled
Woomera	130					Not scheduled
Johannesburg	130	January 3	03:54	07:00	−157	Last signal received from spacecraft
Pioneer	130					Not scheduled
Woomera	131					Spacecraft signal searched for from 20:58 through 03:15 with no success
Johannesburg	131	January 4				Secured from mission
Pioneer	131					Spacecraft signal searched for from 12:00 to 20:46 with no success
Woomera	132					Secured from mission
Pioneer	132	January 5				Not scheduled

Table 18. Summary of DSIF operations, midcourse to end of mission (cont'd)

Station	Pass	Date (1963)	Time of acquisition, GMT	Time of loss, GMT	Maximum received-signal strength, dbm	Remarks
Pioneer	133	January 6				Not scheduled
Pioneer	134	January 7				Not scheduled
Pioneer	135	January 8				Spacecraft signal searched for from 17:10 to 21:00. No signal received
Echo	135					Starting at 18:30, total of 40 RTC-2 commands sent. Starting at 19:12, total of 10 RTC-1 commands sent
Pioneer	136	January 9				Station relieved of tracking and placed on standby until later date

Table 19. Ground and spacecraft modes

Mode	Characteristics
Ground	
GM-1[a]	Tracking 960.05-Mc transponder signal in two-way mode and obtaining angles, two-way doppler, and spacecraft telemetry.
GM-2[b]	Listening to 960.05-Mc transponder signal in two-way mode, two-way doppler, and spacecraft telemetry.
GM-3[c]	Tracking 960.05-Mc transponder signal in one-way mode and obtaining angles, one-way doppler, and spacecraft telemetry.
GM-4[c]	Listening for 960.05-Mc transponder signal in one-way mode and obtaining one-way doppler and spacecraft telemetry.
Spacecraft	
Launch-to-Earth acquisition (Mode I)	Nominal duration of 167 hr. Identified by engineering telemetry transmission of 33-bit/sec data rate.
Cruise (Mode II)	Nominal duration of 10 hr from Earth acquisition to encounter. Identified by multiplexed transmission of telemetered engineering and scientific data at the 8-bit/sec data rate.
Planetary encounter (Mode III)	Nominal duration of 67.5 hr. Identified by only science data being transmitted at 8-bit/sec data rate. After encounter phase, spacecraft will be returned to Mode II.

[a]This mode is possible at DSIF 1, 4, and 5.
[b]This mode is possible at DSIF 5 (with 10-kw diplexer) or at the combination DSIF 2 and 3.
[c]This mode is possible at all DSIF Stations.

B. Launch

On August 25, the space vehicle composed of *Atlas D*-179, *Agena B*-6902, and *Mariner II* was started into launch countdown. At launch minus 205 min, the countdown was cancelled because of a stray voltage in the *Agena destruct* batteries.

Countdown 2 was started at 22:37 GMT on August 26. (Table 15 presents the operations log for launch Countdown 2.) At *T* (liftoff) minus 200 min in the countdown, external power was applied to the spacecraft,and DSIF 0 began pre-launch checkout. Four unscheduled holds delayed launch for a total of 98 min; however, none was of a serious nature nor attributed to the spacecraft.

At 06:50:07 on August 27, inhibit on the central computer and sequencer (CC&S) counter in the spacecraft was released; at 06:53:17, the *Mariner II* spacecraft atop the *Atlas D–Agena B* vehicle was launched.

DSIF 0 was in one-way lock at liftoff, as the space vehicle rose from its pad in the nominal bearing of 105 deg east of north. At injection, control of the flight was transferred from the NASA Launch Operations Center (now Kennedy Space Center) at the Cape to the Space Flight Operations Center (SFOC) at JPL in Pasadena. Shortly after launch, the vehicle rolled to the booster roll azimuth of 107.5 deg east of north.

Booster-engine cutoff (BECO) and staging were successfully executed. A few seconds prior to BECO, however, control of one of the two vernier engines on *Atlas* was lost for an undetermined reason, and the engine moved to the maximum negative mechanical stop. The main booster engines maintained the proper roll attitude during this time. At BECO, booster-engine roll control was terminated, and the companion vernier engine moved to its electrical stop to oppose the roll. However, the vernier-engine forces remained unbalanced, and the vehicle began a negative roll (counterclockwise when viewed from the rear).

Control of the vernier engine was regained approximately 60 sec after loss of control occurred. At this time, the vehicle was rolling at a rate of about 360 deg/sec. The motion was arrested in about 10 sec, after a total of 35 revolutions. Even though the vehicle had no provision for maintaining roll reference in such a case, the roll-attitude error in the new null position was approximately 1.5 deg.

During the period of uncontrolled roll, the *Atlas* was unable to respond effectively to guidance commands, and the altitude at BECO was somewhat high. The vehicle also had an attitude error of approximately 10 deg in pitch.

The *Atlas–Agena* separation sequence prior to *Agena* first burn was executed satisfactorily, although the attitude error previously described caused the shroud to be ejected into a position closer to the *Agena* flight path than was desired. As an additional result of the attitude error, the *Agena* was pitched down 2 deg at first ignition, and the horizon sensors did not complete correction of this error until 15 sec later. The improper altitude of the *Atlas* caused the *Agena* timer-start signal to be sent 8 sec early. However, the *Agena* successfully terminated its first burn when the pre-set velocity increment was sensed by the velocity meter.

At the termination of *Agena* first burn, the *Agena–Mariner II* was in its parking orbit with a nominal altitude of 100 nm. The vehicle coasted in this orbit from a point 64 deg west and 22 deg north to a point 9 deg west and 12 deg south, arriving about 980 sec later. At this point, *Agena* second burn was successfully initiated. Second-burn cutoff by the velocity meter and *Agena–Mariner II* separation were also successful and, at 07:19:19 GMT, the spacecraft was injected into a geocentric escape hyperbola which would carry it to the vicinity of Venus. The *Agena*, by performing a programmed 140-deg yaw maneuver and expelling its unused propellant, reduced its speed and minimized the probability of impact with Venus. Injection occurred over the South Atlantic Ocean at -14.8 deg latitude and $+357.9$ deg longitude.

Coverage of the flight during the *Atlas* boost phase with both optical and electronic tracking devices was, in general, satisfactory. Tracking and telemetry coverage were provided by stations at Cape Canaveral, Grand Bahama Island, and San Salvador. The JPL Launch-Checkout Tracking Station at Cape Canaveral provided coverage until loss of signal at the horizon. This station was in one-way lock at liftoff and maintained lock, with only a few momentary dropouts, for approximately 7.5 min. The signal level at launch was -85 dbm, gradually decreasing to -120 dbm immediately prior to dropout. Telemetry data indicated that all subsystems were performing satisfactorily.

At *Agena* first-burn cutoff, tracking coverage was provided by Antigua; however, systematic errors in the data prevented their use in real-time. In addition, the station at Puerto Rico was reported inoperative a few minutes prior to launch because of equipment failure. Telemetry data for *Agena* first burn were recovered at Echo, Johannesburg, and Antigua.

Telemetry coverage for *Agena* second burn, *Agena–Mariner* separation, and *Agena* retro-maneuver was obtained from Ascension Island; Pretoria, South Africa; and three ships: ORV 1851 (Whiskey), ORV 1852 (Yankee), and ORV 1886 (Uniform, or the Twin Falls Victory Ship). Tracking coverage was provided during this time from Ascension Island, Pretoria, and the Twin Falls Victory Ship.

C. Injection to Midcourse

Mariner II was injected into interplanetary trajectory at liftoff + 26 min, 3 sec. Mobile Tracking Station (DSIF 1) acquired *Mariner II* in one-way lock at 07:21:37 GMT (approximately $L + 30$ min); 3 min later, Johannesburg (DSIF 5) had also acquired the spacecraft in one-way lock.

After this initial acquisition, DSIF 1 achieved two-way lock at 07:30:20. The DSIF 1 transmitter was turned off at 07:48:00, since DSIF 5 was having difficulty maintaining pseudo-two-way lock. DSIF 5 turned its transmitter on at 08:12:00 and began radiating 200 w, attempting to obtain two-way lock until 08:39:00, when it was instructed to turn its transmitter off. During the period in which DSIF 5 was trying to acquire two-way lock, both the Mobile Tracking Station and Woomera (DSIF 4) were tracking the spacecraft, with intermittent loss of lock. DSIF 4 acquired the spacecraft at 07:37:00 in one-way lock, with a received signal level of -110 dbm. At 08:44:32, DSIF 4 acquired two-way lock with a radiated power of 58 w. After this initial period, there were few problems in obtaining two-way lock.

Initial telemetry data indicated that the Sun-acquisition sequence was normal and was completed approximately 2.5 min after command from the CC&S. The high-gain directional antenna was extended to its pre-set acquisition angle of 72 deg. Temperatures were somewhat higher than expected as a result of the post-launch environment of increased power, lack of Sun-oriented attitude, and aerodynamic heating. However, after Sun acquisition, most temperatures slowly decreased and, 6 hr later, showed an essentially stabilized average temperature of 84°F over the entire hexagonal structure.

Approximately 18 min after injection ($L + 44$ min), the solar panels had extended; the time required for full extension was nominal, within 5 min after CC&S command. The solar panel output of 195 w was slightly above the predicted output and represented an excess of 43 w over the spacecraft requirements for this period.

With all subsystems performing normally, the battery fully charged, and the solar panels providing adequate power, the decision was made to turn on the cruise science experiments. The first command, RTC-8, transmitted at 16:13:00 and verified at 16:13:57, was sent to the spacecraft on August 29 from DSIF 5. This command changed the telemetry to the cruise mode, and reduced the telemetry-transmission bit rate from 33.33 to 8.33 bits/sec. This command transmission was a deviation from the test plan in that the telemetry mode change was to have been effected by an internal command in the spacecraft. After this time, the DSIF continued to track the spacecraft on a 24-hr/day basis, as outlined in Table 16.

By August 31, temperatures had become stable within the tolerance limits; tracking had been continuously maintained with two-way lock; telemetry data were good; and all subsystems had operated as intended.

On September 3, 167 hr after launch, the Earth-acquisition sequence was initiated by the CC&S. The Earth sensor and the gyros were turned on, cruise science was turned off, and roll search was initiated. The spacecraft at that time was rolling at a rate of about -720 deg/hr, having steadily accelerated to that value from $+235$ deg/hr following first gyro turnoff. It was also oriented so that the directional antenna and Earth sensor were pointed about 75 deg below the Earth-command attitude, thus causing a loss of data until Earth lock was established 29 min later.

Telemetry data after acquisition indicated an Earth-brightness intensity measurement comparable to that which would have resulted if the Earth sensor had been viewing the Moon. There was, therefore, a possibility that the Moon had been acquired, implying a malfunction in the antenna hinge servo. As a result, execution of the midcourse maneuver sequence (required to correct the dispersions in the original orbit) was postponed one day, so that it could be determined whether or not the antenna actuator was performing properly and whether the directional antenna was pointing at the Earth.

