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Tracking and Data Acquisition Report: Mariner Mars 1964 Mission Volume I. Near-Earth Trajectory Phase

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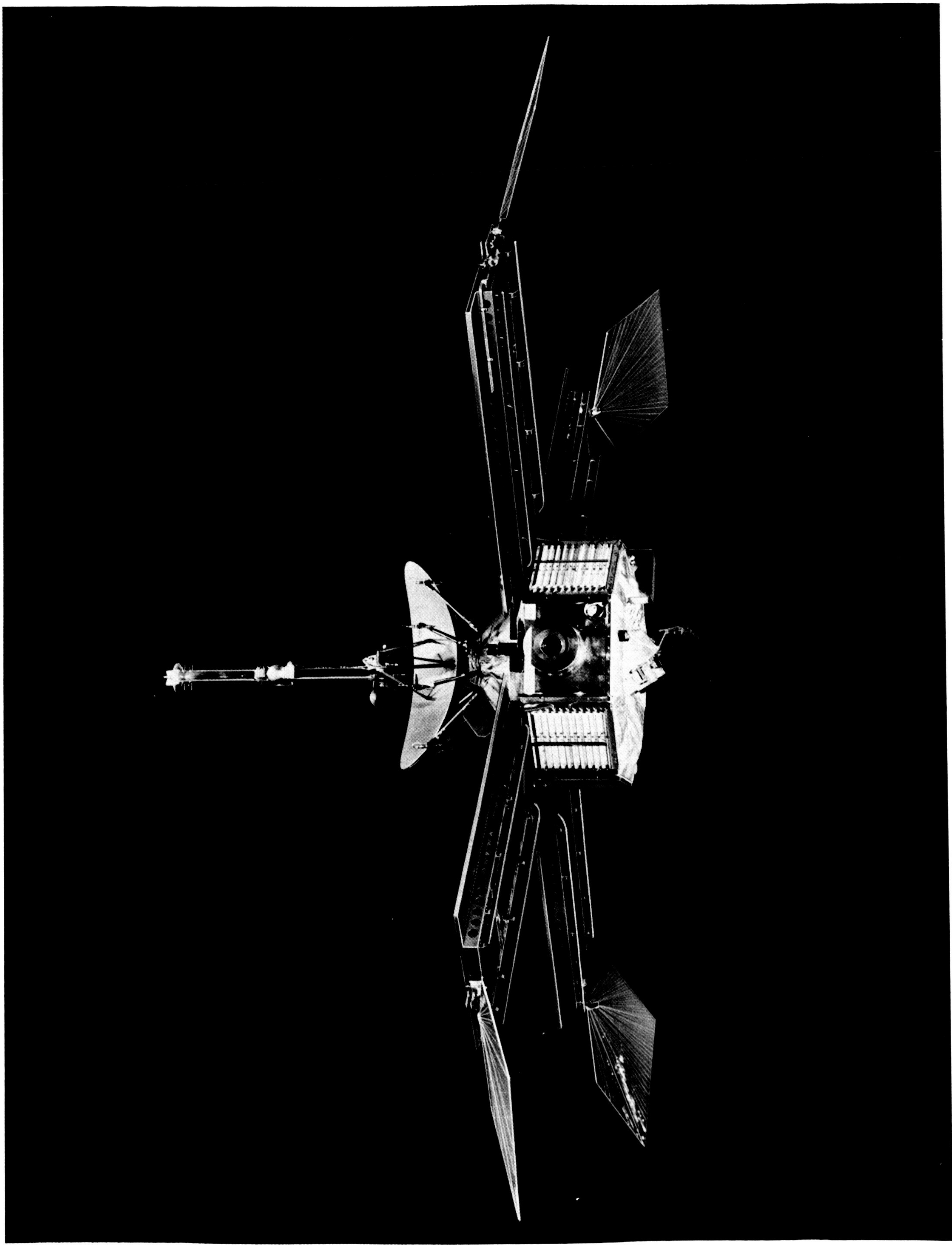

ABSTRACT

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This document summarizes the technical activities of the AFETR, certain stations of the NASA/GSFC Manned Space Flight Network (MSFN) and Satellite Tracking and Data Acquisition Network (STADAN), and the NASA/JPL Deep Space Network (DSN) in support of the near-Earth trajectory phase of the *Mariner* Mars 1964 Mission. Included in this document are the tracking and data acquisition requirements and related support plans for all the participating agencies, a comprehensive account of the tracking operations, and a performance evaluation summary.

I. INTRODUCTION

The purpose of this report is:

1. To summarize the technical activities of the Air Force Eastern Test Range (AFETR), the Goddard Space Flight Center (GSFC) Manned Space Flight Network (MSFN) and Satellite Tracking and Data Acquisition Network (STADAN) stations, and the NASA/JPL Deep Space Network (DSN) in support of the *Mariner* Mars 1964 Mission during the near-Earth trajectory phase.
2. To present the tracking and telemetry data acquisition requirements placed on these agencies and their actual support activities.
3. To provide an historical record of the framework within which the technical data were obtained, transmitted in real-time or near-real-time, and stored on magnetic and paper tapes, Deep Space Instrumentation Facility (DSIF) station logs and

reports, and various types of instrumentation recordings.

This report is issued in two volumes. Volume I deals with tracking and telemetry coverage during the prelaunch and near-Earth trajectory portions of the Mission. Volume II will document the tracking, telemetry, and command support provided by the DSN for the remainder of the Mission, including maneuver operations, cruise, encounter operations, and the postencounter playback of the television picture data.

A. Scope

This report provides technical information concerning *Mariner* Mars 1964 tracking and data acquisition (T&DA) and associated support functions, including communications and the transmission, processing, and reduction of data. Requirements and related support plans of all participating agencies are presented herein, together with observed limitations and capabilities of the individual facilities, where applicable. Preflight support of the Mission is documented in the form of operational readiness tests conducted by the various agencies. Tracking operation summaries for each of the participating agencies, where available, are presented in a narrative format, with emphasis on critical phases of flight control. A brief description of *Mariner* Mars 1964 launch trajectories as well as launch vehicle and spacecraft performance is also provided to convey an understanding of T&DA activities.

B. Related Documents

The tracking and telemetry coverage requirements placed upon AFETR, NASA/GSFC, and NASA/JPL (DSN) are treated in Section III. Documents stating these requirements are presented in the following tabulation:

Source	Document
Mariner Mars 1964 Mission Requirements	
AFETR	*Program Requirements Document* (PRD 4300 Mariner, PAFB, August 18, 1964)
NASA/GSFC	*Network Operations Plan for Mariner Mars 1964* (X-552-64-308, Greenbelt, Md., October 23, 1964)
NASA/JPL (DSN)	*Space Flight Operations Plan (Rev. 1)* (Jet Propulsion Laboratory, Pasadena, August 17, 1964)
SLV-III (*Atlas D*) Booster Requirements[a]	
AFETR	*Booster Requirements Document*[b]
***Agena D* Booster Requirements**[a]	
AFETR	*Booster Requirements Document*[b]

[a] In most instances, independent of payload.
[b] As referenced in Program Requirements Document (PRD 4300 Mariner).

II. MISSION OBJECTIVES AND DESCRIPTION

A. Mission Objectives

The overall objective of the *Mariner* Mars 1964 Mission is to perform a successful mission to the planet Mars during the 1964 period of availability.

The primary objective of the Mission is to conduct close-up (flyby) scientific observations of the planet Mars during the 1964–65 opportunity and to transmit the results of these observations back to Earth. The planetary observations should, to the greatest practical extent, provide maximum information about Mars. TV and cosmic dust experiments together with a reasonable complement of fields and particles experiments are carried. In addition, an Earth occultation experiment was planned for spacecraft launched during the Type I trajectory launch period to obtain data relating to the scale height and pressure in the atmosphere of the planet. The *Mariner* Project Office was given the option of launching one spacecraft on a Type II trajectory and waiving the occultation experiment on Type II trajectories if, in its judgment, such action would maximize the probability of total Mission success.

A secondary objective is to provide experience and knowledge about the performance of the basic engineering equipment of an attitude-stabilized flyby spacecraft (Figs. 1 and 2) during a long-duration flight in space. An additional secondary objective is to perform certain field and particle measurements in interplanetary space during the trip and in the vicinity of Mars.

The *Atlas D/Agena D* launch vehicle used in the Mission was capable of providing a separated spacecraft weight of approximately 575 lb.

During the Mission, two launchings were conducted from two separate launch pads. All activities were planned to exploit the limited launch period to the maximum extent. To accomplish this, spacecraft and launch vehicles were processed in parallel so that, following the launching of the first space vehicle, a second vehicle could be launched without delay (no earlier, however, than two days after the first launch).

B. Mission Description

1. General

The *Mariner* Mars 1964 Mission comprises two flights: *Mariner* launches C (*Mariner III*) and D (*Mariner IV*). The two vehicles were identified by serial number, but *Mariner C* represented the first launch designation, regardless of which vehicle was employed. These missions utilized the *Atlas D/Agena D* vehicles and the *Mariner C* configuration spacecraft. The space vehicles were launched from Launch Complexes 12 and 13 at Cape Kennedy.

Ascent trajectories were similar to those used for the *Ranger* lunar flights. Parking orbit altitude was approximately 100 nm. Tracking data obtained during entry into the parking orbit and through spacecraft injection were used by AFETR and JPL for orbit determination and

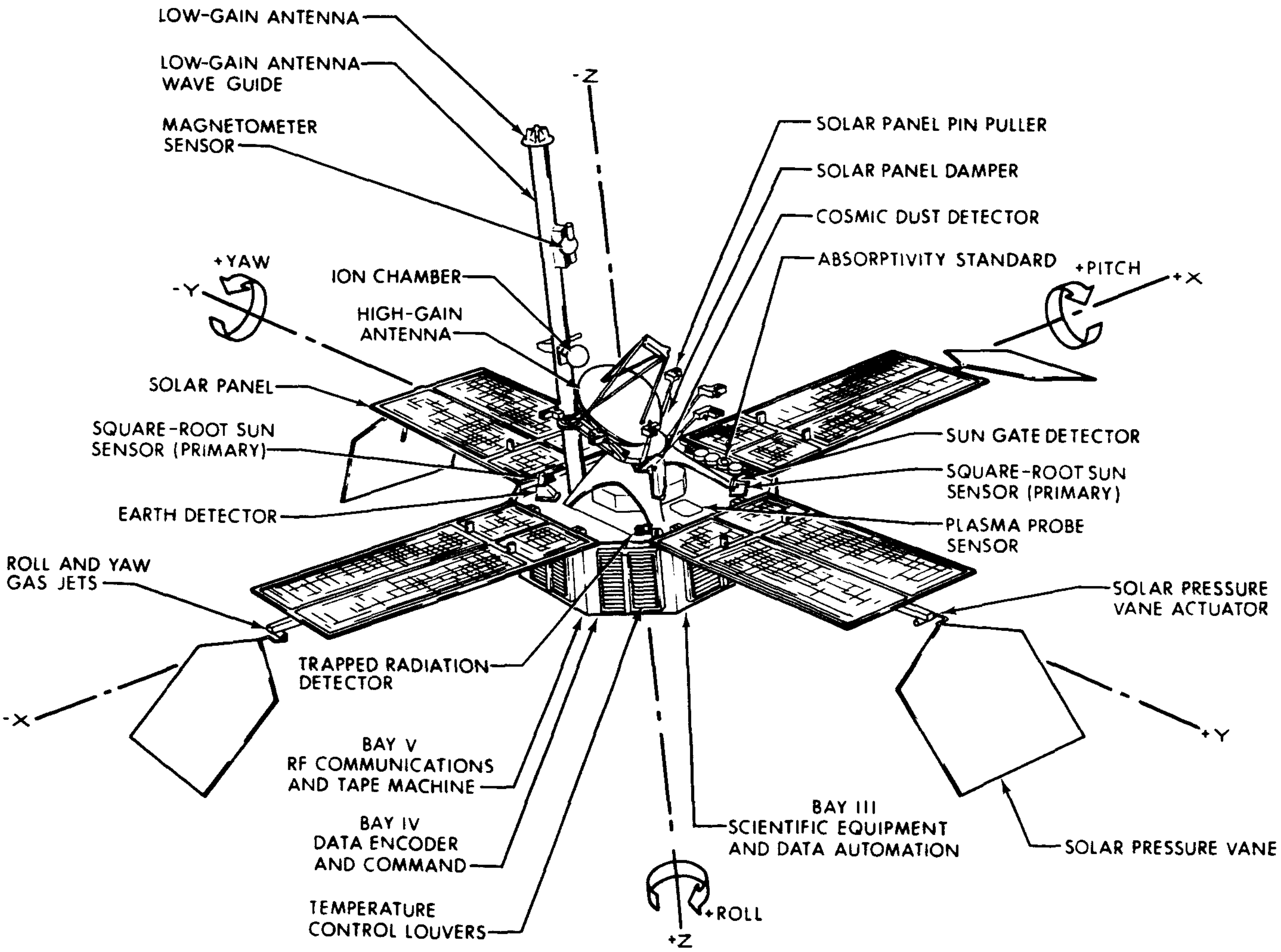


Fig. 1. *Mariner C* spacecraft (top view)

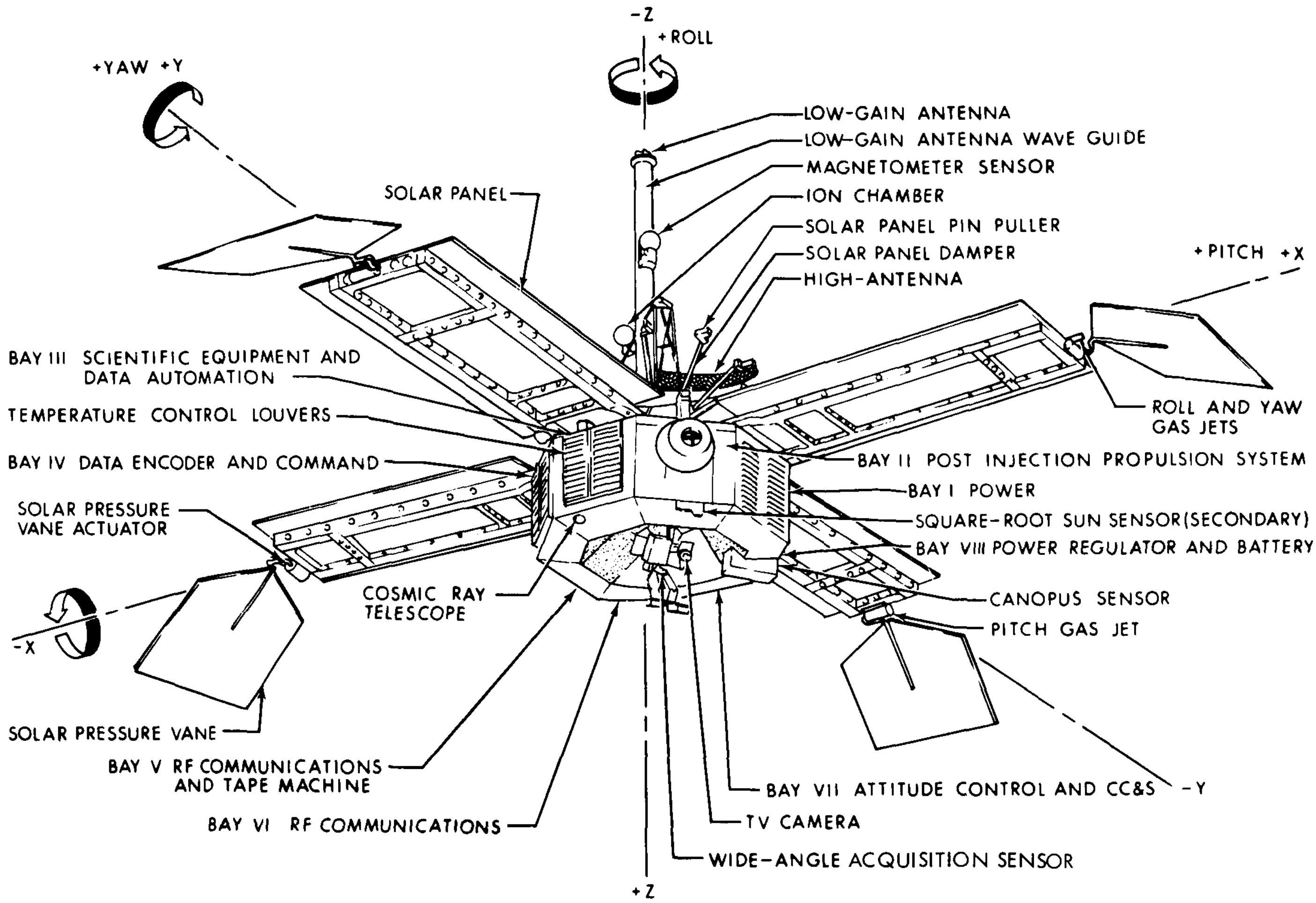


Fig. 2. ***Mariner C*** **spacecraft (bottom view)**

computation of acquisition parameter predictions for use by the DSIF of the DSN, which assumed tracking responsibility after injection of the spacecraft into interplanetary space.

2. Flight Sequence

As indicated by the nominal in-flight event times in Table 1, the *Agena* shroud is ejected after *Atlas*-powered flight, and the *Agena* is separated from the *Atlas*. First burn of the *Agena* then occurs, placing the *Agena/* spacecraft in the parking orbit. The *Agena* second burn injects the combined *Agena*/spacecraft into a Mars transfer orbit after a coast time that varies with launch day and azimuth. Shortly after injection, the spacecraft is separated from the *Agena*. The spacecraft then commences its Sun-acquisition sequence, and the *Agena* performs a retro maneuver. The *Agena* is retarded by a retro thrust to prevent it from interfering with the normal operation of the spacecraft functions and to reduce the possibility of its impacting Mars. (During the actual Mission flight sequence of *Mariner C*, the retro maneuver described here was used. During the *Mariner D* Mission, however, owing to the additional weight of the redesigned spacecraft shroud, the *Agena* retro capability was removed prior to launch, and a biased trajectory was used to preclude the possibility of the *Agena* impacting Mars.)

The initial action of the Sun-acquisition sequence is the extension of the solar panels. The attitude control system and the Sun sensors are activated to align the roll axis of the spacecraft with the Sun and to maintain that attitude, thus placing the solar power system in operation. Subsequently, the spacecraft is internally commanded to turn slowly about its roll axis for approximately 16 hr to permit magnetometer calibration. At completion of the calibration, the roll rate is reduced and the star Canopus sensor is activated. The roll phase continues

Table 1. Nominal in-flight event times

	Time (approx.), min
Mark 1, *Atlas* booster engine cutoff	T + 2
Mark 2, *Atlas* booster engine separation	T + 2
Mark 3, *Atlas* sustainer engine cutoff	T + 5
Mark 4, *Atlas* vernier engine cutoff	T + 5
Mark 5, *Agena* shroud ejection	T + 5
Mark 6, *Atlas/Agena* separation	T + 5
Mark 7, *Agena* first ignition	T + 6
Mark 8, *Agena* first cutoff	T + 9
Mark 9, *Agena* second ignition	variable
Mark 10, *Agena* second cutoff (injection)	variable
Mark 11, Spacecraft electrical disconnect	Mark 9 + 4
Mark 12, *Agena*/spacecraft separation	Mark 9 + 4
Agena yaw maneuver start	Mark 9 + 4
Agena yaw maneuver completion	Mark 9 + 5
Solar panels and solar vanes deployment	Mark 12 + 1
Mark 13, *Agena* retrorocket ignition Sun acquisition complete	Mark 12 + 10
Solar vanes and Canopus sensor turn-on and initiate roll search	T + 997
Canopus acquisition complete	< T + 1072

until the Canopus sensor is pointing toward Canopus. Once this alignment is achieved, the attitude control system maintains the spacecraft in this attitude.

C. Mariner *1964* Trajectories

Since this report is concerned primarily with the early phases of Mission flight, a brief discussion of the near-Earth portion of the *Mariner* Mars 1964 trajectories and related parameters is provided below.

1. The Ascent Trajectory

The *Mariner* spacecraft is delivered to injection by the *Atlas/Agena* launch vehicle. As the vehicle leaves the launch pad it climbs vertically for approximately 15 sec, during which time the *Atlas* rolls to the proper azimuth angle, as determined by the liftoff time. After the initial vertical rise, the vehicle pitches over into a zero-lift trajectory guided by the open-loop *Atlas* autopilot. Booster steering is enabled between 1.5 and 2 min after launch to correct for flight dispersions greater than 1.5 sigma. Approximately 2.5 min after liftoff, the booster engines are jettisoned and the vehicle continues under the power of the sustainer engine only. At this time the ground-based guidance loop is closed again and the sustainer guides the vehicle to the proper *Atlas* cutoff conditions. Following the *Atlas/Agena* separation and coast period, determined by the *Atlas* guidance system, the *Agena* stage (oriented approximately in a local horizontal attitude) ignites and injects the *Agena*/spacecraft combination into a 100-nm parking orbit. Following another coast period in the parking orbit, the *Agena* engine reignites and accelerates the spacecraft to the prescribed injection energy. The spacecraft is then separated, and the empty *Agena* stage executes a yaw turn and performs a retro maneuver in order to prevent its possible impact on the planet. As explained previously, in Section I.B, this retro maneuver was actually performed during the *Mariner III* flight only. Figure 3 is a plot of a typical powered-flight profile in the plane of the trajectory. The illustration depicts the downrange distance traversed vs altitude from launch through the time of *Agena* retro maneuver.

2. The Near-Earth Trajectory

Planetary trajectories near the Earth can be accurately represented by a hyperbola whose perigee is nearly equal to the parking orbit radius. The orientation of the outgoing asymptote and the required injection energy are relatively fixed for a few hours on any launch day, but vary from day to day through the launch period. The injection point for a given launch azimuth is determined by these two parameters. It is found that the injection loci move downrange as declination of the outgoing asymptote increases in algebraic value. The launch window is defined as the length of time during any given day of the launch period when it is possible to launch the vehicle. As the value of the declination of the outgoing asymptote increases, the launch window will increase.

In order to launch the spacecraft, a launch azimuth from AFETR was used that allowed the spacecraft to travel in a plane that contained both the launch site at launch and the geocentric asymptote. Since the asymptote is fixed inertially in space and the launch site is rotating, it is obvious that the launch azimuth must be varied continuously through the launch window. Also, since it is optimum (for maximizing payload) to inject at or near the perigee, the parking orbit coast time must also be varied continuously to meet this condition.

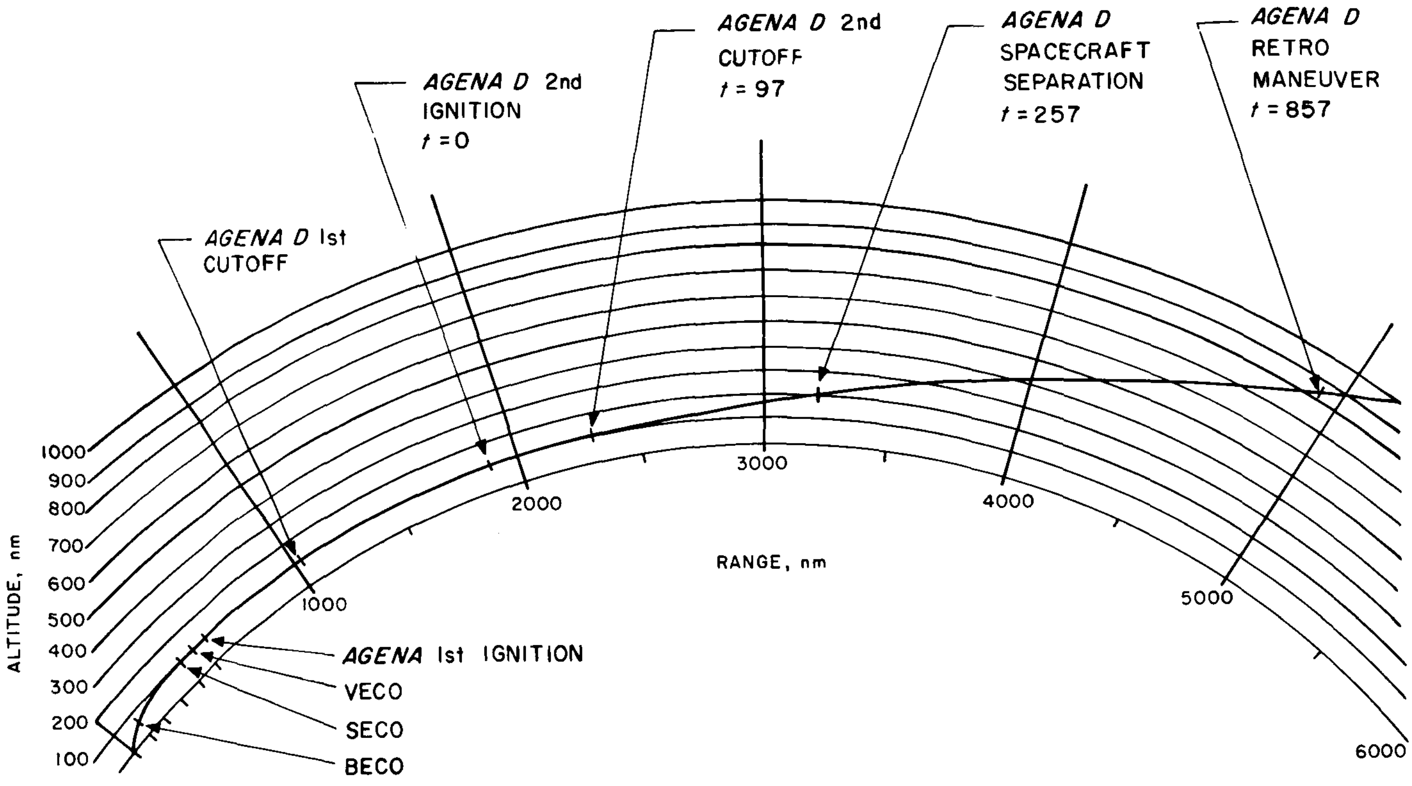


Fig. 3. Typical *Atlas D/Agena D/Mariner* 1964 powered flight profile

Because of AFETR considerations, the maximum allowable launch azimuth sector that could be utilized was 90 to 114 deg east of north. With this azimuth sector, the *Mariner* 1964 trajectories had maximum daily firing windows of between 3 and 4 hr duration owing to the high positive value of the asymptote declination. This high value of declination causes the injection locations to be downrange through most of the period. Figure 4 is a plot of the injection loci for the *Mariner* Mars 1964 Mission.

D. Tracking and Telemetry Support Summary

Tracking and telemetry coverage for the near-Earth phase of the *Mariner* Mars 1964 mission was provided primarily by AFETR and the DSN. In addition to this primary coverage, GSFC provided backup coverage for *Agena*-booster tracking and telemetry requirements (see Table 2). In general, launch vehicle tracking and data acquisition support was provided satisfactorily and without incident. The principal difficulties occurred with support of the spacecraft (unified) S-band system, which saw first use on these *Mariner* flights. As might be expected, most S-band difficulties occurred on the *Mariner III* flight and were largely corrected by the time of the *Mariner IV* flight three weeks later. Flight operations and computer support was consistently good. Support after the first few hours following injection into interplanetary flight has been routine. Detailed information concerning mission tracking and data acquisition requirements, related support plans, and performance evaluation for both *Mariner* flights is provided later in this report. The paragraphs below summarize this area briefly.

