NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Memorandum 33-797

Tracking and Data System Support for the Mariner Venus/Mercury 1973 Project

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JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

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PREFACE

The work described in this report was performed by the engineering and operations personnel of the Tracking and Data Acquisition organizations of the Jet Propulsion Laboratory, Goddard Space Flight Center, Air Force Eastern Test Range, and John F. Kennedy Space Center. This final report covers the activity from initiation of project planning through the launch and entire space flight phase to the end of the mission. The Jet Propulsion Laboratory provided the project management, the spacecraft implementation, and the conduct of mission operations as well as the tracking and data acquisition support function. The Deep Space Network was the primary instrument for providing communications between the spacecraft and earth. Science experiments conducted by instruments on the spacecraft and the use of radio link between the spacecraft and earth were the primary reasons for this mission. It is the first mission which provided data rates in excess of 16,500 bps of spacecraft engineering and science telemetry. The Network not only provided multimission operational capabilities but also some unusual experimental capabilities to enhance the science return.

N. A. Renzetti
Tracking and Data System Manager

ACKNOWLEDGMENT

The authors thank the many JPL people who contributed to the success of the Mariner Venus/Mercury 1973 Project and acknowledge especially the work of A. C. Belcher and M. E. Binkley of the Office of Tracking and Data Acquisition at NASA Headquarters.

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ABSTRACT

The Tracking and Data System provided outstanding support to the Mariner Venus/Mercury 1973 Project during the period from January 1970 through March 1975. In this report, we have chronologically described the Tracking and Data System organizations, plans, processes, and technical configurations, which were developed and employed to facilitate achievement of mission objectives. In the Deep Space Network position of the Tracking and Data System, a number of special actions were taken to greatly increase the scientific data return and to assist the Project in coping with in-flight problems. The benefits of such actions were high; however, there was also a significant increase in risk as a function of the experimental equipment and procedures required. The excellent tracking and data acquisition support provided under these conditions is attributable to the dedication and professionalism of our engineering and operations people.

I. INTRODUCTION

A. PURPOSE AND SCOPE

This report documents the tracking and data acquisition support provided by the Tracking and Data System (TDS) for the Mariner Venus/ Mercury 1973 Project in its scientific investigation of the planets Venus and Mercury. The purpose is to provide an historical summary of TDS activities, as well as to provide information which may be useful in the conduct of data acquisition activities for future missions. Although the Mariner Venus/Mercury 1973 Project eventually evolved into two formal parts, the primary mission (December 1969-April 1974) and the extended mission (April 1974-March 1975), this report treats the Project as one and encompasses TDS events from the time of Project approval through the end of the extended mission.

B. MARINER VENUS/MERCURY 1973 PROJECT DESCRIPTION

1. General

The unusual relative positions of the planets Earth, Venus, and Mercury in 1973 provided a unique scientific opportunity for a Venus-Mercury mission. Use of the Venusian gravitational pull on a spacecraft would allow scientific exploration of the planet Mercury using a relatively inexpensive Atlas/Centaur launch vehicle. Presented with the relative merits of such a mission, the Space Science Board of the National Academy of Science endorsed the program as a low-cost, high-science-return project. The Mariner Venus/Mercury Program was included as a new start in NASA's 1970 fiscal year budget. In December 1969, the Jet Propulsion Laboratory proposed to undertake this ambitious program for a cost not to exceed $98 million. It is interesting to note that this low- cost, high-science-return attitude prevailed throughout the prime and extended missions. Within the Tracking and Data System of the Deep Space Network, emphasis was given to means of increasing scientific data return of high quality.

2. Project Objectives

The primary objective of the Mariner Venus/Mercury 1973 Project was to conduct exploratory investigations of the planet Mercury by obtaining measurements of its environment, atmosphere, surface, and body characteristics, and to conduct similar investigations on Venus during its flyby. First priority was assigned to the Mercury investigations. Secondary objectives included the performance of experiments in the interplanetary medium and the gaining of experience with a dual-planet gravity-assist mission. Again, emphasis was on science return and not on the advancement of technology. Consequently, a tertiary objective evolved which was to preserve the possibility of multiple encounters with Mercury. This was possible because the spacecraft post-Mercury orbital period would be equal to two Mercury orbital periods, thus providing for additional encounter opportunities every six months.

3. Scientific Experimentation

Scientific measurements were made during the interplanetary transit phases and planetary encounters. Specific experimentation and instrumentation involved in Mariner Venus/Mercury 1973 are further defined in Table 1. The plasma science, charged particle, magnetometer, and radio science/ celestial mechanics experiments were designed to collect data continuously during all mission phases. The remaining experiments were to collect data at planetary encounters or other targets of opportunity.

4. Mission Description

The mission was accomplished by launch of a single spacecraft using the Atlas SLVBD/Centaur D-1A launch vehicle. Liftoff occurred at 0545 GMT, November 3, 1973, as planned, with Venus encounter occurring on February 5, 1974. Mercury encounter followed on March 29, 1974, with April 15, 1974, marking the end of the primary mission. An extended mission was approved which resulted in two additional encounters of Mercury on September 21, 1974, and March 16, 1975. Following depletion of the spacecraft attitude control gas on March 24, 1975, the spacecraft radio subsystem was turned off, thus terminating the mission.

Relative to other planetary space missions, the Mariner Venus/Mercury mission was rather short but extremely active, as described in Figs. 1 and 2. In addition to four encounters in the 16-month period, the mission included numerous other critical events such as one solar superior conjunction, one comet observation, six Earth-Moon TV sequences, seven roll calibration maneuvers, eight trajectory correction maneuvers, and various problems which precluded achieving a "quiet cruise" state of any duration.

5. Project Organization

Following NASA assignment of the Mariner Venus/Mercury 1973 Project management responsibility to JPL on December 30, 1969, Mr. W. E. (Gene) Giberson of JPL was appointed as the Project Manager on January 6, 1970. Immediately after his appointment, the Project Manager began to develop the management organization illustrated in Fig. 3. By late January 1970, the Mariner Venus/Mercury Project Office had been established at JPL with the following assignments: J. R. Casani (Spacecraft System Manager), J. N. Wilson (Assistant Spacecraft System Manager), V. C. Clarke (Mission Analysis and Engineering Manager), J. A. Dunne (Project Scientist), N. Sirri (Mission Operations System Manager), D. T. Gant (Contract Manager), and N. A. Renzetti (Tracking and Data System Manager). As Fig. 3 illustrates, the TDS Manager is one of the primary system managers of the Project organization, having technical responsibility to the Project Manager for tracking and data acquisition functions.

Table 1. Mariner Venus/Mercury 1973 science complement

Experiment	Principal objectives	Instrument	Principal investigator
Television science	High resolution (1 km) UV imagery of Venusian cloud patterns and circulation. Full mosaic of lit disc of Mercury at 0.85 - 1.6 km resolution. Selected coverage to 100 meters.	Dual narrow angle (0.48 x 0.37 deg) 700 x 835 pixel TV cameras with color filter wheel.	B. Murray, Caltech
Extreme ultraviolet	Detect and determine composition and structure of Mercury atmosphere.	A 4-channel, 400 - 850A, 1/4 deg FOV occultation spectrometer and a 12-channel 304 - 1659 deg 1/8 x 3 deg slit airglow spectrometer	L. Broadfoot, Kitt Peak
Plasma science	Determine interaction between solar wind and Mercury. Investigate solar plasma between 0.46 and 1 AU.	Two hemispherical electrostatic analyzers mounted on ±60 deg scanning platform.	H. Bridge, MIT
Charged particle telescope	Measure chemical and isotopic species of charged nuclei over wide energy range critical for the study of solar charged particle bombardment of Mercury. Search for trapped high-energy electrons and protons in possible magnetosphere of Mercury.	Charged particle telescope main telescope (MT) has 70 deg circular field of view (FOV), five L-drifted solid-state detectors, a CsI photodiode, and plastic scintillator cylinder/photo multiplier detectors. The low-energy telescope (LET) has 70 deg circular FOV, surface barrier, annular, Li-drifted and flat Li-drifted detectors.	J. Simpson, University of Chicago
Magnetic fields	Study solar wind interaction with Mercury and Venus by means of vector magnetic field measurements. Study characteristics of interplanetary magnetic fields between 0.46 and 1 AU.	Two fluxgate magnetometers mounted on a 6.9-m (20-ft) boom measuring magnetic field intensity in ±16 and ±128 gamma ranges along three mutually orthogonal axes, with bias offset capability up to ±3.072 gamma.	N. Ness, GSFC
Infrared radiometer	Measure infrared thermal radiation from surface of Mercury between late afternoon and early morning, local time.	Infrared radiometer with dual (fore and aft) telescopes with 1/2 deg FOV and two detectors of 30 junction antimony-bismuth thermopiles each.	S. Chase, SBRC
Celestial mechanics and radio science	Determine electron number density of Mercury ionosphere and measure the vertical structure of its atmosphere if greater than 0.01 MB. Determine Mercury's mass, fractional difference in the principal equatorial moments of inertia, radius at two points, and geocentric range to aid in separating solar quadrupole moment and relativistic effects on Mercury's orbital motion.	Precision measurements of spacecraft-Earth range and radial rate using dual-frequency (S-X) radio system.	H. Howard, Stanford

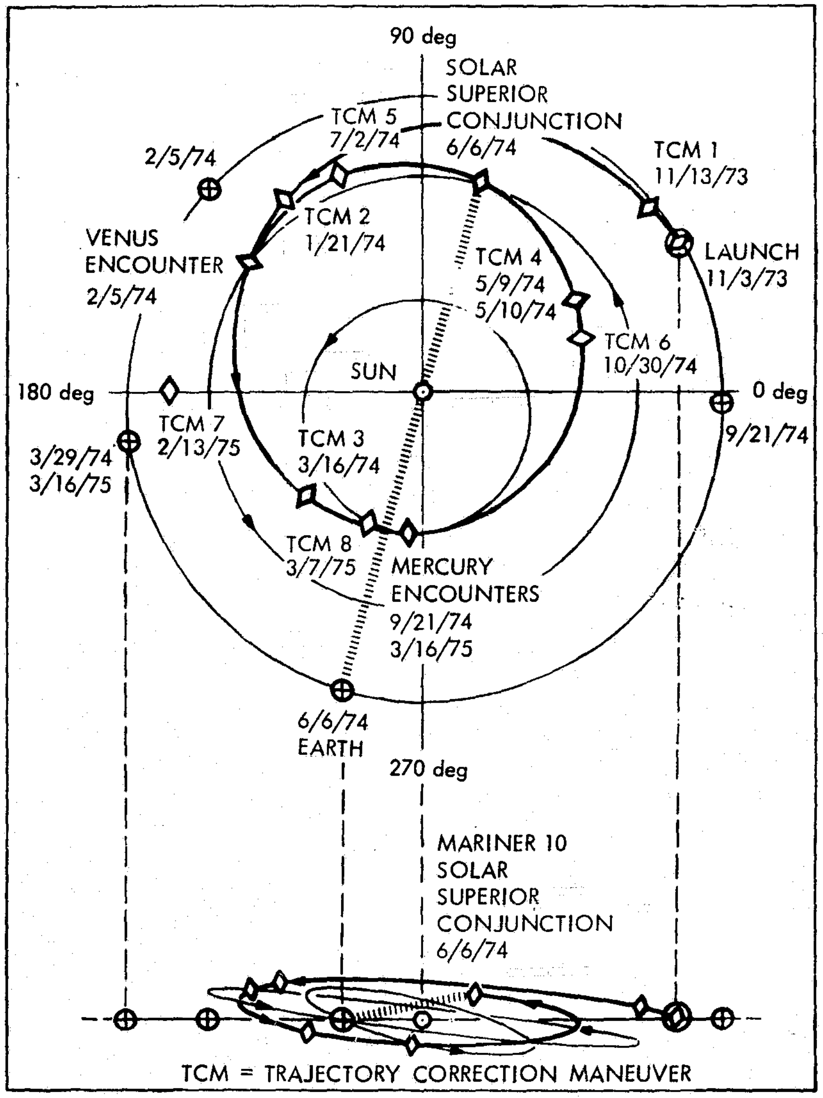


Figure 1. Mission profile

The unique orbital geometry of the spacecraft and Mercury provides for vicinity approaches every 176 days. Mercury rotates once every 58 days and maintains an orbital period of 88 days. Therefore, spacecraft encounters with the planet resulted in the same side of Mercury being exposed to the Sun for all three encounters.

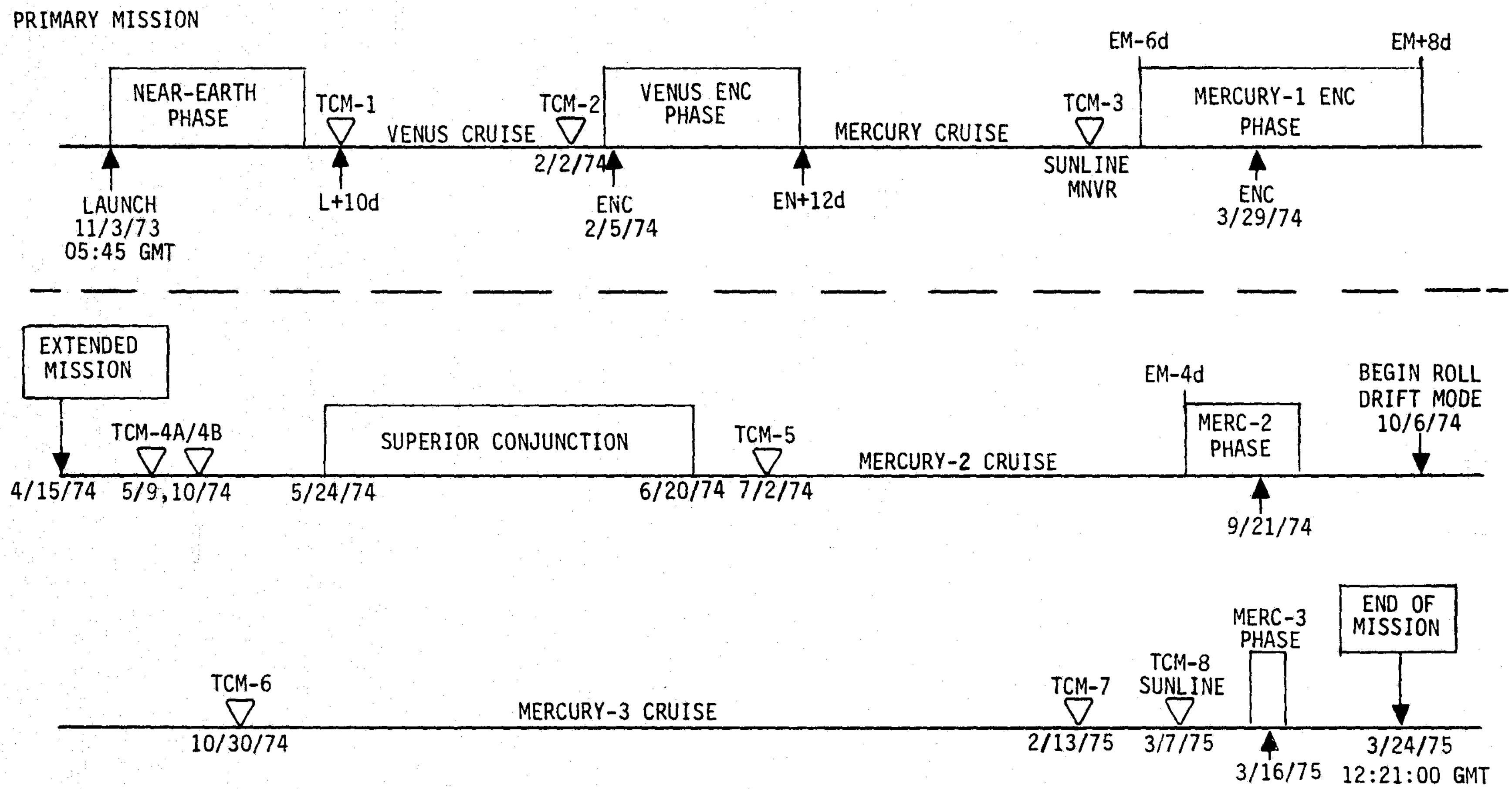


Figure 2. MVM'73 sequence summary

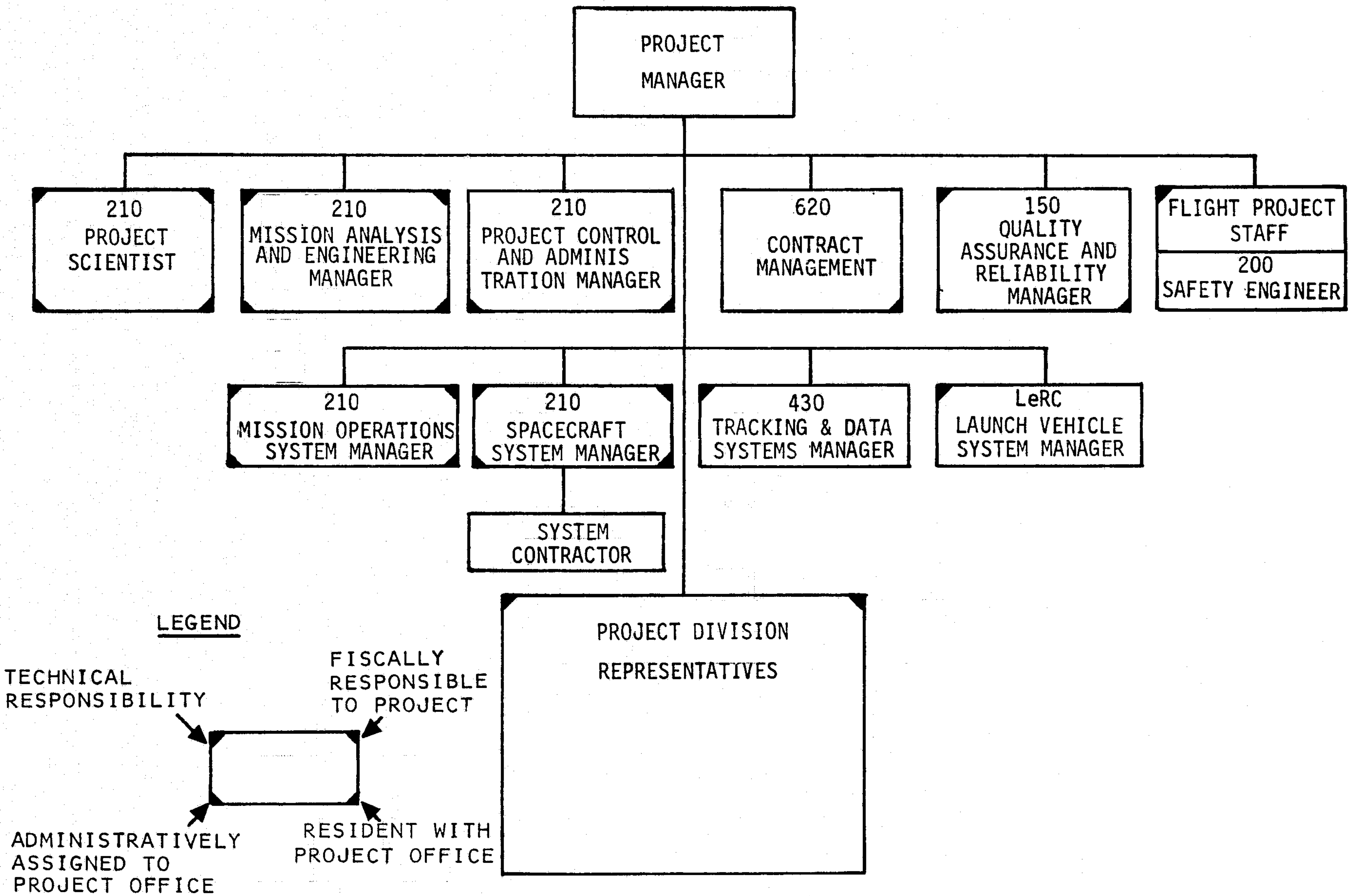


Figure 3. Mariner Venus/Mercury 1973 Project, management organization

C. TRACKING AND DATA SYSTEM DESCRIPTION

1. Tracking and Data Acquisition

NASA management instructions define tracking and data acquisition as the acquisition, transmission, and processing of information that enables the determination of spacecraft position, velocity, direction, system and subsystem performance, and experiment measurements, all with respect to a common time base. Furthermore, NASA management instructions require assignment of a support center which will be responsible for achievement of these tracking and data acquisition functions for newly approved flight projects. Consequently, when the Mariner Venus/Mercury 1973 Project was approved in December 1969, JPL was designated the Tracking and Data Acquisition Support Center. It should be noted, however, that the foregoing definition was significantly changed in October 1971, following the Tracking and Data System functional design phase. This change saw data processing deleted as a NASA Office of Tracking and Data Acquisition funded function and established as a NASA Office of Space Science funded function to be performed by the JPL Mission Control and Computing System rather than the Tracking and Data System. This realignment of responsibilities is more fully discussed later in this section and again in Section III.

2. Tracking and Data System Responsibilities

Upon designation of JPL as the Tracking and Data Acquisition Support Center for Mariner Venus/Mercury 1973, N. A. Renzetti was appointed as the Tracking and Data System Manager. The Tracking and Data System Manager was responsible to the JPL Assistant Laboratory Director for Tracking and Data Acquisition, W. H. Bayley. However, as head of one of the Mariner Venus/Mercury Project's systems, he also reported directly to the Project Manager. This organizational relationship is illustrated in Fig. 4.

In the execution of his system task, the Tracking and Data System Manager performed the following basic functions:

(1) Matched the tracking and data acquisition requirements of the Project with the existing and planned capabilities of the tracking and data acquisition support facilities.

(2) Reported the status of all activities related to this matching process.

(3) Assured all reasonable steps available to him were taken to achieve the proper implementation and operation of the tracking and data acquisition resources which were committed to meet the prescribed requirements of the Project.

(4) Established communications between the Project Manager and the Assistant Laboratory Directors to resolve problems in the event decisions were required which were beyond the scope of TDS authority and responsibility.

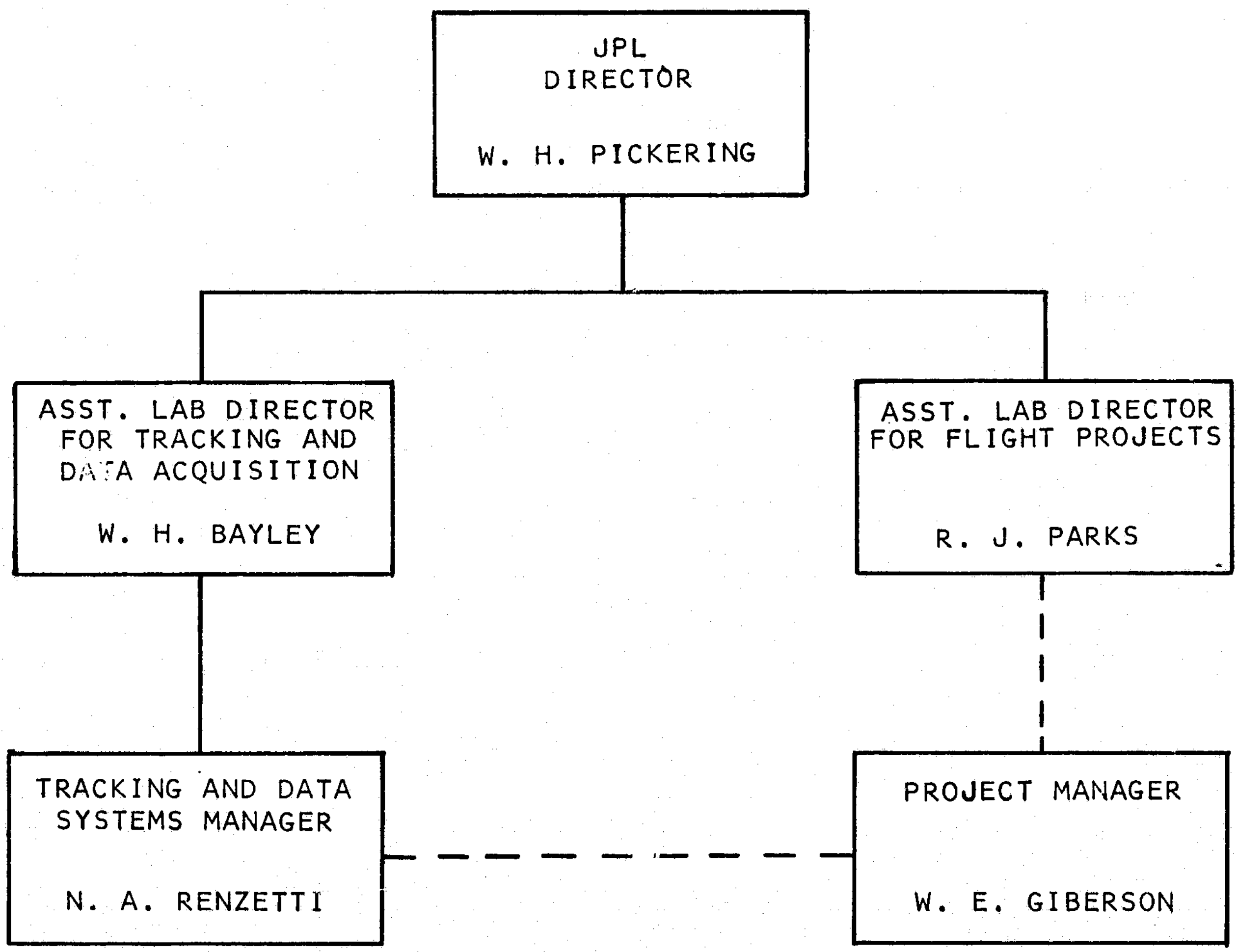


Figure 4. Flight project/TDS organization relationship

The TDS Manager had the authority to establish requirements on NASA and Department of Defense facilities to ensure proper execution of tracking and data acquisition functions. In fulfilling these responsibilities, the TDS Manager performed the following specific tasks:

(1) Ensured consistency between the tracking and data acquisition requirements of the various Project systems.

