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Volume III

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PREFACE

The work described in this report was performed by the Tracking and Data Acquisition organization of the Jet Propulsion Laboratory and the NASA Communications Network (NASCOM) of Goddard Space Flight Center. This volume, the third in a three-part series; covers the Tracking and Data System support for the extended operations phase of the Mariner Mars 1969 mission. Volume I covers the planning phase through midcourse maneuver. Volume II covers the period from the midcourse maneuver through the end of the mission.

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ABSTRACT

The Tracking and Data System support for the scientific and engineering experiments of the Mariner Mars 1969 extended operations mission is summarized in this volume. The report covers the period from the end of the original mission on November 1, 1969, to December 31, 1969, and the extended operations mission from January to December 30, 1970. The tracking, telemetry, and command operations of the Deep Space Network with performance evaluations are presented, including the use of the new improved experimental ranging system, the tricone feed structure, and the experimental 400-kW transmitter at Deep Space Station 14 (Goldstone, California).

I. INTRODUCTION

This document, the third of a series, covers the Tracking and Data System (TDS) activities in support of the Mariner Mars 1969 Project for the extended operations mission of Mariners 6 and 7. Volume I covered the system design phase through midcourse maneuver; Volume II covered the cruise phase through encounter. The three volumes together constitute the complete history of the TDS activities supporting the Mariner Mars 1969 mission.

The primary objective of the Mariner Mars 1969 Project was to conduct flyby exploratory investigations of Mars in order to set the basis for future experiments, particularly those relevant to the search for extraterrestrial life. The six scientific investigations of the primary objective were visual imaging by television, ultraviolet spectrometry, infrared spectrometry, infrared radiometry, planetary occultation of the S-band radio signals, and celestial mechanics. The secondary mission objective was to develop technology needed for succeeding Mars missions.

As a follow-on to the main mission, the objectives of the extended operations mission were to test relativistic gravitational theories, to measure solar coronal and interplanetary electron density profiles, to improve certain astronomical constants and ephemerides, to demonstrate the high degree of accuracy of the ranging system at 2.6 AU, and to determine the utility and accuracy of the differenced range vs integrated doppler (DRVID) method of charged-particle calibration of metric radio tracking data.

The Mariner 6 flight began on GMT Day 056 (February 25) at 01:29:02.013 with midcourse maneuver on Day 029; Mariner 7 began on Day 086 (March 27) at 22:22:01.198 with midcourse maneuver on Day 098. The flight time of Mariners 6 and 7 to Mars was approximately 5 mo, with Mariner 6 passing near the equator to examine the dark regions in a zone east and west of Meridiani Sinus. The second flyby, Mariner 7, passed further south, sweeping down the same area and then on to view the south polar cap and a wheel-shaped light area, Hellas. The closest approach for each spacecraft was approximately 2000 mi above the Martian surface and occurred on Day 212 (July 31) at 05:19:06.9 for Mariner 6 and on Day 217 (August 5) at 05:00:50.0 for Mariner 7.

Since the end of the Mariner Mars 1969 mission on November 1, 1969, the TDS had been providing support on an interim basis pending formal establishment of the Mariner Mars 1969 extended operations mission. During this interim period, tracking operations were on a much reduced scale, being confined to support from DSS 62 in Cebreros, Spain, and DSS 14 in Goldstone, California.

The Mariner Mars 1969 extended operations mission was formally established as a project in January 1970. Formal statement of the project requirements for TDS support was received in the form of a Support Instrumentation Requirements Document (SIRD), and a NASA support plan was prepared in response. In addition, a DSN operations plan was prepared, detailing the characteristics of the support capabilities committed by the NASA support plan. Key features of the support plan provided for tracking coverage from Stations 62, 12, and 14. This coverage, which has been provided since the end of the main mission, continued on a formal basis through December 30, 1970.

The DSN support of the mission was by essentially the same DSN tracking system configuration as used for the main mission. However, to this tracking system, a new improved experimental ranging system, a tricone feed structure, and a new experimental 400-kW transmitter have been added, all installed at the 64-m-diameter antenna station (DSS 14).

DSS 62 had been used to send commands to the spacecraft to prepare it for a tracking pass immediately following its pass over DSS 14. The intention was to maximize the amount of tracking time available from DSS 14 in order to obtain more radio metric data, particularly ranging. This ranging support was provided by the experimental sequential-acquisition ranging system, since the signal strength and doppler rates began (in October) to exceed the design parameters of the R & D ranging system used to support the mission through encounter. Using this experimental system, ranging data have been obtained from Mariners 6 and 7 at ranging signal levels as low as -183 dBmW. Such data provided valuable additional information on charged-particle calibrations by the differenced range vs integrated doppler method.

Both Mariner 6 and 7 spacecraft were sending engineering telemetry at the cruise mode rate of 8-1/3 (or 33-1/3) bits/s during most of the extended operations mission. However, telemetry was received at DSS 14 only until January 25, 1970, when the station was taken out of service for the installation of the tricone feed structure and the 400-kW transmitter. At DSS 62, telemetry was below threshold, as was the carrier shortly before that date. Even though the carrier was below threshold, DSS 62 was able to send commands to the spacecraft, preparing it for its pass over DSS 14; this activity was feasible due to an adequate performance margin in the uplink and the availability of accurate predicts.

After January 25, tracking was feasible only at DSS 12 through the use of a specially prepared, low-noise feed cone on the 26-m antenna. This mode of tracking continued until the return of DSS 14 to service on March 1, 1970. During this time, no commands were sent to the spacecraft; also, ranging data were not generated, since that equipment is operable only at DSS 14.

In late April and early May, tracking at superior conjunction was conducted for Mariner 6 and Mariner 7, respectively. After that period, the DSN operations level was reduced until the engineering experiments were conducted in December. For these special spacecraft engineering experiments, the science data rates of 66-2/3 and 270 bits/s were used for telemetry data.

Scheduling of tracking coverage support in conjunction with other flight projects support during the extended operations presented some difficulty. However, scheduling problems were alleviated somewhat by the incorporation of Model 8 of the real-time telemetry computer program for the IBM 7044 computer into the operating system in the Space Flight Operations Facility. This model introduced no change to the Mariner Mars 1969 operations but permitted simultaneous operation with the Pioneer Project in the same computer string. The previous model, Model 7, permitted simultaneous operation of only the two Mariners.

The TDS organization for the extended operations mission support consisted mainly of a reduced DSN operational structure with the DSN project engineer reporting directly to the Space Flight Operations Director (SFOD), as shown in Fig. 1. However, after the extended operations mission was formalized, the operation was transferred to a new mission-independent operations organization, which is discussed in Section III.

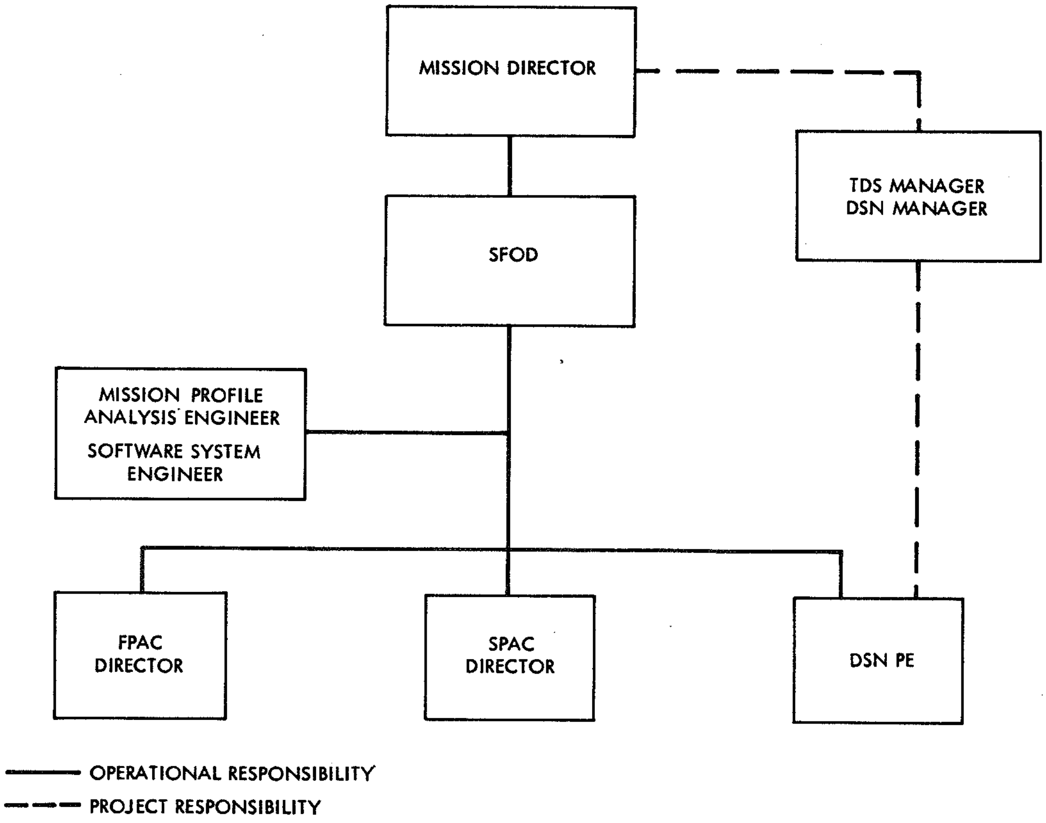


Fig. 1. Initial Mariner Mars 1969 extended operations mission operations organization

II. EXTENDED OPERATIONS TRACKING AND DATA ACQUISITION REQUIREMENTS

The tracking and data acquisition (TDA) requirements for the Mariner Mars 1969 extended operations mission were essentially the same as for the main mission. Basically, the primary requirement was the generation, acquisition, transmission, and processing of information for the determination of spacecraft orbits and experiment measurements, all with respect to a common time base.

The basic tracking requirement for a successful experiment was that range data be generated continuously for several months on either side of superior conjunction. If there were no dispersive effects on the radio signal because of the interplanetary medium, it would be possible to perform the experiment with range data alone. However, it was necessary to use the fact that the phase of the signal is advanced while its group velocity is decreased and to perform a range doppler calibration of the range data. Unfortunately, since interplanetary medium effect on the range signal was greater than 20 m under average conditions throughout all of 1970, an effective calibration would require an horizon-to-horizon pass of continuous doppler every day of the year with two good range measurements at the beginning and end of each pass. To accomplish a good charged particle calibration of the postencounter data would require a station (DSS 14) full time just to track one spacecraft. It was clearly impossible to obtain a highly reliable and accurate calibration for charged particles. The best compromise was to schedule tracking coverage symmetrically about superior conjunction in terms of the elongation angle between the sun and spacecraft. The region near conjunction received daily coverage, and for elongations outside of ~20 deg the tracking was less frequent.

In order to establish the spacecraft orbit accurately, the project requirements for radio metric data are:

Date	Requirement
11/1/69 to 12/20/69	1 pass per week
12/21/69 to 12/10/70	2 passes per week
12/11/70 to 4/15/70	1 pass every other day
4/16/70 to 5/16/70	1 pass per day (a shared pass with the Pioneer Project every other day)
5/17/70 to 7/1/70	1 pass every other day (a shared pass with Pioneer every 4 days)
7/2/70 to 1/1/71	2 passes per week

The required accuracies for doppler and angles of the radio metric data are summarized in Table 1; the required accuracies for ranging are summarized in Table 2. The data processing and display requirements are listed in Table 3.

Table I. Doppler and angle accuracy requirements

Data Accuracy	Effective Noise at 1 Sample/Min[1]			
	Correlation Width, T (min)	Two-way Doppler (1σ) (Hz)	Three-way Doppler (1σ) (Hz)	Angles (1σ) (deg)
A To support Primary Mission Objectives	$T\rho < 10^m$	0.01	0.01	0.05
	$T\rho \geq 10^m$	0.01	0.01[2]	0.2
B To support Secondary Mission Objectives	$T\rho < 10^m$	0.005	0.005	0.01
	$T\rho \geq 10^m$	0.005	0.005[2]	0.06

[1] All 1σ standard deviations are for radio metric data taken above 5° local elevation.

[2] Deviation from a constant bias. Bias <0.01 Hz for A and <0.003 Hz for B throughout the pass.

Note:

S-band RF carrier to be in continuous phaselock throughout station pass during generation of doppler data.

Table 2. Ranging accuracy requirements[1]

Requirement		To Support Primary Mission Objectives	To Support Secondary Mission Objectives	Comments
Ranging System Delay Error	**Stability Period**	(1σ)	(1σ)	
	(1σ)	0.7 ns - 0.1 m	0.3 ns	Calibration of charged particle effects
	10^2 sec	5 ns - 0.8 m	1 ns	
	10^4 sec	40 ns - 6 m	8 ns	Range allows a reduction in quantity of doppler required
	10^5 sec (1.2 days)			
	Absolute Accuracy			
	Strong S/N	100 ns - 15 m	10 ns	1 nanosecond (ns) = 10^{-9} sec = 0.15 meters
	Weak S/N	300 ns - 45 m	200 ns	

[1] Ranging to be taken in continuous phaselock to the extent that it is consistent with the primary mission objectives for absolute accuracy.

Table 3. Data processing and display requirements

Type	Site	Raw Data Recording	Data Processing	Data Display and Recording		Availability Time
				Display	Recording	
8 1/3 and 33 1/3 bps Engineering Telemetry	DSS 14 DSS 62	Magnetic Tape	Real-time data processing in the TCP and formatting for transmission to the SFOF	S/C AGC S/C SPE	TCP Digital Tape	Real Time
Ground Receiver AGC	SFOF	Magnetic Tape	That required to transmit to TCP	None	TCP Digital Tape	Real Time
			Real-time data processing in the 7044	HS TTY Printers 30 by 30 plotters 3070 printers	Magnetic Tape	Real Time
Radio metric	DSS 14 DSS 62	Paper Tape	That required to acquire and transmit to the SFOF	None	Paper Tape	Real Time
Radio metric	SFOF	Magnetic tape and output of TDP	7044/7094 processing	TTY	Magnetic Tape	Non Real Time
Commands	SFOF	None	None	TTY(TV)	None	Real Time
All	SFOF		Non-real-time data processing in the 7094	None	None	Non Real Time

III. TRACKING AND DATA SYSTEM OPERATIONS PLAN

The TDS plan for supporting the Mariner Mars 1969 extended operations mission was predicated on a formal statement of the project requirements for TDS support. During the interim period from the end of the main Mariner Mars 1969 mission on November 1, 1969, to the formalization of the extended operations project, TDS would provide tracking support of the Mariner 6 and 7 spacecraft, but on a much reduced scale.

In early January 1970, the extended operations mission was formally established and was followed by the issuance of a Support Instrumentation Requirements Document (SIRD). A NASA support plan and a DSN operations plan were prepared to detail the support for the scientific and engineering experiments of the extended operations mission. The DSN operations plan established the parameters for the tracking coverage as committed by the support plan to be from Stations 62, 12, and 14, the DSN organizational structure and configurations, the scheduling criteria for tracking coverage as dictated by other flight projects and facility modifications, and the operational support for the extended operations mission.

A. Tracking and Data Acquisition

The generation, acquisition, transmission, and processing of information for the extended operations would be conducted by four DSN facilities, Stations 62, 12, and 14, and the SFOF. The instrumentation and functions of these facilities are summarized in Table 4.

1. Coverage capability. Both DSS 14 and DSS 62 would be capable of providing tracking coverage for radio metric and telemetry data as required subject to scheduling constraints. Detailed scheduling would be regulated by the DSN network allocation schedule according to the guidelines and priorities provided by and negotiated between projects, Office of Space Science and Applications (OSSA), Office of Manned Space Flight (OMSF), and Office of Tracking and Data Acquisition (OTDA).

DSS 14 generated and transmitted in real-time to the project in the SFOF radio metric data and received and retransmitted telemetry data obtained from Mariners 6 and 7 spacecraft as well as recording the data.

2. Radio metric data. The preliminary plan was to generate ranging data by retransmitting the earth-generated uplink from the spacecraft high-gain antenna. Because of limited power and other spacecraft constraints that developed during the main mission, the high-gain antenna could not be pointed to earth during the required time (January 1 to June 15, 1970). Therefore, the DSN would have to provide a high-performance ground ranging configuration to complete the extended operations mission requirements. In addition, DSS 62 was required for commanding to condition the spacecraft before it came into the DSS 14 view to maximize each DSS 14 view period.

The S-band accuracy requirements were to be met, with the following exceptions:

(1) Three-way doppler: The requirement for bias less than 0.01 Hz could not be met (the one sigma bias is 0.23 Hz).

(2) Two-way doppler: At planetary ranges the two-way effective noise was 0.02 Hz.

(3) Ranging delay error: Planetary ranging delay error was less than 1 m for 10^2 s and less than 4 m for 10^4 s. High-frequency noise due to the DSIF was less than 5 m for strong signals and less than 15 m for weak signals.

(4) Frequency stability: The operational system was a rubidium standard with a stability of 5 parts in 10^{11} for more than 1s and 1 part in 10^{11} for 1 year. These numbers did not meet the requirements, which were more stringent by more than an order of magnitude.

(5) Time synchronization: The operational timing systems of the DSS synchronized stations to less than 2 ms.

(6) Radio metric data accuracy (doppler, range): Radio metric data accuracy was specified for antenna elevation angles greater than 10 deg. The R&D sync system synchronized all stations to the time-sync transmitting station (DSS 13) to within 20 µs.

3. Telemetry data. The DSN extended operations support for acquisition of telemetry data would use elements of the DSN telemetry system developed for Mariner Mars 1969 without changes. No major changes in acquiring, handling, and processing telemetry data from support of the main mission were to be made for the extended mission. Telemetry data would be processed in the existing telemetry and command data processors (TCP) at the DSS for local display of selected spacecraft parameters and preparation of the data for transmission to the SFOF. Also, the existing project-supplied computer software would be used.

The DSN would receive and record telemetry data at DSS 14 and 62 (when available), process and transmit the data to the SFOF in real-time as required, and provide validation of the data.

4. Command data. The DSN would provide a command capability at Stations 12, 14, and 62. The transmitter power capability at Stations 12 and 62 was 10 kW. DSS 14 was equipped with a 20-kW transmitter and would be equipped with an experimental 400-kW transmitter, which would be operated at a nominal 200 kW.

5. Support by R&D equipment. Not all the requirements of the Support Instrumentation Requirements Document (SIRD) could be met by the operational systems of the DSN as each existed during the life of the project. Some of these were to be partially supported on an experimental basis, using R&D equipment.

Because the degree of experience with such equipment was not the same as with operational equipment, the personnel would not be as well trained in the operation of the R&D equipment. Furthermore, there was a lack of operational quantities of spares and backup equipment. Thus the use of R&D equipment to meet these requirements was clearly of higher risk.

These conditions applied to the following equipment and software items:

(1) Planetary ranging.

(2) Timing synchronization equipment to achieve 20 μs capability between DSSs.

(3) 400-kW transmitter.

B. Initial Planning and Operations Organization

During the first part of the mission, the DSN Project Engineer (PE), as in the main mission, was responsible for the planning and operations of the DSN resources committed to the Mariner Mars 1969 Extended Operations (EO) Project. In his operational role, the DSN PE reported directly to the Space Flight Operations Director (SFOD), as shown in Fig. 1.

The DSN PE was supported in his operational activities by the DSN/MM69 EO Operations and Design Team and the DSN Control Team. During operations, the DSN PE function was staffed by operations directors. The operations directors were members of the Operations Control Chief (OCC) organization and also performed OCC functions from that position.

1. DSN/MM69 Operations and Design Team. Headed by the DSN PE, the DSN/MM69 Operations and Design Team consisted of project engineers from various technical sections at JPL. The DSN PE ensured that the DSN systems and facilities interface with each other and with the project in a timely and compatible fashion. He was responsible to the DSN manager for matching MM69 EO requirements to DSN capabilities and commitments. The DSN PE approved all scheduling inputs to the DSN from the MM69 EO Project before acceptance into the DSN Scheduling System.

The DSN PE received support from several DSN facility project engineers as shown in Fig. 2. The DSN facility PE assigned technically to the DSN PE was responsible for interface engineering and operations planning. Interface engineering included the system-to-system integration and testing of equipment and software as required. Operations planning included the design and preparation of the operational support to be supplied to the Project by the DSN.

2. DSN Control Team. The DSN operations control function operated on a 24-h basis, 7 days per week, under the OCC. The OCC was responsible for the real-time, mission-independent control of the DSN and for the management of the DSN seven-day schedule activities. Furthermore, he had the delegated responsibility for DSN control in support of MM69 EO. The DSN OCC provided real-time control over the following functions.

a. DSIF net control. A DSIF net controller was available at all times the DSIF was tracking MM69 spacecraft. He controlled the Deep Space Station subnets through the station directors.

b. Communications control. A Communications Chief was provided on a 24-h basis during MM69 EO operations and was responsible for operations and control of the GCF in addition to effecting the real-time changes to the configuration of the GCF.

c. SFOF data control. A Data Chief was provided during all MM69 EO operations and was responsible for the operation of the SFOF data processing system.

d. SFOF support control. The Support Chief position was manned on a 24-h basis to provide real-time response to MM69 EO support requirements.

e. DSN monitor control. The Monitor Chief provided support to the DSN for near-real-time DSN failure isolation and data validation.

C. Final Operations Organization

After the extended operations project was formalized, a new DSN mission-independent operations organization was set up, as shown in Figs. 3 and 4. The DSN operations control was transferred to this new operations organization on January 28, 1970, with the interface to the Project essentially unchanged. The major change occurred in DSN scheduling, where the Project interface was simplified. In the past, the Project was required to have a scheduler who was responsible for combining all Project requests for DSN support, determining the configuration, and then, with DSN PE concurrence, submitting these requests to the DSN Scheduling Office on the appropriate scheduling forms. In effect, this required that the DSN train certain project personnel in procedures to accomplish this interface. In the new system, a scheduling representative was assigned from the DSN scheduling office to work with the Project to convert Project requirements into DSN scheduling formats. Scheduling efficiency was thereby increased, configuration requirements were standardized, and Project visibility over DSN constraints and user conflicts was provided.

1. DSN Operations Chief. In the new organization, the DSN Operations Chief (OC) was responsible for overall direction of DSN operations and, in the context of this document, was specifically responsible for proper operation of the DSN resources committed to the MM69 EO Project. The DSN OC interface with the MM69 EO mission operations organization is illustrated in Fig. 3. In this operational capacity, he acts as the single point of contact between the MM69 EO Project and the DSN. The DSN OC was delegated authority by the DSN operations manager to direct and control DSN operations. He was made responsible to the DSN Operations Manager.

2. DSN Operations Control Team. The DSN OC directs and controls all committed resources through the DSN Operations Control Team (OCT) (Fig. 4). As head of the OCT, he directs

and coordinates the activities of the DSIF Chief, GCF Chief, SFOF Computer Chief, and SFOF Support Chief. He coordinates isolation of equipment and procedural problems and any required corrective or contingency actions. The DSN OC controls real-time configuration of the DSN and advises Project of DSN status. He resolves scheduling conflicts at first level.

Functions and responsibilities of the facility chiefs (and their supporting teams) of the OCT are described in the paragraphs that follow.

a. DSIF Operations Chief. The DSIF Operations Chief provides real-time direction and control of DSIF operations. He controls committed DSIF resources and the real-time configuration of DSIF equipment and procedures.

b. GCF Operations Chief. The GCF Operations Chief directs and controls operation of the GCF in real-time. He coordinates circuit requirements with NASCOM (NASA Communications Network) and controls the real-time configuration of the GCF.

c. SFOF Computer Operations Chief. The SFOF Computer Operations Chief directs and controls the SFOF Central Processing System (CPS) in real-time. He maintains cognizance of the SFOF program data base and establishes data flow to and from the SFOF CPS.

d. SFOF Support Chief. The SFOF Support Chief directs and controls operation of the SFOF physical plant. He controls the DSN operations area mission status and timing displays and is responsible for SFOF reproduction services, access, and security guards.

3. DSN/MM69 Interface Team. The DSN/MM69 Interface Team for the extended operations maintained integrity of mission-dependent documentation and audited DSN performance during operational support of the Project. In addition, members of the Interface Team designated by the DSN OC or Facility Operations Chiefs acted as advisors providing counsel to the DSN Operations Control Team and recommendations as appropriate.

D. DSN System Configuration

The configuration of each of the DSN systems used for MM69 extended operations is defined in the following paragraphs. The systems used were as follows:

(1) DSN Tracking System

(2) DSN Telemetry System

(3) DSN Command System

(4) DSN Monitor System

(5) DSN Operations Control System

A sixth system, the DSN Simulation System, was not used for MM69 extended operations.

1. DSN Tracking System. The DSN Tracking System consists of those DSN elements which generate and transmit validated radio metric data to the flight projects. The DSN Tracking System configuration for MM69 extended operations is shown in Figs. 5-7. The recently developed R&D binary-coded sequential acquisition ranging system (Mu ranging system) was first used on this mission and was of prime importance in permitting a successful mission (Refs. 1 and 2). This system differs in several respects from the planetary ranging system used earlier for Mariner Mars 1969. The significant changes are that the Mu ranging system employs RF doppler rate aiding for range decoder shifting and that it measures the phase of the received binary-coded components to accomplish initial acquisition. Once the full set of components is acquired, the phase of the highest-frequency component is repeatedly measured to increase the precision of the initial acquisition. The Mu ranging data and predicts required special handling as shown in Fig. 8. During the MM69 extended operations mission, the functions performed by the DSN Tracking System were as follows:

(1) Generation of radio metric data.

(2) Data handling.

(3) Data transmission.

(4) Data processing and validation.

(5) Predictions.

2. DSN Telemetry System. The DSN Telemetry System consists of equipment and software that provide telemetry data to the flight project in both real-time and non-real-time. Figures 9 and 10 illustrate the DSN Telemetry System configuration used throughout most of the mission. Before December 1970, it was necessary to revise the Goldstone configuration (Fig. 11) to accommodate the TCP update at DSS 14 for support of Mariner Mars 1971.

During the mission the following telemetry functions were performed by the DSN:

(1) Data acquisition.

(2) On-site data handling and processing.

(3) Data transmission.

(4) SFOF data handling, processing, and display.

(5) Data validation.

3. DSN Command System. The DSN Command System provides the capabilities to generate and transmit commands to a spacecraft. The configuration shown in Fig. 12 was employed. The significant feature of this configuration is the project-supplied, mission-dependent read-write-verify (RWV) equipment.

The command library was comprised of punched paper tapes, prepared by the DSN to project requirements, containing direct command and quantitative commands. Use of these commands was directed by voice or TTY messages. Coded commands were generated in the IBM 7094 and forwarded as a TTY message by the IBM 7044 from the magnetic tape as shown in Fig. 12 or obtained from the shared disc file. The paper tape capability in the SFOF was provided as a backup.

Command generation in the 7094 was accomplished by the mission-dependent project-supplied program (COMGEN). COMGEN is used to prepare CC&S flight programs and to generate coded commands used entirely by the CC&S to control the sequencer, reprogram the computer portion, or select specific memory words for telemetry readout.

4. DSN Monitor System. The DSN Monitor System consists of those DSN elements, equipment, software, and personnel that provide the following:

(1) Maximize recovery of data.

(2) Identify defective or lost data.

(3) Increase overall efficiency of operation.

(4) Provide real-time information for corrective action.

Figure 13 shows the configuration of the DSN Monitor System for the MM69 EO Project.

The DSN Monitor System is composed of a local monitor and control subsystem for each DSN facility and a DSN monitor area in the SFOF. The DSIF, GCF, and SFOF monitor subsystems gather system performance data from local monitor instrumentation and data quality alarms from error detectors within equipment of the other DSN systems in the particular facility. The data are then differenced against predetermined criteria and performance standards by a monitor program, and appropriate alarms are produced for local control. Each facility forwards a prespecified subset of performance measurements to the DSN monitor area in the SFOF. The DSN monitor area provides hard copy, displays, and alarms for selected performance and data quality parameters and makes available to DSN Operations Control information on conditions requiring corrective action. Thus, the basic functions performed by the Monitor System are as follows:

(1) Gather monitor data from the appropriate Deep Space Station.

(2) Gather GCF monitor data.

(3) Gather SFOF monitor data.

(4) Report overall DSN data quality and system performance.

(5) Evaluate performance against criteria.

(6) Produce alarms for conditions requiring corrective action.

5. DSN Operations Control System. The DSN Operations Control System provides information for operational control of the DSN, for management planning, and for DSN systems analysis. This information is supplied by discrepancy reporting, monitor information, and resource allocation. The configuration of the Operations Control System is provided in Figs. 14 and 15.

The DSN Operations Control System satisfies the above objectives by means of two functional structures. The structure for nonoperational functions (Fig. 15) is effective for the design phase of a mission, while the structure for operational functions (Fig. 14) is effective for the test and operational phases.

E. Operational Support

TDS planning included providing the following operational support throughout the extended operations mission.

1. Magnetic and paper tapes. The delivery of magnetic and paper tapes containing data from the DSS was as follows:

(1) From Goldstone: within 24 hours.

(2) From overseas stations: shipped within one week and available in the SFOF within two weeks.

2. DSS records. Records from the DSS, comprising strip chart recordings, operations logs, and calibration sheets were available for microfilm records in the DSN Document Control.

3. Computer support. The DSN provided computer support in the form of a string comprised of an IBM 7044, a 1301 disc file, and an IBM 7094 with input/output devices in the SFOF for use by the Project. The string could configure as a direct-coupled operating system (DCOS) using a 7040 computer with the 7094.

4. GCF support. Initial planning undertaken during November 1969 centered about identifying communications required to support extended operations using two stations: DSS 14 and DSS 62. It was decided at that time to provide and commit one voice circuit, one high-speed data line (HSDL) with a transmission rate of 2400 bits/s, and four full duplex TTY circuits to each Deep Space Station via the serving NASCOM switching center. This was the same DSS to SFOF configuration employed during cruise and postencounter operations of the main mission.

The following guidelines were established and applied to the committed GCF HSD System support of extended operations:

(1) HSD transmission at 2400 bits/s using 600-bit synchronous data blocks from DSS to SCTS (SFOF communications terminal).

(2) HSD capability at DSS 14 retained for the duration of the extended mission. HSD capability at DSS 62 available up to and including the week of December 16, 1970 (this requirement was deleted on January 26, 1970).

In order to work around the tricone installation at DSS 14 starting January 25, 1970, planning efforts to realign communications to GDSCC on an interim basis began during the first week of January 1970. Initial plans required the use of both DSS 11 and DSS 12 but requirements were reduced to only DSS 12, with the following communications provided: one voice circuit and three full duplex TTY circuits. DSS 12 support was deleted on March 1, 1970, when DSS 14 was reactivated for operational support. The communications configuration to DSS 14 did not change from that originally planned in November 1969, except for special provisions made for transmission of R&D Mu ranging data in TTY format and for the DSS 12/14 configuration used in December 1970. The GCF circuit requirements are summarized in Fig. 16.

5. Mission support areas. The existing Flight Path Analysis Area in the SFOF was used. A portion of the existing MM69 Spacecraft Performance Analysis Area was also used with only minor reconfiguration through June 1, 1970. After June 1, 1970, plans called for major reconfiguration of the first-floor SFOF in support of MM71. This impacted the Mission Support Areas (MSA) for MM69 extended operations and Pioneers 6 through 9. Since space within the SFOF was at a premium, it was proposed to combine MM69 extended operations and Pioneer 6-9 support into one area known as the Combined MSA. Pioneer required an MSA in the SFOF for spacecraft emergency support only. A design was prepared and accepted by both projects (Fig. 17).

The proposal actually solved several problems. It fulfilled the requirements of two projects. Also, it provided improved working conditions for the users. Finally, it permitted total decommitment of the formerly used MSAs and allowed construction of the new MM71 MSA. Mission-independent GCF voice conference nets were assigned the combined MSA, thereby removing any conflicts for assigning nets to MM71.

Table 4. Instrumentation Summary

Location	Instrumentation	Use
DSS 14, 64-m Az/El antenna, Goldstone, California	S-band metric data, telemetry and command	Radiometric data (including ranging), telemetry and command
DSS 62, 26-m equatorial antenna, Madrid, Spain	S-band metric data, telemetry and command	Radiometric data, telemetry and command
SFOF, Pasadena, California	Data processing and communications	Mission operations and DSN control
DSS 12, 26-m equatorial antenna, Goldstone, California	S-band radiometric data, telemetry and command	Radiometric data, telemetry and command

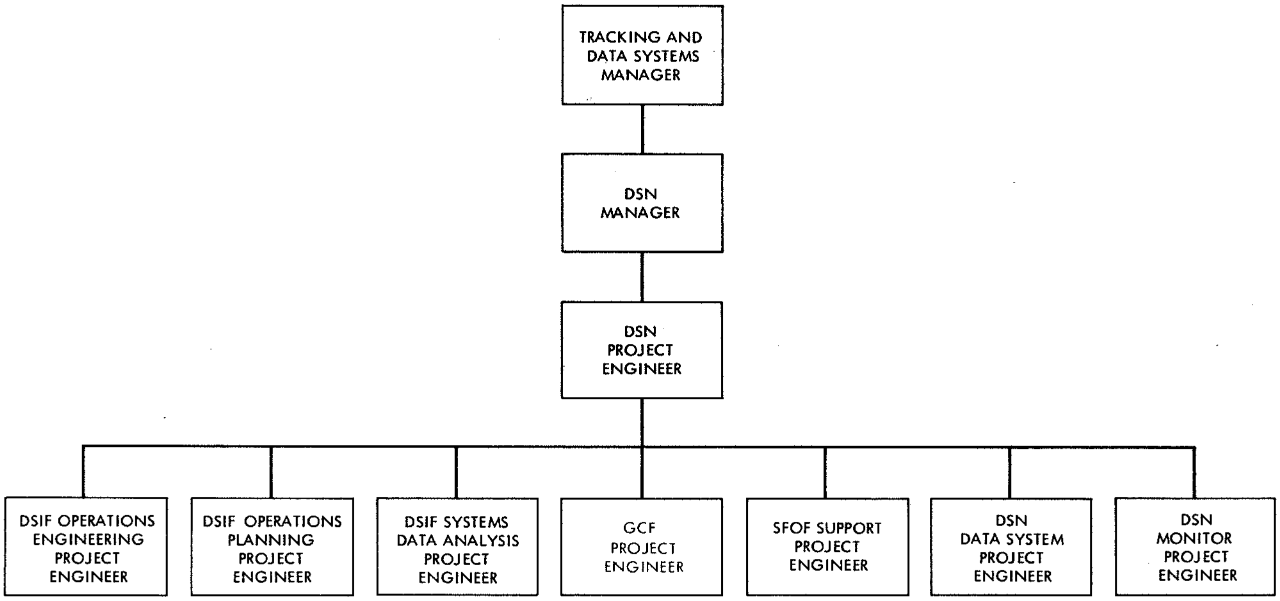


Fig. 2. DSN Project engineering organization

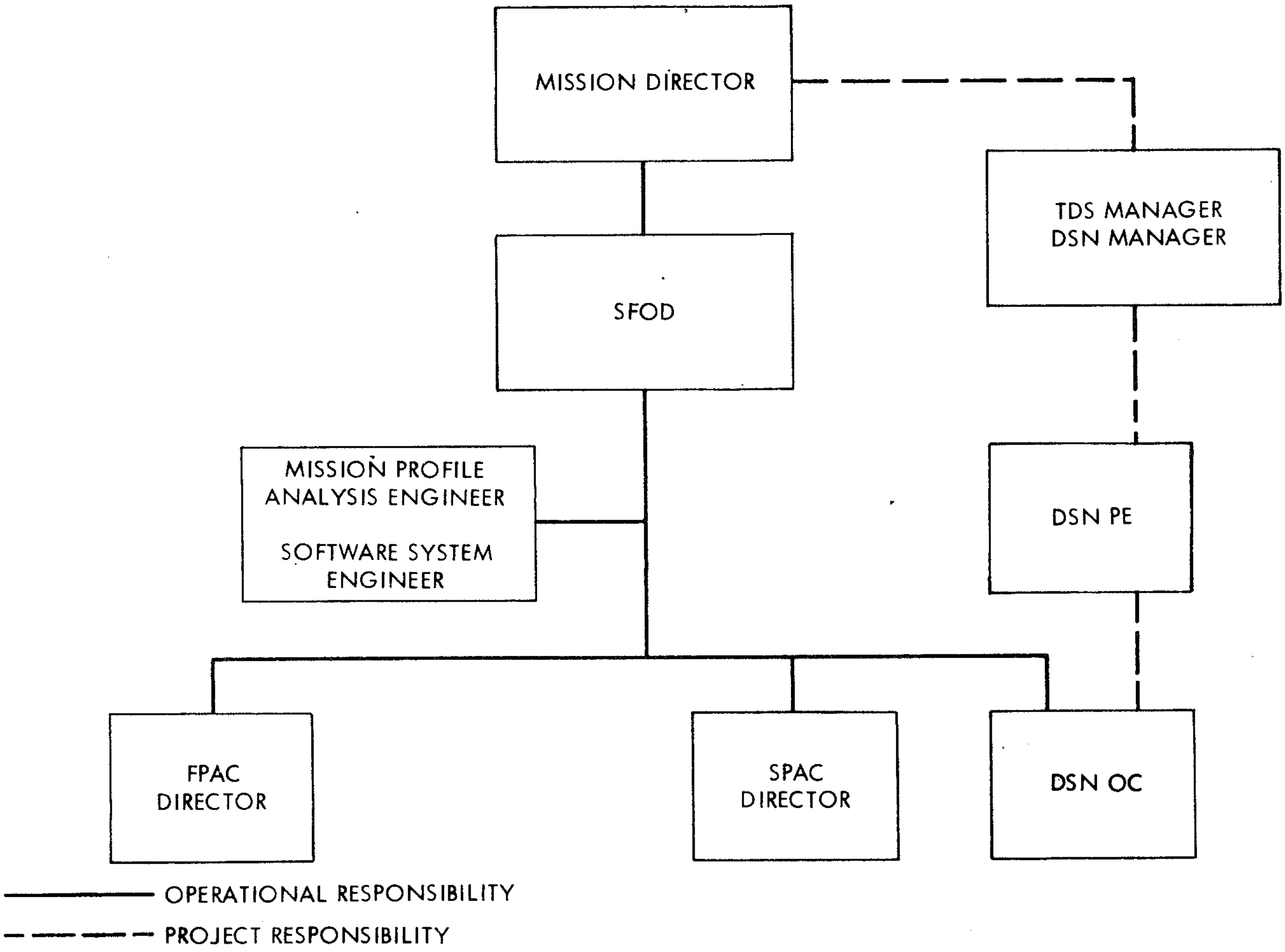


Fig. 3. Final Mariner Mars 1969 extended operations mission operations organization