1. AFETR Support and Evaluation

The tracking and telemetry facilities of AFETR were used to provide the required coverage during *Atlas* and *Agena* flight portions of the Mission. The two basic pre-injection requirements for near-real-time data were for (1) initial acquisition predictions used by the DSIF of the DSN and (2) orbital elements of the parking orbit and the initial estimate of spacecraft injection conditions. AFETR provided support in five major areas. These areas are summarized below along with a brief discussion of performance evaluation.

a. Metric data. From launch to an altitude of 5000 ft, metric data coverage was provided by Cape Kennedy CZR camera sites. Primary coverage from 5000 ft to booster cutoff was provided by C-band radars at

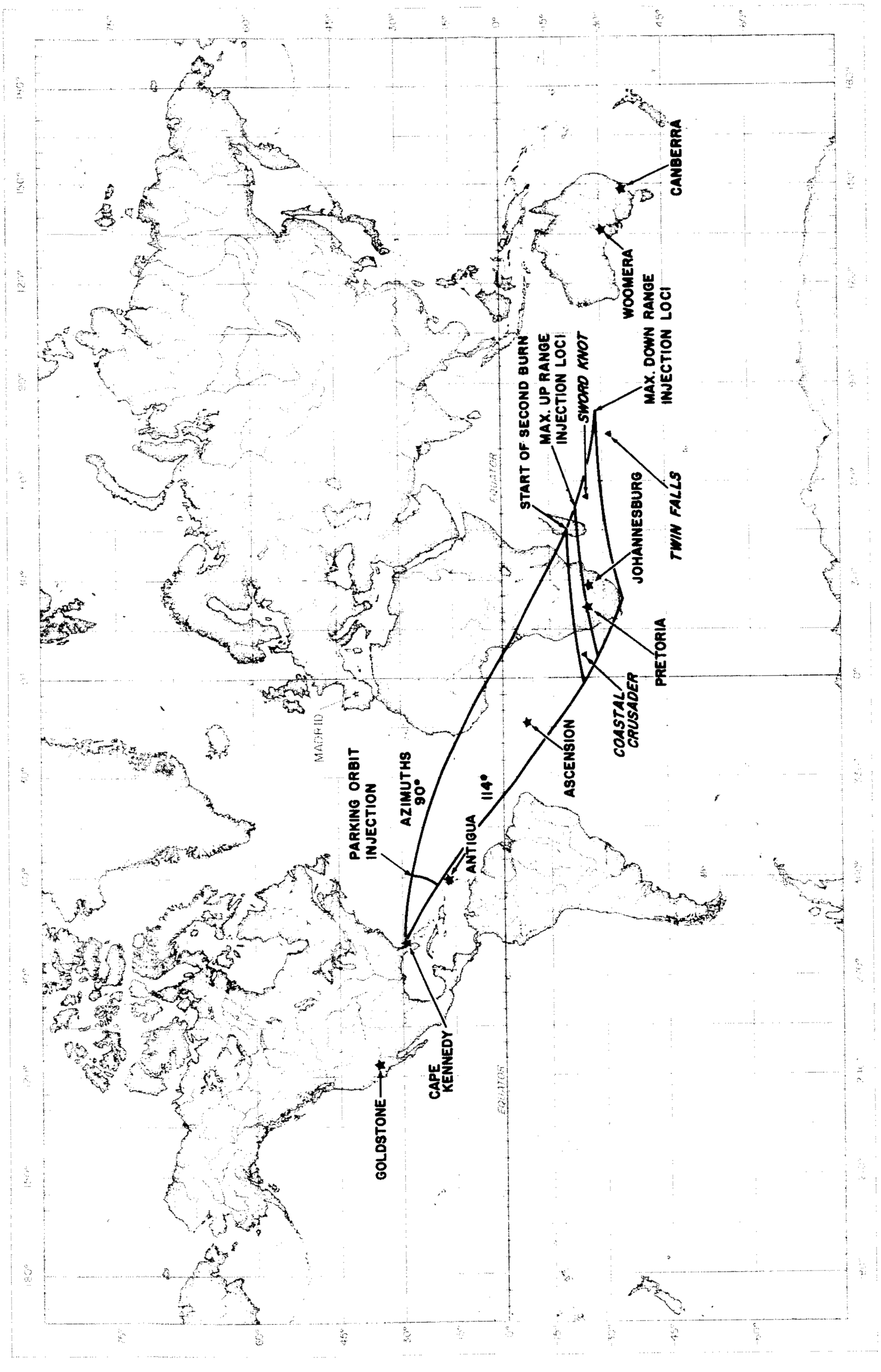


Fig. 4. *Mariner* 1964 injection loci

Table 2. T&DA support facilities: *Mariner* Mars 1964 Mission, near-Earth trajectory phase

Facility	Number
Air Force Eastern Test Range	
Patrick Air Force Base (PAFB), Florida	0.18
Cape Kennedy (Cape K), Florida	1
	1.16
Grand Bahama Island (GBI), Bahama Is.	3
	3.16
San Salvador (SAL), Bahama Is.	5.16
Grand Turk (GTK), British West Indies	7.18
Ascension Island (ASC)	12.
	12.16
Pretoria (PRE), South Africa	13
Merritt Island (MILA)	19.18
Antigua (ANT), West Indies	91
	91.18
Melbourne Beach, Florida	
Vero Beach, Florida	
Williams Point, Florida	
Cocoa Beach, Florida	
Range Instrumentation Ships	
Twin Falls	1886
Swordknot	1852
Coastal Crusader	1851
NASA/GSFC Manned Space Flight Network	
Bermuda (BDA)	
Carnarvon (CRO), Wales	
NASA/GSFC Satellite Tracking and Data Acquisition Network	
Tananarive, Malagasy Republic	
NASA/JPL Deep Space Network	
Deep Space Instrumentation Facility	
Goldstone Pioneer, Goldstone, California	DSIF-11
Woomera, Australia	DSIF-41
Johannesburg, South Africa	DSIF-51

Cape Kennedy, Patrick Air Force Base, and Grand Bahama Island. Midcourse metric data coverage was provided by radars at Cape Kennedy, Grand Bahama Island, San Salvador, Grand Turk, Bermuda, and Antigua. *Agena* second-burn coverage was provided by the Pretoria radar and three Range Instrumentation Ships (*Twin Falls*, *Swordknot*, and *Coastal Crusader*).

During both the *Mariner III* and *Mariner IV* flights, operation of the cine-theodolite system, fixed cameras (ribbon frame), and cine-tracking cameras was satisfactory. No request was made for reduction of the data acquired by these cameras. C-band radar coverage from 5000 ft to booster cutoff during both flights was generally satisfactory, with minor discrepancies. Midcourse metric data coverage was provided during both flights without significant discrepancies. The Ascension radar experienced a failure in the azimuth channel of the function recorder during the *Mariner III* flight, which resulted in noisy but usable data between $T + 1260$ and $T + 1459$ sec. During the *Mariner IV* flight, the Cape Kennedy radar (1.16) lost data from $T + 73$ to $T + 78$ sec owing to an ionized cloud in the exhaust flame. The Ascension radars (12.16 and 12.18) also failed to acquire track during this flight because of target trajectory, while the Grand Turk radar (7.10) lost data from $T + 239$ to $T + 288$ sec because of what was believed to be a malfunction in the DIRAM logic circuitry.

b. Engineering sequential data. Engineering sequential data coverage was provided by camera sites at Cape Kennedy, Williams Point, Cocoa Beach, PAFB, Melbourne Beach, and Vero Beach. Sixty-six cameras were committed during *Mariner C* flight. During this coverage a total of twelve discrepancies occurred, including view loss (due to clouds and smoke), a camera jam, improper exposure settings, lint problems, and processing failures. Forty cameras were committed for the *Mariner D* flight with only three discrepancies. The discrepancies involved view loss (due to steam and smoke) and lack of a timing image on a Mitchell 16mm camera.

c. Telemetry data. Telemetry data coverage was provided to radio horizon at Cape Kennedy, Grand Bahama Island, San Salvador, Antigua, Ascension Island, South Africa, and the three range instrumentation ships.

During *Mariner III* flight, two problem areas were experienced with the S-band telemetry receiver system (inadequate tracking bandwidth and oversensitive frequency adjustment) which resulted in the following discrepancies: (1) RIS *Coastal Crusader* was unable to lock on; (2) RIS *Twin Falls* obtained intermittent lock; (3) RIS *Swordknot* did not observe any signal; and (4) Ascension and Pretoria (Stations 12 and 13) did not lock on the signal.

Telemetry coverage during the *Mariner IV* flight was satisfactory, with minor discrepancies. An oversight in operations planning resulted in the telemetry coverage commitment starting at $T - 0$ instead of $T - 120$ sec (coverage was provided, however, without being committed). This discrepancy also occurred during the *Mariner III* flight. The RIS *Twin Falls* did not acquire a signal from the S-band link because of an equipment problem.

d. Communications support. Communications support was provided mainly on the AFETR by teletype and voice circuits. A subcable through Antigua connected downrange stations with Cape Kennedy; VHF and HF radio links tied the range instrumentation ships and aircraft to land stations. Connection with South Africa and Ascension Island sites was made via teletype and voice circuits.

During the *Mariner III* flight, communications support was satisfactory, without significant discrepancy. During the *Mariner IV* flight, a commercial power failure occurred at the Olifant transmitter which caused loss of communications at Pretoria from 1503Z to 1550Z. All other *Mariner IV* communications support was highly satisfactory.

e. Data processing. Data processing support for film, strip charts, and tapes was conducted at PAFB, and telemetry data were processed at Cape Kennedy for both flights. Due-date commitments for both metric data and engineering sequential films were satisfactorily met, with few exceptions. Any failure to meet due dates was generally caused by heavy work loads and higher priority commitments.

2. GSFC Support and Evaluation

Backup C-band radar tracking coverage was provided by GSFC at the Bermuda and Carnarvon stations of the Manned Space Flight Network (MSFN). The early *Agena* flight was covered by Bermuda; Carnarvon provided support during the post-*Agena* retro period. The Satellite Tracking and Data Acquisition Network (STADAN) station at Tananarive provided FM/FM telemetry coverage of the *Agena*. Telemetry data on the *Atlas* link (299.9 mc) and the *Agena* link (244.3 mc) were recorded by Bermuda; Carnarvon recorded telemetry data on the 244.3-mc *Agena* link only.

The C-band radar beacon tracking operation at Bermuda and Carnarvon was generally successful during the flights of both *Mariner III* and *Mariner IV*. During the *Mariner III* flight, Carnarvon experienced a transmitter overload which resulted in a 2-min 25-sec loss of data. Operation at Bermuda was excellent during both flights.

Telemetry reception and recording for both missions on the *Atlas* and *Agena* links at Bermuda and Carnarvon were highly satisfactory. The Tananarive station received and recorded the *Agena* link satisfactorily and without incident during both flights. Some signal noise was experienced at Tananarive during the *Mariner IV* flight, but valid data were obtained.

3. JPL Support and Evaluation (DSN)

The Deep Space Network (DSN) consists of the DSIF stations, interstation communications, and the mission-independent functions of the Space Flight Operations Facility (SFOF) at Pasadena, California. The DSN support function was to obtain and process angular position, doppler, and telemetry data from the *Mariner* spacecraft during the postinjection phase of the Mission. The three DSIF stations committed to support this Mission phase were Pioneer, Goldstone, California (DSIF-11), Woomera, Australia (DSIF-41), and Johannesburg, South Africa (DSIF-51).

During the *Mariner III* Mission, several equipment problems were experienced at the Woomera and the Johannesburg stations which resulted in delayed signal acquisition (Woomera) and command subsystem difficulties (Woomera and Johannesburg). An SAA isometric amplifier problem in the antenna servo system at Woomera caused the system to drive off at full rate during low signal levels (which were experienced because of the shroud failure). At Woomera, difficulty was also experienced in maintaining RF lock after initial acquisition owing to the use of *L* minus 5-min nominal predictions and the nonstandard trajectory. (The use of AFETR-supplied predictions was precluded owing to a 5-hr epoch error in the data.)

At both Woomera and Johannesburg, considerable difficulty was experienced with the ground command subsystem because of a wiring error in the RWV (read, write, and verify) unit. A command-loop-lock indicating light on the RWV unit received a wrong polarity and indicated that the system was out of lock when the reverse was true.

A portion of the telemetry data received from Woomera during the first 90 min was not useful because of the substandard characteristics of the spacecraft signal and the use of poor angle predictions. After two-way lock was established, the data were satisfactory. All telemetry data received at Johannesburg were good. Ground telemetry and recording systems at both stations performed satisfactorily during the *Mariner III* Mission.

During the *Mariner IV* launch pass at Johannesburg, the station obtained one-way lock for only 3 sec because the spacecraft was below the local horizon. Comparing the acquisition predicts with the actual angles of antenna position showed that the predicted flight path varied from 12 to 1 deg below the local horizon mask and from 13 to 0 deg below the antenna limit stops.

A VCO frequency error during the initial first-pass transfer from Woomera to Johannesburg caused both stations to drop lock. Woomera subsequently relocked one-way, and Johannesburg tried unsuccessfully to search ± 10 cycles about its VCO frequency in an effort to lock the up-link. Johannesburg then switched off its transmitter and locked-up one-way because of requirements for telemetered space science calibrations. It was then discovered that, because of a misunderstanding of instructions, the station was on 10-kw on the S-band monopulse feedhorn and bridge system (SCM) instead of the S-band acquisition antenna (SAA). After using the correct best lock-up frequency, Johannesburg and Woomera successfully transferred control back and forth at 30-min intervals.

The Suitcase Telemetry Station (STS) at Madagascar acquired the *Mariner IV* at a signal strength of -120 dbm approximately 2 min before expected rise time and tracked for about 2½ min. While no trouble was experienced in following the spacecraft (an AGC meter on the antenna was the only pointing guide used), a large static phase error was built up during the time interval in which the operator was checking the performance of the recorder. Playback of the tape indicated a severe change in signal wave shape as a function of the static phase error.

The STS at Johannesburg acquired *Mariner IV* almost at the horizon and tracked for approximately 3½ min. At this time the ground antenna was pointing toward a null of the spacecraft omni antenna, and the signal was too weak to maintain lock.

The first pass at Goldstone, DSIF-11, was uneventful. The spacecraft was acquired near the horizon and two-way lock was effected almost immediately. Tracking and data acquisition proceeded satisfactorily thereafter. SFOF performance during the flights of both *Mariner III* and *Mariner IV* was very satisfactory. All functions were carried out effectively. Deep Space Network performance in general was good, and all major requirements were met satisfactorily for both flights.

III. TRACKING AND DATA ACQUISITION REQUIREMENTS

A. General

The purpose of this section is to describe in detail the tracking and telemetry coverage requirements of the *Mariner* Mars 1964 Mission. The T&DA requirements are divided into two categories: (1) tracking and telemetry coverage requirements placed upon AFETR, GSFC, and JPL/DSN and (2) the technical data and support required by the tracking and telemetry facilities (AFETR, GSFC, and DSN) to satisfy category (1) requirements. Certain AFETR, GSFC, and DSN requirements comprise category (2) above. These requirements must be met and certain limitations of AFETR, GSFC, and DSN capabilities observed in order that these agencies can, in turn, support the requirements placed upon them. These latte requirements and capability limitations are discussed fur ther in Section IV.

1. Development of Requirements

In this section, tracking coverage requirements are de veloped in the following manner:

1. Mission requirements state that the spacecraft mus pass Mars at the desired aiming point, at the desire time, and within a certain accuracy tolerance.
2. A midcourse maneuver is used, if necessary, to co rect trajectory errors at injection.

3. Therefore, there is a requirement for orbit determination accuracy prior to the midcourse maneuver so that the subsequent maneuver can meet mission accuracy requirements at encounter.

4. The tracking coverage, data interval, and data accuracy requirements are then placed on AFETR and DSN to support the orbit determination accuracy requirements.

Telemetry coverage requirements for *Mariner* Mars 1964 are developed in much the same way.

2. Classification of Requirements

The requirements for tracking and telemetry coverage are assigned in accordance with their importance to Mission success and are divided into the following classes, as defined by AFETR:

Class I These requirements reflect the minimum essential needs to assure accomplishment of primary test objectives. These are mandatory requirements. If they are not met, a decision not to launch can result.

Class II These requirements define the needs to accomplish all stated test objectives.

Class III These requirements define the ultimate in desired support. Such support should enable the range user to achieve the test objectives earlier in the test program.

B. Launch Vehicle Tracking Requirements Placed on AFETR

The requirement was placed on AFETR to provide tracking coverage of the launch vehicle to satisfy four specific needs: Range Safety, launch vehicle performance evaluation, AFETR look-angle calculations, and launch vehicle postretromaneuver orbit determination. The mission requirements are discussed in Sections III.D and III.E.

1. Range Safety

Launches from AFETR are monitored during the early phase of flight by AFETR Range Safety. Range Safety has the responsibility of destroying a vehicle in the event that it violates any safety criterion. AFETR maintains a destruct capability throughout the vehicle ascent phase and into parking orbit. (Command destruct capability was actually removed from the *Agena D* during the *Mariner IV* flight because of the increased weight of the redesigned spacecraft shroud, but self-destruct capability was retained.) Tracking (and telemetry) data are needed by AFETR Range Safety during this phase. A launch hold can result if any of the range tracking stations which provide mandatory coverage for Range Safety are inoperative.

2. Launch Vehicle Performance Evaluation

Tracking data are required by the Launch Vehicle System Manager, Lewis Research Center (LeRC), for launch vehicle evaluation. These data are required (as Class I requirements) during vehicle ascent into parking orbit and for a short period after each of the *Agena* burns. Table 3 details these requirements.

3. AFETR Look-Angle Calculations

AFETR provides in-flight data to the downrange tracking stations as an acquisition aid. Generation of these data depends on adequate uprange tracking. These calculations are based on data gathered in support of requirements placed in the other three areas now being discussed. Hence these requirements usually do not of themselves constrain a launch.

4. Launch Vehicle Postretromaneuver Orbit Determination

It is desirable to be able to calculate the orbit of the launch vehicle after it has executed its retromaneuver. However, such information is not essential to Mission success, and it is therefore a Class II requirement, as specified in Table 4.

C. *Agena* Booster Tracking Requirements Placed on GSFC

The Tracking and Data Systems Directorate of GSFC was given the responsibility for providing backup C-band radar support during the tracking and data acquisition of the *Agena*. The radar and telemetry facilities of the MSFN stations at Bermuda and Carnarvon were designated to provide this backup coverage. The Bermuda station covered the early *Agena* flight; Carnarvon provided support during the post-*Agena* retro period. The STADAN station at Tananarive provided FM/FM telemetry coverage of the *Agena*. A brief summary of the tracking requirements is provided below:

1. C-band Radar Tracking. Continuous C-band radar tracking coverage of the *Agena* booster was required until decay of the radar beacon, or until after the retromaneuver.

Table 3. Launch vehicle tracking coverage required of AFETR (LeRC requirements)

Metric launch data							
Item no.	Data required	Interval	Data, points/sec[a]	Class I	Class II	Class III	Purpose and remarks
1	Position X, Y, Z	0–2000 ft	10	±2 ft	±1/2 ft		Required for overall evaluation of stage performance or gross malfunction analysis. Also for analysis of vehicle roll and pitch program performance
2	Velocity V_X, V_Y, V_Z, V_R	0–2000 ft	10	±2 ft/sec	±1/2 ft		
3	Acceleration A_X, A_Y, A_Z, A_R	0–2000 ft	10	±1 ft/sec^2	±1/2 ft/sec^2		
4	Position X, Y, Z	2000–5000 ft	10	±10 ft	±1 ft		Optical position data reference to bottom horizontal Stage II paint pattern line
5	Velocity V_X, V_Y, V_Z, V_R		10	±5 ft/sec	±1/2 ft/sec		
6	Acceleration A_X, A_Y, A_Z, A_R	2000–5000 ft	10	±2 ft/sec^2	±1/2 ft/sec^2		Continuous tracking required
7	Position X, Y, Z	5000–100,000 ft	10	±10 ft	±2 ft		10/sec required; 5/sec acceptable from theodolites[a]
8	Velocity V_X, V_Y, V_Z, V_R	5000–100,000 ft	10	±10 ft/sec	±5 ft/sec		
9	Acceleration A_X, A_Y, A_Z, A_R	5000–100,000 ft	10	±10 ft/sec^2	±5 ft/sec^2		
10	Position X, Y, Z	100,000 ft through VECO +1 sec to Stage I/II separation	10	±500 ft	±250 ft		Evaluation of Stage I and II guidance and control system performance. Continuous tracking required
11	Velocity V_X, V_Y, V_Z, V_R	Same as previous one	10	±10 ft/sec	±5 ft/sec		
12	Acceleration A_X, A_Y, A_Z, A_R	Same as previous one	10	±10 ft/sec^2	±5 ft/sec^2		
13	Radar polar coordinate data, corrected azimuth, elevation and slant range	Launch to Stage I/II separation	10	±500 ft	±250 ft		Items 10 through 12 are joint GD/A, LMSC requirements; item 13 is an LMSC requirement
14	*Position and velocity data (GE requirement)*	*T +20 sec until* Stage I VECO +50 sec	10		*Best* available		

[a]Events are used to determine intervals as they vary with the mission (LMSC requirements).

Table 3 (Cont'd)

Item no.	Data required	Interval	Data, points/sec[a]	Class I	Class II	Class III	Purpose and remarks
Metric midcourse data							
1	Position X, Y, Z	Stage I/II separation through first burn cutoff +60 sec	10	±10,000 ft	±1000 ft	±200 ft	To determine parking orbit injection conditions and to enable trajectory analysis
2	Velocity V_X, V_Y, V_Z, V_R		10	±200 ft/sec	±20 ft/sec	±2 ft/sec	(LMSC requirements)
3	Radar polar coordinate data, corrected azimuth, elevation, and slant range	Same as above	10	±10,000 ft	±1000 ft	±200 ft	
4	H (altitude above Earth)	Same as above	10	±10,000 ft	±1000 ft	±200 ft	
Metric orbital and space data							
1	Position X, Y, Z	Stage II second-burn ignition −10 sec to second-burn cutoff	10		±10,000 ft	±1000 ft	Stage II restart and powered flight, to determine injection conditions and vehicle performance
2	Velocity V_X, V_Y, V_Z, V_R	Same as above	10		±200 ft/sec	±20 ft/sec	(LMSC requirements)
3	Radar polar coordinate data, corrected azimuth, elevation, and slant range	Same as above	10		±10,000 ft	±1000 ft	
4	H	Same as above	10	±10,000 ft	±1000 ft	±200 ft	
5	Position X, Y, Z	Stage II second-burn cutoff to retro maneuver	10	±10,000 ft	±1000 ft	±200 ft	Final stage vehicle mission trajectory, to determine injection conditions and vehicle performance
6	Velocity V_X, V_Y, V_Z, V_R	It is mandatory that any 60 sec of continuous tracking data be obtained during this interval	10	±200 ft/sec	±20 ft/sec	±2 ft/sec	Track of the second stage for as long as possible after retro maneuver (not to exceed 3 hr after injection) is desirable to support secondary test objectives. This requirement for post-retro maneuver shall not be allowed to constrain the possible firing window which might otherwise be available

[a]Events are used to determine intervals as they vary with the mission (LMSC requirements).

Table 3. (Cont'd)

Metric orbital and space data (Cont'd)							
Item no.	Data required	Interval	Data, points/sec[a]	Class I	Class II	Class III	Purpose and remarks
7	Radar polar coordinate data, corrected azimuth, elevation, and slant range	Same as above	10	±10,000 ft	±1000 ft	±200 ft	
8	*H*	Same as above		±10,000 ft	±1000 ft	±200 ft	

[a]Events are used to determine intervals as they vary with the mission (LMSC requirements).

Table 4. Launch vehicle tracking coverage required of AFETR (JPL requirements)[a]

Event and coverage classification	Data required	Amount of data required, data pt/min			Accuracy of data required		
		Class I	Class II	Class III	Class I	Class II	Class III
First *Agena D* burnout to first *Agena D* burnout +60 sec (Class I)	Range	2	10	10	1000 m	10 m	1 m
	Azimuth Elevation				0.5	0.02	0.005
First *Agena D* cutoff to first *Agena D* cutoff +180 sec (Class II)	Range	2	10	10	1000 m	10 m	1 m
	Azimuth Elevation				0.5	0.02	0.005
First *Agena D* cutoff to second *Agena D* ignition (Class III)	Range	2	10	10	1000 m	10 m	1 m
	Azimuth Elevation				0.5	0.02	0.005
Any continuous 60 sec between injection and *Agena D* retro (Class I)	Range	2	10	10	1000 m	10 m	1 m
	Azimuth Elevation				0.5	0.02	0.005
Injection to injection +2 hr (Class II)	Range	2	10	10	1000 m	10 m	1 m
	Azimuth Elevation				0.5	0.02	0.005
Injection to loss of track (Class III)	Range	2	10	10	1000 m	10 m	1 m
	Azimuth Elevation				0.5	0.02	0.005

[a]Requirements for raw data delivery to JPL/AFETR: Class I, no later than *L* +1 hr; Class II, near-real-time (within 2 min of the event).

2. Computation. The GSFC orbital computing system was required for prelaunch testing, determination of injection conditions, providing the network with acquisition messages, and reformatting data for AFETR.

3. Ground Communications. Requirements for the NASA Communications System (NASCOM) consisted of existing voice and teletype circuits between the Mission Control Center (MCC) at Cape Kennedy, GSFC, and all participating stations. The high-speed data lines between Bermuda, MCC, and GSFC were also required during the Mission, but not on a critical coverage basis.

D. Mission Requirements for Tracking Placed on AFETR

1. General

Mission requirements for tracking coverage result from the need to calculate DSIF look angles as an acquisition aid and the need for raw data to contribute to the accuracy and reliability of the spacecraft orbit determination process. AFETR tracks the C-band beacon in the *Agena* stage. (There was no requirement for AFETR tracking of the spacecraft.) Until separation, the orbits of spacecraft and *Agena* are the same. At separation, a relative velocity of about 2 ft/sec is imparted to the spacecraft by separation system springs; however, this does not alter the total momentum. Since this separation velocity is small, AFETR tracking of the *Agena*, both prior and subsequent to separation, is very valuable in determining spacecraft orbit and in checking other tracking systems. Even after the retromaneuver of the *Agena* (several minutes after separation), tracking information is helpful during the flight.

It is clear that the processing of AFETR raw data after injection into the transfer orbit is involved with, and conditional upon, the telemetry identification of certain events. The relative weighting of the different AFETR data types (e.g., range and angles with respect to DSIF data) is a task requiring more information than is available to AFETR; hence it is important that the raw data be supplied. Requirements placed by JPL state that the *Agena* orbit is to be determined by AFETR and that raw tracking data are to be furnished to JPL during launch. Raw data are herein defined as raw azimuth, elevation, and range points which have not been altered by smoothing, weighting, etc. One exception to this definition is exhibited by the desirability to correct tracking ship motion. However, tracking ship range data are valuable even if tracking ship motion has not been removed.

2. Calculation of DSIF Look Angles

The prediction message accuracy for satisfactory look angles is discussed in Section III. In general, these accuracy requirements are met if Class I data accuracy requirements are met during the intervals specified. The Class I intervals of coverage requirements usually appear immediately after injection into the transfer orbit (Table 4). In some cases, data obtained from a single station can meet the requirements of Class I data accuracy and not those of the calculated Class I position and velocity accuracy. Such could be the case when the data were obtained at low elevation angles and the tracking geometry was poor. Such situations prevent a clear-cut specification of all requirements. However, these problems were under continuous surveillance and were not considered critical.

3. Spacecraft Orbit Determination Process

Raw tracking data are required from AFETR by the JPL Space Flight Operations System for spacecraft orbit determination reliability and accuracy. The reliability is closely correlated with the number of tracking stations contributing data. An independent third data source can, for example, prove invaluable in resolving apparent discrepancies between two other data sources, both of which appear to be operating properly. It is obvious that data source redundancy, during the parking orbit and during the transfer orbit, is valuable during each phase, respectively. However, two additional points are very important: (1) Raw data obtained during the parking orbit can be very useful in resolving apparent discrepancies between two stations tracking during the transfer orbit; (2) tracking ship data can be exceedingly valuable under a variety of circumstances. For example, errors in ship locations can, under certain circumstances, have a negligible effect on the value of tracking data. Also, ship range data are always valuable, even if the data are not corrected for ship motion.

Raw data from AFETR are also used in improving the accuracy of the spacecraft preretain midcourse orbit determination process. However, the data must be more accurate for this application than for the improved reliability. In general, data with Class II accuracy can be used in calculating spacecraft orbit prior to midcourse maneuver calculation. Use of Class II data would be particularly likely in situations in which early DSIF data were missing (e.g., in situations involving equipment failure or short overhead pass with excessive tracking rates). These data requirements are also described in Table 4.

4. Data Delivery Requirements

The reliability and accuracy of the spacecraft orbit can be improved with AFETR raw tracking data if the data arrive at the SFOF in time. The postinjection orbit determination process begins shortly after injection. Therefore, Class I data delivery requirements are as follows:

Class I: AFETR raw tracking data must be received at the SFOF from AFETR no later than $L + 1$ hr.

It is desirable to have the data delivered in near-real-time within 2 min of reception. This is necessary to increase the time in which the data can be processed prior to the beginning of the orbit determination requirements. The data would then be available for calculation of DSIF look angles in the event some system failure prevented AFETR from fulfilling this function. Therefore, Class II data delivery requirements are as follows:

Class II: AFETR raw tracking data must be received at the SFOF from AFETR in near-real-time (within 2 min of the event).

E. *Mission Requirements for Tracking Placed on the DSN*

1. General

Requirements were placed on the DSN for the DSIF to track the spacecraft (no requirements existed to track the launch vehicle), enabling it, in turn, to supply the raw tracking data for determination of spacecraft orbits. These spacecraft orbits are necessary for generating prediction messages and calculating the required midcourse maneuver.