(2) Ensured that all requirements were placed on JPL, Department of Defense, or NASA organizations for support.

(3) Reviewed, identified, and corrected any omissions to the NASA Support Instrumentation Requirements Document and the Instrumentation portion of the Department of Defense Program Requirements Document.

(4) Submitted appropriate comments to the Project Manager, affected Project system managers, and the Assistant Laboratory Director for Tracking and Data Acquisition when the total requirements placed upon a TDS facility exceeded the capabilities of that facility.

(5) Assisted the Project Manager in the preparation of the Support Instrumentation Requirements Document in the interest of maximizing the support provided to the Project within the available NASA tracking and data acquisition resources and capabilities.

(6) Ensured that the NASA Support Plan was prepared concurrently with the Support Instrumentation Requirements Document so that the resource implications of requirements could be well understood prior to official submission of the Support Plan.

(7) Reviewed the NASA Support Plan and the Department of Defense Program Support Plan to ensure that all support planning was complete and properly assigned.

(8) Supported the Project in the resolution of problems arising out of nonstandard situations encountered during the mission.

In addition, the Project looked to the Tracking and Data System for accomplishment of the following major tasks:

(1) Preparing the NASA Support Plan.

(2) Preparing a Program Support Plan.

(3) Supporting the demonstration of spacecraft telecommunications compatibility with the DSN through the operation of the DSN Compatibility Test Area (CTA 21) and the availability of facilities at the Goldstone Tracking Stations and at Cape Kennedy (DSS 71) for verification of flight equipment compatibility as necessary.

(4) Providing engineering support to the design of mission operations.

(5) Implementing, maintaining, and operating all stations and facilities which were planned for support of the Project.

(6) Participating in the preparation of the Spacecraft/Mission Operations System/Tracking and Data System/Mission Control and Computing System Interface Control Document.

(7) Planning and carrying out the final performance demonstration tests which would certify the flight readiness of the Tracking and Data System.

(8) Providing tracking, telemetry, and command coverage as defined in the NASA Support Plan consistent with NASA priority assignments to on-going flight projects.

(9) Participating in and supporting tests for the integration, training, and certification of the overall Ground Data System.

(10) Providing narrative analysis and level 3 schedules for the monthly Project Management Report.

(11) Participating in Mission Operations System/Tracking and Data System/Mission Control and Computing System design reviews.

(12) Providing documentation of TDS institutional capabilities committed to the Mission Operations System.

(13) Assuring the existence of adequate provisions for configuration control and maintenance of the TDS.

(14) Assuring operation of a failure reporting and correction process within the TDS.

3. Tracking and Data System Agencies

Tracking and data acquisition capabilities required to meet the needs of the Mariner Venus/Mercury Project were realized through the technical and operational integration of the following four major agencies: (1) the Air Force Eastern Test Range, (2) the Spaceflight Tracking and Data Network, (3) the Deep Space Network, and (4) the NASA Communications Network. Furthermore, TDS support is generally viewed as occurring in two phases, the Near-Earth Phase and the Deep Space Phase. The Near-Earth Phase encompasses tracking and data acquisition activities from the prelaunch countdown through powered flight until such time as the tracking stations of the DSN have continuous view of the spacecraft. The Deep Space Phase then extends from that point of continuous view to the end of the mission.

a. <u>Air Force Eastern Test Range</u>. The U. S. Air Force, through the Air Force Systems Command and the National Range Division, manages the Air Force Eastern Test Range for the Department of Defense. As lead range for the launch of Mariner Venus/Mercury 1973, the Air Force Eastern Test Range provided a portion of the required tracking and data acquisition support from Department of Defense resources which include mobile stations (ships and aircraft) as well as land stations.

b. <u>Spaceflight Tracking and Data Network</u>. The Goddard Space Flight Center manages and operates the Spaceflight Tracking and Data Network for NASA. This network of land stations provided for acquisition of metric and telemetry data during the Near-Earth Phase.

c. <u>Deep Space Network</u>. JPL manages and operates the DSN for NASA. This network of tracking stations provided for Mariner Venus/Mercury 1973 telemetry acquisition, command transmission, and radio metric data generation during the Deep Space Phase.

d. <u>NASA Communications Network</u>. The NASA Communications Network is managed and operated by Goddard Space Flight Center for NASA. This communications network links all Spaceflight Tracking and Data Network and DSN tracking stations and control centers and provided for ground transmission of operational data during both the Near-Earth and Deep Space Phases.

4. <u>Tracking and Data System Management</u>

To facilitate the achievement of described responsibilities throughout the various support elements involved, the TDS Manager employed organizational structures and other management tools as described in this paragraph. It should be noted that this management process is somewhat standard in that the described organizational structures, documentation, schedules, and reporting activities are applied to all assigned missions with only minor variations.

a. <u>Tracking and Data System Organization</u>. The TDS organization was structured to be consistent with the natural grouping of functions into the Near-Earth and Deep Space Phases. Furthermore, the 1970-1972 period saw this organization modified as a function of the aforementioned changes in the scope of Tracking and Data System responsibilities. The initial Tracking and Data System organization was made up of the elements illustrated in Fig. 5. As shown, the first organizational level under the TDS Manager consisted of a Near-Earth Coordinator and a DSN Manager, the former being responsible for all tracking and data acquisition activities in the Near-Earth Phase and the latter for all functions in the Deep Space Phase. Staffing of these two positions followed the "womb-to-tomb" concept in that they were continually filled from the time of Project approval to the completion of mission operations in each phase. Within each phase, the sub-phases of planning, design, implementation, test, and operations support were accommodated by the organization.

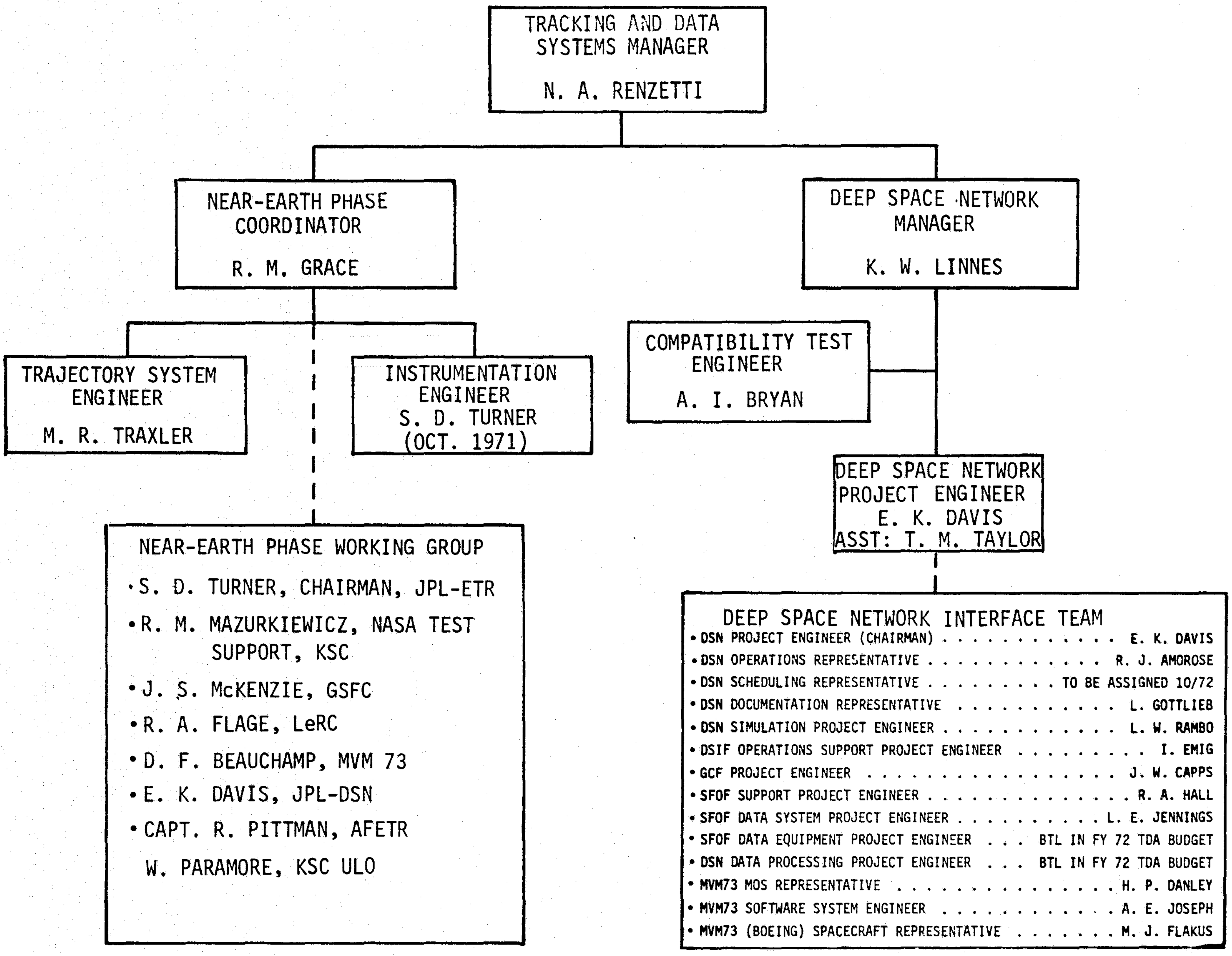


Figure 5. TDS organization, January 1970-July 1972

The Near-Earth Phase Coordination position continued through November 1973, as illustrated in Figs. 5 and 6. However, with the completion of launch and Near-Earth operations in November 1973, this position phased out as shown in Fig. 7. The Near-Earth Coordinator's general role was to serve as the primary interface for tracking and data acquisition matters between the Project and the agencies which provide the required support. Specific responsibilities included the following:

(1) Review of the Project's Support Instrumentation Requirements Document during its formation in order to gain complete and clear statements of requirements and to achieve consistency between requirements and Near-Earth Phase capabilities.

(2) Preparation of the Near-Earth portion of the NASA Support Plan in response to the Support Instrumentation Requirements Documents.

(3) Communication of requirements to the Kennedy Space Center Mission Support Office for preparation of the AFETR Program Requirements Document.

(4) Review and Coordination of the Program Requirements Document to assure complete and clear statements of requirements.

(5) Review of the AFETR Program Support Plan which responded to the Program Requirements Document to assure adequate commitment of services and capabilities.

(6) Negotiation of changes to Project requirements and Near-Earth resource commitments as necessary to accomplish an acceptable Near-Earth Support Plan.

(7) Analysis of launch profile/trajectory characteristics and assisting the Near-Earth phase agencies in planning, tracking, and data acquisition coverage.

(8) Analysis of data acquisition handling requirements and assisting the Near-Earth agencies in developing required instrumentation configurations and interfaces.

(9) Monitoring the planning, implementation, and testing of Near-Earth capabilities to assure proper progress toward operational readiness.

(10) Preparation of Near-Earth Phase test and operations documentation.

(11) Conducting and monitoring Near-Earth engineering and operational tests.

(12) Conducting and supporting readiness reviews.

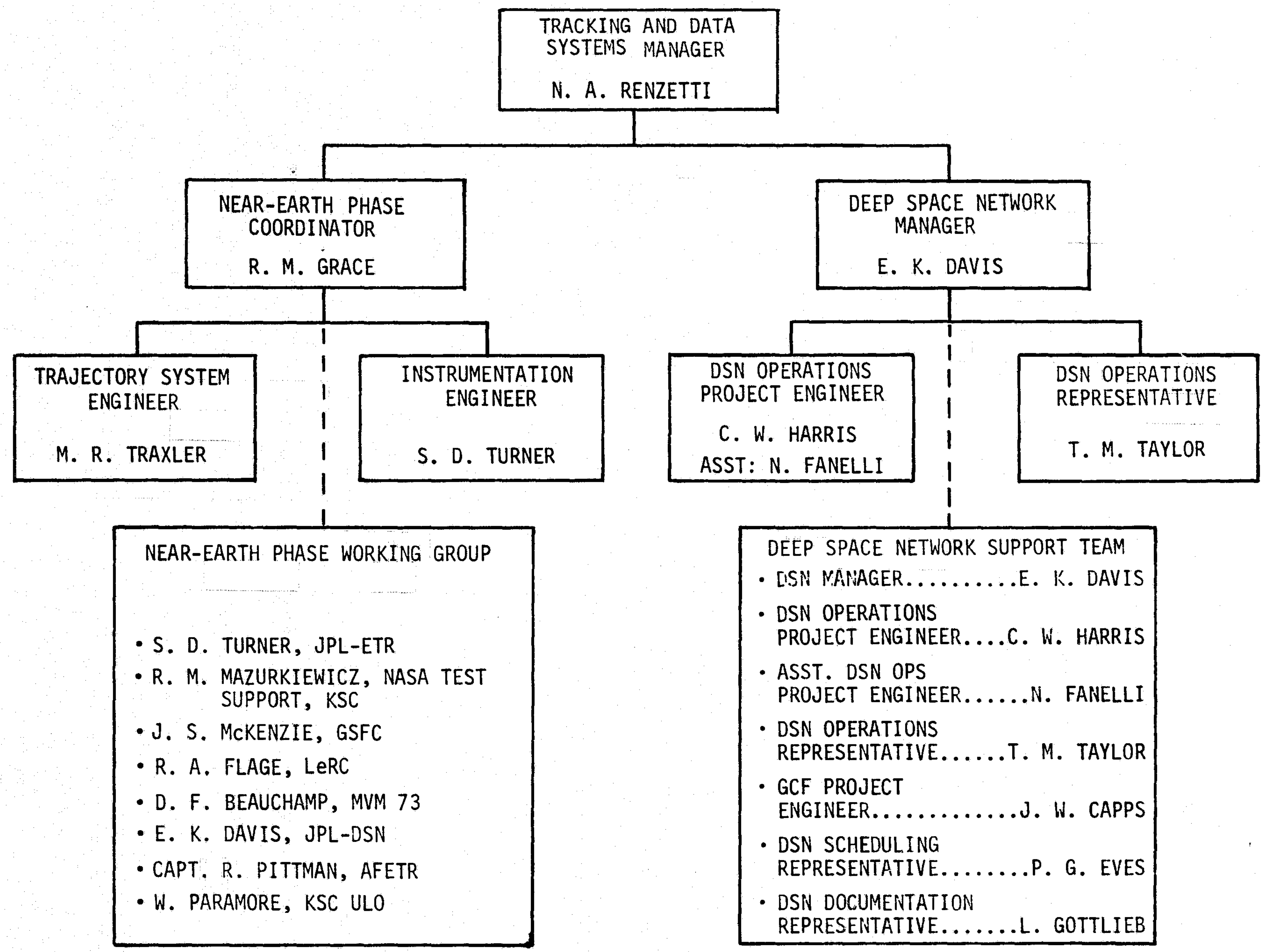


Figure 6. TDS organization, July 1972-November 1973

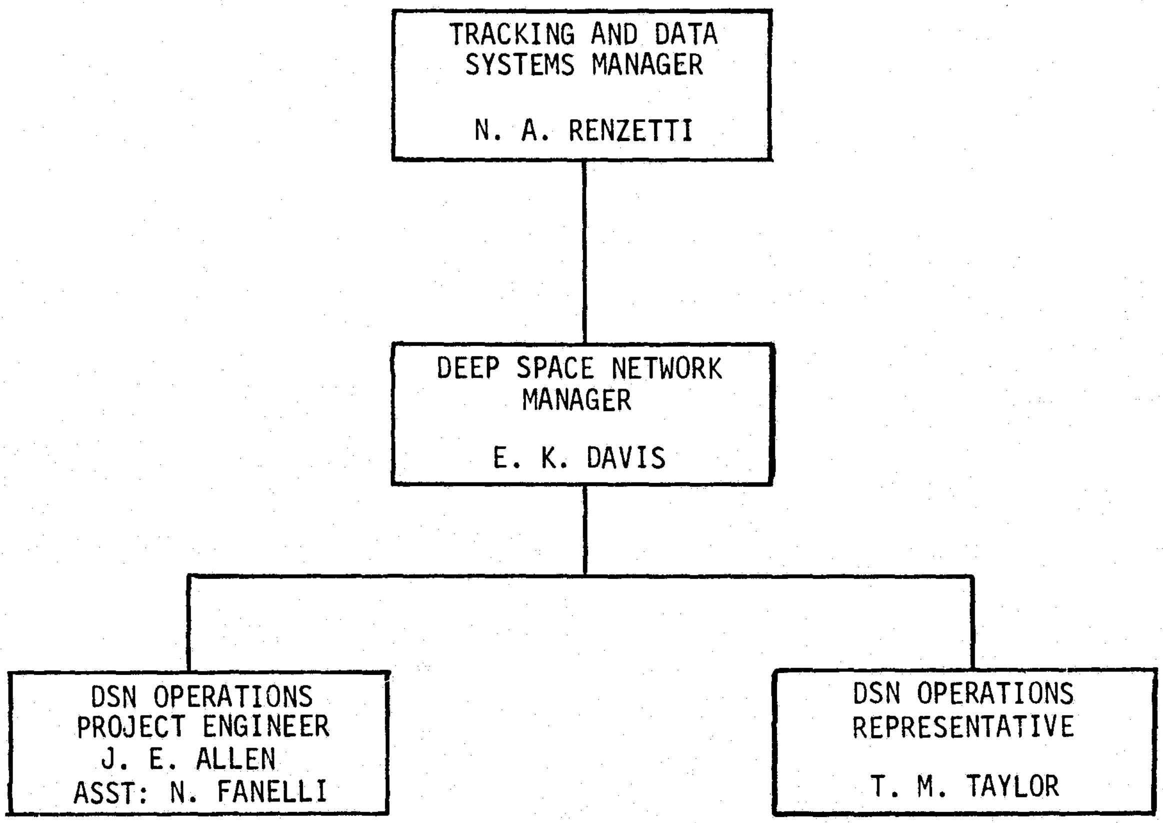


Figure 7. TDS organization, December 1973-March 1975

(13) Preparation of periodic progress reports and inputs to the TDS final report.

(14) Development and supervision of the Near-Earth Phase organization to support achievement of these responsibilities.

To assist the Near-Earth Coordinator in the accomplishment of these responsibilities, additional organizational positions were formed as illustrated in Fig. 5. The Trajectory System Engineer was a part of the initial organization, and the Instrumentation Engineer position was added in October 1971. The matrix nature of the TDS organization is noted here in that these tracking and data acquisition funded positions are assigned to the JPL Eastern Test Range Field Station, managed by H. N. Levy, as part of JPL Section 293, Test and Mission Operations Support. This section reports to the Project Engineering Division under the Assistant Laboratory Director for Flight Projects. It should be noted that this organization provided essentially the same support for other flight projects during the Mariner Venus/Mercury 1973 time period. Furthermore, a Near-Earth Phase working group was formed early in the planning process and served as the primary forum for the conduct of detailed Near-Earth Phase business. This working group consisted of members from the various Near-Earth agencies as listed in Fig. 5 and met regularly to facilitate development of integrated support plans.

The Deep Space Phase portion of the TDS organization saw rather dramatic change prior to the Mariner Venus/Mercury 1973 launch. Not only were key personnel reassignments made, but some positions were eliminated and others were created to accommodate changing conditions within the JPL Technical Divisions. The DSN Manager position continued through the end of the Mariner Venus/Mercury 1973 extended mission in March 1975. However, as shown in Fig. 5 and 6, the DSN Manager assignment was changed in July 1972 when the DSN project engineering function was phased out. At this time, K. Linnes assumed new duties as the DSN Manager for Advanced Projects and E. K. Davis moved into the Mariner Venus/Mercury 1973 DSN Manager position. Concurrently, the position of Network Operations Project Engineer was created and staffed as shown in Fig. 6, and the DSN Interface Team for Mariner Venus/Mercury 1973 was reorganized as a DSN Support Team with a significantly different scope of responsibility. Major JPL organizational changes, which led to these TDS organizational realignments, were as follows:

(1) Separation of the Space Flight Operations Facility (SFOF) from the DSN and its reorganization under the JPL Office of Computing and Information System.

(2) Separation of Deep Space Instrumentation Facility operations functions from Division 33 and Ground Communications Facility (GCF) operations functions from Division 91, and their consolidation under the newly created DSN Operations Office.

(3) The establishment of the DSN Systems Engineering Office which encompassed both system engineering and DSN Manager mission support functions.

The DSN Manager's general role was to serve as the primary interface for tracking and data acquisition matters between the Project and the DSN Engineering and Operations Organizations. Specific responsibilities included the following:

(1) Membership in various Project teams and committees to facilitate spacecraft and mission operations design which were consistent with existing and planned DSN capabilities.

(2) Review of the Project Support Instrumentation Requirements Document during its formulation to assure complete and clear statement of requirements.

(3) Preparation of the Deep Space portion of the NASA Support Plan in response to the Support Instrumentation Requirements Document.

(4) Communication of requirements to the DSN Systems Engineering and Operations Organization.

(5) Review and coordination of DSN Implementation and Operations Plans to ensure availability of required services and capabilities.

(6) Negotiation of changes to Project requirements and DSN commitments as necessary to accomplish an acceptable Operations Plan.

(7) Monitoring the design, implementation, and test of DSN capabilities to assure proper progress toward operational readiness.

(8) Review and approval of DSN test and operations documents for Mariner Venus/Mercury 1973.

(9) Conducting DSN design, progress, and readiness reviews.

(10) Support of Project reviews.

(11) Preparation of periodic DSN progress reports and the TDS final report.

(12) Monitoring and evaluating DSN performance during the operations phase.

(13) Function as the Assistant TDS Manager when required.

b. <u>Tracking and Data System Documentation</u>. TDS documentation for Mariner Venus/Mercury 1973 was accomplished in accordance with Tracking and Data Acquisition Standard Practice 815-1, Revision C, TDS Documentation Requirements, except that the TDS Functional Specification for Mariner Venus/Mercury 1973 was not produced as a separate TDS document. Rather, it was agreed that one Project document, the Mission Operations System Design Book, would serve this purpose for the Mission Operations

System and Mission Control and Computing Center, as well as the TDS, through the functional specification of an end-to-end Ground Data System. Figure 8 illustrates the TDS Documentation Tree for Mariner Venus/Mercury 1973, along with TDS mission-independent documents as well as key Project documents.

Preparation of a preliminary NASA Support Plan was initiated in July 1971 and then required significant revision in November 1971 to conform to the new definition of the DSN and Mission Control and Computing Center responsibilities. The final version of the preliminary NASA Support Plan was released in January 1972 for review. The approved Support Instrumentation Requirements Document and the NASA Support Plan preparation guidelines were received from NASA Headquarters in July 1972. This provided the basis for final TDS capability commitment planning. Subsequently, the preliminary NASA Support Plan was revised accordingly, coordinated with the implementing organization, and correlated with tracking and data acquisition financial plans. The final NASA Support Plan was approved by the TDS Manager and the JPL Director in September 1972, and forwarded to NASA Headquarters for review and approval. NASA Headquarters approval of the final NASA Support Plan was expected prior to January 1973; however, approval was delayed until effects of reduction in the Tracking and Data Acquisition FY 74 and 75 budgets could be evaluated. Work on a revised NASA Support Plan was initiated in June 1973, following the receipt of verbal guidelines from NASA Headquarters. Formal guidelines were received in August 1973, along with instructions that the NASA Support Plan be revised and resubmitted for final approval. The requested revision was prepared and submitted to NASA in October 1973, with final approval coming on October 31, 1973.