Normal dispersions in launch-vehicle performance require inclusion of a midcourse maneuver capability in the spacecraft to provide the necessary orbit correction after the actual spacecraft trajectory is known. This capability in *Mariner II* was adequate to correct the original orbit.

The seventh orbit computation agreed with previous calculations, indicating that continued flight on the original path would result in a Venus dark-side pass with a miss distance of 376,000 km (233,641 mi) and a flight time of 108.576 days. Comparison of these results with the desired Venus Sun-side pass, a miss distance of 20,000 km (12,421 mi) and a flight time of 109.459 days, indicated that the launch-vehicle's injection guidance system had performed within 3 σ of the nominal values. The results indicated, however, that no useful encounter data could be obtained, and that a midcourse maneuver would be required. A desired miss distance of approximately 20,800 km (12,982 mi) on a Sun-side pass, with a flight time of 109.453 days, was used for the maneuver computation.

D. Midcourse

The midcourse maneuver command sequence was performed entirely from the Goldstone Stations; Pioneer functioned as the receiving station and Echo as the transmitting station. The command loop was locked up by Echo at 21:01:00 GMT, after which the transmission of commands was as shown in Table 17. The received-signal level at Pioneer was -129 dbm before the spacecraft started the midcourse maneuver. During the maneuver, the received-signal level dropped as low as −162 dbm. Several momentary out-of-lock periods were experienced by the Pioneer Station during this time. At the completion of the maneuver, the received signal returned to −130 dbm at 02:34:45.

The midcourse maneuver was initiated with the spacecraft at a distance of 2,408,740 km (1,496,762 mi) from Earth. The maneuver sequence required five commands: three stored commands (SC-1, SC-2, and SC-3) and two real-time commands (RTC-4 and RTC-6). The stored commands contained the roll- and pitch-turn duration, and polarity and velocity increments.

Commands SC-2 and SC-3 were transmitted twice because the station lost ground synchronization during transmission; however, the event registers indicated that all transmitted commands were received by the spacecraft. *Mariner's* receipt of the RTC-4 command switched the output of the spacecraft's transmitter from the directional to the omniantenna, so that telemetry data could be recovered during the maneuver. The RTC-6 command initiated the maneuver sequence by causing the CC&S to turn on the accelerometers and gyros. At 1 hr after receipt of the RTC-6 command, the Earth sensor was turned off, the directional antenna extended to 118 deg (nominally 120 deg), and the roll turn began. Exact times for the beginning and end of turns, as well as for motor burn, could not be verified by telemetry because of the time resolution of the data; apparently, however, the roll and pitch turns and motor burn occurred normally. The entire maneuver took approximately 34 min. Telemetry data were lost for approximately 11 min because the spacecraft pitched into a partial null in the propagation pattern of the omniantenna.

At 01:30:23 GMT, Woomera acquired with a received-signal level of −152 dbm and, because of the low signal level, was in- and out-of-lock until 02:34:27 when the received-signal level increased to −130 dbm. Good data were obtained throughout the remainder of the tracking period.

E. Cruise (Midcourse to Encounter)

Post-midcourse trajectory computations indicated that a projected miss distance of approximately 41,000 km and a flight time of 109.546 days had been achieved. Comparison of the desired and achieved encounter parameters indicated that the maneuver was accomplished with about a 10-σ deviation from nominal performance. A number of possible explanations for this out-of-tolerance condition have been offered, but the telemetry system was incapable of supplying data that could isolate the cause in this case.

Initial telemetry data received after the midcourse maneuver indicated that all subsystems were still operating normally. In the Sun-reacquisition sequence initiated by the CC&S at the nominal time following the maneuver, the autopilot was turned off and the directional antenna moved to the reacquisition position of 70 deg. The sequence was normal and took approximately 7 min.

The Earth-reacquisition sequence was also initiated by the CC&S at the nominal time following the maneuver and, again, required approximately 30 min, the spacecraft rolling approximately 351 deg before Earth lock was established. The transmitter was switched to the high-gain antenna at the start of the sequence, just as in the initial Earth-acquisition sequence, causing a loss of signal for approximately 6 min. With the exception of the propulsion subsystem, the spacecraft returned to the normal cruise mode of operation, as observed prior to the maneuver.

The DSIF was originally committed to provide 24-hr/day coverage from launch (L) through $L + 10$ days, 10-hr/day tracking during the cruise phase, and 24-hr/day coverage through September 9, after which date its coverage was reduced to approximately 12 hr/day. On September 16, the DSIF returned to the 24-hr/day schedule and remained on that basis until the encounter phase was completed (Table 18).

The first of several nonstandard flight events was experienced by the midcourse propulsion system. Apparently, the normally open nitrogen-shutoff valve did not close at the commanded motor shutoff, and nitrogen gas leaked slowly into the propellant tank. It was believed that the equilibrium pressure, when reached, would be well below the burst pressure of the propellant tank and associated components; accordingly, no further complications were expected or observed.

The louvers, employed to assist in maintaining temperatures within specified bounds, caused some concern in the early stages of the cruise mode in that they appeared to be open 30 deg when the louver-position measurement indicated that they were closed. However, they performed satisfactorily throughout the flight and reduced the average hexagonal temperature by 12 to 15°F.

On September 8, the cruise science experiments were turned on and off by the gyros. All sensors were in lock, however, before the telemetry measurements could be sampled to determine whether or not an axis had lost lock. A similar occurrence was experienced 3 wk later, on September 29, when the gyros were turned on and the cruise science experiments turned off; here, again, all sensors were back in lock before it could be determined which axis had lost lock. The significant difference between the two events was that, in the second case, telemetry data indicated that the Earth-brightness measurement had increased to the nominal value for that point on the trajectory.

On October 31, the power subsystem began to operate abnormally with loss of power from the 4A11 solar panel, a malfunction diagnosed as a partial short circuit in the panel. As a precaution against the spacecraft's going into a power-sharing mode, an RTC-10 command was transmitted from Goldstone Tracking Station, turning off the cruise science experiments and, thereby, reducing power consumption.

Eight days later, telemetry data indicated that the panel was again operating normally; an RTC-8 command was, therefore, transmitted from Goldstone to reactivate the cruise science experiments. Science telemetry data remained essentially the same as before the experiments had been turned off; however, engineering telemetry data indicated that most temperatures increased shortly after the science experiments were reactivated, because of the increased power requirements of the spacecraft. A recurrence of the panel short was experienced on November 15. However, with the spacecraft nearer the Sun, power supplied by the one operative panel was adequate to meet the spacecraft's demands, and the cruise science experiments were permitted to remain active.

At this time, the magnetometer evidenced a high offset caused by current redistribution when the power failure occurred. This made readings difficult to interpret, but the data recorded indicated reasonably steady magnetic fields. Occasional unscheduled magnetometer calibrations occurred throughout the flight.

Radiometer calibration data received during the cruise phase indicated probable nonstandard operation at the time of encounter, and it was considered possible that, upon initiation of Mode III, the radiometer would be in permanent slow scan, and that no scan-rate change or automatic scan reversal would occur. The data also indicated that only one of the two microwave radiometer channels would have the desired sensitivity. In actuality, however, both the microwave radiometer and the infrared radiometer channels had acceptable sensitivities at encounter, and one scan-rate change occurred which allowed a third scan of the planet.

The calibration data for the cosmic dust experiment indicated that, by November 27, either the instrument sensitivity or the amplitude of the calibration pulse had decreased by 10%; by December 14, a further decrease by a factor of 10 had occurred.

In the Deep Space Instrumentation Facility, occasional problems arose, such as a commercial power failure at Goldstone during the September 22–23 view period, when changeover to local generators was delayed because of an inoperable automatic-transfer switch. In this particular case, about 1.5 hr of data were lost.

During the week ending November 21, an occasional out-of-sync condition in the telemetry data was diagnosed as a telemetry-demodulator problem at the stations; the spacecraft was not at fault. No real-time telemetry was received from Goldstone and Johannesburg during the November 26 view period. The information was not lost, however, since all data were recorded on magnetic tape at the stations and sent to the Space Flight Operations Center in non-real-time.

Except for problems of this nature, the DSIF Stations covered the *Mariner II* operation continuously and successfully. In taking two-way doppler data for orbit determination, spacecraft signals were transmitted by the Echo Station and received by the Pioneer Station. The Woomera Station was faced with virtually no equipment problems and provided excellent data.

On November 14, the reference hinge angle changed by one data number (DN), an event which should normally have occurred only at cyclic update times. This phenomenon had occurred several times during pre-flight system tests. With the exception of this anomaly and the Earth sensor abnormalities previously noted, the attitude control system performed without fault through November.

Spacecraft temperatures became a cause for concern in mid-November. They were higher than the predicted values, but not so high that equipment operated near tolerance limits. On November 16, however, the lower-thermal-shield temperature reached its telemetry limit:

a "pegged" DN of 126, which corresponds approximately to 95°F. Seven out of eighteen temperature measurements were "pegged" before the encounter phase, and these temperatures were estimated.

On December 9, a failure in the data encoder circuitry disabled four telemetry measurements: antenna hinge angle, propellant tank pressure, midcourse motor pressure, and attitude control nitrogen pressure. Loss of these four measurements did not affect the outcome of the mission; the measured values were simply not telemetered.

The CC&S was designed to perform various functions, one of which was to provide the attitude control subsystem with a timing, or cyclic update, pulse every 1,000 min to update the antenna reference hinge angle. Each cyclic update pulse was evidenced by the fact that Event Register No. 3 stepped one count. Until December 12, the pulses occurred with predictable regularity. On that date, however, only 2 days before the encounter phase, the CC&S failed to issue the 155th or any subsequent cyclic pulses. As a result of this malfunction, the spacecraft was switched to the encounter mode of operation by a backup ground command (RTC-7), transmitted from Goldstone Tracking Station on December 14.

On December 14, prior to transmission of RTC-7, seven spacecraft temperature sensors had reached their upper limits. The Earth-sensor brightness data number had dropped to three. Approximately 149 w of power was being consumed by the spacecraft, while a minimum of 165 w was available from the 4A12 solar panel; about 16 w from the 4A12 panel were being dissipated in the 4A11 panel. All science experiments were operating satisfactorily. Coverage by the DSIF remained continuous and virtually normal. Signals were clear and data quality was good.