First, an early orbit of the spacecraft must be determined to allow calculation of look angles for subsequent tracking. In general, the DSIF initial acquisitions are performed with the aid of preflight prediction data in the form of graphs or tabulations and in-flight prediction messages based on the actual orbit as determined by AFETR. Subsequent acquisitions are made with prediction messages based on orbits calculated to satisfy the need for a final premidcourse maneuver orbit (Table 5).

Second, a final premidcourse maneuver orbit of the spacecraft must be determined with sufficient accuracy to permit a midcourse maneuver to be made within its accuracy requirements.

Table 5. Requirements for spacecraft tracking coverage by DSN

Class	Orbit determination accuracy requirements
I	At injection + 5 days: rms error in uncertainty of semimajor axis $\leq$ 2250 km
	An early orbit must be determined shortly after injection
II	At injection + 2 days: rms error in uncertainty of semimajor axis $\leq$ 2250 km
III	At injection + 5 days: rms error in uncertainty of semimajor axis $\leq$ 400 km

2. Accuracy Requirements on Final Premidcourse Maneuver Orbit

The standard sequence of events is structured to permit a maneuver to be conducted while the spacecraft is in view of the Goldstone (Pioneer, DSIF-11) Station. In principle, however, any of the three DSIF stations can execute the necessary commands. Some of the factors involved in the choice of Goldstone as the preferred command station include: (1) proximity of the Goldstone station to the space flight operations technical teams in Pasadena; (2) relative reliability of the communications lines between Goldstone and the SFOF; and (3) the higher degree of equipment redundancy at Goldstone.

In order to satisfy Mission objectives, guidance dispersions at Mars must be held within certain limits. These dispersions arise from three causes:

1. Errors in the premidcourse orbit determination due to noisy data and uncertainties in physical and observational constants
2. Errors in executing the commanded maneuver
3. Unpredictable trajectory perturbations occurring after the maneuver (e.g., solar storms, attitude jets, etc.).

The purpose of this discussion is to specify the allowable error due to (1) above and to develop the reasoning behind the specification. Under normal conditions, Mission objectives can be realized with a single maneuver; however, a backup maneuver is provided in case any of the errors listed above are excessive.

The *Mariner* Mars 1964 science experiments were designed on the basis of an rms error in the miss components of approximately 4650 km. Therefore, errors in (1), (2), and (3) above must not combine statistically to exceed this value.

Errors in executing the commanded maneuver (item 2) are relatively independent of maneuver time and are approximately equal to 4070 km.

Errors due to unpredictable trajectory perturbations after the maneuver (item 3) are assumed to be negligible; therefore, the allowable orbit determination error E_{OD} is

$$E_{OD} = \sqrt{4650^2 - 4070^2} \text{ km} = 2250 \text{ km}$$

It should be pointed out that, in general, since the miss components and time of flight are highly correlated, the time of flight is in allowable tolerance if the miss components are within the acceptable limits.

Since orbit determination accuracy is a function of tracking time, it is necessary to consider the time at which the maneuver is to be applied. The application time depends on many factors, a few of which are:

1. The condition of the spacecraft as determined from telemetry data.
2. The magnitude of the required correction.
3. Midcourse maneuver energy considerations.

It is seen that the choice of application time is an operational decision. However, an attempt was made to obtain a rough *a priori* estimate of the application time. It was estimated that the maneuver would be executed before injection + 2 days, because this amount of time is required to gain a high degree of confidence in the operation condition of the spacecraft and in the computed correction. It is desirable to execute the maneuver before injection + 10 days because this is the approximate threshold of the Earth sensor which can verify Canopus reacquisition following the maneuver. Thus, 2 to 10 days is the range of desirable application times under standard conditions. For some Type II trajectories, because of relative high midcourse-energy requirements, it is necessary to exceed the 10-day limitation on the maneuver time (e.g., 10 to 15 days after injection).

A reasonable time for the midcourse maneuver execution after injection, considering the present orbit determination capabilities, is 5 days. Therefore, the Class I orbit determination requirement that follows from this analysis is that at injection + 5 days the orbit determination errors at 5 days shall not exceed 2250 km. Any requirement dictating a shorter time for attaining this orbit determination accuracy is then placed in a lower classification (i.e., Class II or III). It is desirable to obtain estimates of the orbit as soon as possible after injection for operational reasons: namely, to provide acquisition data for the DSIF as well as to provide an early indication of a nonstandard injection. Also, in the case of nonstandard spacecraft performance, an early midcourse maneuver would be desirable.

In summary, the Class I requirements are:

Class I: At injection + 5 days, the rms error in estimating miss components shall not exceed 2250 km. An early orbit must be determined shortly after injection.

For the reasons mentioned, it is desirable to have the required orbit accuracy as soon as possible but not necessarily utilized until injection + 2 days. This determines the Class II requirements:

Class II: At injection + 2 days, the rms error in estimating miss components shall not exceed 2250 km.

Orbit determination errors are negligible compared to execution errors when they are roughly 400 km (10% of 4000 km). Therefore, the Class III requirement is as follows:

Class III: At injection + 5 days, a 40% rms error in the semimajor axis (SMAA) in estimating miss components of not more than 400 km is required.

Table 5 summarizes these Class I, II, and III requirements.

3. Tracking Data Accuracy Requirements

Raw tracking data in the form of two- and three-way doppler and antenna pointing angles are provided by the DSIF for orbit determination. These data contain noise due to correlations in the data, variations in refraction correction, oscillator drift, cycle-count drops, transmitter variations, etc. Therefore, it is necessary to specify the amount of noise which can be expected so that the *a priori* orbit determination capability can be predicted as the launch azimuth and launch days are varied.

Estimates of the DSIF data accuracy were made prior to the Mars 1964 Mission. These estimates are listed in

Table 6. The S-band system transmits at a frequency of approximately 2295 mc and counts the return doppler tone. The "L to S" doppler system multiplies the L-band transmitter frequency (22 mc) up to S-band frequency (2295 mc) and transmits this signal to the S-band spacecraft transponder. The returning S-band signal is converted to L-band frequencies and counted with L-band equipment. The velocity (m/sec) equivalents of counted doppler (per 1 cps) for L-band, S-band, and L- to S-band doppler are:

1. 1 cps L-band = 0.165 m/sec.
2. 1 cps S-band = 0.060 m/sec.
3. 1 cps L- to S-band = 0.193 m/sec.

During the first few months of flight, Johannesburg and Woomera will use L- to S-band conversion systems and Goldstone a pure S-band system.

The estimates of the data noise expected as tabulated in Table 6 can now be used to establish the data weights that determine the orbit determination accuracy capability. The data weight is a statistical expression of the error on the data which is furnished to the Orbit Determination Computer Program (ODP) which, in turn, predicts a statistical error on the target predictions. Other statistical descriptions of errors in physical constants and station locations must also be an input to the ODP. Certain error sources exist for which statistical description is available. Some of these are:

1. Data biases (low-frequency noise) which are known to exist but whose functional form and magnitude are uncertain.
2. Undetected data biases.
3. Errors in the computational model or procedures, including computer roundoff.
4. Errors in statistical assumptions made about the nature of the errors in data and physical constants (non-Gaussian noise, etc.).
5. Human data-processing errors.

These errors are much more likely to occur in a serious form during the first few days after injection, since not much time is available to analyze data. To have reasonable statistics on target miss, the statistical input to the ODP must be adjusted to try to match the above situation. It has been found that the most satisfactory way to

Table 6. DSIF tracking data accuracy

System noise	2-way doppler ($1-\sigma$), cps	Angles ($1-\sigma$), deg	Time synchronization (1 day after data are taken), sec	Absolute transmitter frequency stability over 1-min interval
Expected noise for *Mariner C* S-band system	0.01	0.02	0.001	1×10^{-11}
Expected noise for *Mariner C* L- to S-band conversion system	0.01	0.02	0.002 (longer than S-band because L- to S-stations are overseas)	3×10^{-11}

Note: High-frequency noise is 1 sample/min; two-way doppler data counted over 1 min.

accomplish this is to increase the data weights. Therefore, the data weights used are always greater than the high-frequency data noise. The weights which are used from preflight stations, and which will be used during the premidcourse maneuver orbit determination operation, are:

1. For L- to S-band (1 min sample rate)

$\sigma_{doppler} = 0.03$ m/sec $= 0.16$ cps

$\sigma_{angles} = 0.18$ deg

2. For S-band

$\sigma_{doppler} = 0.03$ m/sec $= 0.50$ cps

$\sigma_{angles} = 0.18$ deg

For a typical trajectory, Table 7 shows the statistical target errors vs time of tracking from injection, using the above data weights and data weights corresponding just to the high-frequency noise ($\sigma_{doppler} = 0.003$ m/sec). It can be seen that the 0.03-m/sec data weighting accomplishes the desired goal of degrading statistics for short spans of data.

Also shown in Table 7 is the fact that at injection + 5 days the predicted orbit accuracy is virtually unaffected by changing data weights by a factor of 10. This is because the uncertainty in solar pressure becomes the dominant error source. (It should be reiterated that this document is concerned with the launch-to-midcourse phase of the Mission. Therefore, data accuracy requirements for other missions or for the postmidcourse and encounter phase of the Mission are not discussed.)

Table 7. Variation in orbit determination accuracy with assumed data weights

Data from L to:	$\sigma_{doppler}$ = 0.03 m/sec		$\sigma_{doppler}$ = 0.003 m/sec	
	SMAA[a]	SMIA[b]	SMAA	SMIA
L + 5 hr	146500	1717	14919	387
L + 17 hr	1973	202	1172	115
L + 2 days	1471	152	1133	98
L + 5 days	1186	112	1012	92

[a] Semimajor axis.
[b] Semiminor axis.

4. DSN Tracking Coverage Requirements

With the quality of the tracking data defined (Section III.E.1), it is now possible to specify the tracking coverage required to meet the orbit determination accuracy requirements specified in Section III.E.2. Before presenting the tracking coverage requirements, however, it is appropriate to delineate the ground rules upon which the tracking coverage analysis was based.

The first and most basic rule is that the primary objective of this effort is not only to maximize the probability of mission success but also to ensure that a reasonable level of confidence can be achieved. Since the Class I orbit determination accuracy requirement must be satisfied to ensure that the primary Mission objectives are met, it is necessary that these Class I requirements be honored at all times. In some instances, it may be essential (second-order effect) that Class II orbit determination accuracy requirements be met to achieve a reasonable confidence level of success. Finally, the Class III accuracy requirements would not have to be satisfied to ensure achieving a mission success. Therefore, the greatest effort has been given to determining the optimum scheme for meeting the Class I orbit determination accuracy requirements. Enough discussion is included to indicate how the Class II requirements could be satisfied and to promote a general understanding of the problem. Requirements necessary to meet Class III orbit determination accuracy are not discussed.

Specification of the Class I tracking coverage requirements in support of the Class I orbit determination accuracy requirements is based upon the ground rule that each DSIF station supplying necessary data will, in fact, supply data of good quality; thus, the integrity of the Class I definitions would remain intact. However, on several occasions a tracking site has appeared to be operating satisfactorily, and yet the data were in error. This fact went undetected in real-time. Such an occurrence is particularly likely during a difficult first pass. It is therefore very desirable to assign additional DSIF stations to a tracking pattern arranged to provide redundancy, thereby minimizing the possibility of not achieving the Class I orbit determination accuracy. This policy was exploited in establishing Class II tracking coverage requirements in support of the Class I orbit determination accuracy requirements.

Class I and Class II tracking coverage requirements in support of the Class II orbit determination accuracy requirements must also be specified. A policy similar to that used to describe the coverage in support of Class I orbit accuracy was used.

Answers to the following questions were provided for all days and all launch azimuths:

1. Which DSIF stations must be "up" (predicted to be operational at the time of their view) to permit the launch? (This represents the Class I tracking coverage in support of the Class I orbit determination accuracy requirements.)
2. Which tracking pattern will maximize the probability of achieving Class I orbit determination accuracy requirements once liftoff has occurred, and of acknowledging known DSN failures (if any) including potential failures, both detectable and undetectable, in real-time?
3. Can the Class II orbit determination accuracy requirements be met, and can the DSN exploit this capability without degrading the probability of achieving the Class I orbit determination accuracy requirements? This question is answered during both prelaunch planning and postlaunch real-time operations.

It is assumed that the Class I orbit determination accuracy requirements must be met to provide a reasonable probability of mission success. This fact represents the point from which all departures are made. However, it must be emphasized that the mission can succeed (although it could not be so "guaranteed" prior to launch) even though the Class I requirement is not met. For example, the midcourse maneuver could be delayed 5 days so that additional tracking could be obtained defining the orbit to the desired accuracy. This procedure was considered undesirable for preflight standard procedures because the flexibility in planning the maneuver time is reduced and because the midcourse maneuver capability to correct injection guidance dispersions diminishes as the maneuver time is delayed.

F. Telemetry Coverage Requirements

Requirements for coverage of the spacecraft telemetry through the spacecraft S-band or *Agena D* links were placed on AFETR and DSN. A requirement for backup telemetry support was placed on GSFC. Requirements also existed for coverage of the launch vehicle telemetry for vehicle evaluation. These latter requirements were placed only on AFETR. Details of the telemetry coverage and data return and analysis plan are provided in the LMSC document A604289-B.[1] The following paragraphs present a brief review of this material.

1. Requirements Placed on AFETR

Requirements placed on AFETR specified coverage of both launch vehicle and spacecraft telemetry.

a. Launch vehicle evaluation. Evaluation of the *Atlas D* and *Agena D* performance by LeRC required coverage in their telemetry systems during certain phases of the flight. In addition, Range Safety required certain vehicle telemetry data during the boost phase. These requirements are presented in Table 8.

b. Spacecraft evaluation. The spacecraft telemetry can be received by a station equipped at S-band and also a station designed to receive *Agena* telemetry. The spacecraft transmitter is continuously radiating from liftoff, while the telemetry signal modulates the 98-kc subcarrier of the *Agena* telemetry system. AFETR exploited both links to satisfy the spacecraft telemetry coverage summarized in Table 9 and following paragraphs.

Class I: JPL justified Class I requirements as necessary to increase the probability of achieving Mission objectives. Thus it was necessary to obtain data for use in spacecraft performance evaluation, the results of which might influence subsequent flight operation. Evaluation of these data from the first launch (*Mariner III*) was also used in ascertaining the readiness for the second launch (*Mariner IV*). It was required that data be obtained during the entire powered-flight phase of the launch in addition to continuous coverage from *Agena*/spacecraft separation to DSIF continuous view +2 min.

[1] *Mariner Mars 1964, 36-hr Data Return Plan*, A604289-B, Lockheed Missile and Space Co., August 15, 1964.

Class II: It is highly desirable that the performance of the spacecraft be continuously monitored throughout the mission from launch to encounter. The DSN may need approximately 10 min to complete its acquisition process. Therefore, continuous coverage from launch

Table 8. Launch vehicle telemetry coverage required of AFETR (LeRC requirements)

Class I	Class II	Class III
During prelaunch calibrations on internal and external power. Firm $T-2$ min to *Agena* first cutoff, + 25 sec 18 sec before to 20 sec after *Agena* second burn 10 sec before to 5 sec after *Agena*/spacecraft separation	During prelaunch calibrations on internal and external power. Continuous coverage from $T-2$ min to *Agena* retrorocket ignition + 1 min	Same as Class II

Table 9. Spacecraft telemetry coverage (JPL requirements)

Class I	Class II	Class III
Prelaunch calibrations Launch to *Agena* first cutoff + 25 sec From *Agena* second ignition − 8 sec to *Agena* second cutoff, + 20 sec From *Agena*/spacecraft separation − 10 sec to continuous DSIF view + 2 min	From launch to continuous DSIF view + 10 min	From launch to continuous DSIF view + 10 min

Notes:

1. Continuous DSIF view began on all launch days for most of all launch azimuths at Johannesburg first-pass rise (0-deg elevation angle).
2. Continuous DSIF view always began no later than Woomera first-pass rise (0-deg elevation angle).
3. Continuous DSIF view always began between injection and injection + 15 min, depending on launch day and launch azimuth.
4. The spacecraft telemetry is transmitted via the Agena link, as well as the spacecraft link prior to Agena/spacecraft separation. Coverage of either link prior to Agena/spacecraft separation in support of spacecraft telemetry coverage requirements is satisfactory.

to the point at which continuous DSIF view begins, +10 min, was considered a Class II requirement. Table 9 presents these requirements.

Class III: Same as Class II.

c. Data delivery requirements. The requirements for return of data for analysis are documented in detail in the Lockheed document LSMC A604289-B[2]. Data from the first launch (*Mariner III*) were required to be returned and evaluated in 36 hr in order to support the launch of *Mariner IV* as little as 48 hr after the first launch.

Data obtained from the uprange instrumentation sites was returned to the AFETR for analysis. Data from the downrange sites was delivered to a telemetry reader station at Pretoria (AFETR Station 13) as well as to the Cape. Spacecraft data from the downrange sites was delivered to the Johannesburg DSIF site for subsequent transmission to the SFOF. It was not required that this accelerated data delivery plan be utilized for the *Mariner D* launch.

2. Requirements Placed on GSFC

Telemetry coverage requirements placed on GSFC for the Mission consisted of the following:

1. Telemetry data gathered at the participating stations were required for the life of the *Agena* telemetry transmitter via one telemetry link.
2. Certain real-time readouts were required.
3. Magnetic-tape recordings, direct-write (Sanborn) recordings, and telemetry operators' logs were required.
4. Oscillograph (Visicorder) recordings were required at Carnarvon.

3. Requirements Placed on DSN

The DSN was required to obtain spacecraft telemetry coverage beginning at Woomera-rise +2 min. Requirements were also placed on Johannesburg to cover portions of the flight between launch and Woomera-rise. The DSN capabilities during this early period were utilized, where possible, in harmony with the AFETR facilities. As was expected, however, most support during this early phase was provided by AFETR. Data from the DSN were delivered to the SFOF by teletype transmission for analysis.

G. Tracking and Telemetry Requirements Summary

Summarizing briefly, launch vehicle/spacecraft Class I tracking and telemetry requirements are:

1. Launch Vehicle System Requirements:
   a. Telemetry coverage during the entire powered-flight ascent to *Agena* first cutoff +25 sec.
   b. Telemetry coverage from *Agena* second-burn ignition −18 sec to *Agena* second-burn cutoff +20 sec.
   c. Telemetry coverage during *Agena*/spacecraft separation −10 sec to *Agena*/spacecraft separation +5 sec.
   d. Tracking from launch to parking orbit injection.
   e. Tracking coverage for 1 min after transfer orbit injection.
2. Spacecraft System Requirements:
   a. Launch to *Agena* first-burn cutoff +25 sec.
   b. Telemetry coverage from *Agena* second-burn ignition −18 sec to *Agena* second-burn cutoff +20 sec.
   c. Telemetry coverage from *Agena*/spacecraft separation −10 sec to continuous DSIF view +2 min.
   d. Adequate tracking coverage to allow the orbit to be determined to an accuracy (rms uncertainty in semimajor axis) of less than 2250 km at injection +5 days.

IV. TRACKING AND DATA ACQUISITION SUPPORT AND FACILITIES

A. General

Section III presented T&DA requirements for the *Mariner* Mars 1964 Mission. Section IV briefly describes the facilities of AFETR, GSFC, and the DSN that were committed to support Mission T&DA requirements.

B. AFETR Tracking and Data Acquisition Support

Following launch of each spacecraft, extensive use of the tracking and telemetry facilities at AFETR (Figs. 5 and 6) was made in support of the Mission. Two basic requirements for near-real-time data which existed during the preinjection phase of the Mission were as follows:

1. Initial acquisition data for the DSIF were required from AFETR. The raw tracking data obtained from downrange stations were forwarded to the computing center located in the Impact Predictor Building (IPB) and also to the JPL Operations Center (both at Cape Kennedy) for relay to the SFOF (at Pasadena, California). (See Table 10 for format of AFETR data.) These data, in conjunction with pertinent telemetry data, were used to determine spacecraft parking orbit. Acquisition data in the format shown in Table 11 were computed and forwarded to the JPL Operations Center at AFETR for relay to the SFOF and thence to the DSIF stations.
2. AFETR was also required to obtain an initial estimate of spacecraft injection conditions. The orbital elements of the parking orbit and initial estimate of spacecraft injection conditions were forwarded by AFETR to the JPL Operations Center at AFETR for relay to the SFOF. The format of these data is shown in Table 12. This table also provides tracking data nomenclature for AFETR data which were forwarded to the SFOF in near-real-time.

In general, AFETR T&DA support plan covered five areas.

1. Metric Data

From launch to 5000 ft, metric data were obtained by Cape Kennedy CZR camera sites. This system satisfied

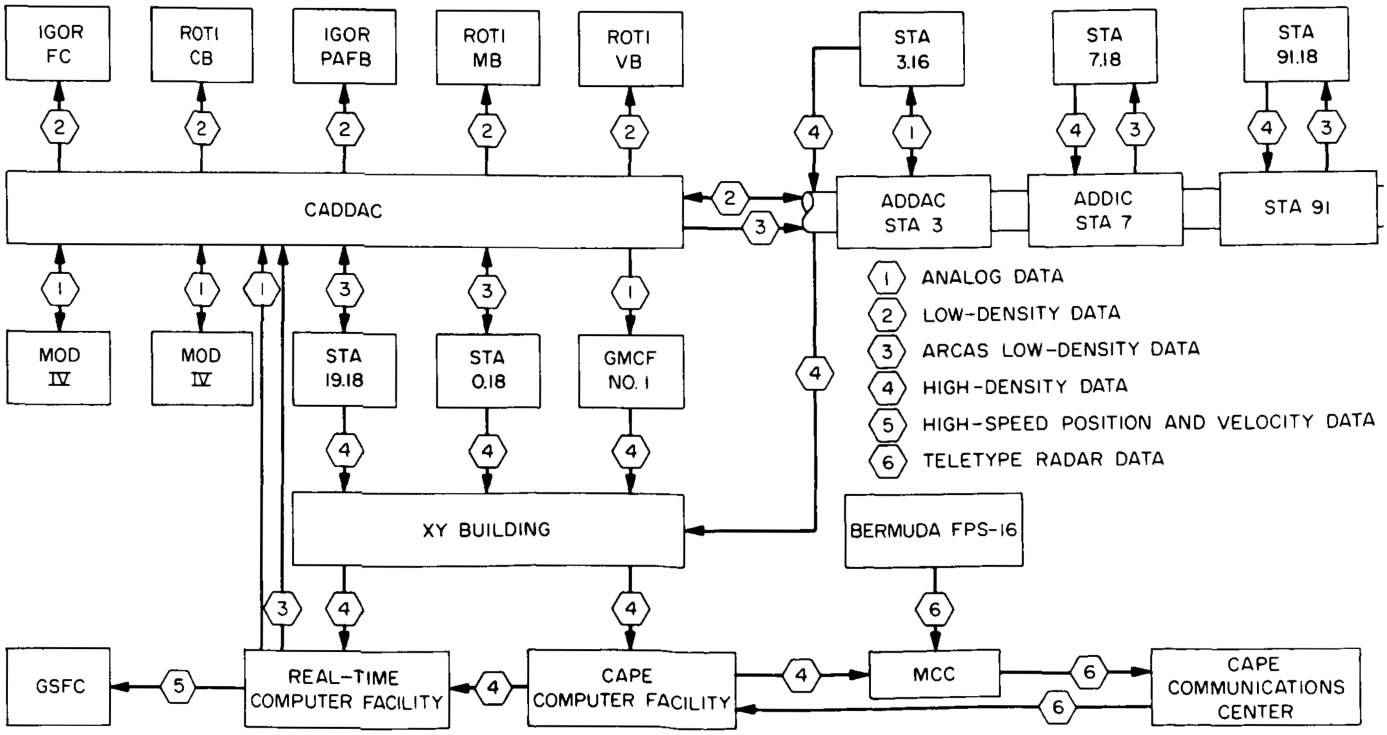


Fig. 5. AFETR tracking facilities and data flow (launch phase)

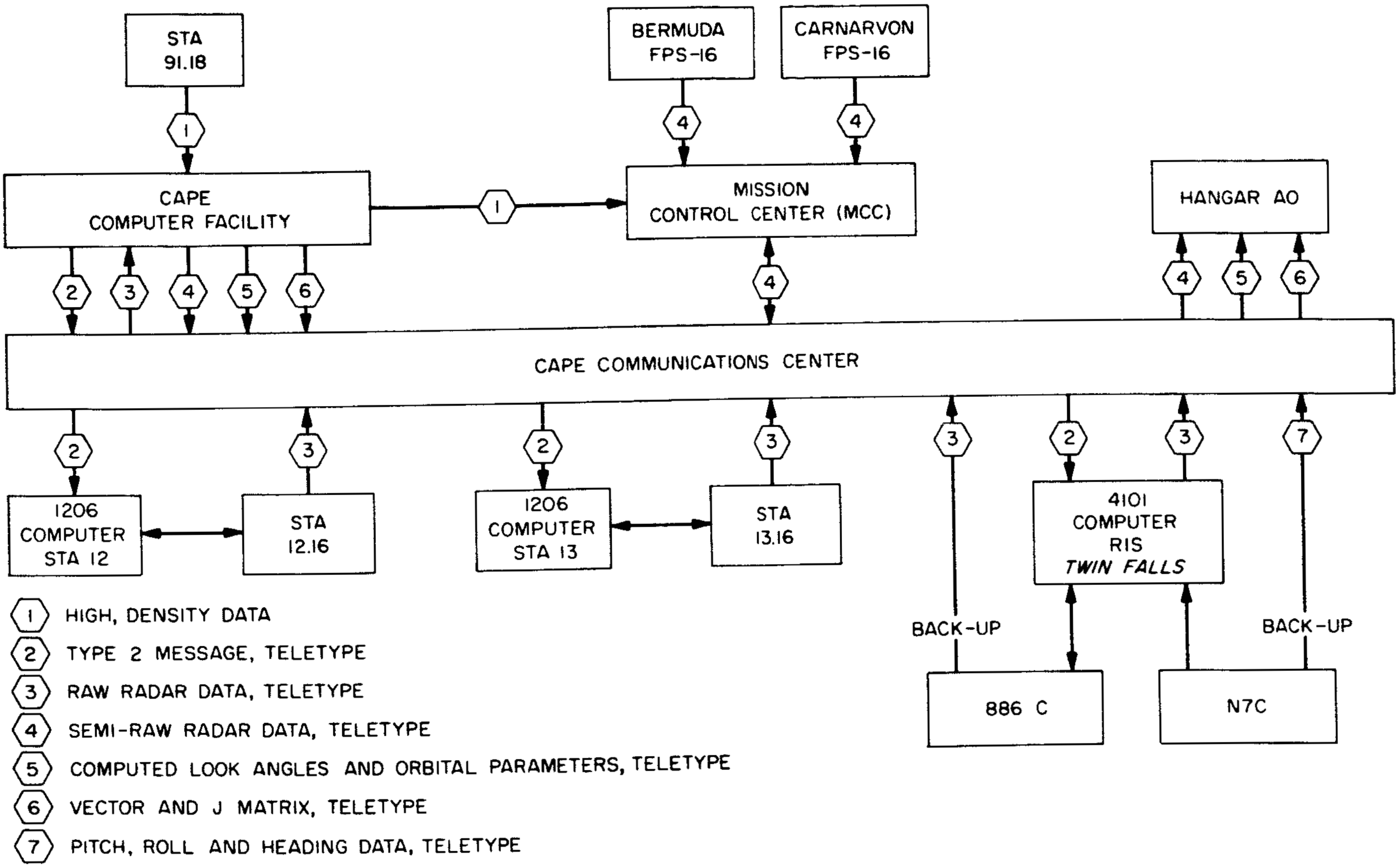


Fig. 6. AFETR tracking facilities and data flow (orbit support)

Class I position accuracy. Primary coverage from about 5000 ft to booster cutoff was provided by C-band radars at Cape Kennedy, PAFB, and Grand Bahama Island. Additional metric coverage was provided from the cinetheodolite system at the Cape. This system, which operated at 5 samples/sec, was committed on a "visibility permitting" basis from an altitude of about 1000 to 90,000 ft. Midcourse metric data from booster cutoff through *Agena* first-burn cutoff were provided by radars at Cape Kennedy, Grand Bahama Island, San Salvador, Grand Turk, Bermuda, and Antigua. *Agena* second-burn coverage was provided by Pretoria radar and tracking ships. The tracking ships *Twin Falls, Coastal Crusader,* and *Swordknot* supported the mission.

2. Engineering Sequential Data

Launch engineering sequential coverage was provided by 16-, 35-, and 70-mm fixed cameras. All image-to-frame ratios were generally as requested by the Mission requirements.