Since the first NASA Support Plan encompassed only the Mariner Venus/Mercury 1973 primary mission (launch through Mercury first encounter), a new NASA Support Plan was required to cover tracking and data acquisition commitments to the extended mission, which was initially scoped to include one additional encounter with Mercury in September 1974. This new NASA Support Plan was prepared and approved by JPL in June 1974 and by NASA Headquarters in September 1974. In the interest of expediency and economy, tracking and data acquisition commitments to the further extension of the Project for a third encounter of Mercury in March 1975 were handled by letter update to the previous NASA Support Plan.

Preparation of TDS progress reports for Mariner Venus/Mercury 1973 was initiated in April 1971. These reports were produced quarterly through September 1972. Subsequent to that date, it was decided that the separate TDS progress reports would be discontinued in favor of incorporating similar information in the DSN progress report document which was produced every two months. Thus, reporting continued through the end of the extended mission as part of the DSN progress reports under the heading "Mariner Venus/Mercury 1973 Mission Support." Other documents shown in Fig. 8 were produced during the course of preparations for the Mariner Venus/Mercury 1973 mission and are discussed under the Near-Earth and Deep Space Network portions of Section III.

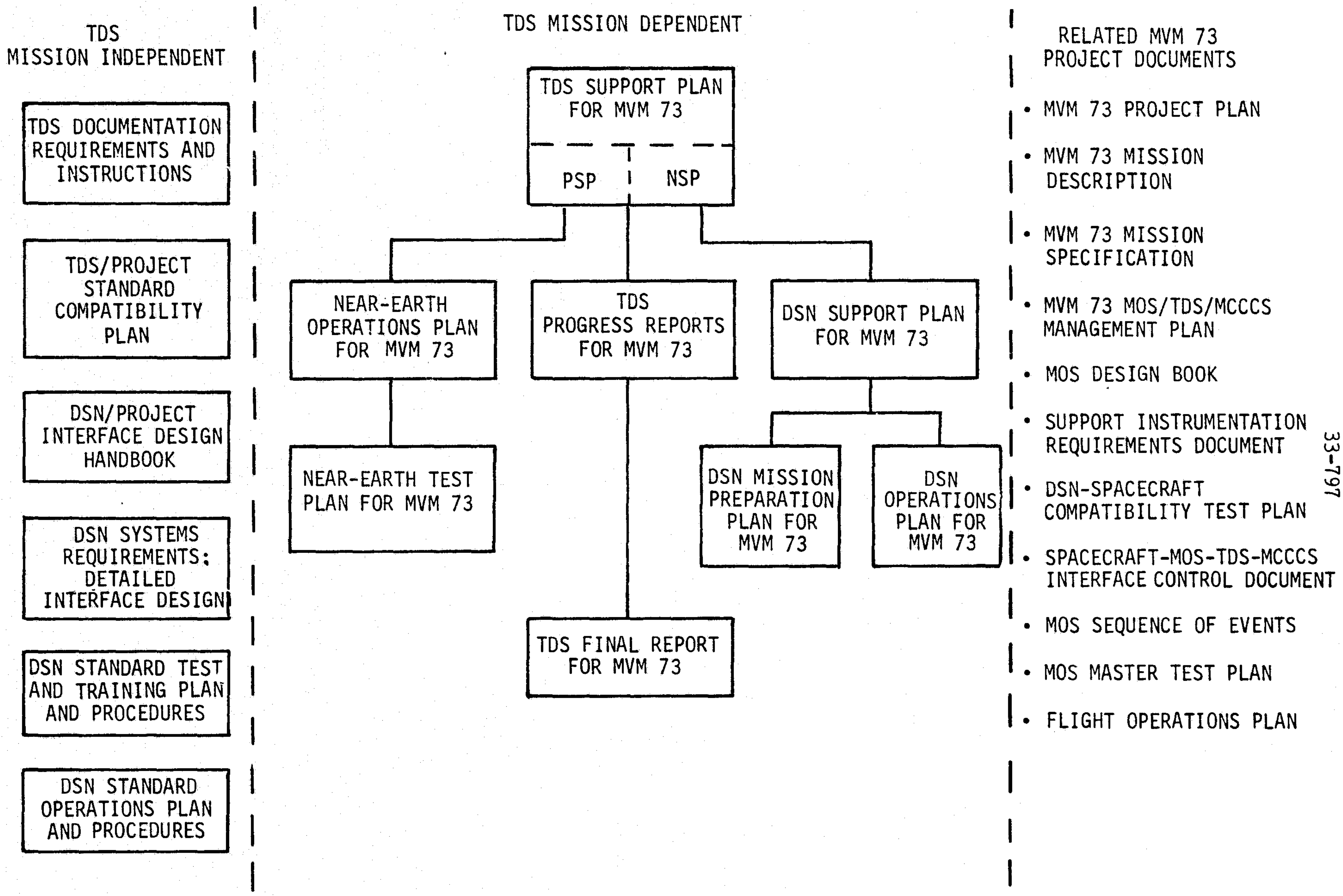


Figure 8. TDS documentation tree for Mariner Venus/Mercury 1973

c. <u>Tracking and Data System Schedule</u>. In keeping with Project/TDS agreements in the Mariner Venus/Mercury 1973 Management Plan, a hierarchy of schedules was developed to provide for control, evaluation, and reporting. Level 3 in this hierarchy was established for the schedules for each Project System. The preliminary TDS level 3 schedule for Mariner Venus/Mercury 1973 was initially developed in April 1971 and formally approved in December 1971. This schedule set forth key milestone dates which governed the timing of subordinate activities in the TDS organization. The status of the level 3 schedule, along with the narrative analysis, was submitted to the Project Manager each month for documentation in the Project Management Report. The February 1974 issue of the TDS level 3 schedule, along with other Near-Earth and Deep Space Network schedules, are contained in Appendix A.

II. TRACKING AND DATA ACQUISITION REQUIREMENTS

A. GENERAL

This section deals with the Mariner Venus/Mercury 1973 Project requirements for tracking and data acquisition. Since every detailed requirement cannot be addressed in this document, emphasis is given to those which had the greatest impact on the Tracking and Data System in regard to capability, implementation, and operations. The purpose here is to establish a basis for understanding the resulting TDS configurations described in Section III and flight support activities described in Section IV.

Although detailed tracking and data acquisition requirements for Mariner Venus/Mercury 1973 evolved over a four-year period, basic requirements were known early in the planning cycle through participation of tracking and data acquisition organizational elements in Project advanced studies and proposals. This close interaction with the Project continued through the TDS planning team's involvement in the development of initial Project documentation such as the Mission Description (April 1970) and the Mission Specification (November 1970). Consequently, when the Project's initial preliminary Support Instrumentation Requirements Document was issued in July 1971, it contained a rather well-understood set of tracking and data acquisition requirements for the Near-Earth and Deep Space Phases. Revision 1 of the Support Instrumentation Requirements Document was distributed in March 1972 and approved in June 1972. The final Support Instrumentation Requirements Document for the primary mission was published after launch. Requirements for the extended mission second encounter of Mercury were documented and approved by JPL in April 1974. The Support Instrumentation Requirements Document covering the third encounter with Mercury was published in August 1974.

B. NEAR-EARTH TRACKING AND DATA ACQUISITION REQUIREMENTS

1. <u>General</u>

Project requirements held that Near-Earth tracking and data acquisition capabilities should be operationally ready by mid-October 1973 to support a launch opportunity from November 3 to November 20, 1973. Both the launch vehicle and the spacecraft systems placed requirements on the Near-Earth Phase which were generally categorized either as metric or telemetry requirements. Within each category, data acquisition intervals were specified and identified as being mandatory, required, or desired. Data handling requirements identified the need for either real-time data or non-real-time recorded data from the specified intervals. Requirements included the real-time computation of trajectory-related parameters derived from the raw metric data. The launch vehicle active thrust periods, with which mandatory tracking and data acquisition coverage requirements are generally associated, are illustrated in Figs. 9 and 10.

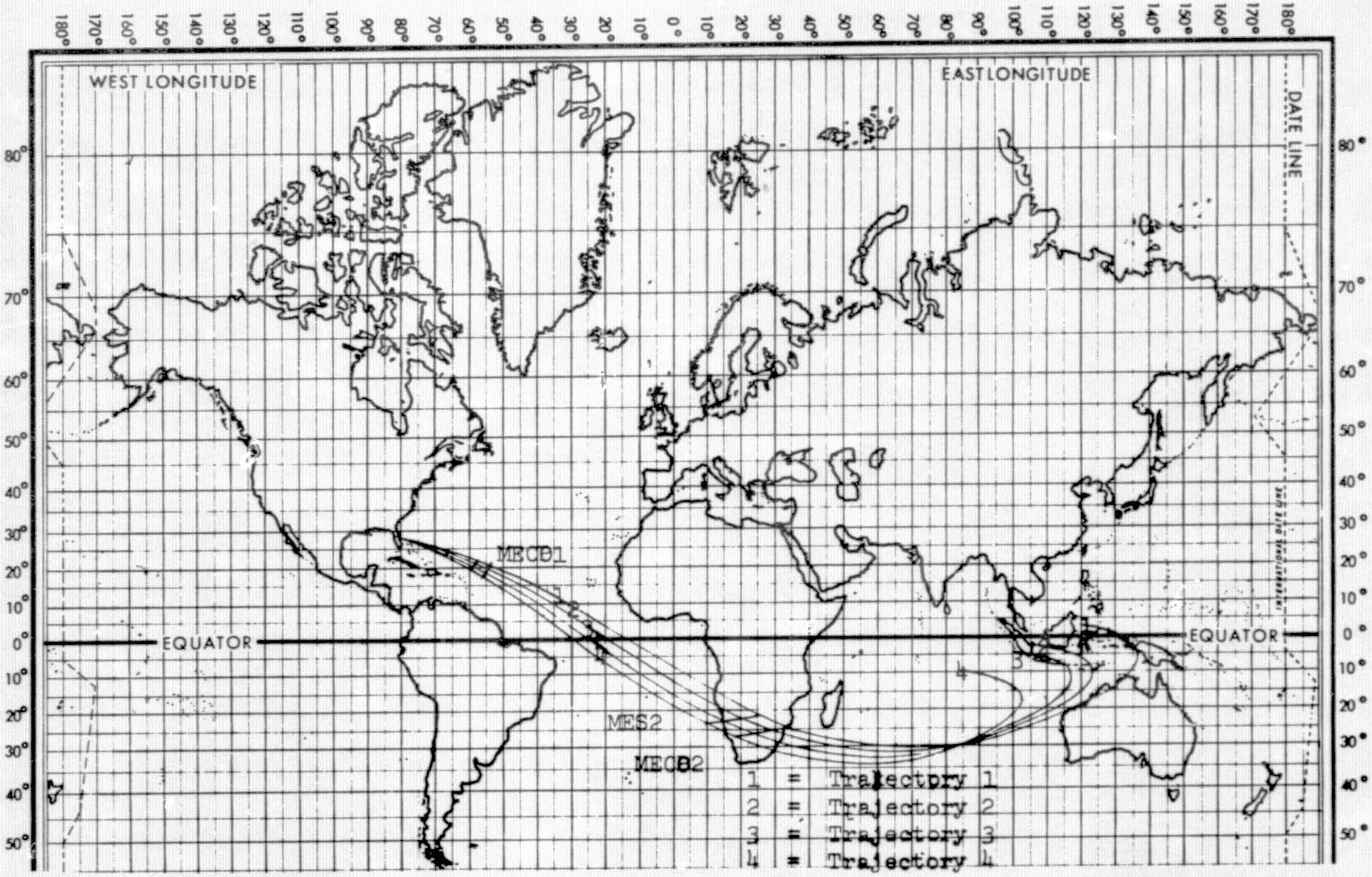


Figure 9. MVM'73 trajectory data, plan view

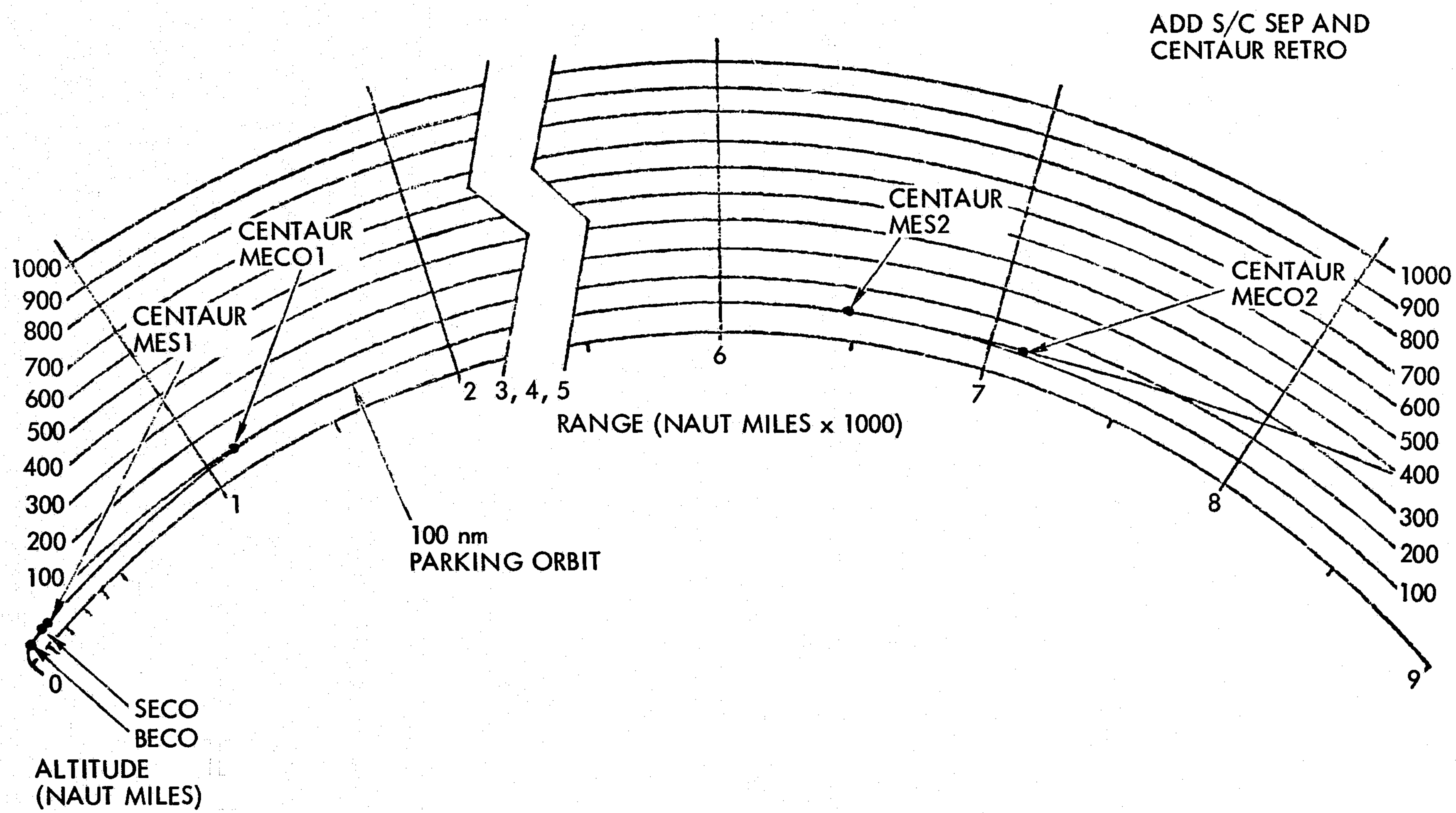


Figure 10. MVM'73 trajectory data, profile views

2. Metric Data Requirements

Metric data acquisition was required by the launch vehicle and spacecraft systems for evaluation of Atlas/Centaur performance and for quick-look projections of the spacecraft trajectory to determine if the desired accuracy was achieved. Also, these metric data were required for the computation of acquisition predictions for AFETR and Spaceflight Tracking and Data Network downrange stations, as well as the DSN's initial acquisition station.

To acquire or generate these metric data, the Near-Earth network was required to track either the Centaur C-band transponder or the spacecraft S-band carrier, as appropriate. Basic characteristics of the Centaur C-band transponder system were as follows: receive at 5690 MHz, transmit at 5765 MHz, 2600 pulses per second, slot antenna, and a set roll position with Centaur X-X axis normal to the trajectory plane, giving a gain of at least -9.5 dB 99% of the time. The Project's metric data requirements are summarized in Table 2.

Using the real-time metric data from the intervals given in Table 2, the AFETR Real Time Computing System was required to provide the following:

(1) Parking orbit elements and theoretical transfer orbit elements based on C-band tracking data after insertion into the parking orbit.

(2) Transfer orbit elements and mapping to Venus based on Centaur C-band tracking data after injection.

(3) Acquisition predictions for Carnarvon, DSS 42 and DSS 62 based on the transfer orbital elements.

(4) Spacecraft orbital elements, mapping to Venus, and I-matrix based on S-band tracking data after separation from the Centaur.

(5) Acquisition predictions for DSS 42 and DSS 62 based on the spacecraft orbital elements.

(6) Centaur post-deflection orbit elements, mapping to Venus, and I-matrix based on C-band tracking data after Centaur blowdown.

3. Telemetry Data Requirements

Acquisition, real-time transmission, processing, and display of Centaur telemetry data were required for the launch vehicle data analyst located in Building AE, Cape Kennedy. Acquisition and real-time transmission of spacecraft telemetry data to the Mission Operations Centaur at JPL, Pasadena, were required for spacecraft analysis and mission operations purposes. These telemetry requirements are summarized in Table 3. Centaur pulse-code-modulated telemetry data were transmitted on an S-band carrier at a frequency of 2202.5 MHz via an omnidirectional

Table 2. Mariner Venus/Mercury 1973 requirements for C-band (radar) and S-band (radio) metric data for the Near-Earth phase

Vehicle and system	Mandatory coverage	Required coverage
Centaur C-band	Launch to Centaur MECO 1 + 120 sec	Acquisition of signal (AOS) to loss of signal (LOS) for Cape Kennedy (1.16), Patrick Air Force Base (PAFB) (0.18), Merritt Island (19.18) and Bermuda (67.18)
Centaur C-band		MECO 2 - 300 sec to MECO 2 + 10 sec
Centaur C-band	MECO 2 + 10 to MECO 2 + 312[a] (any 120 sec)	AOS to LOS for Ascension (12.16) and Carnarvon)
Centaur C-band		MECO 2 + 860 sec to MECO 2 + 1350 sec. The intent of this requirement is to get a good span of metric data after blowdown.
Spacecraft S-band doppler		Injection to injection plus 2 hours for rapid evaluation of orbit.

Note: All data transmitted to the AFETR Real-Time Computer System

[a]Original requirement read "to MECO 2 + 350," was changed to read "MECO 2 + 312" to reflect a new time for the flight event "Start Turn to Centaur Deflection Attitude."

Table 3. Project requirements for launch vehicle and spacecraft telemetry data, Mariner Venus/Mercury 1973

Stage and link	Mandatory coverage	Required coverage	Comments
Centaur (2202.5 MHz)	Liftoff to MECO 1 + 120 seconds	MECO 1 + 120 sec to MES 2 - 120 sec	Only portions of the required interval can be supported.
Centaur (2202.5 MHz)	MES 2 - 120 sec to MECO 2 + 180 sec	MECO 2 + 180 sec to MECO 2 + 1300 sec	The required interval may not be supported in its entirety.
Spacecraft (2295 MHz)		Launch to MECO 1 + 30 sec	Data from MECO 1 + 30 sec to MES 2 - 30 sec is a desired requirement
Spacecraft (2295 MHz)		MES 2 - 30 sec to spacecraft separation	
Spacecraft (2295 MHz)	Spacecraft separation until initial DSN 2-way lock	AOS to LOS for Grand Bahama Island (GBI), Grand Turk (GTK), Antigua (ANT), Ascension, Advanced Range Instrumentation Aircraft (ARIA)	

stub antenna having an effective radiated power of 3.5 W at a rate of 266.7 kilobits per second. Spacecraft uncoded telemetry data were transmitted on an S-band carrier at a frequency of 2295 MHz via the low-power 10-W transmitter and omnidirectional low-gain antenna at a rate of 33-1/3 bits per second.

4. Ground Communications Requirements

The communications requirements implied by real-time metric and telemetry data availability requirements were rather standard for communications of Near-Earth operational data. One exception involved the request for real-time transmission of telemetry data received by range aircraft. This requirement was later deleted in view of substantial implementation costs. In addition, the Project's need for operational communications and coordination during launch operations required a network of voice circuits among the Near-Earth agencies and the Mission Operations Team at JPL. The resulting communications configurations are defined in Section III.

C. DEEP SPACE REQUIREMENTS

1. General

Project requirements held that basic DSN tracking and data acquisition capabilities be available for support of Ground Data System/Mission Operations System testing beginning May 1, 1973. This was followed by a mission support readiness date of July 1, 1973. These negotiated readiness dates involved the availability of one DSN subnet of three 26-meter deep space stations plus one 64-meter deep space station (DSS 14). Two new 64-m deep space stations, which were in their final stages of implementation, were required to be operational by October 1, 1973. Two notable exceptions to these readiness dates were DSS 14's simultaneous S/X-band dual frequency capability and planetary ranging capabilities at DSS 43 and 63 which were required on January 1, 1974, and January 15, 1974, respectively. Furthermore, DSN test station capabilities were required beginning August 1972 to calibrate the spacecraft/DSN telecommunications link and to demonstrate spacecraft/DSN interface compatibility. Ground communications services of the DSN were generally required to be available on a schedule compatible with the deep space station support requirements. However, agreement with the Project held that wideband communications capabilities from Australia and Spain could be delayed in order to realize the significant reduction in NASCOM circuit lease cost.

2. Basic Tracking Coverage Requirements

Tracking coverage is defined as the availability of DSN resources to acquire the spacecraft radio signal, to establish two-way communications with the spacecraft, and to handle-generate the required data types. Specific requirements associated with tracking coverage varied as a function of the mission phases given in Table 4. In addition,

Table 4. Major mission phases

Mission phase	Tracking coverage significance
Primary mission	
1. Postlaunch Near-Earth operations	Extended from DSN initial acquisition through completion of the Earth-Moon photographic sequences at launch plus 10 days. Required 64-m DSS coverage and real-time handling of 115 kbps TV data. Included extensive radio metric data requirements in preparation for the first TCM.
2. Trajectory correction maneuver	Four maneuvers during the primary mission required extensive radio metric coverage for pre- and post-burn orbit determinations and 64-m DSS coverage during the burns to assure acquisition of critical spacecraft engineering telemetry data.
3. Earth/Venus cruise	Between critical events during the cruise, continuous recovery of low-rate telemetry was required via the 26-m subnet. Navigation requirements also dictated periodic use of the 64-m subnet for dual-frequency and planetary ranging data. Special 64-m coverage required for Comet Kohoutek observations.
4. Venus encounter	Full 64-m subnet coverage required with emphasis on high-rate video, low-rate science, and radio science data recovery.
5. Venus/Mercury cruise	Essentially same as Earth-Venus cruise with increased emphasis on radio metric data generation.
6. First Mercury encounter	Full 64-m subnet coverage required with emphasis on high-rate video, low-rate science, and radio science.