F. Encounter

Sixteen orbit computations were made during the interplanetary phase of the flight, covering the period from the midcourse maneuver on September 5 to December 7, when the mass of Venus caused the first detectable perturbation in the *Mariner II* trajectory. During the encounter phase, which (for purpose of trajectory computation) covered the period December 8 to 18, fourteen computations were run. Of these, eight preceded Venus encounter and six followed. On the basis of these fourteen computations, it was determined that the closest approach to the surface of the planet was 34,854 km, or 21,645 mi, occurring at 19:59:28 GMT, December 14, 1962. Spacecraft velocity at the time was 6.743 km/sec relative to Venus. The elapsed time from injection to closest approach was 109.546 days. Additional pertinent data are:

Distance from Earth: 57,785,000 km (35,907,000 mi)

Distance from Sun: 107,557,000 km (66,834,000 mi)

Velocity relative to Earth: 18,115 km/sec (11,256 mi/sec)

Velocity relative to Sun: 39,490 km/sec (24,538 mi/sec)

Mariner II was programmed to encounter Venus during a Goldstone view period. Telemetry data, obtained prior to the encounter data, indicated that it would be necessary to transmit RTC-7 to command the spacecraft to the encounter mode. Pioneer acquired the spacecraft signal in one-way lock at 12:16 on December 14, and two-way lock was obtained at 12:24. Command modulation was turned on by Echo at 12:42; command-loop lock and vehicle synchronization were obtained at 12:56. RTC-7 was initiated at 13:35:00 and verified by the spacecraft at 13:35:57. At 13:46, Pioneer confirmed that the spacecraft was in the encounter mode, and command modulation was turned off by Echo at 13:51. At 20:20, Echo turned on command modulation; RTC-8, the command to end the encounter mode and return to cruise mode, was initiated at 20:32:00 and verified at 20:32:57. Command modulation was turned off at 20:43, and Echo turned off the transmitter at 22:10. Woomera acquired the spacecraft signal at 18:10; therefore, two DSIF Stations were receiving the spacecraft telemetry during the planet scan. Both Pioneer and Echo were secured at 22:11. Pioneer radiated 10 kw throughout the encounter phase. The received-signal level at Echo was approximately −150.5 dbm throughout the period.

During the encounter phase, only scientific telemetry data were transmitted by the spacecraft. The operation of all science experiments was successful, except for the sensitivity decrease in the cosmic dust experiment.

The encounter mode lasted approximately 7 hr, being terminated by a ground command (RTC-8) transmitted from Goldstone. The spacecraft was returned to the cruise mode at 20:40 on December 14.

G. Post-Encounter

The DSIF continued to track on a reduced-time basis after December 16, as indicated in Table 18. In the post-encounter flight of *Mariner II*, engineering telemetry data indicated that all subsystems performed essentially as before the encounter phase. Temperatures still rose and were not expected to decrease until after the attainment of perihelion (point closest to the Sun) on December 28.

As a result of the CC&S malfunction, the antenna reference hinge angle had not been updated since December 12. As a precaution against the spacecraft's losing Earth lock, and to prevent the directional antenna from moving to the last antenna reference hinge-angle setting, two series of commands (RTC-2) were transmitted from Goldstone, once on December 15, and again on December 20, increasing and updating the reference hinge angle. Five of these commands were accepted by the spacecraft, and the effective reference angle change was believed to be 8 deg.

On December 16, the Earth-sensor brightness data number dropped to 1, the telemetry threshold. Nevertheless, negative data number values were extrapolated to a value of about -20 by January 3, 1963, when communication with the spacecraft ceased. Continuous DSIF coverage was changed on December 17 to approximately 10-hr/day coverage.

Perihelion was reached at 05:15 GMT on December 28. On this date, an attempt was again made to command the reference hinge angle to update, but Goldstone verified through its inability to lock up the command loop that command threshold had been reached, as previously predicted.

At 17:28, December 30, a reference-frequency circuit failure resulted in temporary loss of the telemetry signal; however, RF lock was maintained. When the telemetry signal was again locked up, 1.5 hr later, the telemetry bit rate had changed from the nominal 8.33 to approximately 7.59 bits/sec. Simultaneously, internal-temperature readings increased.

After December 30, the DSIF schedule was planned around the spacecraft radiometer calibration periods in order to record the telemetry at this time. Johannesburg completed its scheduled tracking period at 07:00 on January 3, 1963, the received-signal level at that time being -157 dbm. Woomera started its scheduled track at 20:58 on January 3 and searched until 03:15, January 4, without success. The last signal from the spacecraft, therefore, was received by Johannesburg at 07:00, January 3, 1963. The Pioneer Station searched for the signal from 12:00 through 20:46 on January 4, again with no success. On January 5, Woomera and Johannesburg were secured. On January 8, Pioneer searched for the signal from 17:10 until 21:00 without success. During the same period, Echo transmitted 40 RTC-2 (clockwise hinge override) commands and 10 RTC-1 (roll override) commands in an attempt to update the spacecraft antenna hinge angle. There were no indications that any of the commands were received or acted upon by the spacecraft. On January 9, the Goldstone Stations were placed on standby status.

During the last pass on January 3, about 30 min of real-time telemetry data were received. Although the demodulator went out-of-lock at 05:21 and remained out for the balance of the tracking period, good RF lock was maintained throughout the tracking period from 03:54 to 07:00. Examination of the recorded data showed that the spacecraft was still performing normally, with a power consumption of 151 w and available power of 163 w from the 4A12 solar panel. Spacecraft trajectory data during the final tracking period were as follows:

Distance from Earth: 86,677,000 km (53,860,000 mi)

Distance from Sun: 105,857,000 km (65,778,000 mi)

Distance from Venus: 8,994,000 km (5,588,000 mi)

Velocity relative to Earth: 21,980 km/sec (13,658 mi/sec)

Further search for the spacecraft has proved fruitless. It is believed that, although 50 commands were sent on January 8, 1963, they were not received by the spacecraft.

V. POST-MISSION

The tracking of *Mariner II* has been by far the most challenging of all DSIF tracking tasks to date. The DSIF was originally committed to provide 24-hr/day coverage from launch time through $L + 10$ days; 10 hr/day during the cruise phase; and 24-hr/day coverage through the encounter. After encounter, coverage was to be approximately 10 hr/day for the rest of the mission. However, on September 16, or $L + 21$ days, the DSIF returned to the 24-hr/day schedule, and remained on that schedule until the encounter phase was completed some 90 days later. The DSIF operational requirements were such that equipment was operating, tracking and receiving data from the spacecraft for 24 hr/day during virtually the entire mission, or more than 109 days from launch to Venus encounter.

This stringent requirement demanded more than 3,000 hr of continuous and uninterrupted ground support equipment (GSE) operation for tracking and data recovery. More than 10,000 individual electronic components and hundreds of mechanical operations had an effect on the over-all system and the ultimate success or failure of the *Mariner II* mission.

A. Post-Flight Analysis of Station Performance

Post-flight analysis of DSIF performance during the mission is based on real-time tracking data, inflight station reports, station logs, calibration books, and station parameters recorded on Midwestern recordings and magnetic tape.

1. Mobile Tracking Station (DSIF 1)

DSIF 1 acquired the *Mariner II* spacecraft in one-way doppler mode at 07:21:37 GMT, August 27, 1962, at a signal strength of −100 dbm. It reported having trouble establishing two-way doppler lock, and at 07:30:48 reported two-way doppler lock. No data was transmitted from 07:27:21 to 07:41:28 GMT. The time of first good data condition code was 07:45:51. From 07:45:51 until transmitter off at 07:48:00, seven data points with a good data condition code were received at the computing facility at JPL.

The transmitter at DSIF 1 was turned on again from 08:04:00 to 08:11:12 GMT. Attempts to establish two-way doppler lock were unsuccessful. One-way doppler lock was established at 08:11:33; DSIF 1 continued to track in this mode until the end of the first pass (21:08:41 GMT). DSIF 1 was secured from the *Mariner II* mission at the end of the first pass.

Subsequent investigation revealed that the seven two-way doppler (C-2) data points taken from 07:45:51 to 07:48:00 GMT were biased by −13.6 cps. Several orbits had been computed assuming that these C-2 doppler points were valid. Analysis of these orbits indicated a bias of approximately 5.0 cps at 08:49:00, in the C-2 doppler data received from DSIF 4, decreasing to 0.5 cps at the end of the pass. C-2 doppler from the Mobile Tracking and Johannesburg Stations revealed no bias. As a result, it was assumed that the C-2 doppler from Woomera was in error. The following possible causes were investigated:

1. Error in station location.
2. Error in station time.
3. Equipment malfunction.
4. Excessive doppler rates.

Results of the investigation indicated that none of the above would explain the apparent bias.

The *Mariner II* orbit was recomputed, with the data from DSIF 1 deleted, using only data through 02:43:51 GMT, August 28, 1962. Weighting of angular data for Woomera and Johannesburg, and of the two-way doppler data for Pioneer, Woomera, and Johannesburg, were the same as for real-time orbits. The mean error and standard deviation of angular and doppler residuals for the orbit computed, deleting DSIF 1 data and the real-time orbit at the end of the first pass, are presented in Table 20.

From the two-way doppler residuals from Pioneer, Woomera, and Johannesburg for the real-time orbit computed (with DSIF 1 data deleted), it was concluded that the seven data points from DSIF 1 were inaccurate.

Investigation of transmitter voltage controlled oscillator (VCO) and other recordings revealed that DSIF 1 did lock up to the transponder in two-way doppler mode after possibly too fast a transmitter frequency scan. The point of lock coincided within several cycles of the predicted transmitter VCO frequency. No sub-loops were

Table 20. Orbit Determination Program statistics for Woomera C-2 bias investigation

Station	Data type	Number of points	Real-time orbit		Orbit with DSIF 1 deleted		
			Mean	Standard deviation	Number of points	Mean	Standard deviation
Mobile Tracking	C-2, cps	7	−0.208	1.19	0	—	—
Pioneer	C-2, cps	314	−0.007	0.023	314	−0.005	0.027
Woomera	C-2, cps	103	—[a]	—[a]	103	0.005	0.027
Johannesburg	C-2, cps	337	0.006	0.065	337	0.016	0.066
Woomera	HA, deg	285	−0.057	0.029	285	−0.024	0.013
	Dec, deg	308	0.008	0.015	308	−0.003	0.009
Johannesburg	HA, deg	520	−0.010	0.026	509	0.005	0.009
	Dec, deg	520	0.006	0.014	520	0.002	0.009

[a]Woomera Station two-way doppler not used for orbit determination.

reported out of lock, and the bias is attributed to an unrevealed malfunction at DSIF 1.

2. Pioneer Station (DSIF 2)

DSIF 2 acted as a receiver only for the entire *Mariner II* mission. First acquisition was at 19:34:05 GMT; first coherent pseudo two-way doppler (Cc-3) lock was at 20:15:00. Except for short intervals, DSIF 2 tracked as scheduled for the entire mission. The Cc-3 doppler data was extremely noise-free, with a standard deviation on the order of 0.020 cps for the entire mission.

3. Echo Station (DSIF 3)

During the *Mariner II* mission, DSIF 3 acted as the transmitter site and, with the exception of the passes on October 14 and 24 when *Ranger V* pre-flight checkouts were conducted, did not have tracking capability. Successful commands were transmitted and verified for the following:

1. Midcourse maneuver: September 4.
2. Science off: October 31.
3. Science on: November 8.
4. Encounter mode start: December 14.
5. Encounter mode end: December 14.
6. Update antenna hinge angle: December 15 and 20.