3. Telemetry Data

Telemetry coverage to radio horizon was provided by the receiving and recording stations at Cape Kennedy, Grand Bahama Island, San Salvador, Antigua, Ascension Island, South Africa, and the three tracking ships. Booster coverage met Class I requirements.

4. Support Instrumentation

Most of the communications support provided for the mission exists at AFETR. All Florida mainland instrumentation sites are linked by teletype and voice circuits. A subcable through Antigua connected downrange stations with Cape Kennedy. Existing VHF and HF radio links tied the ships and aircraft to land stations. Connection with the radar sites in South Africa and Ascension Island were made via teletype and voice circuits. Metric, engineering sequential, and telemetry data were all recorded against coded time. All major AFETR stations supporting the program used standard 17-digit modified

Table 10. Format for tracking data obtained from AFETR in near-real-time

Semi-raw data placed in the following format for teletype transmission:

Character transmitted	Information		Character transmitted	Information	
1	Line feed		20	Az	6, 5, 4
2	Figure shift		21	Az	3, 2, 1
3	Figure shift		22	El	21, 20, 19
4	Data type		23	El	18, 17, 16
5	Station ID		24	El	15, 14, 13
6	Station ID		25	El	12, 11, 10
7	Radar type		26	El	9, 8, 7
8	On track (Code 2)		27	El	6, 5, 4
9	Time, hr	20, 19	28	El	3, 2, 1
10	Time, hr	18, 17, 16, 15	29	R	27, 26, 25
11	Time, min	14, 13, 12	30	R	24, 23, 22
12	Time, min	11, 10, 9, 8	31	R	21, 20, 19
13	Time, sec	7, 6, 5	32	R	18, 17, 16
14	Time, sec	4, 3, 2, 1	33	R	15, 14, 13
15	Az	21, 20, 19	34	R	12, 11, 10
16	Az	18, 17, 16	35	R	9, 8, 7
17	Az	15, 14, 13	36	R	6, 5, 4
18	Az	12, 11, 10	37	R	3, 2, 1
19	Az	9, 8, 7	38	Carriage return	

Key

Character 4, data type:
- 2—Real time
- 3—Simulated data
- 7—Last sample

Characters 5 and 6, Station ID:

Grand Turk 7-18	51
Antigua 91-18	91
Bermuda	70
Twin Falls (corrected)	77
Twin Falls (uncorrected)	72
Ascension 12-16	75
Pretoria 13-16	76

Character 7, radar type:
- MPS-26, FPS-16—0
- TPQ-18—3

Character 8, on track:
- Off track—0
- On track—2

Characters 9–14, time:
- 20-bit binary coded decimal time code character

Characters 15–21, azimuth data in binary code:
- FPS-16, MPS-25
  - Most significant bit: bit 17, 180 deg
  - Least significant bit: 1, 0.0027465 deg
- TPQ-18
  - Most significant bit: bit 19, 180 deg
  - Least significant bit: bit 1, 0.000686 deg

Characters 22–28, elevation data in binary code:
- FPS-16, MPS-25
  - Most significant bit: bit 17, 180 deg
  - Least significant bit: bit 1, 0.0027465 deg
- TPQ-18
  - Most significant bit: bit 19, 180 deg
  - Least significant bit: bit 1, 0.000686 deg

Characters 29–37, range data in binary code:
- FPS-16
  - Most significant digit: 2^{26}, 67,108,864 yd
  - Least significant digit: 2^{0}, 1 yd
- TPQ-18
  - Most significant digit: 2^{26}, 67,108,864 yd
  - Least significant digit: 2^{0}, 1.953125 yd

Character 38, end of sample: Carriage return

Table 11. Acquisition data message formats for Woomera and Johannesburg, supplied by AFETR

The acquisition data message formats for Woomera from AFETR	The acquisition data message formats for Johannesburg from AFETR
JPL LOOK ANGLES FROM ACTUAL P.O AND NOMINAL 2ND BURN MA C XMITTER REF FREQ XXXXXX XPONDER FREQ XXXXXX HMS XX XX XX.X RANGE XXXXX.XXX HMS HA DEC D1.41 D2.41 XA.41 ID XXXXXX XXX.X XXX.X XXXXXX XXXXX XXXXXX LMNPQR . . . HMS XX XX XX.X RANGE XXXXX.XXX END OF LOOK ANGLES FROM ACTUAL PARKING ORBIT MA C	JPL LOOK ANGLES FROM ACTUAL P.O. AND NOMINAL 2ND BURN MA C XMITTER REF FREQ XXXXXX XPONDER FREQ XXXXXX HMS XX XX XX.X RANGE XXXXX.XXX HMS HA DEC D1.51 D2.51 XA.51 ID XXXXXX XXX.X XXX.X XXXXXX XXXXXX XXXXXX LMNPQR . . . HMS XX XX XX.X RANGE XXXXX.XXX END OF LOOK ANGLES FROM ACTUAL PARKING ORBIT MA C
JPL LOOK ANGLES FROM ACTUAL TRANSFER ORBIT MA C XMITTER REF FREQ XXXXXX XPONDER FREQ XXXXXX HMS XX XX XX.X RANGE XXXXX.XXX HMS HA DEC D1.41 D2.41 XA.41 ID XXXXXX XXX.X XXX.X XXXXXX XXXXXX XXXXXX LMAPQR . . . HMS XX XX XX.X RANGE XXXXXX.XXX END OF LOOK ANGLES FROM ACTUAL TRANSFER ORBIT MA C	JPL LOOK ANGLES FROM ACTUAL TRANSFER ORBIT MA C XMITTER REF FREQ XXXXXX XPONDER FREQ XXXXXX HMS XX XX XX.X RANGE XXXXX.XXX HMS HA DEC D1.51 D2.51 XA.51 ID XXXXXX XXX.X XXX.X XXXXXX XXXXXX XXXXXX LMAPQR . . . HMS XX XX XX.X RANGE XXXXX.XXX END OF LOOK ANGLES FROM ACTUAL TRANSFER ORBIT MA C

Key

H	hr	D2.51	two-way doppler detector output frequency for Station 1, Zone 5
M	min	XA.51	transmitter VCO frequency for spacecraft zero static phase error for Station 1, Zone 5
S	sec	AZ	azimuth
HA	hour angle	EL	elevation
DEC	declination	ID	as listed below:
D1.41	one-way doppler detector output frequency for Station 1, Zone 4	LM	orbit number, from 01 to 99
D2.41	two-way doppler detector output frequency for Station 1, Zone 4	N	denotes nominal second burn
XA.41	transmitter VCO frequency for spacecraft zero static phase error for Station 1, Zone 4	A	denotes actual second burn (replaces N)
D1.51	one-way doppler detector output frequency for Station 1, Zone 5	PQR	day of the year

Table 12. Trajectory data supplied by AFETR

The trajectory data message formats from AFETR

```
LIFTOFF DAY XXX HMS XX XX XX.X GMT  AZL XXX.XX                                      MA C
ELEMENTS AND INJECTION CONDITIONS OF PARKING ORBIT  YYY.YY
HMS XX XX XX.X L PLUS TIME XXXXX.  ALT XXX.XX
SMA XXXXX.X  ECC X.XXXXXX  INC XXX.XXX  C3 XX.XX
LAN XXX.XXX  APF XXX.XXX  TA XXX.XXX
R XXXXX.  LAT XX.XXX  LON XXX.XXX  VE XX.XXX  PTE XX.XXX  AZE XXX.XXX

INJECT COND OF TRANSFER ORBIT FROM ACT P.O AND NOM 2ND BURN  YYY.YY                  MA C
HMS XX XX XX.X L PLUS TIME XXXXX.
R XXXXX.  LAT XX.XXX  LON XXX.XXX  VE XX.XXX  PTE XX.XXX  AZE XXX.XXX

ELEMENTS AND INJECTION COND OF ACTUAL TRANSFER ORBIT  YYY.YY                         MA C
HMS XX XX XX.X L PLUS TIME XXXXX.  ALT XXX.XX
SMA XXXXX.X  ECC X.XXXXXX  INC XXX.XXX  C3 XX.XX
LAN XXX.XXX  APF XXX.XXX  TA XXX.XXX
R XXXXX.  LAT XX.XXX  LON XXX.XXX  VE XX.XXX  PTE XX.XXX  AZE XXX.XXX
```

Key

LIFTOFF DAY	day of the calendar year
HMS (GMT)	time of launch, GMT
AZL	azimuth of launch
YYY.YY	data source of computations. The number before the decimal is the Station ID; the number after the decimal indicates the number of the transmission. (AFETR is to use numbers from 01 to 09; JPL is to use numbers from 10 to 99.)
HMS	epoch—Universal Time (hr, min, sec) time at which osculating conic is calculated
L + (TIME)	launch plus __________, sec
ALT	distance above Earth's surface, km
SMA	semimajor axis of conic section. Negative for a hyperbola, km
ECC	eccentricity of conic section
INC	inclination—angle between the orbital plane and the Earth's (instantaneous) equator, deg
C3	twice the total energy per unit mass or *vis viva*, km^2/sec^2
LAN	right ascension of the ascending node, deg. Measured from the vernal equinox of date in the instantaneous equatorial plane
APF	argument of perigee. The angle, in the orbital plane, eastward from the ascending node to the perigee point, deg.
TA	true anomaly at epoch. The angle measured from perigee to the spacecraft; measured eastward, deg.
R	injection radius, km
LAT	injection latitude, deg
LON	injection longitude, deg
VE	inertial velocity, km/sec
PTE	inertial path angle at injection
AZE	injection azimuth, deg
X	used to indicate number location in message

binary codes. Time correlation between Cape Kennedy, Antigua, and Ascension Island was ±5 msec. Instrumentation summary charts are presented in Table 13.

5. Data Processing

Data recorded on film, strip charts, and tapes were reduced and processed at the Technical Laboratory, PAFB. Telemetry data were duplicated and processed at the Tel 2 Building, Cape Kennedy.

C. GSFC Tracking and Data Acquisition Support

1. Station Coverage

Backup C-band radar T&DA coverage was provided by GSFC at the Bermuda and Carnarvon stations of the MSFN (see Table 14). Bermuda covered the early *Agena* flight and Carnarvon provided support during the post-*Agena* retro period. The STADAN station at Tananarive provided FM/FM telemetry coverage of the *Agena*. Bermuda recorded telemetry data on the *Atlas* link (229.9 mc) and the *Agena* link (244.3 mc). Carnarvon recorded telemetry data on the 244.3-mc *Agena* link only.

2. GSFC Computer Support

The Data Operations Branch was responsible for all Mission computing and coordinating tasks required by GSFC. A summary of this support is provided.

1. Testing. During the prelaunch countdown, all tracking stations supporting the Mission participated in the CADFISS[2] roll call to ensure valid radar data-flow capability.

2. Launch phase. Launch trajectory data were supplied to the GSFC computers by the AFETR com-

[2]Computation and data flow integrated subsystem (test).

Table 13. AFETR instrumentation summary for *Mariner* Mars 1964 Mission

Location	Instrumentation	Use
Cape Kennedy, Merritt Island Launch Area	Cine-theodolites	Metric data
	C-band radar	Metric data, range safety
	Fixed-camera system (CZR and RC-5)	Metric data
	Pad cameras (16, 35, and 70 mm)	Engineering sequential
	Telemetry	Inertial data
	PAM/FM/FM (VHF) 2 links	
	FM/PM (S-band) 1 link	
	Command destruct	Range Safety
	Wire sky screen	Range Safety
	TV sky screen	Range Safety
	Telemetry ELSSE	Range Safety
	L-band radar (AN/FPS-8)	Range Safety
	High-resolution radar tracking (Mod IV)	Range Safety
	IBM 7094 computer	Range Safety
	Igor (35- and 70-mm cameras)	Engineering sequential
Williams Point	Igor (35- and 70-mm cameras)	Engineering sequential
Cocoa Beach	Cine-theodolite	Metric data
	Roti (70-mm cameras)	Engineering sequential
Patrick AFB	Cine-theodolites	Metric data
	C-band radar (AN/FPQ-6)	Metric data, Range Safety
	Igor (35- and 70-mm cameras)	Engineering sequential
Melbourne Beach	Roti (70-mm cameras)	Engineering sequential
Vero Beach	Roti (70-mm cameras)	Engineering sequential
Grand Bahama Island	C-band radar	Metric data
	Telemetry	Internal data
	PAM/FM/FM (VHF) 2 links	
	Command destruct	Range Safety

Table 13 (Cont'd)

Location	Instrumentation	Use
San Salvador	C-band radar (AN/FPS-16)	Metric data
	Command destruct	Range Safety
Grand Turk	Command destruct	Range Safety
	C-band radar (AN/TPQ-18)	Metric data
Antigua	C-band radar (AN/FPQ-6)	Metric data, Range Safety
	Telemetry PAM/FM/FM (VHF) 2 links	Internal data
	Command destruct	Range Safety
Ascension Island	C-band radar (AN/FPS-16)	Metric data
	Telemetry FM/FM (VHF) 1 link FM/PM (S-band) 1 link	Internal data
Bermuda	C-band radar	*Contingent on commitment by NASA*
Pretoria	C-band radar (AN/MPS-25)	Metric data
	Telemetry FM/FM (VHF) 1 link FM/PM (S-band) 1 link	Internal data
RIS *Twin Falls*	C-band radar	Metric data
	Telemetry FM/FM (VHF) 1 link FM/PM (S-band) 1 link	Internal data
RIS *Swordknot*	Telemetry FM/PM (S-band) 1 link FM/FM (VHF) 1 link	Internal data
RIS *Coastal Crusader*	Range user equipment	GE guidance system calibration
Aircraft	None	Return of data

Table 14. Mission-support network configuration

Stations	FM telemetry	C-band radar	SCAMA[a]	Teletype
Bermuda (BDA)	X	X	X	X
Carnarvon (CRO)	X	X	X	X
Tananarive (TAN)	X		X	X
Kano (KNO)[b]			X	X

[a]Signaling, conferencing, and monitoring arrangement.
[b]Kano, Nigeria, is required as a communications relay point for Tananarive.

plex. Events were passed to the GSFC operations director by voice from the mission controller at MCC.

3. Parking-orbit phase. Approximately one week prior to launch day, nominal pointing data were transmitted to the participating stations. During the transmitting lifetime of the vehicle, GSFC computers updated and displayed the data as required. In addition, acquisition messages were generated and transmitted to the participating stations. Radar data from Bermuda and Carnarvon were reformatted into standard 38-character *Gemini* format and transmitted to AFETR in near-real-time.

3. Acquisition Aids

The acquisition aids provided pointing information to the radars and telemetry RF inputs during the life of the on-board telemetry transmitter.

4. Radar Coverage

The MSFN at Bermuda and Carnarvon provided backup C-band radar tracking coverage of the *Atlas* and *Agena* vehicles.

a. Radar communications. Communications between the AFETR radar controller and the remote sites were established over the GSFC conference loop and the Department of Defense (DOD) tie lines.

b. Handover plan. Bermuda exercised standard phasing techniques as directed by the AFETR Radar Controller (CAT I). As the downrange radar, Carnarvon was responsible for phasing with *Twin-Falls* and Pretoria during acquisition. Pretoria and *Twin-Falls* used 80-PRF, 1,024,000-yd separation, and neither was equipped with ID coders.

5. Telemetry Coverage

The required GSFC backup telemetry coverage for the *Agena* booster was provided by the Bermuda, Carnarvon and Tananarive Stations, which received and recorded the telemetry signal. Limited real-time readouts were provided by Carnarvon. A brief summary of the telemetry support follows.

a. Receivers. Two 1455/1455A receivers were employed by Bermuda, Carnarvon and Tananarive for telemetry reception. IFM-300/500 modules were used; 244.3-mc crystals were shipped to Bermuda, Carnarvon, and Tananarive in support of the Mission.

b. Oscillograph. The Visicorder was set up, at Carnarvon only, to record IRIG Channel 14 in order to display velocimeter information with a minimum galvonometer deflection of 3 in. Recording speed was 8 ips.

c. Sanborn recorder. The Sanborn recorder speed used for recording of signal strength was 10 mm/sec.

d. Magnetic-tape recording. Ampex FR-600 tape recorders were used for the Mission. Signals were recorded on 1-in., 14-track magnetic tape at Bermuda and Carnarvon (Ampex FR-614) and on 1/2-in., 7-track tape at Tananarive (Ampex FR-607) at a speed of 60 in./sec with a 100-kc reference.

6. NASA Ground Communications

Participating stations used existing full-time voice, teletype, and high-speed data circuits. Part-time circuits were not committed for the Mission.

During countdown, launch, and parking-orbit phase, the GSFC Communications Center and all participating stations were fully activated. Mandatory communication coverage periods during prelaunch were called up by the communication manager as required by the network controller. The communication links to all participating stations are indicated in Fig. 7.

No critical coverage was required during the Mission; however, special coverage was called on the voice, teletype, and high-speed data circuits from Cape Kennedy, GSFC, and Bermuda during the launch phase. Communication circuits as shown in Table 15 were designated for use during the Mission.

Subswitching centers at London, Honolulu, and Adelaide, were committed to support as required. Kano was used as a communications relay point for Tananarive.

7. Support Arrangement

The Mission Control Center at Cape Kennedy was used for control of the GSFC support during the mission. No special modifications were required for the support of the mission. However, Tananarive was not yet operational and certain local modifications were implemented to ensure support.

8. Special Data-Handling Requirement

In support of the "36-hr Data-Return Plan," the Tananarive Station was required to deliver the telemetry tape from the first *Mariner* launch to the Jan Smuts Airport, Pretoria, South Africa, within $T + 15$ hr. The Tananarive Station Director was required to inform the network controller via SCAMA that the tape had left the station and the estimated time of arrival at Pretoria. The *Mariner* Project then informed AFETR Station 13 (Pretoria).

Table 15. NASA ground communications

Site	Routine indicator	Voice	Teletype	HSD
Bermuda	GBDA	X	X	X
Mission Control Center	GMCC	X	X	X
GSFC	GSPA	X	X	X
Carnarvon	ACRO	X	X	
Tananarive	LTAN	X	X	

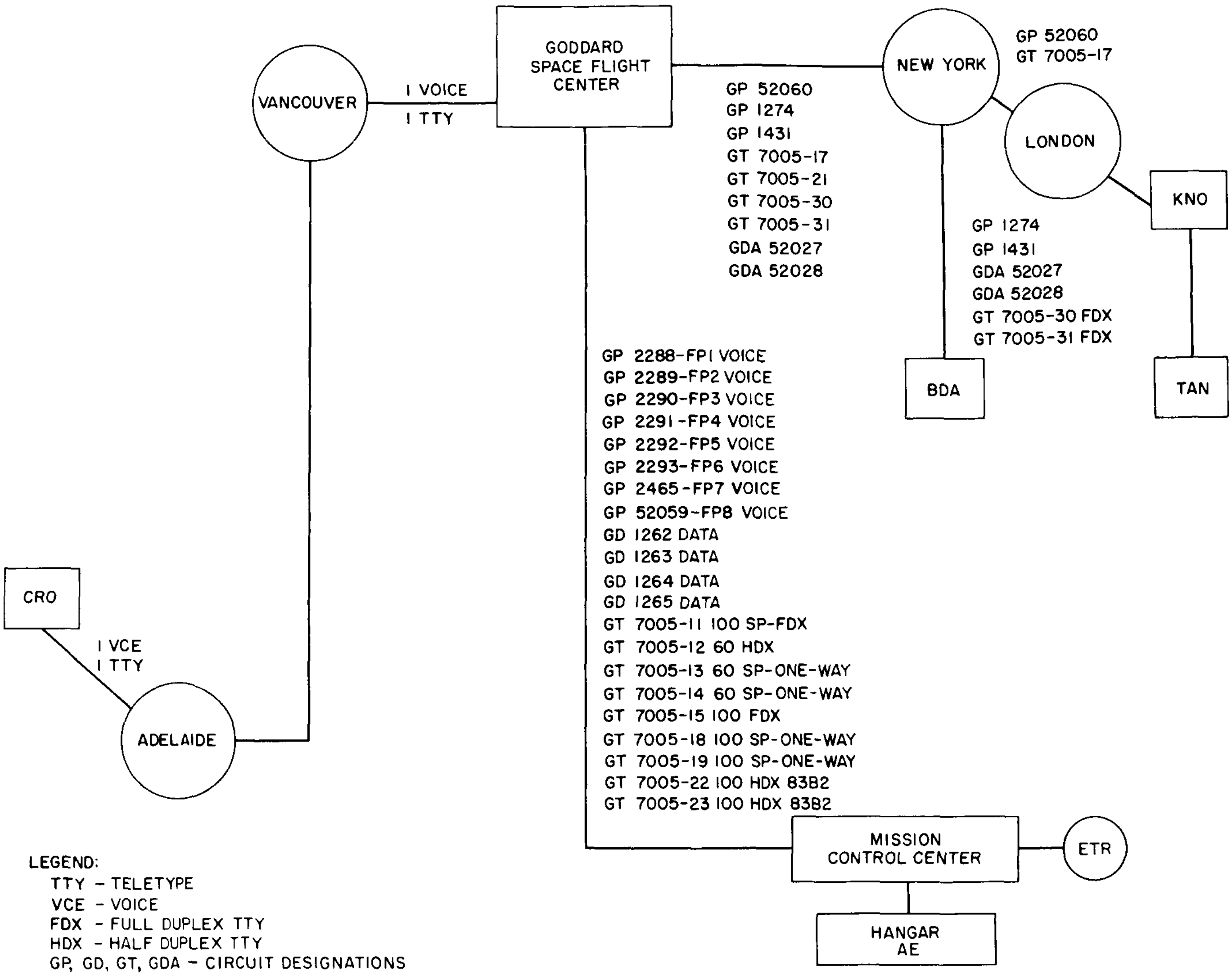


Fig. 7. Network ground communications configuration

D. DSN Tracking and Data Acquisition Support

Deep Space Network T&DA support for the *Mariner* Mars 1964 Mission consisted of providing the facilities, equipment, and personnel necessary to meet the space-flight operations requirements of the *Mariner* Mars 1964 Project. The DSN consists of the DSIF, interstation communications, and the mission-independent portion of the SFOF.

1. DSIF Mission Support

The function of the DSIF was to obtain angular position, doppler, and telemetry data from the *Mariner* spacecraft during the postinjection phase of the Mission. Ranging-data capability, in addition to two-way doppler, is available at the DSIF-11 (Pioneer) Station only. The DSIF also sends ground-computed commands in accordance with the procedures outlined in the *Mariner Tracking Instruction Manual* (TIM). The Spacecraft Checkout Facility at Cape Kennedy provided telemetry coverage from launch to local horizon.

Data obtained by the DSIF were transmitted to the SFOF in real-time or near-real-time by teletype and high-speed data circuits. In addition, the same data were recorded on magnetic tape at each DSIF station and dispatched to JPL by airmail.

a. DSIF stations. The following were designated as primary stations for the *Mariner* Mars 1964 Mission:

1. DSIF-11: Pioneer Station, Goldstone, California.
2. DSIF-41: Woomera, Australia.
3. DSIF-51: Johannesburg, South Africa.

The L- to S-band conversion system was used at Woomera and Johannesburg during the Mission. The telemetry system and angle tracking are compatible with either the L- to S-band conversion system or the Goldstone Duplicate Standard (GSDS) S-band system. However, there is a significant difference in the doppler format; use of the ranging subsystem is not possible with the L- to S-band conversion receiver.

One of the *Mariner* Mars 1964 Project requirements was for dual spacecraft coverage. Thus, the DSIF station incorporates the capability of simultaneously transmitting near-real-time data from one spacecraft while recording and storing telemetry data from a second spacecraft for subsequent transmission or transportation to JPL. While this capability existed for two spacecraft within the beamwidth of a single antenna, it was never utilized owing to the short life of the *Mariner III* spacecraft.

Table 16. DSIF capabilities for *Mariner* Mars 1964 Mission

Station name	Goldstone Pioneer GSDS S-band	Goldstone Venus	Woomera L- to S-band conversion kit	Canberra GSDS S-band	Johannesburg L- to S-band conversion kit
Station ID	DSIF-11	DSIF-13	DSIF-41	DSIF-42	DSIF-51
Receiver capability	Two	None	One	Two	One
Antenna	85-ft parabolic	85-ft parabolic	85-ft parabolic	85-ft parabolic	85-ft parabolic
Mount	Polar (HA-Dec)	Equatorial (Az-El)	Polar (HA-Dec)	Polar (HA-Dec)	Polar (HA-Dec)
Maximum angular rate (both axes)	0.7 deg/sec	1 deg/sec	0.7 deg/sec	0.7 deg/sec	0.7 deg/sec
Antenna gain					
Receiving	53.0 db ± 1	—	53.0 db ± 1	53.0 db ± 1	53.0 db ± 1
Transmitting	51.0 db ± 1	53.0 db ± 0.5	51.0 db ± 1	51.0 db ± 1	51.0 db ± 1
Antenna beamwidth	~0.4 deg	~0.4 deg	~0.4 deg	~0.4 deg	~0.4 deg
Typical system temperature	60 k	—	60 k	60 k	60 k
Transmitter power	10 kw	100 kw	10 kw	10 kw	10 kw
Data transmission (TTY)					
a) Angles	Real-time[b]	None	Real-time	Real-time	Real-time
b) Doppler	Real-time	None[c]	Real-time	Real-time	Real-time
c) Ranging (to 800,000 km)	Real-time	None	None	Real-time	
d) Telemetry	Real- & near-real-time	None	Real- & near-real-time	Real- & near-real-time	Real- & near-real-time
Demodulated telemetry	Dual channel	None	Single channel	Dual channel	Single channel
Command capability	Yes	Yes	Yes	Yes	Yes
Data-pack air shipment time to JPL	1 day	1 day	7 days	6 days	5 days

[a]Capability difference between L- to S-band conversion kit stations and GSDS S-band stations:
a. No ranging
b. Doppler format
c. Single receiver

[b]Real-time is defined in the *Mariner* C SFO System Design Specifications, Section III.

[c]Coherent two-way doppler when operating at 100 kw with Pioneer station.

Woomera was designated a primary station during the early part of the mission. Canberra was scheduled to supplement Woomera if the requirement existed to provide coverage for two spacecraft and was to become the primary station at that time or sooner, depending on DSN loading and Canberra operational readiness.

Dual spacecraft coverage at Johannesburg was to have been provided by using the L- to S-band conversion system to cover one spacecraft and either a portable telemetry package or a modified angle channel of the S-band receiver to cover the other spacecraft.

The parameters and capabilities of each DSIF station are given in Table 16. The operational frequency assignments are listed in Table 17. Approximately 2 hr are required to change the operating frequency at a station. Compatible telecommunications modes are listed in Table 18. Block diagrams of the stations are presented in Figs. 8 and 9. The tracking-data format is shown in Table 19. The ground-encoded telemetry data formats are described in Table 20. Ground modes are listed in Table 21.

Acquisition and prediction information required by the DSIF has previously been listed in Table 11. The sample-rate capability for these data is described in Table 22. Station reports, as detailed in Section IV.D.1.c are periodically transmitted by each DSIF station to the SFOF. These reports are then distributed, as required, within the SFOF.

b. DSIF coverage. Three DSIF stations were committed to meet the requirements placed on the DSIF by the *Mariner* Mars 1964 Project and were designated as the prime stations: Goldstone (Pioneer), Johannesburg, and Woomera.

Table 17. Operational frequency assignments: frequencies employed during Mission

Channel	Receive, mc	Transmit, mc
21	2297.592593	2115.699846
22	2297.962963	2216.040895
23	2298.333333	2116.381944
24	2298.703704	2216.722994

Table 18. Compatible telecommunications modes

(Letters on top row are identical with 1st-column designation)

	a	b	c	d	e	f	g
a. 1-way doppler				X			X
b. 2-way doppler				X	X	X	X
c. 2-way noncoherent doppler				X[a]		X	X[a]
d. Angle tracking	X	X	X[a]		X	X	X
e. Ranging		X		X			X[b]
f. Command		X		X			X
g. Telemetering	X	X	X[a]	X	X[b]	X	

[a]Only at receiving station.

[b]Simultaneous operation not yet demonstrated.

The DSIF will provide coverage equivalent to 24-station-hr/day for the duration of the Mission. During critical portions of the Mission, additional coverage is provided as follows:

1. *Injection.* Coverage is provided by the prime stations up to the full view-period of each station.
2. *Maneuver.* Same as 1.
3. *Encounter.* Same as 1. The Goldstone Venus station (100-kw transmitter) will provide command backup.