Table 4 (contd)

Mission phase	Tracking coverage significance
Extended mission	
7. Trajectory correction maneuvers	Four maneuvers during the extended mission required extensive radio metric coverage for pre- and post-burn orbit determination and 64-m subnet coverage during the burn to assure acquisition of critical spacecraft engineering telemetry data.
8. Mercury I to Mercury II cruise	Between critical events during cruise, near continuous coverage of low-rate telemetry was required via the 26-m subnet. Navigation requirements dictated periodic use of 64-m subnet for dual-frequency and planetary ranging data.
9. Solar occultation	A special event during cruise requiring 64-m subnet coverage, particularly DSS 14's generation of dual-frequency radio metric data and occultation recordings for radio science purposes.
10. Second Mercury encounter	Full 64-m subnet coverage with emphasis on recovery of high-rate video and low-rate science. Included 26- and 64-meter antenna arraying to improve video data quality. No planetary occultation and no radio science support.
11. Mercury II to Mercury III cruise	Near continuous low-rate telemetry recovery with emphasis on attitude gas conservation/spacecraft survival for third Mercury encounter. Increased emphasis on 64-m subnet radio metric data generation.
12. Third Mercury encounter	Full 64-m subnet coverage with emphasis on recovery of low-rate science and high-rate video.

coverage requirements varied as a function of the DSN system data types (telemetry, radio metric, command, and radio science) which are discussed in the remainder of this section. Basically, however, the composite coverage requirements for Mariner Venus/Mercury 1973 resulted in a need for continuous tracking via a combination of 26- and 64-meter deep space stations during the primary mission (see Fig. 11) and for near-continuous tracking coverage during the extended mission.

3. Telemetry Data Requirements

Telemetry coverage requirements were stated either in terms of DSN 64-meter subnet or 26-meter subnet support as a function of planned data rates, bit error rate requirements, and expected telecommunications link performance. Coverage requirements for the prime and extended mission are summarized in Table 5.

To acquire Mariner Venus/Mercury 1973 telemetry data, the DSN was required to track the spacecraft radio signal having the following characteristics: (1) S-band carrier at 2295.0 MHz, (2) right circular polarization, (3) either 10 or 20 W transmitter power, (4) single-lobe high-gain antenna having a gain of 27.6 dB or omnidirectional low-gain antenna having a gain of -2.6 dB, (5) pulse code-phase modulation, (6) two channels consisting of one low rate subcarrier at 88.55 kHz and one high rate channel at 177.1 kHz, and (7) both uncoded and block coded data. Capabilities were required in the DSN for the combinations of subcarriers, rates, modulation indexes, coding, and error rates given in Tables 6 and 7 and Figs. 12 and 13.

The requirement for acquisition and handling of real-time video at a rate of 117,600 bps represented a large increase over past Mariners, which operated at a maximum rate of 16,000 bps. Significant increases in DSN capabilities were required to accommodate the real-time handling and recording of these data. Also, to gain an improvement in low-rate subcarrier power when in the dual subcarrier mode, the Mariner Venus/Mercury 1973 telecommunications link design employed for the first time a technique called interplex modulation. When two subcarriers are phase-modulated onto a single carrier, the relative power in the data channel and the residual carrier depends on the modulation index angle of the two subcarriers. Modulation angles used for Mariner Venus/Mercury 1973 provided for this improvement. However, subcarrier demodulator assembly modifications were required to gain optimum demodulation of the low rate subcarrier while operating in the interplex mode.

Theoretically, the ground telemetry system is capable of delivering 100% of the data transmitted by the spacecraft. However, something less than 100% is actually provided in real-time owing to an occasional ground equipment failure or communications outage and communications errors. Data which were not recovered by the user in real-time are usually obtainable from DSS analog or digital recordings. However, the process of digitizing analog tapes and replaying digital tapes to recover very small quantities of randomly distributed outages is very time consuming and costly. Therefore, based on each experiment's needs, telemetry data quality and quantity criteria were developed

Table 5. Deep space telemetry coverage requirements

Primary mission

64-m subnet

1. Goldstone coverage during the Earth-Moon TV calibration sequences. Required approximately six DSS 14 passes during the first 10 days of the mission beginning with the first DSS 14 pass following initial acquisition.

2. Continuous, 24-h/day coverage during the Venus encounter phase, which was defined as Venus encounter minus 1 day through Venus encounter plus 17 days.

3. Continuous, 24-h/day coverage during the Mercury encounter phase, which was defined as Mercury encounter minus 7 days through Mercury encounter plus 13 days.

4. Coverage during any portion of the Venus-Mercury cruise phase wherein the 26-m subnet could not meet the bit error requirements of 1×10^{-4} for the 2450-bps science data.

26-m subnet

1. Telemetry coverage by the 26-m subnet was required whenever a 64-m DSS was not tracking to provide continuous data acquisition from DSN initial acquisition through the end of the primary mission.

Extended mission (Mercury II)

64-m subnet

1. Continuous coverage for a 24-h period associated with all trajectory correction maneuvers.

2. Continuous coverage during the Mercury II encounter phase, which was defined as second encounter minus 4 days through encounter plus 4 days.

Table 5 (contd)

Extended mission (Mercury II) (contd)
26-meter subnet
1. Telemetry coverage by a 26-m subnet was required whenever a 64-m DSS was not tracking to provide a net coverage of 24 h/day for the duration of the second Mercury encounter mission.
An alternative to this requirement allowed coverage gaps of up to 20.5 h since cruise; data could be recorded on the spacecraft recorder and later played back at a higher rate during a 64-m DSS tracking period.
Extended mission (Mercury III)
64-m subnet
1. Continuous coverage for a 26-h period associated with all trajectory correction maneuvers.
2. Continuous coverage during the Mercury III encounter phase, which was defined as third encounter minus 4 days through encounter plus 4 days.
3. Two passes per week were required for special spacecraft and science activities.
26-m subnet
1. Telemetry coverage by a 26-m subnet was required whenever a 64-m station was not tracking to provide a net coverage of 12 h/day for the duration of the mission.

Table 6. Mariner Venus/Mercury 1973 telemetry channel description

FDS Mode	High-rate channel (S_c = 177.1 kHz)				Low-rate channel (S_c = 88.55 kHz)			
	Name	Rate, kbps	Mod index, deg	Code	Name	Rate, bps	Mod index, deg	Code
1	IM-1	117.6	72	None	NIS-1	2450	16	B-C
2	IM-3	22.05	75	B-C	NIS-1	2450	30	B-C
3	PB-A	22.05	72	B-C	NIS-1	2450	30	B-C
4	PB-B	7.35	72	B-C	NIS-2	490	30	B-C
5					NIS-1	2450	70	B-C
6					NIS-2	490	70	B-C
7					Eng'g A	2450	70	B-C
8					Eng'g B	33-1/3	41	None
9					Eng'g C	8-1/3	41	None

FDS = flight data system; IM = imaging; PB = playback; NIS = Non-imaging science; Eng'g = engineering; B-C = block coded.

Table 7. Mariner Venus/Mercury 1973 telemetry rates and modes

Channel	Description	Bit rate	Maximum acceptable BER	Block coded
High rate	Imaging data	117.6 kbps	5 10^{-2}	No
		22.05 kbps	5 10^{-2}	Yes
	Playback data	22.05 kbps	5 10^{-2} (a)	Yes
		7.35 kbps	1 10^{-4} (a)	Yes
Low rate	Non-imaging science data (includes engineering)	2.45 kbps	1 10^{-4}	Yes
		490 bps	1 10^{-4}	Yes
	Engineering data	2.45 kbps	1 10^{-2}(b)	Yes
		33-1/3 bps	1 10^{-2}(b)	No
		8-1/3 bps	1 10^{-2}(b)	No

[a] 1×10^{-4} for non-imaging data (playback at E_V + 1 day at 22.05 kbps and E_M + 1 day at 7.35 kbps of data taken during occultations). The bit errors introduced by the Ground Data Handling System shall not degrade the bit error rates specified above by more than 1%. All data during receiver in-lock time will be provided to the user.

[b] 1×10^{-4} during CC&S memory readouts.

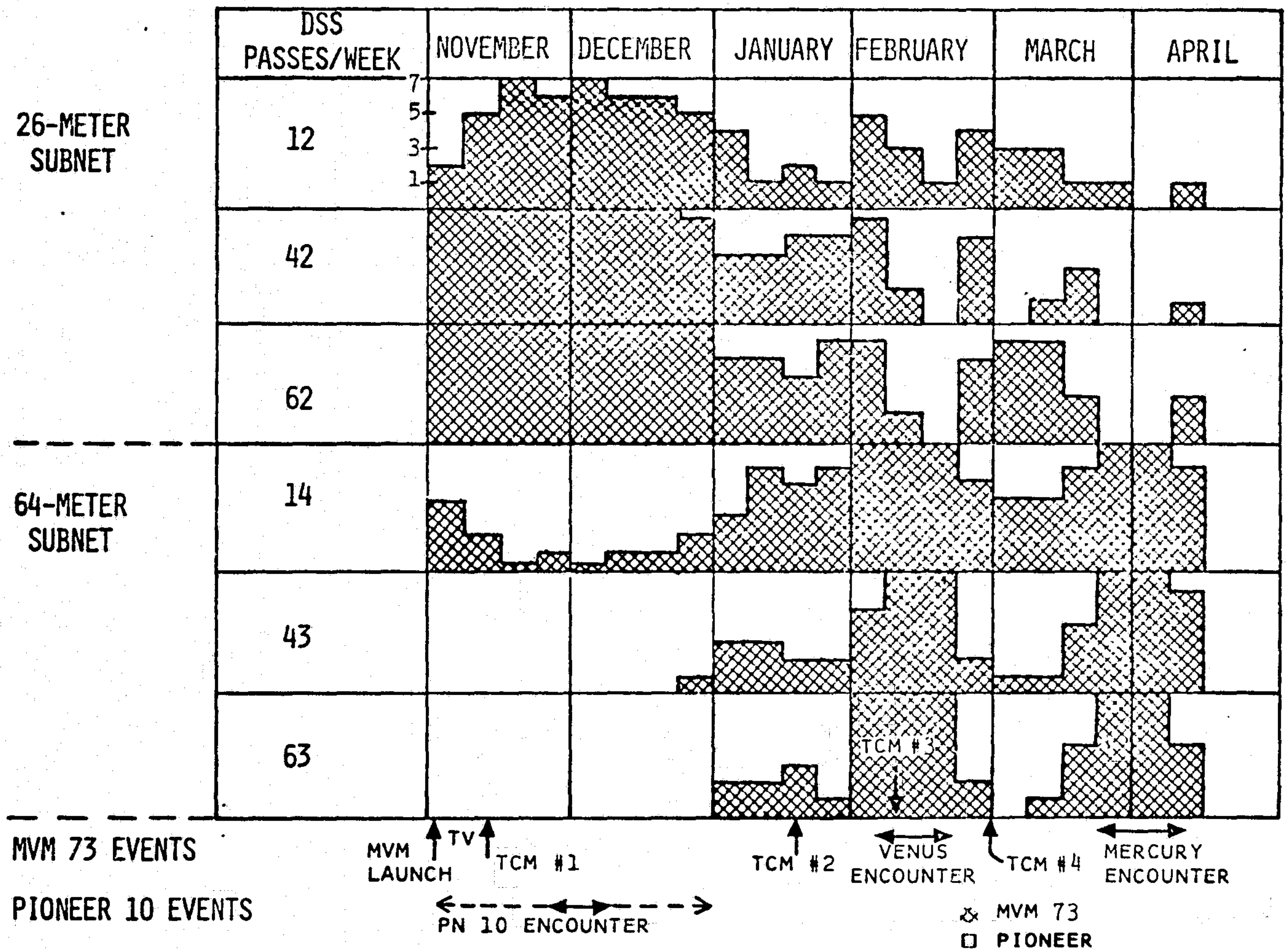
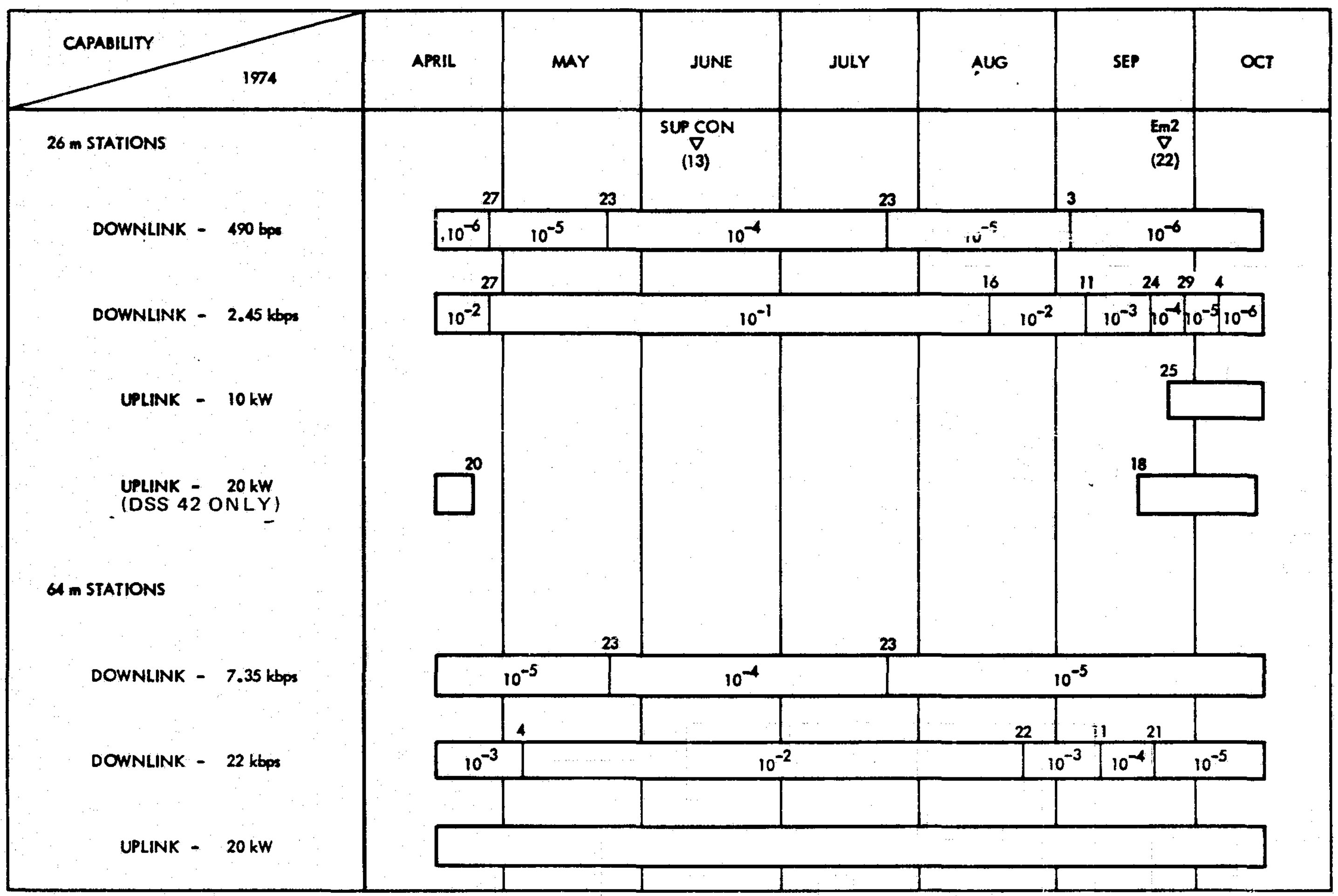
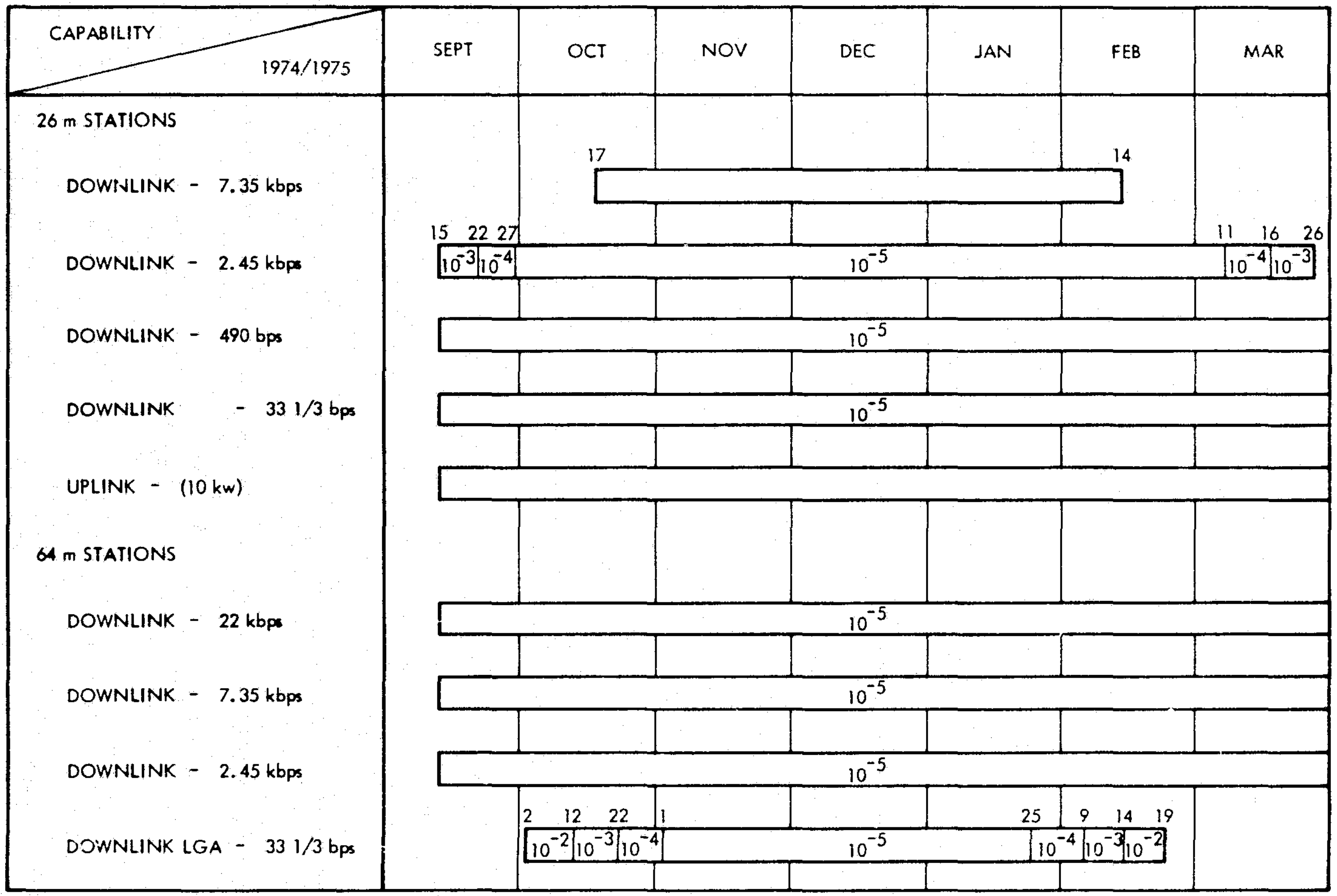


Figure 11. General 26- and 64-m subnet composite coverage requirements



Capabilities exist whenever a bar is shown. Bit-error rates for the downlink are equal to or less than the numbers shown in the bars.
Numbers outside the bars show day of the year

Figure 12. Mariner 10 Mercury II encounter telecommunication link characteristics (nominal performance based on primary mission experience)



Capabilities exist whenever a bar is shown. Bit-error rates for the downlink are equal to or less than the numbers shown in the bars. Numbers outside the bars show day of the year.

Figure 13. MVM'73 Mercury III encounter telecommunication link characteristics (nominal performance based on primary mission experience)

to provide a decision model regarding the initiation of secondary recovery procedures. Criteria were developed for three basic data types: imaging, non-imaging science type 1, and non-imaging science type 2. These criteria were further specified for critical and normal periods. Figure 14 illustrates the encounter critical periods. Specific criteria are given in Tables 8 through 13. These criteria reflect the requirements for each 24-hour "data day," wherein qualifiers such as good picture and good superframe are relative to the spacecraft flight data subsystem's count interval of 42 seconds.

These rather demanding quality and quantity requirements implied a large secondary data recovery effort in order to obtain missing data from the stations' original data records. To preclude this additional workload on the Network , a decision was made to ship original data recordings directly to the Project for processing. This decision resulted in the following expected tape delivery requirements: (1) shipment from DSS 12 and DSS 14 within three hours from the end of each critical encounter pass for a total of three shipments at each encounter, (2) one shipment from Australian stations within 48 hours following each encounter, and (3) one shipment from Spanish stations within 24 hours following each encounter.

4. Command Requirements

The DSN was required to maintain capabilities to command the Mariner Venus/Mercury 1973 spacecraft from the point of initial acquisition to the end of the extended mission. Under normal mission conditions, the DSN command system was to be ready for operational commanding within one hour following notification of the requirement. However, under emergency conditions, the Project required the DSN to be capable of supporting command activities within 15 minutes, excluding one-way light time and spacecraft lockup time. For most mission phases, the 26-m deep space station capability, at a transmitter power of 10 kW, was sufficient to meet uplink performance requirements. However, 64-m deep space station command coverage was required during the solar conjunction period and during those spacecraft maneuver activities which resulted in the spacecraft high-gain antenna being pointed off the earth line; for example, trajectory correction maneuvers, roll calibration maneuvers, and Canopus acquisition maneuvers. A 64-m deep space station transmitter power of 20 kW was sufficient to meet uplink performance requirements under these adverse uplink conditions; however, DSS 14 was requested to provide a transmitter power of 100 kW as an additional measure of insurance during a portion of these critical events.

The Mariner Venus/Mercury 1973 spacecraft employed essentially the same command system as that used on Mariner Mars 1971. Key characteristics of the spacecraft command system included the following: (1) dual channel consisting of PN sync and bi-phase data, (2) spacecraft receive frequency at 2113.312500 MHz, (3) receive high-gain or low-gain antenna at right circular polarization, (4) phase modulation/pulse code modulation coding, (5) command transmission rate of 1 bps with a word length of 26 bits, and (6) command bit error rate of less than or equal to 1 bit error in 10^5 during any mission phase with a probability of an undetected

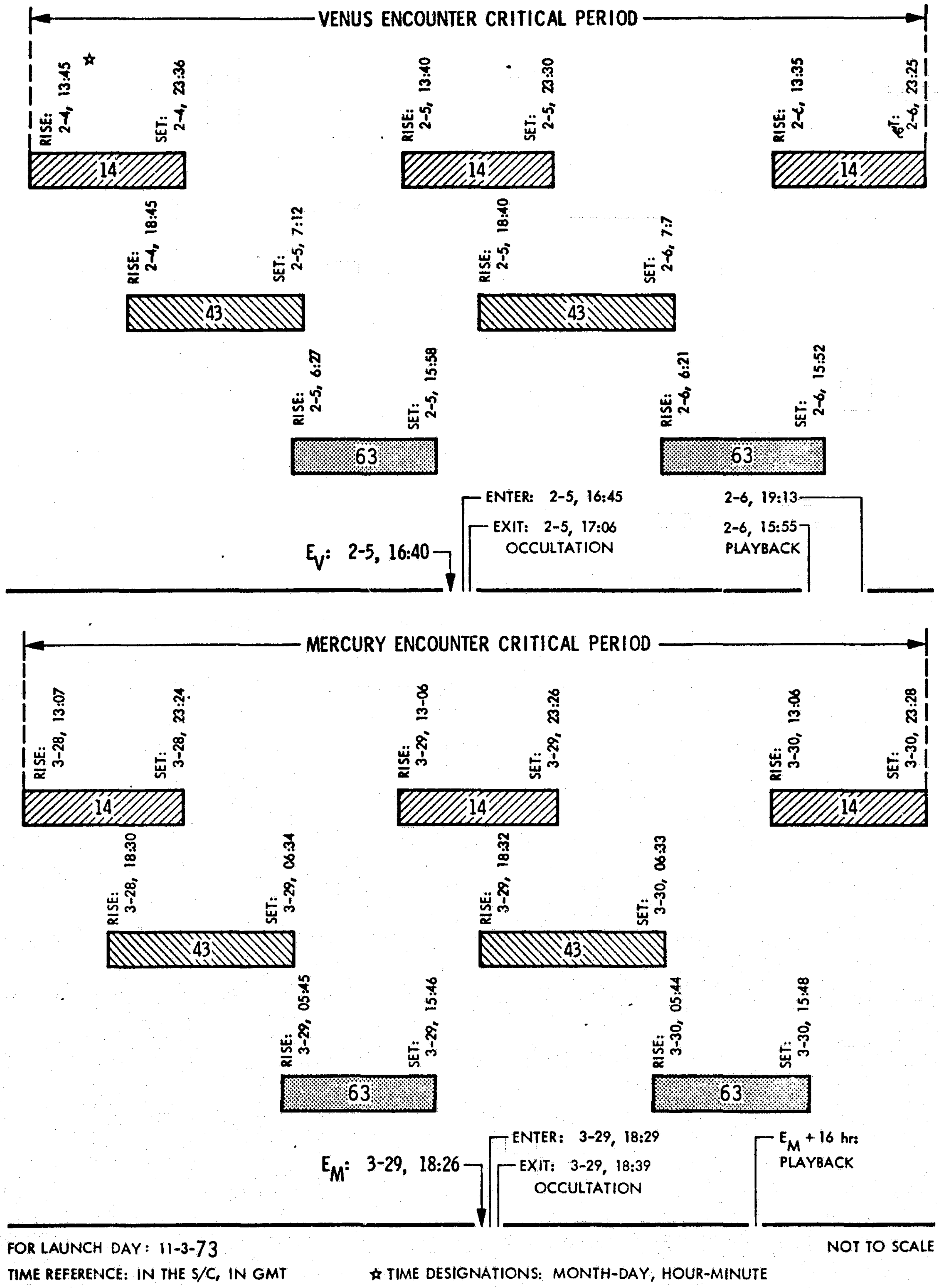


Figure 14. Coverage of critical periods

Table 8. Critical imaging data criteria

Data type	Data quality requirements
IM-1	Good picture
117.6 kbps minor frames = 7056 bits = 1 line	Within a 42-sec TV frame 693 or more minor frames are present (99% or higher), and no continuous sequence of missing minor frames is greater than 3 minor frames (0.5%)
IM-3	
22.05 kbps minor frame = 60 msec = 1323 bits = 1 line	In a given data day 99% or more pictures will be good pictures
For IM-1 and -3	
700 minor frames = 700 lines = 1 picture	No continuous sequence of bad pictures will be greater than 0.5% of the total pictures

A bad picture is one which does not satisfy the good picture requirements shown above. In special cases, when in a given data day total pictures are less than 100, the percent quality requirement will not apply and there will be no more than 1 bad picture.