During periods of Cc-3 doppler tracking, the output of the Pioneer Station doppler detector was transmitted via microwave to the doppler counting system at Echo. Data were then counted in a continuous mode at Pioneer and in a 50-sec *destruct* mode at Echo. Results compared favorably between the two counting systems.

4. Woomera Station (DSIF 4)

DSIF 4 acquired the spacecraft at 07:37:30, and the transmitter was turned on at 07:51 in an attempt to acquire two-way doppler lock. The transmitter was turned off at 07:54 to ensure telemetry data during Sun acquisition. Two-way lock was not achieved primarily because of lack of time for sweeping of the transmitter VCO frequency for acquisition. The receiver was in and out of lock from 08:12 to 08:39 while the Johannesburg Station was attempting two-way lock. The transmitter was turned on at 08:44; two-way lock was achieved at 08:44:32. Woomera continued in the two-way doppler mode until 10:00 when the transmitter was turned off on instructions by Network Control.

Angular data were corrected for the optical pointing error determined from star tracks during 1961–1962. The error remaining was attributed to RF pointing error due to thermal deflections, uncompensated refraction, and additional deflections due to gravity. There was an additional discontinuity of 0.02 deg in the hour angle (HA) residuals at the HA corresponding to approximately 18-deg elevation angle. (The method of refraction correction is changed at this elevation angle and results in this discontinuity.)

Pre-flight calibration tests indicated a bias of 0.05 deg between the optical axis and the RF axis in both hour angle and declination. Biases observed during tracking were approximately 0.06 deg in hour angle and 0.07 deg in declination. The discrepancy between pre-flight and inflight is attributed to the change in declination (declination of the collimation tower: 47 deg; nominal inflight declination: 350 deg). However the close agreement between the pre-flight and inflight RF-axis biases indicates that the pre-flight boresight/polarization angle test may be used as a calibration tool. Additional investigation of the effectiveness of the pre-flight/polarization angle test as an angular calibration test should be conducted for all stations on all missions.

The standard deviation of the hour angle residuals increased from 0.013 to 0.033 deg between Passes 4 and 5. The mean error also changed from -0.006 to -0.063 deg. Investigation of the residual plots revealed that the residuals contained a sinusoid of 0.050 deg peak-to-peak and frequency of 8 cycles/hr. The amplitude of this sinusoid increased on subsequent passes to 0.130 deg peak-to-peak just prior to Earth acquisition and changeover to the high-gain antenna at 05:29 on September 3. After changeover to the high-gain antenna, the hour angle residuals no longer indicated the sinusoid, and the standard deviation decreased from 0.047 to 0.006 deg. The hour angle RF error channel on the CEC recording indicated the same periodic function and became stable after Earth acquisition. This sinusoidal error is attributed to the instability of the servosystem when the received signal strength is < -135 dbm and varying.

The two-way doppler (C-2) for Woomera was normal for Passes 1 and 2, but the standard deviation of the residuals exceeded those of Johannesburg by a factor of 2 for Passes 3 and 4. The increase in standard deviation is attributed partly to the limited transmitting power of 50 w. Additional contribution is due to the unstable transmitter VCO used at Woomera. The transmitter VCO frequency drift exceeded specifications of 1 part in 10^8 per 15 min for over 25% of two-way doppler tracking, which was discontinued after Pass 4 on instructions from DSIF Network Control.

Biases were observed in the pseudo two-way doppler (C-3) when Echo was transmitting utilizing the ultra stable frequency standard. The bias was 4.43 cps on September 29 increasing at approximately 0.26 cps/day to 16.0 cps on October 6, 1962. The bias then changed to -8.95 cps on October 14 and varied systematically through encounter.

Investigation of frequency standard setting errors revealed a setting error of approximately 0.9 msec/day and a frequency standard drift error of 0.025 msec/day^2. Station standard specifications are that the setting error must be $>$ 1 msec/day^2, which is equivalent to 9.3-cps bias in C-3 doppler data. The station standard error was responsible for approximately 50% of the bias observed during *Mariner II*. Sources of the remaining bias were: (1) Orbit Determination Program or (2) the setting of the station reference oscillator. C-3 data during *Mariner II* were not considered primary; however, for future missions (when the rubidium standard is GSDS), detailed investigation of error sources will be conducted so that C-3 data may be used as good secondary data.

One-way doppler data (C-1) were spot checked during the mission to determine the spacecraft transponder stability, and also compare C-1 doppler during periods of mutual coverage.

Hour angle and declination angular data were investigated each week after midcourse maneuver to determine the adequacy of the total error coefficients. Examination of the hour angle and declination residuals from the Orbit Determination Program indicates that the hour angle bias was $<$ 0.02 deg; declination bias was $<$ 0.05 deg. (The inconsistency of the declination bias is due to the tracking procedure of locking in declination at the maximum signal strength with an estimated resolution of $<$ 0.07 deg.)

5. Johannesburg Station (DSIF 5)

DSIF 5 acquired the spacecraft at 07:21:58 GMT with the receiver going in and out of lock several times until 07:53:57. The transmitter was turned on from 08:12 to 08:39 in an unsuccessful effort to obtain two-way doppler lock. Reacquisition in Ground Mode 3 (GM-3) was established at 08:39:42 and remained in GM-3 until 10:00 when the transmitter was again turned on and two-way lock established at 10:02:20.

The transmitter VCO frequency was not recorded while attempting two-way doppler lock from 08:12 to 08:39, thus making it impossible to determine whether the search procedure was accurate. The spacecraft automatic gain control indicated two-way lock from 08:33 to 08:38.

The stability of the transmitter VCO frequency was well within specifications for all passes during which two-way doppler was taken.

Angular data at DSIF 5 were taken in the automatic tracking mode for Passes 1 through 5. The angular error coefficients obtained from star tracks during 1961–1962 were used to correct the optical pointing error. There was a shift of approximately 0.01 deg in the declination residual at a 350-deg hour angle on each pass. The discontinuity was the effect of bearing shift due to change in loading. A similar discontinuity was noted during Pass 2 at Pioneer at an hour angle of 8 deg.

There was a discontinuity of approximately 0.02 deg in the hour angle residuals at hour angles corresponding to approximately an 18-deg elevation angle. The method for refraction correction is changed at this elevation angle, and results in this discontinuity.

In order to better represent the total pointing error (optical + RF), the hour angle and declination residuals (corrected for optical error only) from Pass 2 were each fitted to a polynomial by a linear least squares. The combined angular error coefficients were then used to correct the angular data during Pass 1.

The hour angle and declination error during high tracking rates before effective turnaround (Δ HA changing from $-$ to $+$) could not be entirely corrected by the angular error coefficients. The error was due to lag in the servosystem due to angular acceleration.

Another source of error was the change in RF pointing error as a function of declination. (There is a change in declination from 318 deg at acquisition to 335 deg at effective turnaround.) After turnaround, declination remained nearly constant. In Spring of 1962, tests conducted at DSIF 5 to determine quadripod deflection due to gravity indicated that an error of < 0.008 deg could be expected in hour angle.

DSIF 5 continued to track in the two-way doppler mode through Pass 13 on September 8, 1962. Two-way doppler tracking was discontinued after Pass 13 on instructions by DSIF Network Control; however, tracking in the one-way (C-1) and pseudo two-way (C-3) doppler modes was continued, as scheduled, until the end of the mission on January 4, 1963.

A plot of two-way doppler standard deviation versus range showed a definite increase in the standard deviation, and was attributed to the transmitter VCO frequency instability and increase in delay time between transmitting and receiving.

Pseudo two-way doppler (C-3) with Echo transmitting, utilizing the ultra stable frequency standard, contained a bias of 1.73 cps on Pass 2 on August 28, 1962. The bias increased on subsequent passes at the rate of 0.04 cps/day, reaching a maximum of 2.87 cps on September 30, 1962. Between September 30 and November 10, the bias changed from 2.87 to -7.36 cps. A similar shift in the C-3 bias was noted between October 6 and 14 at Woomera. History of station standard checks was not available from DSIF 5. Biases observed in the C-3 doppler at DSIF 5 were within station time standard capability. Improved station standards are available at the present time.

One-way doppler (C-1) was checked periodically during the mission to check the stability of the spacecraft transponder and also to compare station doppler during periods of mutual coverage. Table 21 presents the comparison of C-1 doppler residuals during mutual coverage.

Table 21. C-1 mutual coverage comparison

Date (1962)	Pass	Day	C-1 Orbit Determination Program residuals, cps			
			Time (GMT)	DSIF 2	DSIF 4	DSIF 5
October 6	41	280	01:20	−235.0	−199.0	
October 6	41	280	09:20		−195.0	−208.0
November 9	75	314	06:00		411.0	410.0

B. Orbit Determination Prior to Encounter

The *Mariner II* pre-midcourse orbit was determined on the basis of data received from DSIF Tracking Stations. The target parameters corresponding to the converged conditions of the pre-midcourse orbit are given in Table 22; the data used for determining this orbit are shown in Table 23. The primary data types were coherent, pseudo-two-way doppler from Goldstone and two-way doppler from the other two stations. Angle data were also used for the first 15 hr of flight.

The *Mariner II* post-midcourse orbits were determined on the basis of data received from DSIF Tracking Stations in Johannesburg, South Africa, and Goldstone, California.

Table 22. Target parameters (Venus)

Parameter	B, km	B • T, km	B • R, km	Radius of closest approach (RCA), km	Time of closest approach (GMT) (12/14)
No advance information[a] on pre-midcourse orbits epoch (07:19:19, August 27, 1962)	394293	291715	−265272	384180	
Post-midcourse orbits, advance information[a] epoch (00:23:32, September 5, 1962)					
Data used from epoch to:					
September 9	53139	−42655	31725	43314	19:31:46
September 15	49921	−39768	30176	40153	19:12:59
September 24	49850	−39722	30120	40083	19:14:47
October 7	50839	−41473	29404	41042	19:47:05
October 15	50869	−41590	29291	41071	19:50:35
October 25	50690	−41581	28992	40895	19:55:12
October 28	50549	−41549	28798	40756	19:56:50
November 5	50177	−41351	28420	40392	19:59:18
November 11	50050	−41282	28298	40269	19:59:53
November 17	49931	−41189	28223	40152	20:00:05
November 26	49712	−41068	28012	39938	20:00:32
December 1	49709	−41066	28009	39935	20:00:32

[a]The advance information consisted of a covariance matrix corresponding to a set of nominal position and velocity components at epoch. This matrix expresses the uncertainty assumed to exist in the pre-midcourse orbit solution and in knowledge of the midcourse maneuver.