During the critical portions of other missions (e.g., *Ranger*), the DSIF may not be able to provide coverage of the *Mariner* Mars 1964 Mission for the full 24-hr/day period. The amount of reduced coverage is negotiated between the DSIF Operations Manager and the *Mariner* Mars 1964 Space Flight Operations Director.

c. DSIF Station Tracking Reports. Tracking reports are submitted during a tracking period as follows:

1. Every 30 min from launch to midcourse maneuver.
2. After midcourse maneuver, station reports were transmitted at 1-hr intervals.

Each tracking report is identified with the launch-referenced time (e.g., L +60 min), and contains the following information:

1. XXP1: last five digits of T x VCO frequency (10-sec count), GMT, and day of year every 5 min throughout the period covered by the report.

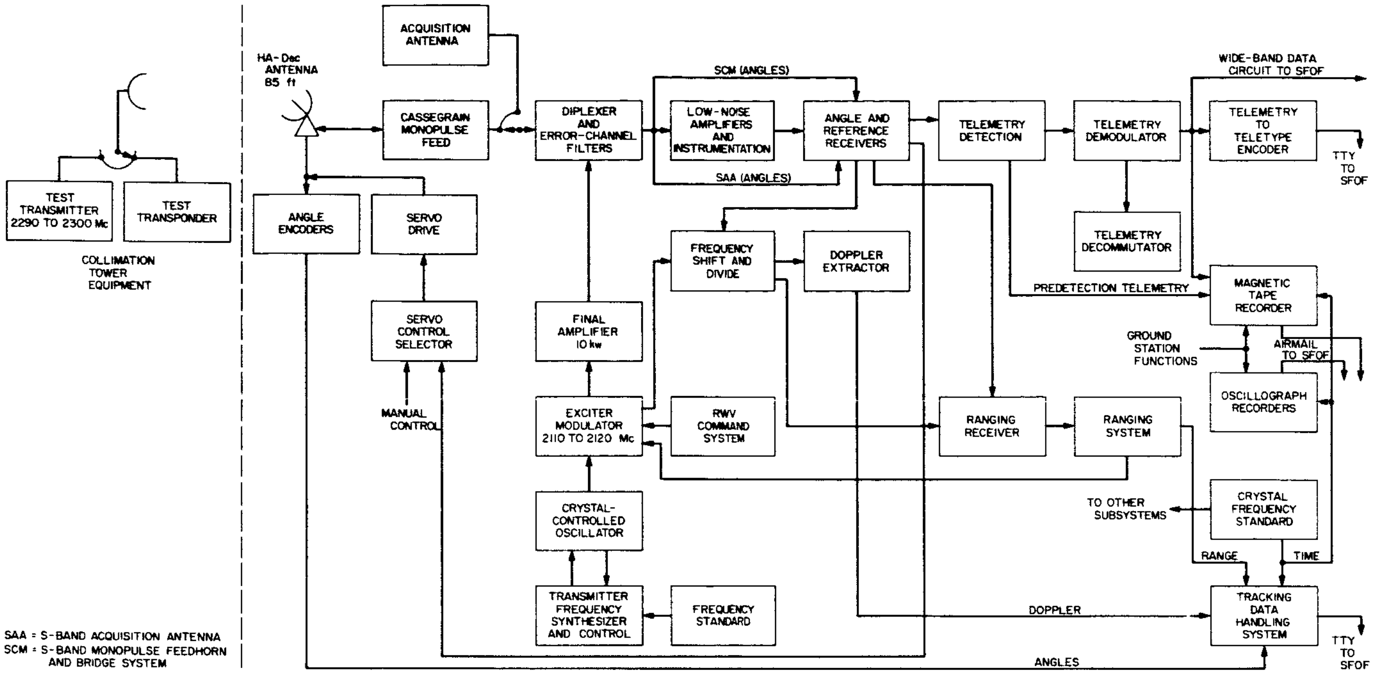


Fig. 8. ***Mariner*** **Mars 1964 typical deep space station (S-band)**

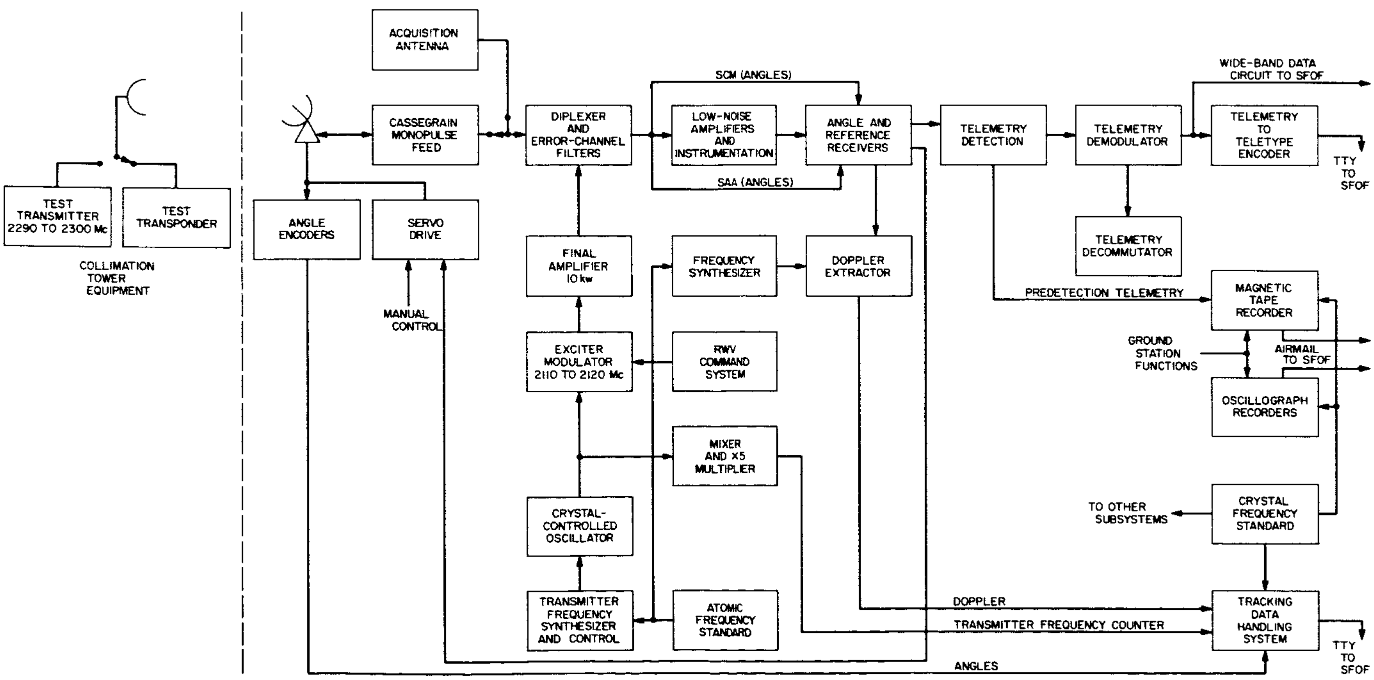


Fig. 9. ***Mariner*** **Mars 1964 typical deep space station (L- and S-band conversion)**

Table 19. Tracking data from the DSIF[a]

DESCRIPTOR	C/R	L/F	F	XX	SF	XX	SF	XX	SF	XXXX	SF	XXXXXX	SF	XXX	SF
				STA ID		FORMAT ID		S/C ID		DATA CONDITION		GMT		DAY	

S-BAND LONG FORM FORMAT ID = 02	DESCRIPTOR	XXXXXXXXXX DOPPLER	SF	XXXXXXXXXX RANGE AND RANGE DC	SF	XXXXXX LHA	SF	XXXXXX DEC
S-BAND SHORT FORM FORMAT ID = 03	DESCRIPTOR	XXXXXXXXXX DOPPLER	SF	XXXXXXXXXX RANGE AND RANGE DC				
L-S BAND LONG FORM FORMAT ID = 04	DESCRIPTOR	XXXXXXXXXX DOPPLER	SF	XXXXX SYN	SF	XXXXXX LHA	SF	XXXXXX DEC
L-S BAND SHORT FORM FORMAT ID = 05	DESCRIPTOR	XXXXXXXXXX DOPPLER	SF	XXXXX SYN				

LHA local hour angle
DEC declination
SYN synthesizer (last 5 digits)

[a]Tracking data from the DSIF are in one of four forms, depending upon the station configuration and the use of the long form or the short form. All transmissions are preceded by a descriptor.

2. Modes:
   a. Start and/or end time of the ground station tracking mode and the actual GMT.
   b. The spacecraft telemetry mode.
3. The average signal level in dbm and AGC volts, any variation about this level, and the GMT of the signal level reading.
4. The telemetry condition (in- or out-of-lock condition of each channel, etc.).
5. The transmitter power and the transmitter on and off times.
6. Time (GMT) of significant events, e.g.,
   a. Time of acquisition.
   b. Time of loss of signal.
   c. Time of significant changes in the tracking system, e.g., receiver and servo bandwidth changes.
   d. Time of abrupt frequency shifts.
   e. Time of changes in signal level corresponding to spacecraft events or commands.
   f. Time of command transmission.
   g. Time of verification of command transmission.
   h. Equipment failures and time of occurrence.

2. DSN-SFOF Mission Support

The DSN provided the *Mariner* 1964 Mission with areas in the SFOF in which premission planning and testing and mission execution were conducted. The DSN provided the technical and operational control areas, operational communications, and the data processing within the SFOF required to support the Mission spaceflight operations.

a. DSN coverage in the SFOF. The DSN supplied support coverage in the SFOF to the Mission for the operational functions, beginning 1 week prior to the first flight and extending for the duration of the Mission. Technical coverage is varied in accordance with Mission needs. However, technical monitoring coverage is essentially the same as operational coverage. Detailed coverage plans for the various groups were presented in the Space Flight Operations Plan document.

b. Operations and control areas in the SFOF. All Mission flight operations, direction, and control originate in the SFOF. The DSN provided the areas required

Table 20. Ground-encoded telemetry data formats

Mode I							
CR	LF	Engrg sync word			19 engrg data words	P	One data frame
CR	LF	Engrg sync word			19 engrg data words	P	One data frame
Mode II							
CR	LF	Engrg sync word			19 engrg data words	P	One data frame
CR	LF				20 science words[a]	P	One data frame
CR	LF				20 science words	P	One data frame
Mode III							
CR	LF				20 science words	P	One data frame
CR	LF				20 science words	P	One data frame
CR	LF				20 science words	P	One data frame
Mode IV							
Same line length as Mode III except that the data frame (video picture line) consists of 182 data words or 9 page-print lines. Time tag format (interjected into data every 5 min)							
CR	LF	SS	SID	SID	9 characters of time	P	
Key							
CR	carriage return (teletype) character						
LF	line feed (teletype) character						
P	horizontal line parity character						
SS	space						
SID	station identification						

[a]Seven binary bits per teletype word, actually 10 binary bits, constitute most science words. However, science words can be as short as one bit or as long as 15 bits.

Table 21. Ground modes

Transmit/receive	Feed (Cassegrain mount)
0. No receive (transmit only)	0. Horn
1. One-way doppler (receive only)	1. Horn–diplexer combination (receive and transmit up to 10 kw)
2. Two-way, one station (transmit/receive)	2. Tracking–diplexer combination (receive and transmit up to 200 w)
3. Two-way, two stations noncoherent (receive only)	3. Acquisition antenna
4. Two-way, two stations coherent (receive only with reference signal from transmit station)	4. Horn, no diplexer (receive only)
5. Receive only; no doppler	

Example: GM 21; transmitting to spacecraft and receiving two-way doppler using a horn feed and diplexer.

Note: Telemetry is available in all receive modes except zero.

Table 22. Acquisition and prediction information for the DSIF

Sample rate

The sample rate for the earlier part of the initial view period was one sample/2 min; for the remainder of the view period the rate was one sample/5 min. One hour of data was transmitted every hour. For all other view periods, one sample/5 min will be supplied for each pass. The data will be updated each day. Transmission time/day of data is approximately 15 min.

Availability of data

Time, min	Origin	For DSIF	Sample rate and amount
$L + 22$	IPP	51, 59	1 sample/2 min, sta rise to rise +24 min
$L + 25$	IPP	41	1 sample/2 min, sta rise to rise +24 min
$L + 30$	IPP	41, 51	1 sample/5 min, sta rise to rise +100 min
$L + 100$	CCC	41, 51	1 sample/5 min, L +90 min to L +4 hr
$L + 220$	CCC	41, 51	1 sample/5 min, L +4 hr to L +30 hr
$L + 520$	CCC	11, 41, 51	1 sample/5 min, L +9 hr to L +30 hr
$L + 1440$	CCC	11 ,41, 51	1 sample/5 min, L +26 hr to L +10 days

for the *Mariner* Mission in the existing SFOF building during the *Mariner III* flight and during launch, midcourse maneuver, and cruise phase of *Mariner IV*. Upon completion of the west wing of the SFOF building in January, 1965, the *Mariner* Project was provided with additional room in a Mission Support Area (MSA). The MSA serves as the control point during both the low-activity (cruise) phase as well as the high-activity phases of the flight. During high-activity phases, each technical area has a representative located in the MSA. These representatives inform the SFOF of their respective activities and also inform the personnel in their respective analysis areas of other activities that might affect performance in those areas. During the low-activity phase of flight, all data monitoring and data analysis are performed in the MSA. Cognizant personnel from the various analysis groups are situated in the MSA during this time.

*c. **Technical areas.*** The DSN provided technical areas in the SFOF for the analysis and evaluation of Mission data. These areas include the Flight Path Analysis Area (FPAA), the Spacecraft Performance Analysis Area (SPAA), and the Space Science Analysis Area (SSAA). Additionally, a Spacecraft Model Room is located in the SPAA. Computer inquiry stations (input/output) and status displays are available in the technical areas. These technical areas, supervised by an area director, are operated according to procedures outlined in the Space Flight Operations Plan.

*d. **Operational communications.*** The Operational Communications System (OCS), controlled from the communications center in the SFOF, serves to provide two basic functions for the *Mariner* Mars 1964 Mission: (1) it controls the connecting of the various operational and technical areas to each other and to external networks, and (2) it routes information in both directions between the DSIF stations and AFETR and the appropriate areas in the SFOF.

Communication lines between the various DSIF stations and the SFOF are shown in Fig. 10 along with AFETR communications. Although the high-speed data lines are shown as being available, it must be understood that their use is primarily on an engineering basis only, and that they are not fully qualified as operational since reliability and error rates have not been established.

*e. **Data processing.*** The amount of data processing required for *Mariner* varied as a function of spacecraft activity; however, it was a Mission requirement that full

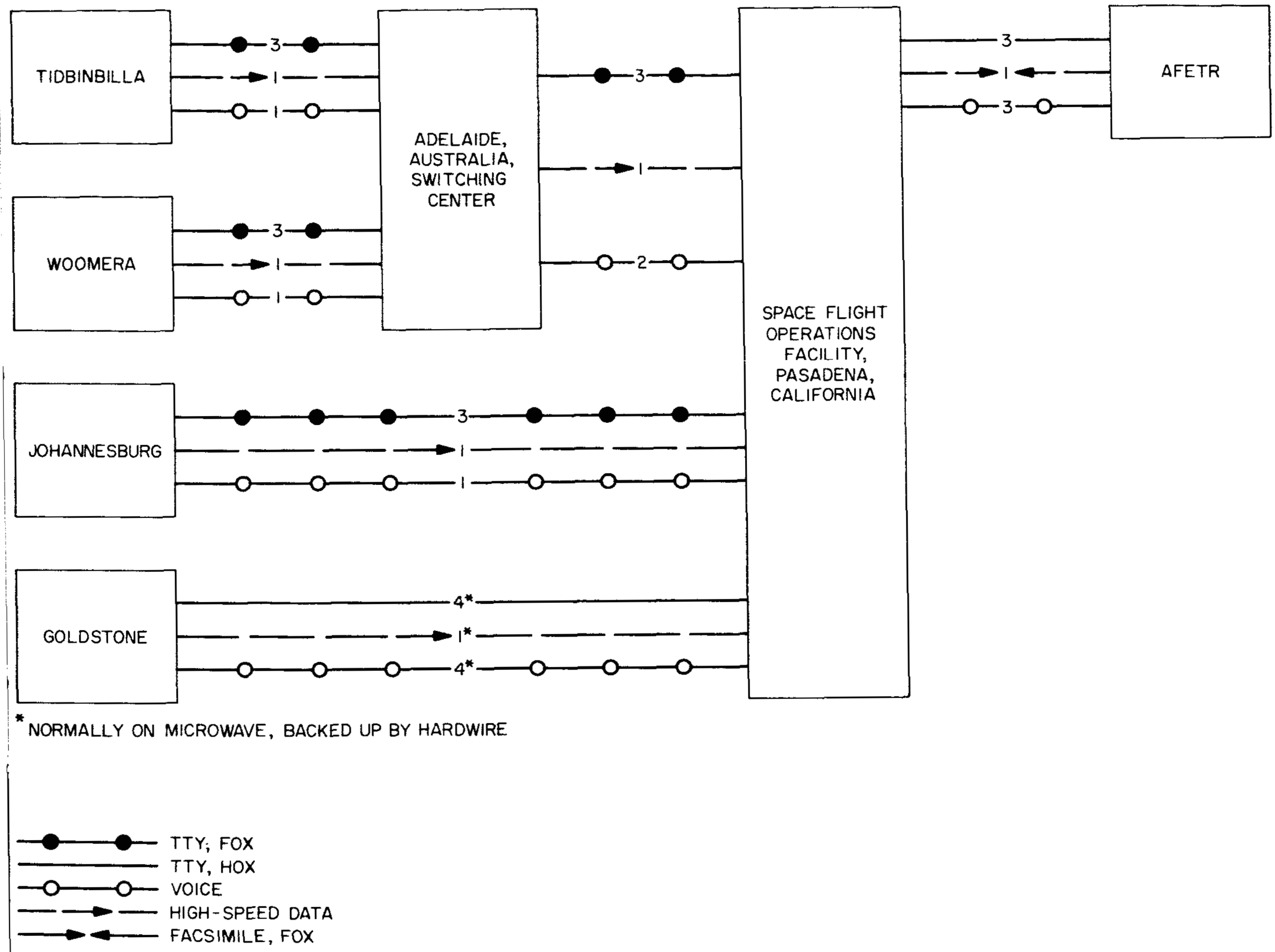


Fig. 10. Communications lines: NASA/NASCOM–DSN/GCS

data processing be available 30 min after a request has been initiated by the SFOF or designated representative. The various types of data processing available in the SFOF are discussed in the following subsection.

3. Data Flow and Processing

a. General. The paragraphs below depict the data flow paths to, from, and within the facilities that support the *Mariner* Mars 1964 Mission. The facilities covered are AFETR, the DSIF, and the SFOF. Also discussed below are data flow, raw data flow, the Data Processing System (DPS), and data processing hardware, configurations, and controls. The mode of data processing used at any given time is primarily dictated by the Standard Sequence of Events.

The nature of the spaceflight operation is such that real-time data flow is of prime concern. Control of this flow and of data processing is necessary so that the proper data are received and processed at the proper intervals. The *Mariner* Mars 1964 Mission is concerned with real-time and non-real-time data:

1. Real-time data. These are data received in real or near-real-time via hardline or radio communication link and entered automatically in the DPS. The data are operated upon by the processing system and displayed on-line in the user areas as rapidly as operational priorities and user programs permit. Data are classified as real-time if they are transmitted via microwave, phone line, or teletype

within 5 min (in the case of Goldstone) or 10 min (in the case of other DSIF Stations) from time of receipt at the DSIF station. If buffered in the link (including the DPS) for more than 5 min but less than 30 min, they are classified as near-real-time.

2. Non-real-time data. These are data received by the DPS either in the form of magnetic-tape recordings or of delayed transmission from a communications link (more than 30 min after receipt of data at the DSIF station). Their main characteristic is that the processing is delayed and the results are prepared off-line from the DPS. There is no necessity for a feedback path from the analysis area or for very rapid throughput and display. Data from the sources are entered, directly or by magnetic tape, in either of the two available 7040s, which perform the same input functions performed on real-time data but record the collected and formatted input data on magnetic tape only. These tapes are then batch-processed on the 7094 at prescheduled intervals, and magnetic tapes are generated to drive the off-line display devices.

The complete data flow to, within, and from the SFOF is shown in Fig. 11, 12, and 13. The flow from the SFOF comprises acquisition and tracking information and commands for the DSIF, general status information, and spacecraft performance data. The incoming data circuits are routed through the Communications Center to the 7288 for processing by the 7040. These data are also made available on teletype machines and closed-circuit TV in the user areas.

b. Data processing system. The mathematical processing of incoming data constitutes the major effort in data handling in the SFOF. The type of incoming data (whether telemetry or tracking) as well as the ultimate users determines the type of computation required. The principal groups using spacecraft or spacecraft-related data and the type of data they use are listed below. It is the responsibility of these groups to interpret, analyze, and evaluate the type of data of which they are cognizant.

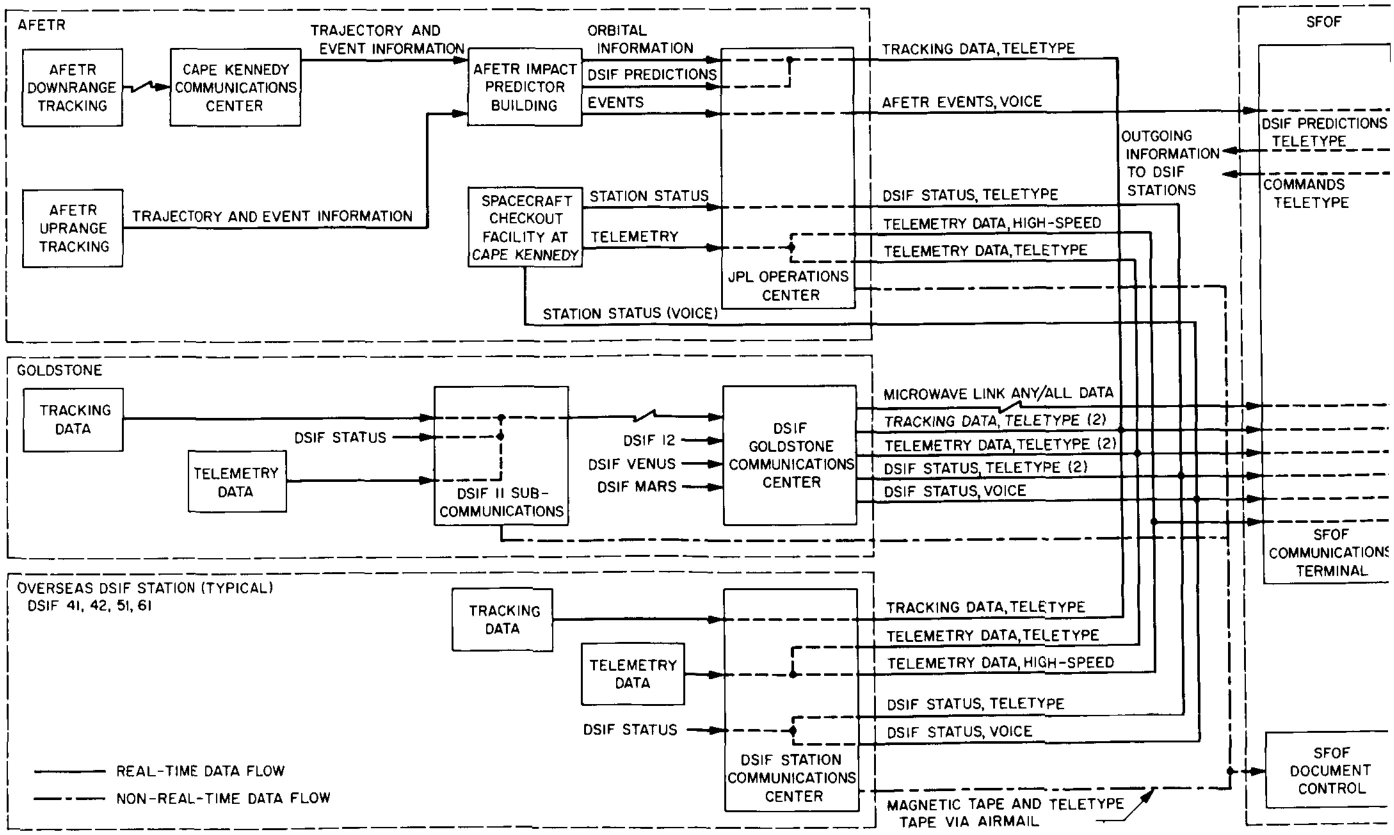


Fig. 11. Data flow from AFETR and the DSIF to the SFOF

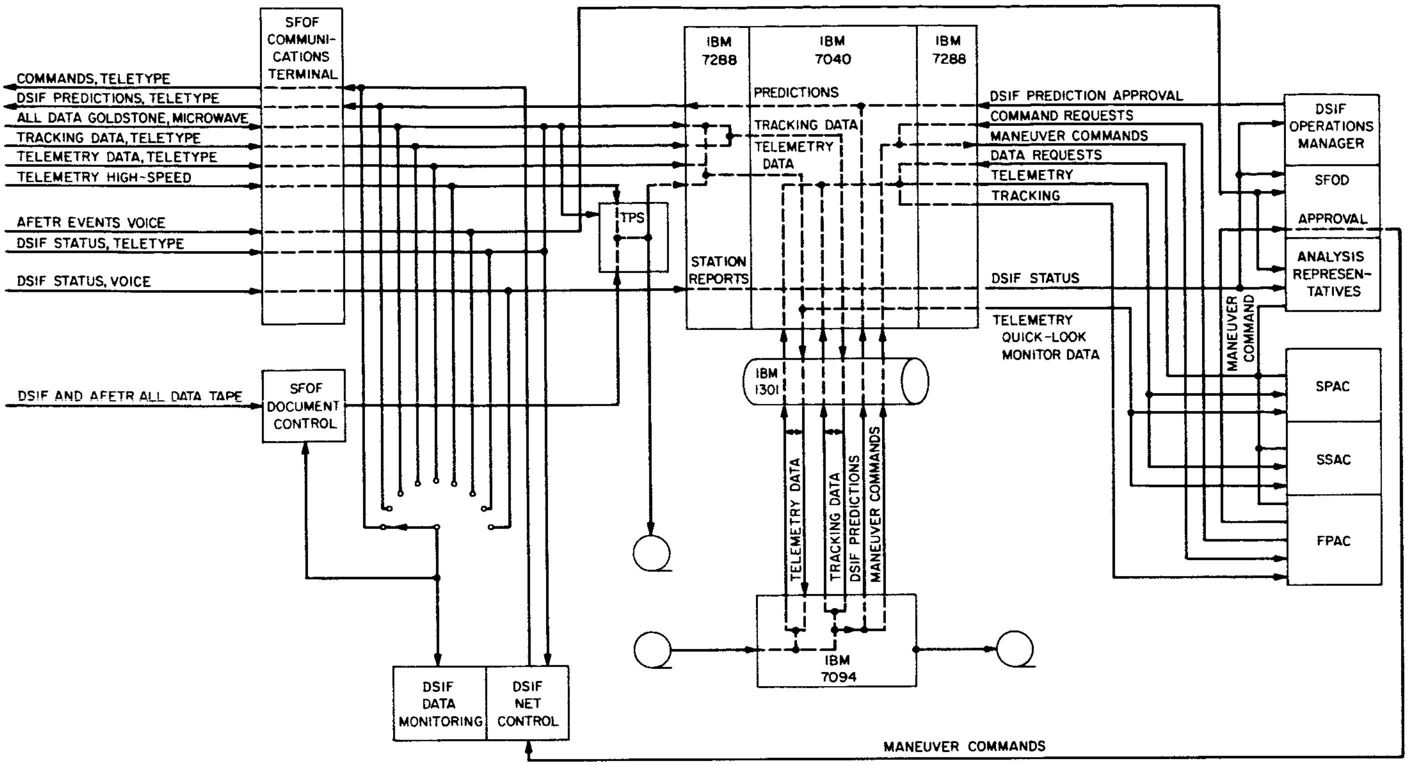


Fig. 12. Complete data flow within the SFOF

Group	Type of data
Spacecraft Performance Analysis and Command	Engineering telemetry
Space Science Analysis and Command	Science telemetry
Flight Path Analysis and Command	Tracking data
DSIF Net Control	DSIF status
Mission and Operations Control	Summary of all data and status

The DSN DPS in the SFOF provided the services described below in support of the above-mentioned operations.