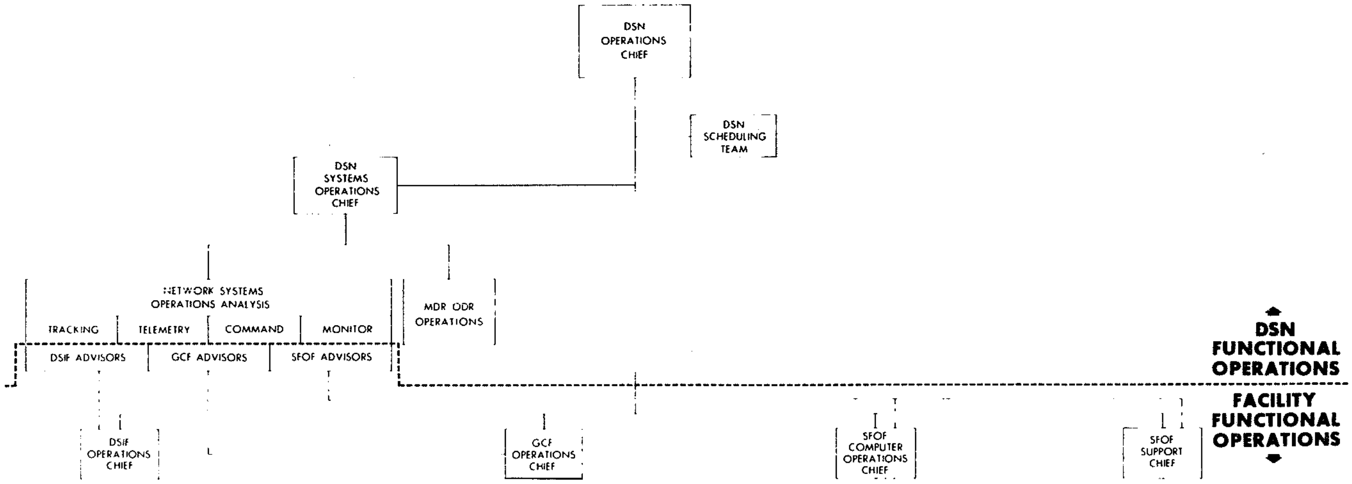


Fig. 4. DSN operations control team

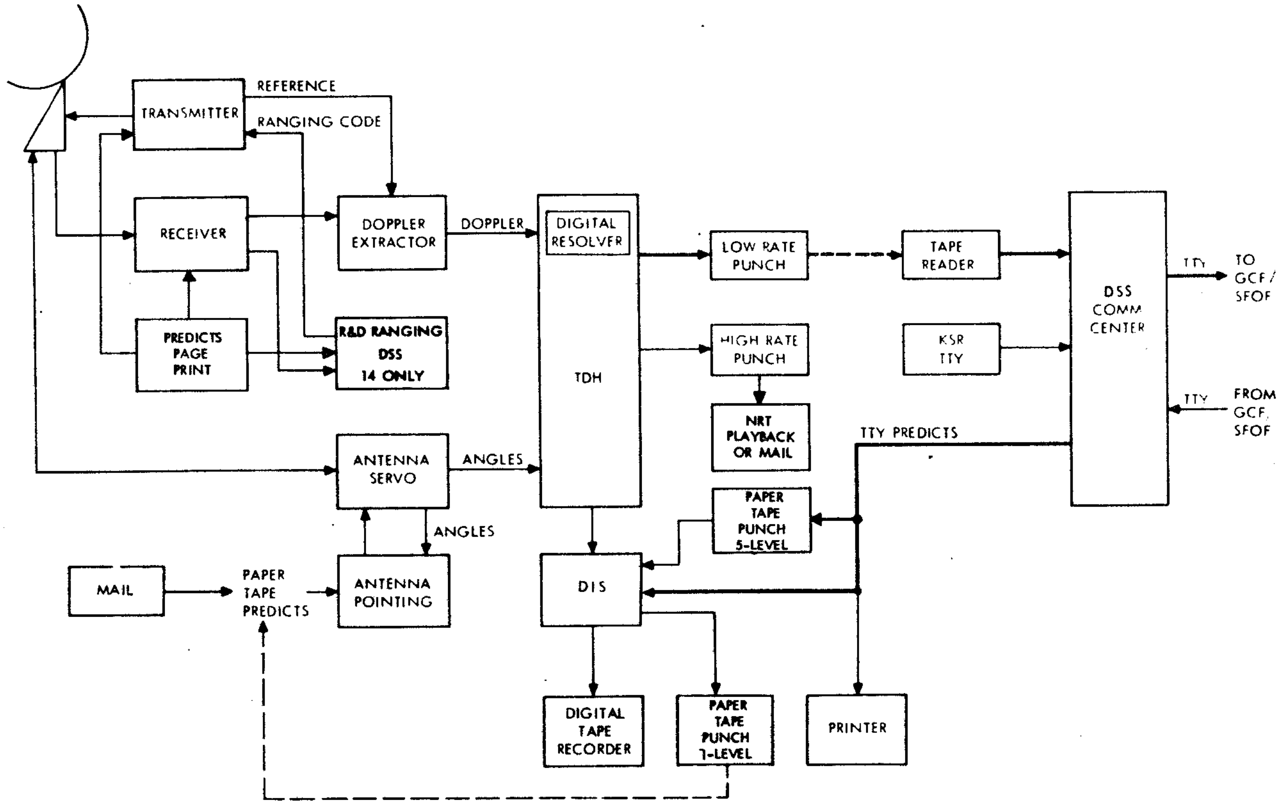


Fig. 5. DSS tracking configuration

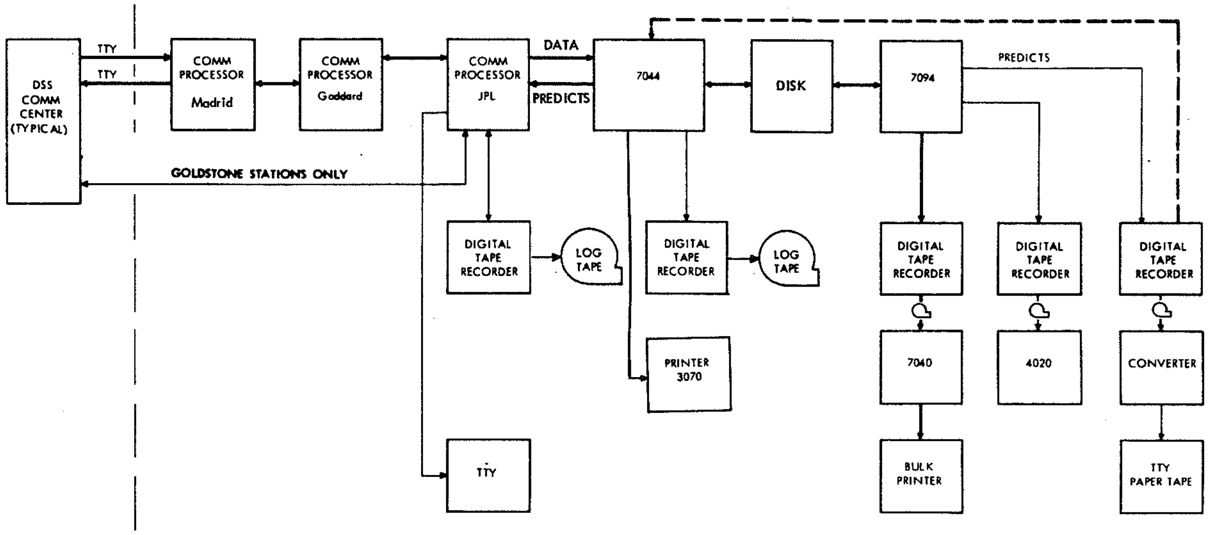


Fig. 6. SFOF/GCF tracking configuration

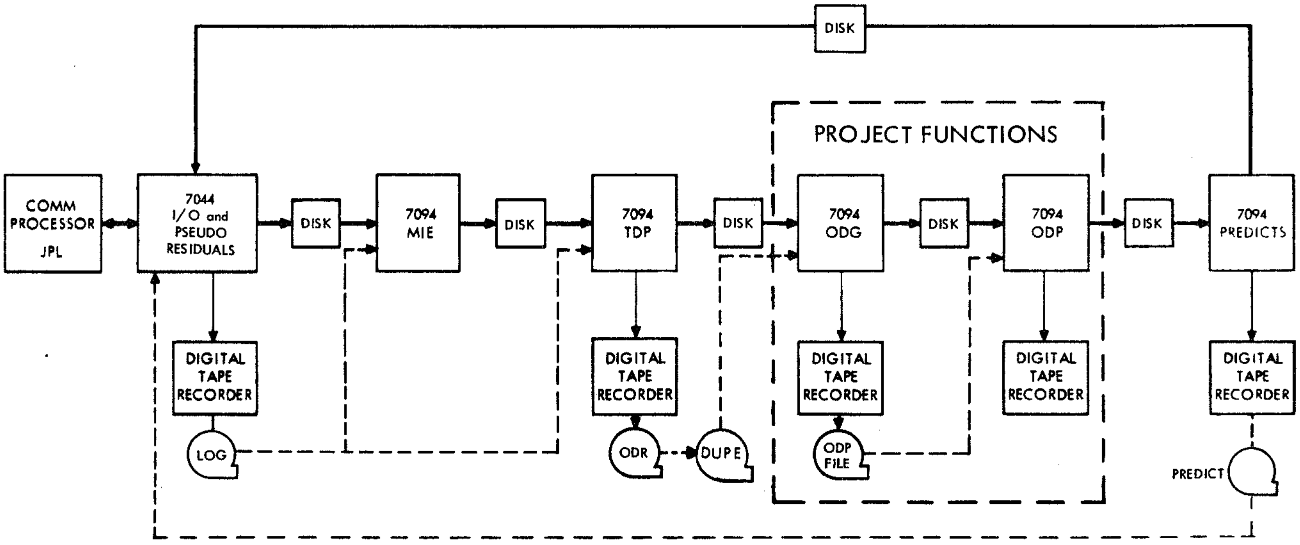


Fig. 7. Radiometric data functions in the SFOF

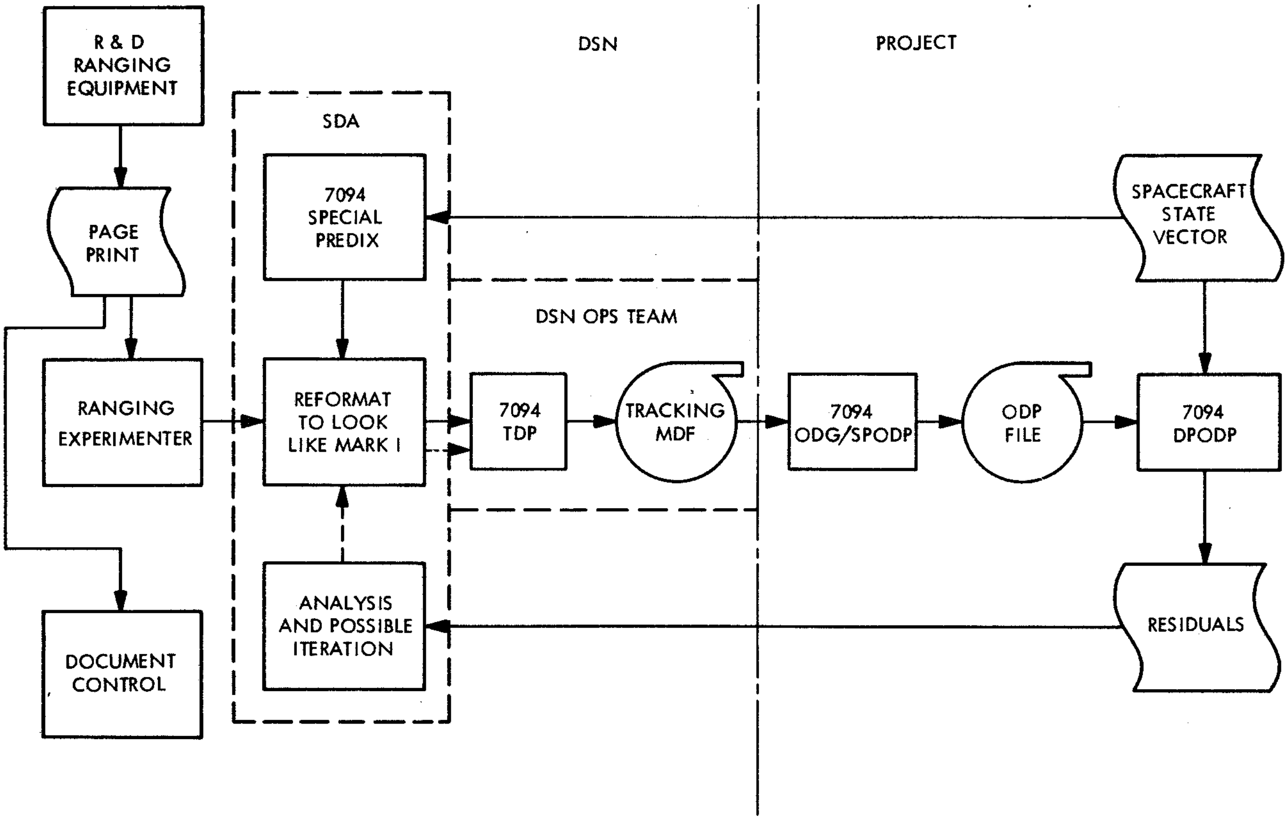


Fig. 8. Mu R&D ranging data handling

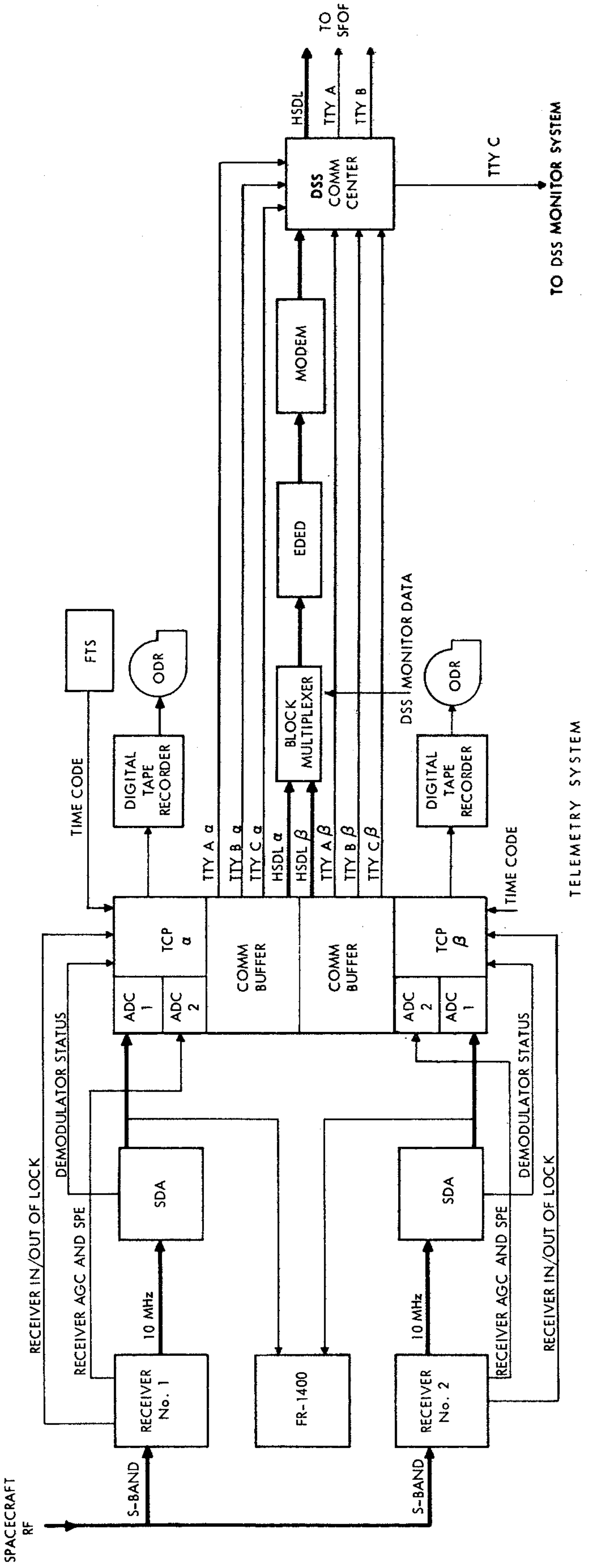


Fig. 9. DSS/GCF telemetry configuration

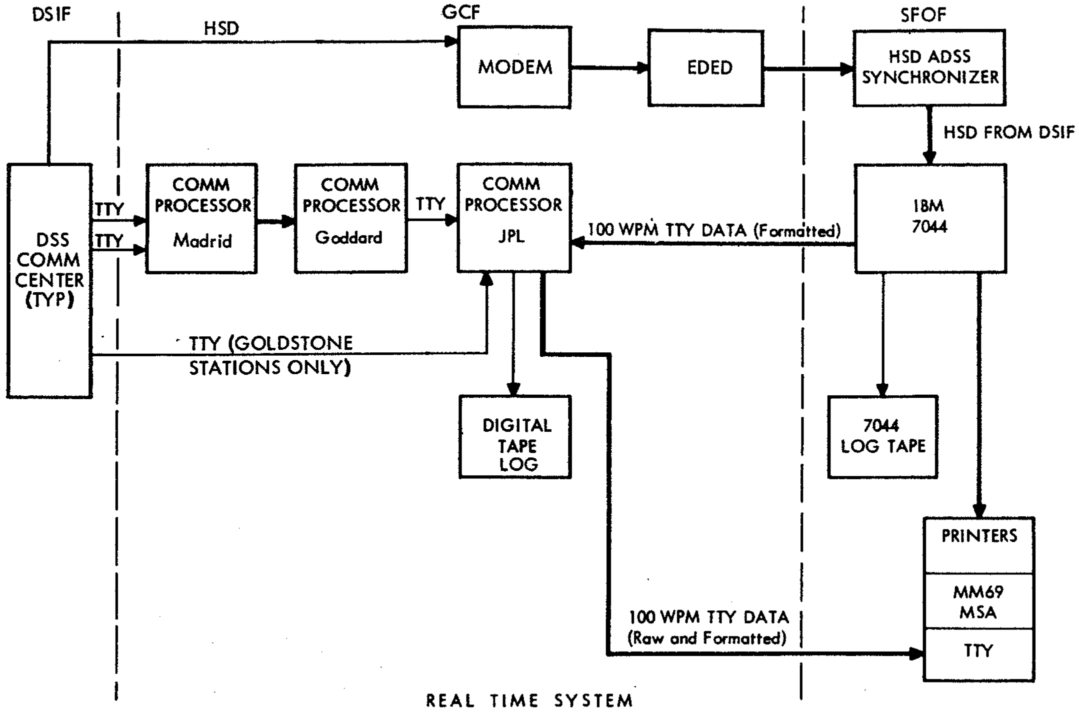


Fig. 10. SFOF/GCF telemetry configuration

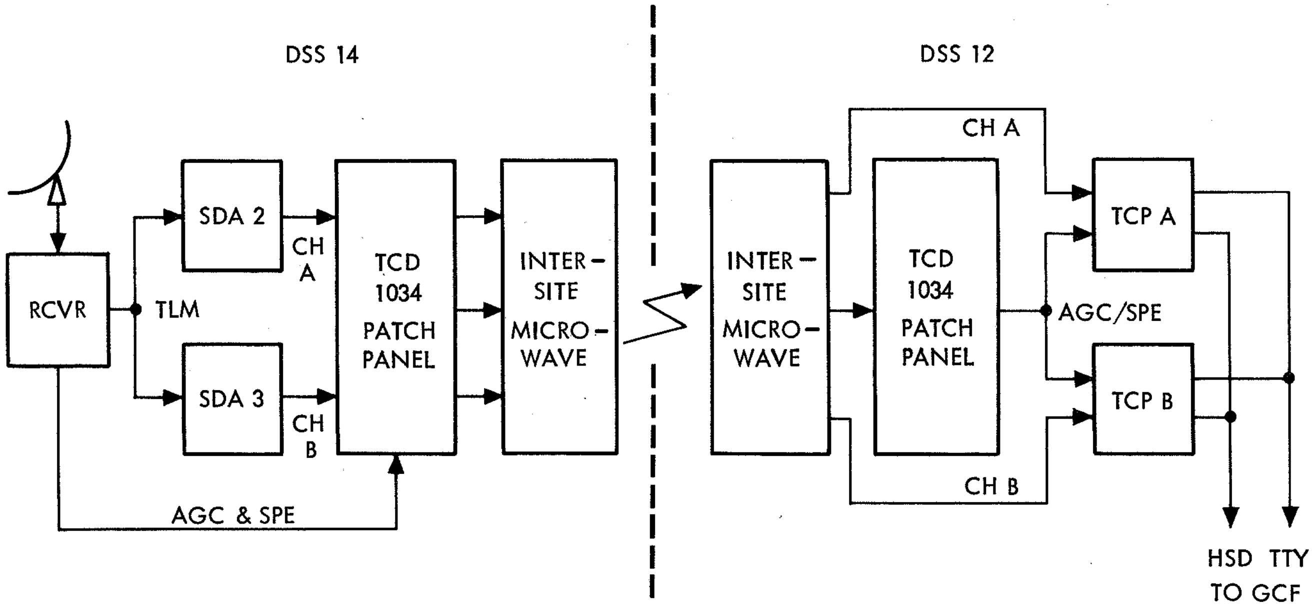


Fig. 11. DSS 14/DSS 12 Mariner Mars 1969 extended operations telemetry data flow

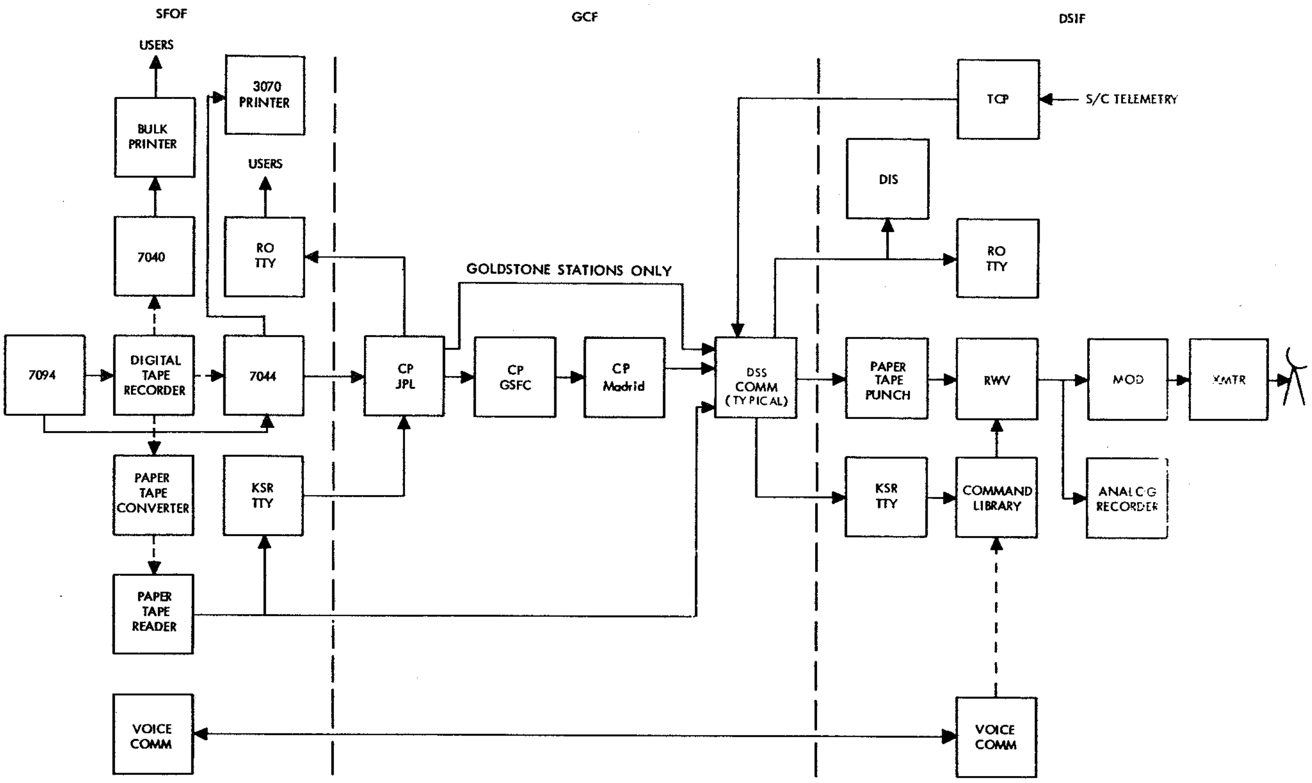


Fig. 12. DSN command configuration

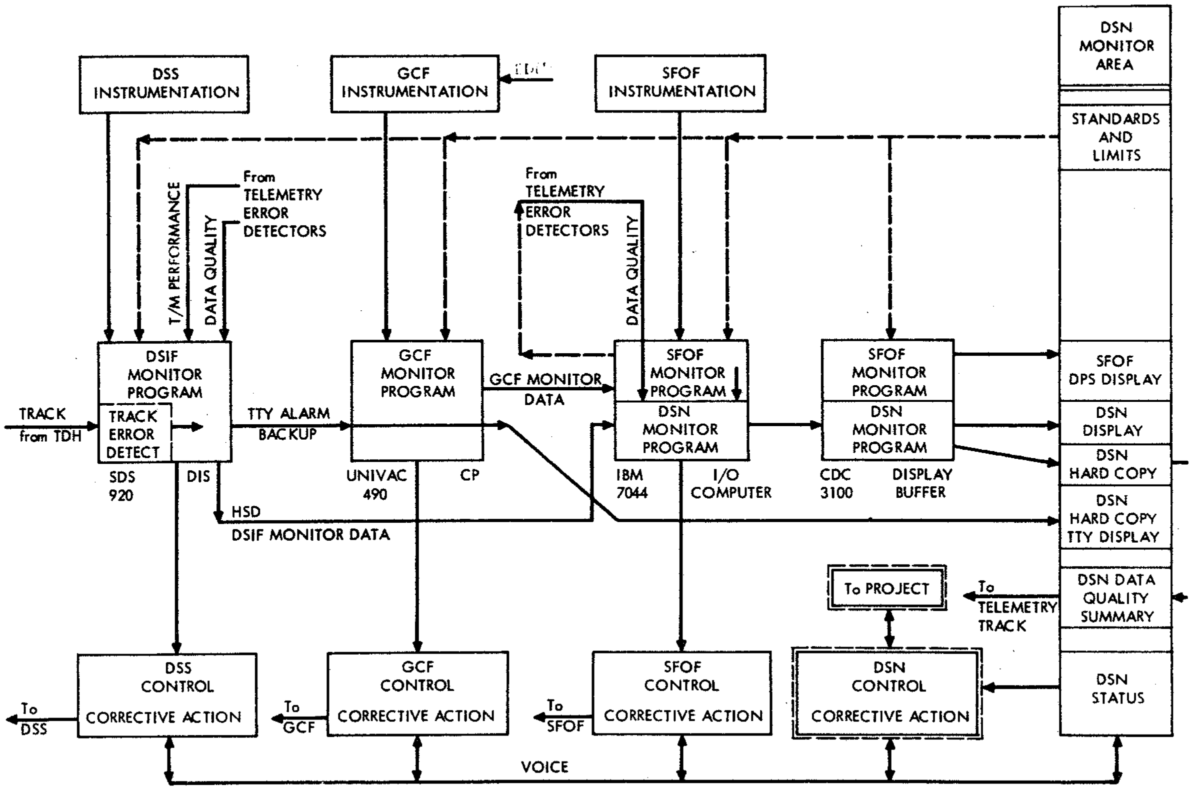


Fig. 13. DSN monitor configuration

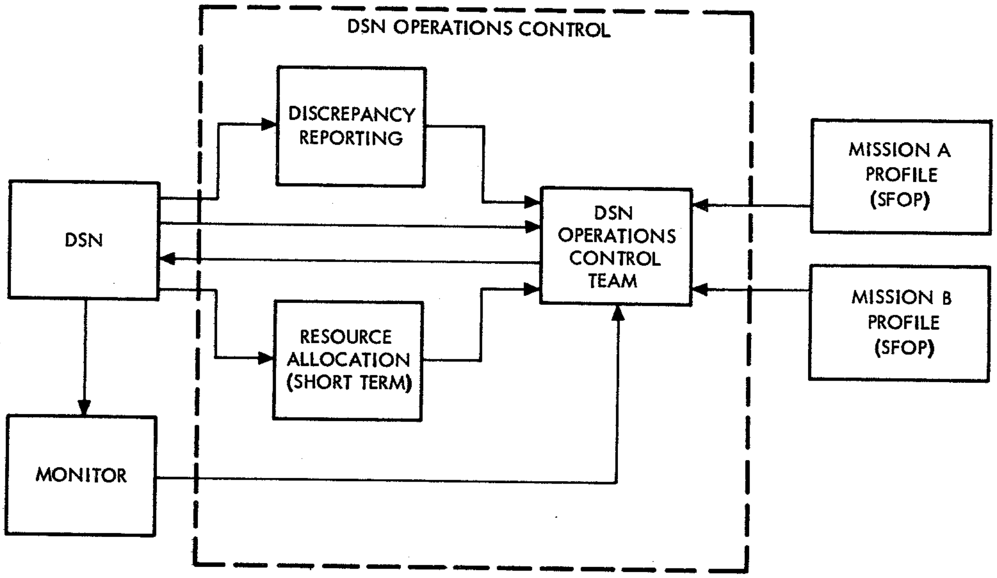


Fig. 14. DSN operations control functions, operational structure

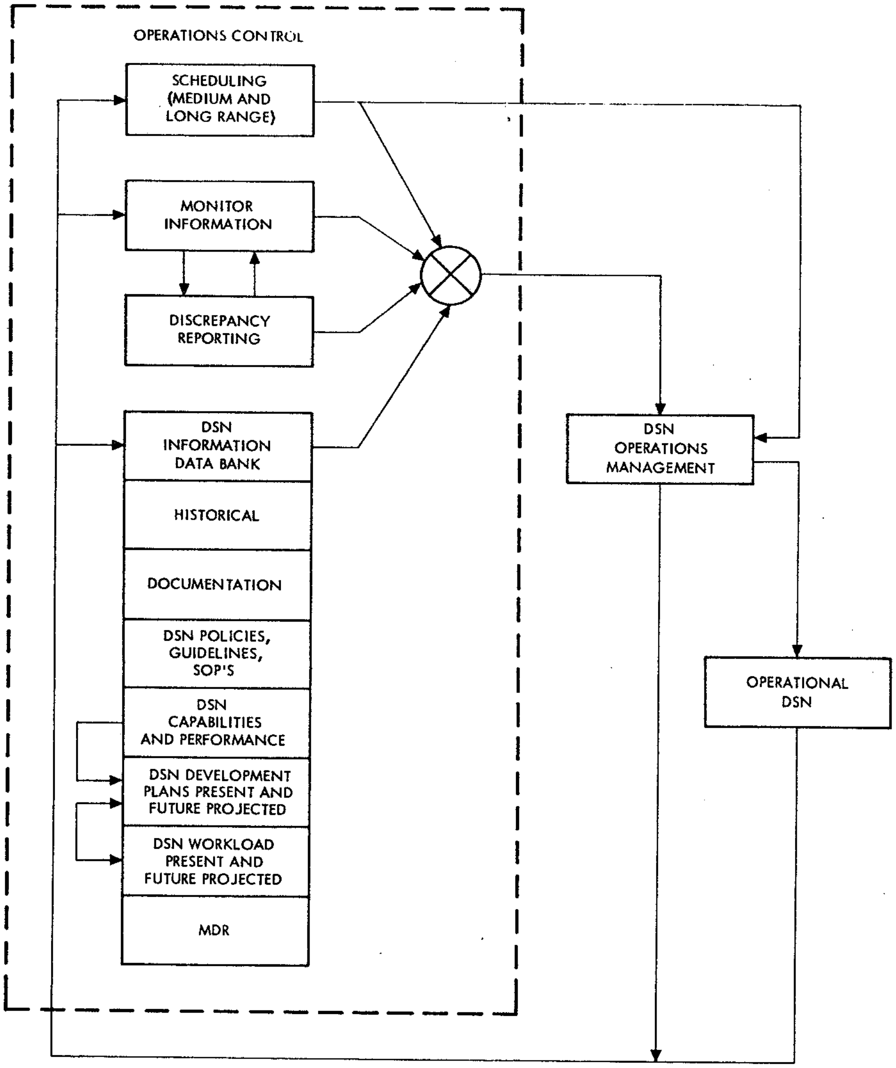


Fig. 15. DSN operations control functions, nonoperational structure

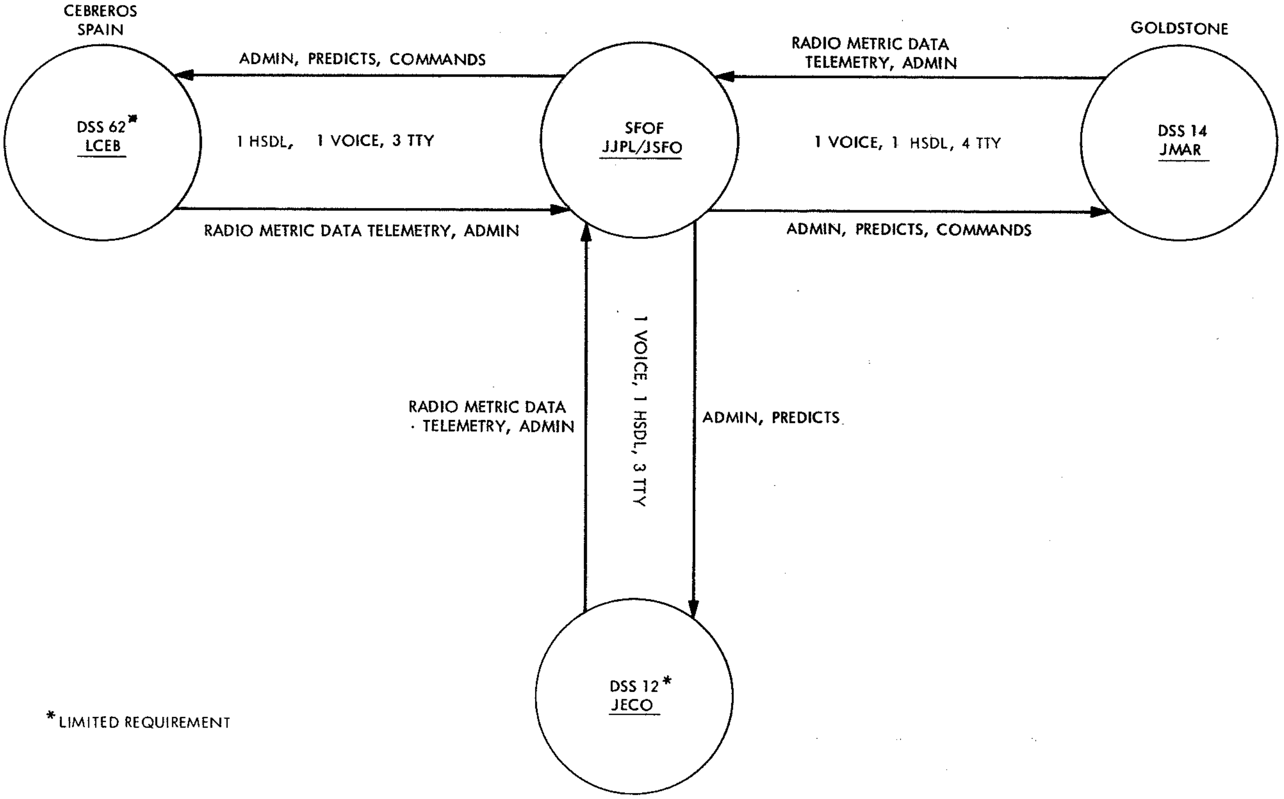


Fig. 16. Mariner Mars 1969 extended operations DSN GCF-NASCOM circuit requirements

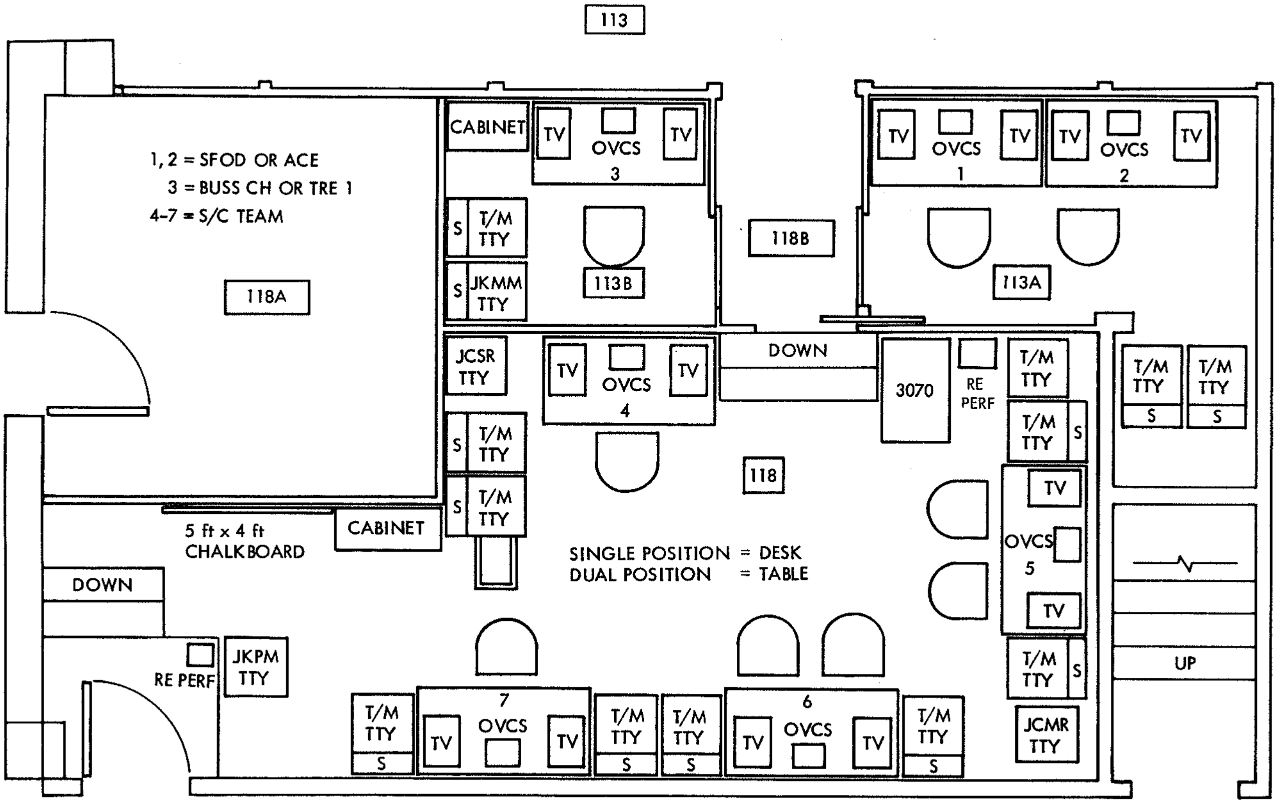


Fig. 17. Combined Pioneer/Mariner Mars 1969 extended operations MSA

IV. FLIGHT SUPPORT

This section presents the significant items that formed the constraints for operations not considered routine and changed the usual mode of operation, the tracking activities, and the verification tests conducted during the mission.

A. Operational Conditions

The following factors affected DSN support during the mission: spacecraft condition, marginal telecommunications performance, and equipment modification. These factors interacted with each other and affected the tracking schedule, spacecraft configuration, and DSN configuration.

1. Spacecraft condition. Initially, the contributing spacecraft problems were (1) the Mariner 7 battery was dead; (2) the Mariner 6 battery had about 10 h of usable life and could not safely be recharged; (3) the Canopus sensor on Mariner 7 had failed, requiring gyro control of roll position; and (4) solar panel output had degraded approximately 12% since launch. These problems, coupled with spacecraft position and the planned DSS 14 downtime, restricted the two spacecraft to the configuration plan in Table 5.

In mid-December 1969, it was determined that pointing the Mariner 6 high-gain antenna (HGA) toward earth caused an undesirable effect on the orbit. As a result, further HGA pointing maneuvers were eliminated from the plan except for the spacecraft engineering experiments performed near the end of the mission. In addition, it was found that the spacecraft power estimates were conservative, and Mariner 6 TWT high power could be used earlier than planned. On Mariner 6, TWT high-power mode was tested on March 6, 1970, and used during the solar eclipse on March 7 and thereafter. Plan option 1 was used for Mariner 7 with the switch to TWT high power occuring early on April 29, 1970.

Throughout most of the mission, both spacecraft were roll-stabilized by gyro control because of Canopus sensor deterioration. Roll position for the spacecraft engineering experiments was determined by the HGA radiation patterns.

2. Trajectory characteristics. After successfully completing close encounters with Mars, the two Mariner spacecraft gained energy so that they were in solar orbits with perihelion distances significantly greater than earth aphelion distance. Though not primarily designed as Mars swingby missions, the trajectories were fairly efficient in this respect. If Mars had been a massless planet, and an impulsive maneuver had been done to change the pre-encounter orbits into the resulting post-encounter orbits, the velocity requirements would have been 1.584 km/s for Mariner 6 and 1.446 km/s for Mariner 7.

Table 6 summarizes the postencounter trajectory parameters. Both orbits have periods of approximately one and three-quarter years, and solar conjunctions occur nine and one-half days apart at the end of April and beginning of May 1970. During near-solar conjunction, it was possible to perform an extremely sensitive test of the general relativity theory by measuring the effect of the sun mass on radio signals transmitted from the spacecraft.

Figures 18 and 19 show a heliocentric view of the orbits of the earth, sun, and the spacecraft. Near the time of conjunction, maximum probe-earth distance is attained so that maximum free space attenuation of signal strength occurs. The low-gain antenna (LGA), which always points towards the sun in cruise configuration, also points towards the earth at this time. Since the HGA axis makes an angle of 41.6 deg with the LGA axis, it would be necessary to reorient the spacecraft in order to increase received signal power by transmitting with the HGA.

3. Telecommunications performance predictions. Mariner telecommunications performance predictions were based upon actual performance characteristics of the DSN stations, the spacecraft transmitting and receiving characteristics, and the latest trajectory estimates. To provide a comprehensive, logical method of handling numerous variables involved in defining spacecraft and ground station parameters, design control tables (DCT) were generated for specific operating conditions and ranges.

Although the DCTs provide an accurate representation of expected performance, the tables essentially deal with static situations, whereas real situations present dynamic conditions involving time-varying quantities such as trajectories, spacecraft orientations, operational modes, ground station antenna elevation angles vs time, etc. A communications predict program (CP2M) was used to allow inputting of this information and outputting the predicted performance parameters of interest for any point in time. It is from this output that the extended mission performance curves were derived.

A discussion of the primary link performance parameters is given in the following paragraphs, with emphasis on the implications as applied to the extended mission objectives.

Uplink carrier levels depicted for Mariner 6 and 7 were those total power levels present at the input to the radio frequency subsystem (RFS). In Fig. 20, carrier levels are plotted assuming no modulation was applied. A -2.50 dB correction was required when command modulation was on, and a -9.0 dB correction was required for ranging modulation.

The downlink signal level plots of Figs. 21 and 22 depict carrier levels present at the ground station maser input with the spacecraft in cruise telemetry mode and ranging channel off. When the ranging channel was on, a correction of -0.9 dB was added regardless of the presence or absence of ranging modulation.

At DSS 14 and DSS 62, 3-Hz tracking loops were installed. For DSS 62, with a nominal zenith system temperature of 44°K, receiver threshold occurred at 176.7 dBmW. For DSS 14, at 29°K, threshold occurred at -178.5 dBmW. Marginal doppler tracking data acquisition occurred over the 26-m stations when the spacecraft was transmitting over the LGA.

Command performance was presented in terms of margin above a ST/N_0 of 16.5 dB in the command bit detection bandwidth. This corresponded to a bit error rate equal to 1×10^{-5}. Adequate margin existed throughout 1970. Figure 23 illustrates command margin vs date for Mariners 6 and 7.

Telemetry performance predicts assumed the spacecraft was in cruise telemetry mode at a bit rate of 8-1/3 bits/s. An error rate of 5×10^{-3} corresponded to an ST/N_0 of 5.2 dB. If the ranging channel was on, -0.9 dB was added to the predictions. Figures 24 and 25 illustrate telemetry SNR vs date for Mariners 6 and 7.

Ranging performance was presented in terms of ranging signal power level at the receiving station maser input for the planned operational configurations. Figures 26 and 27 illustrate code acquisition times for probability of error of 0.1 and 0.01, respectively. Figures 28 and 29 illustrate planetary ranging levels vs date for Mariner 6 and 7.

4. Equipment changes.

a. 400-kW transmitter. On April 22, 1970, the 400-kW transmitter was used for the first time, operating successfully at a nominal 200 kW. Power levels above this have not been used because of potential cooling problems. The increase to 200-kW, a 10-dB improvement over the 20-kW transmitter, was reflected directly in the downlink ranging power. The 400-kW transmitter performance characteristics are as follows:

(1) RF power output: 40-kW nominal, +86 dBmW ±0.45 dB under saturated conditions.

(2) Bandwidth: -10 dB points, 25 MHz minimum (12.5 MHz each side of center frequency).

(3) Method of modulation: Drive frequency, phase, amplitude, double- and single-sideband suppressed carrier.

(4) Linearity: ±10% from zero to 50% of maximum saturated power output.

(5) Coolant water flow (liter/min):

Main loop	1500
Alidade loop	1500
MG clutch loop	90
Auxiliary heat exchanger	265

(6) Input power requirements: 480 vac, 60 Hz, 3-phase; 2400 vac, 60 Hz.

Figures 30 and 31 show the major components of the 400-kW transmitter system.

b. Tricone installation. Mariner tracking operations were resumed by DSS 14 on March 2, 1970, following the scheduled downtime (January 25 to March 1, 1970) for control room reconfiguration and tricone installation. For passes before March 6, the S-band Cassegrain ultracone (SCU) was used. After March 6, the S-band megawatt transmit (SMT) cone became the standard configuration for Mariner tracking, with transmit power limited to 20 kW until installation of the 400-kW transmitter. Following is a brief description of the capabilities and limitations of the new multiple primary feed system or so-called tricone, illustrated in Fig. 32.

The tricone assembly is intended to increase the flexibility and improve the capabilities of the 64-m-diameter antenna at DSS 14 for tracking, data acquisition, and command of deep space probes supported by the DSN. The tricone assembly is also used for R&D activities.

The change of feed systems to a multiple feed cone was made to eliminate the excessive time required (approximately one day) for feed cone replacement. This cone replacement time had made the station inefficient in employing different feed systems for different missions.

The assembly provides three separate cones which can be selected and controlled by station personnel from the station control room. One cone, devoted entirely to R&D projects, is not covered by this discussion. The two cones for operational support are described herein.

The specific cone is selected by rotating the subreflector so as to focus RF signals into the appropriate feed horn. Signal flow paths to and from the control room are then switched to the selected cone. This process takes less than 70 s; the pacing item is the subreflector rotation. Most electrical configuration changes take less than 10 s.

Figure 33 is a basic block diagram of the equipment located in modules II and III of the tricone assembly (Fig. 32) and shows the interfaces with the cones and the receivers. Figure 34 shows the SMT cone used for MM69 extended operations.

The system noise temperatures for these cones are approximately 18°K in the low noise mode and approximately 26°K in the diplex mode. These low noise temperatures are primarily due to improved masers, short waveguide runs, improved diplexers, improved waveguide switches, and an improved feed horn design.

A summary of the capabilities and limitations of the SMT cone configuration (Fig. 34) follows:

(1) RCP polarization only.

(2) 400-kW diplexed capability.

(3) Can be used in low noise mode (no diplexer or transmitter).

c. R&D ranging. The R&D ranging system used for MM69 extended operations was called the "Mu" ranging system. This system was used operationally for the first time on this mission.

The system will operate at very weak signal levels without sacrificing accuracy. The design employs up to 18 sequentially transmitted square-wave components with periods from 2 μs to 0.25 s. This system is open-loop and uses received doppler, properly scaled, to establish the incoming symbol rate. High-frequency digital logic, operating at decision rates on the order of 6 ns, is used for implementation.

Figure 35 is a simplified block diagram of the ranging system interface with the DSS receiver/exciter and TCP subsystem. The Mu ranging system (Fig. 36) uses the ×3 output from the exciter to generate both the range modulation in the transmitter coder and the receiver code in the receiver coder. The range modulation is used to phase-modulate the uplink power to the spacecraft. The spacecraft transponder receives and retransmits the ranging modulation to the DSS receiver. The DSS receiver output to the ranging system is the 10-MHz carrier with the ranging code shifted by doppler. The ranging system requires the 10-MHz reference from the receiver for detection of the ranging code. The UHF doppler from the doppler extractor serves to modify the receiver coder frequency. This is necessary to maintain coherence between the received code from the spacecraft and the locally generated receiver code.

Before a ranging operation, the receiver coder generates a receiver code without a doppler input, and the transmitter and receiver codes operate in synchronism. During ranging, the receiver coder is shifted by the UHF doppler and the received code may be correlated with the receiver code. The ranging process is accomplished by shifting the phase of the receiver code until correlation between the codes is achieved. The amount of phase shifting required is a measure of the spacecraft range.

The period of the square-wave range code modulation determines the system resolution. In the Mu ranging system, up to 18 different code components may be generated. The highest-frequency component yields the greatest resolving power. The frequency of the code components is a function of the DSIF exciter frequency and is given by

$$f_n = \frac{3f_{exc}}{64 \times 2^n}$$

where

f_{exc} = the DSIF exciter frequency

n = the code component number

The highest-frequency component is then the first and has a resolution of 285 m.

Performance of the Mu ranging system is such that satisfactory range data have been obtained at downlink ranging powers of less than -200 dBmW. This performance can be realized with a system temperature of 25°K and an integration time of 800 s, with a total acquisition time of 800 s for 10 components. For lower system temperatures and longer integration times, the capability of weak signal ranging is increased accordingly. The one fundamental requirement, however, of the Mu ranging system is that the DSIF carrier tracking loop must maintain lock.

d. DSS modifications. To prepare for MM71 support at DSS 14, it was necessary to remove the TCP from MM69 EO support on November 30, 1970. The special DSS 12/14 configuration shown in Fig. 11 was developed and tested in November 1970. The extensive effort required to prepare this configuration was warranted by high-activity MM69 EO spacecraft engineering experiments in December 1970. The following developments were involved in preparation:

(1) MM69 software modification for the previously updated DSS 12 TCP wideband HSD I/O unit.

(2) SCA procedures and data tapes to simulate MM69 EO science and engineering data for use in addition to the MM69 EO telemetry simulator.

(3) TCP program verification test procedures to test the modified TCP software at CTA 21 and DSS 12.

(4) Several telemetry data flow tests using CTA 21, DSS 12, DSS 14, and the SFOF.

e. SFOF computer support. Also in preparation for MM71, changes in the computer configuration in the SFOF were required. By negotiating with the MM69 EO Project and others, it was determined that the IBM 7044 and 7094 could be removed from support following the scheduled track on December 21, 1970. For the period December 21 to December 31, 1970, the following constraints to the normal operations were imposed:

(1) Processing of HSD was not available. TCP TTY raw data were available in the SFOF for Project spacecraft telemetry.

(2) Doppler data could not be handled in the SFOF in real-time, but were recorded for processing at a later time.

(3) Tracking predictions and orbit updates could not be generated.

(4) Real-time DSN telemetry system analysis was curtailed and telemetry data validation could not be accomplished.

(5) Real-time DSN tracking system analysis and metric data MDF status could not be accomplished.

Though this reduced support greatly reduced the ability of the DSN to rapidly detect and correct substandard performance, all tracking during this period was satisfactory.

f. GCF modifications. Two significant GCF modifications were made during MM69 EO. First, a revised scheme for distributing mission-oriented TTY traffic within the SFOF was implemented by GCF operations on March 4, 1970. The old method of routing and display within user areas at SFOF followed the standard DSN TTY channel utilization plan. This convention resulted in user viewing of quasi-discrete DSS TTY channels. It was necessary that the user know the utilization of each channel in order to view a specific message/data type. The user was then required to correlate the appropriate channel with the assigned TV/TSS (teletype switching system) selector button number on the GCF TTY status display. TTY channel TV/TSS selector button number correlation was not static and, in fact, would change on a daily basis (if not more frequently), depending on the display load. From a user viewpoint, this was the most undesirable aspect of the old display method.