Table 23. Tracking data used in *Mariner II* pre-midcourse orbits

Station	Number of two-way or coherent three-way doppler data points	Number of angle data points	
		Hour angle	Declination
Pioneer and Echo	2539	None	None
Woomera	730	308	308
Johannesburg	1920	476	476

The target parameters corresponding to various solutions are given in Table 24. Two-way doppler from Johannesburg and Echo and coherent, pseudo-two-way doppler from Pioneer were used. Table 24 gives the approximate distribution in time of the doppler observations. After September 9, the DSIF normally tracked 1 day/wk. No angle data were used in the post-midcourse

Table 24. Tracking data used in *Mariner II* post-midcourse orbits[a]

Date (1962)	Coherent three-way doppler points (Pioneer)	Two-way doppler points (Echo)	Two-way doppler points (Johannesburg)
September 5–9	2600	0	1600
September 15	625	0	0
September 22–24	1121	0	0
October 7	1172	0	0
October 15	588	0	0
October 25	504	70	0
October 28	547	0	0
November 5	510	0	0
November 11	545	0	0
November 17	623	0	0
November 26	555	0	0
December 1	466	0	0
December 7	496	0	0
December 8	408	0	0
December 11	552	0	0
December 12	433	0	0
December 13	174	0	0
December 14	404	0	0
December 15	296	0	0
December 16	469	0	0
December 17	369	0	0
December 19	277	0	0
December 20	410	0	0
December 28	209	0	0
December 30	164	0	0
Total	14517	70	1600

[a]After September 9, DSIF normally tracked one pass/week.

orbit determination. The post-midcourse orbit target parameters in Table 22 changed with the addition of each weekly pass of data. However, the changes were small and are explained by the fact that the effects of inaccuracies in station locations and the astronomical unit were not considered in arriving at the result.

C. DSIF Equipment Reliability

Reliability of the DSIF, when analyzed from a systems standpoint, may be generally considered excellent. Operation was consistent at each station, and the quality of the recovered data was good. There were, however, a number of areas in which reliability problems did exist; these areas are the basis of discussion.

1. Parametric Amplifier

The parametric amplifier is one of the newest subsystems to be incorporated into the DSIF Network. It was introduced into the system at all the Tracking Stations shortly before the integration testing for the *Mariner* mission. Because of its complexity and susceptibility to conditions of instability, the system presented a number of operational problems during the course of the mission. In most cases, personnel were not adequately trained to perform functions that were essential to efficient equipment operation. Repeatedly, undue stress and strain were placed on equipment because of unfamiliarity with their basic operating principles. Over-tuning, or excessive tuning, was a problem at almost every station.

Each DSIF Station that had an operating parametric amplifier system, at the time of launch of *Mariner II*, experienced difficulty and eventual failure of that system at some time during the 109-day mission. It should be noted here that the parametric amplifier has a 1,000-hr life expectancy, which is considerably less than the total operating hours required for the entire *Mariner* mission. This dictated preventive maintenance and parts replacement during the mission, or a failure was, not only predictable, but imminent.

The Pioneer Station lost the use of its parametric amplifier during the tenth tracking period. Calibration equipment indicated equipment malfunction early in the tracking period; when replacement by a spare unit did not correct the malfunction, further investigation disclosed the calibration equipment to be at fault. Replacement of the original unit and bypassing the calibration equipment returned the station to operation, although drift in gain continued to be a problem.

The original configuration of the parametric amplifier had all components rigidly affixed to the chassis. Stresses and strains produced by this type of construction caused output irregularities that were passed on to the RF equipment. This design problem was the cause of a malfunction early in the mission. (Basic redesign has since been completed, and the irregularities eliminated.)

With the exception of the parametric amplifier, Woomera equipment operation was generally satisfactory. Both parametric amplifiers at this station had a history of unexplained gain limiting prior to the mission. Two parametric amplifier failures occurred during the mission; both required klystron replacement. The spare klystron was accidentally damaged by station personnel so that, for a while, the station was without a spare.

At the Johannesburg Station, the faulty parametric amplifier caused excessive drift, which was noticed just prior to the encounter phase. A great deal of time was lost in troubleshooting and replacing diodes in this unit before the trouble was corrected by exchanging signal cavities with a spare parametric amplifier unit. Following this, gain returned to a stable condition, and the parametric amplifier remained operational throughout the rest of the mission. (The parametric amplifier is currently undergoing engineering evaluation and extensive redesign to eliminate or reduce the effects of a number of environmental conditions affecting the over-all stability of the subsystem. Future units will be able to operate at reduced environmental temperatures, and improvements in mounting will reduce stress now damaging diodes. Basic improvement in the construction of the parametric amplifier diode is also expected to increase the reliability of the parametric amplifiers.)

2. Consolidated Electrodynamics Corporation (CEC) Recorders

Throughout the DSIF Network, the CEC oscillograph recorders were a frequent source of problems during the *Mariner* mission. At Pioneer and Woomera, they failed early in the eighth tracking period because of transmission gear troubles; minor loss of spacecraft data resulted in each case. The unit at the Echo Station was somewhat better; however, its transmission failed on the tenth pass.

The situation was even more difficult at the Johannesburg Station. Here, the CEC recorder was inoperative a number of times during the mission. New transmission gears were installed on the 19th, 32nd and 74th pass.

A backup recorder of another manufacturer was used during each failure to prevent the loss of data. (CEC recorder transmissions have since been redesigned and "beefed-up" by the manufacturer. The new transmissions are now in the process of being sent to all stations as field modifications. With the installation of the modification, transmission problems should be all but eliminated, and the reliability of this piece of equipment should return to an acceptable level.)

3. Mission-Oriented Equipment

Mission-oriented equipment did not arrive at the DSIF Stations early enough in the program schedule to permit adequate testing. These equipments were often unreliable with excessive maintenance problems stemming from the technical design and component quality. This situation was compounded by the fact that delivery was, in most cases, too late to allow for proper personnel training; in addition, there was a lack of proper documentation, as well as a lack of spare parts.

The following suggestions were made as possible solutions:

1. A monitoring program should be established for monitoring the design of all mission-oriented equipment. Monitoring should include the responsibility for having the design of all equipment to be compatible with operating DSIF equipment.

2. So that extensive testing can be conducted at the Laboratory and at Goldstone prior to shipment of equipment to the overseas stations, early delivery dates should be set for all mission-oriented equipment and these delivery dates should be met. (This is imperative to the success of future missions.)

3. A Special Engineering Team (SET) should be assembled to take the equipment overseas and to supervise equipment installation and checkout as well as training of overseas personnel. In this manner, much of the pre-mission work load on resident station personnel could be eased. Personnel from overseas stations might be returned to JPL for indoctrination and familiarization.

4. As the complexity of mission-oriented equipment increases, testing becomes of major importance; therefore, testing must be conducted to determine the inherent reliability characteristics of the equipment so that maintenance programs can be established.

5. It should be the responsibility of the operation Project Engineer to determine whether documentation, spare parts, and training are adequate to support the mission.

4. Human or Operator Error

Throughout the mission, operational errors reflected the lack of an adequate personnel training program. All of the stations, at one time or another, experienced accidents caused by human error which resulted in a loss of data. These accidents, though varied, could have been prevented had the personnel been adequately instructed prior to the tracking mission.

Operator inexperience was demonstrated early in the mission by the difficulty in locking-up at the 8-bit/sec rate at the lower signal levels. This problem diminished as the mission progressed and personnel became more confident of their capabilities.

Frequent loss of lock in the precision doppler bias loop was experienced because the doppler data condition switch was in the wrong position. (Despite determined briefing efforts, good/bad data switches were operated improperly throughout the mission.) Poor adjustment of scope controls also caused frequent problems. Proper indoctrination could have prevented or eliminated these operational reliability problems. (Continued effort must be concentrated to eliminate all possible human errors from system operation. Training programs will be established to indoctrinate personnel in the proper use and maintenance of new equipment hardware. Procedures will be established to ensure that equipment is operated in the manner intended by its designer, and that design limits are not exceeded by careless operation.)

5. Over-All Reliability Performance

The operation of the Network was unquestionably excellent; however, the formalization of reliability measures is vital to future reliable system operation. This need is acknowledged by the addition of a Systems Reliability Unit to the DSIF, which is currently formalizing programs in over-all systems reliability and maintenance.

(A formal DSIF Reliability Program is now being established for the entire Network. This program includes development of procedures for maintenance and installation of safeguards that guarantee an improved reliability status of the DSIF Network on all future missions.)

VI. PARTICIPATION OF NON-DSIF AGENCIES

The Space Flight Operations System comprised the Earth-based facilities and personnel required for the conduct of space flight operations, which covered the phase from injection of the spacecraft into a Venus transfer trajectory through termination of the mission. For the *Mariner II* flight, the System included the Space Flight Operations Center (SFOC), the Launch Control Center, the Communications Center, the Central Computing Facility (CCF), the Deep Space Instrumentation Facility (DSIF), and certain Atlantic Missile Range (AMR) facilities. The *Mariner II* System was operational 24 hr/day from launch through the encounter phase.

The Space Flight Operations Center at the Jet Propulsion Laboratory in Pasadena, California, was the coordinating focal point for all activities associated with the mission; all managerial, analysis, and directorial functions were performed at this Center. Within the Space Flight Operations Center, the following activities were in progress throughout the flight of *Mariner II*:

1. All spacecraft commands were originated.
2. Current over-all status of the operation was displayed on the status display boards.
3. Control was exercised over DSIF tracking operations.
4. Information pertaining to the flight path and to spacecraft performance was analyzed by the Spacecraft Data Analysis Team (SDAT), the Scientific Data Group, the Tracking Data Analysis Group, the Orbit Determination Group, and the Midcourse Maneuver Commands Group.

The Launch Control Center, located at Cape Canaveral, provided coordination of countdown and launch activities involving the spacecraft and AMR facilities.

The Communication Center (Fig. 45) controlled all communication lines over which data flowed throughout the SFOC, except for the high-speed data line between Goldstone and the CCF. The Center was the terminus for all communications associated with *Mariner II* operation.

The Central Computing Facility (CCF) incorporated a Primary Computing Facility, a Secondary Computing Facility, and a Telemetry Processing Station (TPS). The CCF processed and reduced tracking and telemetry data to forms required by the users for analysis of spacecraft performance, flight-path information, and command generation. Figures 46 and 47 depict the flow of these data.