Table 9. Normal imaging data criteria

Data type	Data quality requirements
IM-1	Good picture
117.6 kbps minor frame = 7056 bits = 1 line	Within a 42-sec TV frame 665 or more minor frames are present (95% or higher), and no continuous sequence of missing frames is greater than 14 minor frames (or 2%)
IM-3	
22.05 kbps minor frame = 60 msec = 1323 bits = 1 line	In a given data day 95% or more pictures will be good pictures
For IM-1 and -3	
700 minor frames = 700 lines = 1 picture	No continuous sequence of bad pictures will be greater than 1% of the total pictures

A bad picture is one which does not satisfy the good picture requirements shown above. In special cases, when in a given data day total pictures are less than 100, the percent quality requirement will not apply and there will be no more than 1 bad picture.

Table 10. Critical non-imaging science (NIS-1) data criteria

Data type	Data quality requirements
NIS-1	
2450 bps minor frame = 0.24 sec = 588 bits	Good superframe
	Within a 42-sec superframe, 173 or more NIS-1 minor frames are present (~99%), and no continuous sequence of missing minor frames is greater than 2 minor frames (1%)
175 minor frames in 42 sec 2057 42-sec periods in a day 360,000 minor frames in a day	In a given data day 99% of superframes will be good superframes, and no continuous sequence of bad superframes will be greater than 0.5% of the total major frame

A bad superframe is one which does not satisfy the good superframe requirements shown above. In special cases, when in a given data day total superframes are less than 100 (1 hr, 10 min), the percent quality requirement will not apply and there will be no more than 1 bad superframe.

Table 11. Normal non-imaging science (NIS-1) data criteria

Data type	Data quality requirements
NIS-1	
2450 bps minor frame = 0.24 sec = 588 bits	Good superframe Within a 42-sec superframe, 166 or more NIS-1 minor frames are present (95%), and no continuous sequence of missing minor frames is greater than 4 minor frames (2%)
175 minor frames in 42 sec	
2057 42 sec periods in a day	In a given data day 95% of superframes will be good superframes, and no continuous sequence of bad superframes will be greater than 1% of the total superframe
360,000 minor frames in a day	

A bad superframe is one which does not satisfy the good superframe requirements shown above. In special cases, when in a given data day total superframes are less than 100 (1 hr, 10 min), the percent quality requirement will not apply and there will be no more than 1 bad superframe.

Table 12. Critical non-imaging science (NIS-2) data criteria

Data type	Data quality requirements
NIS-2	
490 bps minor frame = 1.2 sec = 588 bits 35 minor frame in 42 sec	Good superframe Within a 42-sec superframe, 33 or more NIS-2 minor frames are present (95% or higher), and no continuous sequence of mission minor frames is greater than 2 minor frames (5%)
257 42 sec periods in a day 72100 minor frames in a day	In a given data day 99% of superframes will be good superframes, and no continuous sequence of bad superframes will be greater than 0.5% of the total superframes

A bad superframe is one which does not satisfy the good superframe requirements shown above. In special cases, when in a given data day total superframes are less than 100 (1 hr, 10 min), the percent quality requirement will not apply and there will be no more than 1 bad superframe.

Table 13. Normal non-imaging science (NIS-2) data criteria

Data type	Data quality requirements
NIS-2	
490 bps minor frame = 1.2 sec = 588 bits 35 minor frame in 42 sec	Good superframe Within a 42-sec superframe, 32 or more NIS-2 minor frames are present (92%), and no continuous sequence of missing minor frames is greater than 3 minor frames (8%)
2057 42 sec periods in a day 72100 minor frames in a day	In a given data day 95% of superframes will be good superframes, and no continuous sequence of bad superframes will be greater than 1% of the total superframes

A bad superframe is one which does not satisfy the good superframe requirements shown above. In special cases, when in a given data day total superframes are less than 100 (1 hr, 10 min), the percent quality requirement will not apply and there will be no more than 1 bad superframe.

error being less than 1×10^{-6}. In addition, the DSN command system was required to be capable of transmitting commands singly or in blocks of up to 550 commands without interruption, and a capability to manually initiate limited commands at the deep space stations was required as a backup to the computer-driven command system. Commanding operations were required concurrently with the acquisition of telemetry data and ranging data.

5. Radio Metric Data Requirements

Mariner Venus/Mercury 1973 was the first multiplanet flyby mission. Consequently, it posed orbit determination challenges requiring a factor of 4 improvements beyond that of the previous missions. The Earth-to-Venus portion of the trajectory was particularly critical in regard to orbit determination accuracy since each kilometer of error at Venus would map to a 1000 km error at Mercury if not corrected. Furthermore, a trajectory error at Venus of approximately 400 km would require more change in velocity than the spacecraft propulsion system was capable of delivering. The implications were clear: mission success depended upon significant improvement in orbit determination capability.

These mission requirements for precise navigation of the spacecraft translated into a rather demanding set of radio metric data coverage and accuracy requirements on the DSN. These requirements in turn not only necessitated improvements in existing DSN tracking system performance but also resulted in the development and use of new radio metric data types and operational techniques, some of which were provided for the first time on an experimental basis during the MVM'73 mission.

Radio metric data pertains to that portion of the tracking and data acquisition function which enables the determination of spacecraft position, velocity, and direction. Radio metric data are generated at the deep space stations and consist of basic angle, doppler, and range types. Variations of these types include (1) one-way, two-way, and three-way doppler, (2) discrete range points or continuous ranging, and (3) near-simultaneous range points from separate deep space station locations during a period of common spacecraft viewing. Generation of supplementary radio metric calibration data, such as differenced range vs integrated doppler, Faraday rotation data, and ground weather data, was also required for Project use in calibrating the basic radio metric data types when used for precise orbit determination and navigation purposes.

To generate doppler and ranging data, the deep space stations were required to track the spacecraft radio subsystem having the following basic characteristics: (1) S-band downlink carrier at 2295.0 MHz, (2) X-band downlink carrier at 8415.0 MHz, (3) frequency stability of 2.8 parts in 10^5 over 10 hours in the spacecraft receiver-transponder, (4) range code phase modulation on the carrier, (5) either 10 or 20 W transmitter power, (6) right circular polarization, (7) high-gain or low-gain antenna with gains of 27.9 and 38.5 dB respectively, and (8) an uplink carrier frequency at 2113.312500 MHz.

Mariner Venus/Mercury 1973 radio metric requirements were stated in terms of data types, coverage, and accuracy. Coverage requirements related to the various mission phases are summarized in Table 14. Accuracy requirements for various elements of the basic data types are given in Table 15.

The MVM'73 spacecraft was the first interplanetary vehicle to employ an X-band downlink carrier. Use of the dual-frequency S-band and X-band link was stated as required to meet a mission engineering objective of demonstrating navigational accuracy improvements through the use of dual-frequency doppler and range data for calibrating the effects of charged particles in the interplanetary medium. This engineering objective required that one 64-m deep space station be equipped with simultaneous dual-frequency receive and radio metric data generation capabilities. The mission requirement for S-band ranging data throughout the flight necessitated the development and employment of planetary distance ranging capabilities throughout the network. Furthermore, the stated accuracy requirements for DSN observables and deliverables were tighter than those emposed on any previous mission.

Table 14. Radio metric data coverage requirements

Primary mission

During injection, maneuvers, and encounters

1. Continuous tracking and generation of radio metric data required.

2. Station handovers arranged such that uninterrupted data are provided during the elevation angles of 10-20 deg and during the interval of meridian crossing minus 1 hour to plus 1 hour.

3. One horizon-to-horizon pass every four days from each of the three DSS longitudes.

Orbit determination critical (Venus encounter minus 33 days to encounter plus 21 days)

1. Same as above, except continuous coverage desired but not required.

2. Design goal to obtain many horizon-to-horizon passes with uninterrupted doppler, ranging, and differenced range vs integrated doppler data.

3. Design goal to obtain maximum number of pairs of near-simultaneous range points from different deep space stations as is consistent with other requirements.

Non-critical periods

1. One pass approximately every four days from three different DSN longitudes required.

2. During passes, provide interrupted data from horizon to plus 30 deg and at meridian crossing from minus 1 hour to plus 1 hour.

3. Coverage for additional data stated as design goals under "Orbit Determination Critical" also highly desirable.

Table 14 (contd)

Navigation enhancement demonstration (engineering objective)

1. One DSS 14 pass every other day to generate dual-frequency (S/X-band) doppler and ranging to demonstrate navigational accuracy improvement through the use of the dual-frequency technique for charged particle calibration.

2. Design goal to obtain S-band ranging from other DSS simultaneously with the generation of S/X-band data at DSS 14.

Ground Based Radio Science (Planetary Radar)

1. Use of DSS 14 planetary radar ranging capability required from February 28, 1972, to October 15, 1973, to obtain data for the improvement of Venus and Mercury ephemerides. Passes of 6-8 hours duration required.

Mercury second encounter mission

1. Continuous two-way doppler whenever telemetry data received.

2. One cycle of simultaneous two- and three-way doppler twice per week.

3. One good range point twice per week.

4. One cycle of near-simultaneous ranging once every four days.

5. Dual-frequency S/X-band data three times per week, but continuous around superior conjunction (May 24, 1974-June 18, 1976)

6. Differenced range vs integrated doppler twice per week, but continuous during the superior conjunction interval.

Table 14 (contd)

Mercury third encounter mission

1. Continuous two-way doppler whenever telemetry data received.
2. Simultaneous two- and three-way doppler twice per week.
3. Three weeks of two-station tracking following Mercury second encounter and each trajectory correction maneuver, to include northern and southern hemisphere coverage.
4. S-band ranging twice per week.

Table 15. Metric data accuracy requirements

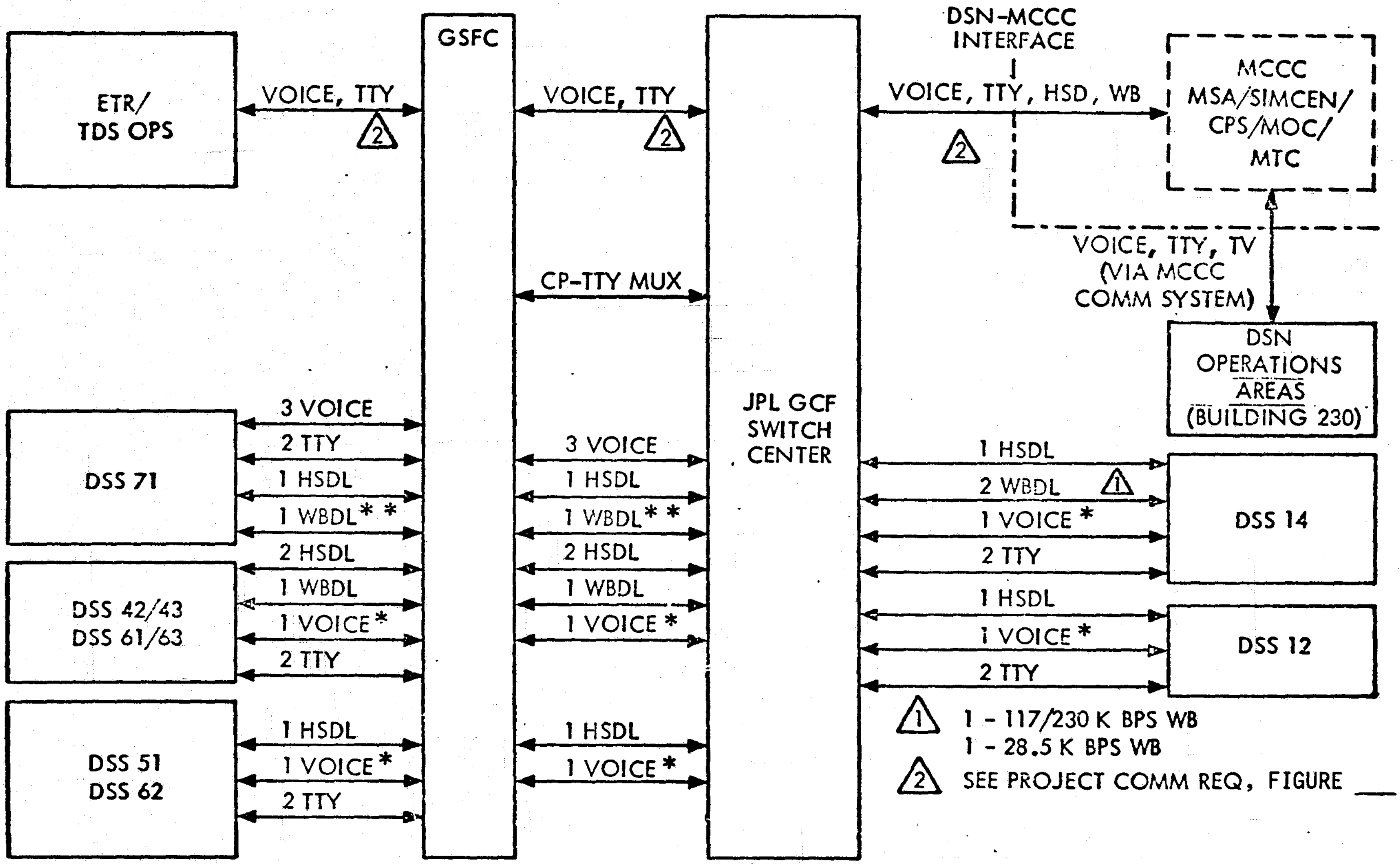
Parameter	Value (3σ)
Platform parameters, including DSS locations, Universal time, and polar motion	
Longitude (λ)	12.0 m
Distance parallel to earth spin axis (x)	45.0 m
Distance perpendicular to earth spin axis (r_s)	3.6 m
Bureau International de l'Heure data	As available
Transmission media, including troposphere, ionosphere, and space plasma	
Change in radio path length over 12 h for elevation angles greater than 15 deg	
Stations with ranging (64-m sites)	3.0 m
Stations without ranging (26-m sites)	24.0 m
DSS equipment	
Time synchronization; accumulated timing offset between stations	150 sec
S-band integrated doppler, including FTS instability, phase path drift, and quantization error	
Short term, greater than 1 ksec	2.1 m
Diurnal	3.9 m
S-band range	
Ranging bias	150 nsec
Ranging noise	450 nsec
Minimum unambiguous range	1500 km

Table 15 (contd)

Parameter	Value (3σ)
DSS equipment (contd)	
S-band differenced range vs integrated doppler (DRVID)	21 nsec (E_V-3)
High frequency (>5 min at E_V-3; >15 min at E_M)	81 nsec (E_M)
Diurnal (10 h) drift in the ranging channel with respect to the doppler channel	21 nsec (E_V-3) 81 nsec (E_M)
DSN angle data	
Accuracy	0.05 deg
Resolution	0.005 deg
Differential S/X phase	150 cm/pass
Differential S/X range	3 m

6. Ground Communications Requirements

Project requirements for real-time handling of control, command, radio metric, and low-rate telemetry data during the deep space phase translated into a rather standard set of requirements for voice, teletype, and high-speed data circuits between the deep space stations and the JPL Mission Operations Center. However, requirements for communication of high-rate telemetry data from all 64-m stations necessitated a significant increase in ground communication wideband transmission capabilities. Spacecraft data rates through 22,050 bps were required to be communicated in real-time from all 64-m stations. More significantly, the Goldstone 64-m station was required to also communicate real-time imaging data to the Mission Operations Center at a rate of 117,000 bps. These requirements for DSN internal communications for the prelaunch test support and post-launch mission support activities are illustrated in Figs. 15 and 16 respectively. In addition, the MVM'73 Project imposed new and unique requirements for the communication of processed data between the JPL central operations area and remote locations, termed Remote Information Centers. These requirements are illustrated in Figs. 17 and 18 for prelaunch and for postlaunch activities, respectively.