Although effective, past methods did not always ensure a one-to-one correspondence between identity of traffic received by the CP and identity of preamble switching instructions provided to the CP. In addition, distribution and display of TTY traffic at the SFOF required correction in near-real-time and did not always meet user requirements.

Feasibility studies were made to determine both the message/data types expected from any combination of DSS and spacecraft and the desired distribution of such traffic at the SFOF. These studies indicated that such actions were not only feasible but highly desirable.

The new method discarded the previous convention of displaying DSS TTY channels. User attention was then directed to specific TV/TSS selector button number assignments keyed to message/data type. As a result, the user no longer had to correlate between TTY channel and selector button. Also, the GCF TTY status display was changed to assume a more coherent role in depicting nontelemetry data display. Display of TTY-formatted telemetry data was handled by the SFOF TTY TLM buss, which contained DSIF TLM, MM69 EO TLM, DSN TLM, and Pioneer Ames routing indicators.

The TTY equipment within the SFOF was reconfigured to be compatible with this new method and consisted of two 36-button TTY selector busses and various discrete routing indicators, all driven by the CP. Discrete routing indicator teleprinters were provided to satisfy specialized routing requirements of DSIF, GCF, and DSN system operations analysis.

Implementation was accomplished without major problems; the new method continued to be functionally responsive to daily TTY data routing and display requirements. MM69 EO was the first flight project with on-going mission operations at SFOF to use this new method.

The second major modification was that special provisions for display of R&D ranging data were made. The Mu ranging data in TTY format became available from DSS 14 as a result of DSIF engineering efforts that were completed late in March 1970. Before that time, Mu ranging points were available on-site only and had to be voice-relayed in real-time to DSIF Control at the SFOF. To improve this situation, the following GCF capability was provided to obtain real-time transmission of ranging points to the SFOF:

(1) A spare TTY circuit was used from DSS 14 to SCTS via DSC 10; this circuit did not interface the GCF CP at SCTS because a NASCOM header routine was not available within the computer that processed the ranging data at DSS 14.

(2) The spare TTY circuit was then patched into a spare channel of the GCF TTY buss to provide distribution and hard copy within the SFOF.

(3) A TTYA reperforator was slaved to one of the GCF TTY buss teleprinters located in the joint MSA to provide punched paper tape records of the ranging points.

The GCF capability for R&D ranging data display was committed for the remaining portion of the mission only. It is mandatory that the Mu ranging DSIF TCP program be modified to provide NASCOM TTY header capability for support of future flight projects.

B. Tracking Coverage

The extended operations tracking coverage was provided generally in accordance with the requirements, using DSSs 12, 14, and 62. Table 7 summarizes the coverage provided during the extended operations mission to its conclusion on December 30, 1970, including the interim period of November and December 1969.

At Robledo, Spain, DSS 62 was used to transmit commands to the spacecraft necessary to update the central computer and sequencer (CC&S) and prepare the spacecraft for the tracking pass by the 64-m station. In March, the command link threshold was reached for Mariner 6; in April, the threshold was reached for Mariner 7. Since the spacecraft could no longer be commanded from a 26-m antenna station, DSS 62 was no longer used.

Following January 25, when the DSS 14 was taken out of service for the installation of the tricone feed structure and the 400-kW transmitter, tracking was feasible only at DSS 12 through the use of a specially prepared low-noise feed cone on the 26-m antenna. This special cone could be switched into either a listen-only mode or a diplex mode with cone temperatures of 24 and 17°K, respectively. Using a 3-Hz loop bandwidth in the listen-only mode, the spacecraft signal was received satisfactorily at -174 dBmW; usable two-way doppler data were obtained. In the diplex mode, the receivers were in lock only about one data point out of three. Periods of two-way doppler data were, therefore, obtained by turning on the ground transmitter for about 40 min, or 1 RTLT, and then turning it off a few moments before the signal arrived back from the spacecraft. Usable two-way doppler data were obtained for the length of time the transmitter was on. This process was repeated in a checkerboard pattern, providing about six periods of good data per tracking pass. Although telemetry data was only about 0.5 dB above threshold, the subcarrier demodulator assemblies were able to be locked up; the data were quite noisy, producing about one error in 10. Nevertheless, some insight into the spacecraft condition was maintained through analysis of this data.

This mode of tracking continued until the return of DSS 14 to service about March 1, 1970. During this time, no commands were sent to the spacecraft. Ranging data were not received after January 25, since that equipment is operable only at DSS 14.

After the superior conjunction on April 29 and May 10 for Mariners 6 and 7, respectively, the amount of tracking coverage was reduced in accordance with the requirements. The data became less noisy, and the generation of ranging data and good two-way doppler data resumed a routine nature.

In December 1970, a special DSS 12/14 configuration was used to conduct the special spacecraft engineering experiments. The support for these experiments and other special constraints on operations during the entire tracking coverage for the extended operations mission are presented in the following discussions.

1. DSS 12 support during DSS 14 scheduled downtime. DSS 14 was down during the entire month of February 1970 for control room reconfiguration and tricone installation. It had been planned to provide Mu-machine ranging support and command capability from DSS 11 during this period by pointing the HGA toward earth, with telemetry data received by DSS 12 in an ultracone/ listen-only mode. However, the MM69 EO Project decided not to perform ranging from DSS 11 in order to conserve the Mariner 6 spacecraft battery for possible use later in the mission.

The plan to obtain two-way doppler data from DSS 62 during the DSS 14 downtime period had to be abandoned because of inadequate downlink RF carrier performance margin. Even using the 3-Hz receiver tracking loop bandwidth configuration, the signals were too weak to lock onto. Therefore, it was necessary to use the ultracone/diplex capability at DSS 12 to obtain the two-way doppler data needed to offset lack of ranging data during this period.

Because of excessive noise in the DSS 12 doppler data from passes on February 2 and 4, 1970, it was decided to run an uplink test with Mariner 6, using both DSS 11 and 12 on February 6, 1970. The objective of this test was to check the effects on the doppler data received by DSS 12 when DSS 11 was transmitting to the spacecraft at different power levels (40, 20, and 10 kW). This would also provide a comparison, between DSS 11 and DSS 12 transmitters, of noise induced into the doppler data when the stations alternately transmitted at 10 kW. Features of the test were:

(1) DSS 12 used the ultracone in listen-only mode until a time specified for switching to diplexing.

(2) DSS 11 used a nonstandard configuration and tuning procedure for phasing together and operating the two 20-kW transmitters.

(3) The conditions for the desired uplink power were:

Total power, kW	Transmitter 1, kW	Transmitter 2, kW	Remarks
40	20	20	Transmitters phased
20	10	10	Phased, drive reduced
10	20	0	Increased transmitter 1 drive before reducing transmitter 2

(4) With DSS 11 transmitting, DSS 12 three-way doppler data were good (ultracone in listen-only mode). It was also determined that the DSS 12 two-way doppler data with the diplexer off were as good as the three-way data at 10 kW. With the diplexer on, the doppler data were excessively noisy when either station transmitted at 10 kW.

The results of the test described above led to the adoption of a checkerboard tracking pattern, an operational innovation that enabled reception by DSS 12 of 1 RTLT (about 43 min) of good two-way data in the listen-only mode, alternated by about 50 min of one-way data received while transmitting to the spacecraft in the diplex mode. This checkerboard tracking pattern (Fig. 37) greatly increased the number of good data points and reduced noise in the data received by about 70%. The receiver was out of lock less than one-tenth as often as formerly.

In addition, each spacecraft was tracking approximately half a pass during each view period, and the order of tracking was alternated on each pass. This made it possible, in two tracking periods, to obtain for both spacecraft the full sine-wave effect on the doppler data of the earth's rotation. Furthermore, the sequence of events was designed to meet the following requirements of the principal investigator:

(1) Generate as much two-way doppler data as possible above 17 deg elevation at beginning and end of track.

(2) Generate one block of two-way doppler data beginning near zenith of track.

2. Quadripod effect. It was recognized from previous experience during the Mariner 4 solar occultation (Ref. 3) that the proximity of the sun to the DSS 14 antenna beam caused significant increases in system noise temperature (SNT). This temperature was monitored periodically during superior conjunction from April to May 1970. Predicted SNT was used during this period to influence the choice of operating time for each spacecraft during a given day. Specifically, it

was known that, although the feed radiation patterns of the antenna are very highly rotationally symmetric, the presence of the quadripod feed support members introduces secondary radiation pattern ϕ dependence. Figure 38 shows the 64-m-antenna reflector with the 30-deg quadripod geometry employed; Fig. 39 shows the coordinate system with LSEP (sun-earth-probe) equal to θ. Tables 8 and 9 show the predicted times of the quadripod effect for Mariners 6 and 7 respectively.

3. Operational ranging sequence, Mariner 6. As indicated previously, ranging on Mariner 6 was over the HGA during certain phases. When the HGA was employed for ranging, the spacecraft was maneuvered to point the boresight of the HGA at earth. The ground commands and CC&S events necessary to accomplish the maneuver are shown in Fig. 40. A description of this operational ranging sequence follows.

Initially, from DSS 62 several commands are transmitted to precondition the spacecraft for the DSS 14 pass. When this spacecraft preconditioning is achieved, a maneuver can be initiated at any time by DC-32. The transmit time for DC-32 will be chosen such that the spacecraft turns will be completed and the HGA pointed at earth just at DSS 14 rise.

When DC-32 is received at the spacecraft, a computer-only maneuver is initiated, and the CC&S issues the M1 command to turn on the gyros. From this point to the end of the maneuver (sun and Canopus reacquisition signal), the spacecraft position is under the functional control of the CC&S. A 60-min gyro warmup period follows, which permits the gyros to come up to the operating temperature at which the commanded spacecraft turn rates are known.

The M2, M3, M4 events are issued, followed by M4 150 ms later. This produces a zero-pitch turn, and the spacecraft remains stationary. These events are required by the relay logic of the CC&S.

A 3-min wait permits a reading (at 8-1/3 bits/s, if telemetry is available) of channel 220 (a spacecraft event counter), from which the timing of the turn is established to 1.6 s resolution.

Next, the M3 (if the turn is positive), M5 events are issued, which starts the first roll turn; an $\overline{\text{M5}}$ event terminates the first roll turn. Then a 3-min wait, a pitch turn, a 3-min wait, and the second roll turn complete spacecraft positioning. The HGA is now pointing at earth.

At the end of the second roll turn, a DC-11 arrives at the spacecraft, placing the spacecraft transmitter on the HGA. Ranging data become available on the ground OWLT later.

Acquisition of ranging data continues until the DC-10 command switches downlink transmission to the LGA.

A DC-13 3 min after DC-10 is shown as an option to end the maneuver and reacquire the sun and canopus. Otherwise, M1 issued by the CC&S will perform the reacquisition.

4. Operational support of spacecraft engineering experiments. Several spacecraft engineering experiments (Table 10) were planned by the Project for as late in the mission as possible in order not to significantly impact primary mission objectives. The experiment that required maximum DSN effort was the second maneuver/motor burn with associated experiments of each spacecraft. Additional support requirements are listed in Table 11. The level of activity is indicated by the number of commands transmitted during this period. A total of 686 commands were transmitted to both spacecraft from November 30 to December 30, 1970.

5. Scheduling. Two major scheduling problems occurred during the extended operations mission, both involving DSS 14. The first concerned Apollo 13 during the period April 11-17, 1970. The high priority of Apollo in the past had traditionally eliminated any competition for DSS 14 support. Through the special efforts of the DSN scheduling office, a schedule was developed where MM69 EO was able to share DSS 14 with Apollo 13 at the loss of only two passes of a daily tracking requirement during critical lunar activities. The plan was approved by both Projects and was effective until the Apollo 13 anomaly, which significantly changed flight plans and requirements, resulting in the deletion of one MM69 EO pass.

The second problem was a scheduling impact in the mercury bi-static radar (R&D tracking) experiment which occurred during the solar conjunction period of MM69 EO with a nearly coincident view period. A block of time was allocated to both projects. After the MM69 EO Project had gotten a minimum amount of good ranging, the station was turned over to the Mercury experiment and back in real-time.

The tracking schedule for November and December 1970 was altered to allow further R&D tracking (Venus radar) and to accommodate Pioneer solar occultation experiments. The effect on MM69 EO was minimal in that, although the frequency and duration of the passes were changed significantly, the total tracking time remained about the same.

C. TCP Program Verification Tests

The following tests were conducted in November 1970 to verify the compatibility of the TCP program of Mariner Mars 1969 extended operations with the updated TCP configuration and to check out the DSS 14 telemetry data microwaved to DSS 12 for processing.

1. Preliminary compatibility test at CTA 21. The equipment and CTA 21 configuration for support of this test is shown in Fig. 41. The TCP operational program was to be used with the HSD routine overfill tape. The test was scheduled for November 13, but was cancelled because of TCP equipment problems.

2. CTA 21/SFOF data flow test. The configuration for support of this test is shown in Fig. 42. The CPS computer equipment at the SFOF and the SFOF configuration were as in standard 7044 computer operations for Mariner Mars 1969.

The test, which was conducted on November 16, was only partially successful because of a problem with the science data time tags using the 7044 Model 8 system. Also, the older (Model 7) system could not be loaded because of the removal of the 7044 status sense unit (SSU).

3. DSS 14/DSS 12/SFOF data flow test. This test, conducted at DSS 14 on November 20, 1970, during normal extended operations tracking, processed telemetry data in the TCP and microwaved SDA-3 and SDA-4 data to DSS 12 for dual processing. The test objective was to switch between DSS 14 and DSS 12 at the SFOF to verify that no data degradation was experienced at DSS 12. Both DSS 14 SDA outputs were processed at DSS 12 for certification.

Both DSS 14 and DSS 12 were configured for normal extended operations tracking, as shown in Fig. 11. The DSS 14 SDA-3 and SDA-4 outputs were routed to the intersite microwave equipment, which then transmitted the data to the TCD 1034 transfer rack and TCPs of DSS 12.

The test was repeated because the telemetry simulator at DSS 14 was inoperative and the DSS 12 SCA simulated telemetry backfed to DSS 14 via microwave check unsuccessfully. The repeats of the test were conducted on November 23, 25, 28, and 29, with the equipment and continuing telemetry simulation problems; however, all test requirements were completed.

Table 5. Mariner 6 and 7 configuration plan

Dates	XMT Antenna	HGA Pointing	TWT Power Mode	Gyros
Mariner 6				
11/3 - 12/16	HGA	Optimum	High	On
12/17 - 1/24/70	LGA	NA	Low	Off
1/25 - 3/1[1]	HGA	Optimum	Low	Off
3/2 - 7/31	LGA	NA	Low	Off
8/1 - 8/25	HGA	Optimum	Low	On
8/26 - 12/31	HGA	Optimum	High	On
Mariner 7 Option 1				
11/3 - 12/16	LGA	Na	High	On
12/17 - 5/9/70	LGA	NA	Low	On
5/10 - 12/31	LGA	NA	High	On
Mariner 7 Option 2 (Irreversible once adapted)				
11/3 - 12/16	LGA	NA	High	On
12/17 - 8/4/70	LGA	NA	High	Off
8/5 - 12/31	LGA	NA	High	On

[1] Assumed the use of DSS 11 for ranging during DSS 14 down time (see paragraph C.1.)

Table 6. Mariner postencounter trajectory parameters[1]

	Mariner 6	Mariner 7
Semi-major axis (km x 10^6)	216.57	210.43
Semi-minor axis (km x 10^6)	211.68	205.93
Period (days)	636.24	609.35
Longitude of ascending node (deg)	342.64	347.13
Argument of periapsis (deg)	203.54	173.08
Eccentricity	0.2113	0.2056
Inclination (deg)	1.78	1.82
Time of aphelion (GMT)	2/3/70 13:20	1/19/70 09:10
Aphelion distance (km x 10^6)	262.35	253.70
Time of solar conjunction (GMT)	4/30/70 01:20	5/9/70 13:50
Distance from Sun at conjunction (km x 10^6)	251.13	236.32
Distance from Earth at conjunction (km x 10^6)	401.96	387.07
Sun-Earth-probe angle at conjunction (deg)	0.95	1.79
Earth-Sun-probe angle at conjunction (deg)	178.48	177.06
Earth-probe-Sun angle at conjunction (deg)	0.57	1.16
Time of perihelion (GMT)	11/18/70 16:10	11/20/70 01:20
Perihelion distance (km x 10^6)	170.80	167.16

[1] Based on osculating conic at conjunction

Table 7. DSN coverage of Mariners 6 and 7

Month (1969-1970)	Tracking coverage			Deep Space Station	Transmitter power, kW	Remarks
	Mariner	Number of passes	Number of commands sent			
1969 Nov	6 7	9 10	46 158	12, 14, 62	20	Extensive commanding of Mariner 7 due to spacecraft anomaly
Dec	6 7	12 11	86 89	14, 62	20	
1970 Jan	6 7	13 12	13 8	14, 62	20	
Feb	6 7	9 11	0 0	12	10	DSS 14 out of service for tricone and high-retain power transmitter installation. Good two-way data obtained in the listen-only mode (transmitter off) for 1 RTLT (about 43 min), followed by about 50 min of one-way data received while transmitting to the spacecraft in the diplex mode
Mar	6 7	15 15	28 20	62 and 14	20	Tricone installation at DSS 14 completed. High-power transmitter not ready. Command by DSS 62 to conserve coverage time from DSS 14
Apr	6 7	22 19	174 0	62 and 14	200	High-power transmitter output limited to 200 kW. DSS 62 support discontinued March 18 for Mariner 7 and April 21 for Mariner 6; command link threshold reached. Mariner 6 superior conjunction on April 29
May	6 7	27 28	80 0	14	200	20-kW transmitter used on three days when high-power transmitter was down. Superior conjunction for Mariner 7 on May 10

Table 7 (contd)

Month (1969-1970)	Tracking coverage			Deep Space Station	Transmitter power, kW	Remarks
	Mariner	Number of passes	Number of commands sent			
Jun	6 7	15 16	3 49	14	200	20-kW transmitter used on three days
Jul	6 7	9 12	25 10	14	200	20-kW transmitter used on one day
Aug	6 7	10 10	0 0	14	200	
Sep	6 7	9 9	4 208	14	200	20-kW transmitter used on one day
Oct	6 7	9 11	299 19	14	200	20-kW transmitter used on four days
Nov	6 7	7 6	364 13	14	200	20-kW transmitter used on two days
Dec	6 7	8 9	446 160	12, 14	200	20-kW transmitter used on five passes. Special DSS 12/14 telemetry configuration used for all passes. Extensive commanding required by special spacecraft engineering experiments

Table 8. Predicted times of quadripod effect, Mariner 6

Local Date Apr-May	060° GMT Start 065°	060° GMT End 055°	0120° GMT Start 0125°	0120° GMT End 0115°	0240° GMT Start 0245°	0240° GMT End 0235°	0300° GMT Start 0295	0300° GMT End 305°
18	19:50	2000	13:50	17:10	After Set		After Set	
19					↓		↓	
20	19:42	19:54	14:20	16:15	↓		↓	
21					↓		↓	
22	19:35	19:48	14:40	16:00[2]	↓		↓	
23			14:55	15:40[1]	↓		↓	
24	19:20	19:34	Before Rise		↓		↓	
25			↓		↓		↓	
26	18:52	19:44	↓		↓		↓	
27	18:15	18:44	↓		↓		23:40	01:00[1]
28	13:30	18:00[3]	↓		↓		21:30	02:02[3]
29			↓		↓		20:28	20:46
30	Before Rise		↓		23:40	02:00[2]	19:55	20:10
1	↓		↓		22:24	02:00	19:34	19:48
2	↓		↓		21:02	21:44	19:20	19:36
3	↓		↓		20:46	21:15	19:12	19:28
4	↓		↓		20:22	20:54	19:05	19:22
5	↓		↓					
6	↓		↓		20:12	2030	18:44	19:04
7	↓		↓					
8	↓		↓		20:10	20:28	18:42	1900
9	↓		↓					
10	↓		↓		20:00	20:12	18:38	18:52
11	↓		↓					
12	↓		↓		19:50	20:02	18:34	18:44

[1] Some increase in T_{op} (90° to QUAD LEG comes within 3° to 4° of sun — doesn't sweep through it).

[2] Partial increase in T_{op} (90° to QUAD LEG comes within 4° — 5° of sun).

[3] Partial increase in two parts with fall off in center

Table 9. Predicted times of quadripod effect, Mariner 7

Local Date Apr-May	60° GMT		120° GMT		240° GMT		300° GMT	
	Start	End	Start	End	Start	End	Start	End
28	19:30	19:40			After Set		After Set	
29	19:25	19:35	14:40	16:40[1]	↓		↓	
30	19:22	19:32	Before Rise		↓		↓	
1	19:18	19:28	↓		↓		↓	
2	19:12	19:22	↓		↓		↓	
3	19:06	19:16	↓		↓		↓	
4	19:00	19:12	↓		↓		↓	
5	18:33	19:00	↓		↓		↓	
6	18:20	18:40	↓		↓		23:30	01:50[1]
7	17:45	18:15	↓		↓		22:50	01:40[2]
8	15:00	16:15[1]	↓		↓		21:12	22:50
9	15:30	19:40[2]	↓		↓		20:34	21:10
10			↓		↓		20:12	20:32
11	Before Rise		↓		↓		20:00	20:15
12	↓		↓				19:45	19:58
13	↓		↓		23:15	01:10[1]	19:35	19:48
14	↓		↓		22:50	02:00[2]	19:28	19:45
15	↓		↓		20:50	01:00		
16	↓		↓		20:45	21:50	19:22	19:34
17	↓		↓		20:22	21:12		
18	↓		↓		20:28	21:00	19:22	19:38
19	↓		↓					
20	↓		↓		20:10	20:25	19:12	19:24
21	↓		↓					
22	↓		↓		20:04	20:18	19:08	19:18

[1] Partial Increase — about 30% to 70%

[2] Some Increase — about 15% to 50%

These percentage estimates refer to percentage of a HIGH Top peak (disregarding baseline).

Table 10. Planned Mariner Mars 1969 extended operations spacecraft engineering experiments

Date	Activity
30 Nov	Mariner 6 preparation track for second motor burn Battery test Data storage subsystem conditioning HGA pointing maneuver Scan/science power turnon Playback test
2 Dec	Mariner 7 preparation track for second motor burn Determine Canopus cone angle and low-gate position
15 Dec	Mariner 7 second motor burn
16 Dec	Repeat Mariner 7 post-encounter battery test Command negative roll turnon Mariner 7
18 Dec	Mariner 6 second motor burn HGA pointing maneuver Motor burn Scan/science power on, UVS scan of motor burn plume Record science data on digital tape recorder
19 Dec	Playback Mariner 6 science data HGA pointing maneuver Spacecraft to playback one mode Step Canopus cone angle
20 Dec	Mariner 6 and 7 redundant element switch
21 Dec	Mariner 6 temperature control flux monitor calibration Mariner 6 derived rate Sun acquisition Mariner 6 pitch turn for power determination of battery share mode
23, 29, 30 Dec	Place both spacecraft in final state

Note: Not all experiments were completed because of schedule changes and operational sequences. Major changes are reflected in Appendix B.

Table 11. Mariner Mars 1969 extended operations, engineering experiment support requirements

Spacecraft Activity	DSN Support Requirement
1. HGA pointing maneuver (Roll position determined by HGA radiation pattern because of Canopus sensor problems on both spacecraft)	Special AGC calibrations and manual real-time AGC readout to Project during maneuver
2. Motor burn	33 1/3 bps engineering telemetry
3. Scan platform/science power on (Science instrument - primarily UVS - scan of motor burn plume)	66 2/3 bps science telemetry
3. Spacecraft to playback one mode (Playback recorded science data)	270 bps science telemetry