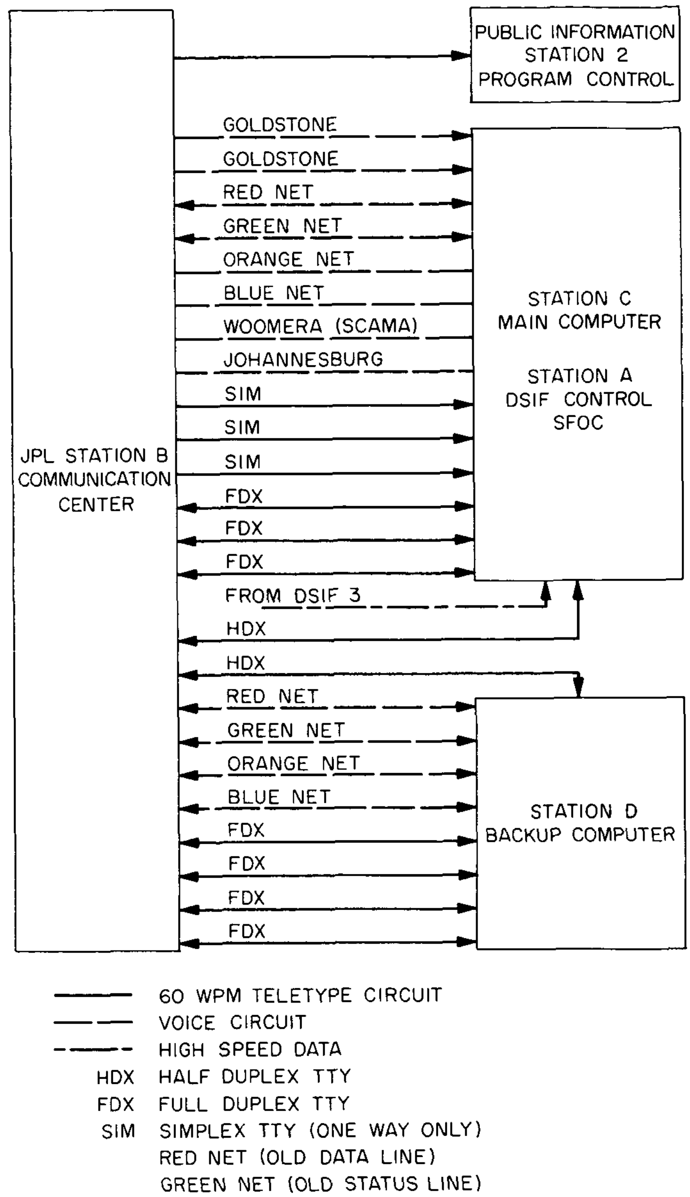


Fig. 45. Interior Communications Network for *Mariner II*

The capabilities of the SFOC were designed to fulfill, and be adaptable to, the requirements of the mission. The Space Flight Test Director was required to be cognizant of these capabilities and, prior to the flight, to compile

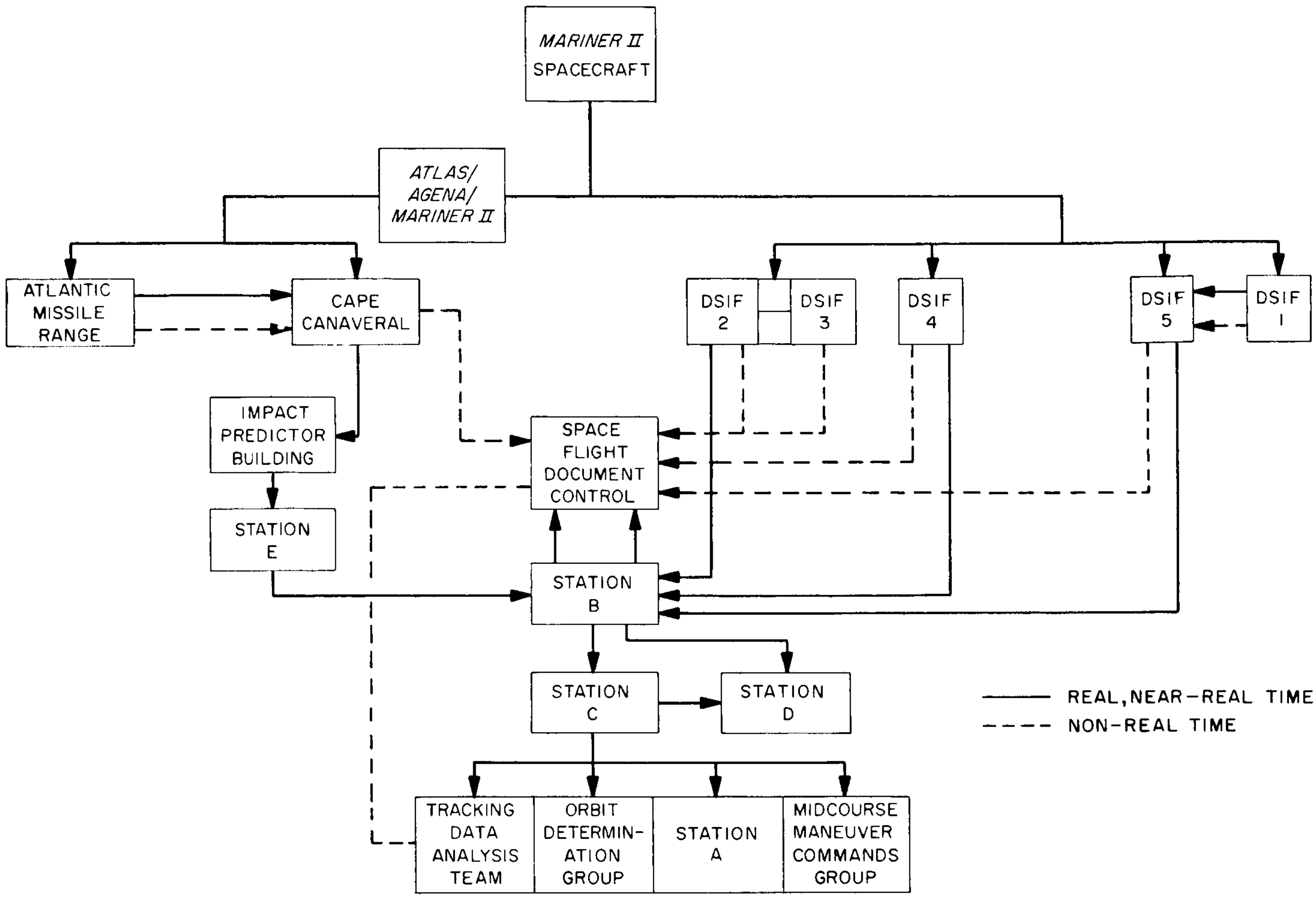


Fig. 46. Tracking data flow

the Space Flight Operations Plan (SFOP), which defined the method by which the operation would be conducted in both standard and nonstandard cases. He was further responsible for making work assignments consistent with the SFOP to the various operating groups, resolving ambiguities arising from application of the SFOP, and making decisions requiring emergency action when the Project Manager was not available. Also, prior to the flight, the Test Director organized and conducted a series of operational systems-integrated tests in order to familiarize participants with the operation and to permit any necessary modifications to equipment or procedures within the established operational framework.

During the flight of the spacecraft, the Test Director exercised primary control of the System, maintaining liaison with the leaders of the operations groups and with the facilities coordinators. Determination of priorities, as well as major operational decisions, were made by him with the concurrence of the Project Manager.

A. Atlantic Missile Range Support

The Atlantic Missile Range (AMR) supplied JPL with real-time tracking data on the *Agena* parking orbit from the Antigua and Ascension Island Stations (Fig. 48). The Antigua data covered that part of the trajectory from first *Agena* cutoff to the horizon. Data prior to this time were concerned with powered flight and were, therefore, not usable in the parking-orbit-determination program.

Good data were received at low elevation angles but, because of the uncertainty of refraction effects in the atmosphere, no data below 3.7-deg elevation were regarded as usable. Between first *Agena* cutoff and the horizon, a maximum of 37 data triplets could have been received; because of radio-frequency transmission problems, however, only 16 of the data triplets were received at AMR in real-time. In addition, some of these 16 triplets were not received intact. Of the 48 total measurements, only 39 were usable in the final orbit determination; these