* VOICE CKTS TO DSS's CONFERENCED IN LOOP CONFIG AT GSFC AND DSC 10 SW CENTERS DURING NON-CRITICAL PERIODS

** WBDL TO BE SHARED WITH BLDG AO (MTC)

Figure 15. Prelaunch requirements for DSN internal communications

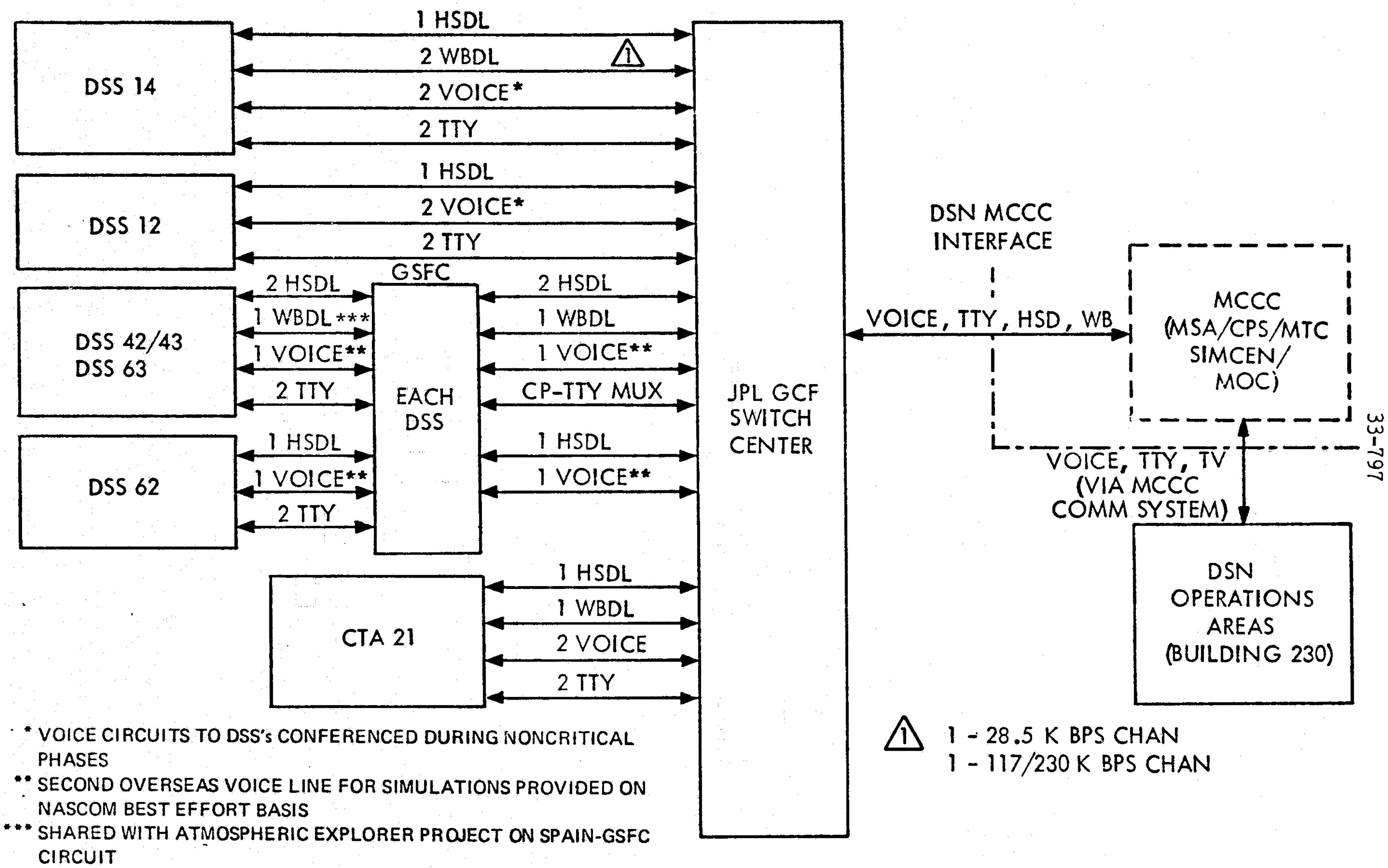


Figure 16. Postlaunch requirements for DSN internal communications

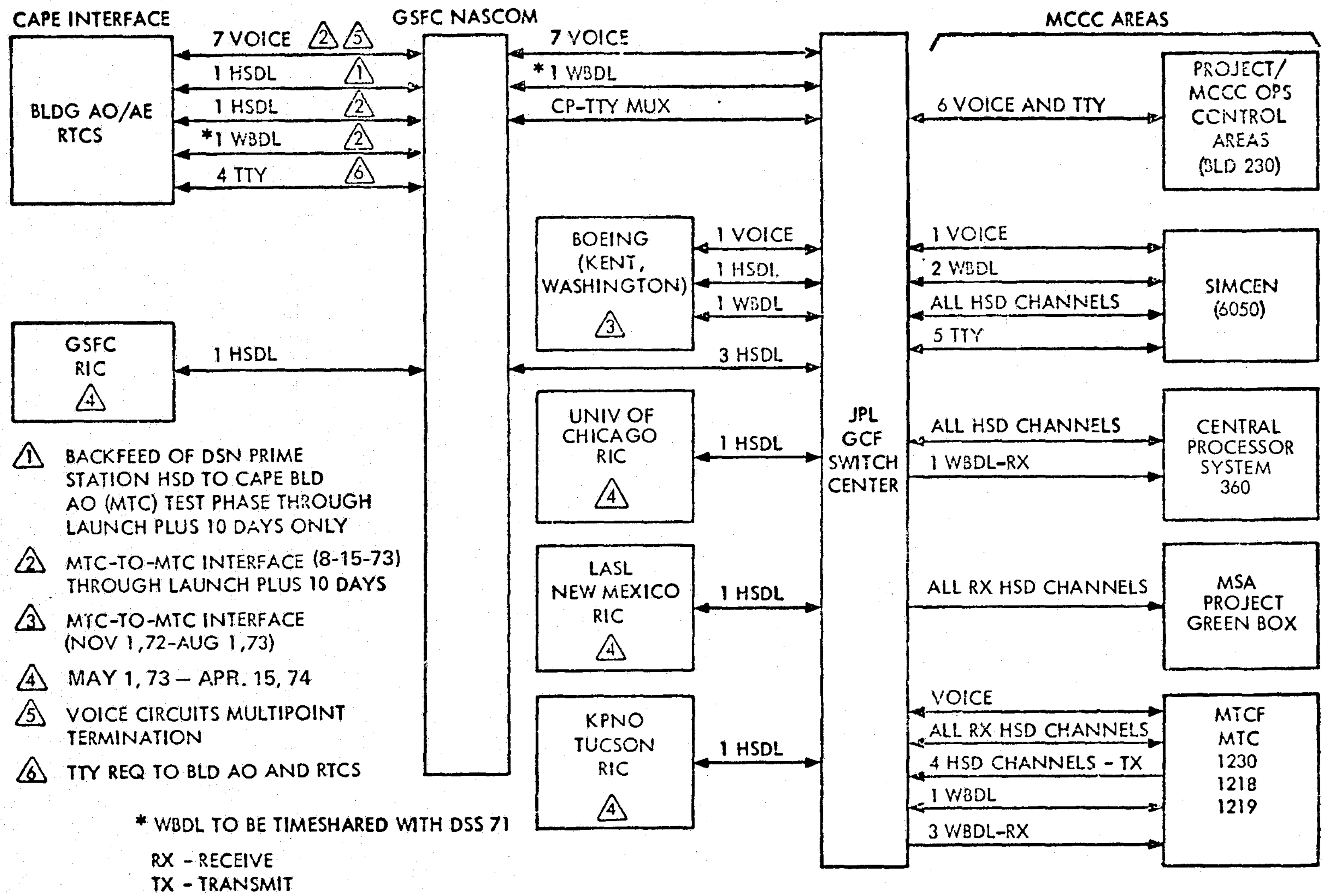


Figure 17. Prelaunch requirements for project-unique communications

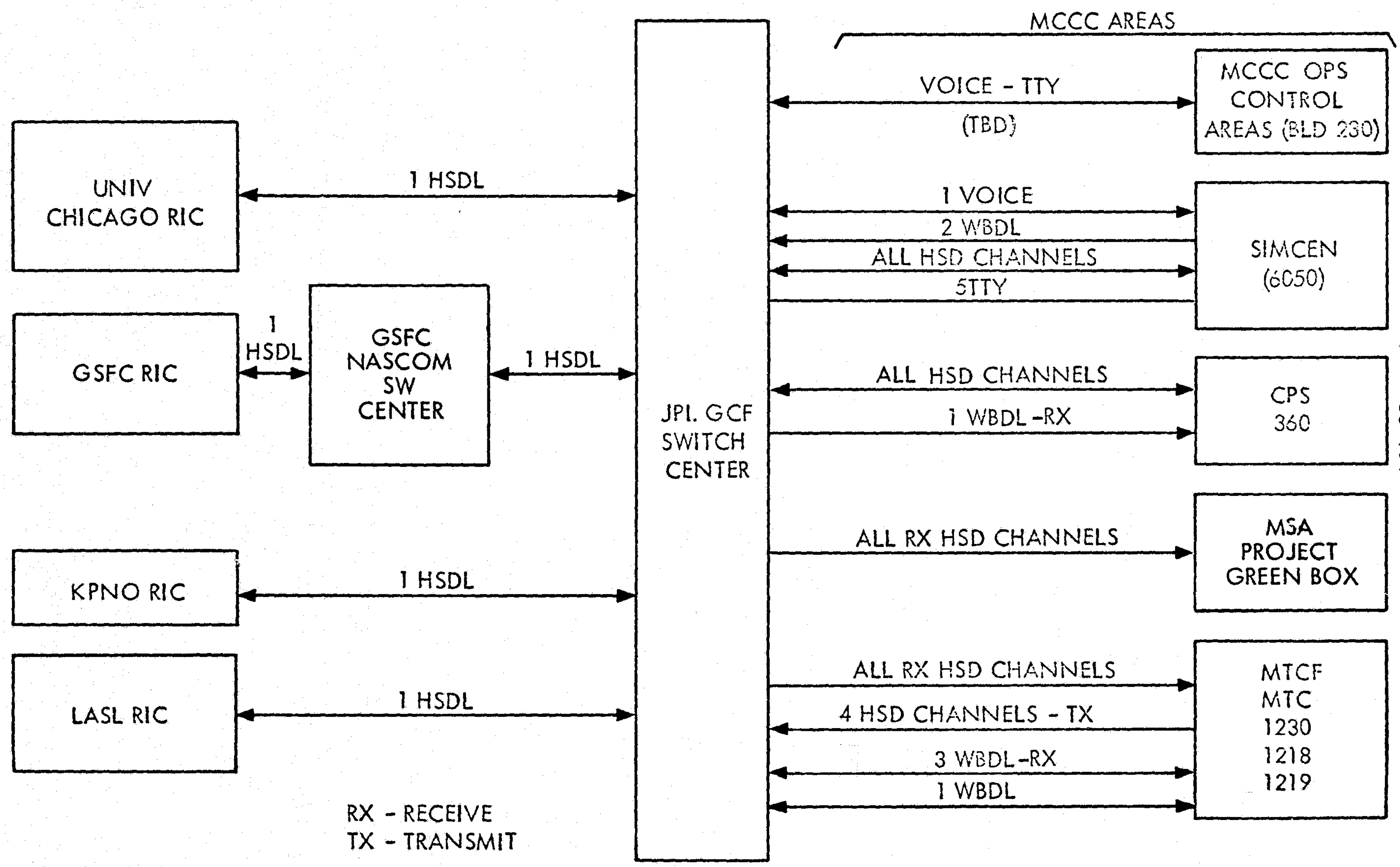


Figure 18. Postlaunch requirements for project-unique communications

7. Celestial Mechanics and Radio Science Requirements

Unlike other MVM'73 experiments which utilized specific scientific instruments on the spacecraft, the celestial mechanics and radio science experiment made direct use of the radio link for generating its data. It is noted, however, that the X-band transmit capability was added to the spacecraft for the primary purpose of supporting this experiment. The deep space stations were directly involved in terms of equipment and operations required to acquire and record the RF carriers and to generate the associated radio metric data. Consequently, this experiment is singled out for special attention.

The DSN was required to implement a dual-frequency (S-band and X-band) receive capability at one 64-m station, DSS 14. It was generally requested that this dual-frequency capability be available for use anytime DSS 14 was tracking and the spacecraft was in the S/X-band mode. Analog recordings of open-loop receiver data were required at both frequencies during Earth occultation at planetary encounters, during solar superior conjunction, and during other periods upon request. These recordings were also to include static AGC and dynamic AGC of the received signals during planetary encounter periods. Furthermore, the experimenter required that the AGC values be made available to the operations center in real-time via either the DSN telemetry or monitor data blocks. The DSN was also required to digitize the open-loop analog recordings and to provide these digital tapes to the experimenter as the primary deliverable. Requirements for auxiliary calibration data included the following: solar flare forecasts from Boulder, Colorado, Faraday rotation data for ionospheric calibration, ground weather data (wind direction, wind velocity, temperature, pressure, rain rate, and humidity) from the tracking station, and station equipment pre-post calibration measurements.

8. Test, Training, and Simulation Requirements

The DSN was required to support Project end-to-end ground data system tests and to participate in mission operations training exercises. Project software residing in MCCC computers provided most of the simulated data required for these test and training activities. Therefore, the DSN was required to interface with the Project simulation capability in order to receive the data generated and to process it for insertion into the DSN data systems. This capability was required for both the long-loop mode, wherein data are transmitted to the DSS for processing and return, and for the short-loop mode, wherein data are received at the DSN central communications terminal and simply looped back to the appropriate Project-MCCC computer for processing. In addition, the deep space stations were required to provide simulated data for Project tests involving telemetry rates higher than 22.05 kbps (44.8 and 117.6 kbps) due to communications circuit limitations. Repetitive pattern data were acceptable as long as the data were capable of being frame-synchronized and included an incrementing frame count.

III. TRACKING AND DATA SYSTEM IMPLEMENTATION AND CONFIGURATIONS

A. GENERAL

This section describes TDS implementation activities which resulted in accomplishment of the required tracking and data acquisition capabilities for MVM'73. In this context, implementation includes planning, coordination, design, acquisition, installation, and testing of data system equipment and the training of operations people to achieve mission support readiness. The resulting data system detailed configurations which were actually used for mission support are illustrated in appropriate data flow diagrams. In keeping with the previous categorization of TDS activities, this section first deals with the Near-Earth Phase, followed by discussion of Deep Space Phase implementation.

B. NEAR-EARTH PHASE IMPLEMENTATION

1. Near-Earth Implementation Process

The TDS organization described in Section I accomplished near-Earth implementation required for MVM'73. The primary function involved the assignment of Project tracking and data acquisition requirements described in Section II to the appropriate support agencies, NASA and the Department of Defense. To do this effectively, launch vehicle trajectory data were first obtained and then analyzed to determine the viewing tracking stations and their relationship to the required data coverage intervals. The MVM'73 Centaur performance, trajectory, and guidance working group, which was established by Lewis Research Center, served as the primary source of launch trajectory design information. Data obtained were analyzed by the Near-Earth trajectory system engineer as a primary input to the implementation process. This process was initiated during the second half of 1971, and comprehensive trajectory data were generated during the early part of 1972.

As a standing objective, tracking and data acquisition requirements are planned to be met with NASA resources to the maximum extent possible. Requirements on NASA facilities were further categorized as pertaining to Kennedy Space Center, Goddard Space Flight Center (STDN and NASCOM), and JPL (DSN). In turn, these requirements were formally communicated through standard documents of the named organizations. Requirements which could not be met by NASA resources were identified and formally communicated to AFETR through the standard Program Requirements Document. The Near-Earth Phase TDS working group served as the primary forum for the planning and coordination associated with these assignment and documentation activities. The initial Near-Earth Phase working group meeting was held on March 20, 1972, and these meetings continued periodically to meet assigned responsibilities.

In addition to making inputs to the appropriate NASA and Department of Defense documents, the JPL Field Office at Cape Canaveral prepared the Tracking and Data System documents listed in Table 16 to facilitate accomplishment of the Near-Earth implementation process. The process was further governed by the Near-Earth level 5 milestone schedule given in Fig. 19. The Near-Earth Launch Operations Plan presented an integrated description of the total support to be provided for launch. The Interface Description document defined technical interface requirements between the assigned supporting agencies, while the System Description set forth the planned data system configurations for telemetry and radio metric data support. The Expected Coverage Capability document provided an overview of Near-Earth Phase station data acquisition characteristics and an analysis of the support to be expected from these stations.

Table 16. TDS Near-Earth Documents for MVM'73

Near-Earth Phase Operations Plan
Vol. IA - Launch Operations Plan
Vol. II - Near-Earth Phase Interface Description
Vol. III - Near-Earth Phase System Description
Vol. IV - Near-Earth Phase Expected Coverage Capability
Vol. V - Near-Earth Phase View Periods
Near-Earth Phase Test Plan
Near-Earth Phase Quarterly Reports
Near-Earth Phase Final Report

2. <u>Near-Earth Coverage Planning</u>

Through the process described above, detailed coverage analysis was accomplished by the Near-Earth trajectory analyst. Preliminary polynomial approximations of the MVM'73 launch vehicle main engine cutoff 1 and 2 were received and analyzed by mid-1972. Launch azimuths between 82 and 103 deg were studied. For those azimuths north of 93 deg, an instrumentation ship and aircraft were clearly required. Only aircraft support was required to fill coverage gaps between land stations for launch azimuths between 93 and 103 deg. In addition, a study of the effects of spacecraft antenna patterns on Near-Earth support was accomplished. This analysis led to a recommendation to the performance, trajectory, and guidance working group that the Centaur vehicle accomplish a specific roll orientation prior to separation of the spacecraft.

From a coverage standpoint, acquisition of data during the Centaur second burn and spacecraft separation intervals became the major area of difficulty and concern. This was particularly true of the more northerly launch azimuth, since the Vanguard instrumentation ship was firmly committed to support the Skylab Project during the same general time period. Use of the Vanguard was subsequently deleted from the plan and the launch azimuth span was reduced so that coverage requirements

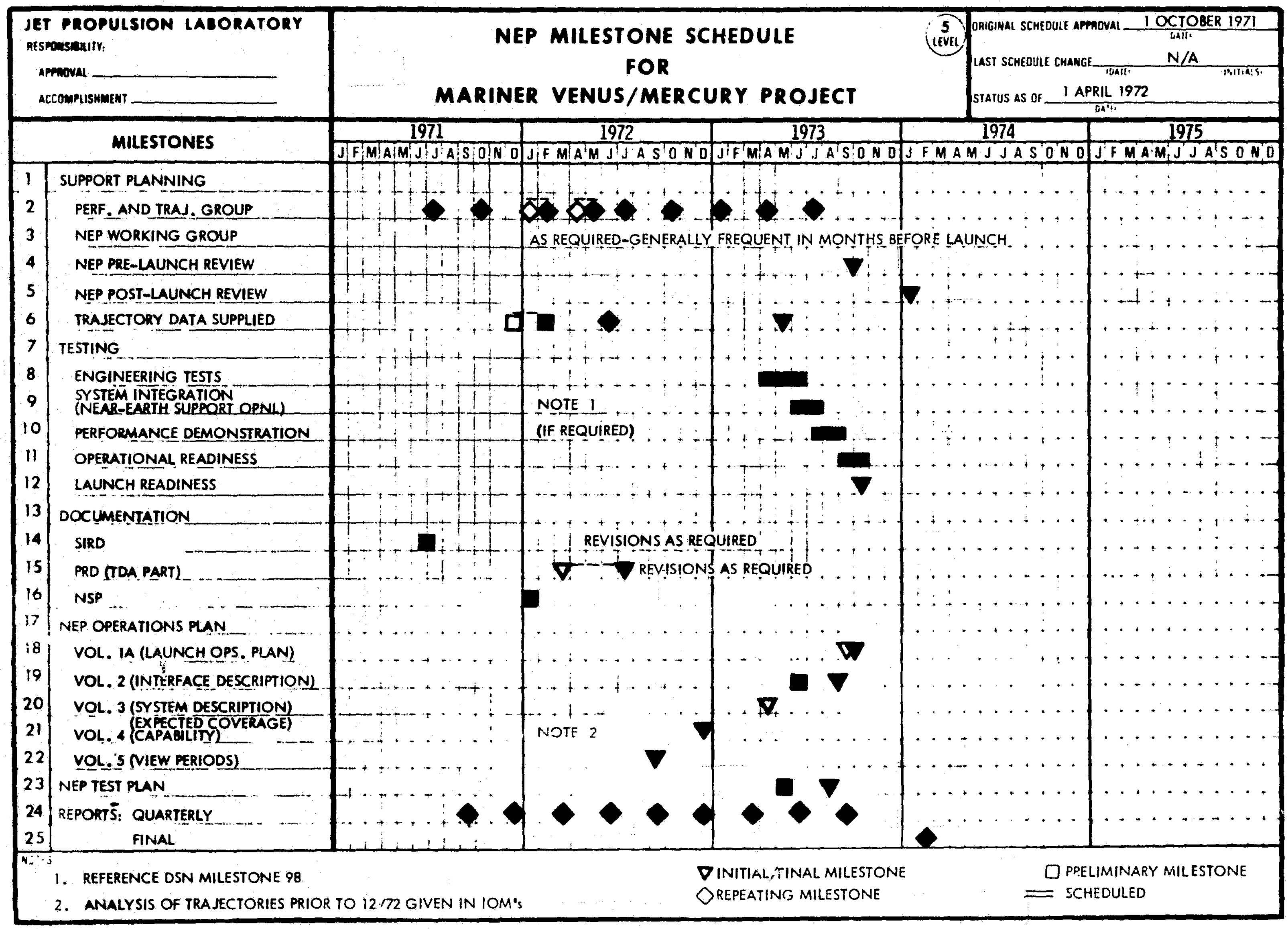


Figure 19. TDS Near-Earth Phase milestone schedule for MVM'73

could be accommodated with land stations and aircraft. A summary of the Near-Earth coverage plan for mandatory requirements is given in Table 17.

Table 17. Near-Earth TDS coverage plan summary for mandatory requirements

Mandatory requirement interval	Type of data	Stations required to provide the support requested
Launch to Centaur MECO 1 + 120 sec	Centaur C-band	Merritt Island or Patrick or Cape and Antigua. Antigua data used after MECO 1 + 76 sec for the mandatory parking orbit solution.
MECO 2 + 10 sec MECO 2 + 350 sec (any 120 sec interval)	Centaur C-band	Primarily Tananarive but possibly Carnarvon[a]
Liftoff to MECO 1 + 120 sec	Centaur telemetry (2202.5 MHz)	CIF or Merritt Island and Antigua
MES 2 - 120 sec to MECO 2 + 180 sec	Centaur telemetry (2202.5 MHz)	ARIA 1 or ARIA 3, Johannesburg, Tananarive and ARIA[b]
Spacecraft separation until initial DSN 2-way lock	Spacecraft telemetry (2295 MHz)	Johannesburg[c], Tananarive and Carnarvon

[a]Carnarvon can support this requirement only at some of the long coast times approaching 29 min.

[b]ARIA 2 needed near the end of each daily window.

[c]Needed only for the short parking orbit coast times.

Goddard Space Flight Center's Network Analysis Section contributed significantly to the coverage planning by accomplishing comprehensive viewperiod and signal level analyses for the Spaceflight Tracking and Data Network supporting stations. For MVM'73, 55 trajectories consisting of varying launch azimuths and outgoing asymptotes were originally simulated. In addition, three nominal check trajectories were generated for each of the 33 days in the MVM'73 launch period for the openings, middle, and closing of the 90-min daily launch window. Subsequently, 24 trajectories which formed the bounds of the launch corridors for the entire MVM'73 launch opportunity were selected and analyzed in detail. Analysis showed that launch azimuths varied between 93 and 105 deg, while the declination of the outgoing asymptotes decreased from +5 to +3 deg during the first 13 days of the launch opportunity. Figure 20 illustrates the ground traces of the bounding trajectories for this early portion of the launch period. In later days, the launch azimuth varied between 90 and 102 deg, while the declination of the outgoing asymptotes varied between +2 and -3 deg. Figure 21 illustrates the composite ground traces of the bounding trajectories for this case.

The preceding trajectory analysis constituted only the initial effort of comprehensive coverage planning for MVM'73. Additional factors, such as the timing of critical events, antenna patterns, and RF downlink characteristics of the launch vehicle and spacecraft, as well as ground station receiving capabilities, were studied to achieve a best estimate of coverage. Using these data, acquisition of signal and loss of signal times were calculated for each supporting station for each of the launch trajectories. A representative set of acquisition and loss of signal plots with varying flight azimuths (FAZ), outgoing asymptote declination (DLA), and relative launch times (TREL) is given in Figs. 22 through 31. Given that dual station coverage of the critical flight events, such as Centaur second main engine start (MES-2), main engine cutoff (MECO-2), and spacecraft separation, was required, these figures show that in the early portion of the launch period coverage of Centaur, second main engine start by Bermuda (BDA) was marginal or impossible as a function of the particular launch azimuth.

A representative number of signal-to-noise ratio vs elevation angle plots are given in Figs. 32 through 43 for the actual launch azimuth of 93 deg. These plots show that an adequate launch vehicle signal level would exist for all stations; however, the spacecraft signal would at times be obstructed due to the position of the solar panels. These blockage periods, as applicable, appear as a shaded area under the elevation angle curve on the 2202.5-MHz launch vehicle vs elevation angle plots. At Centaur-spacecraft separation plus 4 min and 28 sec, the spacecraft solar panels would unfold, thus terminating the blockage condition. In a similar manner, AFETR analyzed and established expected coverage capabilities for acquisition of metric and telemetry data from the Department of Defense stations. These coverage commitments were documented in AFETR Operations Directive 300. An area of special interest involved use of the Advanced Range Instrumentation Aircraft (ARIA) for coverage of critical events wherein land station viewing was marginal. Figure 44 illustrates AFETR's aircraft coverage plan and reflects the test support position (TSP) for a November 3, 1973, launch. ARIA 1 and its backup ARIA 3 were at the same test support position and were altitude-separated. This aircraft coverage plan included a contingency wherein ARIA 1 would be withdrawn from MVM'73 support and relocated for Skylab coverage should the MVM'73 launch slip into the latter's operational period. Measured relative to point of closest aproach to the aircraft, launch vehicle coverage was expected to be from -200 to +250 sec, while spacecraft elemetry coverage was expected from -200 to only +40 sec, due to the spacecraft adverse antenna pattern.