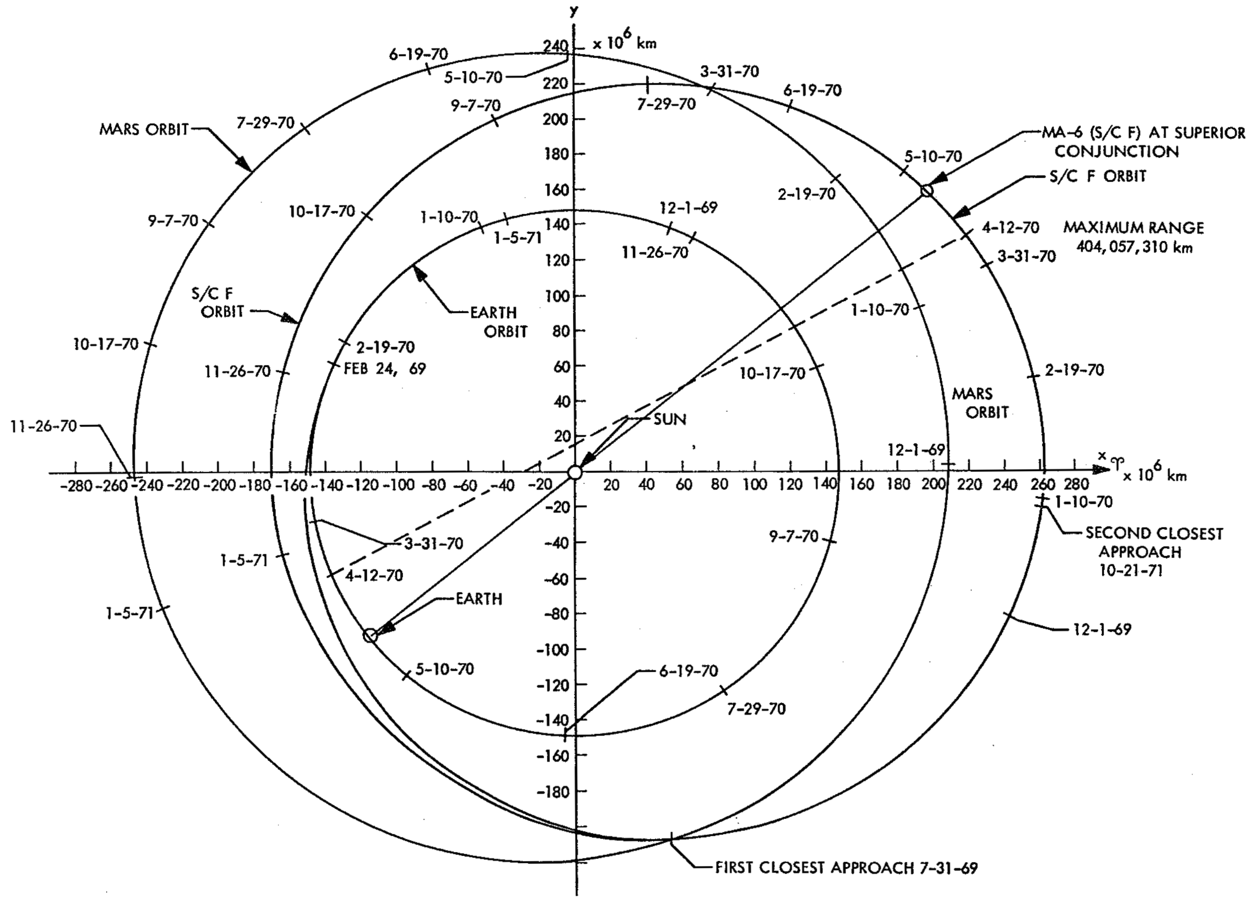


Fig. 18. Heliocentric view of Mariner 6

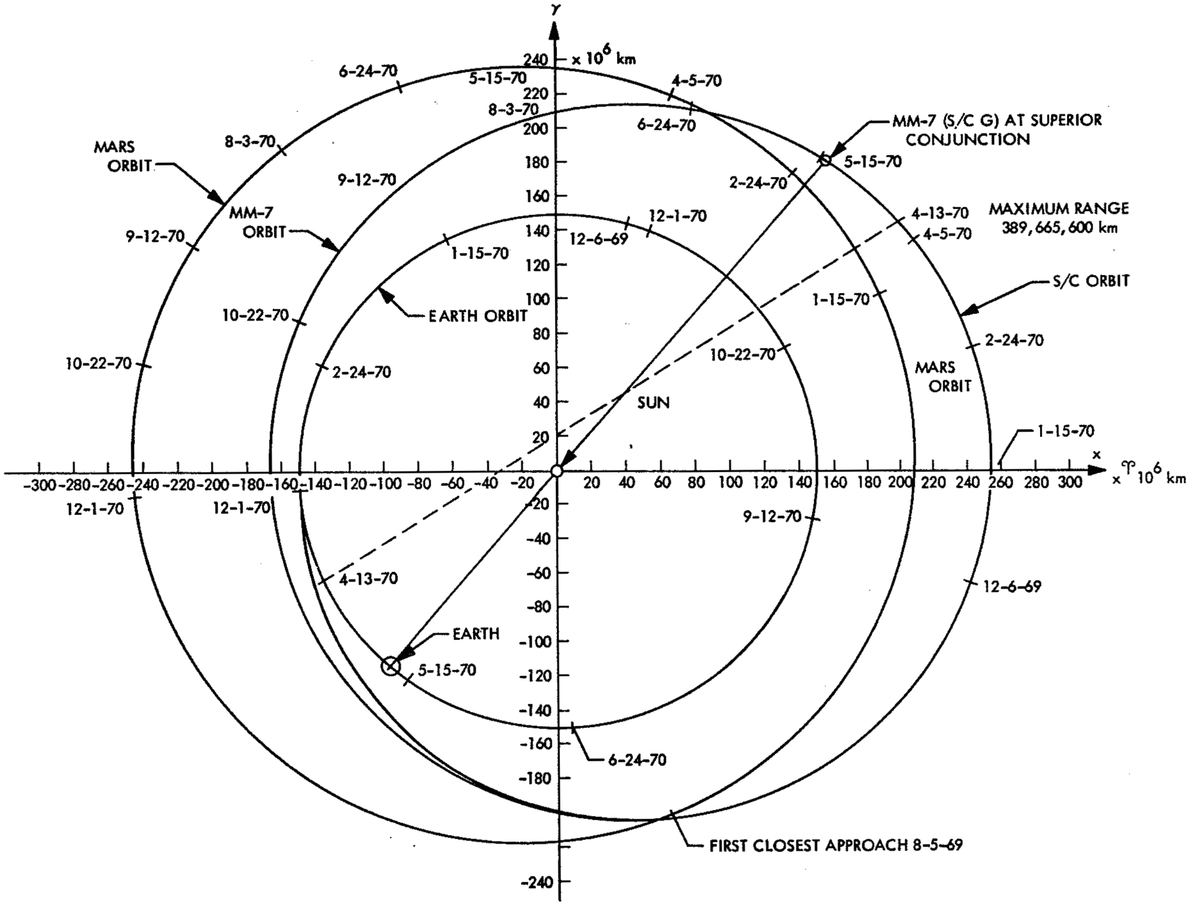


Fig. 19. Heliocentric view of Mariner 7

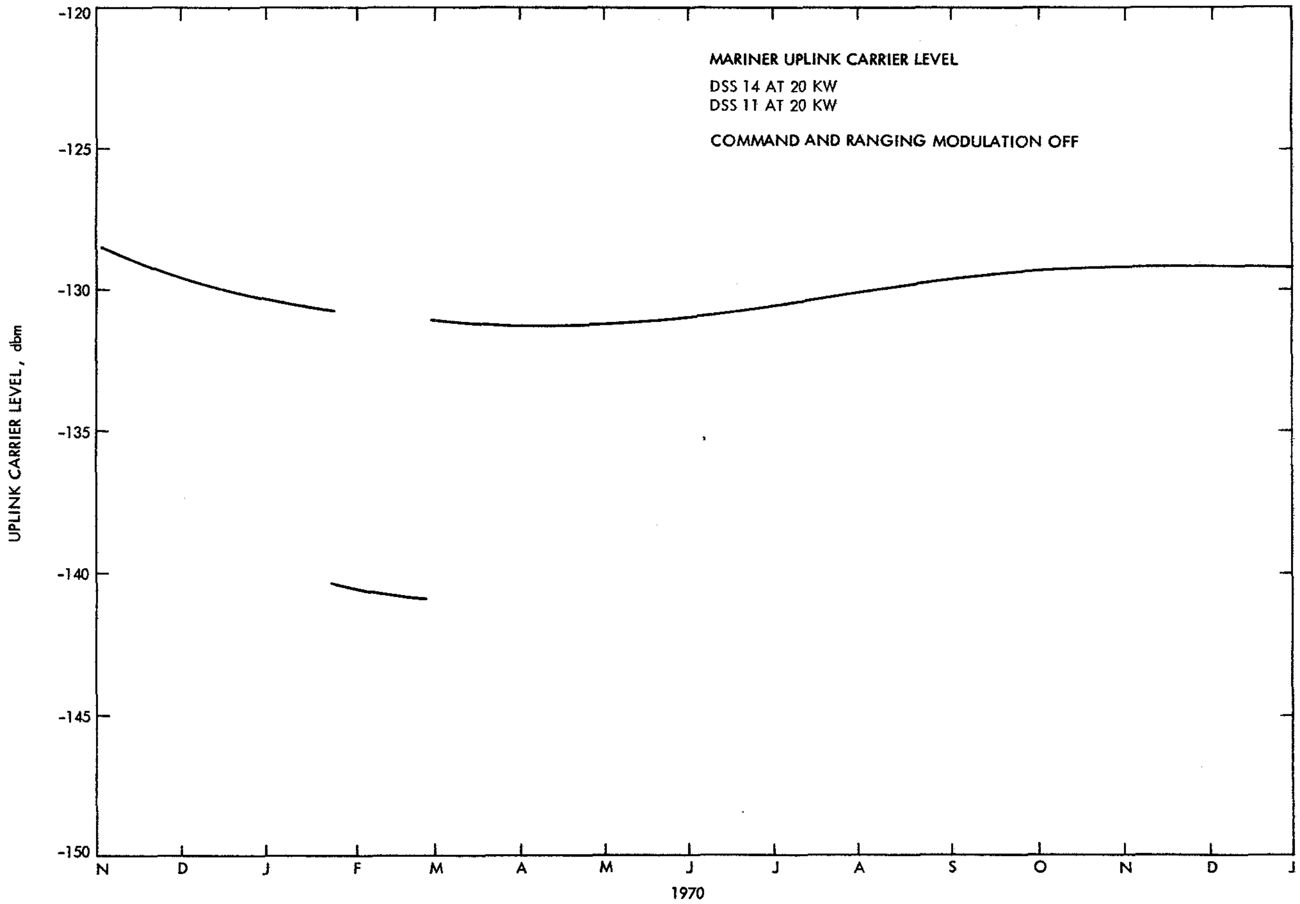


Fig. 20. Mariner 6 and 7 uplink carrier level

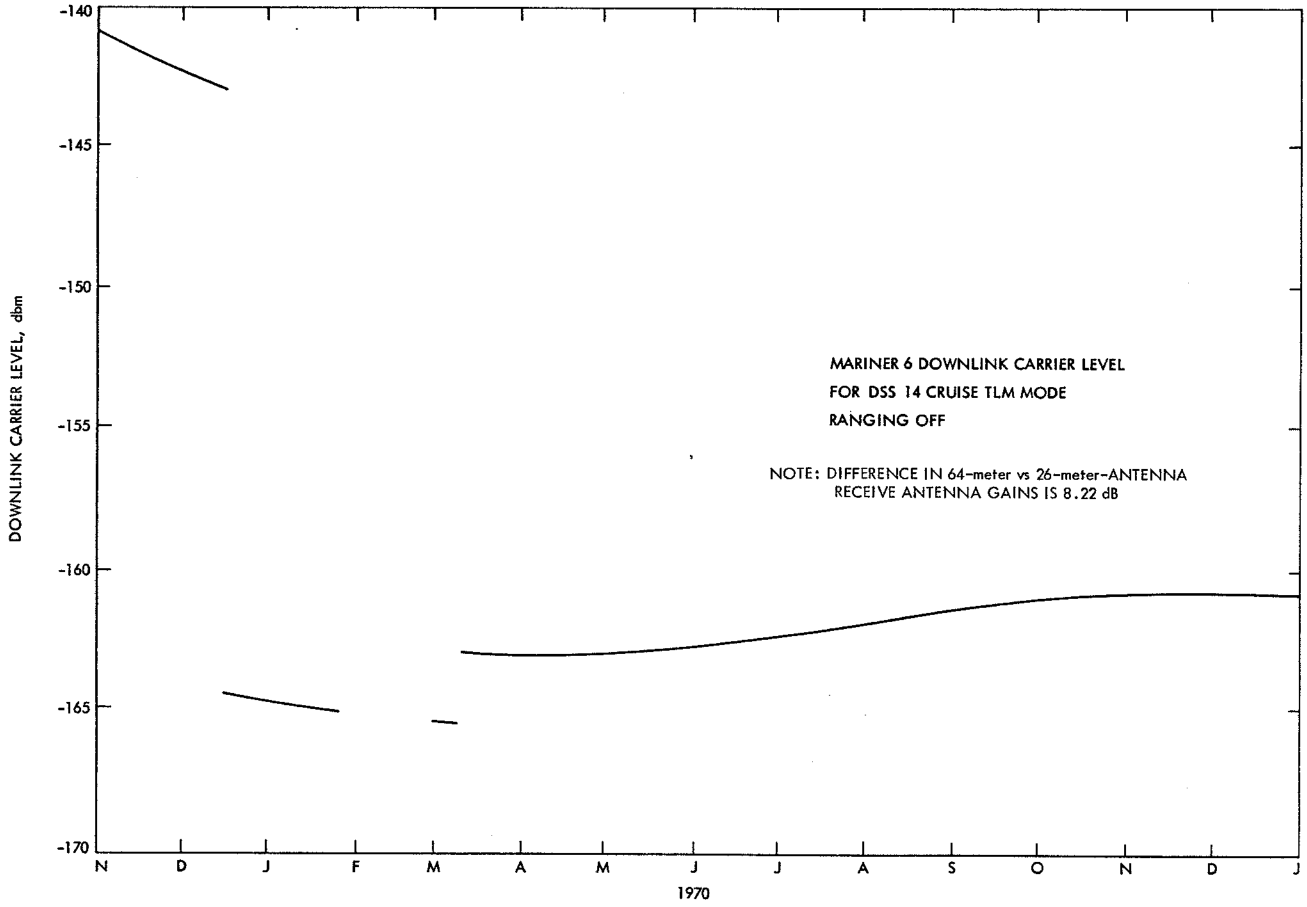


Fig. 21. Mariner 6 downlink carrier level

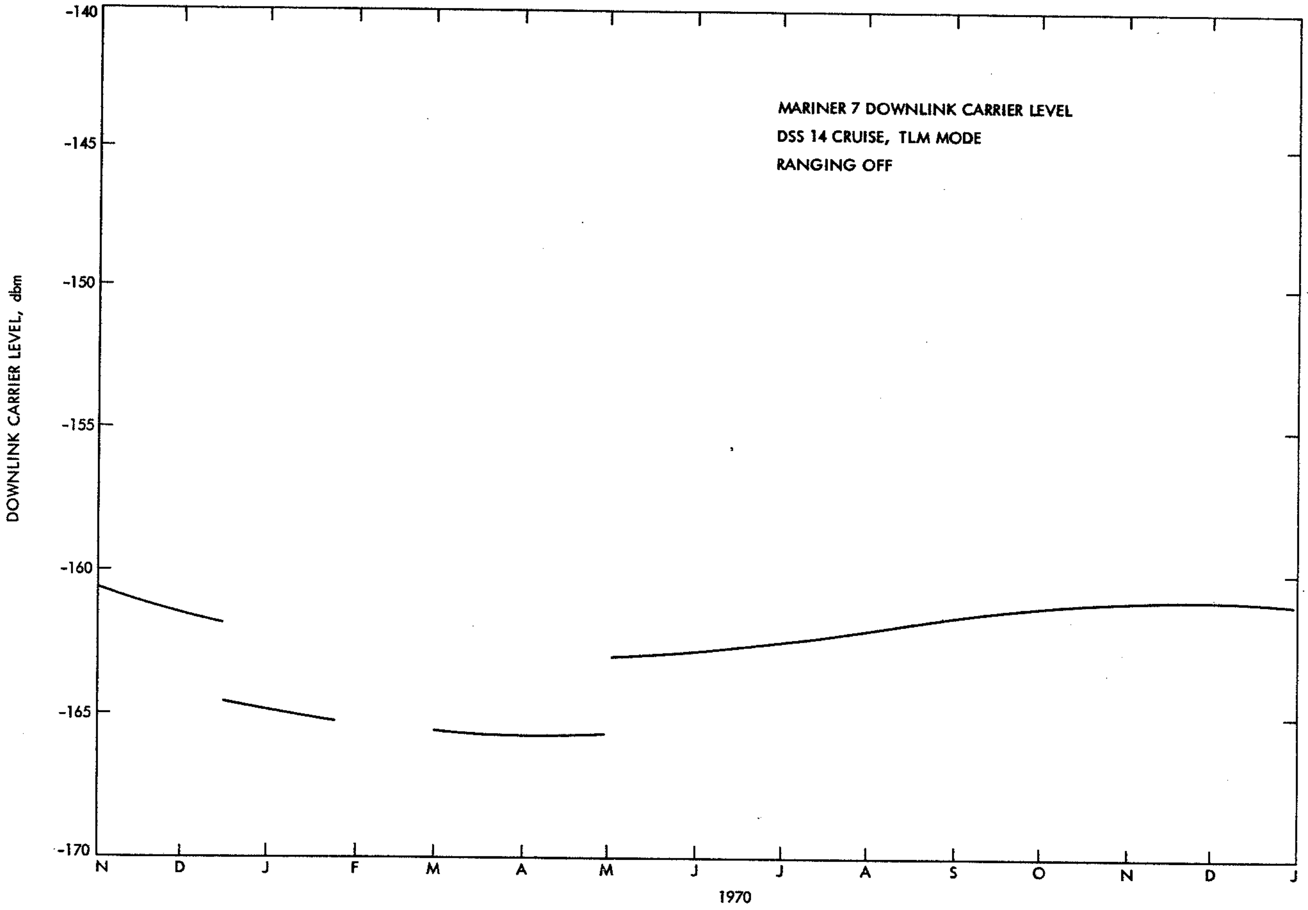


Fig. 22. Mariner 7 downlink carrier level

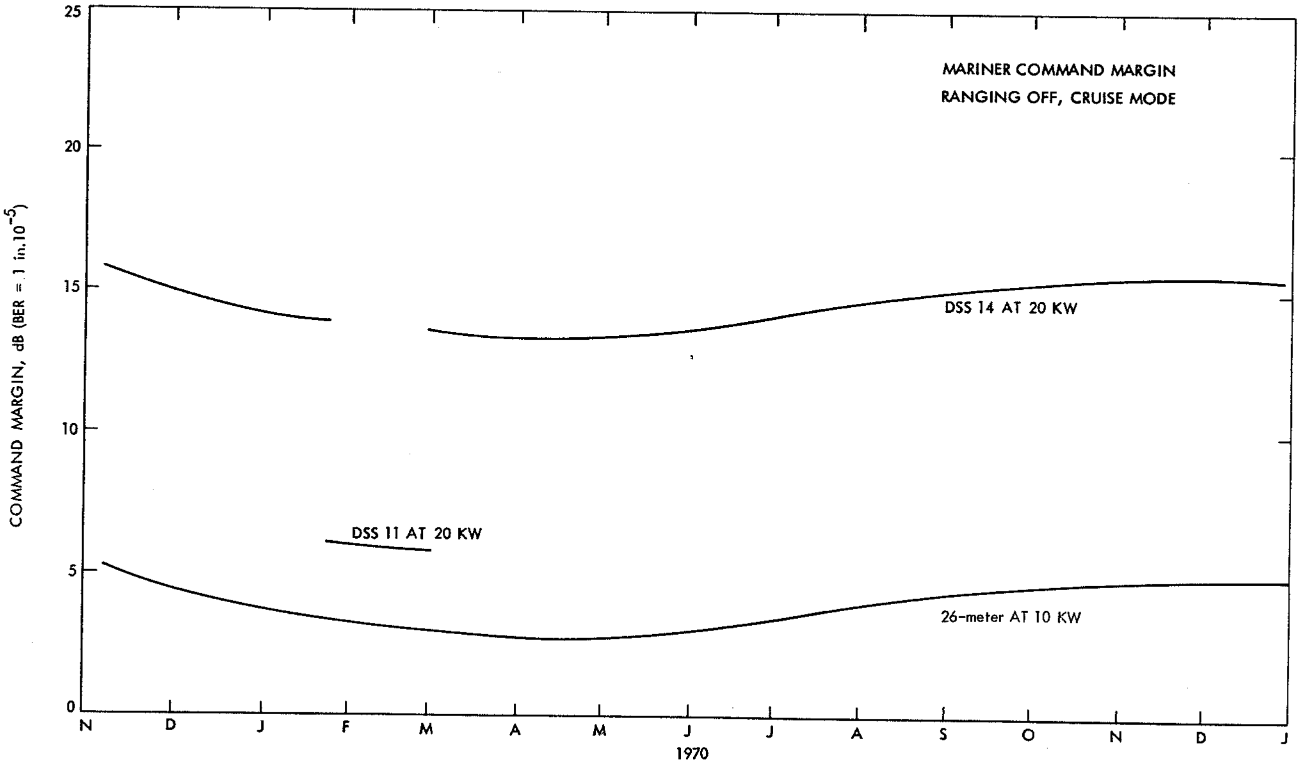


Fig. 23. Mariner command margin vs date

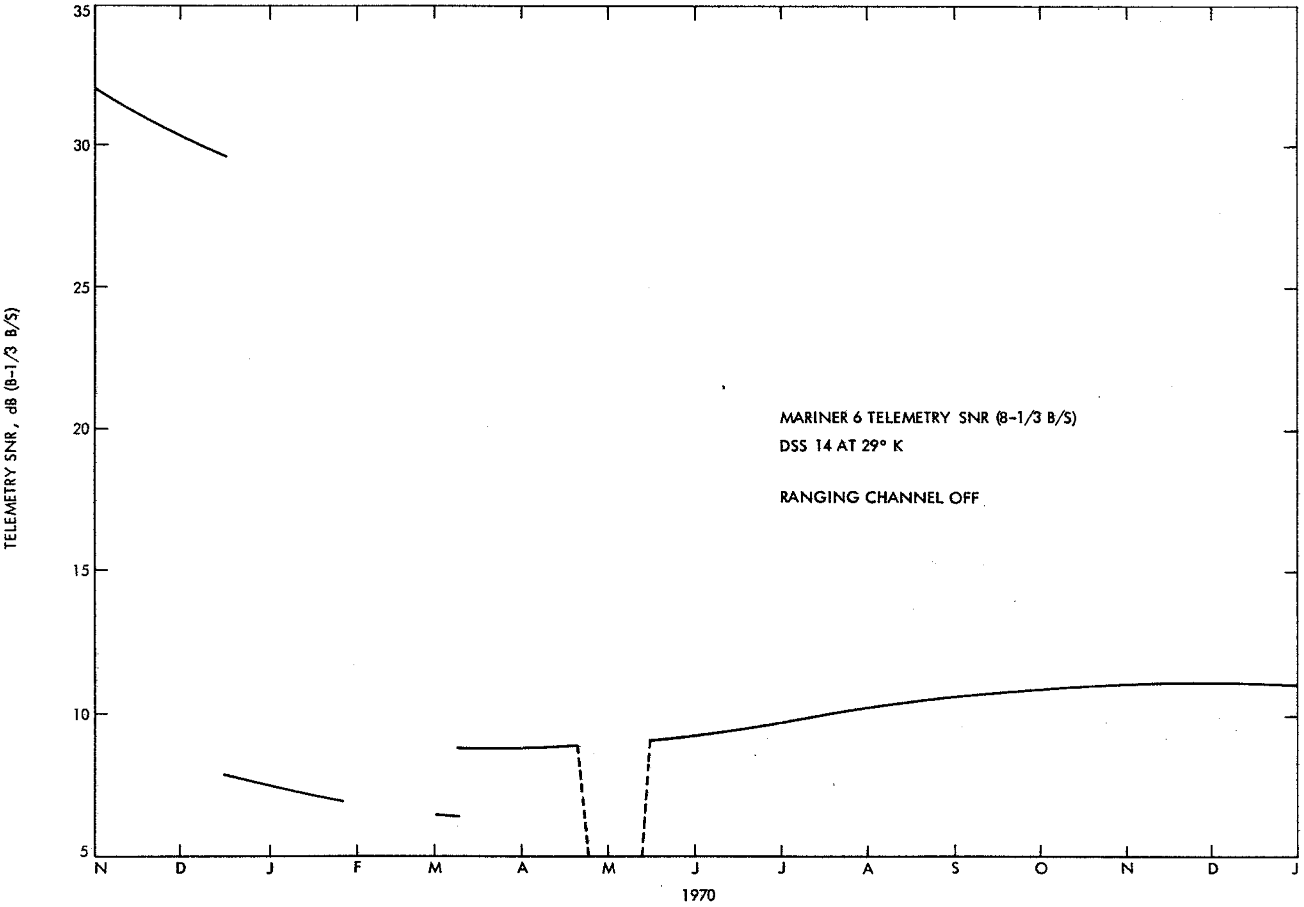


Fig. 24. Mariner 6 telemetry SNR vs date

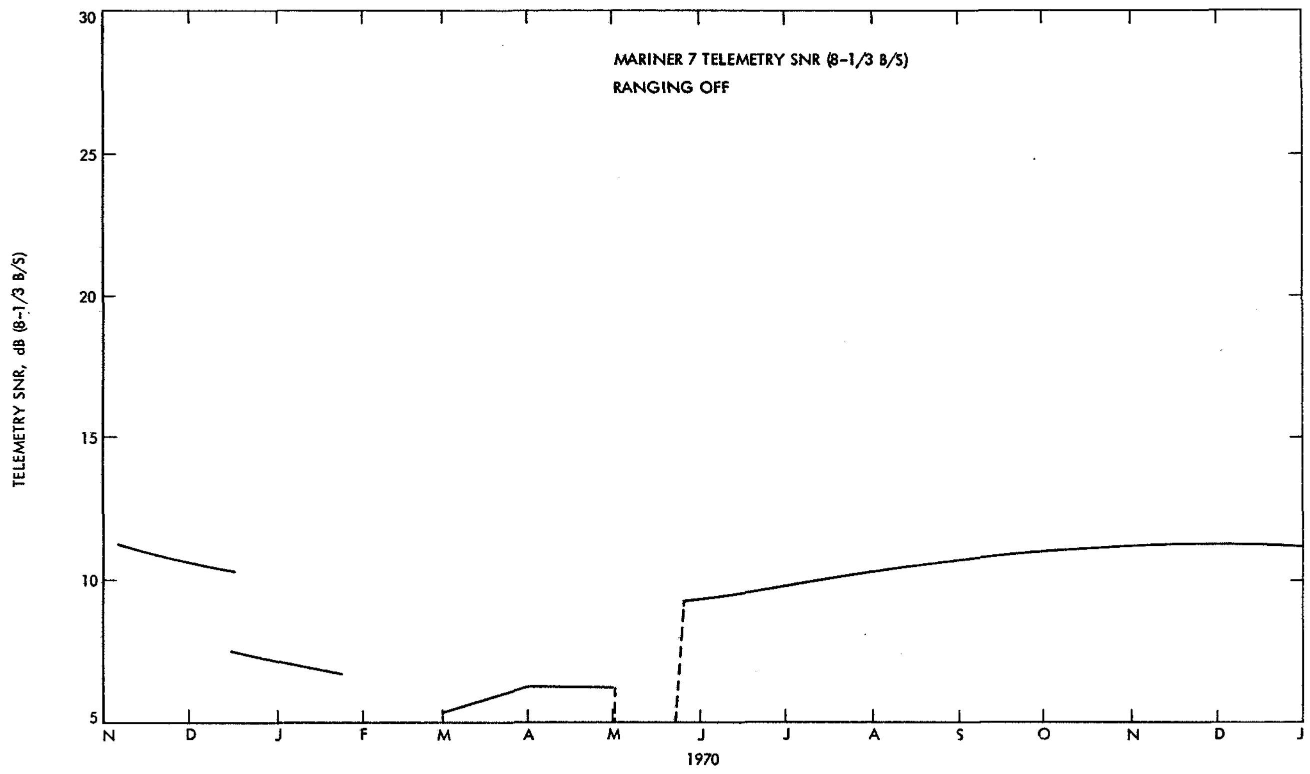


Fig. 25. Mariner 7 telemetry SNR vs date

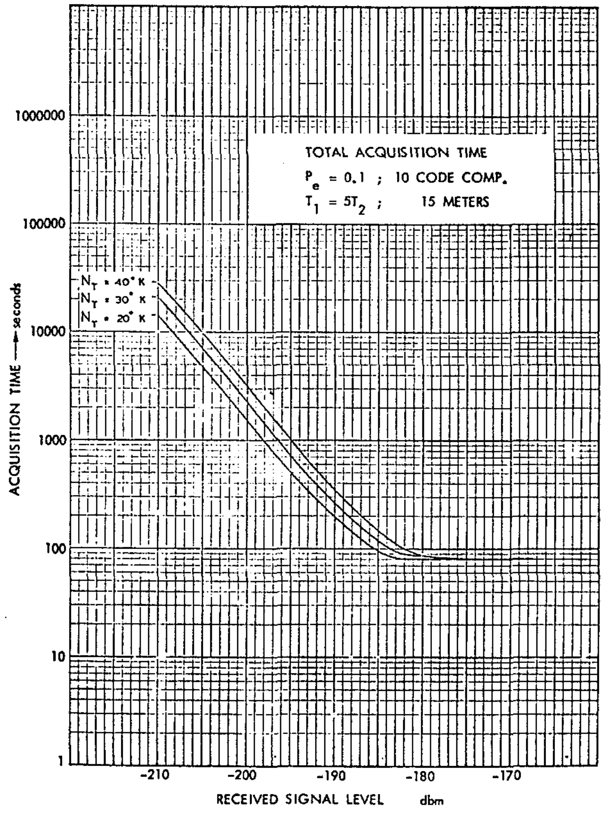


Fig. 26. Total acquisition time for P_e = 0.1

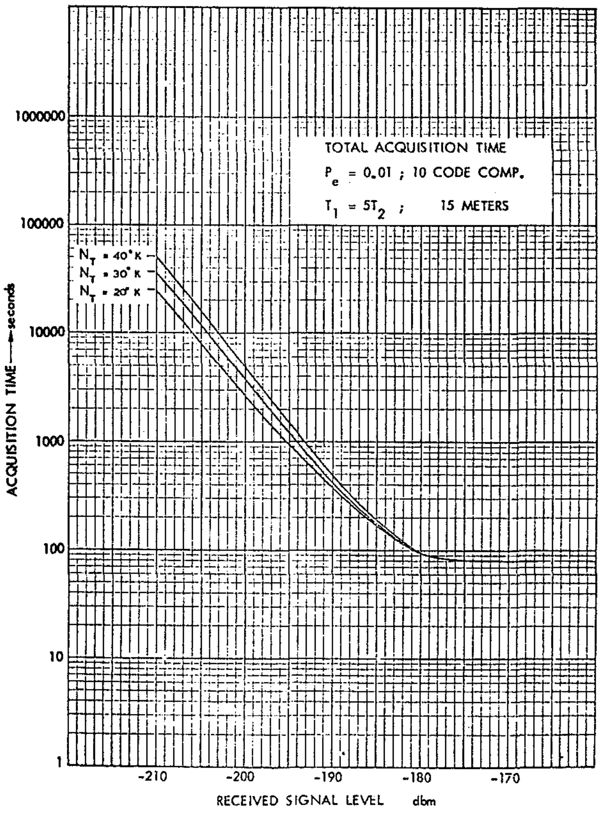


Fig. 27. Total acquisition time for P_e = 0.01

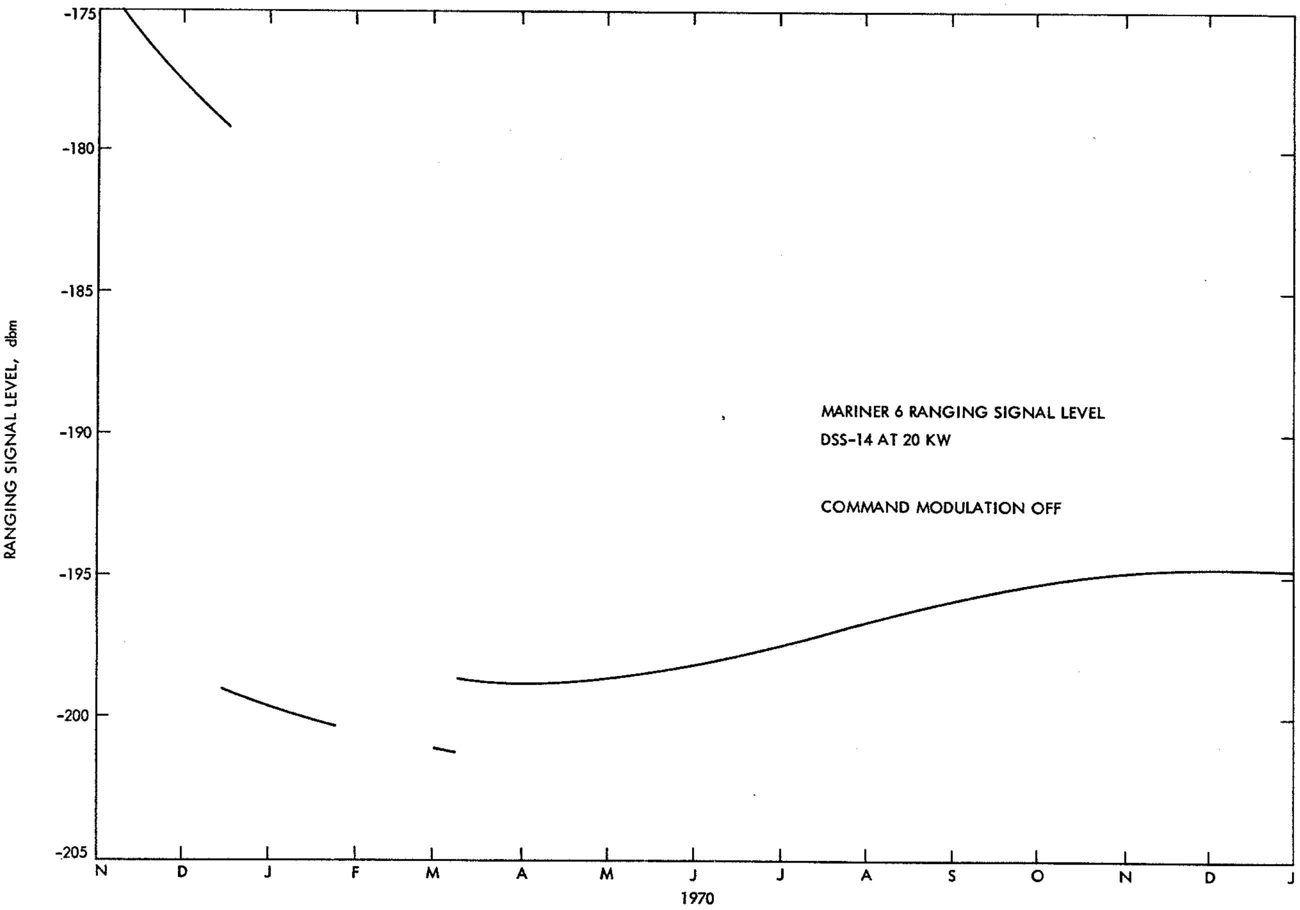


Fig. 28. Mariner 6 planetary ranging level vs date

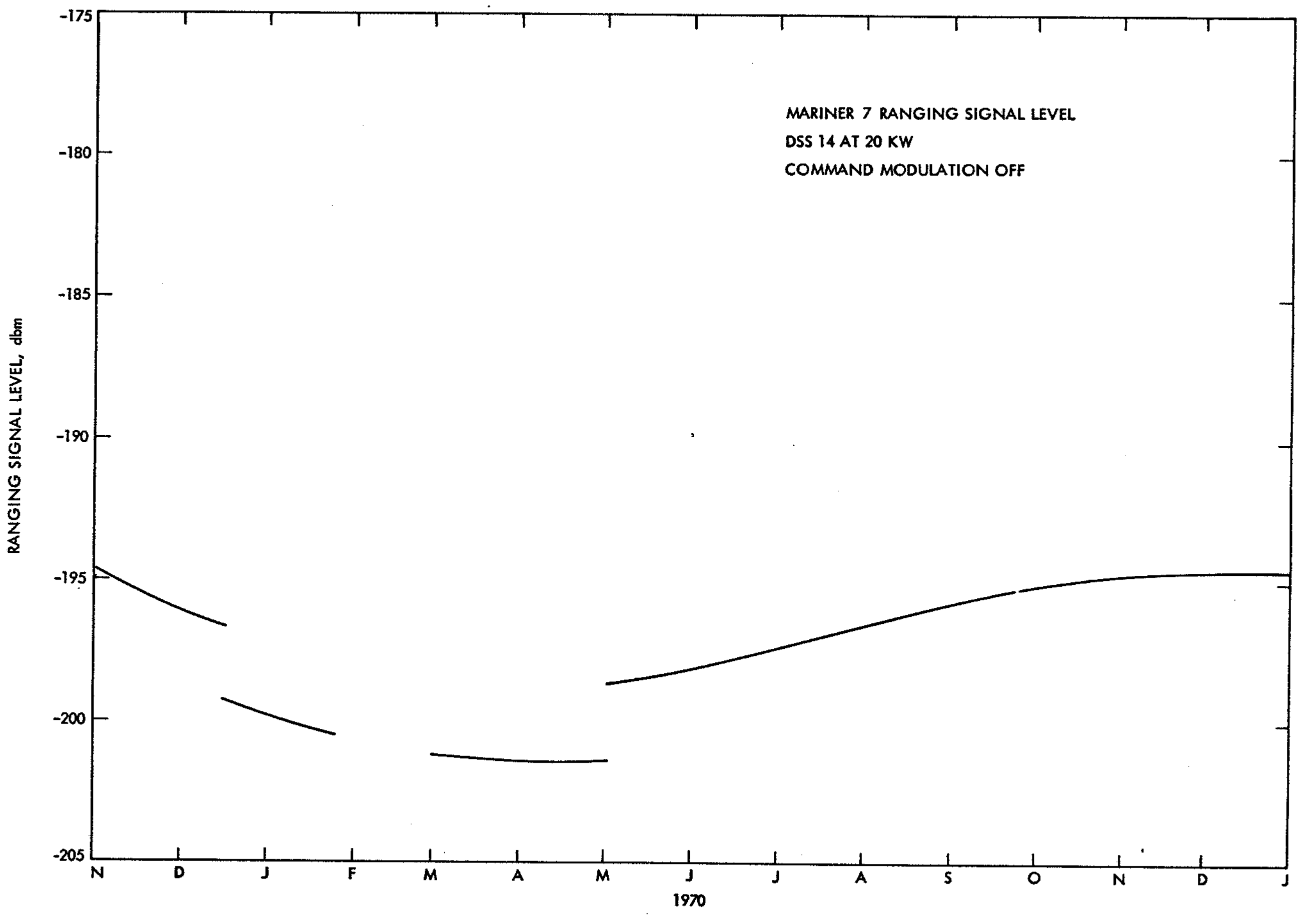


Fig. 29. Mariner 7 planetary ranging level vs date

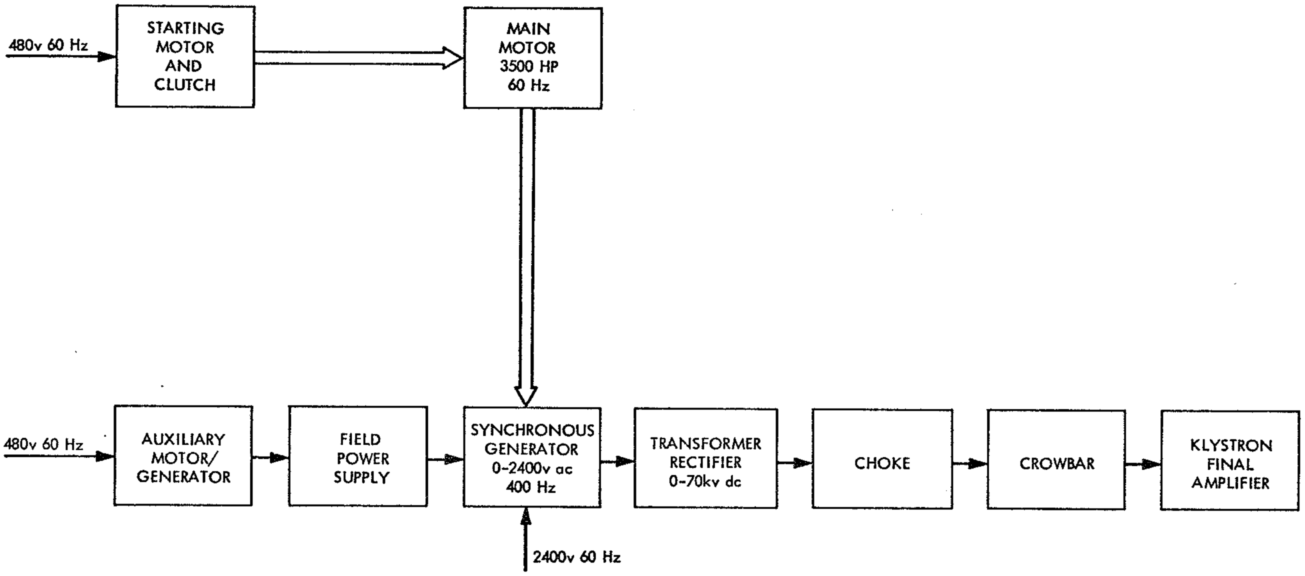


Fig. 30. Simplified functional block diagram of 400-kW transmitter power supply

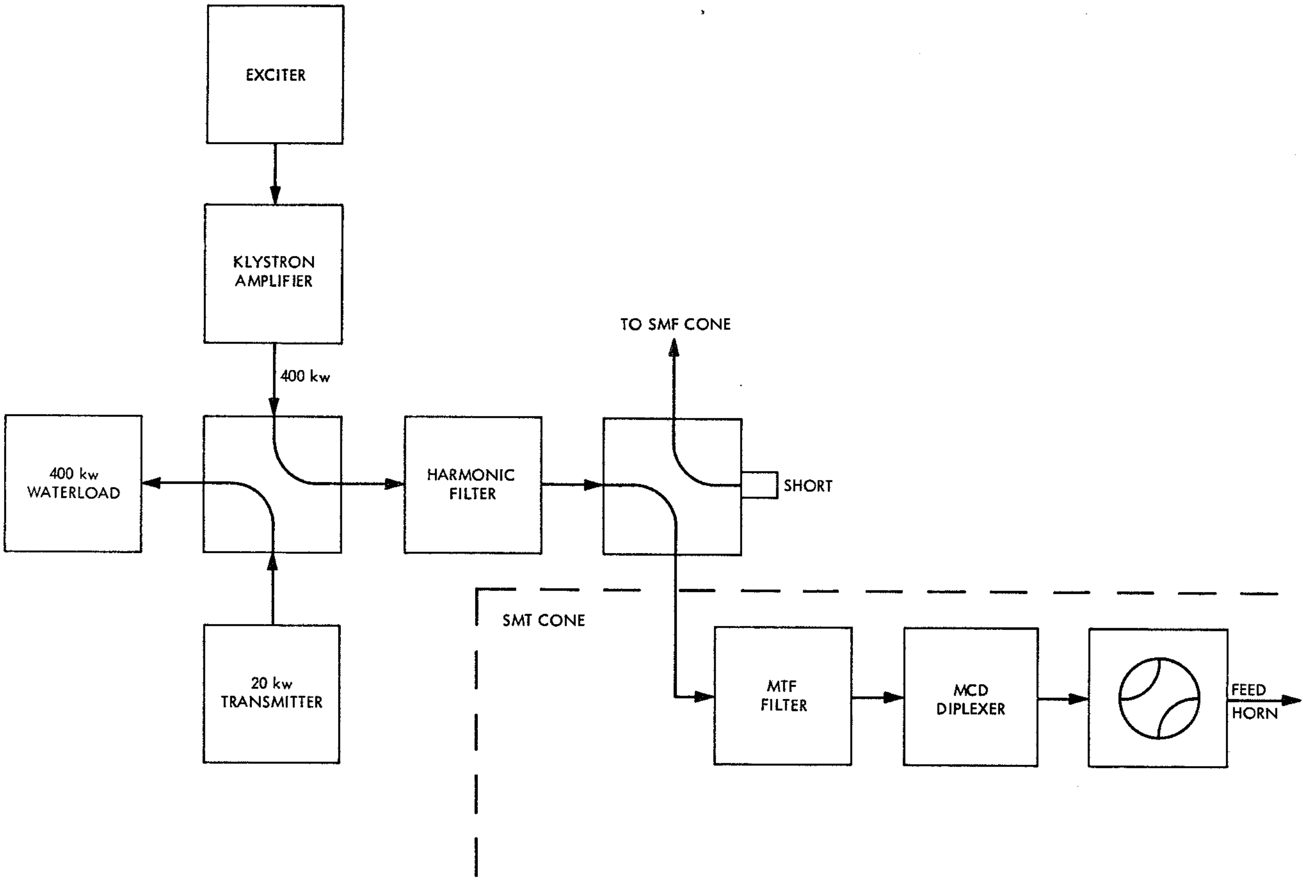


Fig. 31. 400-kW transmitter RF path

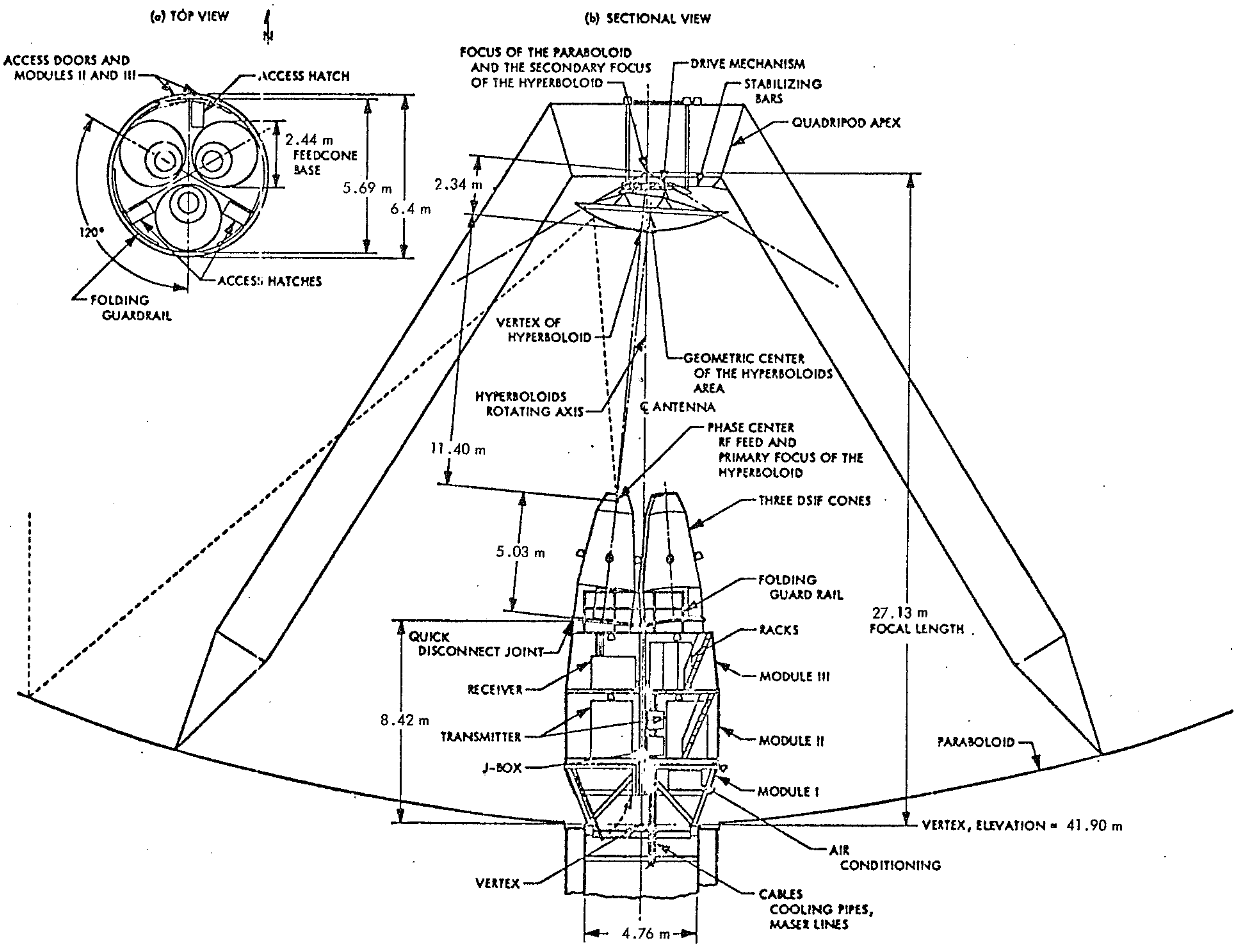


Fig. 32. Multiple primary feed system

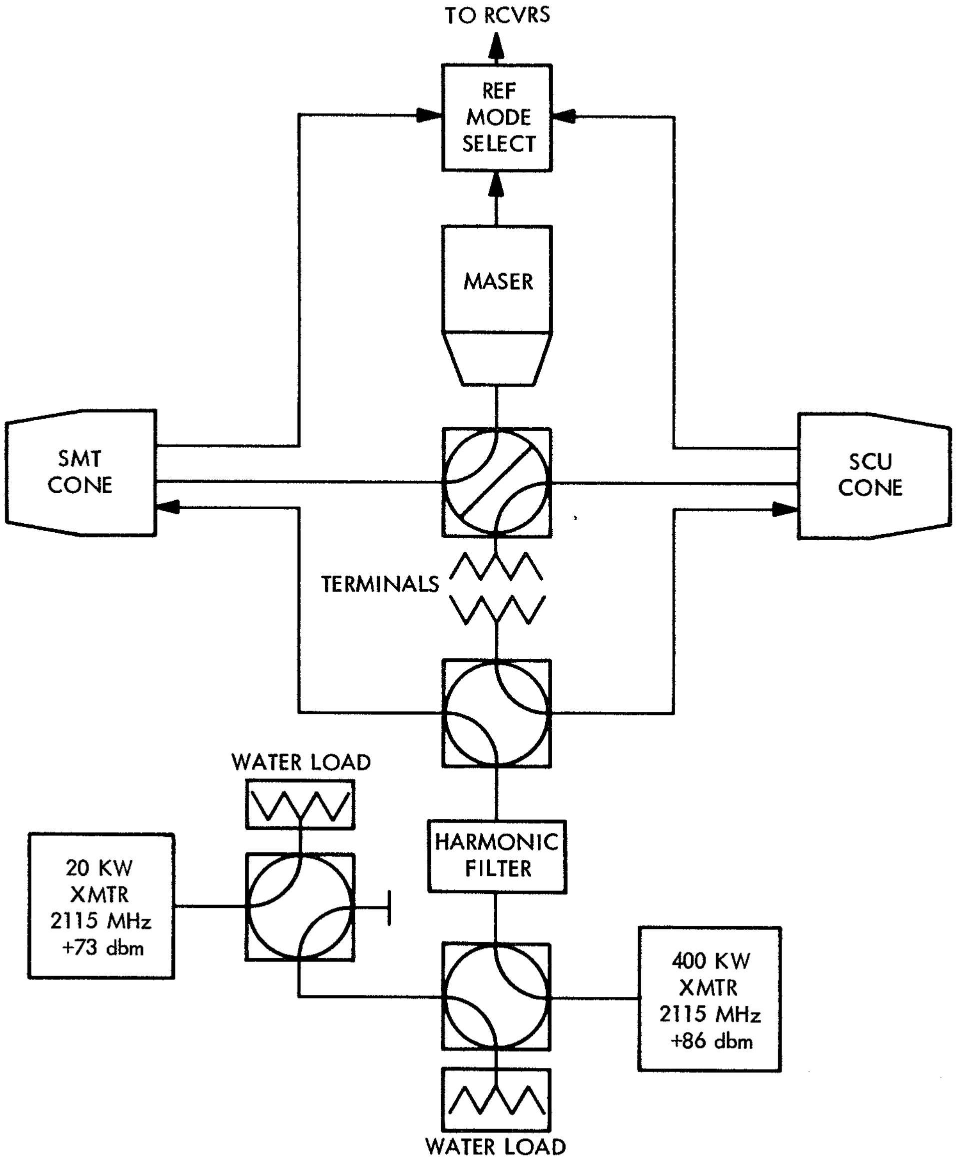


Fig. 33. Tricone block diagram

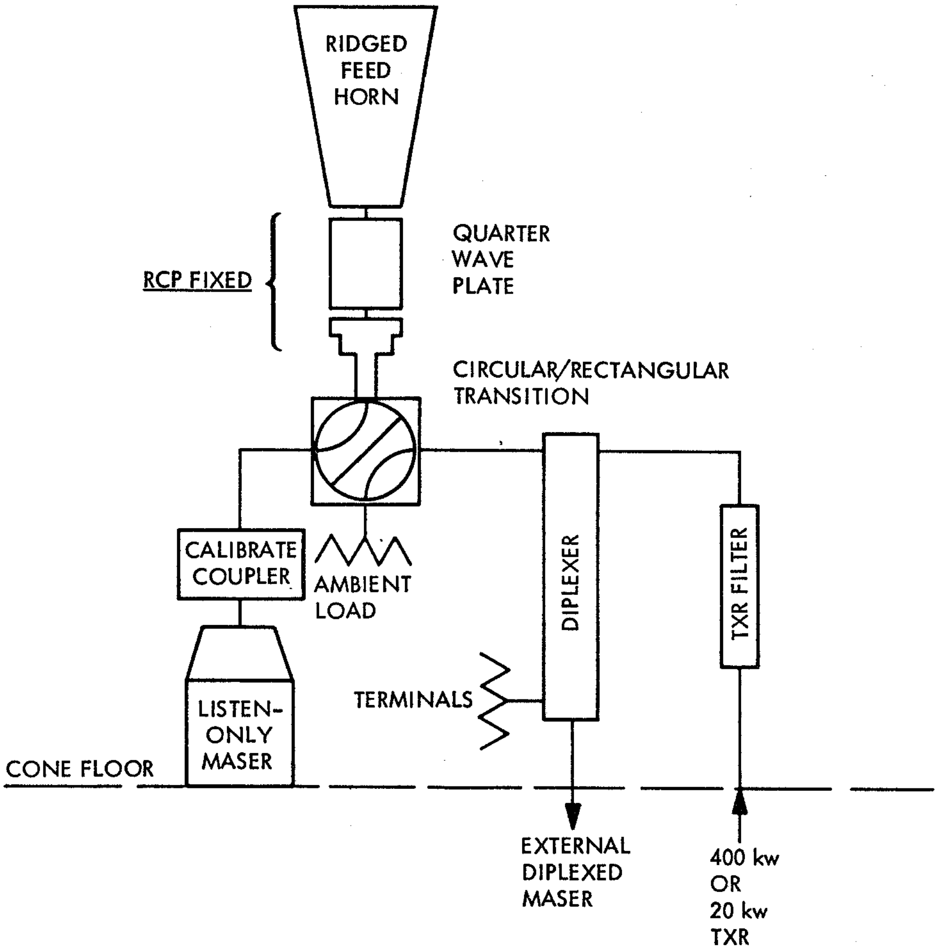


Fig. 34. SMT cone

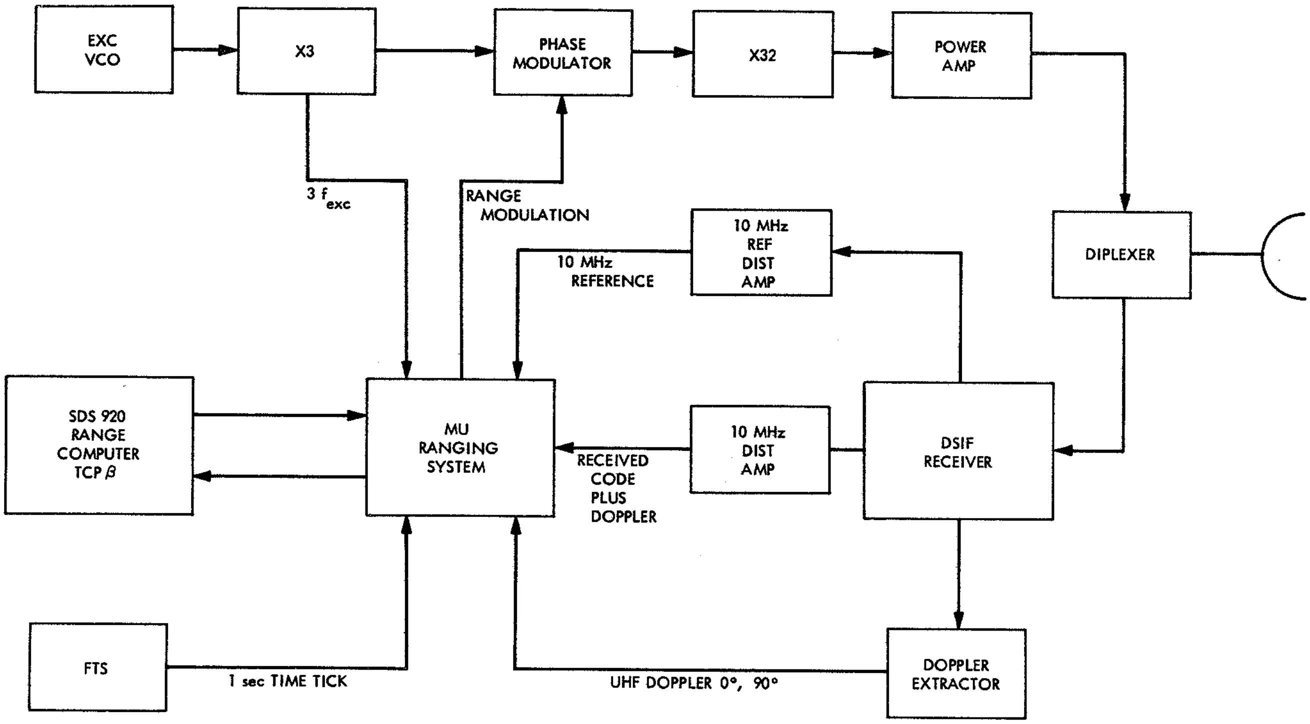


Fig. 35. Mu ranging system interface block diagram

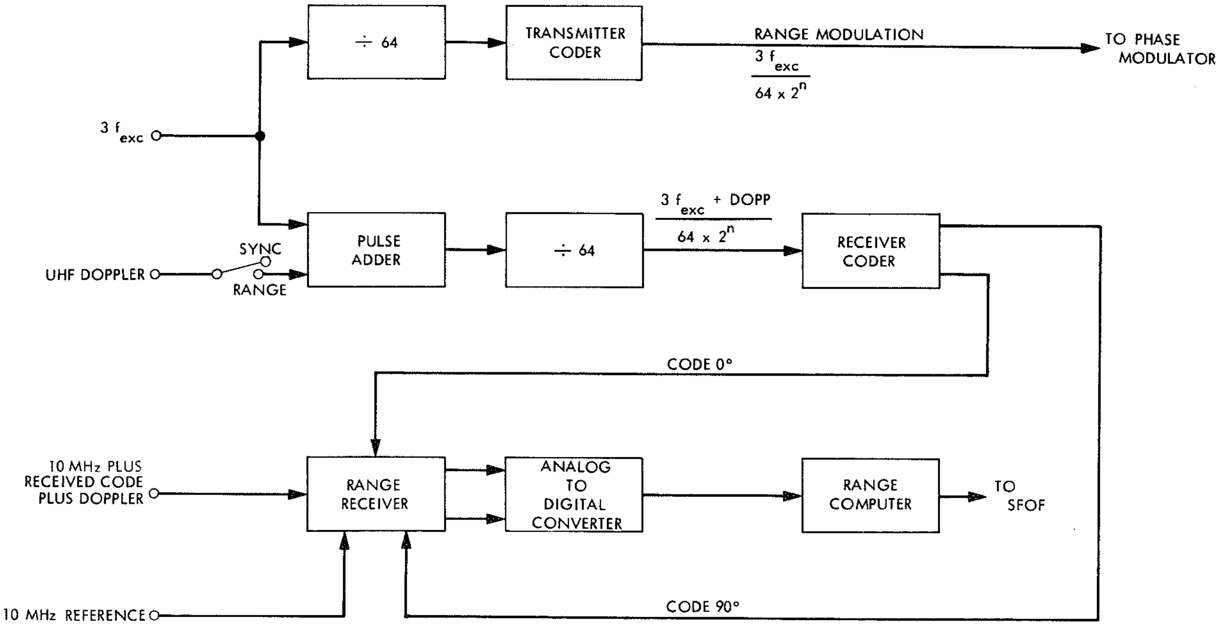


Fig. 36. Mu ranging system block diagram

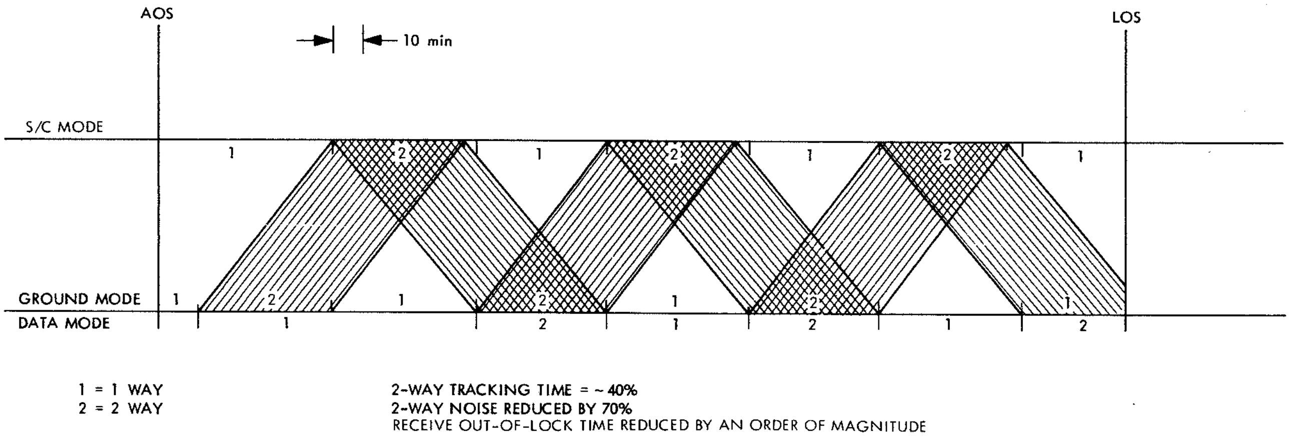


Fig. 37. DSS 12 special doppler support, typical pass

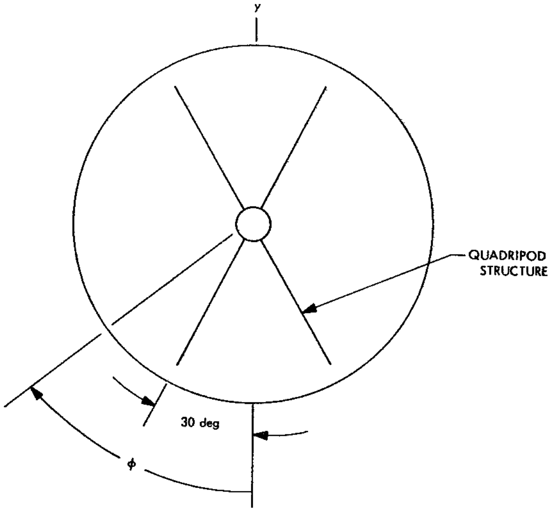


Fig. 38. Mars station reflector with 30-deg quadripod geometry

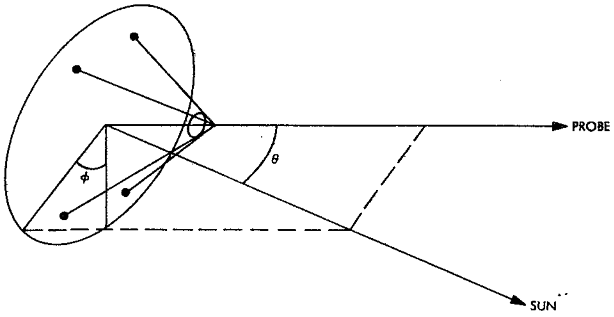


Fig. 39. Coordinate system

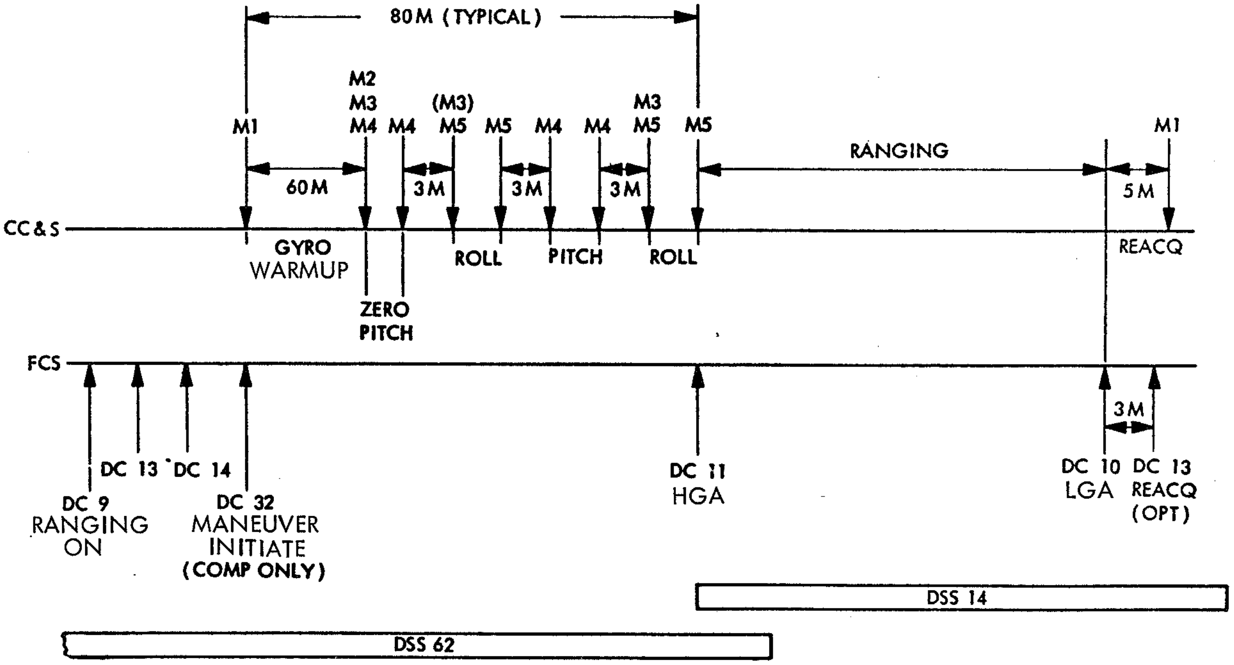


Fig. 40. Operational ranging sequence

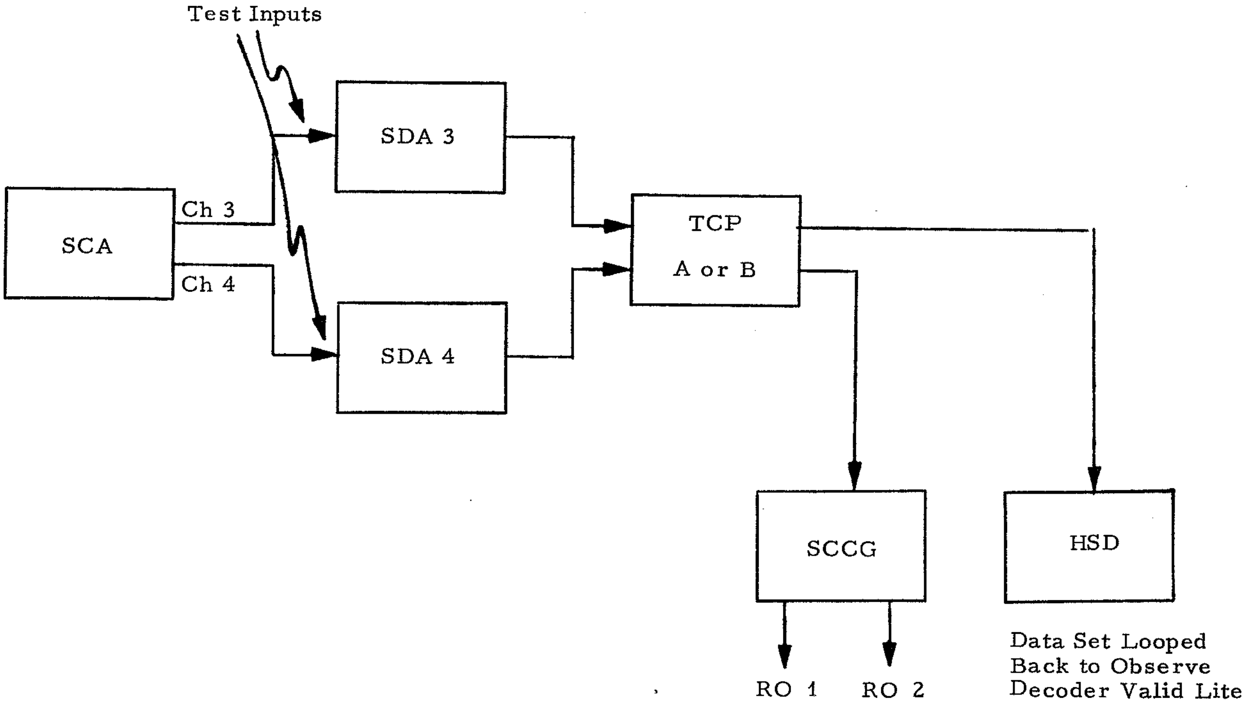


Fig. 41. CTA 21 configuration for preliminary test

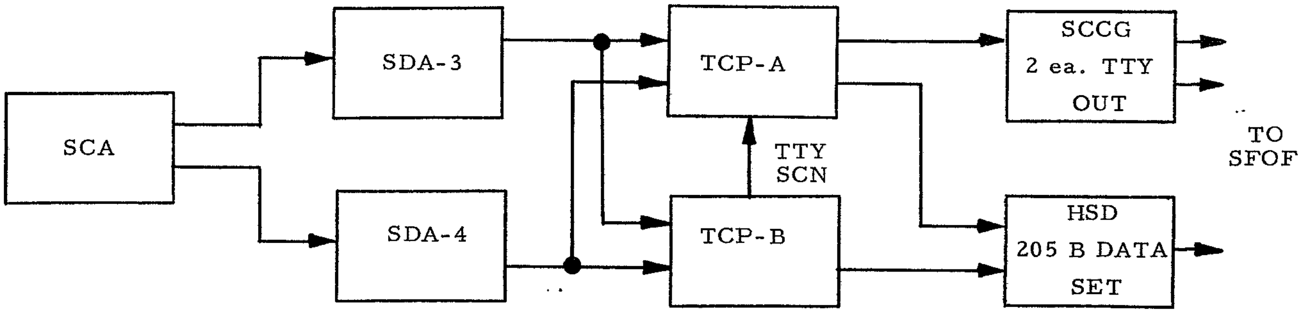


Fig. 42. CTA 21 configuration for CTA 21/SFOF data flow test

V. PERFORMANCE EVALUATION

The TDS system performance was monitored daily by the DSN monitor group. Performance analyses were provided to the operations control team to allow corrective action to be initiated when performance fell below predicted or committed levels. Results of the analysis indicate that the performance of the TDS was excellent.