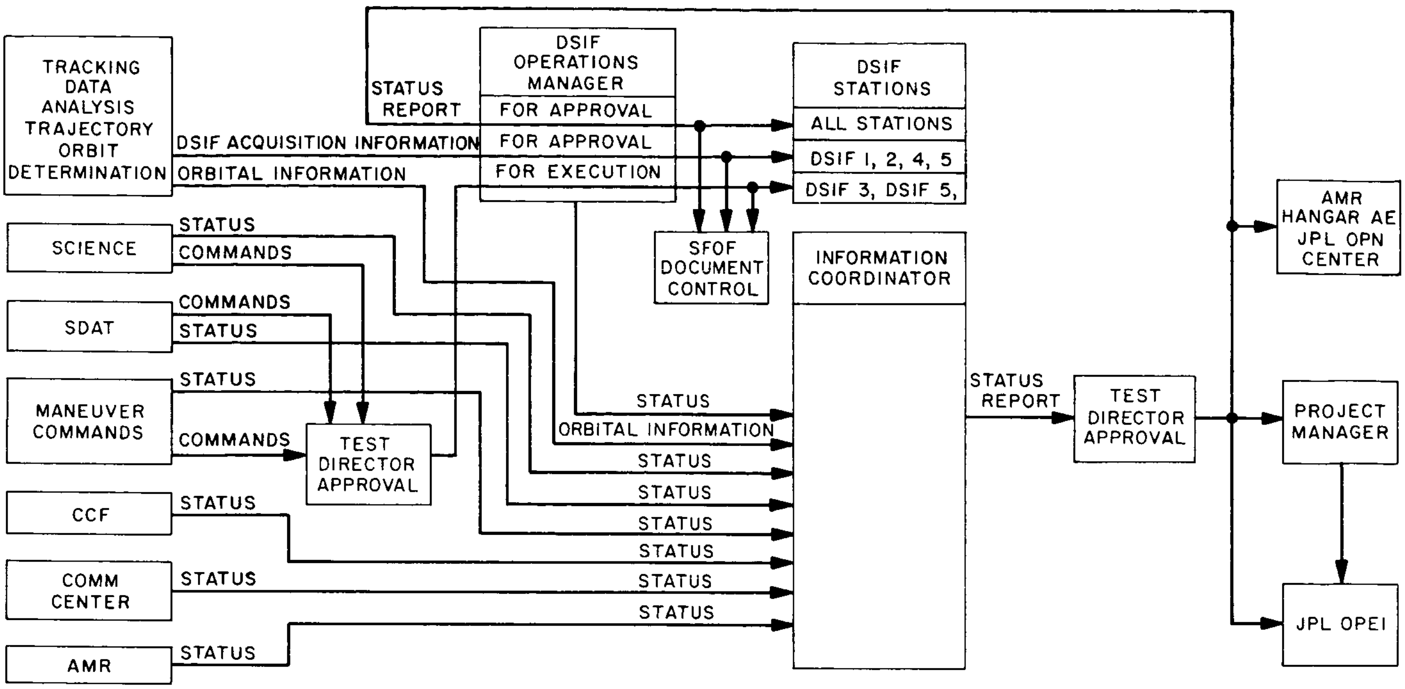


Fig. 47. Complete data flow from SFOC

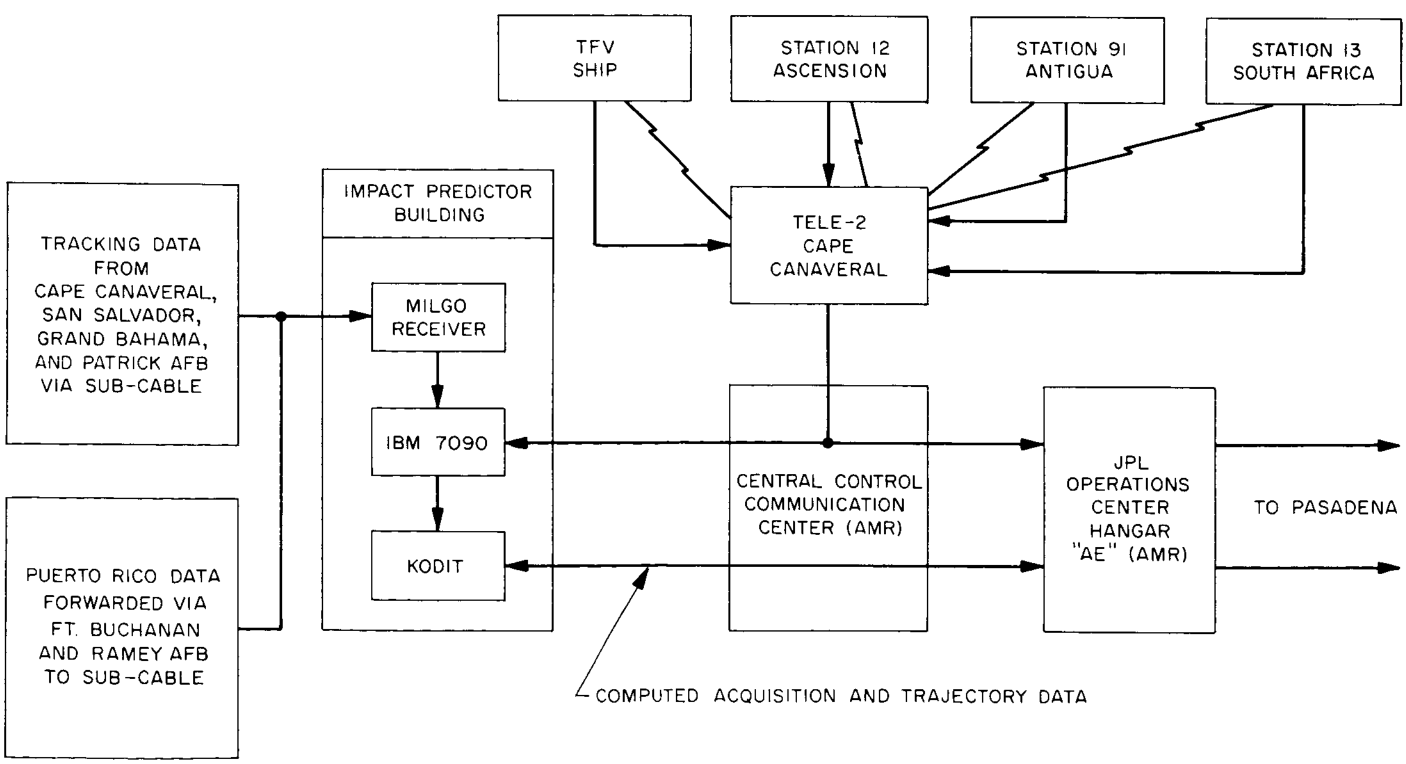


Fig. 48. Tracking facilities supporting *Mariner II* at AMR

consisted of 16 range points, 13 of 16 azimuth points, and 10 of 16 elevation points.

The Ascension Island Tracking Station sent a full pass of data, ranging from an initial elevation angle of 5 deg to a maximum angle of 73 deg and back down to 12 deg. Range at the peak elevation angle was 190 km. *Agena* second ignition occurred toward the end of the pass at the 12-deg elevation angle. No data were accepted after this, because powered-flight data are not applicable in the parking-orbit-determination program. All data were of excellent quality.

A relatively new Tracking Station at Pretoria, South Africa, equipped with an FPS-16 radar set, tracked the *Agena* after second burnout. However, an equipment malfunction caused a loss of the time-word in the data message. Approximately 10 hr later, when sufficient DSIF tracking data had been received to give a good orbit determination, the Pretoria data were compared with this orbit and time correlation was obtained. The Pretoria data covered the time period from 9 min, 25 sec to 34 min, 30 sec after second *Agena* burnout. At the end of the tracking period, the *Agena* was approximately 14,000 km from Pretoria. These data were subsequently compared with five optical fixes of the *Agena* obtained from the Mount Palomar Observatory. The Mount Palomar data were partially reduced, yielding an accuracy on the order of 0.2 min of arc. The two data sources were found to be statistically consistent. The transfer orbit thus determined for the *Agena* indicated that it was not on a collision course with Venus. A final transfer-orbit determination and data evaluation were conducted when a reduction to 1 sec of arc in accuracy was completed on the Mount Palomar data.

Because of an equipment failure in the 4101 computer on board the Twin Falls Victory Ship, no tracking data were available from this source. The computer's function was to remove the ship's motions in pitch, roll, and heading from the tracking data obtained by the shipboard radar. Useful range data were taken, but were not used in real-time because of the availability of the Pretoria data.

B. Central Computing Facility

The Central Computing Facility (Fig. 7), located at JPL, Pasadena, California, had the function of reducing the tracking and telemetry data from *Mariner II* so that required orbital calculations and command decisions could be made. After the magnetic tapes of telemetry data recorded by the DSIF had been received at JPL, the CCF processed the raw data into the form required by the user. All real-time data processing and normal non-real-time data were processed in the CCF.

Three stations comprise the CCF. They are discussed in the following paragraphs.

1. Primary Computing Facility

Tracking and telemetry data, which included both real- and non-real-time data, received from the DSIF were processed at this Facility. The processing equipment included:

IBM 7090 Computer (and Associated Card Handling Equipment). The IBM 7090 is a large, high-speed, general-purpose, digital computer. The JPL installation had a 32,168-word core memory, and was equipped with two input–output channels, with each channel containing seven 729 IV tape units.

Telemetry-to-Magnetic-Tape Translator. This data translator accepted up to seven channels of digital data (asynchronously) and converted these data into blocked IBM format; it then recorded them on magnetic tape for entry into the IBM 7090 computer.

Teletype-Tape-to-Magnetic-Tape Translator. This device took the bit configuration of a five-level teletype character and put it into Channels A, 8, 4, 2, and 1 of an IBM magnetic tape character. One magnetic tape record comprised 1026 of these characters. The normal rate in this mode was 300 characters/second and the maximum rate was 600 characters/second. The device was also capable of punching paper tape from IBM magnetic tape. The rate in this mode was 60 characters/second.

IBM 1401 Computer (Two Units). This computer acted as a satellite to the IBM 7090. It was primarily a bookkeeping and input–output processing unit which would relieve the 7090 of these time-consuming functions. It was equipped with a 600-line/min printer, a card punch, a card reader, and two magnetic tape handlers. The 1401 communicated with the 7090 by magnetic tape, thereby eliminating card punching, card reading, and listing as on-line functions of the 7090.

Stromberg Carlson (SC) 4020 Printer–Plotter. The SC 4020 was a high-speed microfilm recorder. It was intended to record on microfilm real-time information supplied by the 7090 computer. Standard options extended its capabilities as a plotter and printer, and permitted off-line operation from magnetic tape. "Quick-look" was available in the form of a hardcopy camera option which provided one copy, 7.5 × 7.5 in., of each frame of information generated by the SC 4020. The copy was developed at the site in the F85 oscillogram processor. The quick-look copy was available within 30 min of processing the raw data.

Paper-Tape-to-Card (IBM 047) and Card-to-Paper-Tape (IBM 063). These devices were used for the tracking operation of *Mariner II*. For the initial orbit determination, the data points were entered into the computer as quickly as possible. By putting these points on cards, human checking of transmission errors was made possible.

Digital Equipment Corporation PDP-1 Computer. The computer handling of telemetered data for *Mariner II* was accomplished with the PDP-1 as the prime data handling equipment. The IBM 7090 was still used to perform complex reduction and analysis, but was relieved of bookkeeping, quick-look, and near-real-time monitoring. The PDP-1 was a small, fast computer designed specifically for data processing. It was equipped with 4,096 18-bit words of core storage, two Plotter 906 II tape units connected through a high-speed tape channel, a paper-tape reader and punch, a typewriter, and a word buffer to accept data from a telephone line. Generally, the PDP-1 was able to perform simultaneously the following functions:

1. Prepare for analysis a magnetic tape file of all telemetered measurements, which were used as input to the IBM 7090, and for preparing a final report.

2. Prepare magnetic tapes to drive the IBM 1401 printer.

2. Secondary Computing Facility

The basic function of this Facility was to provide backup computational facilities in case of a failure in the Primary Computing Facility. The normal mode of operation for this backup facility was to parallel the effort of the Primary Facility during the critical phase of flight (i.e., launch and initial orbit determination). The Secondary Facility was used for processing other data, as needed. The processing equipment duplicated that of the Primary Facility.

3. Telemetry Processing Station (TPS)

It was the responsibility of the TPS to process telemetry magnetic tapes recorded at the DSIF Stations. All signals recorded on the tape (including DSIF Station functions) were processed by the TPS except the spacecraft telemetry composite signal. The decoded spacecraft telemetry composite signal was recorded on this tape by the DSIF for processing by the TPS.

C. *Ground Communications Network*

The Ground Communications Network used during the *Mariner II* mission is shown in Fig. 49. Teletype lines, the primary communication links for the mission, were used for transmitting data from the DSIF Stations to the Central Computing Facility and for passing command, acquisition, prediction, and administrative information to the stations. The voice circuits were available for high-priority, real-time communications during the launch and any other critical phase of the *Mariner* operation. All these communications links were monitored and controlled by DSIF Network Control. All messages pertaining to the mission passed through or originated from Network Control. The Communications Organizational Chart for *Mariner II* is shown in Fig. 50.

1. Data Circuits Communication Links

a. Goldstone. The Communications Center had three half-duplex teletype circuits available for data transmission to or from the Echo Station. There were two half-duplex circuits between the Pioneer and Echo Stations, and one wide-band telephone data circuit available for one-way transmission from Goldstone to JPL. These circuits were available, as required, for full-time usage. Data transmissions were restricted on any one circuit to transmission in one direction only.

b. Woomera and Johannesburg. One full-duplex circuit was available to each of the overseas stations on a full-time basis. A second circuit was available to each station on a limited basis during critical periods or when primary circuits failed. Due to the necessity of utilizing radio teletype, over a significant portion of the transmission path, both circuits were not 100% reliable during periods of poor high-frequency radio propagation. Therefore, to gain a measure of redundancy, the primary and secondary circuits were routed over different paths. Data transmission over these circuits took place simultaneously in both directions.