1. The following are fed into the 7040: all data from teletype, phone lines, microwave channels, and the telemetry processing station (TPS); also all requests, parameters, and data from the user areas (see Fig. 14) via the inquiry station or the card readers. These inputs are identified and separated by mission number and type of data; tracking, telemetry, and administrative types of data are included. All incoming data are written on raw data tape in a sequential mode with proper identification to allow separation and processing in the 7094 in non-real-time. If overlaps occur in DSIF coverage and two stations send identical telemetry data to the SFOF, the choice of transmission to be inserted in the 7040 is determined through the DPCC. The transmission from the rejected station is recorded but is not available for further real-time processing.

2. The 7094 complex performs functions in both on-line and off-line modes. By means of it, the Raw Data Table is sorted into a Master Data Table for analysis routines. From these routines final reduced data prints and plots of all data are generated for the Disc, 1401, and 4020. Through the 7094, telemetry data from the TPS and raw data tapes recorded by the 7040 are also processed, and the midcourse maneuver commands and DSIF predictions are computed and generated for transmission to the DSIF.

3. The TPS (Fig. 15) is used to convert telemetry data received in analog, digital, or composite subcarrier

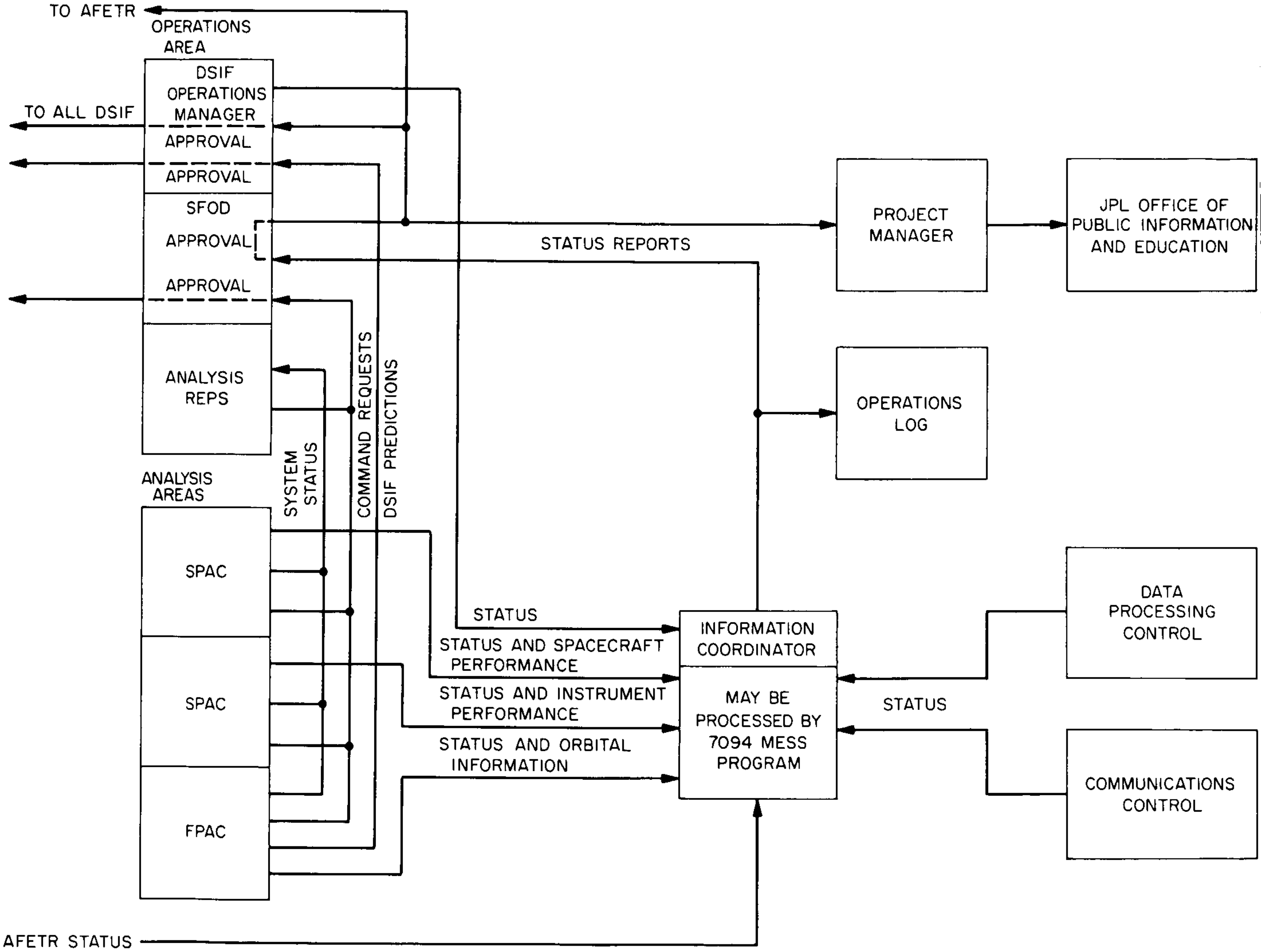


Fig. 13. Complete data flow from the SFOF

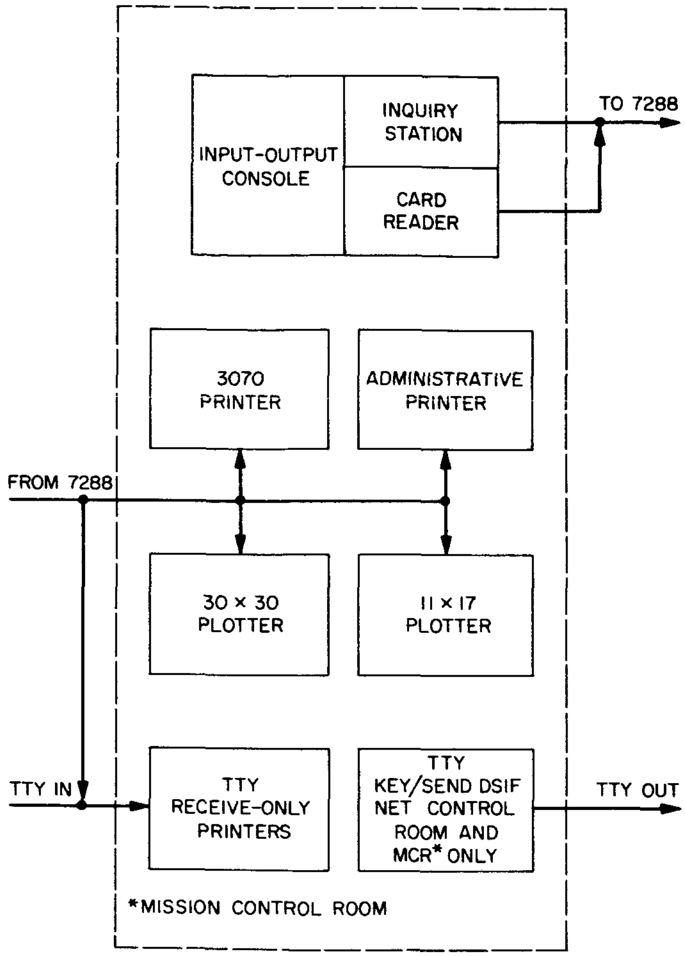


Fig. 14. Typical user area equipment

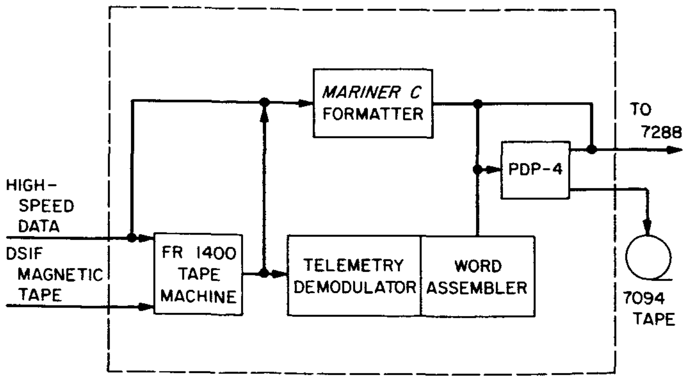
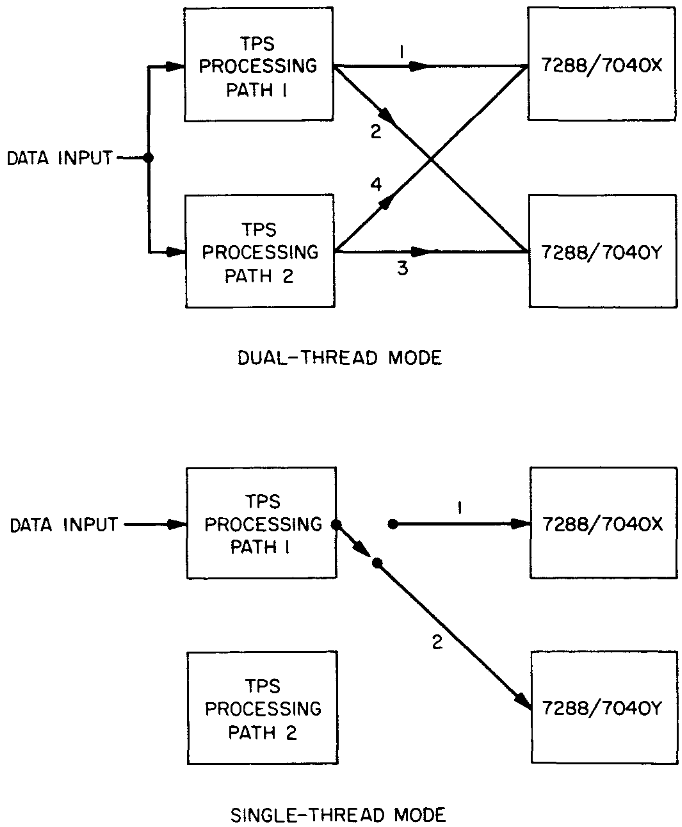


Fig. 15. Telemetry processing station

form to a format compatible with a 7288 high-speed subchannel and with 7094-compatible magnetic tape. The conversion process is accomplished either in real-time, using the High-Speed Data Communications System, or in non-real-time, using data recorded on magnetic tapes. During the most critical portions of the Mission, it is possible to provide parallel processing through the TPS, thereby providing a backup capability in the event of prime TPS failure. Each TPS is equipped with two parallel output buffers that feed subchannels in two different 7288s. In the event of prime 7040 failure, the two parallel output buffers permit the backup 7040 to be switched into the prime position without disturbing the data flow. The TPS will operate in four different modes as follows:

a. Mode I: dual-thread mode. When the computer subsystem is operating in a backed-up mode (Modes I, IIA, or IIIA), the TPS provides dual-thread processing (see Fig. 16) of the data inputs, and a simultaneous output from each processing path. Each of these outputs is patched to a different 7040 complex.



NOTE: TPS OUTPUT PATHS 1 AND 3 ARE NORMAL OUTPUT CABLE PATCHES. OUTPUT PATHS 2 AND 4 CAN BE PATCHED ALSO IF REQUIRED

Fig. 16. Single- and dual-thread TPS processing modes

b. Mode II: single-thread mode. When the computer subsystem is operating in a non-backed-up mode (Modes IIB, IIIB, or IV) the TPS provides single-thread (see Fig. 16) processing of the data inputs and provides one output for the mission.

c. Mode III: logging. When the TPS subsystem is not sending high-speed data directly to the 7040s, the data are logged in one or more of the manners described in Table 23.

d. Mode IV: analog tape playback. Analog tapes recorded at the DSIF and the SFOF are processed in the manner described in Table 23.

*c. **Data processing control.*** Flight status and data type determine the DPS mode of operation and the control programs. The DPS has six operational modes (see Table 24). These modes provide different data throughput and failure recovery times as required for various Mission conditions. The flow of data through the DPS is controlled from the Data Processing Control Console (DPCC). All switching of computer subsystem and input-output equipment, as well as the control of the computer program priorities, is initiated at this console. Control functions at the DPCC are based on equipment performance and on operational requirements specified by the Space Flight Operations Director (SFOD). The seven user areas in the SFOF contain computer input-output equipment. These areas perform data analysis and/or command/control functions in the DPS.

The *Mariner* Mars 1964 mission-dependent data processing programs were divided into three categories:

1. Real-time operational monitoring and processing programs that include all 7040 computer programs.
2. Near-real-time operational spaceflight analysis programs that are processed in the 7094 computer for operational flight path analysis and spacecraft and science instrument performance analysis.

Table 23. Data logging and processing capabilities

Mode	High-speed line input	FR-1400 recording	IBM compatible recording	Strip-chart recording	High-speed output to 7040
I	X	X	X	X	X
II	X	X	X	X	X
III	X	X	X	X	X
IV			X	X	

3. Non-real-time spaceflight analysis and research programs that have multiple options and functions.

The 7094 computer programs are controlled by a percentage time-sharing scheme (Fig. 17). The percentages are fixed by the SFOD and are based on user preflight requests and the Standard Sequence of Events.

A detailed description of the operation of the 704C and 7094 control programs is contained in *Programming Standards for SFOF User Programs,* a document published by JPL.

E. Operational Readiness Testing

1. General

The *Mariner* Mars 1964 Mission operational readiness tests served to verify design of certain portions of the SFO system, their operational compatibility, and the operational compatibility of the spacecraft/SFO system. The tests also provided operational training in certain areas of the SFO system. This section summarizes test procedures in the following areas:

1. Phase I: Internal tests within the DSIF, AFETR and SFOF.
2. Phase II: Spacecraft/SFO system operations compatibility tests.
3. Phase III: SFO system operational tests.

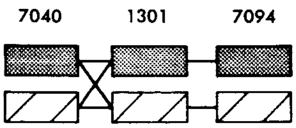
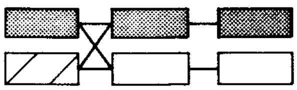
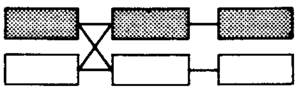
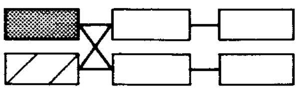
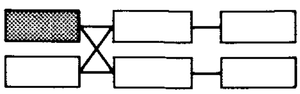
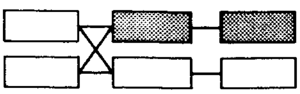
2. Phase I: Facility Internal Tests

Facility Internal Tests were intended to verify design and internal compatibility of the DSIF, AFETR, and SFOF (independently of each other) in much the same manner as the spacecraft prototype system and subsystem design tests were intended to verify the design and internal compatibility of the spacecraft.

*a. **DSIF Internal Tests.*** *These* tests served to verify the operational status of the DSIF systems used during the mission as required by the Space Flight Operations Plan. The plan and procedures required for the DSIF Internal Tests were the responsibility of the DSIF Operations Manager.

*b. **AFETR Internal Tests.*** These tests served to verify the operational status of the AFETR facilities and systems to be used during the mission as delineated in the Program Requirements Document (PRD). The plan and procedures for the AFETR Internal Tests were the responsibility of the Manager of Operations Control at AFETR.

Table 24. Operational modes of the data processing system

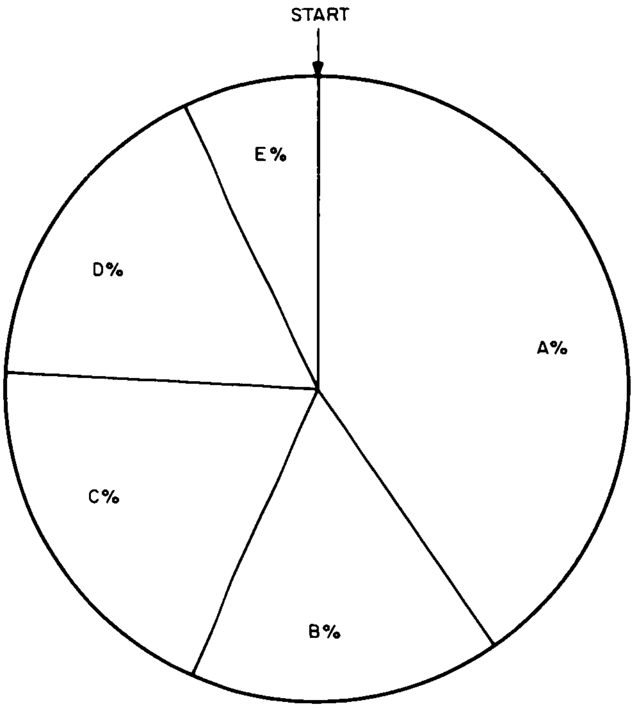
Mode	Equipment configuration	Data processing paths	Uses
I		Two complete real-time parallel processing paths using two each 7040, 1301, and 7094. Failure recovery time: immediate.	This mode is designed for use in the most critical portions of a mission when the quickest reaction time of the SFOF is required. Mode I takes maximum advantage of the redundancy built into the system and affords shortest recovery time in the event of failure.
IIA		One complete real-time processing path with 7040 backup only. 7040 failure recovery time: immediate. 7094 failure recovery time: 30 min maximum.	This mode of operation incorporates the 7040 backup feature described in the Mode I configuration. However, there is no backup available for the Disc and 7094 Complexes.
IIB		One complete real-time processing path with no backup. 7040 failure recovery time: 5 to 50 min. 7094 failure recovery time: 30 min maximum.	In Mode IIB one complete subsystem (a 7040, a Disc File Complex, and a 7094) is assigned to the mission. No backup of input or processing is assigned.
IIIA		Real-time processing by two parallel 7040s only. Data for 7094 processing is batched.	Mode IIIA is used when the throughput time achieved in either Mode IIA or ModeIIB is not required. In this mode, all 7094 processing is performed on a batch basis. As in Mode IIA, all data from remote sites is flowing in parallel to both 7040s. The active 7040 is used to provide real-time outputs for user areas and to prepare tapes for 7094 input. The standby 7040 is used to log all input data on magnetic tape for use in recovery in the event of a failure requiring the standby 7040 to become active. Recovery, in the event of an on-line 7040 Complex failure, will take a maximum of 10 sec. The standby 7040 is also used for testing failing external devices.
IIIB		Real-time processing by one 7040 only, with no backup. Data for 7094 processing is batched.	This mode is similar to Mode IIIA with the exception that the second 7040 is not in standby mode and is not available for test purposes. This mode provides the same operational capability as Mode IIIA, but failure recovery time may be significantly longer. In the event of a 7040 failure recovery may, as in Mode IIB, take up to one hour.
IV		Noncritical, non-real-time 7094 disc processing of batched data. Output is via IBM 1403 and SC 4020.	Mode IV is a non-real-time mode that involves only the 7094 or 7094 Disc operation. All operation in this mode will consist of batch processing of previously collected data. Because of the noncritical nature of this mode, failures are significant only in that they cause the operation to be suspended until recovery is accomplished. Processing is at prespecified intervals in this mode and output is via the 4020 and the IBM 1403 printers.

Key

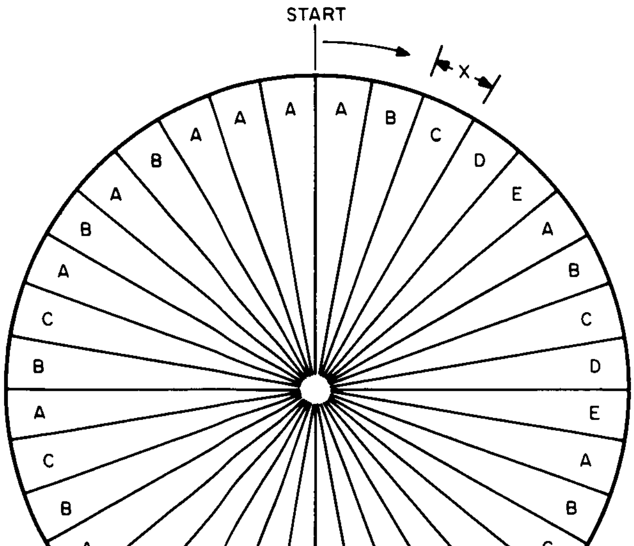
— Primary Data Processing Path for Two Spacecraft

— Backup Data Processing Path for Same Two Spacecraft

— Available for Processing Data from Additional Spacecraft



a. ALLOWABLE PROGRAM RUN TIME IN PER CENT OF SOME ARBITRARY TOTAL CYCLE TIME



b. PROGRAM RUN SEQUENCE; X = FIXED EXECUTION INTERVAL OF EACH PROGRAM

Fig. 17. IBM 7094 processing control scheme

c. SFOF Internal Tests. These tests verified the operational status of the SFOF systems used during the mission as required by the SFOP. The plan and procedures required to accomplish the SFOF Internal Tests were the responsibility of the SFOF Operations Manager.

d. SFOF familiarization. These lectures and demonstrations were designed to familiarize the *Mariner C* operations personnel with the SFOF.

3. Phase II: Spacecraft/Operations Compatibility Tests

Spacecraft/Operations Compatibility Tests served to verify the design and operational compatibility between the spacecraft and the SFO System.

a. Spacecraft (SAF)/DSIF/SFOF operations compatibility tests. The following three types of tests were employed to verify the operational status and compatibility of the spacecraft, AFETR and DSN/SFOF systems to be used during the mission:

Non-Real-Time Tests. Non-real-time tests employed the plan listed and defined in the following paragraphs.

Systems tests were conducted using all of the *Mariner C* spacecraft. These tests were conducted and controlled by procedures established by the Spacecraft Test Director and in accordance with the SAF test schedule.

The spacecraft, which was monitored by the SAF/STC, transmitted telemetry data in real-time to the DSIF Ground Data Handling System located in the STC. The DSIF Ground Data Handling System received, processed, and produced a teletype paper tape record of the spacecraft telemetry in agreement with a defined format.

On a non-real-time basis, the teletype paper tape record of the spacecraft telemetry was hand-carried from the SAF/STC to the SFOF for processing by the Data Processing System. The Data Processing System, utilizing the SPAC and SSAC 7040 basic telemetry computer programs, processed the spacecraft telemetry data via the teletype paper tape input; the output of the system was in agreement with the defined formats. Video data were processed by the IBM 7094, the Link film recorder, and the JPL photo lab.

These tests were accomplished in conjunction with the computer program checkout efforts and during program integration into the SFOF programming subsystem. The use of the spacecraft-generated data during this period ensured compatibility of spacecraft data with the programming subsystem. Because of the lengthy time period involved in this effort, periodic demonstrations of the data processing were held for the analysis area directors and the SFOD.

Real-Time Tests. Real-time tests employed the plan listed and defined in the following paragraphs.

These tests were conducted during *Mariner* PTM and flight spacecraft systems tests on a noninterference basis with SAF. The procedures for the spacecraft portion of the tests were the responsibility of the Spacecraft Test Director. The procedures for the SFOF portions of the tests were the responsibility of the SFOD.

The spacecraft, which was monitored by the SAF/STC, transmitted telemetry data, in real-time, to the DSIF Ground Data Handling System located within the SAF/STC. The teletype encoder output (teletype paper tape and/or high-speed) data was transmitted to the SFOF Data Processing System in real-time via the SFOF Communications System.

The SFOF, utilizing the DPS and the SPAC and SSAC 7040 and 7094 telemetry programs, received, processed, and displayed, through the various types of output devices, the spacecraft telemetry data being received in real-time. The 7040 monitored the tests throughout the entire SAF test period and was used periodically to drive the display devices in the SPAA, SSAA, and POR. At various intervals, the 7040-recorded data were processed in the 7094 and bulk output was obtained for examination by the analysis groups. Video data were processed by the IBM 7094, the Link film recorder, and the photo lab.

No formal test sequences were used during these tests because they are used mainly as a source of real-time (spacecraft) data for hardware and programming compatibility and output capability checkout.

The group of SFOF 7040/7094 program demonstrations exercised all of the available user programs, both in the 7040 and in the 7094. (Many of the user programs were not ready at launch time.) The demonstrations served to acquaint the users (SPAC, SSAC, FPAC) with the program capabilities and restraints. The analysis area personnel exercised all of their programs at designated times, and the data used were spacecraft data or simulated tracking data, depending upon the program.

Real-Time Closed-Loop Tests. Real-time closed-loop tests employed the facilities, equipment, personnel, and plan listed and defined in the following paragraphs.

The Real-Time Closed-Loop Tests were conducted as scheduled by the SAF Test Director, utilizing the spacecraft PTM. Requirements for the spacecraft PTM operations were generated by the SFOD and then implemented into a spacecraft operations procedure by the Spacecraft Test Director. The loop tests were conducted in accordance with the procedures and sequence of events established by the SFOD. A voice line was established and maintained between the SFOD and the Spacecraft Test Director for coordination of the test.

The spacecraft PTM is operated through discrete portions of the flight in corresponding blocks of time; these blocks cover the spacecraft events from Launch −30 min through planet postencounter. The spacecraft operates in each of two data rates (33-1/3 or 8-1/3 bps) and in each of the following four data modes:

Data Mode I. Engineering data only.

Data Mode II. Engineering and science.

Data Mode III. Planet encounter science only.

Data Mode IV. Planet postencounter science and engineering.

The DPS in the SFOF received, processed, and displayed the telemetry data in real-time. These data were then analyzed by the SPAC and SSAC personnel.

All spacecraft commands were used during this test to verify their validity and spacecraft reactions.

Four days were required to complete the Real-Time Closed-Loop Test. This test is divided into four parts, each requiring one day (approximately 8 hr) of spacecraft operation.

Part I exercised the spacecraft through the periods from Launch −30 min to Launch +1 hr, and from Canopus acquisition −30 min to Canopus acquisition +30 min. During those times, all spacecraft commands pertinent to those time phases of spaceflight were transmitted to the spacecraft. Part I was performed twice.

Part II exercised the spacecraft through the period of Midcourse −30 min to Midcourse +3 hr. During this time, all spacecraft commands pertinent to the midcourse maneuver were transmitted to the spacecraft. Part II was performed twice.

Part III exercised the spacecraft through Encounter −2 hr to Encounter +1 hr. During this time, all spacecraft commands pertinent to Encounter were transmitted to the spacecraft. Part III was performed twice.

Part IV was the playback of the spacecraft video information recorded on the spacecraft tape recorder. One picture was played back and required approximately 8 hr of spacecraft operation. Video data were processed by the IBM 7094, the Link film recorder, and the photo lab in order to produce hard-copy pictures.

b. Spacecraft/DSIF Operations Compatibility Tests. Three tests were employed to verify operational status and compatibility of the spacecraft with the DSIF station equipment used during the mission. These tests were conducted and controlled in accordance with the schedule and procedures established by the DSIF Operations Manager.

The Spacecraft/DSIF Operations Compatibility Tests included:

RF Up-Link Test. The RF Up-Link Test employed the facilities and equipment at the Goldstone Pioneer Station (DSIF-11) and the plan listed and defined in the following paragraphs. The DSIF transmitter was operated to:

1. Demonstrate the RWV Command System with the 10-kw transmitter.
2. Verify modulation indices of the 10-kw transmitter.
3. Verify spacecraft lock stability with the RWV command modulation turn-on.
4. Verify bit-to-bit correspondence of RWV inputs with decoder output. (This is not an error rate check.)
5. Verify command transmission at various spacecraft receiver-signal levels and frequency offsets.
6. Verify command lock through the spacecraft telemetry.
7. Verify polarity requirements.
8. Determine lock-up periods as a function of signal level.
9. Demonstrate use and necessity of bass-boost network for command-system lockup (false locks) at high signal strengths.

RF Down-Link Test. The RF Down-Link Test employed the facilities and equipment at the Goldstone Pioneer Station and the plan listed and defined in the following paragraphs. The DSIF station receiving equipment and data system was operated to:

1. Demonstrate real-time decommutator readouts such as static phase error (SPE), automatic gain control (AGC), and command-verify telemetry from the spacecraft transponder.
2. Determine demodulator and decommutator lockup periods as a function of a signal level and bit rate (Rate 1 and Rate 2 lock).
3. Determine relative system thresholds for both carrier and subcarrier.
4. Verify bit error rate at a given signal-to-noise ratio.
5. Verify polarity compatibility for the complete system (receiver-to-demodulator, demodulator-to-teletype encoder, etc.).
6. Demonstrate use of bass boost to compensate for ground receiver response with various receiver-signal strengths.

Ranging and Doppler Systems Compatibility Test. This test employed the facilities and equipment at the DSIF Pioneer and Venus stations. Pioneer Station (DSIF-11) equipment comprised: receiver (S-band), transmitter (10-kw), spacecraft transponder and OSE. Venus Station (DSIF-13)[3] equipment comprised: transmitter (S-band 100-kw). The DSIF station transmitters and receivers were operated to check their compatibility with:

1. Ranging System
   a. Lockup period demonstration.
   b. Mutual interference measurements with command telemetry functions.
   c. System thresholds.
2. Doppler System
   a. Verification of lockup periods at various $\frac{\dot{f}}{f}$ (doppler frequency change rate).