A. Tracking System

The DSN monitor group provided an analysis of tracking system performance. The analysis results on the Mariner 6 and 7 extended operations for GMT days 307 (November 3, 1969) through 365 (1970) are shown in Figs. 43 and 44, respectively. The figures include only the usable two-way data, which were flagged with a good data condition code, transmitted by the DSS, and actually processed by the TCP and contained on the master data record (MDR). The percentage shown on the figures is the ratio between the usable data transmitted vs the usable data received. Recall was initiated when less than 95% of the available data was processed or when a data outage of at least 15 min occurred.

In addition, separate evaluations were made of the tracking performance during superior conjunction of each spacecraft by the new DSN operations organization.

1. Superior conjunction. The crucial part of the experiment and mission occurred in the vicinity of superior conjunction in the latter part of April and first part of May 1970. As the radio signal, traveling about 2.5 AU from spacecraft to earth, passed closer and closer to the sun, ground system noise temperature (SNT) increased as higher and higher antenna side lobes successively scanned across the sun. Figures 45 and 46 show the predicted and measured SNT for Mariners 6 and 7: Predicted values were estimated from average antenna patterns. Measured values showed not only the increase with nearness to the sun but also a variation in the values taken on one day. Diurnal variation was caused by the 64-m antenna Az-El mount. As the antenna tracked the spacecraft through its pass, its principal E-H planes rotated slightly with respect to celestial coordinates. Since the side lobes were not cylindrically symmetrical about the antenna axis, the sun moved through the antenna pattern slightly, varying SNT according to the side lobe structure.

As SNT and average doppler noise rose, receivers maintained lock with increasing difficulty. Figures 47 and 48 show how average doppler noise increased as the sun-earth-spacecraft angle decreased until the receivers could no longer maintain lock a significant percentage of the time. Because of the high incidence of receiver-out-of-lock indicators automatically sensed in the TDH, a great amount of data was prevented from being placed on the MDF because of rejection by the TDP program. By manually overriding the data condition code, data were recovered and processed in the TDP for subsequent use in the Orbit Determination Program (ODP) and orbit data generator (ODG) programs. This special procedure remained in effect from April 29 to May 19, 1970.

Throughout tracking coverage, the experimental ranging system was employed. Not all attempts at locking the ranging system were successful, however. Figures 47 and 48 also show the degree of success in the vicinity of superior conjunction.

2. DSN operations organization tracking analysis. Starting in March 1970, the new DSN operations organization provided a more complete analysis of DSN performance than had been available previously. To provide a reasonably consistent view of DSN performance for the entire mission, performance information before March 1970 was consolidated from logs and tracking reports into the format used by the new DSN operations organization.

In general, marginal RF performance, caused by spacecraft location and configuration, and the short length of some passes limited DSN performance. In addition, because of operational constraints, data were not recalled from the DSS to increase data availability at the Project interface. The Project was satisfied with DSN performance in this area, however. These conditions were also applicable to the telemetry system.

An analysis of the DSN Tracking System is illustrated in Figs. 49-54. The comments that follow are an addition to the information displayed in the graphs:

(1) Week of March 9, Mariner 6, pass 383, DSS 14: A problem with the ranging system delayed acquisition 1 h.

(2) Week of March 9, Mariner 7, pass 352, DSS 14: Receiver dropped lock several times due to transmitter feedback.

(3) Week of March 16, Mariner 6, pass 391, DSS 14: High doppler noise continued throughout the pass.

(4) Week of March 16, Mariner 7, pass 360, DSS 14: High doppler noise continued throughout the pass.

(5) Weeks of March 23-April 13, Mariners 6 and 7, DSS 14: When transmitting at 20 kW, RF noise spikes continued to cause high doppler noise.

(6) Weeks of April 2-May 11, Mariners 6 and 7, DSS 14: Because of the distance of both spacecraft from earth and the proximity of the spacecraft-to-earth signal path to the sun, a great amount of tracking data was automatically flagged as bad data. The DSIF was instructed to override this flag and place these data in the MDF for further analysis. These data are reflected as good data on the bar charts.

(7) Week of August 3, Mariners 6 and 7: Processing errors in the 7044 D-5 resulted in less than 90% of the data being received on Mariner 6 pass 525 and Mariner 7 pass 494.

(8) Week of August 24, Mariner 7, pass 522, DSS 14: Low data-received figures were caused by 7044 D-5 processing errors.

(9) Weeks of August 31-November 23, Mariners 6 and 7, DSS 14: High doppler noise continued to be a problem.

(10) Week of September 28, Mariner 7, pass 554, DSS 14: TDH data were defective throughout entire pass. Doppler field indicated all zeros. Problem appeared to be in conversion from doppler counter to Baudot coding.

(11) Week of October 5, Mariner 7, pass 557, DSS 14: TDH data were defective until 21:17 (same problem as on pass 554), at which time the problem was corrected by replacing a faulty circuit card in the TDH subsystem. Good TDH data were on line at 21:21.

(12) Week of December 7, Mariners 6 and 7, DSS 14: High doppler noise, which had been under investigation since August 1970, was apparently corrected on December 7 by reconnecting a faulty grounding wire in the antenna cone assembly. Doppler noise remained within nominal limits following this corrective action.

B. Telemetry System

1. DSN monitor group telemetry analysis. The DSN monitor group provided an analysis of telemetry system performance. The analysis results on the Mariner 6 and 7 extended operations for GMT day 307 (November 3, 1969) through 365 (1970) are shown in Figs. 55 and 56, respectively. The percent of available data from the station recorded on 7044 log tape was on a pass basis. Day 29-58 (1970) on Mariner 6 and Day 33-61 (1970) on Mariner 7 were doppler-only passes from DSS 12; therefore, no data are shown on Figs. 55 and 56. Also, information was not available on day 115-124, 363, and 364 for Mariner 6 and days 317, 321, 324, 339, 128-135, 196, 203, 210, 280, 338, 353, 357, and 364 for Mariner 7 because of low telecommunications performance, configuration availability or failures, short passes, short turnaround between spacecraft, or waived posttrack calibrations.

2. DSN operations organization telemetry analysis. The operational conditions presented in the tracking system performance analysis were also applicable to the telemetry system. An analysis of the DSN Telemetry System is illustrated in Figs. 57-70. The comments that follow, beginning with the resumption of telemetry activities (see Section IV), are in addition to the information displayed in the graphs.

(1) Weeks of March 9, 16, Mariner 6, DSS 14: Several passes at TWT high power increased downlink and SNR by +2.7 dB. DSS 14 downlink was low by 1.5 dB because of a cable calibration error that was corrected.

(2) Weeks of March 9, 16, Mariner 7, DSS 14: Downlink was low by 1.5 dB because of a cable calibration error that was corrected.

(3) Week of April 6, Mariner 6, DSS 14: Percent of data logged was low because of a TCP failure, causing a 2 h, 25 min loss of telemetry data.

(4) Week of April 13, Mariner 6, DSS 14: SNR and percent of data logged were both low because of the proximity of the spacecraft-to-earth signal path to the sun.

(5) Weeks of March 23-April 13, Mariners 6 and 7, DSS 14: Transmitter noise spikes continued to intermittently cause receiver glitches and generally degrade telemetry data.

(6) Weeks of April 27-May 11, Mariner 7, DSS 14: SNR and percent data logged were both low or not available because of the proximity of the spacecraft-to-earth signal path to the sun.

(7) Weeks of June 1, 8, Mariner 6: Percent data logged was low because of TCP problems.

(8) Week of June 1, Mariner 7: SNR and percent data logged were both low because of continuing effects of superior conjunction.

(9) Week of August 3, Mariner 6, pass 529: Low percentage figures (7044 computer fault).

(10) Week of August 24, Mariner 6, pass 549 and pass 553: Low percentage figures (HSDL pre-emption and HSDL patch panel problem).

(11) Week of August 31, Mariner 6, pass 557: Approximately 48 min of data was lost to the 7044. During this 48-min interval, continuous alarms, causes unknown, were visible on the monitor system, including receiver out-of-lock, AGC, receiver-loop filter bandwidth, and transmitter drive. These data losses resulted in a low validation percentage of 83.36.

(12) Week of August 31, Mariner 7, pass 526: 1 h, 41 min of data was lost to the 7044 as a result of HSDL data set patching/switch setting error in SDCC. These data losses resulted in a low validation percentage of 64.35.

(13) Week of September 7, Mariner 7, pass 530, DSS 14: Scheduled noise-burst test. Approximately 2 h of data was lost. These data losses resulted in a low validation percentage of 73.85.

(14) Week of September 28, Mariner 6, pass 581, DSS 14: Pass terminated early because of R&D ranging equipment failure. Because of the short pass, a 9-min loss of data on the D-5 tape at the end of the pass resulted in a low validation percentage of 77.62. The buffer in the 7044 accumulates data and then dumps to the D-5 tape. At the end of the pass, the buffer had not filled sufficiently to dump to tape, and the data were lost when the 7044 was secured. Small data losses have occurred in this manner previously, but the percentage of data in longer passes was not adversely affected.

(15) Week of September 28, Mariner 6, pass 585, DSS 14: 25 min of data was lost because of a TCP exchange that transferred the ranging data to TCP-B in place of TCP-A. TCP-A would not process ranging data. When no problem was found, TCP-A was loaded for telemetry data processing.

(16) Week of September 28, Mariner 7, pass 554, DSS 14: 6 min of data was lost because of HSDL failure between the DSS and SFOF.

(17) Week of October 5, Mariner 6, pass 592: 1 h, 2 min of data was lost to the 7044 computer because of incorrect block size switch setting on the ADSS synchronizer.

(18) Week of October 5, Mariner 7, pass 561, DSS 14: 8 min of data was lost at the 7044 computer because of a mode A (7044 automatic) recovery. Cause of recovery not determined.

(19) Week of October 12, Mariner 6, pass 595: 45 min of data was not logged on 7044 D-5 tape. Cause of this loss not determined.

(20) Week of October 26, Mariner 6, pass 613: 2 h, 56 min of data was lost at the 7044 computer because of a loose cable connection on the 7288 subchannel control interface. This problem prevented access (for computer initialization) to the 7044.

(21) Week of October 26, Mariner 7, pass 580: 32 min of data was lost at the 7044 computer because of an apparent late process request to the computer.

(22) Week of November 2, Mariner 6, pass 616, DSS 14: Approximately 4 h, 30 min of HSD was lost in real-time because of a program fault in the TCP-B. After a program reload, the HSD output was resumed. TTY data were received in real-time during the HSDL outage.

(23) Week of November 2, Mariner 7, pass 585, DSS 14: Approximately 38 min of HSD was lost during this pass because the TCP-B computer dropped lock occasionally for short periods. The station posttrack summary states that the nature of the problem is unknown and that no corrective action was taken at the station. There are log indications during this pass of SDA VCO frequency drift. SNR fell off quite rapidly at the horizon. No definite information was obtained to correlate these indications with the TCP-B out-of-lock conditions.

(24) Week of November 9, Mariner 6, pass 627: 1 h, 14 min of 7044 computer-processed HSD was not logged on D-5 tape. The master D-3 7044 log tape showed valid data being received at 12:11:07; however, the first data point logged on the D-5 tape was at 13:25:18.

(25) Week of November 16, Mariner 6, pass 630, DSS 14: 10 min of data was lost when the antenna was driven to zenith position to correct a problem with the 400-kW transmitter. (A lead shield around the transmitter klystron tube slipped out of position, causing a short circuit that would not allow the transmitter beam voltage to be applied.)

(26) Week of November 16, Mariner 7, pass 599: 6 min of data received by the 7044 computer was not transferred to the D-5 log tape at the end of this pass. The 7044 computer apparently failed to dump the buffer when the data ceased to flow at the end of the pass. Buffered data, which were transmitted at that time, were held in the buffer, not transferred to the D-5 tape. This condition, observed during Mariner 6 pass 627, was inherent in the processing; i.e., a data block must have been completed before it could be logged on the D-5 tape. These end-of-pass data losses were a problem only when the few minutes of buffered data held in the computer were needed to obtain a required percentage of recovered data (90%) for a short pass.

(27) Week of November 16, Mariner 7, pass 603, DSS 14: Normal high-speed engineering data were interrupted on numerous occasions throughout the pass because of special high-bit-rate science data flow testing with DSS 12. These interruptions to normal engineering data, sanctioned by the MM69 EO Project, resulted in a low D-5 validation percentage figure.

(28) Week of November 23, Mariner 6, pass 637, DSS 14: High-speed engineering data were interrupted on several occasions as a result of special configuration testing with DSS 12 for the upcoming MM69 EO spacecraft experiments. These data interruptions, sanctioned by the MM69 EO Project, resulted in a low D-5 validation percentage figure.

(29) Week of November 23, Mariner 7, pass 606, DSS 14: D-5 validation percentage figure was very low for reason indicated on pass 603.

(30) Weeks of November 30-December 28, Mariners 6 and 7, DSS 14/12 combined equipment configuration (see Section IV): Telemetry data flow (all types) was interrupted on numerous occasions as a result of extensive engineering experiments conducted by Project on both spacecraft. The combined data outages caused by this activity and those additional items mentioned below account for the low validation percentages.

(31) Week of November 30, Mariner 6, pass 646: 41 min of 8-1/3 bits/s engineering data and 6 min of 66-2/3 bits/s science data were lost because of a spacecraft CC&S readout malfunction.

(32) Week of November 30, Mariner 7, pass 615, DSS 14: Receiver out-of-lock for 79 min because of a spacecraft maneuver that caused the received signal level to fall below threshold. Engineering data (8-1/3 bits/s) were lost.

(33) Week of December 7, Mariner 6, pass 651: 28 min of 8-1/3 bits/s engineering data was lost because of a TCP out-of-lock condition for 13 min and two CC&S readouts. The cause for TCP drop-lock was not definitely determined; however, the SNR was fluctuating because of spacecraft maneuvers. (The data validation program VAL-X, does not recognize CC&S dump data.)

(34) Week of December 7, Mariner 6, pass 655: Numerous science and engineering data outages were caused by a delay in DSS 14/12 precalibrations (DSS 12 TCP lock delayed approximately 30 min) and receiver and TCP out-of-lock conditions. Spacecraft maneuvers and CC&S readouts caused the receiver and TCP out-of-lock.

(35) Week of December 7, Mariner 7, pass 621: 45 min of 8-1/3 bits/s engineering data was not logged on the D-5 tape.

(36) Week of December 14, Mariner 6, pass 662: Acquisition of both science and engineering data suffered in general because of sizable fluctuations in received signal level resulting from the spacecraft transmitting alternately from high- and low-gain antennas. The major cause for the extremely low percentage (2%) of science data logged on the D-5 tape was HSD errors emanating from DSS 14/12. The errors were detected by the 7044, causing the computer to lose sync on the science data. There was no apparent reason for these errors, and an investigation by the stations failed to reveal the source of the problem during the pass.

(37) Week of December 14, Mariner 7, pass 628: Fluctuations in received signal level (spacecraft alternately switching from high- to low-gain antennas), problems with the intersite microwave, which required calibration during the pass, and problems with the uplink (initiated by a failure of the 400-kW transmitter) all contributed to data losses for this pass. D-5 validation percentages were low as a result, with the 66-2/3 bits/s science data the lowest (3.5% of data logged).

(38) Week of December 14, Mariner 7, pass 629: Again on this pass fluctuations in the received signal level (spacecraft maneuvers for motor burn) and problems with the intersite microwave resulted in both science and engineering data losses at all four bit rates. Low D-5 validation percentages reflect these data losses.

(39) Week of December 21, Mariner 6, pass 665: 1 h of 8-1/3 bits/s engineering data was lost because the station went off track to perform RF systems test using the Mariner 7 spacecraft.

(40) Week of December 21, Mariner 7, pass 634: Low received signal level and the resultant poor SNR caused numerous TCP drop-locks throughout this brief 1 h, 9 min track. Lost engineering data (8-1/3 bits/s) was reflected in a low validation percentage for the pass.

(41) Week of December 28, Mariner 7, pass 643: Downlink signal was lost from the spacecraft because the spacecraft lost attitude control and began tumbling (attitude control gas supply apparently was depleted).

It should be noted that the weekly average numbers for percent data logged were computed using engineering data only. Because of the removal of the Mark II Data System on December 21, 1970, no data validation was possible beyond Mariner 6, pass 665, and Mariner 7, pass 634.

C. Command System

Totals of 1531 commands to Mariner 6 and 734 commands to Mariner 7 were transmitted by the DSN command system during the extended operations mission (Fig. 71). The extensive commanding in December 1970 was in support of the special spacecraft engineering experiments.

D. Operations Control System

1. DSN Network allocation schedule. The DSN provided tracking coverage and telemetry support for several independent missions simultaneously. The interleaving of the various mission activities, including contingencies, required careful planning and efficient assignment of available network time.

The DSN management compared the planned activities of the flight projects and then committed and scheduled network time in support of users. The DSN made these commitments to the limit of its total resources, using guidelines specified in such documents as the SIRD and the NSP, using priorities established by NASA Headquarters.

The DSN scheduling office was responsible for overall development, implementation, and operation of the network allocation schedules, under policies established by the TDA Office.

The DSN scheduling office scheduled all user requirements according to established priorities and within the TDA-approved constraints and guidelines supplied by each DSN facility. When violation of the facility guidelines appeared to be required, negotiation with the affected facility was accomplished before the schedule was published. When user requirements exceeded resources and adequate guidelines were not available, the DSN scheduling office requested flight project or TDA interpretation of the priority guidelines.

Comparative scheduling parameters are illustrated in Figs. 72 and 73.

2. DSN discrepancy reporting system. A DSN-wide system of failure reporting, engineering analysis, and management action has been developed to (a) aid in assuring that the DSN is properly prepared to support flight operations, and (b) improve the reliability of DSN equipment. To realize these two objectives, the DSN Discrepancy Reporting System (DRS) was developed as a two-level system. The first level, Level A, applied to all operational failures and problems that occurred throughout the DSN during flight project operational tests or an actual mission only. The second level, Level B, applied to all equipment failures in the DSN whenever they occurred. The Level A and Level B systems were designed to achieve the above objectives.

Figure 74 compares numbers of discrepancy reports (DRs) issued by the various flight projects.

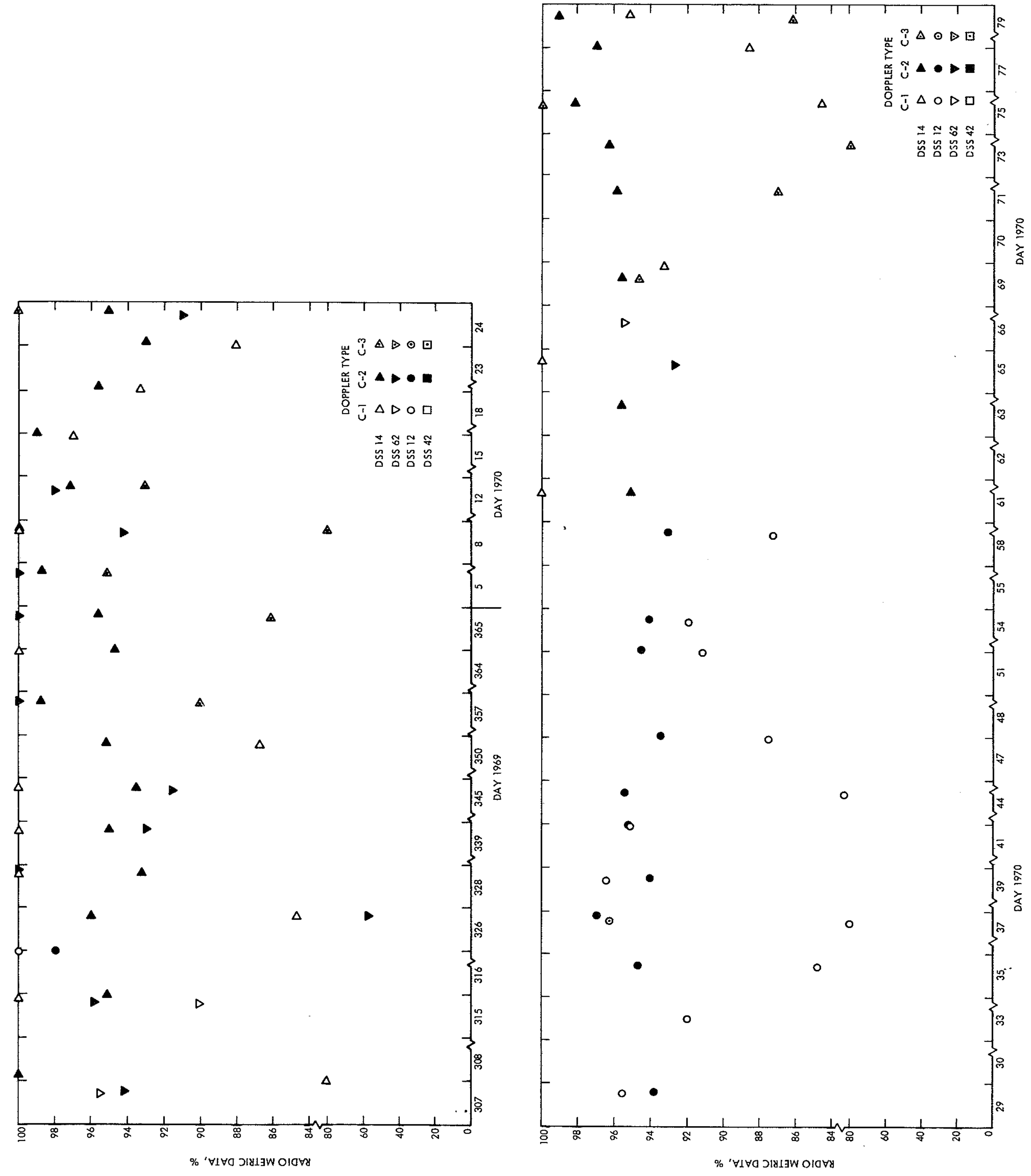
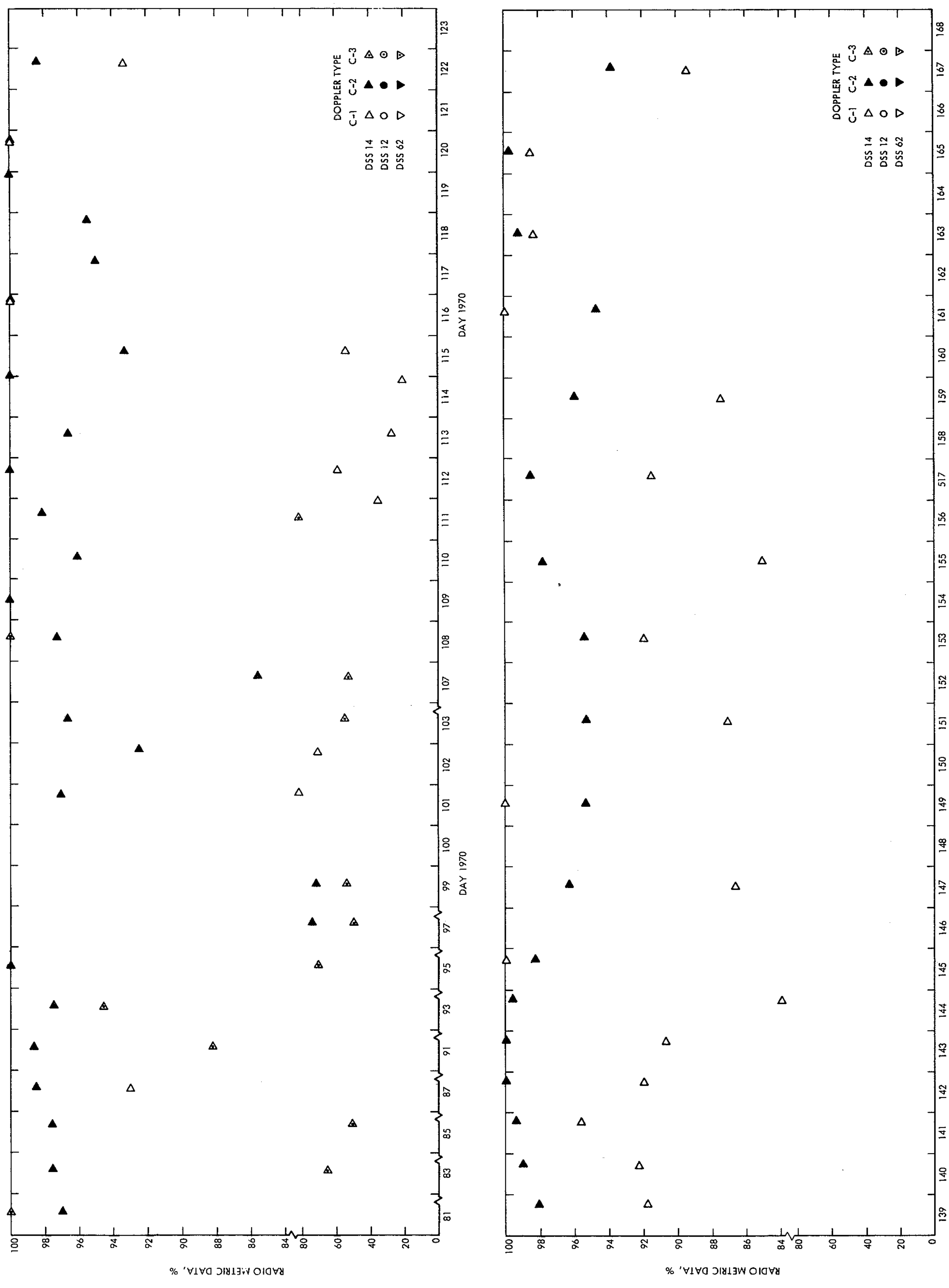


Fig. 43. Mariner 6 tracking system performance



DOPPLER TYPE
C-1 C-2 C-3
DSS 14 △ ▲ ◬
DSS 12 ○ ● ⊙
DSS 62 ▷ ▶ ⊳
RADIO METRIC DATA, %
DAY 1970
100
98
96
94
92
90
88
86
84
80
60
40
20
0
81
83
85
87
91
93
95
97
99
100
101
102
103
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
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156
517
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159
160
161
162
163
164
165
166
167
168

Fig. 43 (contd)

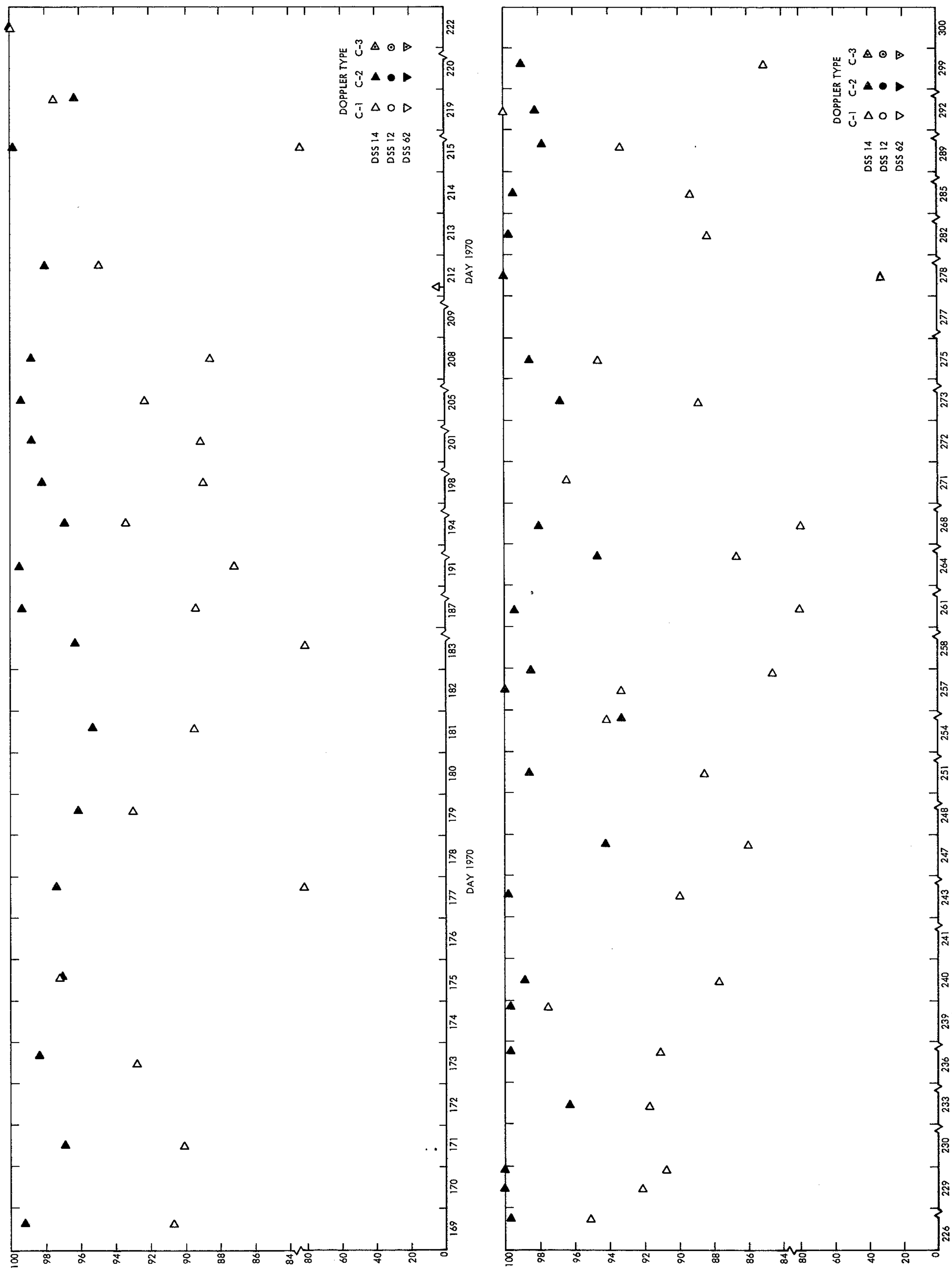
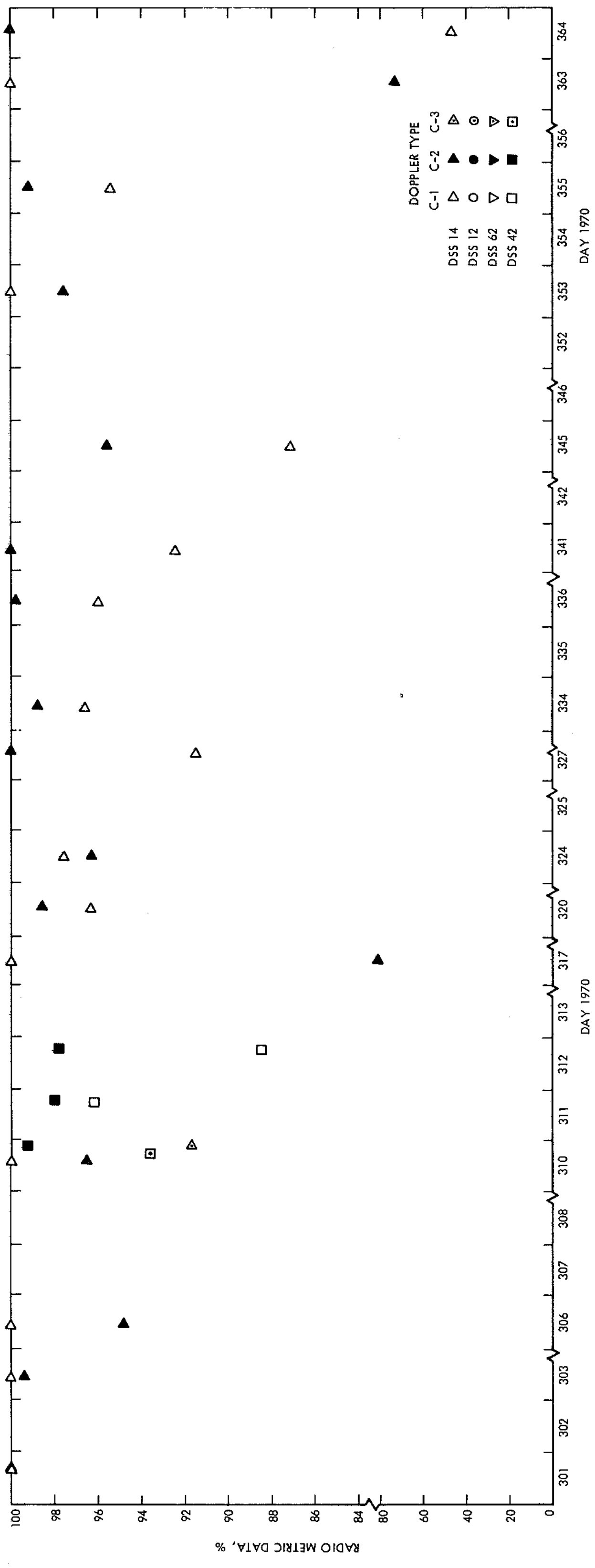

RADIO METRIC DATA, %
100
98
96
94
92
90
88
86
84
80
60
40
20
0
DAY 1970
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
187
191
194
198
201
205
208
209
212
213
214
215
219
220
222
DOPPLER TYPE
C-1 C-2 C-3
DSS 14 △ ▲ ◬
DSS 12 ○ ● ⊙
DSS 62 ▷ ▶ ⊳
RADIO METRIC DATA, %
100
98
96
94
92
90
88
86
84
80
60
40
20
0
DAY 1970
226
229
230
233
236
239
240
241
243
247
248
251
254
257
258
261
264
268
271
272
273
275
277
278
282
285
289
292
299
300
DOPPLER TYPE
C-1 C-2 C-3
DSS 14 △ ▲ ◬
DSS 12 ○ ● ⊙
DSS 62 ▷ ▶ ⊳

Fig. 43 (contd)


RADIO METRIC DATA, %
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98
96
94
92
90
88
86
84
80
60
40
20
0
301
302
303
306
307
308
310
311
312
313
317
320
324
325
327
334
335
336
341
342
345
346
352
353
354
355
356
363
364
DAY 1970
DAY 1970
DOPPLER TYPE
C-1
C-2
C-3
DSS 14
DSS 12
DSS 62
DSS 42

Fig. 43 (contd)

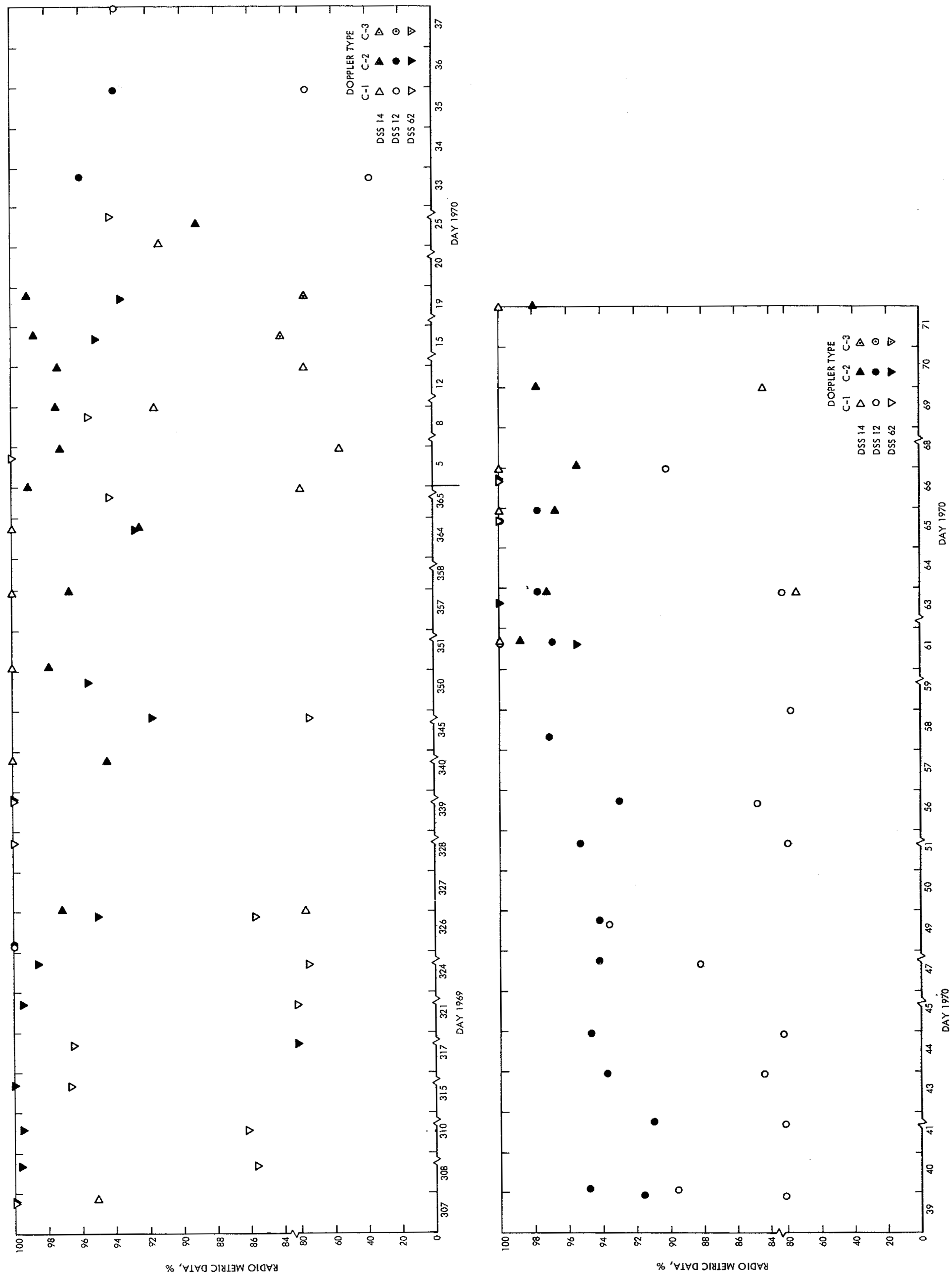
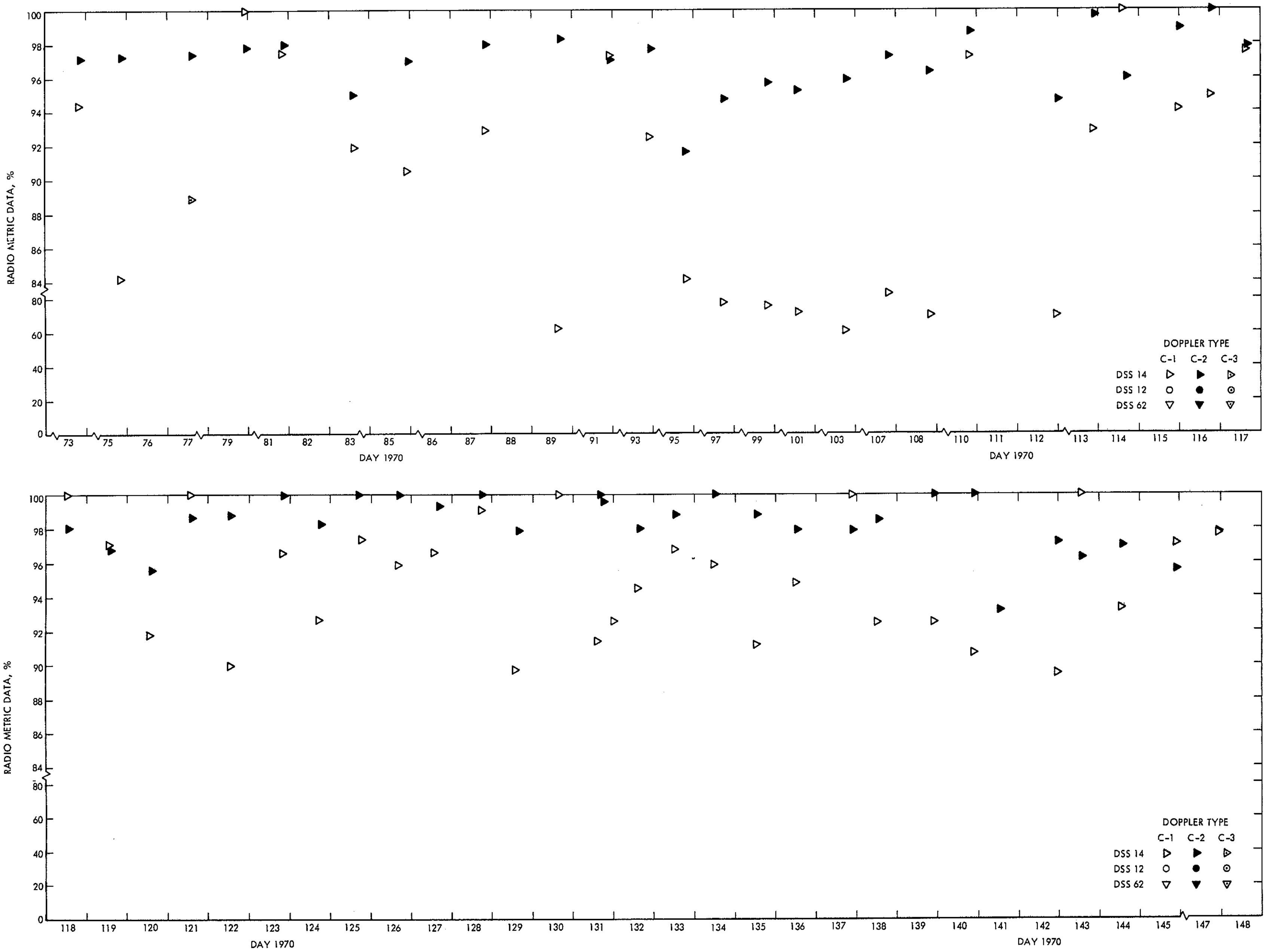