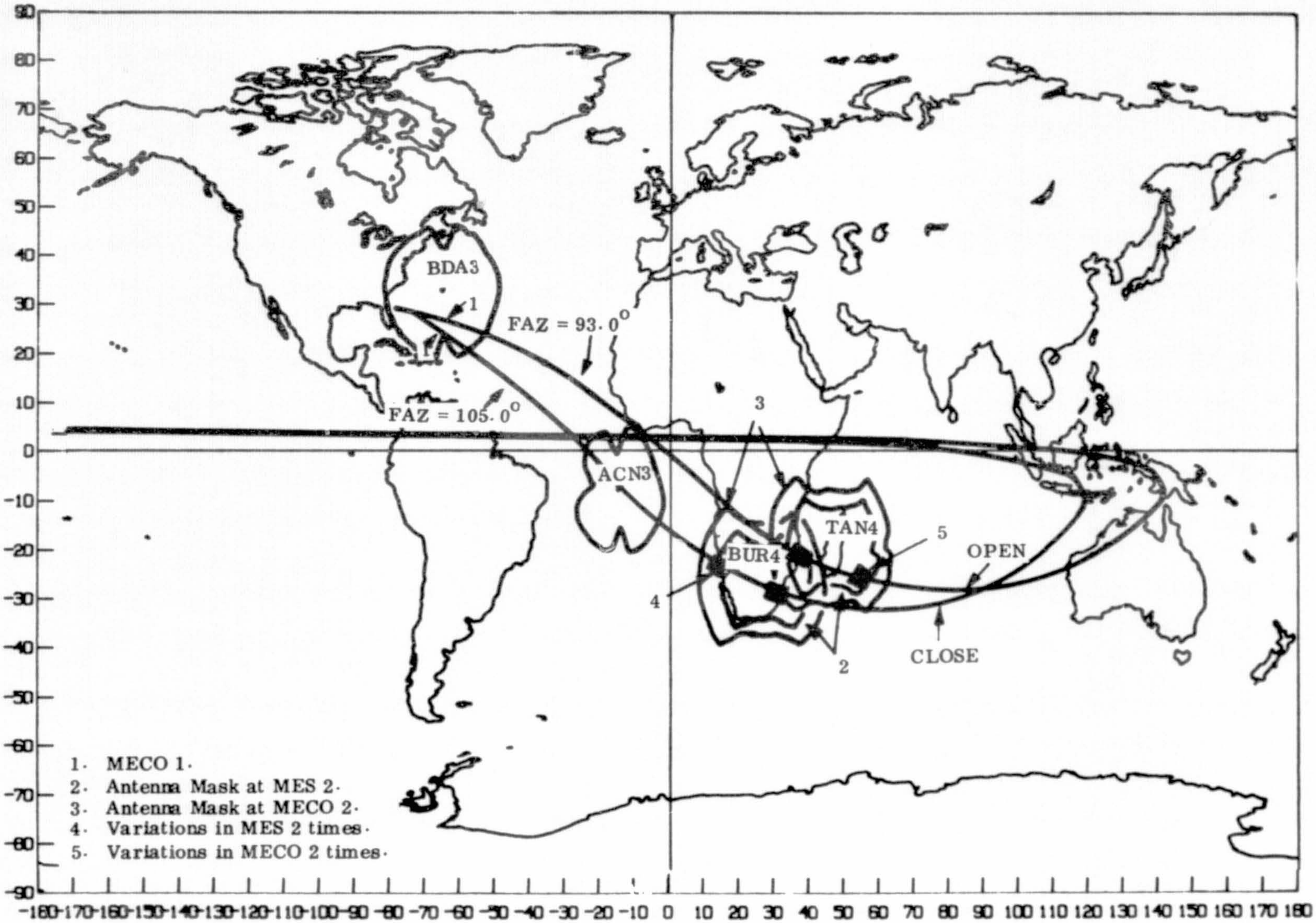


Figure 20. Composite ground tracks with DLA = 5.0, 4.0, and 3.0 deg

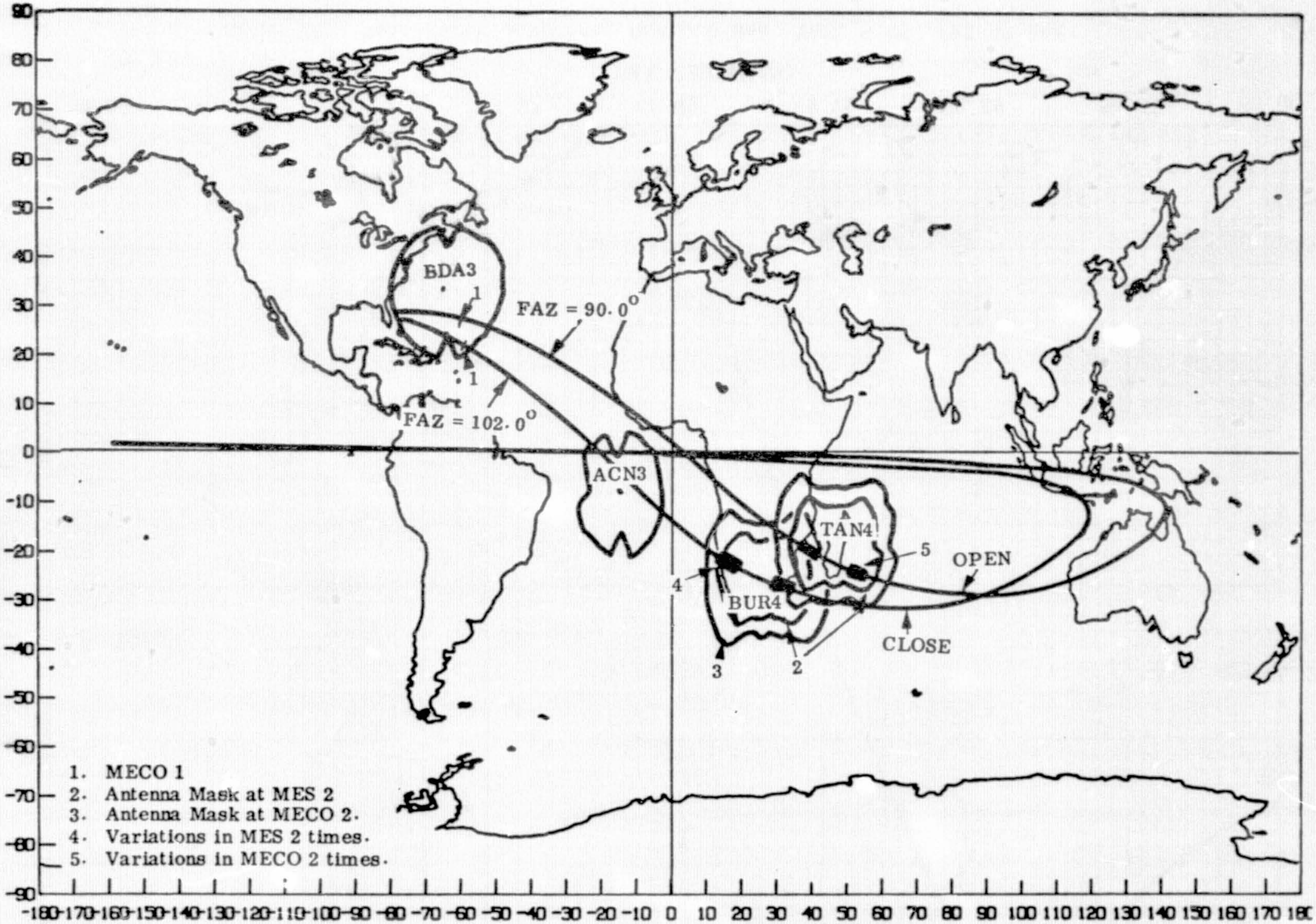


Figure 21. Composite ground tracks with DLA ranging from +2.0 to -3.0 deg

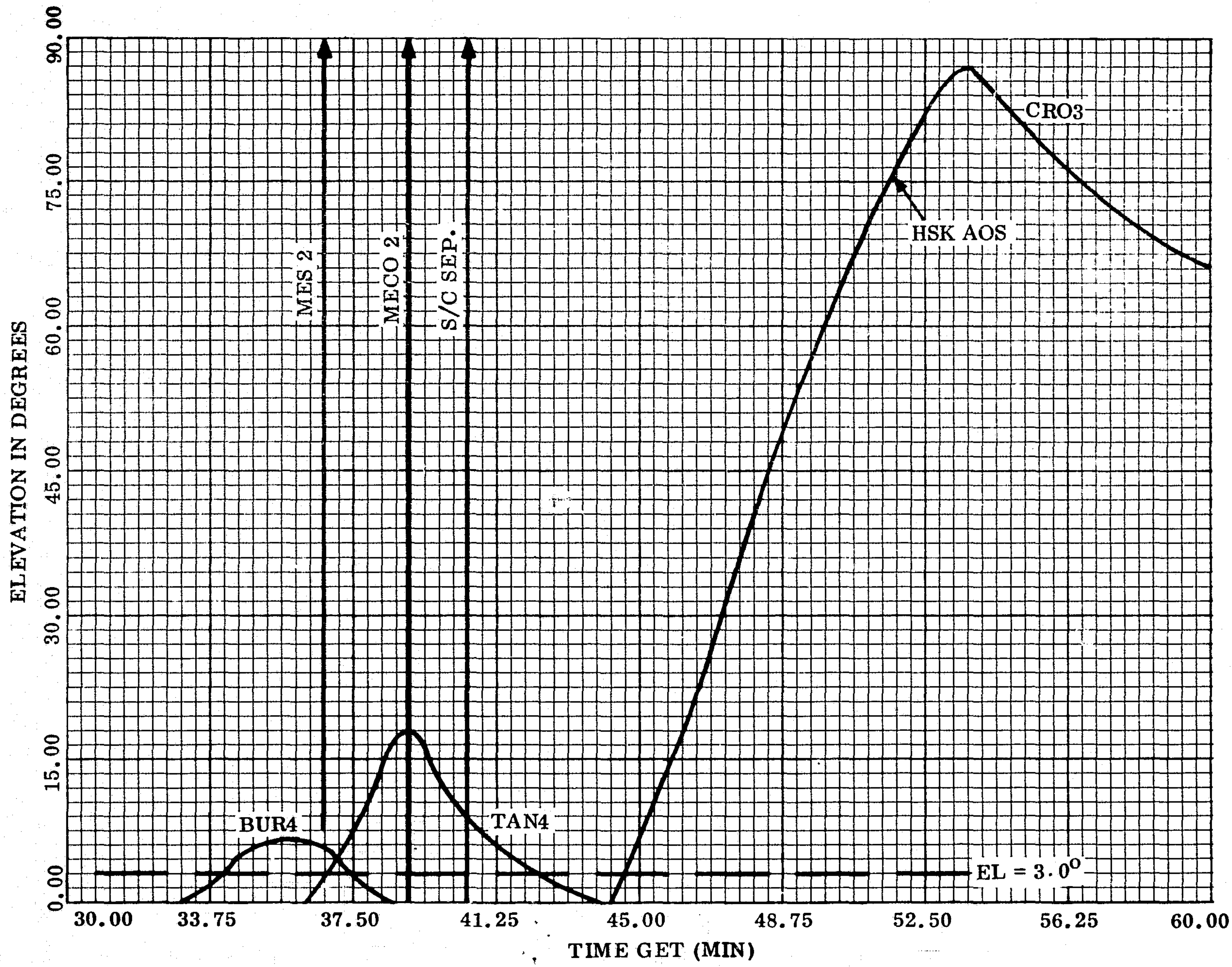


Figure 22. Near-Earth coverage, DLA 5.0 deg, TREL 5:45, FAZ 93 deg

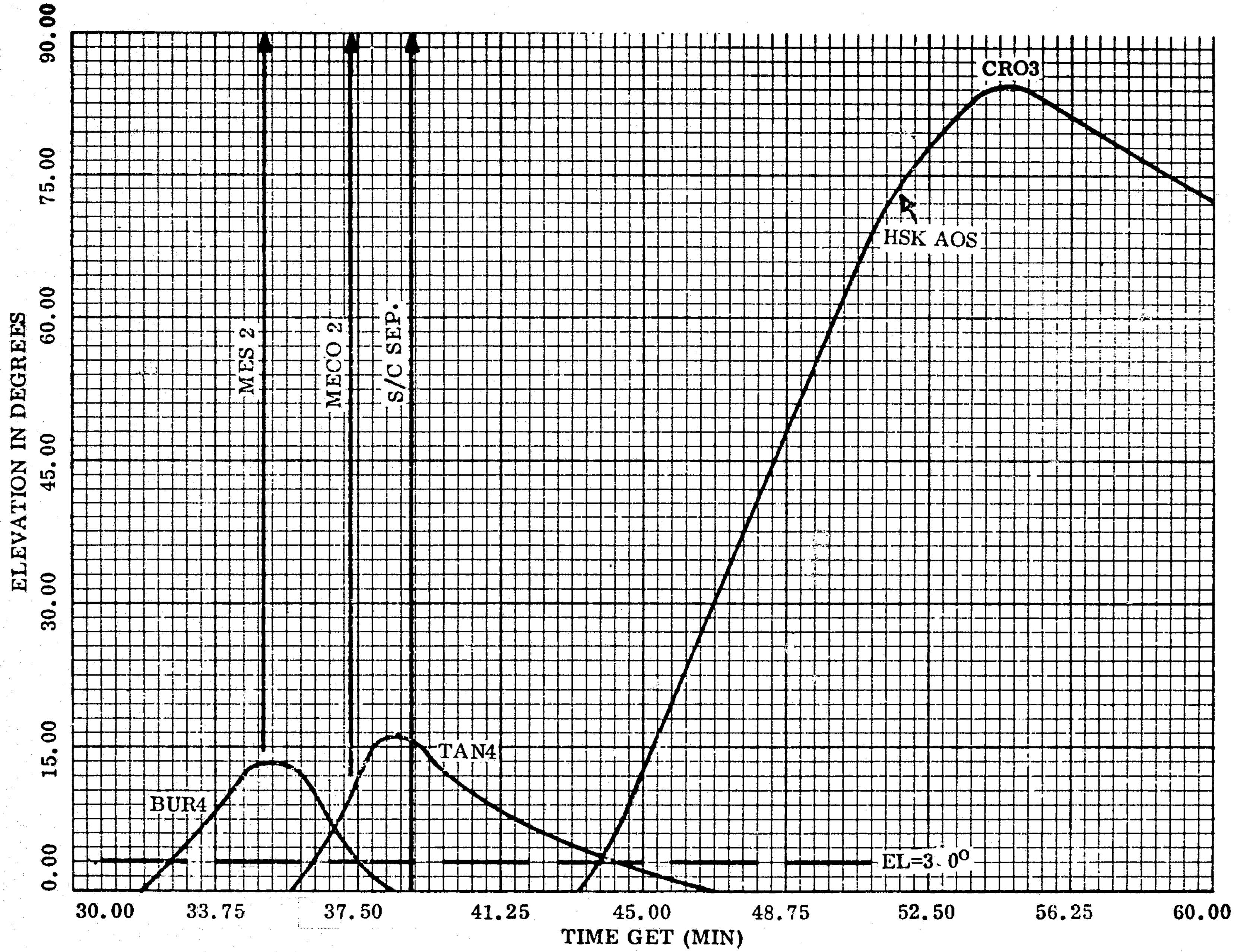


Figure 23. Near-Earth coverage, DLA 5.0 deg, TREL 6:13, FAZ 96 deg

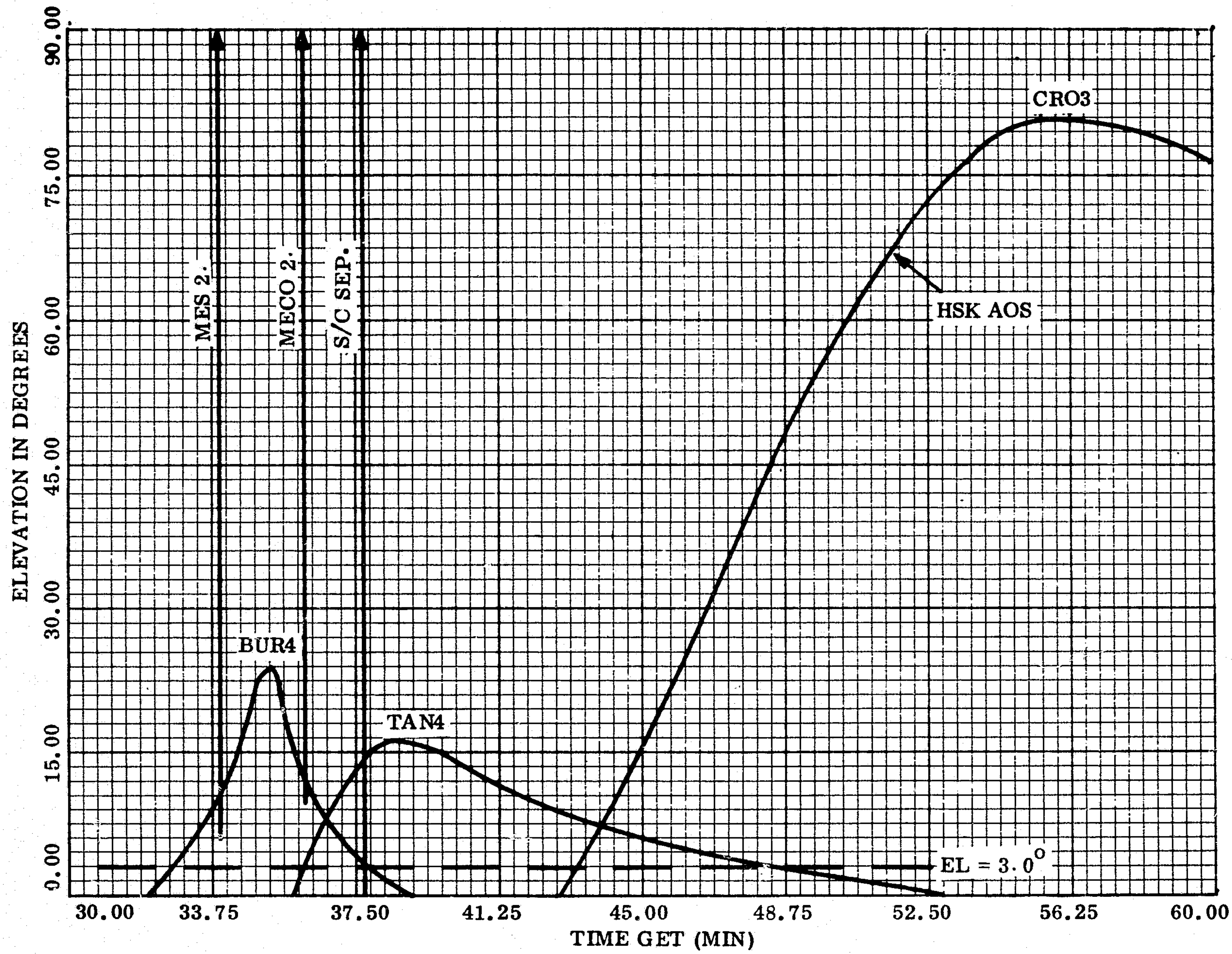


Figure 24. Near-Earth coverage, DLA 5.0 deg, TREL 6:38, FAZ 99 deg

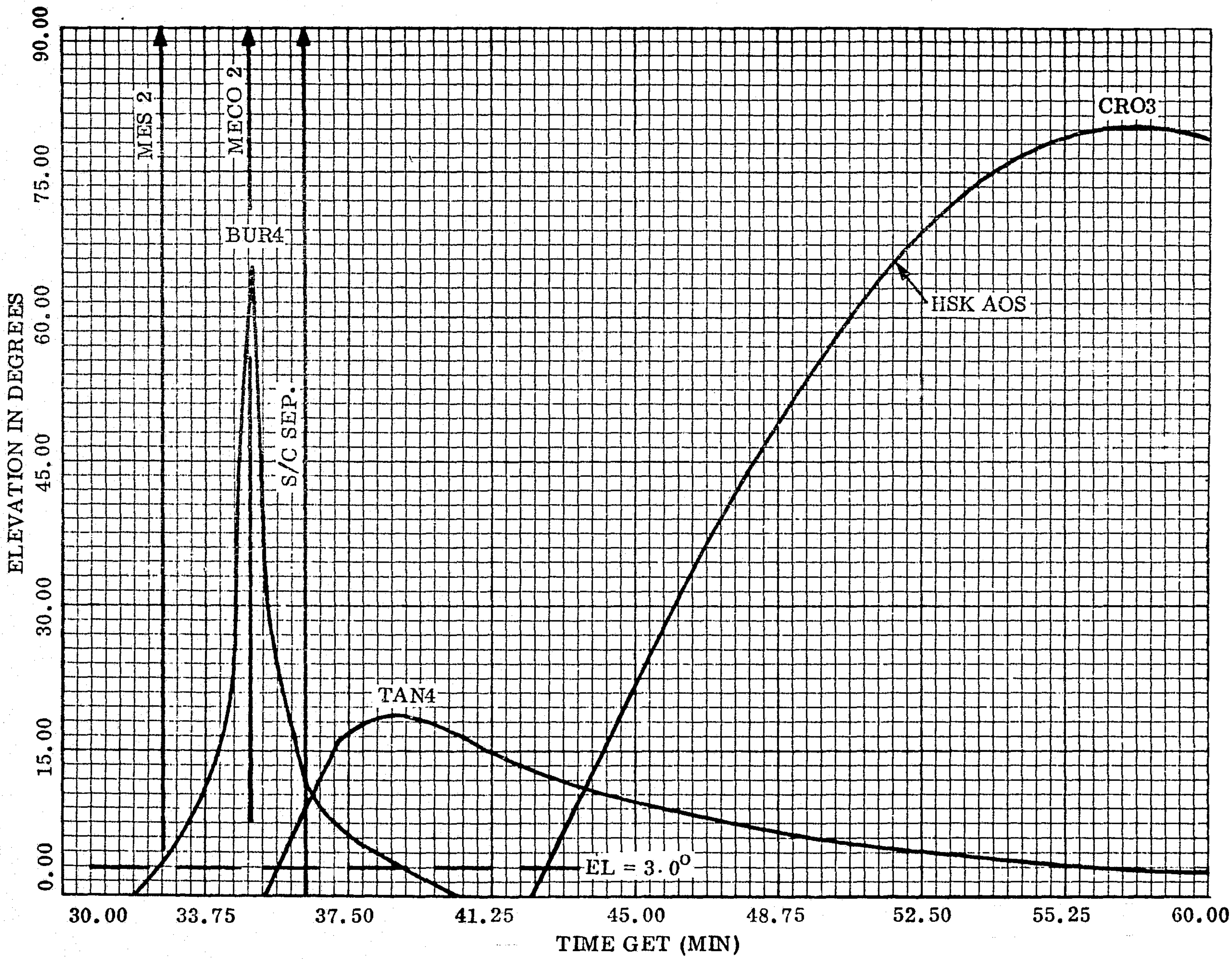


Figure 25. Near-Earth coverage, DLA 5.0 deg, TREL 7:02, FAZ 102 deg

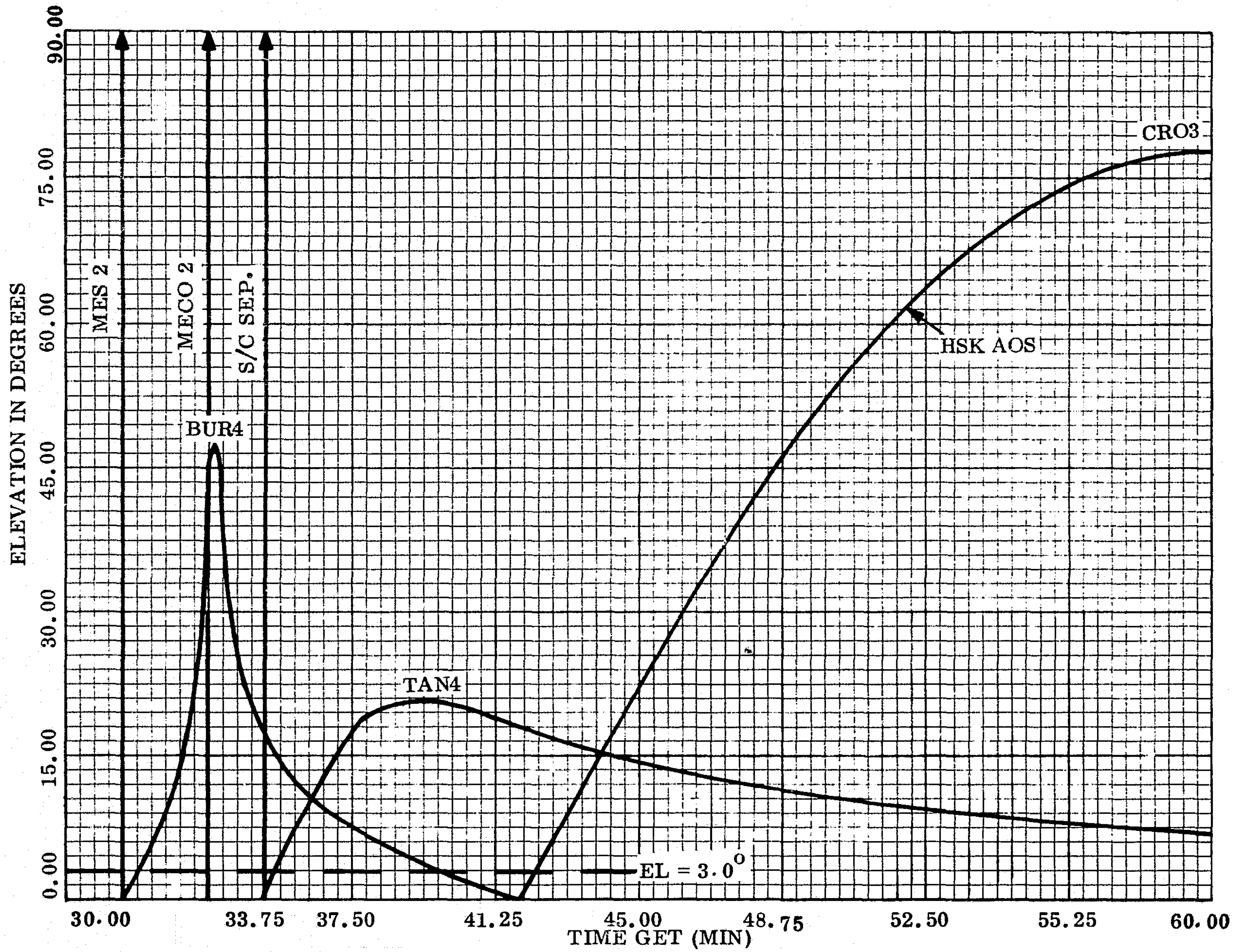


Figure 26. Near-Earth coverage, DLA 5.0 deg, TREL 7:25, FAZ 105 deg