[3]Venus station tests were conducted during January through April 1965.

b. Verification of maximum in-lock $\dot{f}$

c. Determination of maximum permissible amplitude rates of both up- and down-links.

d. Determination of two-way thresholds.

3. Venus–Pioneer Compatibility Test.

a. Measurements of doppler jitter due to microwave link.

b. Verification of lockup times.

c. Two-site, two-way operations: loop test between Venus Station (DSIF-13) and Pioneer Station (DSIF-11).

c. DSIF/SFOF Compatibility Test. This test was repeated three times for three different DSIF stations. The test established the compatibility of the stations tested with the SFOF using *Mariner C* data and commands.

DSIF equipment comprised: receiver (S-band), transmitter (S-band), RWV command system, *Mariner C* demodulator, TTY encoder, high-speed data equipment, TTY communication equipment.

DSN equipment and facilities in the SFOF comprised: data processing system (Type III), SPAA, SSAA, MSA.

d. Test Plan. This test consisted of *Mariner C* telemetry input to the DSIF S-band receiver and then messaged by the *Mariner C* demodulator and teletype encoder. The resultant data were forwarded to the SFOF, where they were compared with the original data. Commands were transmitted to the DSIF via teletype or high-speed data lines and then transmitted by the station and verified by the RWV command system.

4. Phase III: Operational Tests

Phase III tests served to indoctrinate and exercise the SFO System operational and technical personnel in the systems and procedures to be used for the mission. The DSN provided support to the SFO during the Phase III system tests.

a. SFO Training Tests. The SFO Training Tests were designed to indoctrinate and exercise the SFO mission-oriented and facility-oriented operational and technical support personnel in the procedures and systems to be used for the Mission under both standard and anticipated nonstandard flight conditions.

The Training Tests employed the plan listed and defined in the following paragraphs:

There were seven SFO Training Tests, each utilizing the SFOF only. The duration of each test was approximately 24 hr. The procedures and sequence of events for each test were established by the SFOD.

The data (tracking, telemetry, and station messages) for the SFOF Training Tests simulated discrete portions of the spacecraft flight in corresponding blocks of time; these blocks covered the spacecraft events from Launch −30 min to planet postencounter.

The data for the Training Tests were used to exercise the DPS in both the prime and backup modes.

The SFOF TPS simulated the DSIF stations during the internal SFOF Training Tests. The data package for each test was given to the cognizant communications engineer with a procedure and a sequence of events for the transmission of the data to the SFOF Data Processing System.

The DPS received, processed, and displayed the incoming tracking and telemetry data and station messages for analysis and action by the appropriate SFO personnel (SPAC, SSAC, FPAC) in real-time.

Appropriate commands, as required by the sequence of events or as indicated by the data being received, were prepared for simulated transmission in real-time to the DSIF. The commands were prepared in accordance with the procedures delineated in the SFOP.

b. Facility Integration Tests. The Facility Integration Tests served to indoctrinate and exercise the DSIF and SFOF operational and technical support personnel, both mission-oriented and facility-oriented, in the systems and procedures to be used for the Mission under both standard and anticipated nonstandard flight conditions.

Test Plan. There were two Facility Integration Tests. The duration of each was approximately 24 hr. The procedures and sequence of events for each test were established by the SFOD.

The spacecraft tracking and telemetry data for the Facility Integration Tests simulated a mission in the same manner as in the SFOF Training Tests. The data were generated to activate the DSIF station equipment and systems to the greatest extent possible.

DSIF Participation. The DSIF stations participated as follows:

1. The DSIF stations processed the simulated spacecraft tracking and telemetry data through the station equipment and systems and transmitted the data to the SFOF via the Communications System. The data were transmitted in accordance with the procedures and sequence of events delineated in the Tracking Instruction Manual.
2. The DSIF stations received and acknowledged receipt of the spacecraft commands and tracking predictions in accordance with procedures delineated in the Tracking Instruction Manual.
3. The DSIF stations executed the spacecraft commands and verified the execution times in accordance with procedures established in the Tracking Instruction Manual.

DSN Participation. The DSN participated in the SFOF as follows:

1. Received, processed, and displayed the incoming tracking and telemetry data in real-time. The SFO personnel within the SFOF analyzed and took appropriate action as required.
2. The SFOD prepared and the DSN transmitted spacecraft commands, prediction data, and station messages in real-time to the appropriate DSIF stations in accordance with the established procedures.

c. Space Flight Operational Readiness Tests. The purpose of the Operational Readiness Tests was to verify the readiness of the SFO System to support the mission under both standard and anticipated nonstandard flight conditions.

Test Plan. There were two Operational Readiness Tests. The duration of the first was approximately 72 hr; the duration of the second was approximately 24 hr.

The procedures for these tests were as delineated in the SFOP. The sequence of events for the tests was as established in extracted portions of the SFOP Sequence of Events.

The spacecraft tracking and telemetry data for the Operational Readiness Tests were generated to simulate the mission in the same manner as the data used in the Facility Integration Tests. The data for the tests were generated to activate and exercise the DSIF station equipments and systems to the greatest extent possible.

AFETR Participation. AFETR participation was as follows (approximately 6 hr for each test):

1. Simulated and provided *Atlas/Agena* booster launch countdown and boost-phase flight events through injection.
2. Simulated and provided AFETR tracking data (Cape Kennedy and downrange facilities).
3. Calculated the parking orbit, transfer orbit, injection criteria, and the DSIF look-angles.
4. The above data were transmitted to the SFOF via the Communications System as delineated in the *Mariner C* PSP and SFOP.

Spacecraft Checkout Facility (Hangar AO) Participation. Spacecraft Checkout Facility participation was as follows (approximately 6 hr for each test):

1. Provided simulated prelaunch and launch spacecraft telemetry data.
2. Provided launch countdown status and spacecraft flight events through injection phase.
3. The above data and information were transmitted to the SFOF via the communications system as delineated in the SFOP.

DSIF Participation. DSIF Stations 11, 41, and 51 (Goldstone Pioneer, Woomera, and Johannesburg) participated as follows:

1. Processed the simulated spacecraft tracking and telemetry data through the station equipment and systems and transmitted the data to the SFOF via the communications system. The data were transmitted in accordance with the procedures and sequence of events delineated in the Tracking Instruction Manual.
2. Received and acknowledged receipt of the spacecraft commands and tracking predictions in accordance with procedures delineated in the Tracking Instruction Manual.
3. Executed the spacecraft commands and verified the execution times in accordance with the procedures established in the Tracking Instruction Manual.

DSN/SFOF Participation. During this phase of SFO operational readiness testing, the SFOF provided space and equipment necessary for the tests, with the actual functions being performed by the Project groups. Participation was as follows:

1. Tracking Data. The SFOF responded to the incoming data from AFETR and the DSIF stations in real-time. The tracking data from AFETR were processed, and spacecraft tracking look-angles and prediction data were transmitted to appropriate DSIF stations in accordance with the procedures established in the SFOP. The tracking data from the DSIF stations were processed to establish the orbit of the spacecraft, and additional prediction data were then transmitted to the appropriate DSIF stations. The tracking data established the orbit of the spacecraft and determined the requirements for the midcourse correction. Midcourse maneuver commands were prepared and transmitted to the appropriate DSIF station for simulated transmission to the spacecraft.
2. Telemetry Data. The spacecraft telemetry data were processed and analyzed in real-time. Backup commands that might be required because of spacecraft on-board malfunctions were prepared in the SFOF and transmitted to the appropriate DSIF station for simulated transmission to the spacecraft. The preceding functions were executed in accordance with the procedures established in the SFOP. The SFOF monitored and displayed the incoming tracking and telemetry data and reported the status of the mission as delineated in the SFOP.

V. TRACKING OPERATIONS

The tracking operations of AFETR, GSFC, and the DSN in support of the near-Earth trajectory phase of the *Mariner III* and *IV* Missions are summarized here. The tracking operations are presented in narrative form with emphasis on significant operating events. Volume II of this T&DA report will document the cruise-to-planetary-encounter phase of the *Mariner* Mars 1964 Mission tracking operations.

A. Mariner III *Mission Tracking Summary*

After a one-day delay in the launch attempt of the *Mariner C*, the spacecraft was launched on an azimuth of 102.9 deg from Complex 13 at Cape Kennedy on November 5, 1964, at 192204.920 GMT(Z) (11:22 AM PST). Preliminary analysis of vehicle trajectory data, sequence of flight events, and vehicle systems data indicated that the flight performance of the first stage (*Atlas*) was nominal. The *Agena* first burn was about 1.5 sec longer than nominal, and the second-burn shutdown was at a lower than desired velocity. The *Agena/Mariner C* spacecraft combination was successfully placed into a parking orbit with an apogee of 100 nm, a perigee of 100 nm, and an inclination of 30.6 deg during the initial *Agena* burn period.

At liftoff, Station 1 (Cape Kennedy) and Station 0.18 (PAFB) were tracking *Mariner III*. The Spacecraft Checkout Facility acquired the spacecraft in two-way lock at 140600Z (T−217M) and went to one-way lock prior to launch. The station remained in lock until 192433Z (launch plus 2 min 28.08 sec). During this period the station provided spacecraft telemetry to the SFOF. The station had problems with its time code generator and, as a result, was inserting bad times in the telemetry stream. This problem was corrected prior to launch. The Mark 1 event was confirmed at 192418.6Z and Mark 2 at 192421.4Z, with the signal level at −135 dbm during the Spacecraft Checkout Facility view period. Bermuda was also tracking the vehicle during this time period (1925Z) and was sending data to JPL. At 1927Z, the Antigua station 91 began sending tracking data to JPL, and the Bermuda data were interrupted. The Antigua data ended at 1935Z.

Confirmation of Mark 3 through 7 events was entered in the log at 1932Z. Events occurred as follows: Mark 3 at 192707.2Z, Mark 4 at 192725.2Z, Mark 5 at 192727.35Z, Mark 6 at 192729.52Z, and Mark 7 at 192819.52Z. Data from the Ascension station were first received at 1944Z, and the quality appeared good. The Pretoria tracking station acquired the spacecraft at 1954Z and began transmitting data. The Mark 10 event (injection) was observed during the Pretoria track at 195541.15Z.

Johannesburg acquired the spacecraft signal in one-way RF lock at 195445Z at a received level of −142 dbm and maintained lock until 195552Z. Johannesburg used the S-band acquisition aid antenna during this period and, because of the 16-deg beamwidth, was able to achieve RF lock. The spacecraft was still in Earth orbit and was exceeding the angular rate capability of the 85-ft antenna. At 2001Z, RIS *Twin Falls* acquired the signal and sent data until the MSFN participating station at Carnarvon acquired at 2005Z and transmitted data in place of the *Twin Falls,* which finally lost track at 2013Z.

Woomera acquired the spacecraft on the horizon at 200804Z and, following standard procedures, switched from the acquisition aid antenna to the automatic tracking antenna at 201029Z, with the received signal level at −141 dbm. After approximately 30 sec, the antenna lost the spacecraft, and the receiver dropped RF lock at 201108Z. For the next 90 min, Woomera had considerable difficulty in maintaining RF lock with the spacecraft. The two major problems in Woomera acquisition were (1) the transmitted power from the spacecraft was 10 to 15 db low, and (2) the predictions being used by the station (L minus 5-min nominals) were in error because of the nonstandard trajectory. The effects of these two problems, together with the servo problems occurring late in the countdown, caused difficulty in making correct interpretations of various indications. Had these indications been correctly interpreted, an earlier acquisition might have resulted. At approximately 2141Z, Woomera acquired the spacecraft with the SCM/maser configuration and tracked satisfactorily for the duration of the view period. GMT(Z) times for Mark events 9, 11, 12, and 13 were confirmed as follows: Mark 9 at 195405.95Z, Mark 11 and 12 at 195822.9Z, and Mark 13 at 200825.8Z.

At 2017Z, the Space Science Analysis team at SFOF reported a preliminary indication that the spacecraft science instruments had been turned on. The Carnarvon data ended at 2025Z, at which time the uncorrected data from the *Twin Falls* was resumed. The end of raw data from AFETR was recorded at 2108Z.

At 2127Z, the first indication of nonstandard spacecraft performance was reported by the JPL SPAC group: the spacecraft was still operating on battery power without benefit of solar panel power. The spacecraft was then declared to be in a nonstandard mode. Analysis of the Pretoria data produced a C_3 of 4.04 rather than the C_3 of 10.4 required to inject the spacecraft into a Mars trajectory. However, since the epoch corresponding to this calculation was in error by 5 hr, it was decided to use the nominal DSIF acquisition predictions until the problem could be solved.

Woomera was requested to go into two-way lock at 220200Z. The station reported two-way command lock at 223400Z. At this point, the command detector at Woomera went in and out of lock so often that the station was directed to send the commands whenever lock could be achieved during the command transmission periods. At 225800Z, the transmitter power was reduced to 1 kw. Direct Command DC-15 was initiated at 230602Z. Power data indicated that the gyros were off at 231209Z. The purpose of the DC-15 was to turn off the gyros for power conservation and to back up deployment of the solar panels and effect turn-on of the attitude control system. A decision was made to transmit DC-25 followed by DC-26 in order to determine whether the scan platform would move; this would presumably have determined whether the *Agena* was still attached to the spacecraft. DC-25 was initiated 'at 232130Z and verified at 232300Z. Data revealed little or no scan platform movement and almost immediate wide- and narrow-angle acquisition. The use of this command failed to verify whether or not the *Agena* was attached to the spacecraft. DC-26 was initiated at 232905Z and verified at 233000Z. This command turns off planet and cruise science and the battery charger, thereby reducing the consumption of spacecraft power. Science instruments were verified as being off at 233200Z.

Subsequent to turn-off of the gyros, both engineering and science telemetry data indicated that the spacecraft had not become attitude-stabilized, denoting that either the *Agena* or the shroud was still on the spacecraft. It was decided to perform a maneuver which might shake the spacecraft free of the *Agena* or shroud. Because of command equipment malfunctions at Woomera, however, the emergency maneuver sequence was not completed.

At 014400Z, command transmission was changed from Woomera to Johannesburg. Johannesburg was instructed to reduce its transmitter power from 10 to 1 kw. Johannesburg was in command lock at 021200Z. At that time, SPAC estimated the spacecraft life as 2 hr 13 min

(042300Z). A second maneuver was attempted from Johannesburg. The maneuver command series was sent and stored in the spacecraft. The execution of the maneuver was not verified, however, as the last telemetry reception from the spacecraft occurred prior to the time of maneuver start. Before it ended at 0405155Z, telemetry showed a steady drop of battery power from the spacecraft. Johannesburg acquired the spacecraft at 000138Z and maintained track until 040624Z, when track was lost.

Following a detailed failure analysis, *Mariner* Project officials concluded that the shroud did not completely jettison as scheduled some 5.5 min after launch. Further investigation indicated that the shroud, a light-weight Fiberglas, laminated honeycomb structure, may have failed when exposed to the combined vacuum–temperature environment. As a consequence, *Mariner III* could not be separated from the shroud and was prevented from deploying the solar panels.

B. *Mariner III Tracking and Data Acquisition Support Summary*

The following is a brief summary of T&DA support provided for the near-Earth phase of the *Mariner III* Mission. A complete summary of the support will be provided in Volume II of the T&DA report. Much of the information offered below was extracted from the AFETR Test Evaluation Report and the GSFC Performance Analysis Report.

1. Optics Coverage

There were 15 metric, 32 engineering sequential, and 33 documentary cameras committed to the *Mariner III* launch. All metric and documentary cameras and 29 of the engineering sequential cameras were operating at liftoff.

2. Radar Coverage

Eleven radar stations provided radar tracking data during the *Mariner III* launch. Continuous coverage was obtained from $T+0$ to $T+1554$ sec. There was a gap in the coverage from $T+1554$ to $T+1872$ sec. Radar coverage was again obtained from $T+1872$ to $T+2218$ sec and from $T+2278$ to $T+2396$ sec. The radar tracking coverage provided by individual radar stations and the Range Instrumentation Ships is summarized in Table 25.

Table 25. Radar coverage: *Mariner III*

Station	Mode	Automatic track time, T +sec	Estimated reducible data, T +sec
Cape Kennedy	A/S A/B	8–65 65–299	8–299
PAFB	A/B	8–467	8–467
Merritt Island	A/S A/B A/B	16–103 103–410 422–449	16–408 422–449
Mod IV 1.1 (Cape)	TV IR A/S	0–1.5 1.5–38 38–130	N/A
1.2 (Cape)	TV IR A/S	0–2 2–38 38–130	N/A
Grand Bahama Island	A/B	63–386	N/A
San Salvador	A/B	132–572	N/A
Grand Turk	A/B	193–696	193–696
Antigua	A/B	392–768	392–719
Ascension Island	A/B	601–1554	632–1503
Pretoria	A/B	1872–2218 2278–2396	1883–2218 2278–2360
RIS *Twin Falls*	A/B	2268–2338 2378–4129 4168–5019	2292–2338 2380–2528 2858–3076 3117–3321 3376–3572 3732–3842 3900–4127

A/S: skin-track mode.
A/B: beacon-track mode.

3. Telemetry Coverage

Continuous telemetry coverage was obtained from $T-484$ through $T+788$ sec. There was a gap from $T+788$ to $T+1101$ sec. Additional coverage was obtained from $T+1101$ to $T+3698$ sec. A summary of coverage by land stations and shipboard instrumentation is presented in Table 26.

4. Vehicle Instrumentation

The telemetry signal quality was excellent with the following coverage times for usable signal:

Station	Time, T +sec
Cape Kennedy Hangar AE	471
Cape Kennedy, Tel 2	490
Antigua	T +790

Table 26. Telemetry coverage: *Mariner III*

Station	Frequency, mc	Usable coverage time, sec
Cape Kennedy, Tel 2	229.9	−484 to 480
	244.3	−484 to 475
Grand Bahama Island	229.9	46 to 521
	244.3	25 to 518
Antigua	244.3	300 to 788
Ascension Island	244.3	1101 to 1625
Pretoria	244.3	1837 to 2447
RIS *Coastal Crusader*	244.3	1609 to 1982
RIS *Swordknot*	244.3	2090 to 3698
RIS *Twin Falls*	244.3	2234 to 3149

C. Mariner IV *Mission Tracking Summary*

Following a one-day delay from the planned launch on November 27 due to an RF anomaly in the spacecraft communications subsystem, *Mariner IV* was launched on an azimuth of 91.4 deg east of true north from Complex 12 at Cape Kennedy on Saturday, November 28, 1964, at 142201.309Z (6:22 AM PST). A preliminary analysis of vehicle trajectory data, real-time, flight events, and vehicle systems data indicates that first- and second-stage vehicle flight performance, including spacecraft separation, was excellent. The *Agena* and *Mariner D* spacecraft were successfully placed in a parking orbit with an apogee of 99.7 nm, a perigee of 93 nm, and an inclination of 28.3 deg during the initial *Agena* burn period.

After a predetermined coast period, the *Agena* was restarted and injected the spacecraft into its planned Mars transfer orbit. The launch and near-Earth trajectory phase of the mission thus far completed have been considered highly successful. The following paragraphs offer a capsule summary of mission tracking operations.

At liftoff, AFETR Station 1 and the DSIF Spacecraft Monitoring Station 71 locked on the spacecraft. PAFB Station 0.18 acquired the spacecraft some 14 sec later and began sending trajectory data to AFETR. At this point the trajectory was reported as nominal. The Mark 1 and 2 events were confirmed at 142414.52Z and 142417.4Z, respectively. Bermuda began tracking at 1425Z and data appeared good. Starting at 1426Z, AFETR confirmed the following Mark events: Mark 3 at 142700.4Z, Mark 4 at 142718.9Z, Mark 5 at 142720.9Z, Mark 6 at 142723.1Z, Mark 7 at 142813.8Z, and Mark 8 at 143038.6Z.

The Antigua station acquired *Mariner* at 1435Z and began sending data which ended at 1436Z. At 1438Z, Bermuda data were back on the line. The Grand Turk tracking station (7.18) began transmitting data at 1443Z, and at this time the flight trajectory was reported as nominal. At 1455Z, the Suitcase Telemetry Station at Ft. Dauphine, Republic of Malagasy, locked on the spacecraft and maintained lock until 1459Z. The Pretoria tracking station acquired the spacecraft at 1458Z and sent tracking data until loss of track at 1502Z. At this time, RIS *Twin Falls* acquired the spacecraft, and AFETR began sending corrected ship's tracking data at 1506Z. The Mark 9 event was confirmed by AFETR at 150250Z; the Mark 10 event (injection) was confirmed at 150427.4Z.

At 151048Z, Woomera acquired the spacecraft in lock and reported a signal level of −120 dbm. The signal level reported by Woomera at 1514Z was −87 dbm; AFETR confirmed Mark events 11 and 12 at 150708.6Z and 150710.1Z, respectively.

Spacecraft RF power was reported up by JPL at 151242Z. At this time the spacecraft science was also reported good. JPL reported the start of Sun acquisition by the spacecraft at 1523Z, and 1 min later, at 1524Z, the spacecraft was on solar power. Sun acquisition and two-way lock were confirmed at 1531Z. At 1535Z, the Net manager at JPL reported the signal level at Woomera as −90 dbm, and the near-Earth trajectory phase of the mission was considered successfully covered.

D. Mariner IV *Tracking and Data Acquisition Support Summary*

The following is a brief summary of T&DA support provided for the near-Earth phase of the *Mariner IV* Mission. Much of the information was extracted from the AFETR Test Evaluation Report and the GSFC Performance Analysis Report.

1. Optics Coverage

There were 15 metric, 32 engineering sequential, and 8 documentary cameras committed to the *Mariner IV* launch at Station 1 (Cape Kennedy). All of the cameras were operating at liftoff.

2. Radar Coverage

A total of nine land-based radar stations and three Range Instrumentation Ships provided tracking coverage during the mission. Continuous coverage was ob

Table 27. Radar coverage: *Mariner IV*

Station	Mode	Automatic track time, T +sec	Estimated reducible data, T +sec
PAFB (0.18)	A/B	14 to 487	14 to 438
Cape Kennedy (1.16)	A/S	11 to 73	11 to 73
	A/B	78 to 298	78 to 298
Mod IV 1.1	TV	0 to 2	N/A
	IR	2 to 74	
	A/S	74 to 130	
1.2	TV	0 to 2	N/A
	IR	2 to 72	
	A/S	72 to 129	
Merritt Island (19.18)	A/B	0 to 6	0 to 3
	A/S	14 to 90	14 to 452
	A/B	90 to 478	
Grand Bahama Island (3.16)	A/B	61 to 399	61 to 399
San Salvador (5.16)	A/B	141 to 561	N/A
Grand Turk (7.18)	A/B	171 to 174	
	A/B	201 to 239	201 to 239
		261 to 275	288 to 600
		288 to 600	
Antigua (91.18)	A/B	401 to 704	401 to 640
RIS *Swordknot*		Limited commitment	2201 to 2428
RIS *Twin Falls*		Limited commitment	None

A/S: skin-track mode.
A/B: beacon-track mode.

tained from T +0 to T +704 sec. A summary of the coverage provided by the individual stations is shown in Table 27.

3. Telemetry Coverage

Continuous telemetry coverage was provided from T −420 to T +728 sec. A summary of the coverage available at time of report publication is provided in Table 28.

4. Vehicle Instrumentation

The telemetry signal quality was excellent, with the following coverage times for usable signal:

Station	Time, T +sec
Hangar AE (Cape Kennedy)	477
Tel 2 (Cape Kennedy)	500
Antigua	719

Table 28. Telemetry coverage: *Mariner IV*

Station	Frequency, mc	Usable coverage T +sec
Tel 2, Cape Kennedy (1)	229.9	−420 to 500
	244.3	−420 to 500
Grand Bahama Island (3)	229.9	25 to 513
	244.3	25 to 513
Antigua (91)	244.3	343 to 728

VI. PERFORMANCE EVALUATION SUMMARY

Presented here is a brief summarization of tracking performance and associated problem areas recognized during the *Mariner* Mars Mission. Material presented was extracted primarily from minutes of the "*Mariner* T&DA Support Critique" and the "Space Flight Operations Memorandum." Volume II of this document summarizes tracking performance during Mission cruise-to-encounter phase.

A. *Mariner III Mission Tracking and Data Acquisition Performance Evaluation*

1. AFETR Metric and VHF Telemetry Support

AFETR representatives reported that no significant problems had been encountered in providing the required metric and VHF telemetry support.

2. AFETR S-Band Support

An attempt to evaluate S-band performance of these four range stations is complicated because of the reported shroud failure. Collapse of the shroud prior to attempted ejection leads to speculation that the antenna pattern was deformed. It is therefore not possible to predict the spacecraft antenna pattern with certainty. The span of time during which the stations could receive the S-band signal was doppler-limited, but during the possible receive time, the actual received signal strength is not known with sufficient certainty to indicate why the coverage was limited to the extent observed.

***a. RIS* Coastal Crusader.** On the *Coastal Crusader* the S-band signal should have been visible for approximately 5.5 min, with doppler acquisition at +50 kc and tracking to −50 kc. Later tests showed that the actual capability with the receiver used at this location (Receiver SN106) should have been limited to acquisition from +2 to −75 kc. This would have limited the receive time to 3 min as the spacecraft was receding from the site. With a spacecraft transmitter power of 1 w and an antenna gain of 0 db, the maximum received signal strength at the input to the S-band preamplifier at this site should have been −115 dbm. With a receiver sensitivity of −140 dbm, a signal strength margin of 25 db exists. With the spacecraft antenna pattern undistorted from that predicted, the actual gain would be from −5 to −20 db for the aspect angles existing for the *Coastal Crusader* during the possible receive time. Any significant distortion or skew in the antenna pattern could reduce the signal to the marginal level indicated.

***b. RIS* Sword Knot.** On the *Sword Knot* a similar situation existed for the doppler frequency acquisition capability of the S-band receiver. The signal could be acquired from +0.9 to −71 kc or for approximately 3 min as the spacecraft was receding from the site. The same signal considerations as noted above are encountered, with the additional complication that the spacecraft had separated from the *Agena* launch vehicle; therefore, the exact orientation of the antenna is also unknown.

c. Pretoria. At Pretoria the doppler frequency range was limited to acquisition from +18 to −54 kc. The signal was within this range for 25 sec. With the high elevation angle of 81 deg, the maximum signal level should have been approximately −100 dbm. The maximum signal level indicated on site was −108 dbm. The signal apparently passed through the receiver frequency range so rapidly that the receiver operator was not able to tune the receiver within 2.5 kc of the received frequency to obtain a receiver beat note.

***d. RIS* Twin Falls.** On the *Twin Falls* the doppler acquisition range was limited to +31 to −46 kc. With the high elevation angle and the larger antenna system, the *Twin Falls* had a 20-db greater signal margin than any of the other stations. Even so, the received signal fluctuations were great enough to cause minor dropouts on the initial track, up to the antenna elevation limits, and major dropouts as the spacecraft receded from the site. The large signal fluctuations are believed to have been created by the spacecraft since the independent antenna systems on the *Twin Falls*, the broadband and the CTS, reported the same signal fluctuations.

3. Manned Space Flight Network

The MSFN was assigned as the lead division within GSFC to provide the T&DA support of the *Mariner* mission. The MSFN stations providing this support were Bermuda, Carnarvon, and Tananarive. Telemetry through the *Agena* and metric support for range safety were provided by Bermuda. The VHF telemetry and FPS 16 radar support were provided by Carnarvon. Only VHF telemetry support was provided at Tananarive.

a. Operational readiness at Tananarive. A minor problem was experienced in the level of operational readiness at Tananarive owing to the schedule on which the station was made operational. In addition, communications to Tananarive were interrupted more than would have otherwise been desirable.

b. 36-hr data return problem. A serious problem in meeting the MSFN commitment to deliver the telemetry data recorded at Tananarive to Pretoria for the 36-hr data return plan would have developed if a NASA aircraft had not happened to be in Madagascar. More careful planning was recommended for any future attempt at rapid data return plans.

c. Minor radar handover problems at Bermuda and Carnarvon. None of the minor problems experienced were sufficiently serious to degrade the support provided. A problem did exist in getting valid pointing data to Carnarvon, which resulted in Carnarvon acquiring the *Agena* by use of acquisition aids.

4. NASCOM Support

GSFC representatives indicated that no serious communications problems had been experienced in supporting the *Mariner III* Mission. Special coverage had been provided by the common carriers during the launch, and it was pointed out that this coverage was provided without charge to NASA. Some concern was voiced regarding the reliability and quality of the voice and teletype communications to the Johannesburg Station. It was pointed out that problems had existed in attempting to provide clear instructions to the station because of the intermittent outages of the voice lines. On the other hand, the reliability of the teletype lines seems to be greater than that of the voice. A suggestion was made to develop adequate operational procedures using the teletype as the prime method of communication of operational instructions to the station.