Fig. 44. Mariner 7 tracking system performance


RADIO METRIC DATA, %
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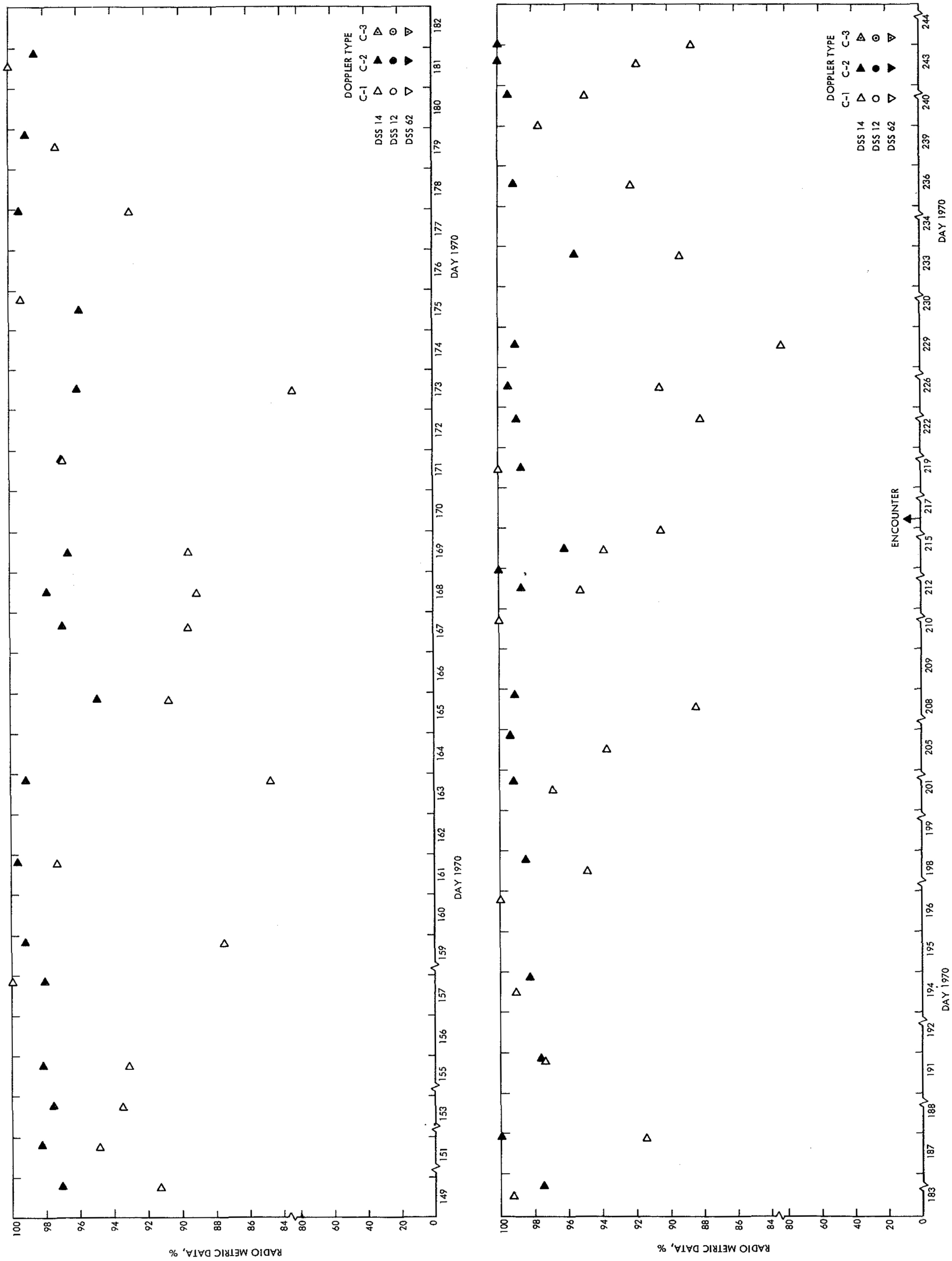
98
96
94
92
90
88
86
84
80
60
40
20
0
73
75
76
77
79
81
82
83
85
86
87
88
89
91
93
95
97
99
101
103
107
108
110
111
112
113
114
115
116
117
DAY 1970
DAY 1970
DOPPLER TYPE
C-1 C-2 C-3
DSS 14 ▷ ▶ ▷
DSS 12 ○ ● ⊙
DSS 62 ▽ ▼ ▽
RADIO METRIC DATA, %
100
98
96
94
92
90
88
86
84
80
60
40
20
0
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
147
148
DAY 1970
DAY 1970
DOPPLER TYPE
C-1 C-2 C-3
DSS 14 ▷ ▶ ▷
DSS 12 ○ ● ⊙
DSS 62 ▽ ▼ ▽

Fig. 44 (contd)


DOPPLER TYPE
C-1 C-2 C-3
DSS 14 △ ▲ △
DSS 12 ○ ● ⊙
DSS 62 ▷ ▶ ▷
RADIO METRIC DATA, %
100
98
96
94
92
90
88
86
84
80
60
40
20
0
DAY 1970
149
151
153
155
157
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
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181
182
183
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188
191
192
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196
198
199
201
205
208
209
210
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239
240
243
244
ENCOUNTER

Fig. 44 (contd)

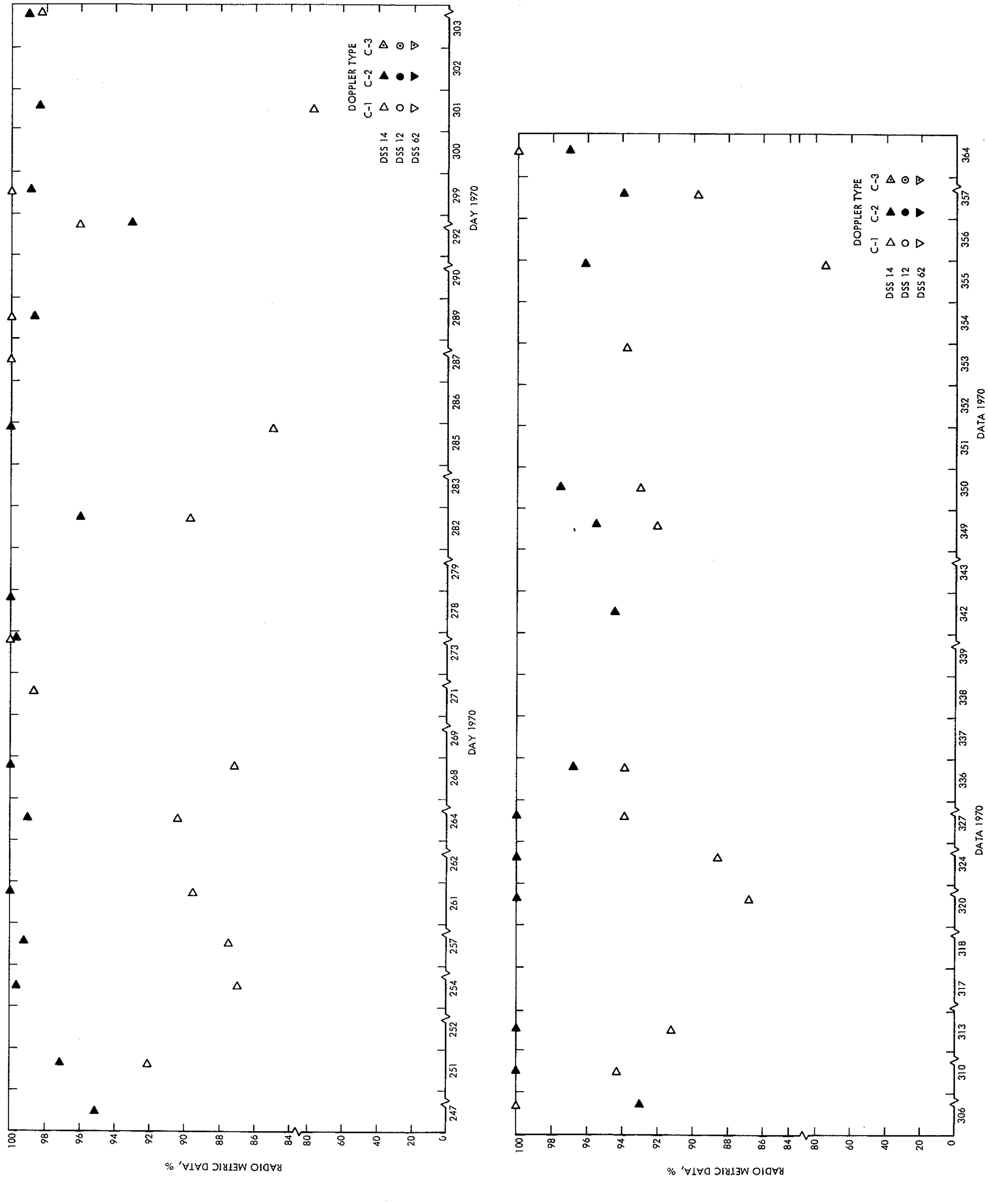

RADIO METRIC DATA, %
100
98
96
94
92
90
88
86
84
80
60
40
20
0
247
251
252
254
257
261
262
264
268
269
271
273
278
279
282
283
285
286
287
289
290
292
299
300
301
302
303
DAY 1970
DAY 1970
DOPPLER TYPE
C-1 C-2 C-3
DSS 14 △ ▲ △
DSS 12 ○ ● ⊙
DSS 62 ▷ ▶ ▷
RADIO METRIC DATA, %
100
98
96
94
92
90
88
86
84
80
60
40
20
0
306
310
313
317
318
320
324
327
336
337
338
339
342
343
349
350
351
352
353
354
355
356
357
364
DATA 1970
DATA 1970
DOPPLER TYPE
C-1 C-2 C-3
DSS 14 △ ▲ △
DSS 12 ○ ● ⊙
DSS 62 ▷ ▶ ▷

Fig. 44 (contd)

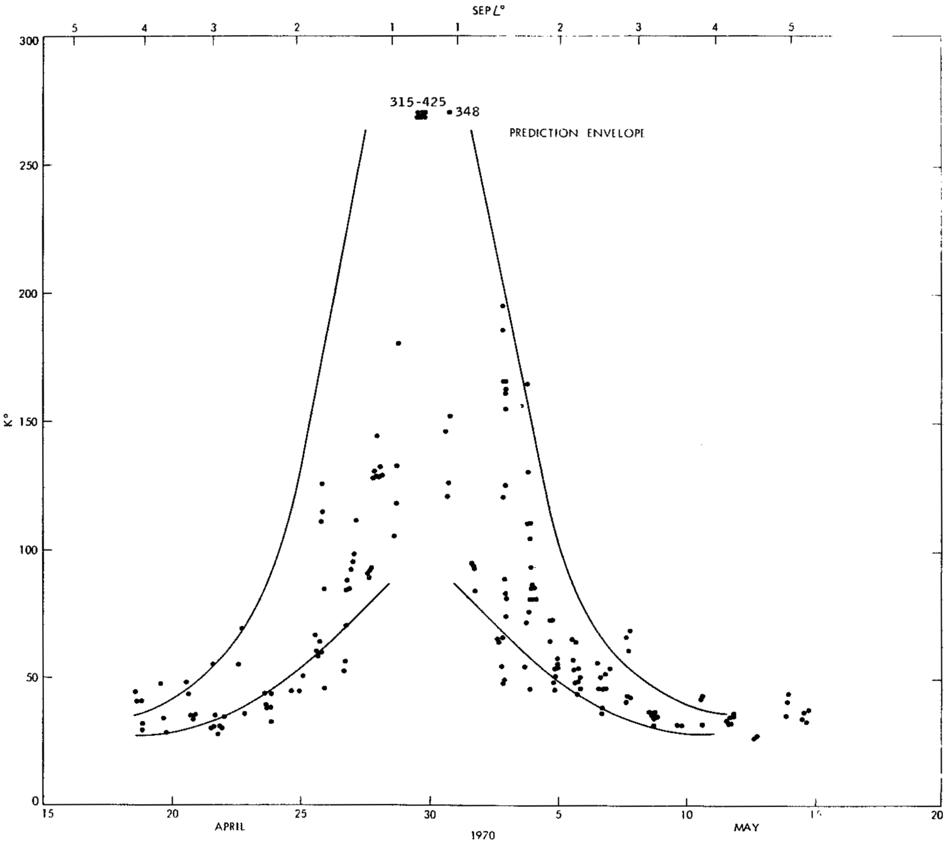


Fig. 45. Mariner 6 measured system noise temperature about superior conjunction at DSS 14

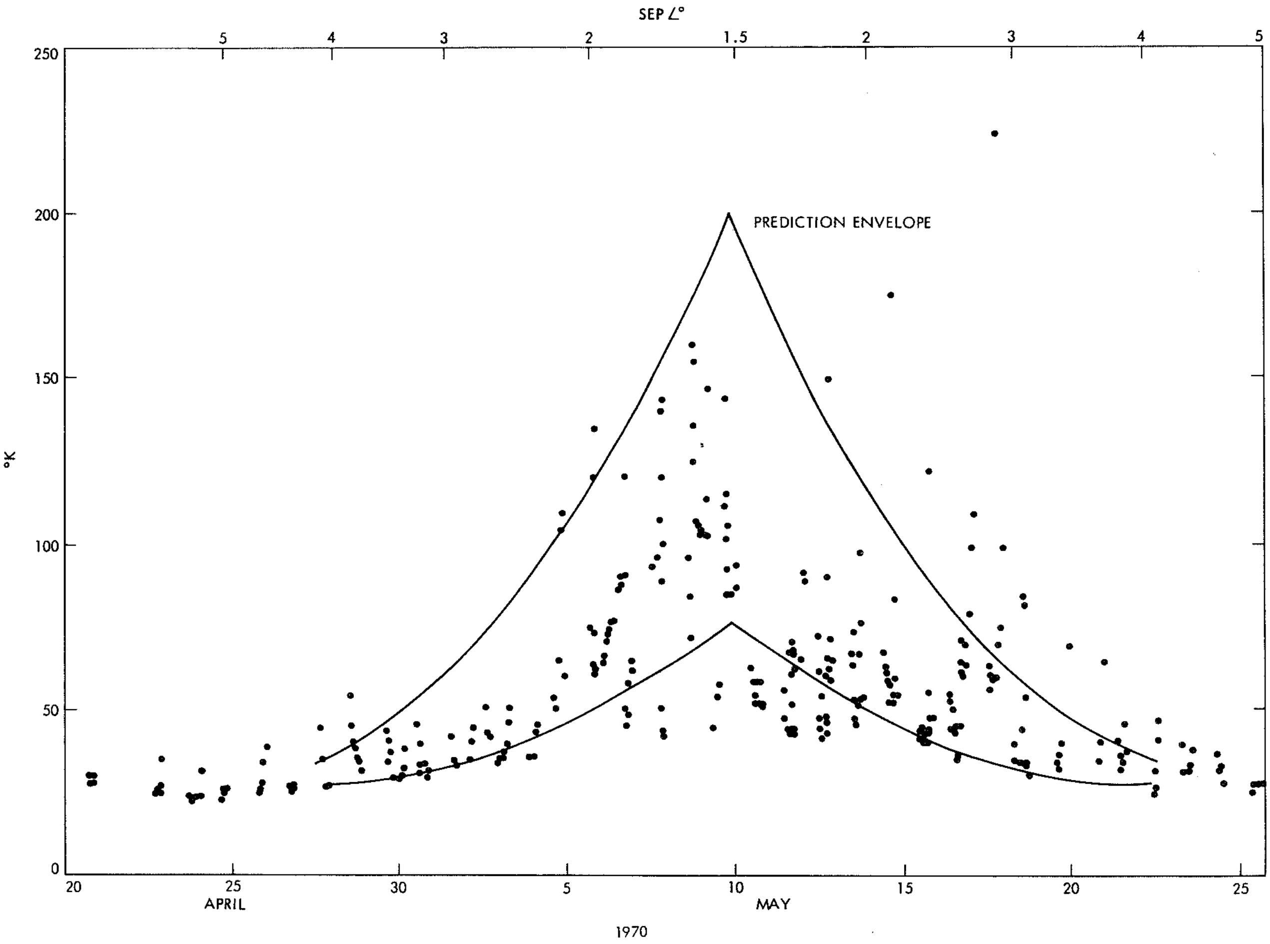


Fig. 46. Mariner 7 measured system noise temperature about superior conjunction at DSS 14

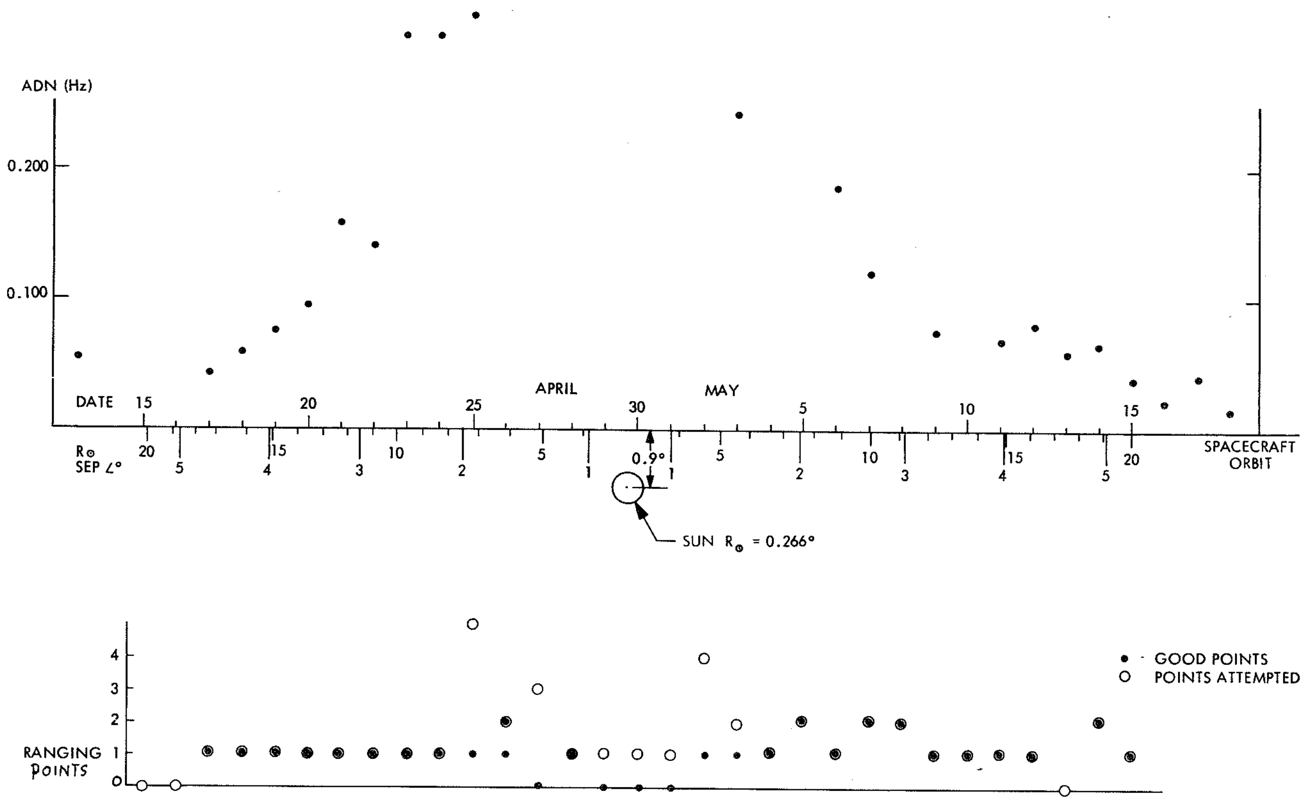


Fig. 47. Mariner 6 superior conjunction 1800 GMT, April 29, 1970; spacecraft 401 million km from earth

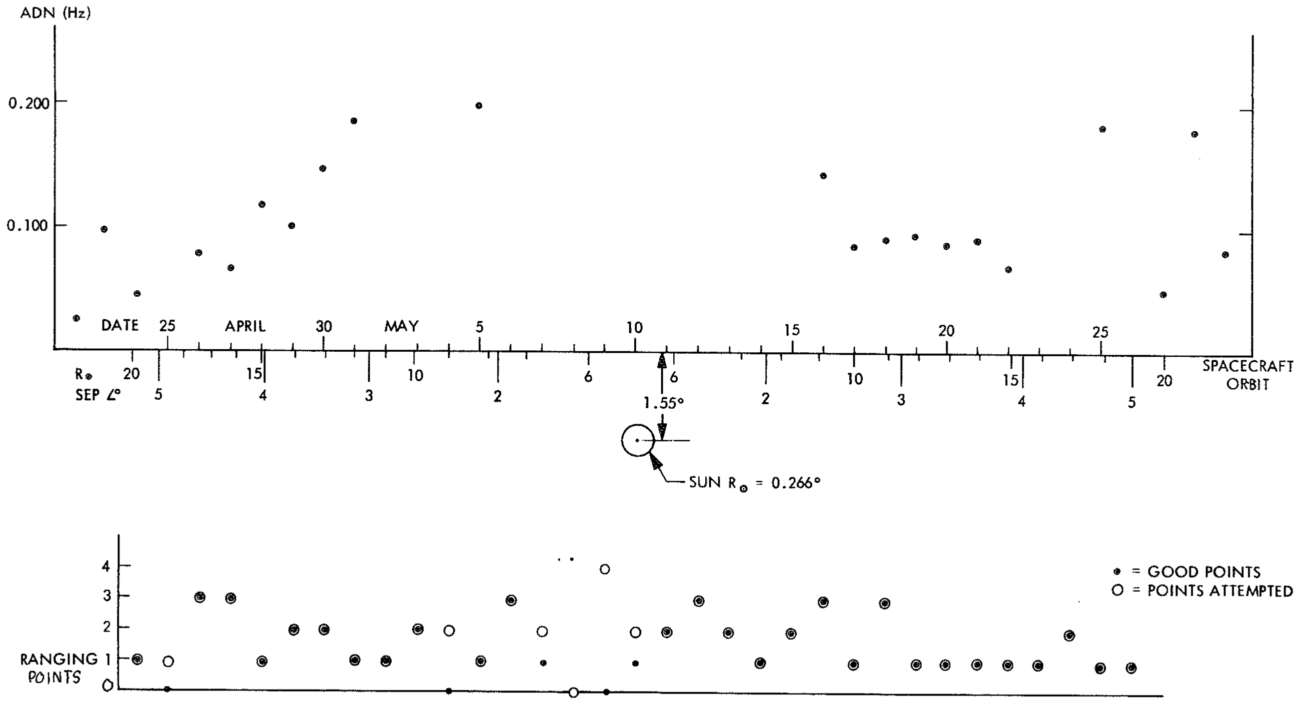


Fig. 48. Mariner 7 superior conjunction 0100 GMT, May 10, 1970; spacecraft 385 million km from earth

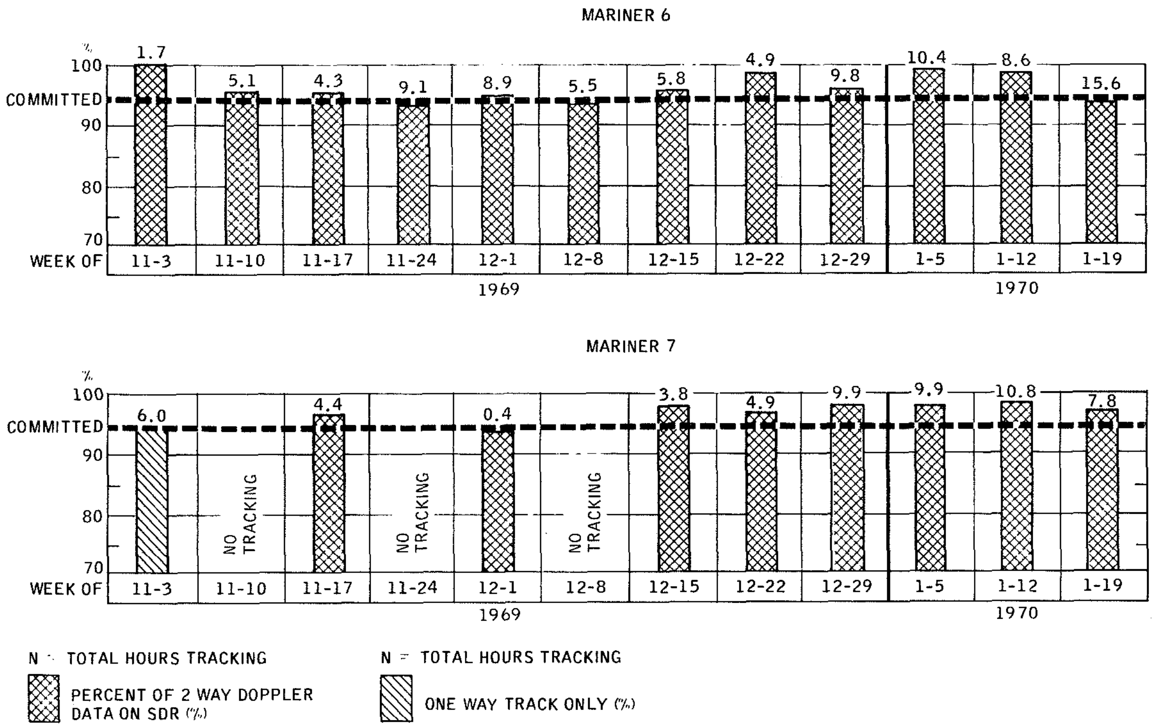


Fig. 49. DSN tracking system performance, week of November 3, 1969 through January 19, 1970

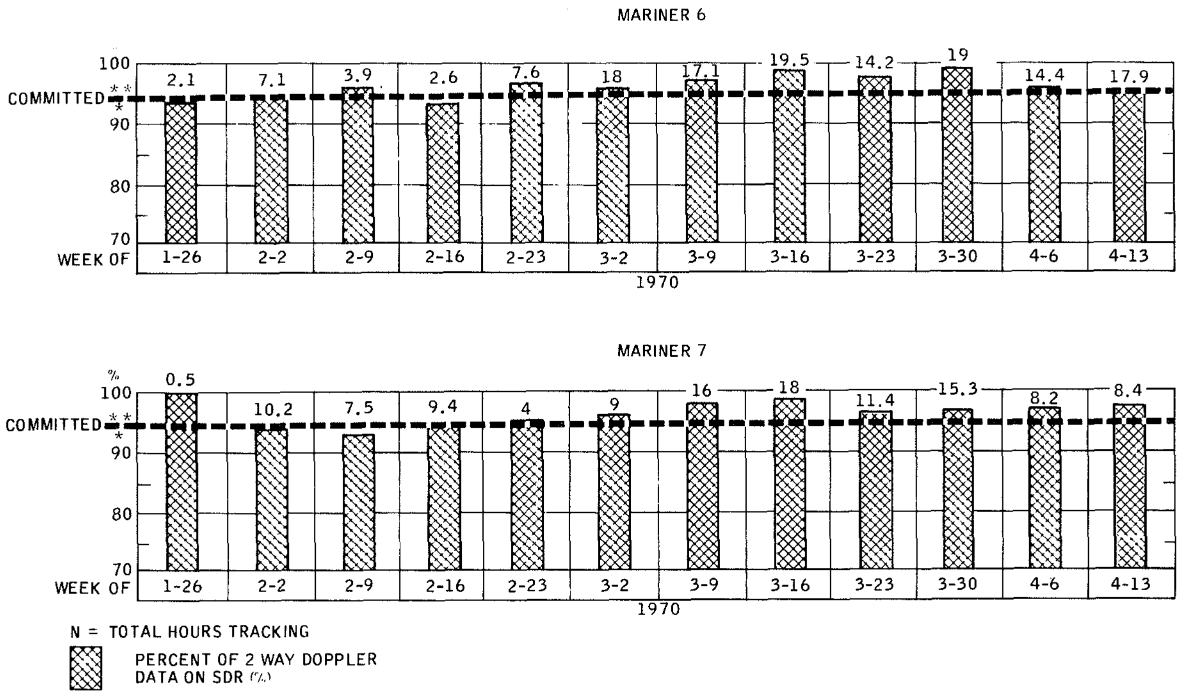


Fig. 50. DSN tracking system performance, week of January 26, 1969 through April 13, 1970

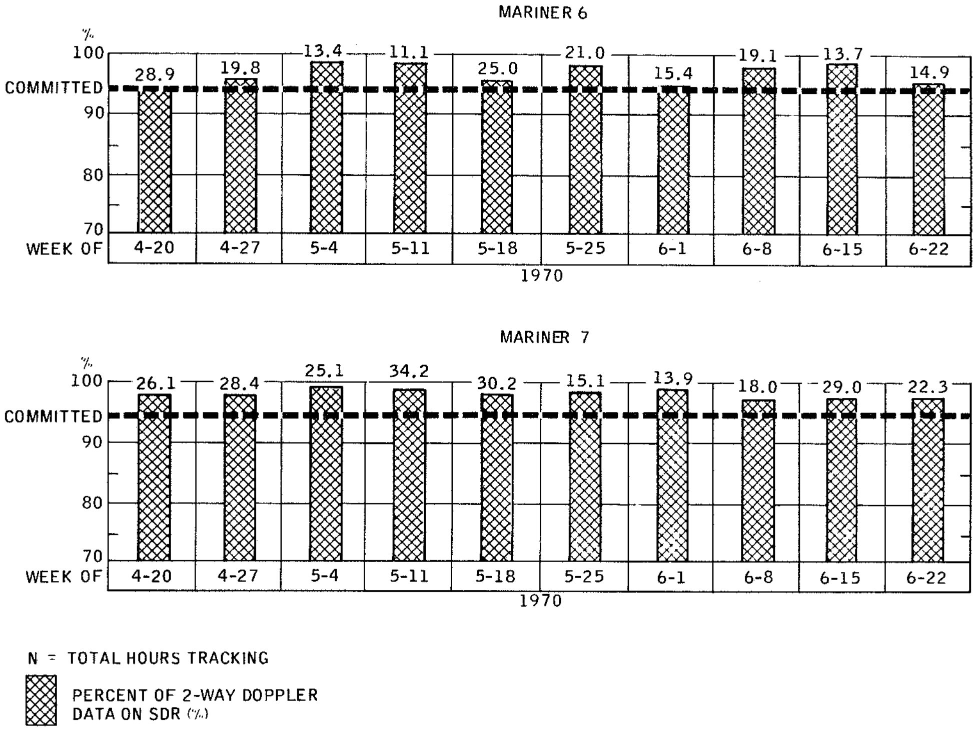


Fig. 51. DSN tracking system performance, week of April 20 through June 22, 1970

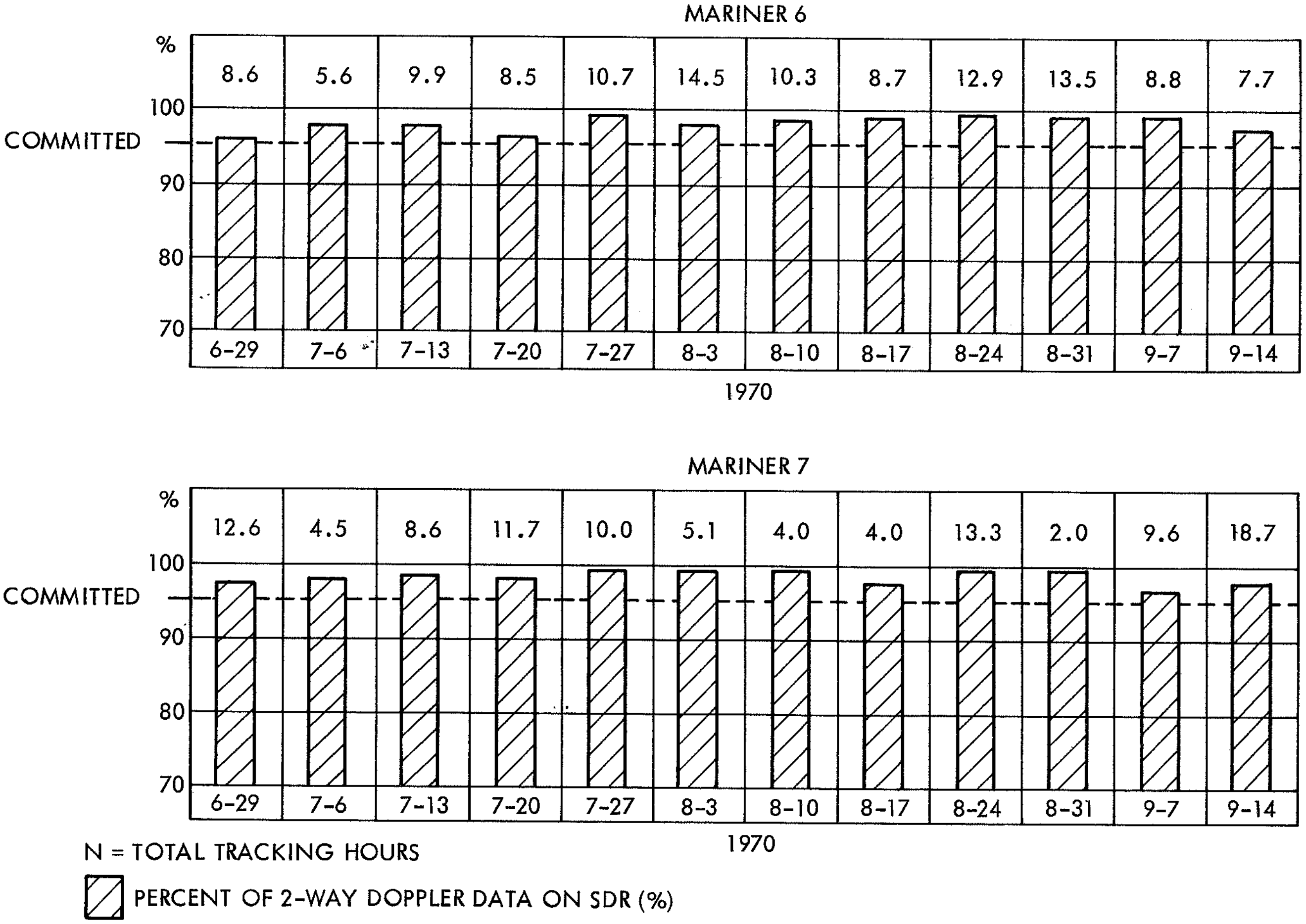


Fig. 52. DSN tracking system performance, week of June 29 through September 14, 1970

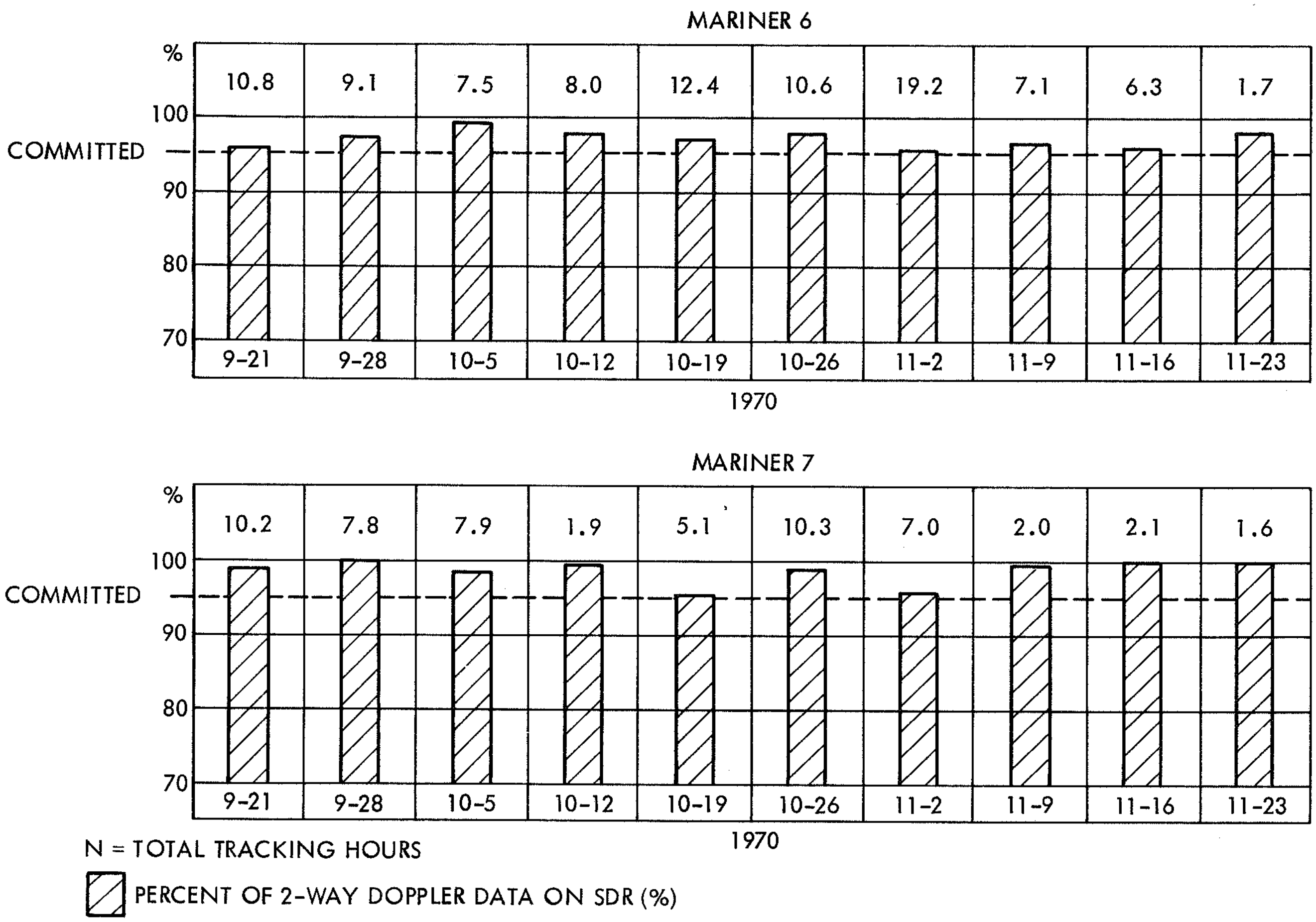


Fig. 53. DSN tracking system performance, week of September 21 through November 23, 1970

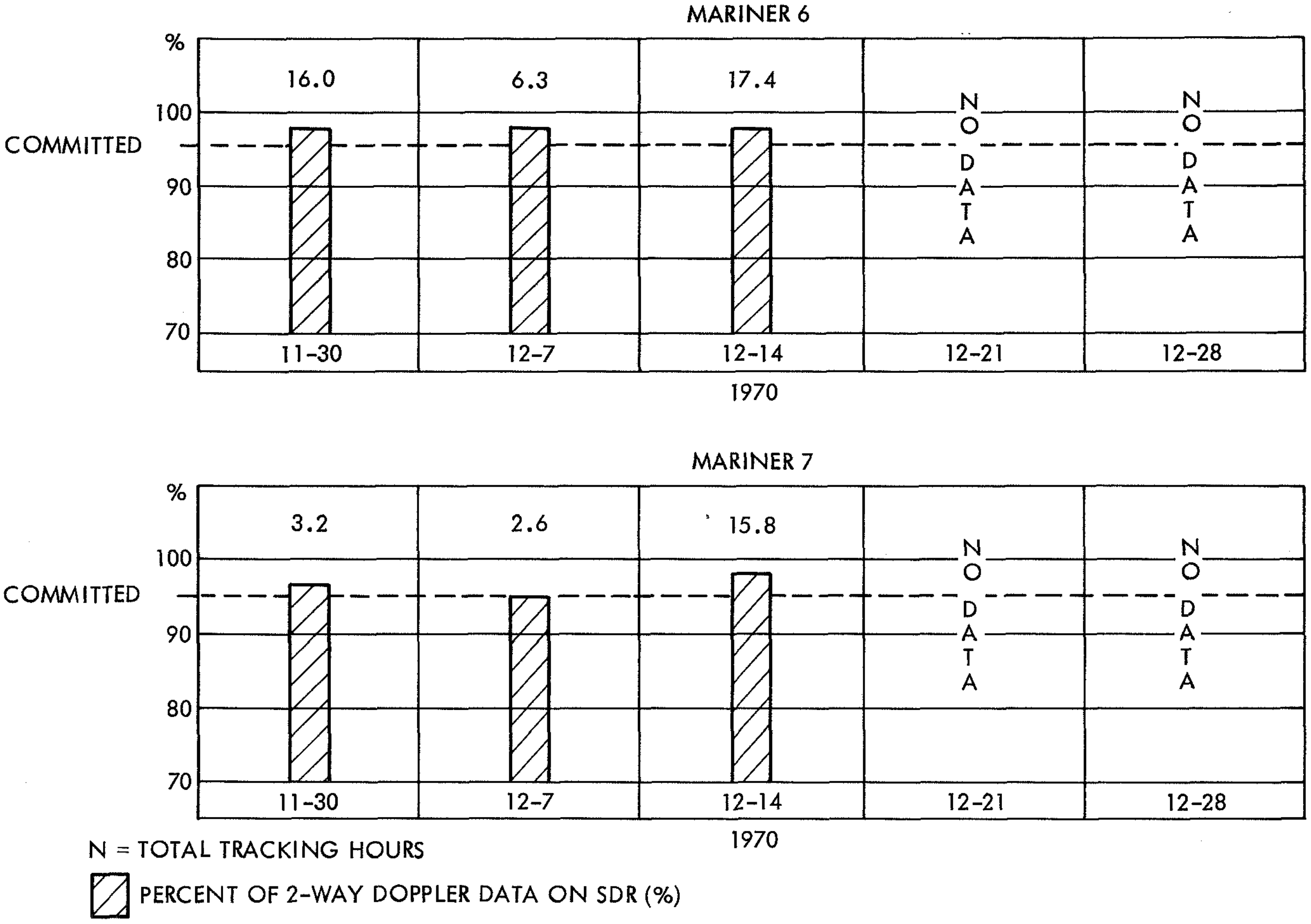


Fig. 54. DSN tracking system performance, week of November 30 through December 28, 1970