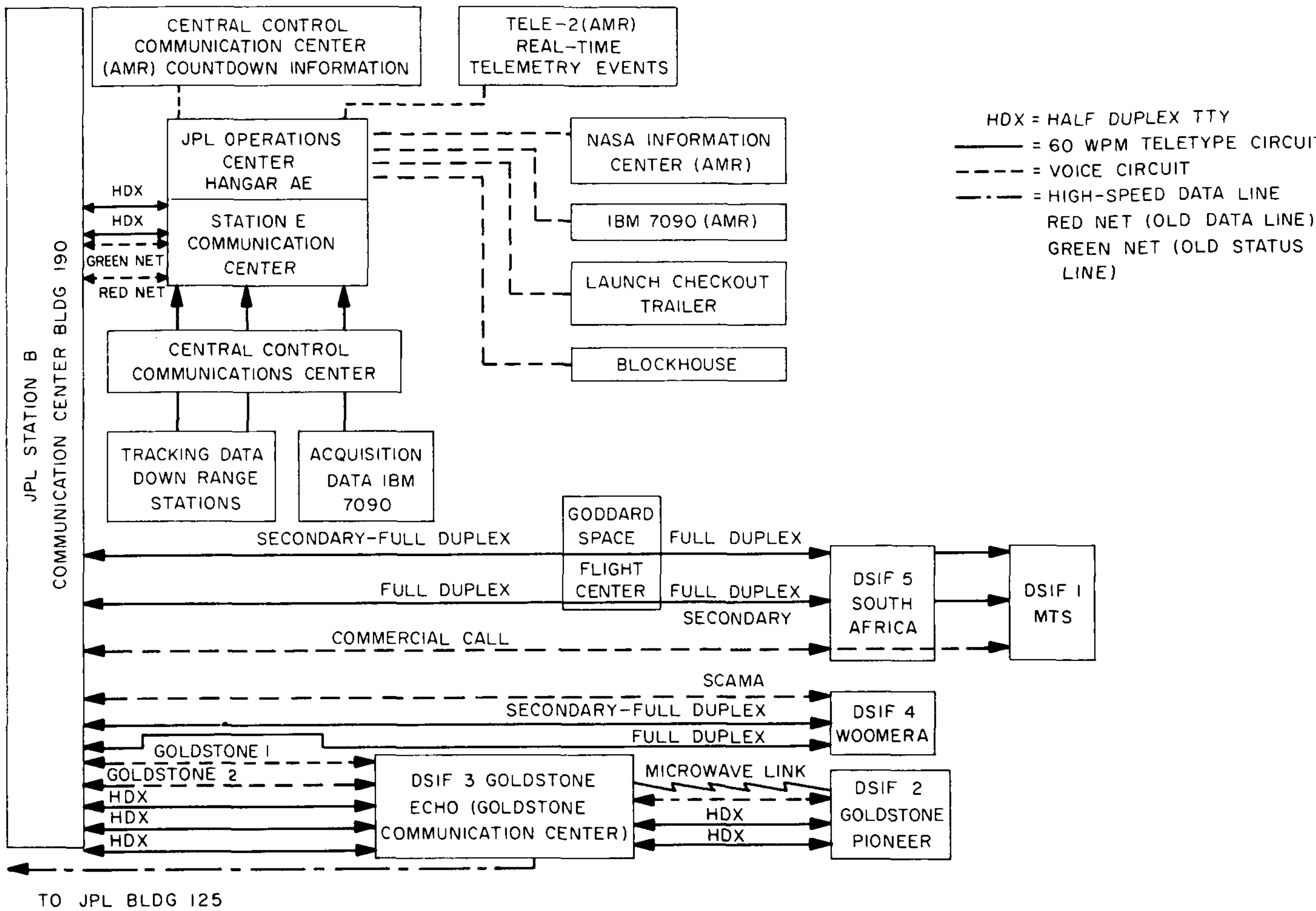


Fig. 49. Ground Communications Network for *Mariner II*

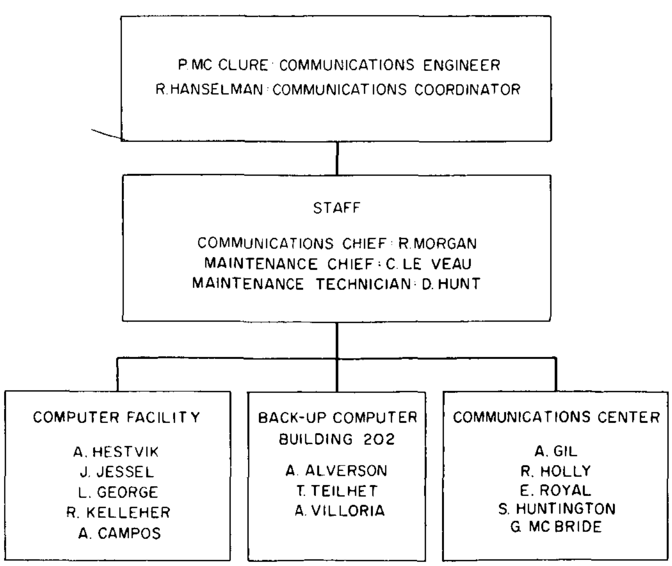


Fig. 50. Communications organization

c. Mobile Tracking Station (MTS). The MTS utilized the same teletype circuits as the Johannesburg Station.

d. Cape Canaveral. Two half-duplex circuits were available to Cape Canaveral during the *Mariner II* launch period. These circuits were available 2 wk prior to the mission, and were used for data flow between the Launch Complex and the JPL Communications Center at Pasadena, California.

2. Voice Circuits

a. Goldstone. Two voice circuits were available to Goldstone. These circuits consisted of four-wire telephone circuits capable of being conferenced at JPL (SFOC) with other voice circuits that were used as part of the DSIF operations.

b. Woomera and Johannesburg. A commercial toll call was placed to South Africa prior to each *Mariner* operation. Voice communications to Woomera used either the Mercury Network on a noninterference basis or a commercial toll call. These circuits were used, as required, for the first 3 operating days after launch of *Mariner II* and were not available on a full-time basis.

c. Mobile Tracking Station (MTS). The MTS used the same voice circuits as the Johannesburg Station.

d. Cape Canaveral Computing Center. Two voice circuits were available during the launch period for communications with the launch complex. One circuit connected the Central Computing Facility with the Cape Canaveral Computing Facility; the second was used to coordinate the DSIF and launch activities (data and status lines).

e. Space Flight Operations Center (SFOC). Numerous circuits interconnected the DSIF Network Control (JPL) with the Test Director and other personnel within the Space Flight Operations Center, and with the JPL Communications Center. These circuits included two four-wire hot lines, an intercom system, and a conventional telephone system.

f. Central Computing Facilities. Four-wire conference circuits and an intercom system connected the Primary Computing Facility to the SFOC and the Secondary Computing Facility.

Four-wire conference circuits and an intercom system connected the Secondary Computing Facility to the SFOC and the Primary Computing Facility.

D. Spacecraft Data Analysis Team

The Spacecraft Data Analysis Team (SDAT) was composed of the Director and one or more cognizant engineers for each subsystem of the spacecraft. The primary function of the Director was to coordinate, from analysis of the telemetry data received, the efforts of the SDAT in determining the performance of the spacecraft in flight.

It was initially planned that the SDAT would convene daily during cruise-mode periods to examine and evaluate all data received since the previous session, and that the Central Computing Facility would monitor all incoming data during nonstandard working hours; the cognizant engineer would be notified in the event that an alarm situation developed. This method of monitoring, however, proved inadequate early in the operation. The CCF was not able to identify enough low-rate data to permit the computer to operate in the automatic alarm mode. The computer's failure to identify these measurements was primarily due to the inadequacy of the data-reduction program to deal properly with noise or intermittent transmission, characteristic of most of the data received from the overseas tracking stations. The inability of the computer to identify low-rate data hampered the SDAT in evaluating the spacecraft's performance and necessitated a change in the method of operation, with a simultaneous effort to improve the computer's capability of processing noisy data.

Rather than relying on computer-generated tabulated listings for low-rate measurements, the SDAT assigned a technician to the task of monitoring the teletype page printers to identify these subcommutated measurements. Printed data were supplied by the teletype page printers in commutated form; therefore, in effect, the technician assumed one of the computer's initial functions of decommutating the data.

In addition, an engineer was made available 24 hr/day, 7 days/wk, to examine and evaluate the data identified and decommutated by the technician. This arrangement worked satisfactorily and was continued for the remainder of the mission.

E. Orbit and Trajectory Determination Group

This Group computed the spacecraft's path with respect to the Sun, the Earth, and the target planet. Determinations were made at least once per day prior to midcourse, once per week during the cruise phase, and once per day during the encounter phase, which encompassed the period from December 8 to 18. For purposes of data analysis and emergency-action planning, current information on orbital elements, target parameters, and spacecraft trajectory and attitude was supplied to the other operational groups. An important contribution of the Orbit and Trajectory Determination Group was establishment of the target-miss parameters, both prior and subsequent to the midcourse maneuver.

F. Midcourse Maneuver Commands Group

In order to fulfill its responsibility for generating the commands for the midcourse maneuver, this Group, during that portion of the flight preceding the maneuver, maintained liaison with the Spacecraft Data Analysis Team, the Scientific Data Group, and the Communications Coordinator. Information obtained from these sources pertaining to spacecraft status and scientific objectives was coordinated with additional information developed by the Group itself; this, in turn, was correlated with an analysis of the operational situation. The resulting study was presented to the Test Director in the form of a recommended midcourse maneuver and a detailed analysis of the effect of such a maneuver on the accomplishment of the mission objectives.

G. Scientific Data Group

The Scientific Data Group membership was composed of the Project Scientist, and certain of the JPL Cognizant Scientists, for data handling. As the occasion demanded, the remaining JPL cognizant scientists served in a consulting capacity. Throughout the *Mariner II* operation, the Group translated the scientific aspects of the mission into a format permitting their utilization.

The Group began to function early in May 1962 and was active in the formulation of the scientific requirements of the mission, as reflected in the Space Flight Operations Plan. This effort served, primarily, to establish the scientific data requirements, and to bring to the determination of the planet aiming point, the optimal correction permitted by the constraints imposed on the trajectory by the scientific instrumentation. Procedures to be followed during nonstandard modes of operation were also formulated.

During the mission, close liaison was maintained with the SDAT scientific team. The AGIWARN service[1] of the North Atlantic Radio Warning Service was closely followed. No Class 3 or larger solar flares occurred during the mission; only one of the several Class 2 flares was reported through the AGIWARN Alert Program. The purpose of following the AGIWARN alert was to enable the DSIF Stations to be alerted for continuous coverage should a significant solar event occur.

H. Post-Flight Data Analysis

Tracking and telemetry data received during the *Mariner II* flight have been subjected to general and detailed evaluation in real-time, near-real-time, and non-real-time. Tracking data, which included angular-position and doppler information, constituted a functional operations requirement for purposes of orbit and trajectory determination during the flight and for evaluation of tracking-station performance. Telemetry data, consisting of spacecraft-system performance and scientific-experiment information, were required for continuous inflight analysis of spacecraft status.

The tracking and telemetry data met user requirements and served as a test of processing capabilities to help establish procedural guidelines for testing and checkout of the Space Flight Operations System for future missions.

[1]This is a world-wide reporting service on solar activity and associated geophysical phenomena, administered by the United States National Bureau of Standards.

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