5. DSN Support

The three DSIF stations supporting the *Mariner III* Mission were located at Goldstone, Johannesburg, and Woomera. The DSN Space Flight Operations Facility (SFOF) is located in Pasadena. The project requirements for standard Woomera operation on the first pass was for the station to acquire the spacecraft in one-way lock and maintain this mode of operation for 80 min before trying two-way lock in order to optimize reception of maximum valid telemetry data.

a. Woomera (DSIF-41) T−7 min hold and SAA acquisition problem. Prior to launch, when the station was working on the near collimation tower, it was found that, in hour angle, the antenna drove right through boresight and failed to snap on. At this point the station was declared "red" and the servo system rebalanced. Successful but rather sluggish snap-ons were then achieved. Further checks were carried out on the far collimation tower with satisfactory results. The station was then declared "green"—even though the early failure to snap on was not fully understood—because it was felt that the aided track mode of manually nulling the SAA errors would give adequate back-up. While this was true for the signal levels expected (above −130 dbm), it was not true for the signal levels (below −140 dbm) actually received from *Mariner III*.

The primary reason for the delayed acquisition was a failure of the servo system when operated in the SAA mode. A significant factor here was the unexpectedly low and fluctuating *Mariner III* signal level. The problem was traced to the SAA isometric amplifier in the servo system. Under large error conditions, including noisy conditions associated with low signal levels, this amplifier would "hang up" in an out-of-balance condition, which resulted in the system driving off at full rate during low signal levels below −140 dbm. With large misalignments at any signal level, the system would fail to acquire because of the time constant associated with release from this out-of-balance condition.

Investigation of the amplifier problem revealed that the output-voltage-limiting zener diodes were connected from output to ground rather than from output to the input of the stage. Placement of these diodes caused the amplifier to be overdriven and therefore slow to recover. Placement of the diodes across the amplifier merely limits the output without overdriving the amplifier. The problem was resolved by eliminating the amplifier. Aside from obviating the "hang-up" problem, it also simplified setting up, since there was one less DC amplifier to balance, and the polarity reversal introduced by the isometric amplifier was removed. Reconnection of the diodes causing the problem was not accomplished because of the limited time before the next launch and the satisfactory performance of the system resulting from the amplifier removal. The station was later modified to the standard configuration.

Considerable difficulty was also experienced in maintaining RF lock with the spacecraft after initial acquisition because of the nonstandard trajectory and the use of *L* minus 5-min nominal predictions. Postflight analysis showed these predicts to be out of nominal by about 1 deg in declination and 7 deg in hour angle. Use of AFETR predicts was precluded when it was found that they contained a 5-hr epoch error caused by a computer garble. The SFOD advised Woomera to use the nominal preflight predicts until the anomaly could be resolved. When the second run of AFETR predicts were made available for use, Woomera had already achieved RF lock on the spacecraft.

b. Ground command subsystem problems at Woomera and Johannesburg. Considerable difficulties were experienced during operation of the RWV system during the mission. These difficulties were a result of equipment design errors and procedural problems not recognized before the mission. A light on the RWV, which indicates command loop lock, received a wrong polarity voltage from the ground telemetry system because of a wiring error, indicating to the RWV operator that the system was out of lock, when in truth it was locked up. Since the in-lock indication voltage is received from the telemetry decommutator, it was determined that the command system was in lock and plans were made to proceed with command transmission. The next procedure was to normalize the RWV frequency offset, but because of an incorrect procedure in adjusting the frequency too rapidly, the command loop lock was dropped. When this was resolved, the command loop was locked up and commands were transmitted. While DC-14 was being attempted, the command loop dropped lock and the last spare amplifier appeared to have failed, so that it became necessary to transfer command operations to Johannesburg. Later it was determined that the amplifier had saturated and not failed; this was a condition that had been noticed during spacecraft system tests prior to launch.

c. Quality of tracking data from Woomera. JPL indicated that the Manson synthesizers in the doppler tracking system at Woomera developed trouble in the 10- and 1-cps frequency synthesizer adapter at L−48 hr. Two Hewlett-Packard synthesizers were sent to the station and installed in parallel with the Manson units. After installation, no further trouble was experienced. The station instrumentation configuration was then arranged so that the Hewlett-Packard synthesizers were used with the Manson as backup.

It was reported that good doppler data were received from Woomera between 2208 and 0134 GMT. Based on *Ranger* experience, 0.01-cps noise was expected; 0.033-cps noise was experienced. A two-cycle bias apparently existed in the doppler counters; however, this could also have been a trajectory discrepancy (likely under the circumstances). An intermittent power supply in the transmitter doppler section was suspected. The failure occurred at the same time that the station attempted two-way lock. This hardware was repaired prior to the *Mariner IV* launch.

d. Quality of telemetry data from Woomera (DSIF-41) and Johannesburg (DSIF-51). JPL indicated that less than 20% of the first 90 min of Woomera tracking contained useful telemetry data. This performance was due to the characteristics of the spacecraft signal, the use of poor angle predictions, and a partially failed spacecraft transponder. After Woomera acquired at 2144 GMT, good data were received until 0344 GMT, partly due to the fact that establishment of two-way lock resulted in bypassing the failed portion of the spacecraft transponder and a resultant signal increase. All data received at Johannesburg were good, from acquisition to loss of signal at 0408 GMT. The ground telemetry and recording subsystems at the stations performed satisfactorily.

e. Suitcase telemetry operation at Fort Dauphine and Johannesburg. The beamwidth of the antenna for this system is approximately 15 deg, and the spacecraft probably stayed within the beam for 2 min. The system temperature is 1200°K, $2B_{LO}$ = 80 cps, and a tracking threshold is −150 db. The tape recorder is capable of recording 20 min of data on two 4-in. tapes. The recorder is equivalent to an FR-100.

This system was designed for an expected performance of nominal trajectory with acquisition at 900 nm at a signal level of −121 to −122 dbm. The only available comparison, since the station did not acquire any data, is with the DSIF acquisition aid which has an 8-db advantage. Based on this, the suitcase telemetry would have received a signal level of −142 to −143 dbm, which is just at threshold for aural acquisition.

f. SFOF and 36-hr data return operations. JPL reported that the SFOF and 36-hr data return operations functioned as designed. There were no major problems.

6. Performance Evaluation

The overall tracking and data acquisition support for the *Mariner III* Mission was satisfactory, with all major commitments being fulfilled. Tracking and telemetry coverage was virtually uninterrupted from liftoff at 192204Z on November 5 to 040555Z on November 6, when the last audible signals were issued from the spacecraft. Sufficient information was recovered for a detailed failure analysis, which disclosed the cause of the failure, and consequent determination of remedial action to be taken for future missions.

B. Mariner IV *Mission Tracking and Data Acquisition Performance Evaluation*

1. AFETR Support

a. Metric and VHF telemetry support and problems. No significant problems were encountered in providing the required metric and VHF telemetry support.

b. Loss of radar tracking data at San Salvador. Tracking data were lost from T +239 to T +288 sec owing to an undetermined equipment problem. When the target reached 520-nm slant range, the track was lost. This range is the upper end of an interference zone which extends from 504- to 520-nm slant range. When the target was abeam of the station, the target was reacquired. The interference zones present between range intervals caused no problems as the target was tracked at increasing range. Loss of track is believed to have been caused by a malfunction in the logic circuitry of the DIRAM.

c. Agena telemetry coverage commitment. The *Program Requirements Document* required telemetry coverage to start at $T-120$ sec. However, the commitment did not start until $T-0$ sec. The discrepancy occurred because of an oversight by Operations Planning, Telemetry. The coverage was provided without being committed. This problem was brought to the attention of the planning engineer.

d. Pretoria. The maximum spacecraft time above the horizon, as viewed from Pretoria, was 4 min, with a maximum elevation of 2.5 deg. Receiver 1 acquired the signal at the horizon; Receiver 2 acquired at its maximum positive tuning capability, and both receivers tracked to the horizon. The reported signal fluctuations were probably caused by multipath propagation phenomena at the low elevation angles.

e. RIS **Swordknot.** On the *Swordknot* there was an apparent offset of approximately 30 sec in the horizon times between those predicted and those reported by the stations. This offset reflects the error in the predictions and in using 90-deg launch azimuth information instead of the actual 91.4 deg. Receiver 1 acquired at the horizon and tracked through the maximum elevation of 25.5 deg to approximately 13 deg above the horizon. Receiver 2 acquired the signal 30 sec after and lost the signal 23 sec before Receiver 1. There are two possible causes for loss of the S-band signal at an elevation angle this high. One is a drop in signal strength below the receiver threshold; the other is the exceeding of the receiver doppler capability.

To investigate the signal strength that should have existed, the same range and spacecraft parameters assumed earlier will be used. The transmitted power is 1 w with a 0-db gain antenna, and the receiving antenna has an effective gain of 16 db. With the range existing at this time of 3.2×10^6 ft, the received signal level would be approximately -114 dbm. The spacecraft antenna pattern indicates that, because of the aspect angle existing at this time, the signal level received at the ship could have dropped 20 db below the value obtained using the above parameters. The manual tracking antenna could not be accurately positioned with this signal level since it is well below the minimum discernible signal level of the pan scope of -115 dbm.

The possibility of exceeding the receiver doppler limits is based upon TWX information received from the *Swordknot* as a result of prelaunch tests. The doppler offset measured previously had apparently shifted such that the doppler acquisition ranges for Receiver 1 were from $+74$ to -28 kc, and for Receiver 2 were from $+55$ to -48 kc, giving a system capability to acquire at $+74$ kc and track to -60 kc. No effort was made to change the crystals prior to launch, since any area restricted by this lessened capability was completely overlapped by adjacent stations.

The indication on the ship for loss of receiver lock was complete loss of signal. At the time of receiver signal loss, the pan scope would have given no signal indication, and if the receiver lost lock due to exceeding the doppler limits there would be no receiver signal strength (AGC voltage) indication. However, for Receiver 2 to have lost the signal first there must have been a difference in the two receiver sensitivities. Complete resolution of this problem must await return of the receivers to PAFB for further evaluation.

f. RIS **Twin Falls.** To clarify the evaluation of the *Twin Falls* S-band performance, the receiving system capability will be reviewed. A tracking receiver and a data receiver were connected by means of multicouplers to S-band preamplifiers and down converters driven by right-circular and left-circular antenna outputs. The tracking receiver outputs to the tracking electronics were at 30 mc. The IF amplifier in the tracking electronics had a predetection bandwidth of 1 mc, giving a tracking sensitivity of -110 dbm with the 4-db noise figure of the S-band system.

The data receivers had a predetection bandwidth of 2.5 kc, giving an effective receiver input noise level of -136 dbm. Laboratory tests made with a transmitter modulated in the same manner as the *Mariner* spacecraft transmitter have shown that the data receiver will lock to signal levels below the receiver noise level: as low as -144 dbm. The sensitivity of the same type of spectrum display used on the *Twin Falls* was measured and found to be -115 dbm. It was determined that the signal strength predicted during the time of required Class I coverage was well above the minimum signal levels required for the S-band receiver system. Note that the spacecraft signal level was increased from 1 to 10 w at approximately 45.1 min. With a plotted range and using antenna gains of 0 db for the spacecraft and $+35$ db for the ship, the signal level is always in excess of -99 dbm. The data receivers were offset in frequency to provide optimum coverage of the anticipated doppler frequency shift. Data Receiver SN107 had a frequency acquisition range from $+91.2$ to -13.7 kc and was connected to the left-circular antenna channel. Data Receiver SN113 had a frequency acquisition range from +41.2 to −64.5 kc (hold in range to −78 kc) and was connected to the right-circular antenna channel.

Based upon the above information, two possibilities for not receiving data part of the time arise. First, the spacecraft antenna was designed for right-circular polarization. The input to the left-circular channel of the CTS antenna would be attenuated below that predicted, but no measurements were made on this component of the spacecraft-radiated signal. With signal margins for the data receiver greater than 40 db and for the tracking receiver greater than 15 db, this effect would probably not have completely prevented signal acquisition in the left-circular receiver channel. Second, no receiver lock would have been achieved by transferring Data Receiver SN107 to the broadband antenna from $T+3030$ to $T+3210$ sec, since the negative doppler shift of the S-band signal was outside of this receiver's capability at this time. The signal frequency would have been within the frequency range of the spectrum display unit connected to this receiver, but the signal level was too low when using the broadband antenna to be detected at the slant range existing during this time period. With a transmitting antenna gain of 0 db, a receiving antenna gain of 16 db, a spacecraft S-band power output of 10 w on a range of from 5.1 to 7.0×10^6 yards, the signal level would have been between −118 and −120 dbm.

Testing by ship's personnel after the mission turned up a problem with the tracking receivers that will be presented before pursuing further the data receiver performance. Operation in the crystal controlled mode causes the antenna carrier relay to lock up with no receiver input present, so the receiver was operated in the automatic frequency control (AFC) mode. This problem existed when the system was delivered and accepted and, therefore, the receiver always operated this way. In the AFC mode the receiver is designed to lock to, and cause the tracking receiver first local oscillator to follow, any change in the input frequency. When no signal is present in the receiver, the first local oscillator is offset in frequency owing to the unbalance in the discriminator. Both tracking receivers on the *Twin Falls* were measured and found to have a large frequency offset. The receiver in the right-circular channel was offset +598 kc. The offset in the left-circular channel was sensitive to the IF gain setting. When set as would be normal for the mission, the offset was +300 kc. Original measurements indicated it was also offset +590 kc. Increasing the IF gain setting could reduce this offset to +100 kc. The discriminators were exchanged between the receivers, and the frequency sensitivity with gain was noted in the left-circular channel, indicating that the phenomenon is truly a function of the discriminator characteristic.

The procedure for setting up the tracking receiver was to use the crystal controlled mode to tune the first local oscillator and the preselector to exactly the mission input frequency. A signal received at the receiver input (e.g., 395 mc) would be mixed with the first local oscillator (in this case, 425 mc) in the first mixer to produce a 30-mc signal that would be provided to the antenna automatic tracking electronics, having a predetection bandwidth of approximately 1 mc. In the tracking receiver, the 30-mc signal is fed to a second mixer that is also driven with a 40-mc second local oscillator tunable ±250-kc signal in the second IF amplifier. The second IF amplifier has a 1-mc bandwidth filter. In the crystal controlled mode of operation the AFC voltage from the discriminator is disconnected from the first local oscillator. With the receiver switched to the AFC mode of operation, the first local oscillator would remain at 425 mc if the discriminator were perfectly balanced. To relax the requirement for a perfect discriminator, AFC modes of operation are normally employed after a signal has been acquired in the crystal controlled mode, or gated frequency sweep is employed to overcome the discriminator offset during signal acquisition. With a 598-kc offset in the first local oscillator, the received signal would have been 98 kc outside of the tracking electronics and second IF amplifier passbands.

Even with the above problems in the AFC mode of operation, this system could have worked if the ship's personnel had been advised of the problems and instructed in the corrective action necessary. With the second local oscillator tuned to 40 mc, the received signal would also be outside of the 1-mc passband in the second IF amplifier. Adjustment of the second local oscillator −100 kc or more would put the received signal within the passband of the second IF amplifier. The output of the discriminator would correct the frequency of the first local oscillator and, with this AFC loop closed, center the signal in the 30-mc IF. The offset at 30 mc would be approximately equivalent to the second local oscillator offset.

With the setup existing for the *Mariner IV* launch there is a more than equal chance that the automatic tracking receiver system would not have a chance to function. The manual frequency control of the second local oscillator would have had to be offset in the proper direction. Further considerations of lack of S-band signal reception will be considered with the CTS antenna system slaved to the radar.

Even without the automatic tracking capability, the data receivers should have locked to the spacecraft signal as long as the S-band antenna was slaved to the C-band radar and the *Agena* vehicle and the spacecraft were close together. This situation exists until the *Agena* retro maneuver is exercised long after the end of Class I requirements. Tests performed after the mission, with a test aircraft, indicated that the maximum boresight error existing between the radar and telemetry antennas was 0.4 deg. This is well within the 3-db beamwidth of 2.5 deg. If no search mode was initiated during this slave to the radar the degradation to the received signal should be approximately a 1.2-db amplitude modulation at the 30-cps conical scan rate. During the time the circular scan mode was employed, the received signal would have had superimposed upon the conical scan modulation an amplitude modulation of approximately 4.6 db, at a rate of 2.3 sec per cycle. During the $\pm$5-deg sector scan, approximately one 400-millisec pulse would be received every 2.1 sec. It is possible during this last scan mode for the data receiver to have been tuned through the spacecraft frequency during a period when there was an absence of signal. If this were the only scan mode used, this could explain loss of the signal part of the time, but not for the entire search period. A "blip-scan" ratio might exist that would have also degraded the pan scope presentation. The exact amount has not been evaluated.

Another factor in the possible loss of S-band signal strength deals with the spacecraft antenna pattern. After separation at L +45.1 min, the tumble could easily have caused 30-db nulls in the anticipated signal strength. Determining the actual null periods is virtually impossible with the available information.

To summarize, no single reason has been found to account for the fact that the *Twin Falls* received no S-band data in the entire 10-min Class I period, or in the subsequent time period when acquisition should have been possible. Return of the tracking and data receivers to PAFB for further evaluation may bring additional information to help resolve this problem. With reasonable certainty that the tracking receivers were operating outside of the frequency acquisition range, there was evidently a combined frequency and space search problem with the data receivers that was not successfully solved within this time period.

2. MSFN Support

The MSFN stations providing T&DA support for the mission were Bermuda, Carnarvon, and Tananarive. Telemetry through the *Agena,* metric support, and Range Safety were provided by Bermuda. VHF telemetry and FPQ-6 radar support were provided by Carnarvon. Only VHF telemetry support was provided at Tananarive.

a. Bermuda angle system problem. The FPS-16 angle system was in a "red" condition for 10 min as the result of a short-circuited −150-vdc bus in J-6101 of the elevation equalizer and switching unit. Support of the CADFISS test was thus delayed. The CADFISS test was made at 1052, and was very well coordinated with voice cues.

b. Bermuda tracking gate problem. In addition to the angle system problem, an ADRAN *n*th-time tracking gate problem developed at 1350Z which was quickly traced to the line carrying interference-region-switching information to the event recorder. The line was disconnected and the trouble cleared 1 min later. Interference-region-switching information did not appear on Channel 7 of the event recorder for this mission.

c. 100-μv noise level at Tananarive. Prior to the Mission, a 20-db attenuator pad was inserted between the preamplifier and the multiplex input because, without the presence of a signal, a 100-μv noise level was indicated on the receiver signal-strength meter. After insertion of the 20-db pad, the noise level decreased to approximately 10 μv.

d. Acquisition aid problem at Bermuda. Both acquisition aids provided good tracking with an excellent signal. Acquisition Aid 1 encountered one brief burst of interference which pulled the antenna 15 to 20 deg off track. However, it reacquired track within 3 sec and tracked smoothly for the remainder of the pass. Acquisition Aid 2 also experienced a short burst of interference, causing the system to lose track momentarily. No reasons for the interference were readily apparent.

e. Manual tracking at Tananarive. Because of a noisy signal, most of the tracking was performed manually.

f. Multipath reception at Carnarvon. Acquisition Aid 1 experienced multipath reception at elevation angles up to 14 deg. Tracking was very good, with good signal strength. Tracking was deliberately broken at 160130Z. Acquisition Aid 2 had poor signal strength at AOS because of multipath reception, but the signal strength increased rapidly and tracking became very good in all respects. Tracking was deliberately broken at 160130Z, after the required commitments had been completed.

3. NASCOM Support

a. Circuit outages. Communications support for the Mission was generally good. While certain circuit outages, some of which are listed in Table 29, did exist, at no time did it appear that the mission was in jeopardy owing to faulty communications.

b. Communications outage at DSIF-51. A complete power failure occurred at the South African radio terminal transmitter site (Olifantsfontein) approximately 50 min after liftoff. When the main (commercial) power failed, an automatic cutover switch did not actuate the auxiliary power supply. Investigation showed that the cutover switch was not properly adjusted. This failure left the Johannesburg Station (DSIF-51) without communications for approximately 45 min. Fortunately, the failure occurred when the spacecraft was not within the view period of the station. Communications were restored to Johannesburg prior to the next view period.

Table 29. Circuit outages

Outage time	Circuit	Remarks
0800Z–0830Z	AADE/NS-3772	Out both ways. Carrier failure between New York and Chicago (beam failure).
0830Z–0918Z	AADE/NS-3772	Out receive. Outage due to equipment failure (FRXD unit) at RCA Honolulu.
1200Z–1225Z	NS-3732/NS-3731	Out receive. Two interruptions occurred—(a) equipment failure: stuck tape in FRXD unit at AOMJ; (b) operator error at AOMJ: mispatch.
1425Z–1445Z	RA-54	Both ways. LJOB advised JPL experiencing a loop problem. Location unknown.
1505Z–1610Z	ETR-13	Out receive (send side QRK-4). Power failure at MUX-PTA: main power transformer failed.
1503Z–1552Z	RA-30; RA-54; RA-63; TGP-18	Out both ways. Power failure at MUX-PTA (transmitter site): main transformer failed. RA-63 still out; came back in at 1604Z.

4. DSN Support

a. Launch pass at Johannesburg (DSIF-51). During the launch pass at Johannesburg, the station obtained one-way lock for 3 sec (starting at GMT 145710). The predicted angles used for the acquisition attempt were obtained from the L −5 min predicts. In comparing the predicts with the actual angles of the antenna position obtained from the tracking data, it was found that the predicted flight path varied from 12 to 1 deg below the local horizon mask and 13 to 0 deg below the antenna limit stops. The spacecraft was below the horizon throughout the entire pass. The short one-way RF acquisition occurred when the actual and predicted declination angle difference became less than 2 deg. The predicted values should be within 1 deg of the true angles in both hour angle and declination.

b. VCO frequency error during Woomera (DSIF-41)-to-Johannesburg (DSIF-51) initial transfer. In preparation for the initial first-pass transfer from Woomera to Johannesburg, the frequency of the incoming station transmitter VCO (X_{A}) was calculated by the Tracking Data Analysis (TDA) group at the SFOF. The equation used to calculate this frequency is designed to provide a ground transmitter VCO frequency which will reach the spacecraft transponder at the zero SPE voltage point. This gives the station the best frequency to achieve instantaneous two-way lock with the spacecraft. In calculating X_{A}, a value of +44 cps instead of −44 cps was used in the equation. The effect of this error was to set the incoming station transmitter VCO 88 cps higher than its correct value for instant lock. When the incoming station (Johannesburg) switched its transmitter on, both ground receivers dropped lock. Woomera subsequently relocked one-way and Johannesburg was instructed to search ±10 cycles about its VCO frequency in an effort to lock the up-link. This was not successful and Johannesburg was instructed to switch off its transmitter and lock-up one-way because of requirements to receive telemetered space science calibrations. At this time, it was discovered that the Johannesburg transmitter was on 10 kw on the SCM instead of the SAA as intended because of a misunderstanding of instructions. Both Woomera and Johannesburg were instructed to remain in one-way lock.

At the end of the science calibration period, Woomera turned on its transmitter and went into two-way lock. Johannesburg was provided with the corrected X_{A} frequency and modified to transmit through the SAA; a smooth transfer between stations was effected. Subsequently, control was successfully passed back to Woomera and again back to Johannesburg at approximately 30-min intervals to provide orbit comparison data to TDA.

*c. **Suitcase Telemetry Station at Madagascar.*** The spacecraft was acquired by this STS approximately 2 min before it was expected to rise, and was tracked for approximately 2-1/2 min. The signal was maximized at approximately 4 deg from the initial pointing angle and the doppler was as expected. Signal strength at acquisition was -120 dbm. No trouble was found in following the spacecraft, using only the remote AGC meter on the antenna as a pointing guide. The change of bias potentiometer setting to compensate for the change in doppler was accomplished. However, a large static phase error was built up during the time interval in which the operator tried to check the performance of the recorder. Shortly after this the doppler rate became quite high, indicating this was probably the point of closest approach, and a dropout occurred. The signal was reacquired, but was soon lost again and was not reacquired.

Playback of the tape indicated a severe change in signal wave shape as a function of the static phase error. This was due to the change from the center point of the slope of the telemetry detector, which caused the detector to be nonlinear. Reduction of the data indicated the demodulator had no problem in locking on the signal, but acquisition of synchronization sometimes took almost a minute. One time point was quickly defined on the tape, the 1600Z mark of WWVH, but no other points during the time of data recording were readily discernible.

*d. **Suitcase Telemetry Station at Johannesburg.*** The spacecraft was acquired almost on the horizon and was tracked for approximately 3-1/2 min. At this time the ground antenna was pointing toward a null of the spacecraft omniantenna and the signal was too weak to maintain lock.

This STS tape had three time marks, each a minute apart, but they were garbled and very difficult to read. More care needs to be exercised in future time labeling, and the use of separate tracks for time and voice messages is important.

*e. **Phase termination.*** The first Goldstone pass was uneventful, with the spacecraft being acquired near the horizon and two-way lock effected almost immediately. Tracking and data acquisition proceeded routinely thereafter.

The performance of the SFOF was very satisfactory. All functions were carried out effectively and in a timely manner.

ABBREVIATIONS

AADA	Adelaide (Australia)
AADE/NS	Adelaide/NASA switching (circuit designation)
A/B	Beacon-track mode
ADRAN	Computer function (Cape Kennedy)
AFETR	Air Force Eastern Test Range
ANT	Antigua (West Indies)
AOMJ	Teletype routing indicator for Woomera Station
A/S	Skin-track mode
ASC	Ascension Island
BDA	Bermuda
CADFISS	Computation and Data Flow Integrated Subsystem (test)
CAT 1	Cape Radar Controller (radio nomenclature)
CCC	Cape Communications Center (automated control center)
CRO	Carnarvon (Wales)
CTS	*Twin Falls* S-Band Antenna
DIRAM	Digital Range Machine (Integral Computer/Radar)
DPCC	Data Processing Control Console
DPS	Data Processing System
DSIF	Deep Space Instrumentation Facility
DSN	Deep Space Network
FPAA	Flight Path Analysis Area
FPAC	Flight Path Analysis and Command
FRXD	Frequency receiver transmitter distribution
GBI	Grand Bahama Island (Bahama Is.)
GD/A	General Dynamics/Astronautics
GMT	Greenwich Mean Time
GSFC	Goddard Space Flight Center
GTK	Grand Turk (British West Indies)
I/O	Input/Output
IPB	Impact Predictor Bldg (Cape Kennedy), now called RTCF (Real-Time Computer Facility)
IPC	Impact Predictor Computer (Cape Kennedy)
JPL	Jet Propulsion Laboratory
KNO	Kano, Nigeria
LeRC	Lewis Research Center
LJOB	Teletype routing indicator for Johannesburg Station
LLDN	London
LMSC	Lockheed Missiles and Space Company
MA C	*Mariner C*
MCC	Mission Control Center (Cape Kennedy), controls GSFC support
MILA	Merritt Island
MSA	Mission Support Area
MSFN	Manned Space Flight Network
MUX-PTA	Multiplex—Pretoria, South Africa Post Office Dept.
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications System
NS	NASA switching (circuit designation)
OCS	Operations Communications System
PAFB	Patrick Air Force Base
PHON	Honolulu
POR	Project Operations Room (now called MSA or Mission Support Area)
PRE	Pretoria (South Africa)
PTM	Proof Test Model
RA	Radio Corporation of America (circuit designation)
RIS	Range Instrumentation Ship
RWV	Read, write, verify
SAA	S-Band Acquisition Antenna

ABBREVIATIONS (Cont'd)

SAF	Spacecraft Assembly Facility
SAF TD	Spacecraft Assembly Facility Test Director
SAL	San Salvador (Bahama Is.)
S/C	Spacecraft
SCAMA	Signaling, Conferencing, and Monitoring Arrangement
SCM	S-Band Monopulse Feedhorn and Bridge System
SFO	Space Flight Operations
SFOD	Space Flight Operations Director
SFOF	Space Flight Operations Facility
SFOS	Space Flight Operations System
SMAA	Semimajor axis
SMIA	Semiminor axis
SPAA	Spacecraft Performance Analysis Area
SPAC	Spacecraft Performance Analysis and Command
SPE	Static phase error
SSAA	Space Science Analysis Area
SSAC	Space Science Analysis and Command
STADAN	Space Tracking and Data Acquisition Network
STS	Suitcase Telemetry Station
TAN	Tananarive (Malagasy Republic)
T&DA	Tracking and data acquisition
TGP	Telegraph Public (GSFC circuit designation)
TIM	Tracking Information Manual
T/M	Telemetry
TPS	Telemetry Processing Station
TTY	Teletype
VECO	Vernier engine cutoff