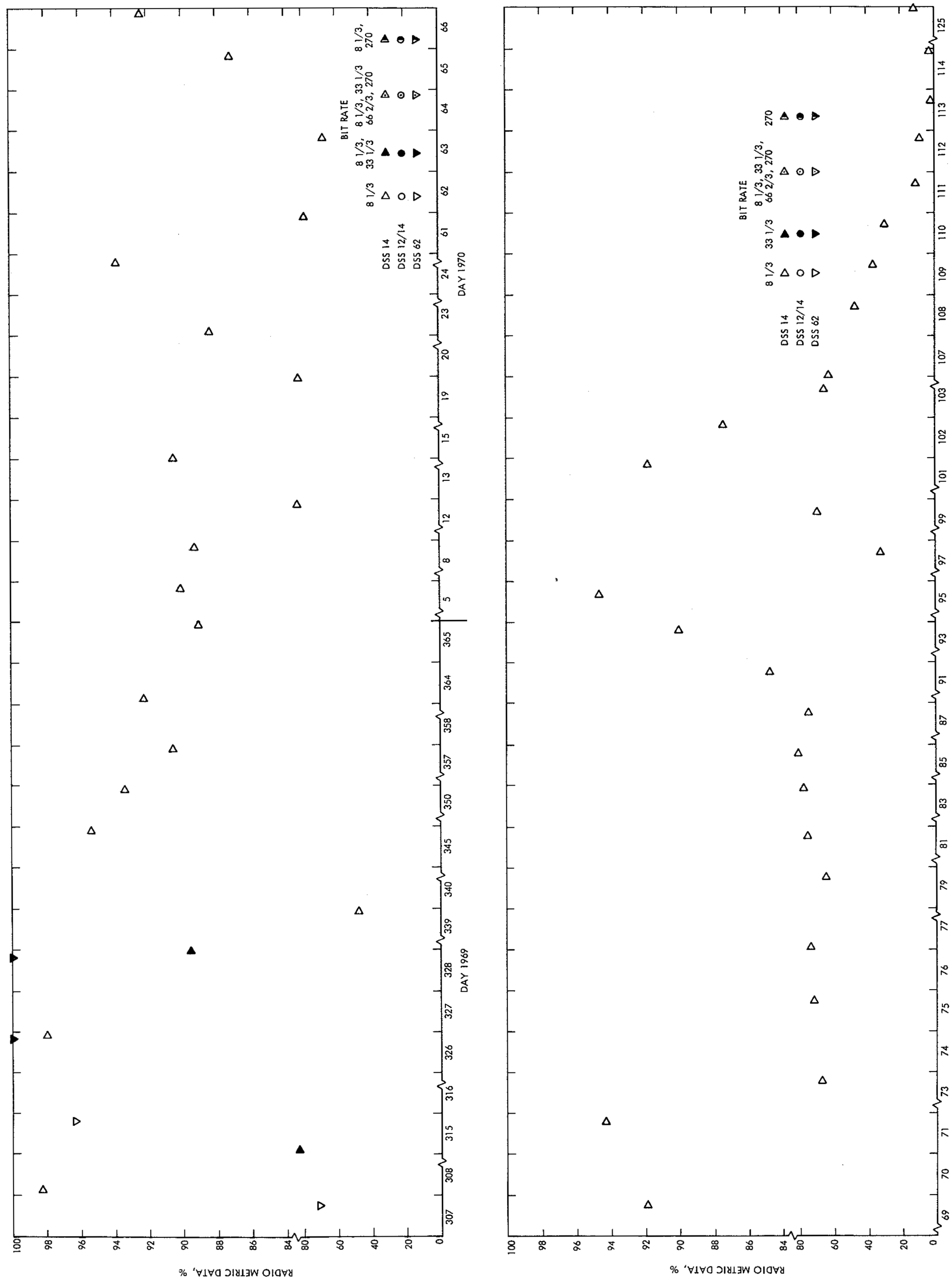


Fig. 55. Mariner 6 telemetry performance

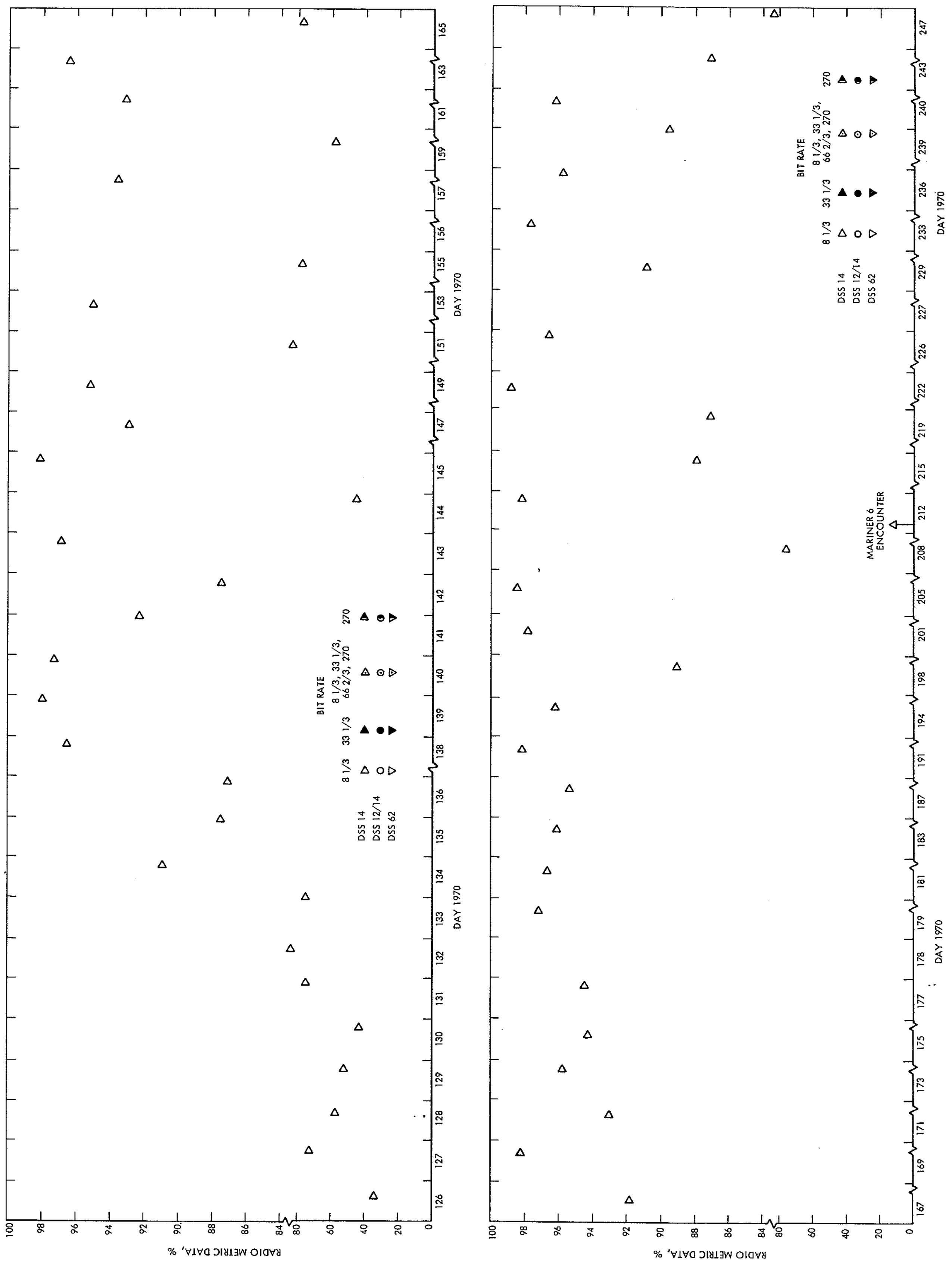
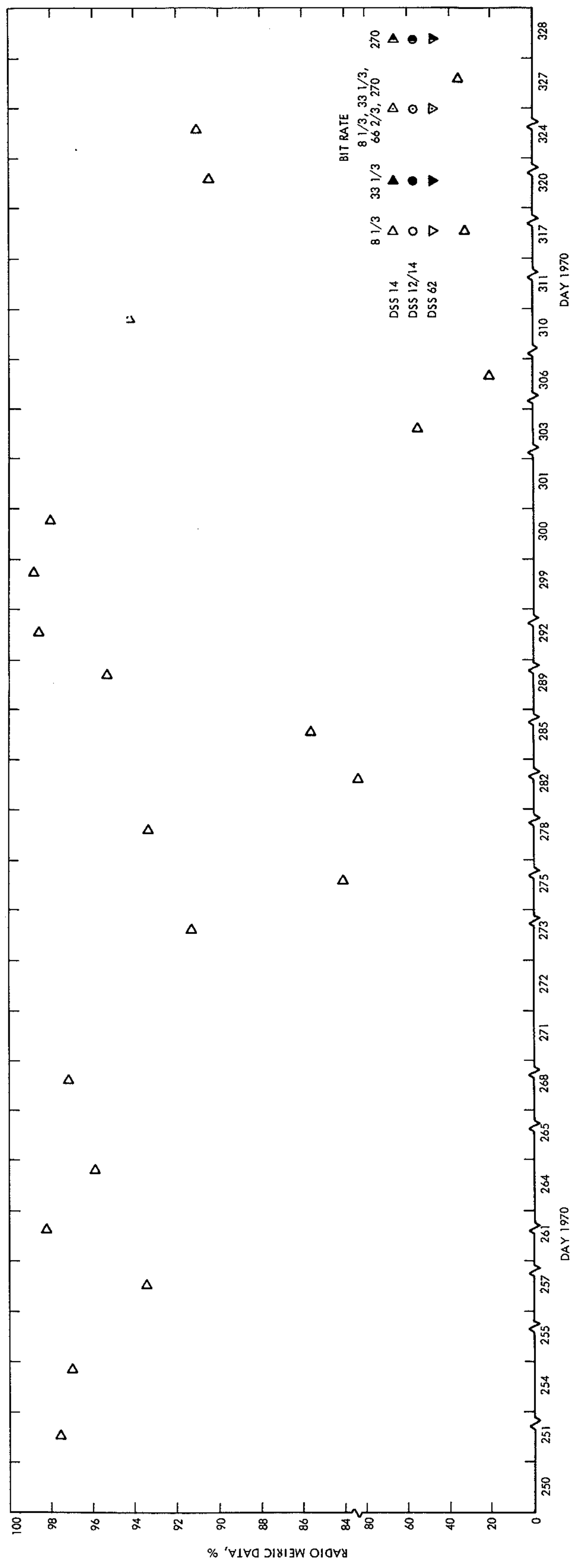

RADIO METRIC DATA, %
100
98
96
94
92
90
88
86
84
80
60
40
20
0
126
127
128
129
130
131
132
133
134
135
136
138
139
140
141
142
143
144
145
147
149
151
153
155
156
157
159
161
163
165
DAY 1970
167
169
171
173
175
177
178
179
181
183
187
191
194
198
201
205
208
212
215
219
222
226
227
229
233
236
239
240
243
247
DAY 1970
BIT RATE
8 1/3
33 1/3
8 1/3, 33 1/3, 66 2/3, 270
270
DSS 14
DSS 12/14
DSS 62
MARINER 6 ENCOUNTER

Fig. 55 (contd)


RADIO METRIC DATA, %
100
98
96
94
92
90
88
86
84
80
60
40
20
0
DAY 1970
250
251
254
255
257
261
264
265
268
271
272
273
275
278
282
285
289
292
299
300
301
303
306
310
311
317
320
324
327
328
BIT RATE
8 1/3
33 1/3
8 1/3, 33 1/3, 66 2/3, 270
270
DSS 14
DSS 12/14
DSS 62

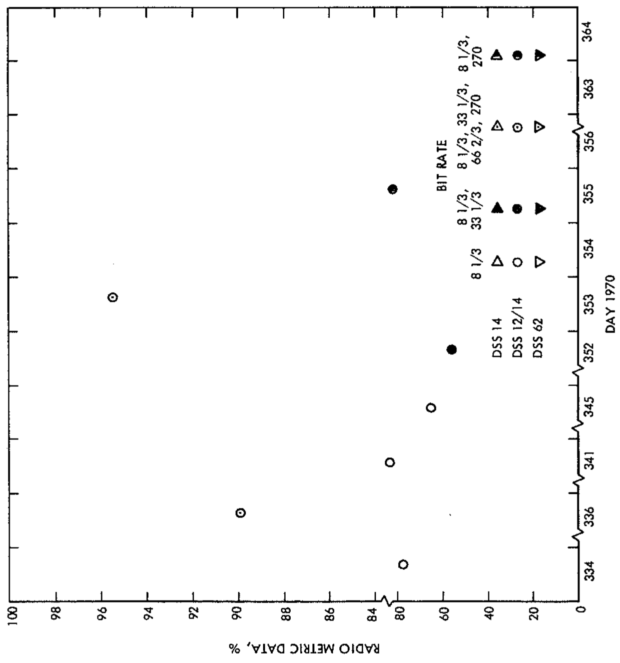

RADIO METRIC DATA, %
100
98
96
94
92
90
88
86
84
80
60
40
20
0
DAY 1970
334
336
341
345
352
353
354
355
356
363
364
BIT RATE
8 1/3
8 1/3, 33 1/3
8 1/3, 33 1/3, 66 2/3, 270
8 1/3, 270
DSS 14
DSS 12/14
DSS 62

Fig. 55 (contd)

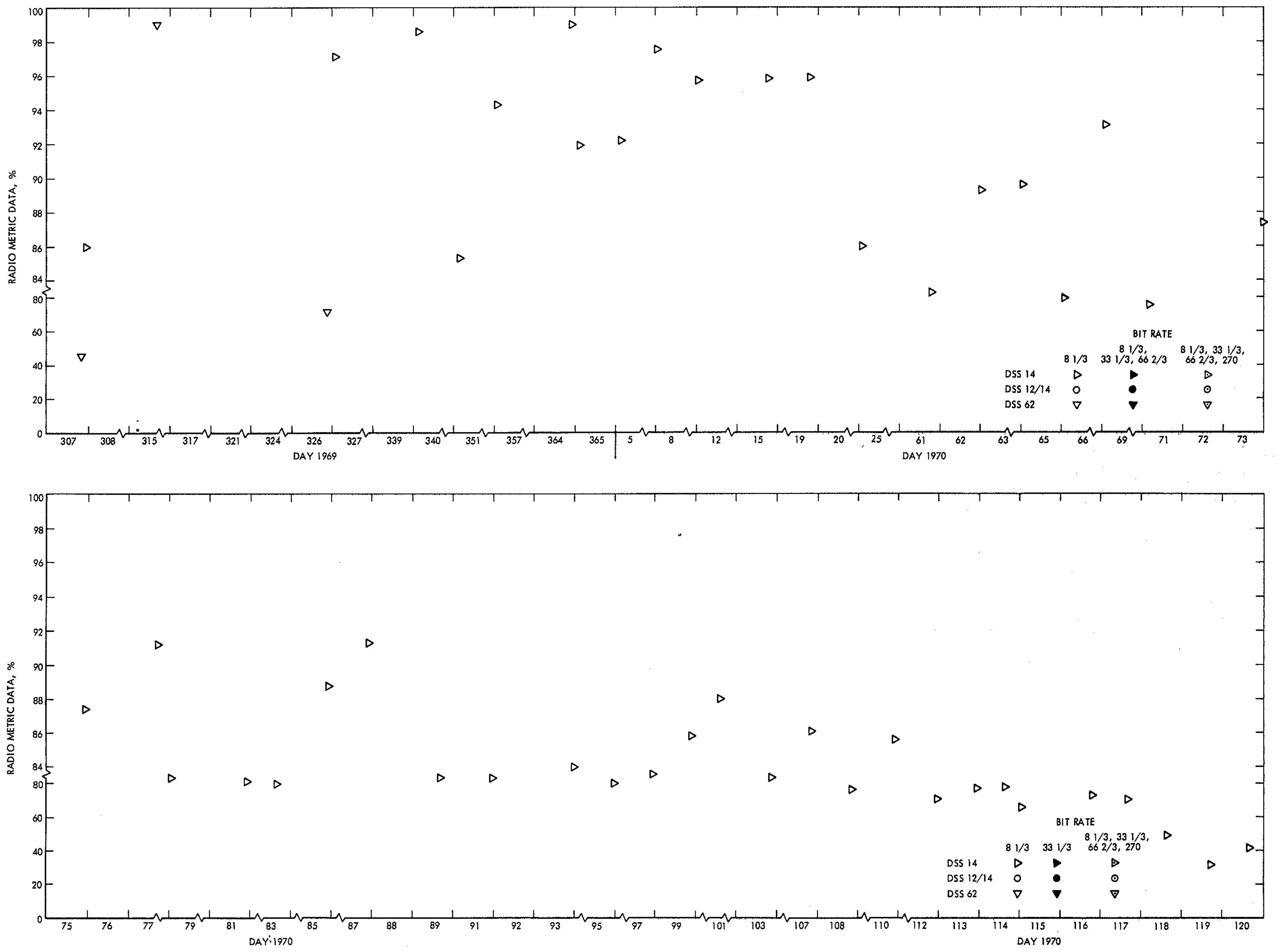


Fig. 56. Mariner 7 telemetry performance

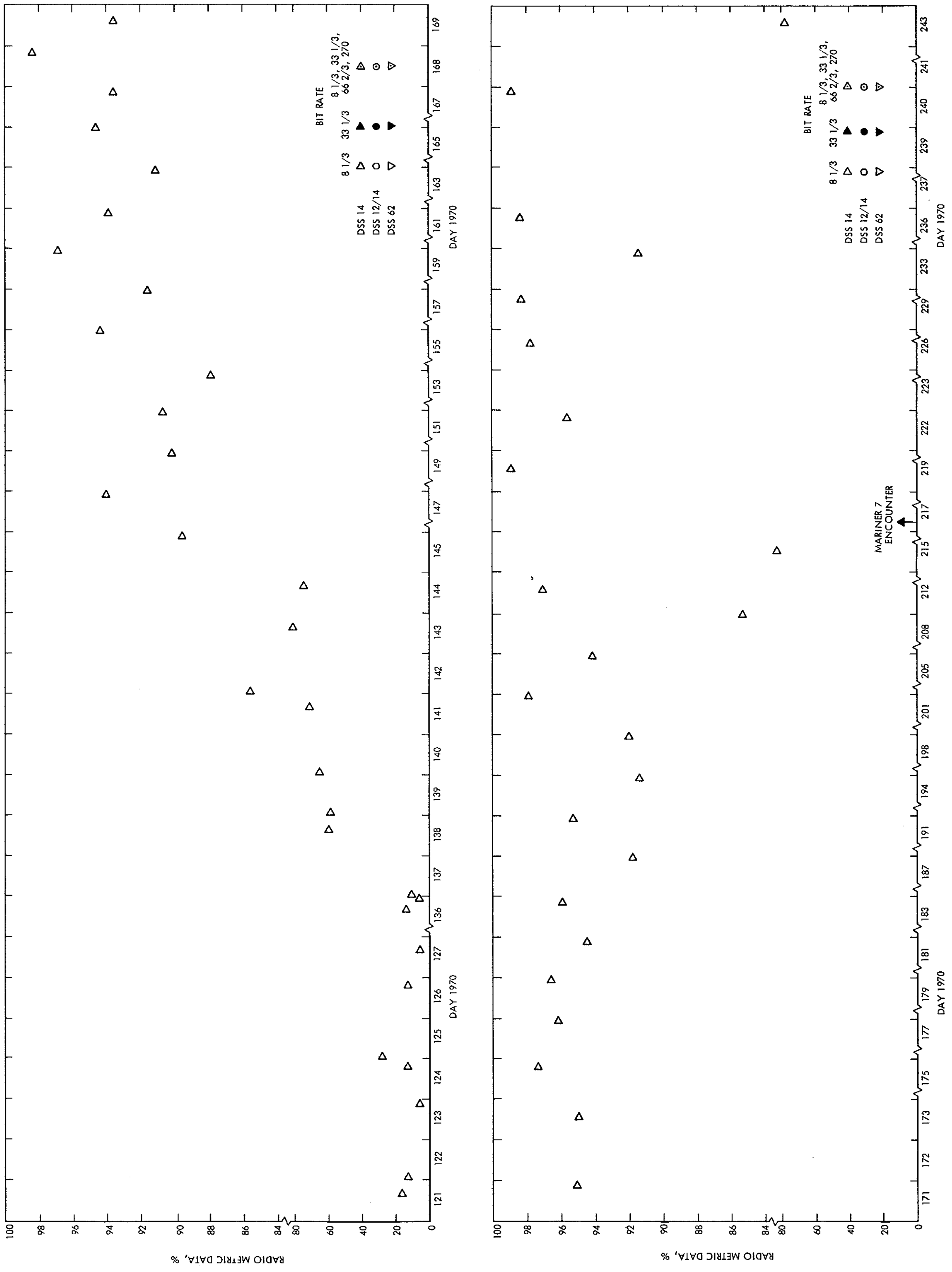

RADIO METRIC DATA, %
100
98
96
94
92
90
88
86
84
80
60
40
20
0
DAY 1970
121
122
123
124
125
126
127
136
137
138
139
140
141
142
143
144
145
147
149
151
153
155
157
159
161
163
165
167
168
169
171
172
173
175
177
179
181
183
187
191
194
198
201
205
208
212
215
217
219
222
223
226
229
233
236
237
239
240
241
243
DSS 14
DSS 12/14
DSS 62
BIT RATE
8 1/3
33 1/3
8 1/3, 33 1/3, 66 2/3, 270
MARINER 7 ENCOUNTER

Fig. 56 (contd)

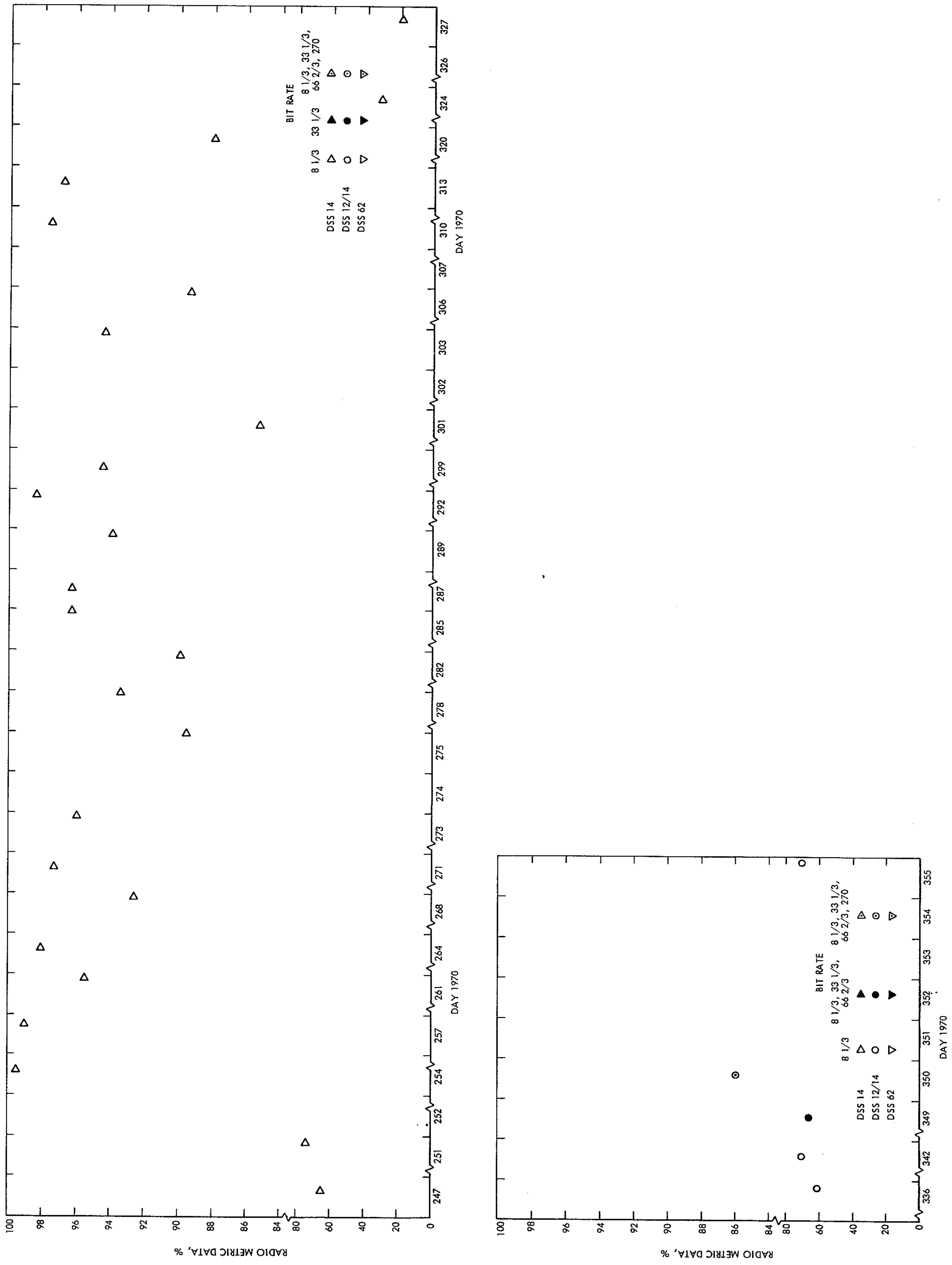
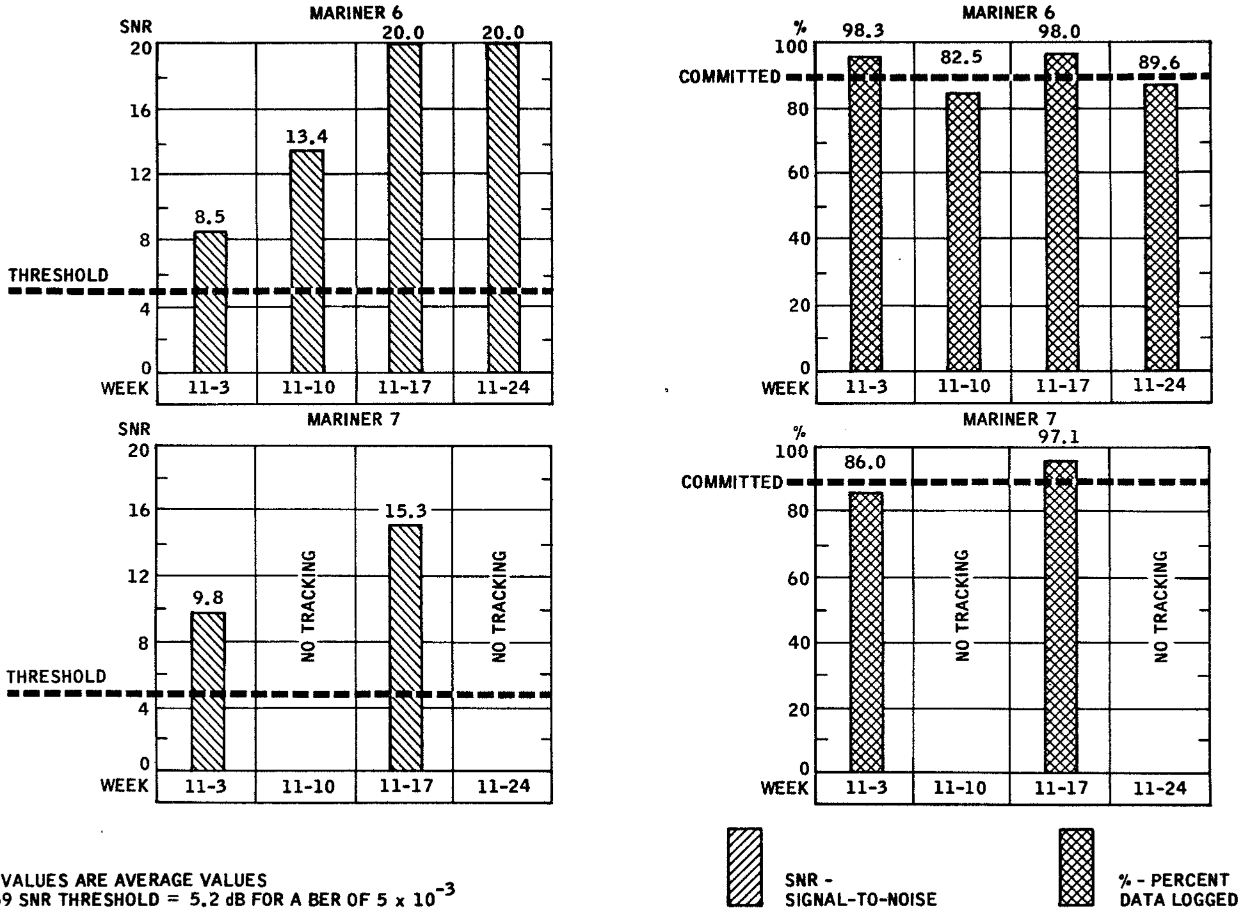

RADIO METRIC DATA, %
100
98
96
94
92
90
88
86
84
80
60
40
20
0
DAY 1970
247
251
252
254
257
261
264
268
271
273
274
275
278
282
285
287
289
292
299
301
302
303
306
307
310
313
320
324
326
327
BIT RATE
8 1/3
33 1/3
8 1/3, 33 1/3, 66 2/3, 270
DSS 14
DSS 12/14
DSS 62
RADIO METRIC DATA, %
DAY 1970
336
342
349
350
351
352
353
354
355
BIT RATE
8 1/3
8 1/3, 33 1/3, 66 2/3
8 1/3, 33 1/3, 66 2/3, 270
DSS 14
DSS 12/14
DSS 62

Fig. 56 (contd)



ALL VALUES ARE AVERAGE VALUES
MM69 SNR THRESHOLD = 5.2 dB FOR A BER OF 5×10^{-3}

Fig. 57. DSN telemetry system performance, week of November 3 through November 24, 1969

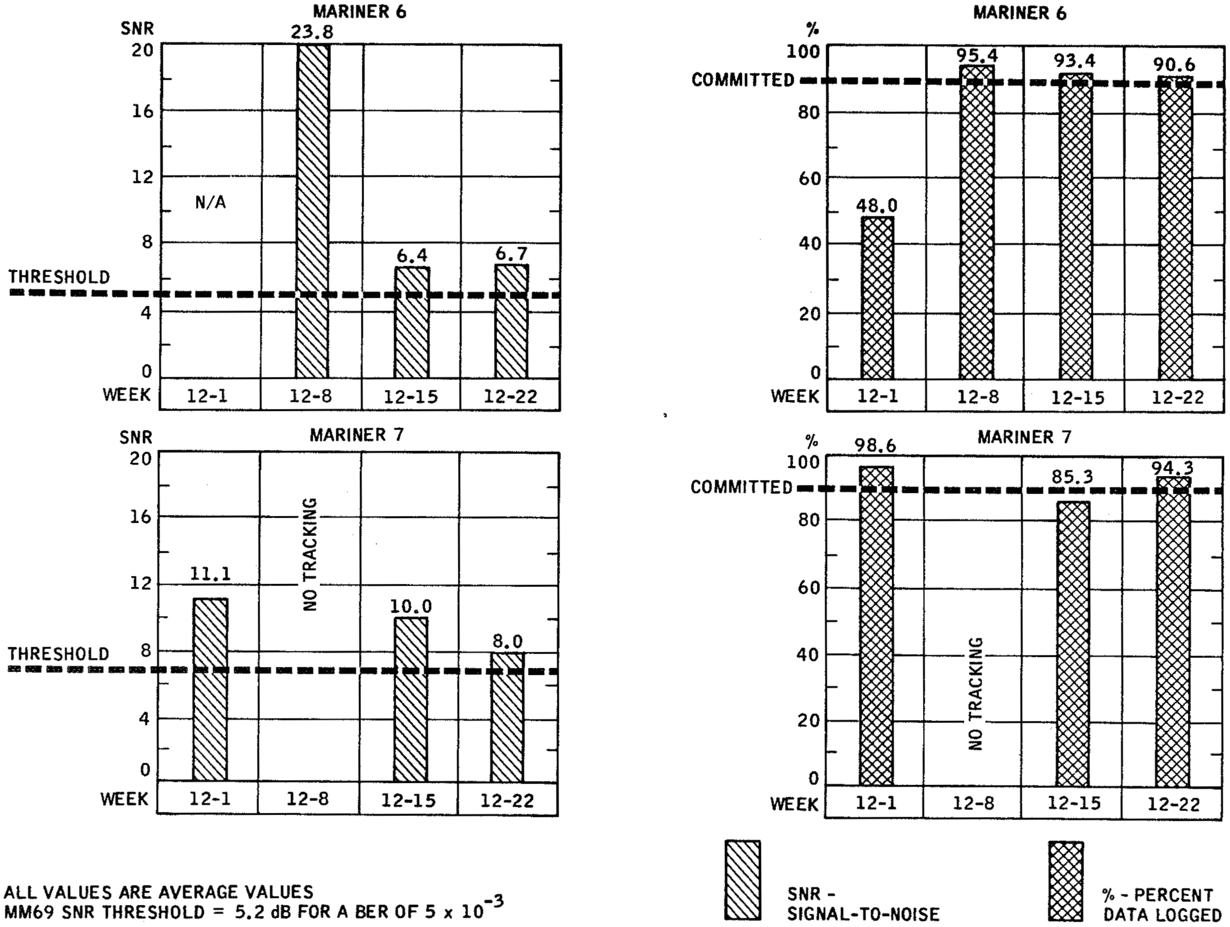


Fig. 58. DSN telemetry system performance, week of December 1 through December 22, 1969.

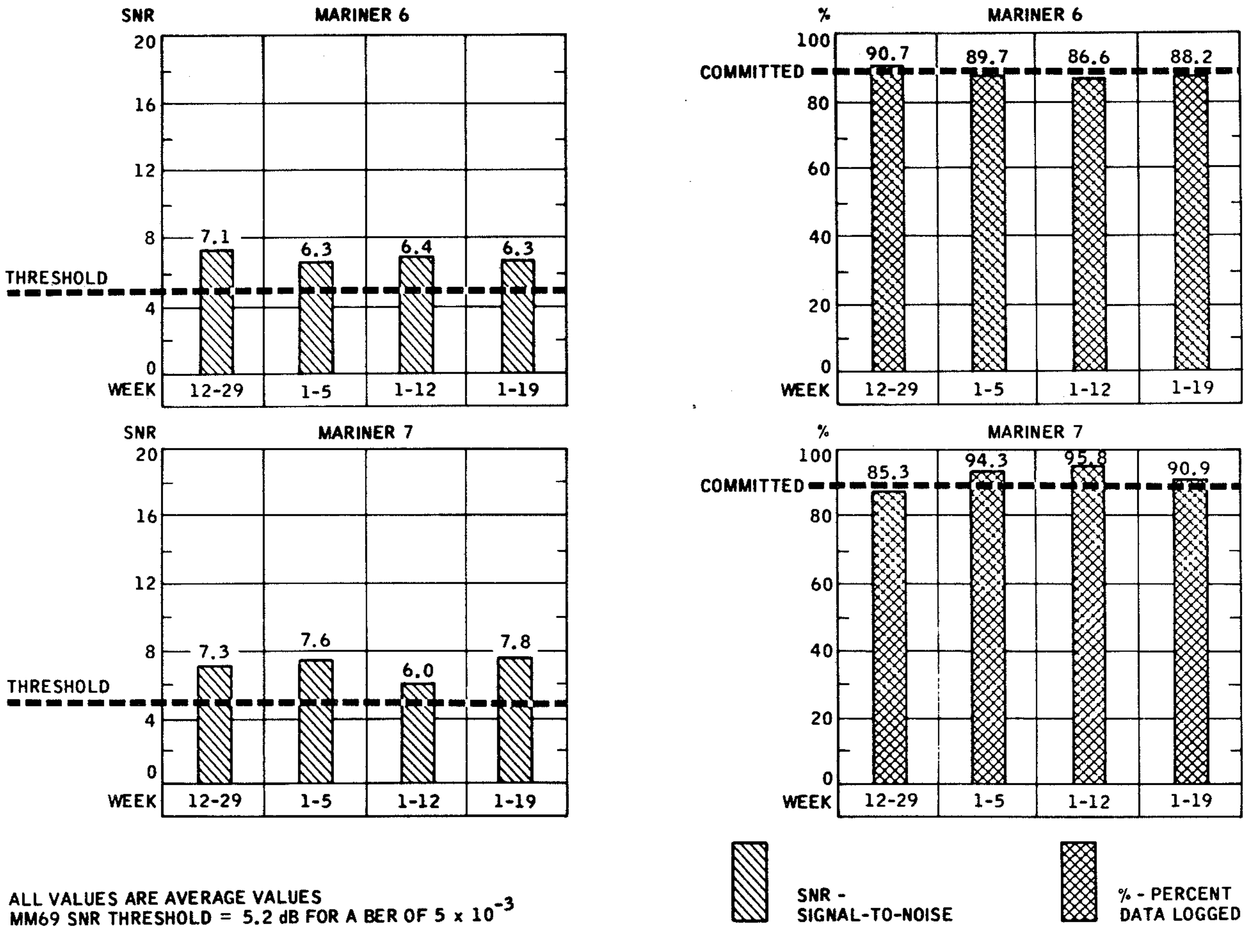
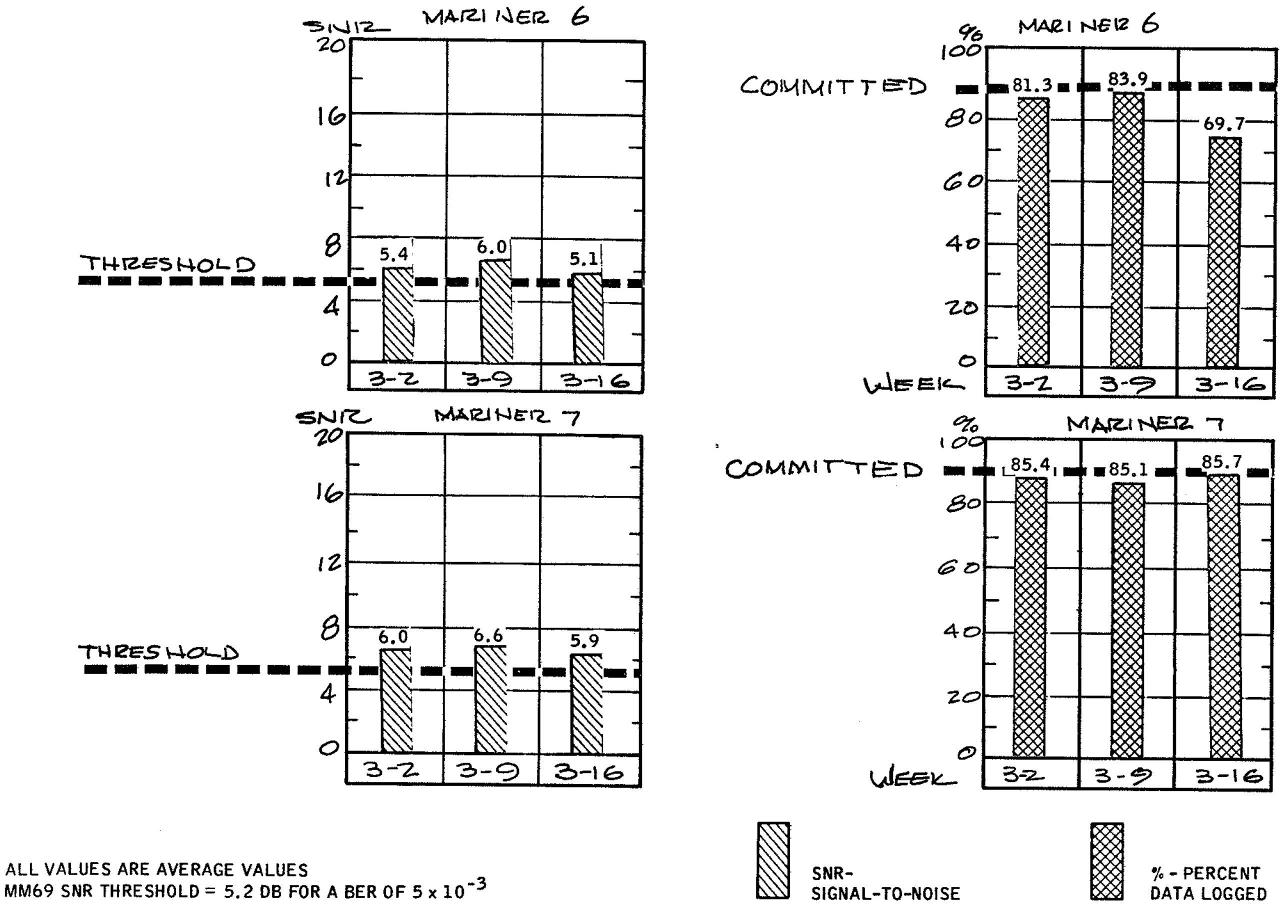
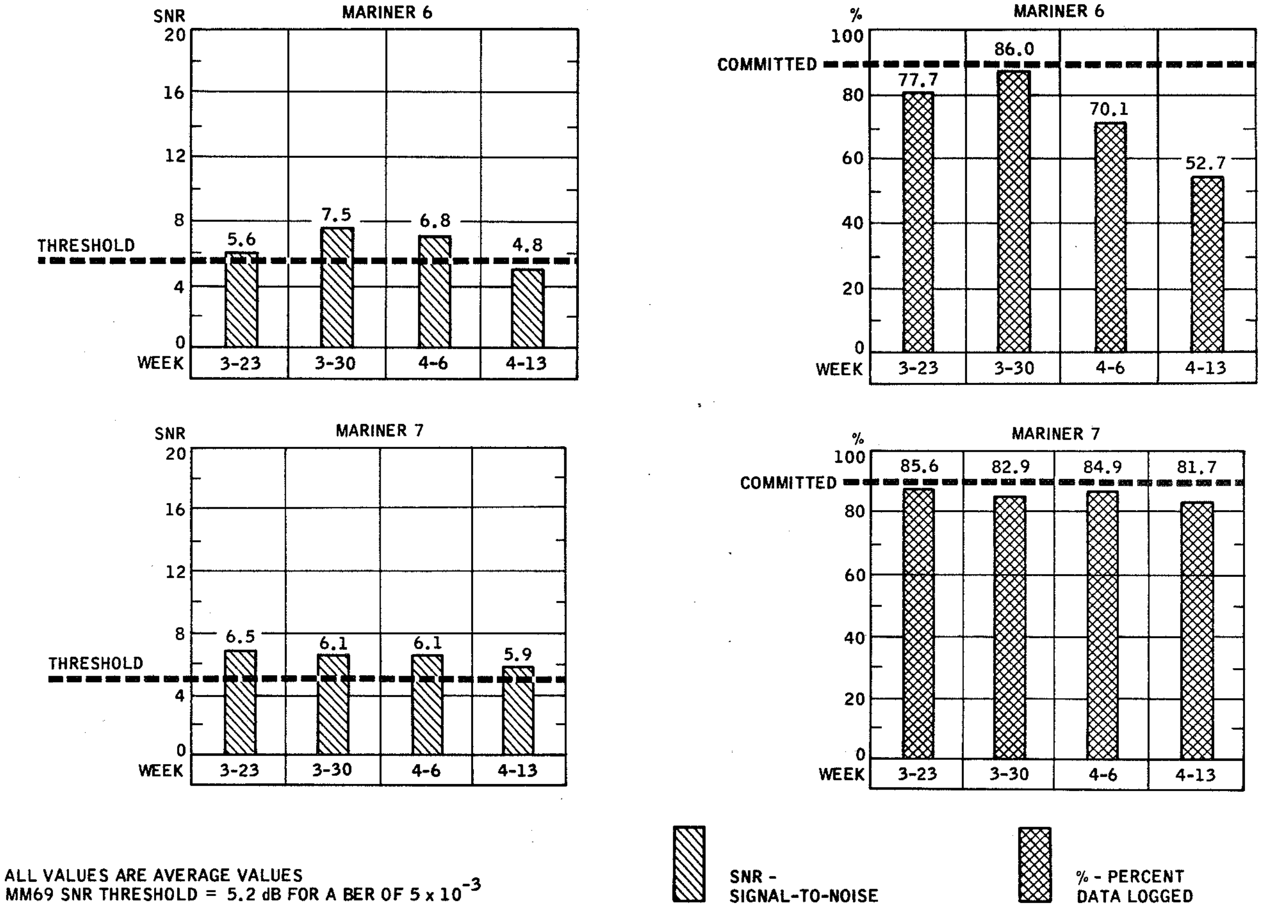


Fig. 59. DSN telemetry system performance, week of December 29, 1969 through January 19, 1970



ALL VALUES ARE AVERAGE VALUES
MM69 SNR THRESHOLD = 5.2 DB FOR A BER OF 5×10^{-3}

Fig. 60. DSN telemetry system performance, week of March 2 through March 16, 1970



ALL VALUES ARE AVERAGE VALUES
MM69 SNR THRESHOLD = 5.2 dB FOR A BER OF 5×10^{-3}

Fig. 61. DSN telemetry system performance, week of March 23 through April 13, 1970

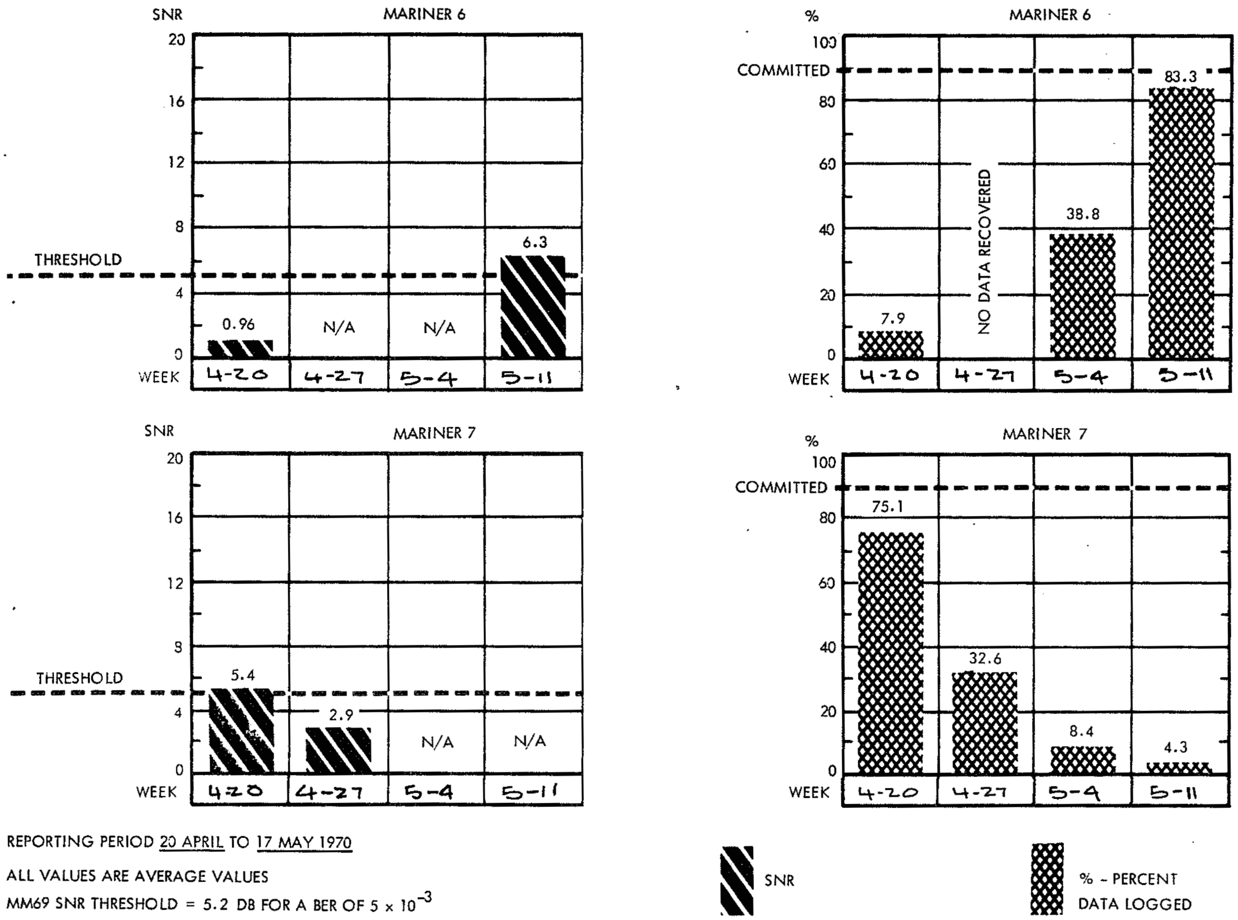
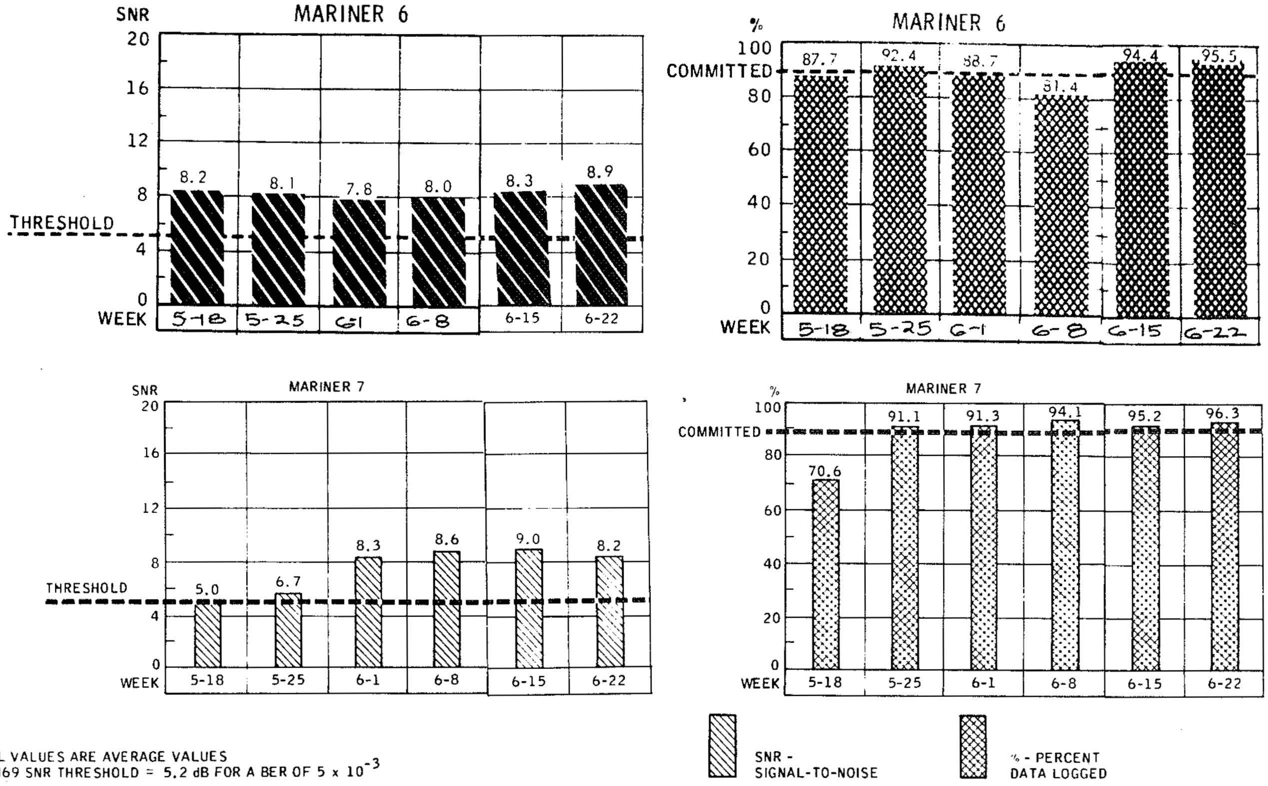
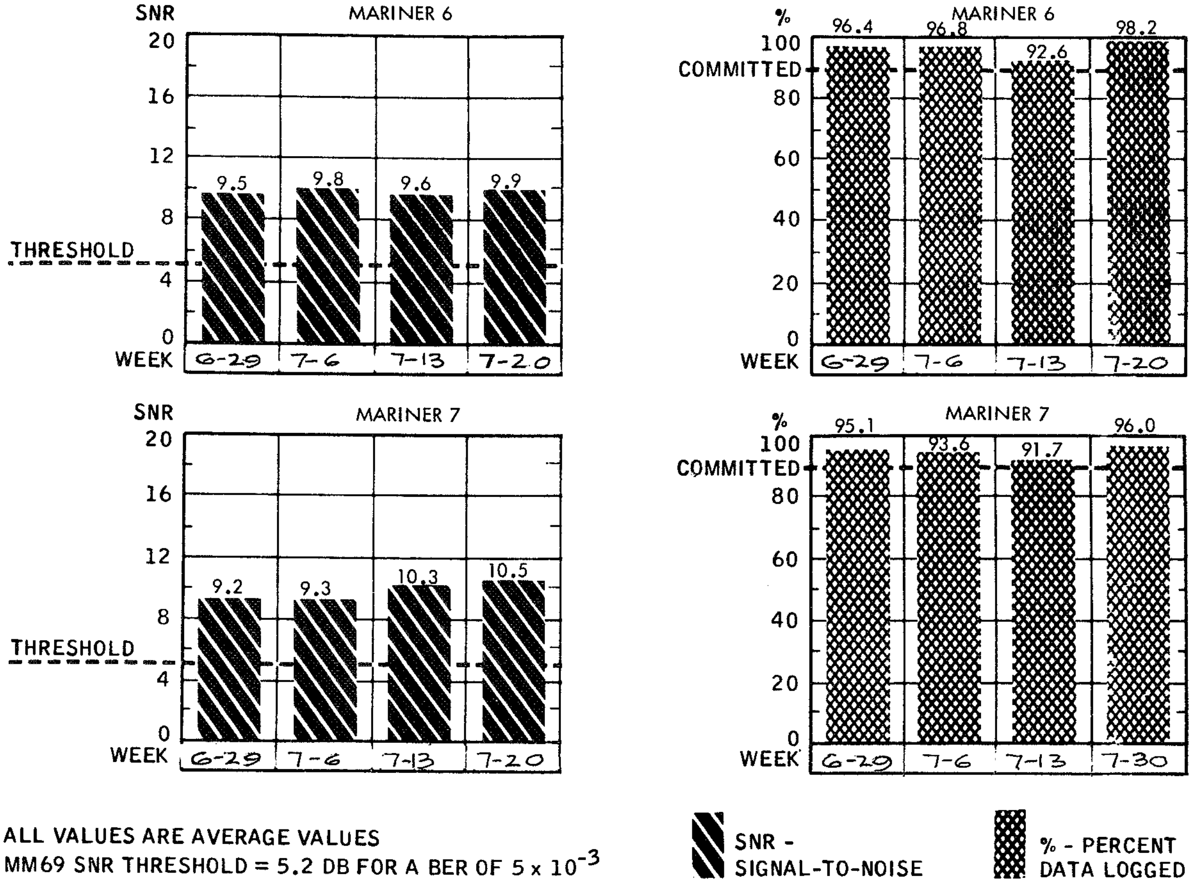


Fig. 62. DSN telemetry system performance, week of April 20 through May 11, 1970



ALL VALUES ARE AVERAGE VALUES
MM69 SNR THRESHOLD = 5.2 dB FOR A BER OF 5 x 10^{-3}

Fig. 63. DSN telemetry system performance, week of May 18 through June 22, 1970



ALL VALUES ARE AVERAGE VALUES
MM69 SNR THRESHOLD = 5.2 DB FOR A BER OF 5 x 10^{-3}

Fig. 64. DSN telemetry system performance, week of June 29 through July 20, 1970

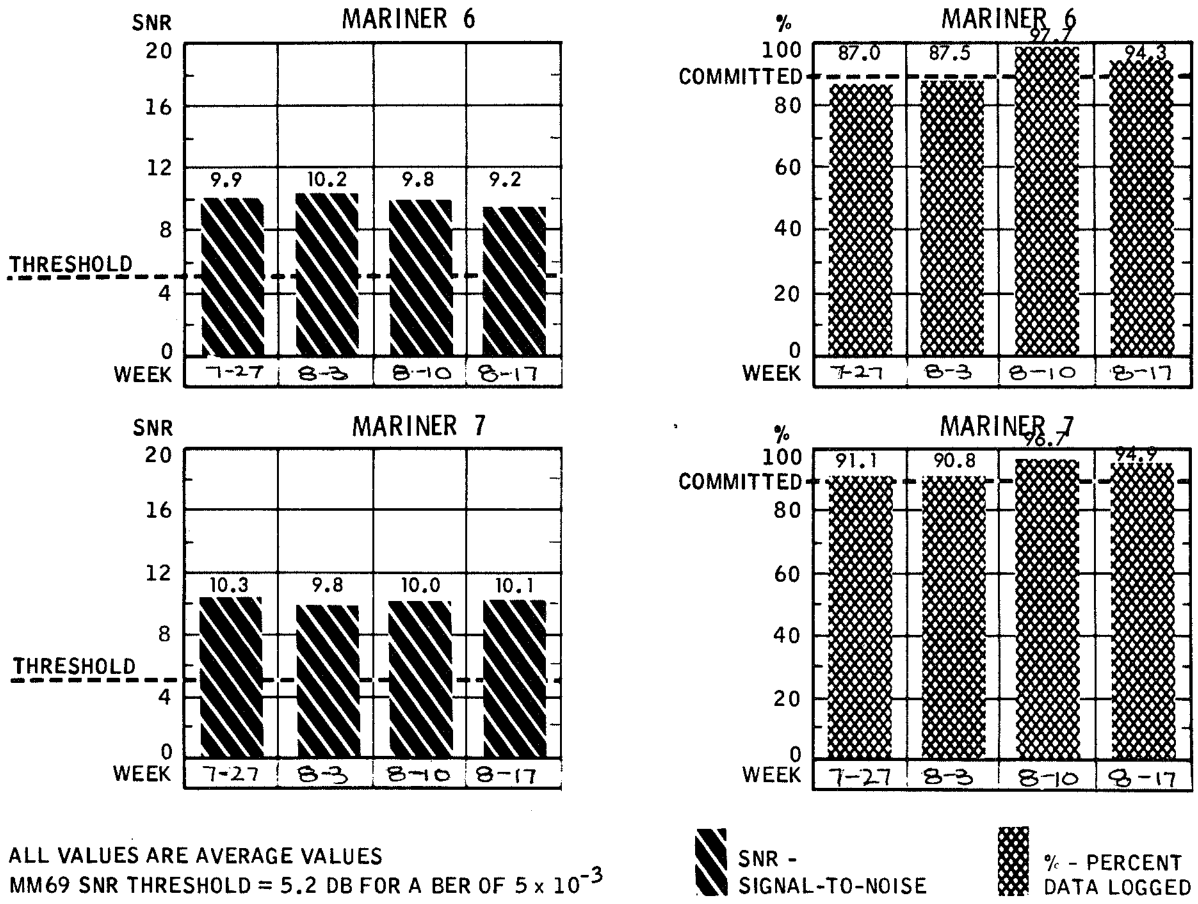
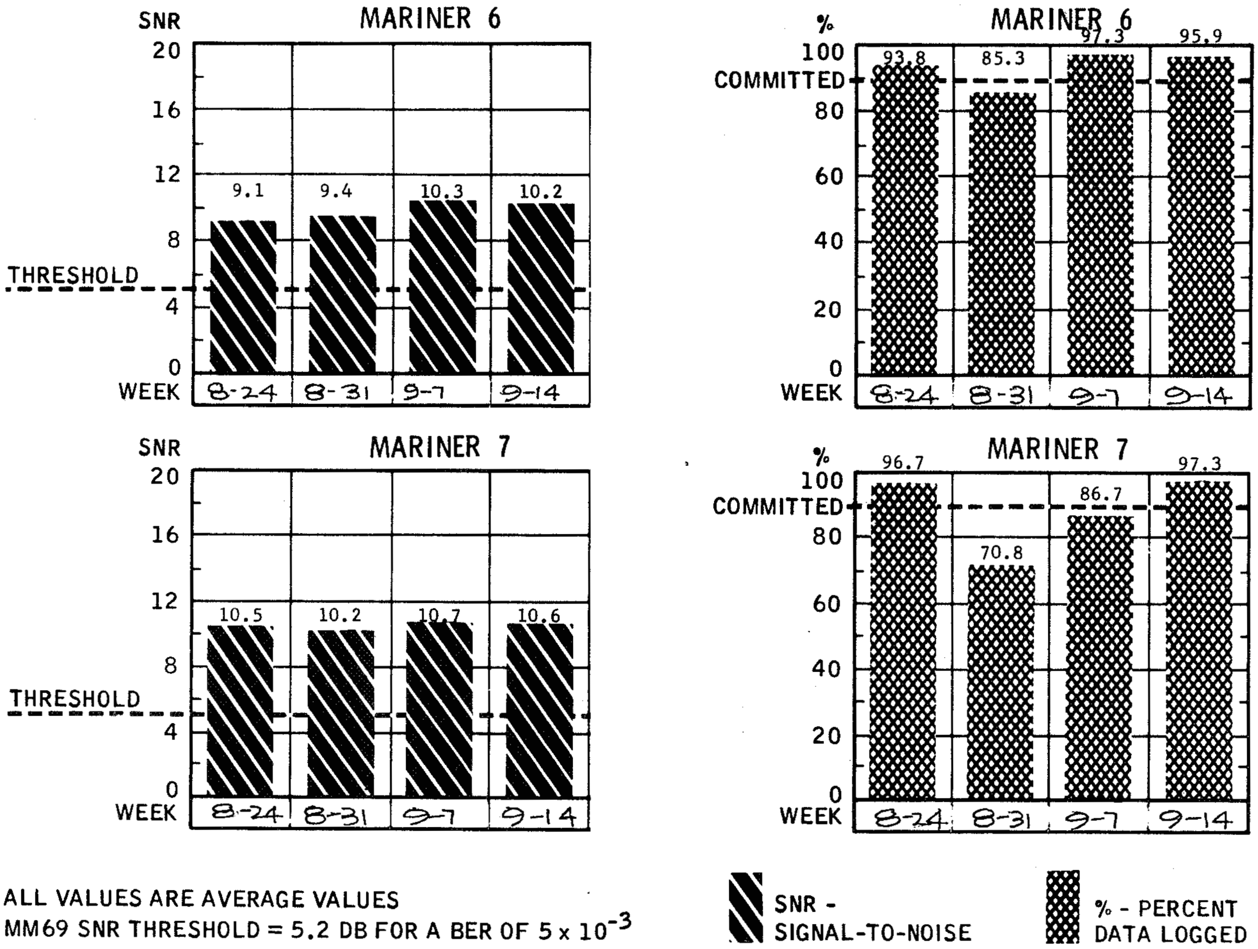


Fig. 65. DSN telemetry system performance, week of July 27 through August 17, 1970



ALL VALUES ARE AVERAGE VALUES
MM69 SNR THRESHOLD = 5.2 DB FOR A BER OF 5 x 10^{-3}

Fig. 66. DSN telemetry system performance, week of August 24 through September 14, 1970

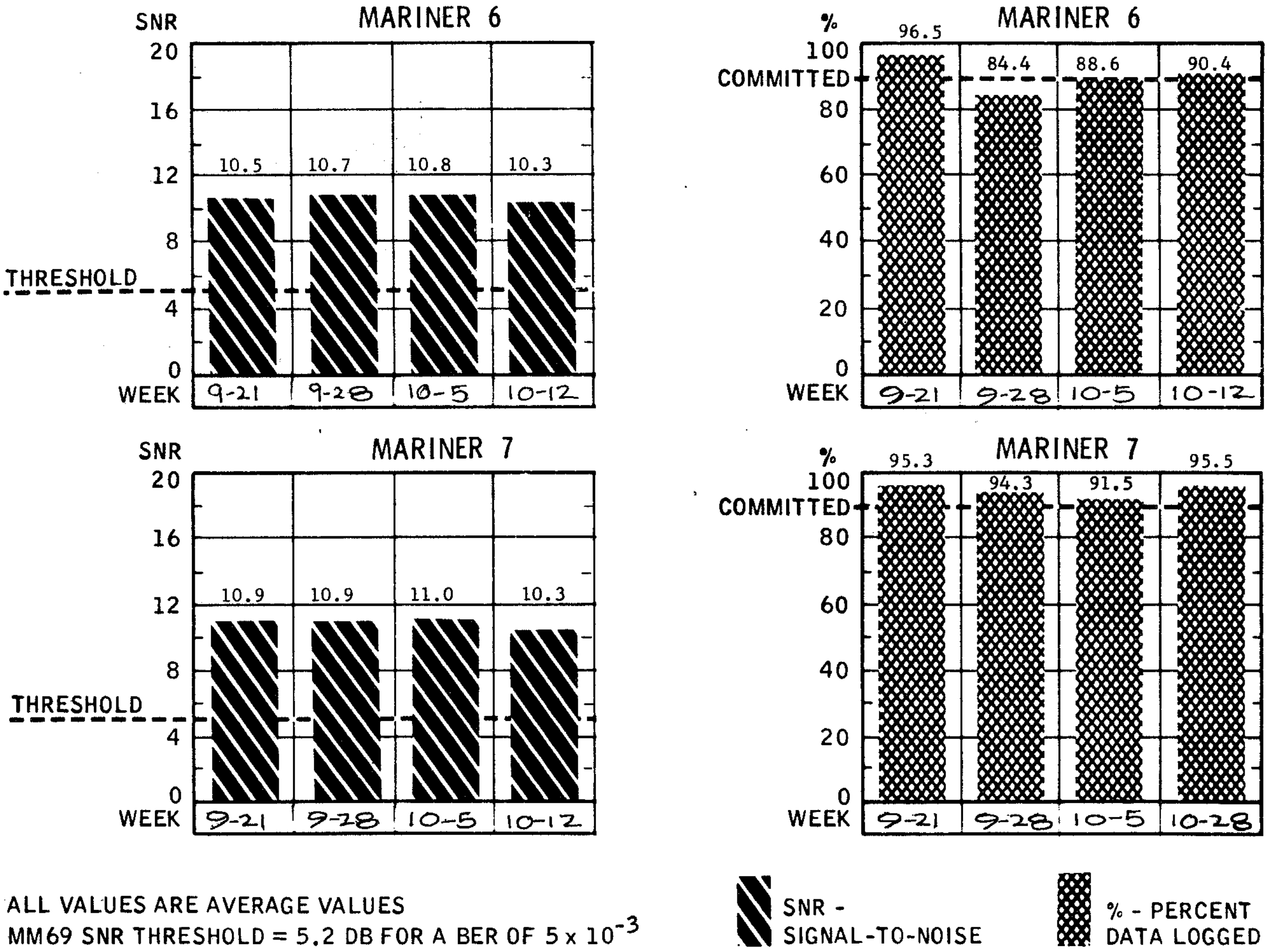


Fig. 67. DSN telemetry system performance, week of September 21 through October 12, 1970

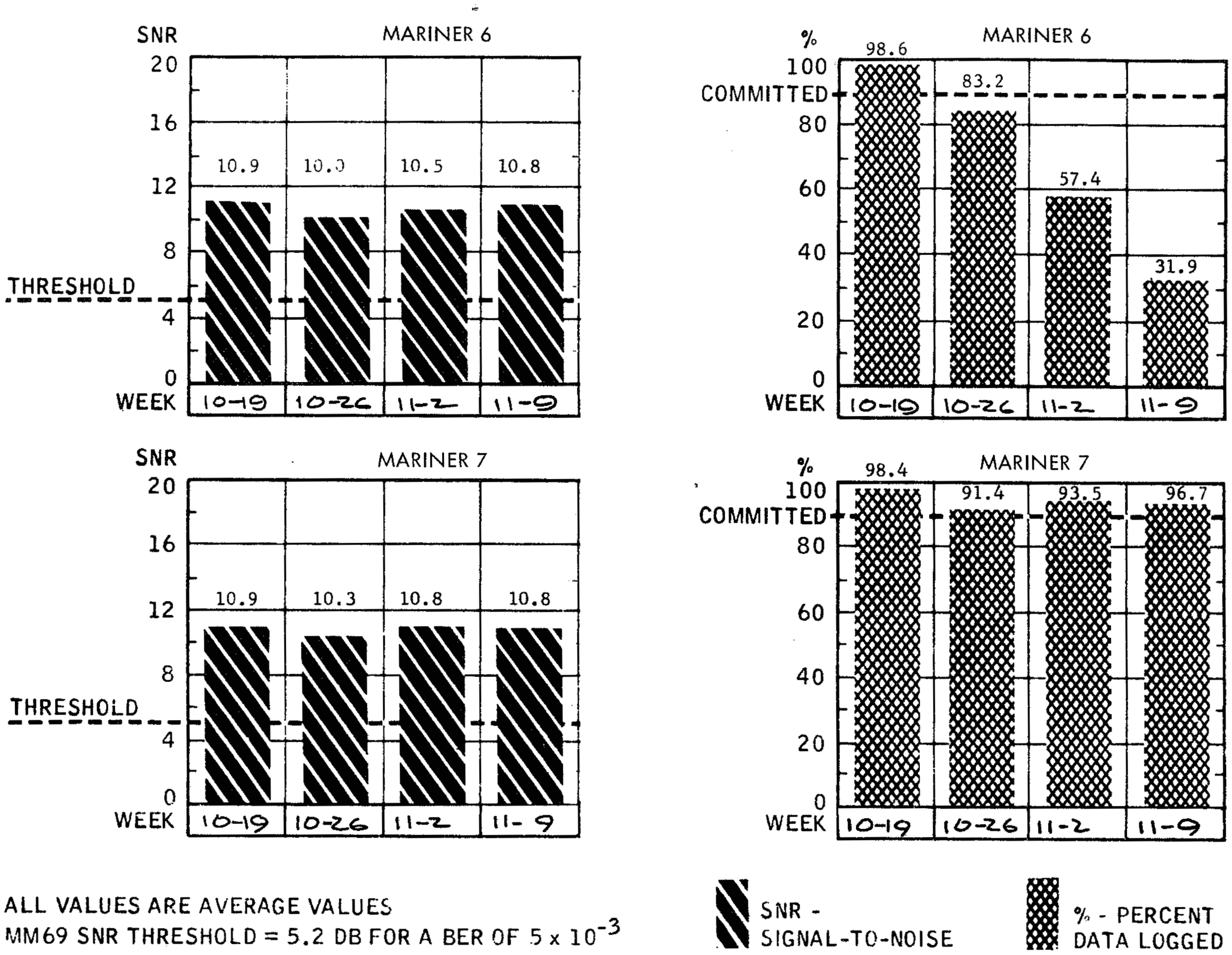
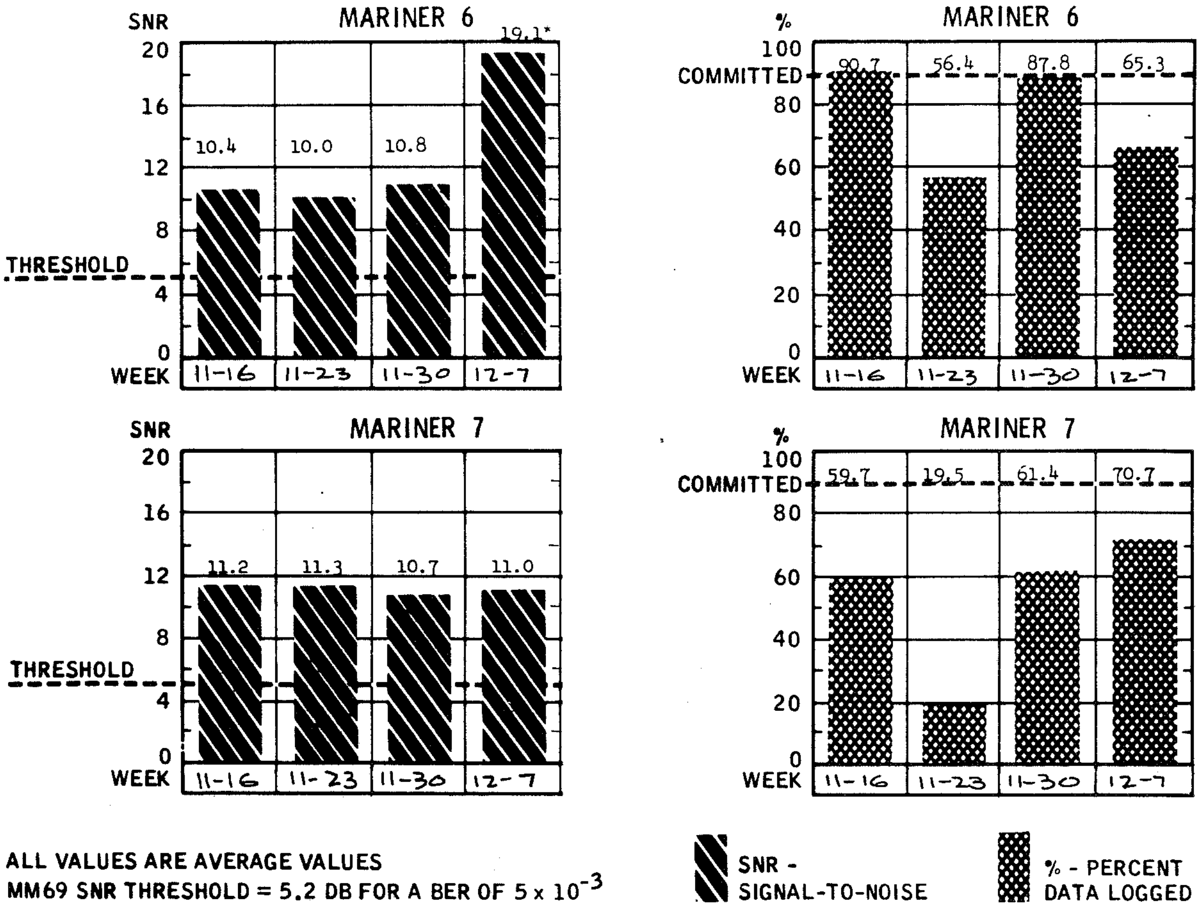


Fig. 68. DSN telemetry system performance, week of October 19 through November 9, 1970

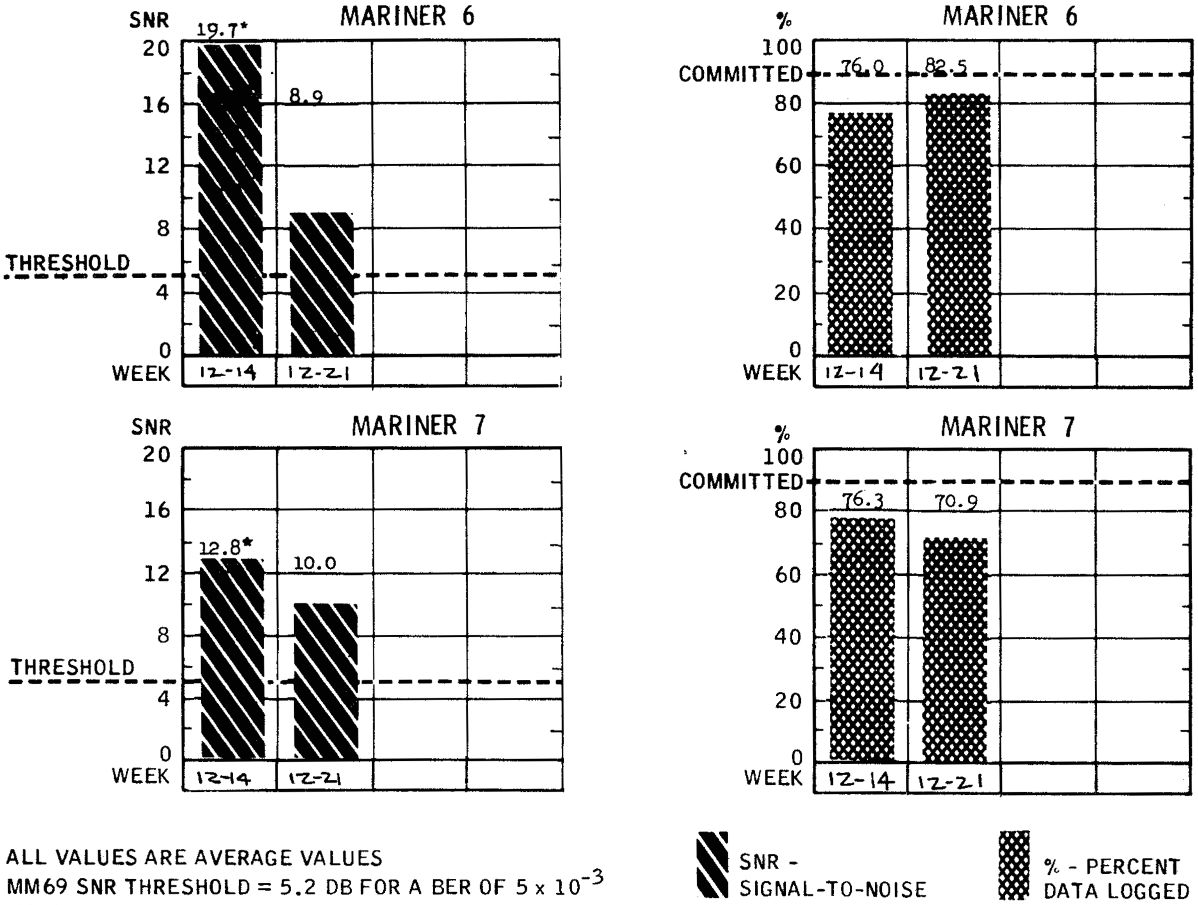


ALL VALUES ARE AVERAGE VALUES

MM69 SNR THRESHOLD = 5.2 DB FOR A BER OF 5 x 10^{-3}

*SPACECRAFT ON HIGH GAIN ANTENNA

Fig. 69. DSN telemetry system performance, week of November 16 through December 7, 1970



ALL VALUES ARE AVERAGE VALUES

MM69 SNR THRESHOLD = 5.2 DB FOR A BER OF 5 x 10^{-3}

*SPACECRAFT ON HIGH GAIN ANTENNA

Fig. 70. DSN telemetry system performance, week of December 14 through December 21, 1970

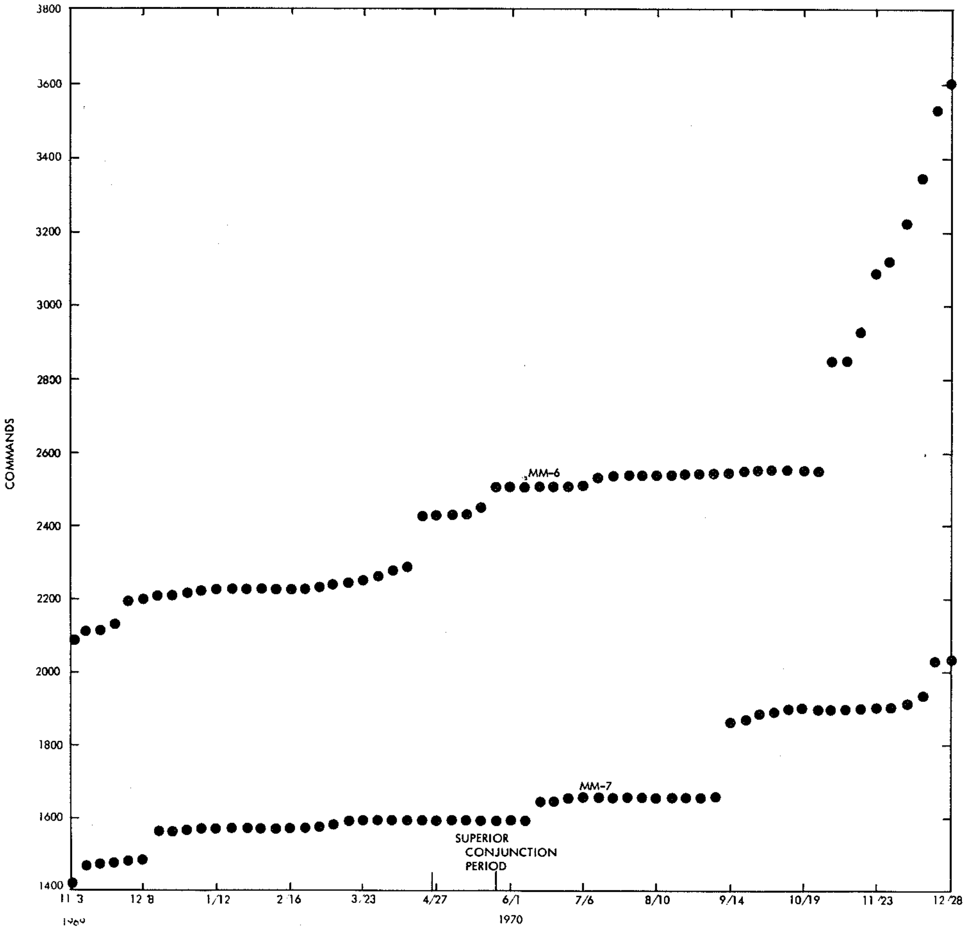


Fig. 71. Mariner Mars 1969 extended operations commanding

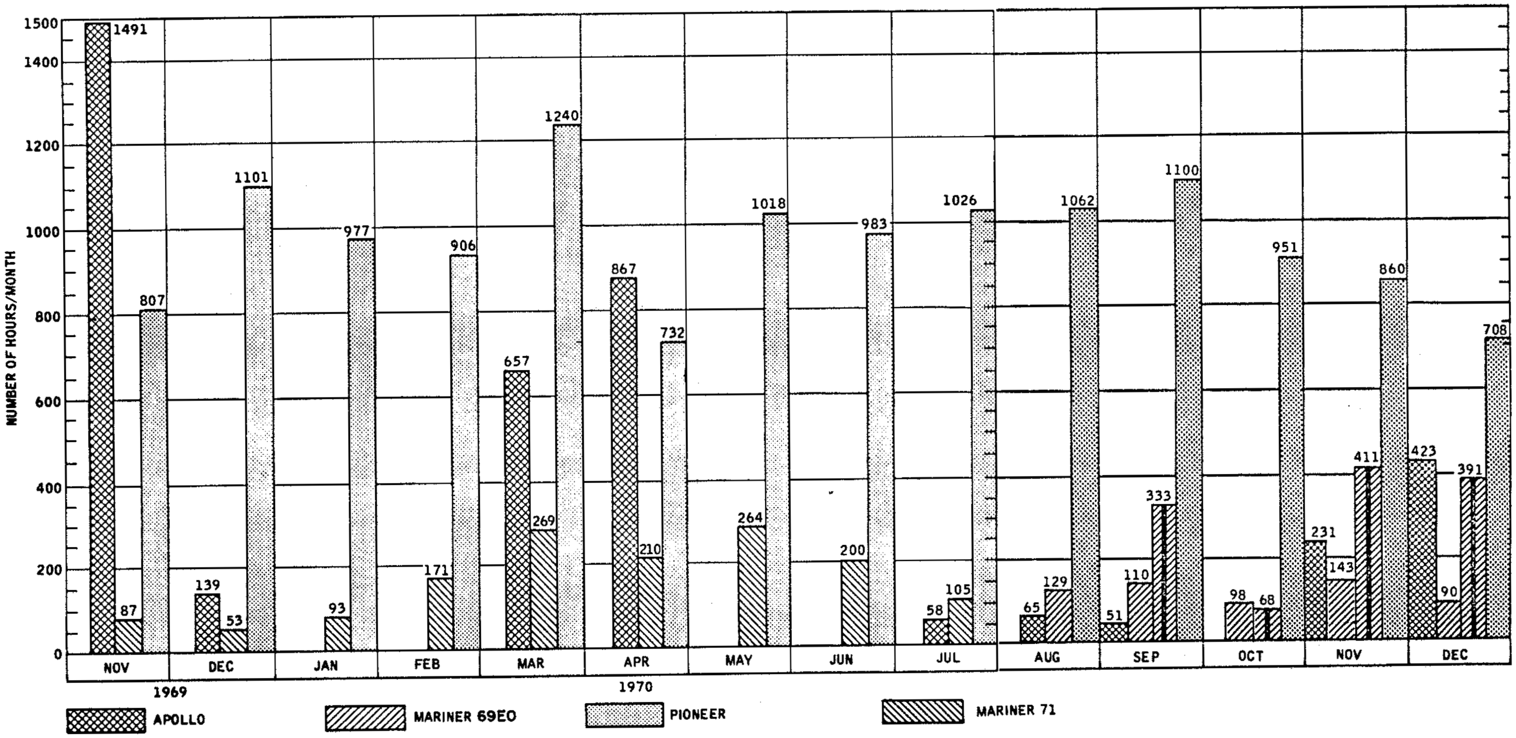


Fig. 72. Flight project tracking and test hours achieved

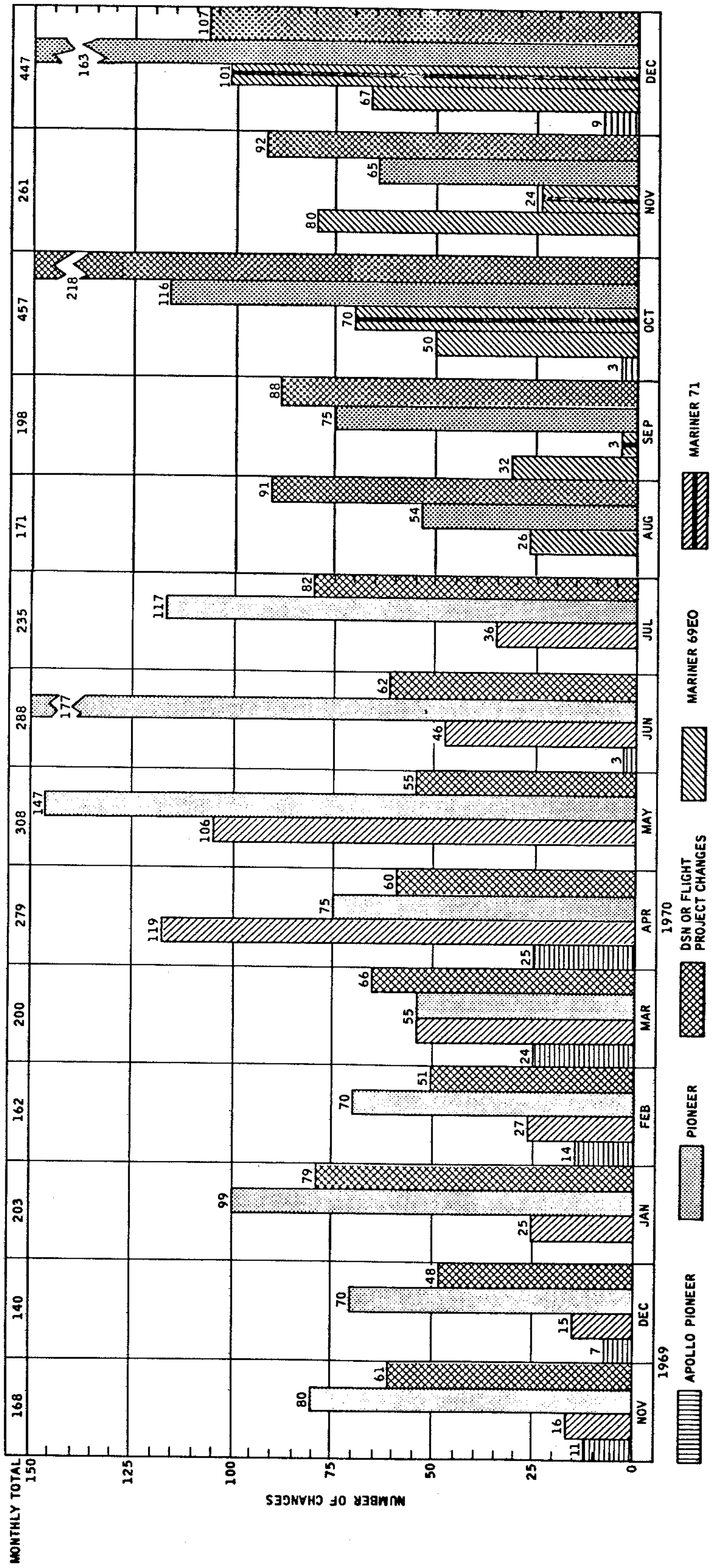


Fig. 73. Scheduling changes after published schedules

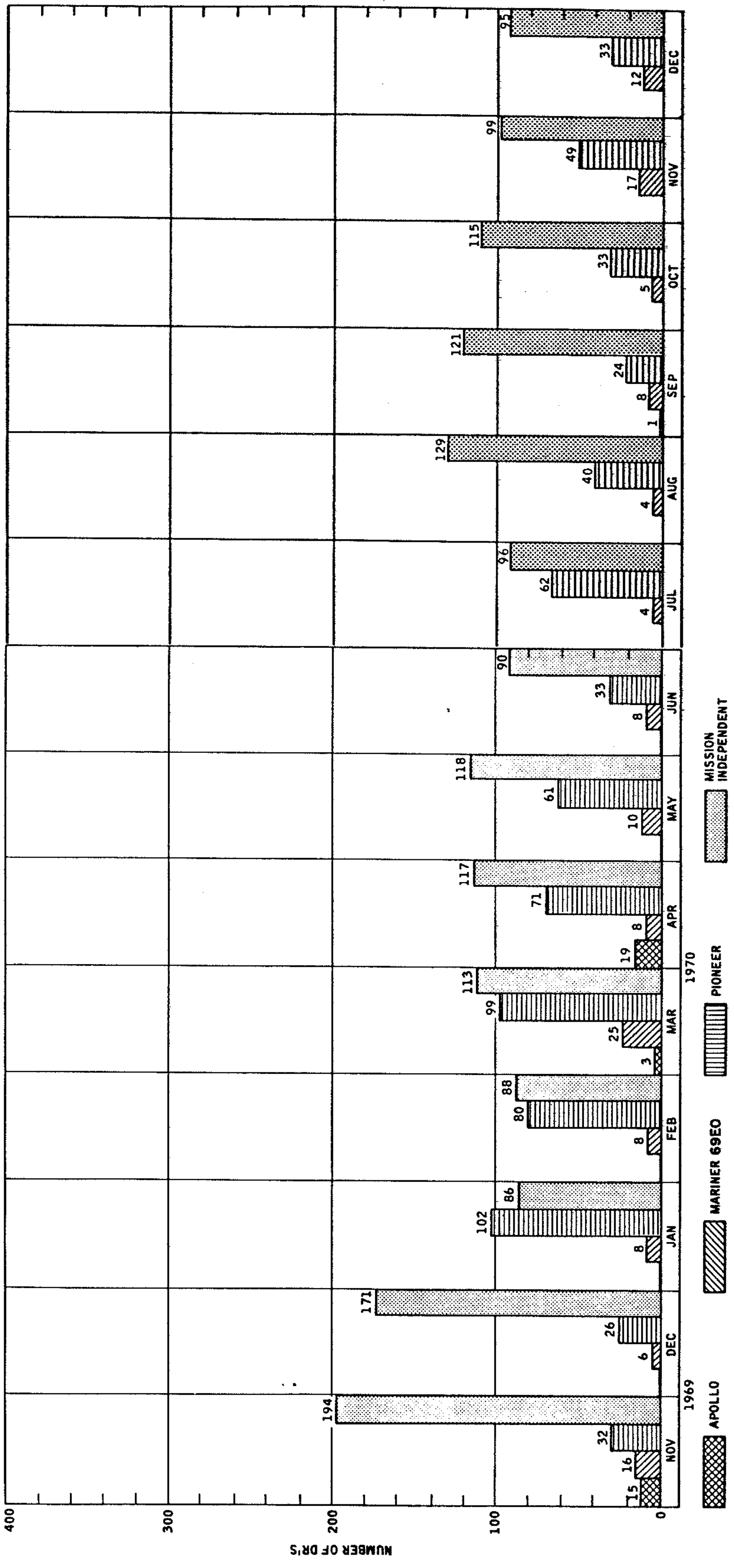


Fig. 74. Flight project-initiated discrepancy reports

GLOSSARY

CPS	Central Processing System
CTA	compatibility test area
DC	direct command
DCT	design control tables
EO	extended operations
GCF	ground communications facility
HGA	high-gain antenna
HSD	high-speed data
HSDL	high-speed data line
LGA	low-gain antenna
MDR	master data record
OC	Operations Chief
OCC	Operations Control Chief
OCT	Operations Control Team
ODG	orbit data generator
ODP	Orbit Determination Program
OWLT	one-way light time
PE	Project Engineer
RCP	right circular polarization
RFS	radio frequency subsystem
RTLT	round trip light time
RWV	read-write-verify
SBU	S-band Cassegrain ultracone
SDA	systems data analysis
SFOD	Space Flight Operations Director
SIRD	Support Instrumentation Requirements Document
SMT	S-band megawatt transmit
SNR	signal-to-noise ratio
TCP	telemetry and command processor
TDS	Tracking and Data System
TTY	teletype
TWT	travelling wave tube

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