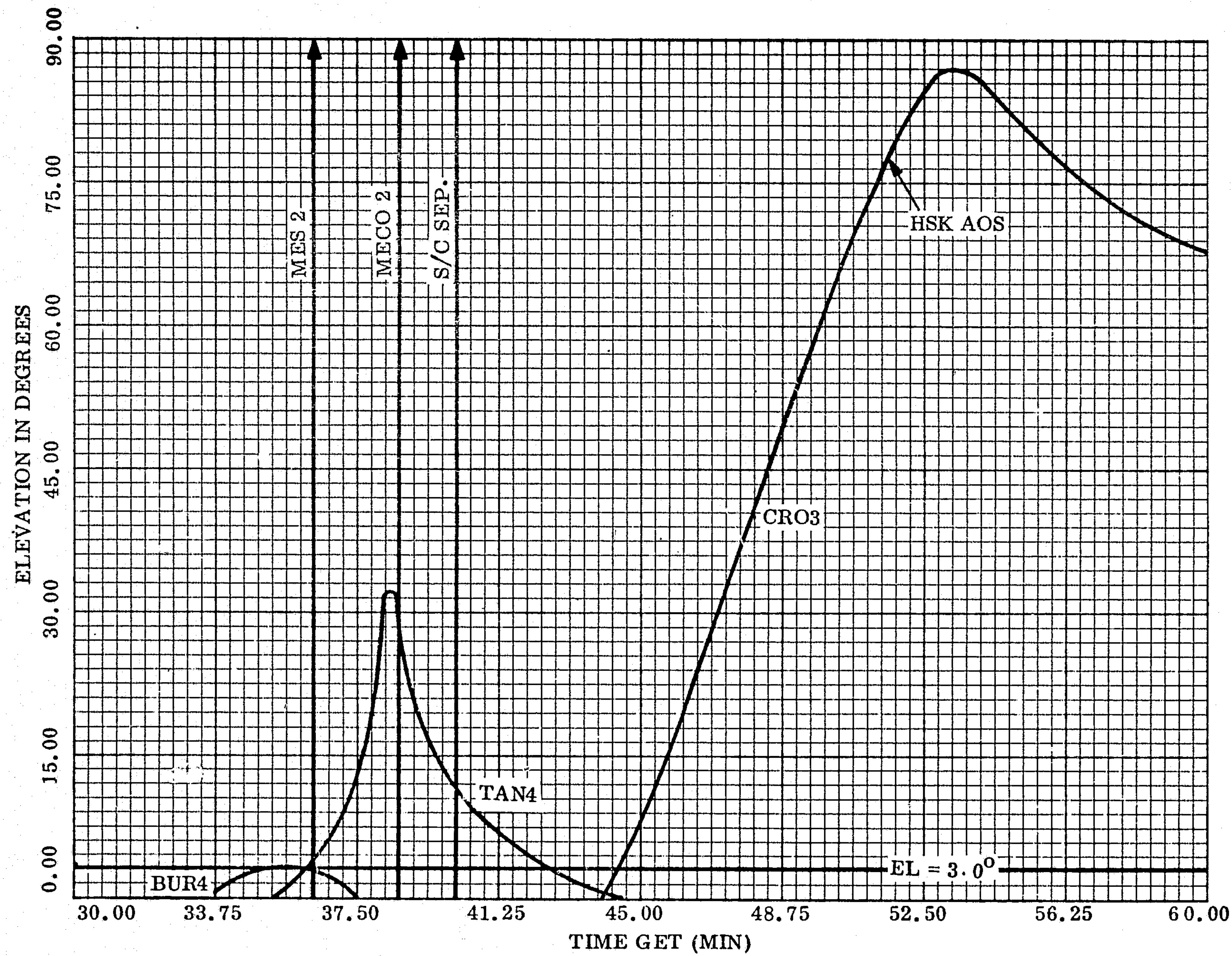


Figure 27. Near-Earth coverage, DLA 2.0 deg, TREL 5:45, FAZ 90 deg

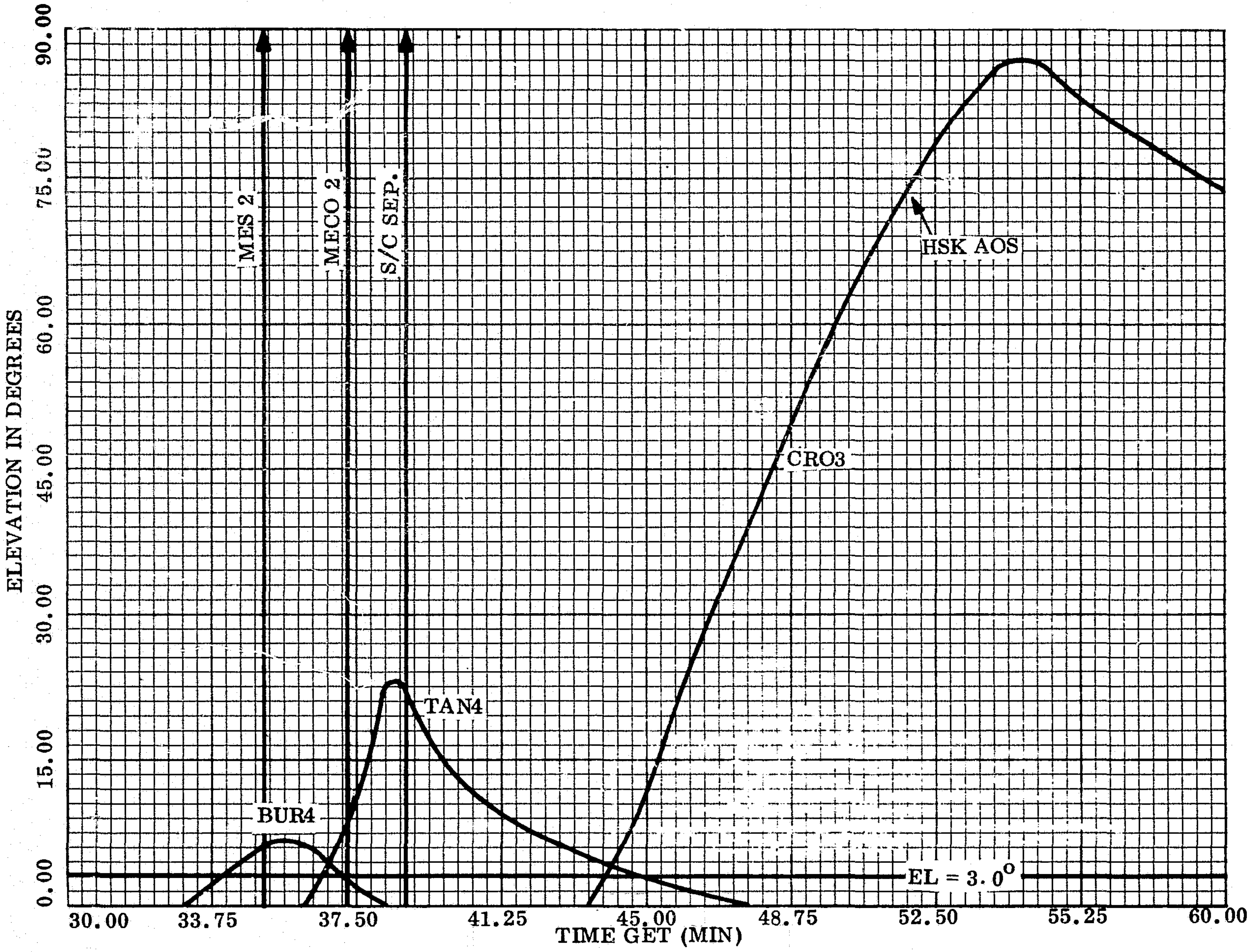


Figure 28. Near-Earth coverage, DLA 2.0 deg, TREL 6:10, FAZ 93 deg

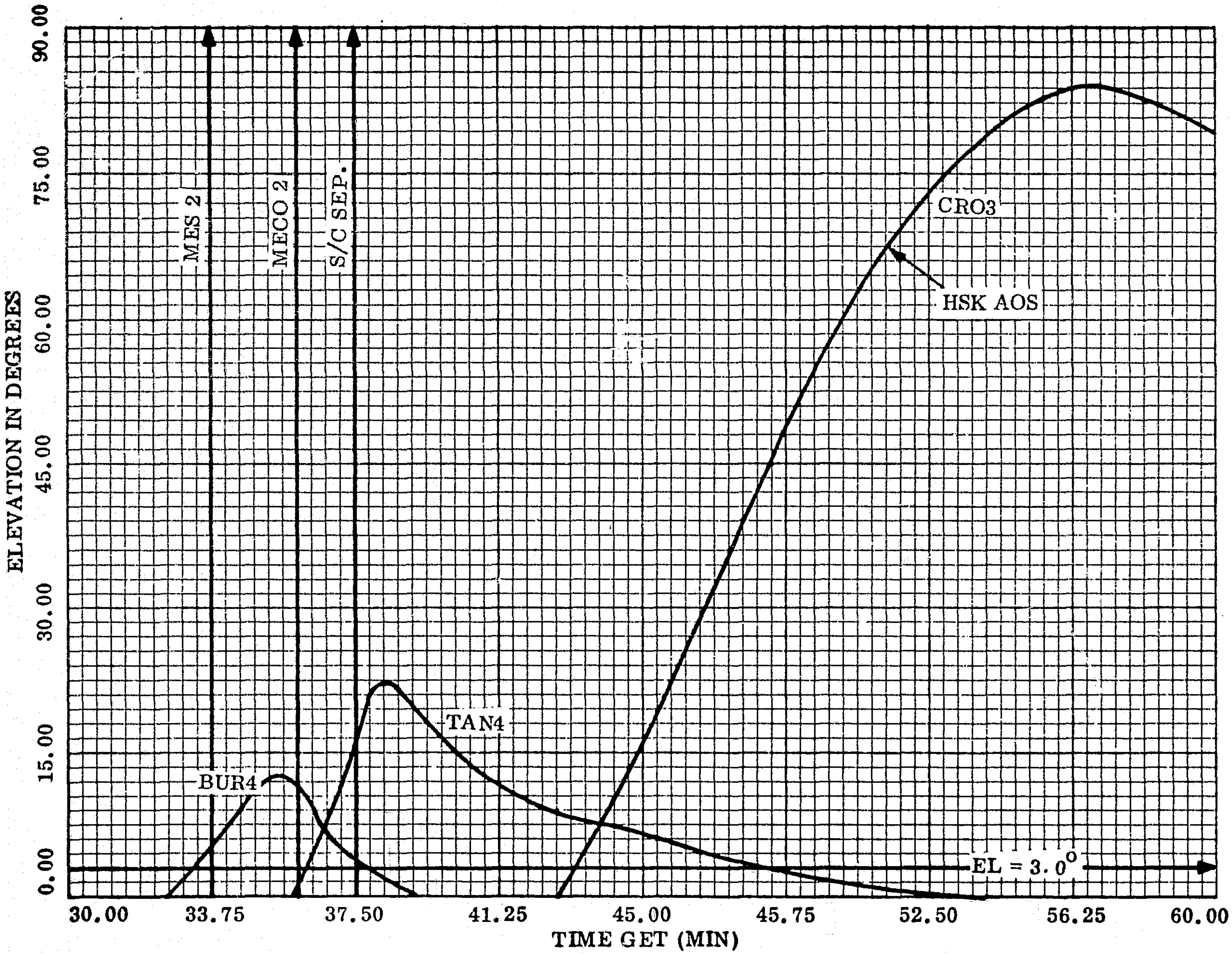


Figure 29. Near-Earth coverage, DLA 2.0 deg, TREL 6:35, FAZ 96 deg

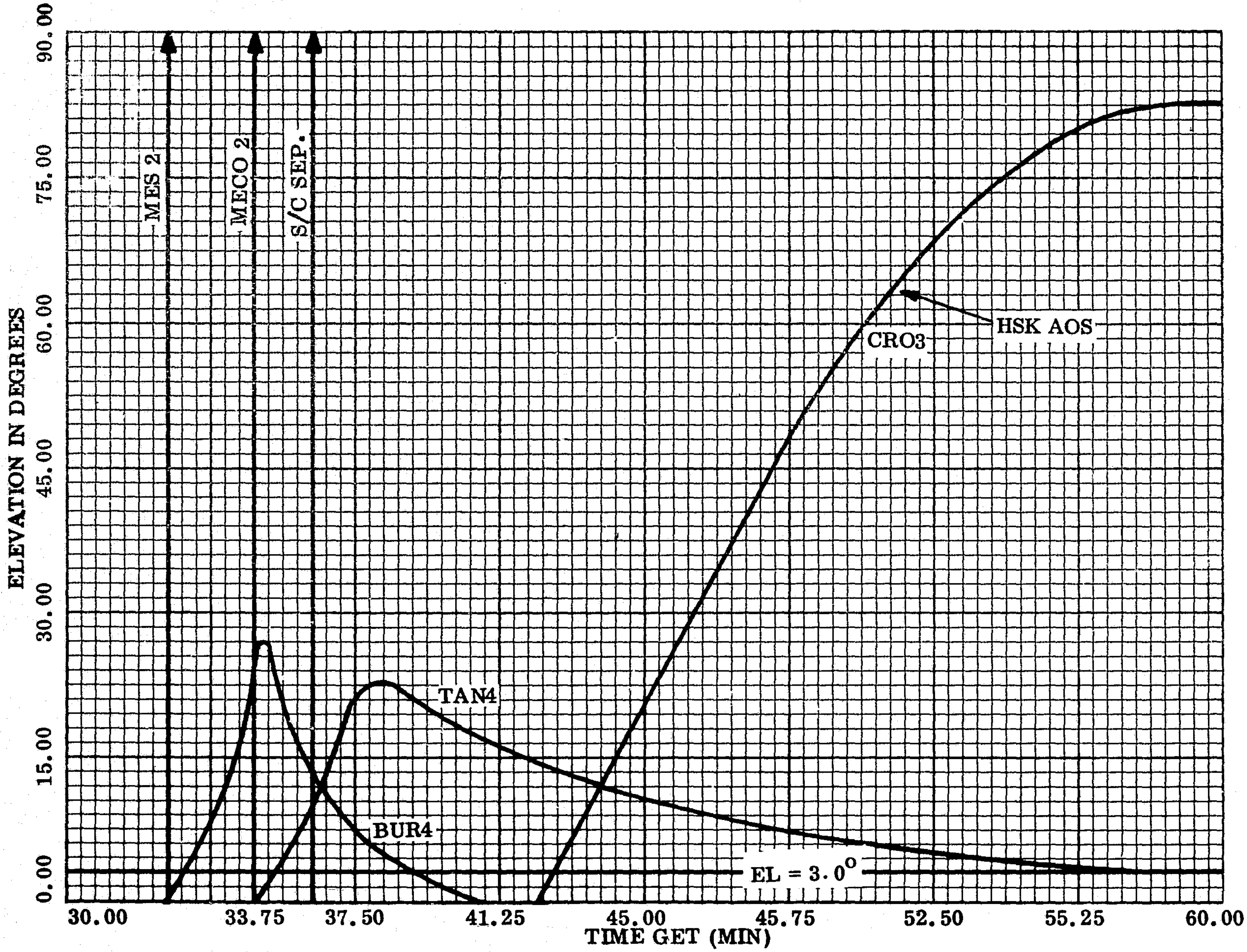


Figure 30. Near-Earth coverage, DLA 2.0 deg, TREL 6:59, FAZ 99 deg

33-797

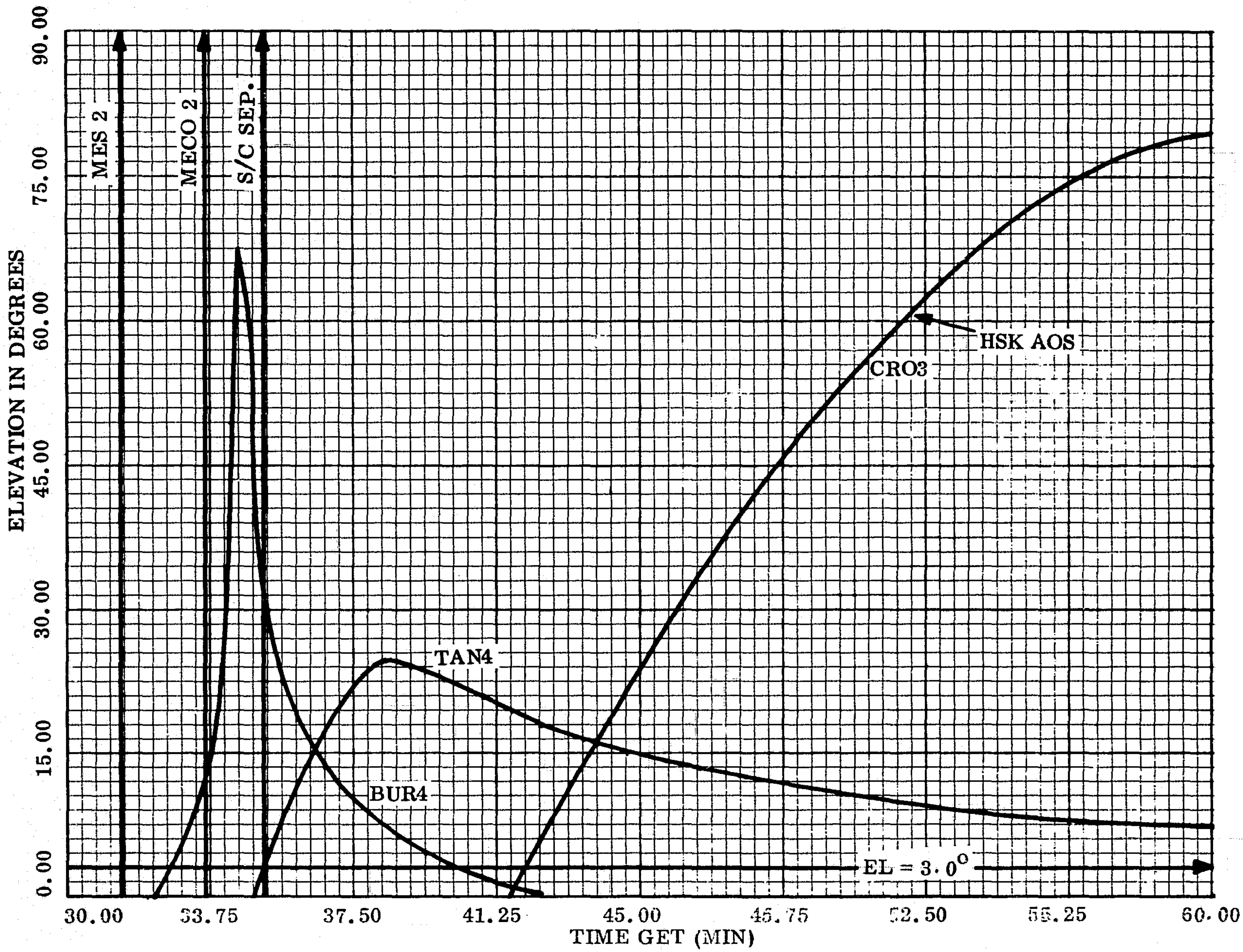


Figure 31. Near-Earth coverage, DLA 2.0 deg, TREL 7:23, FAZ 102 deg

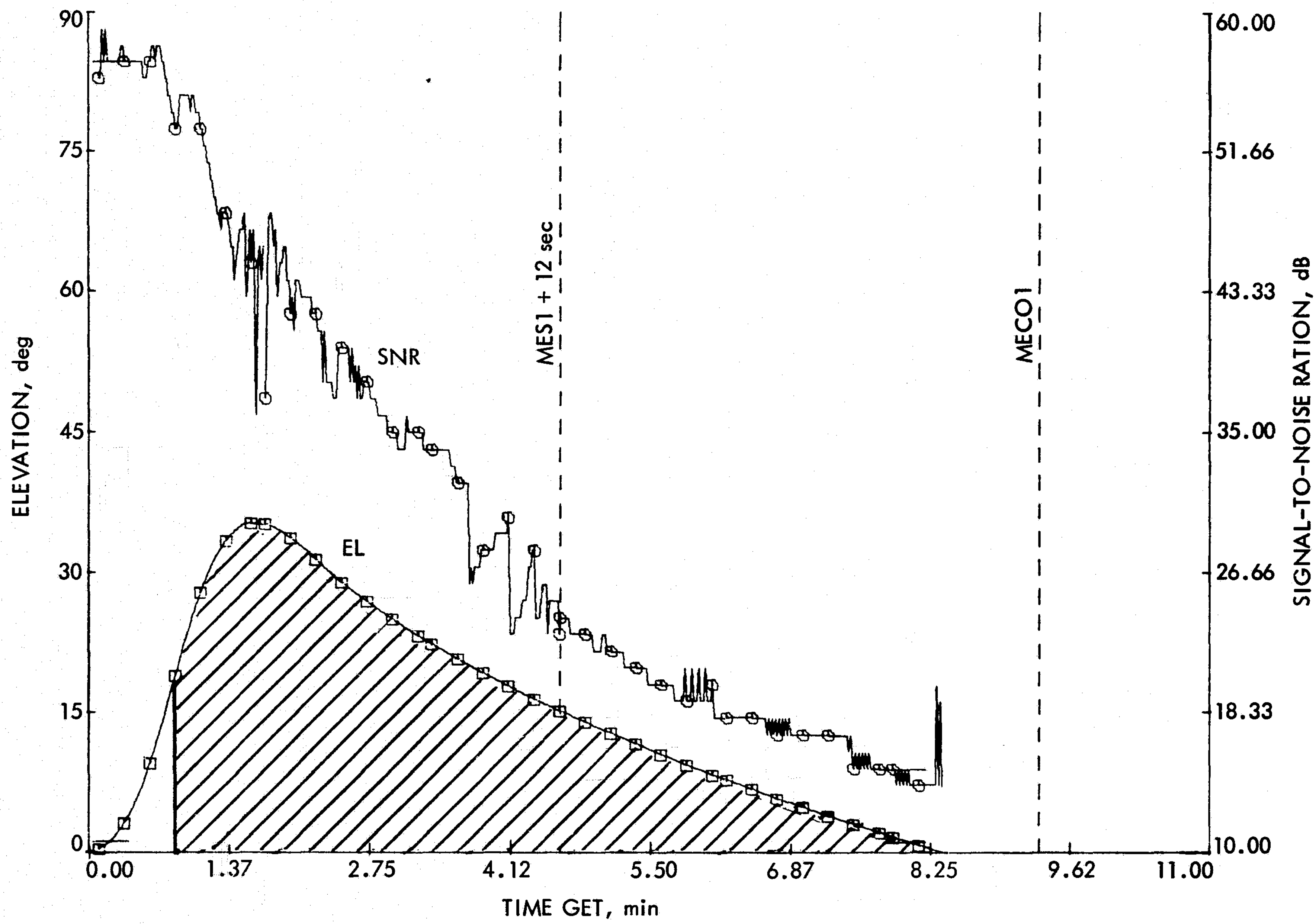


Figure 32. Near-Earth signal levels, MIL 3, FAZ 93 deg, L/V 2202.5 MHz, SNR vs EL

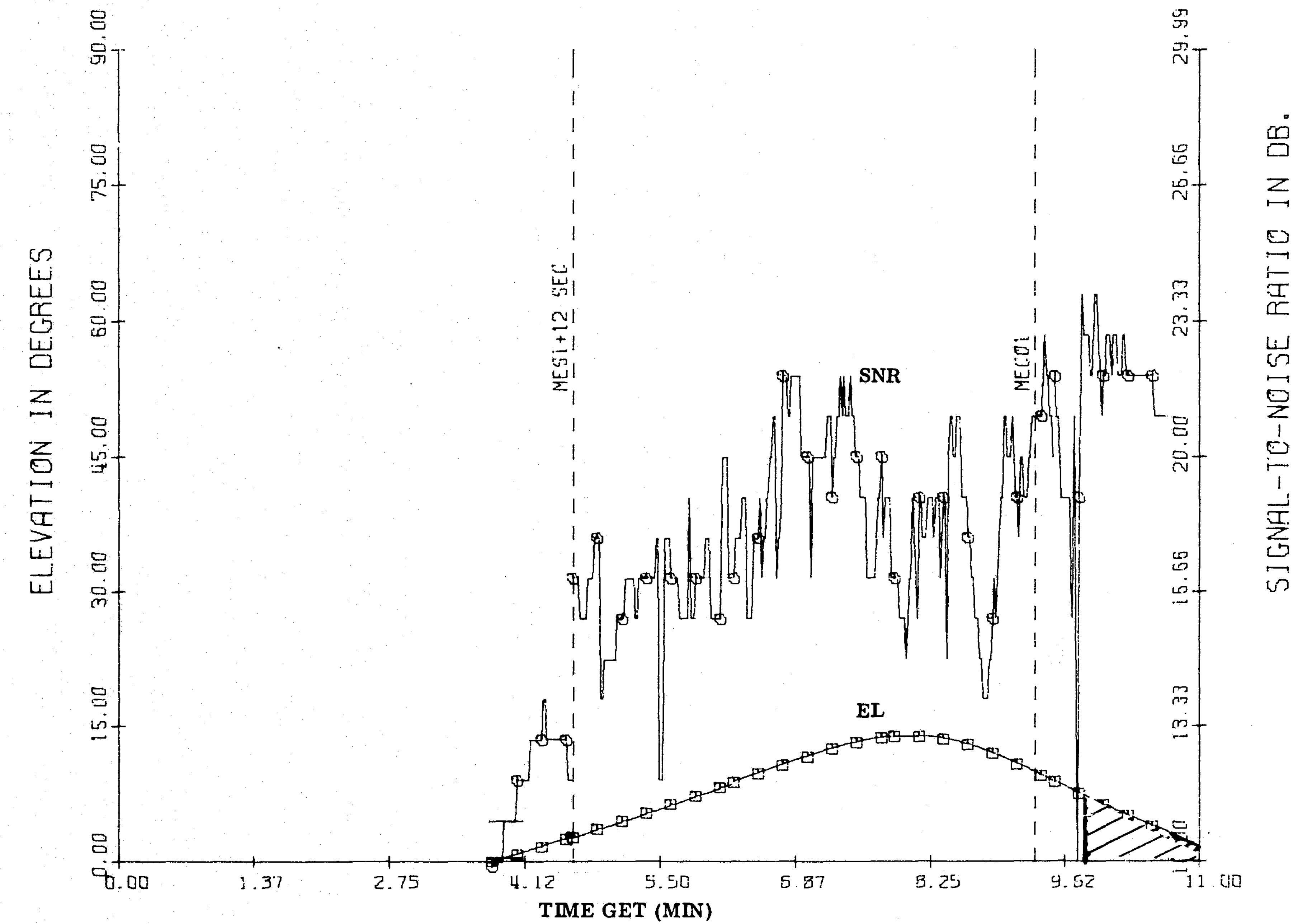


Figure 33. Near-Earth signal levels, BDA 3, FAZ 93 deg, L/V 2202.5 MHz, SNR vs EL

33-797

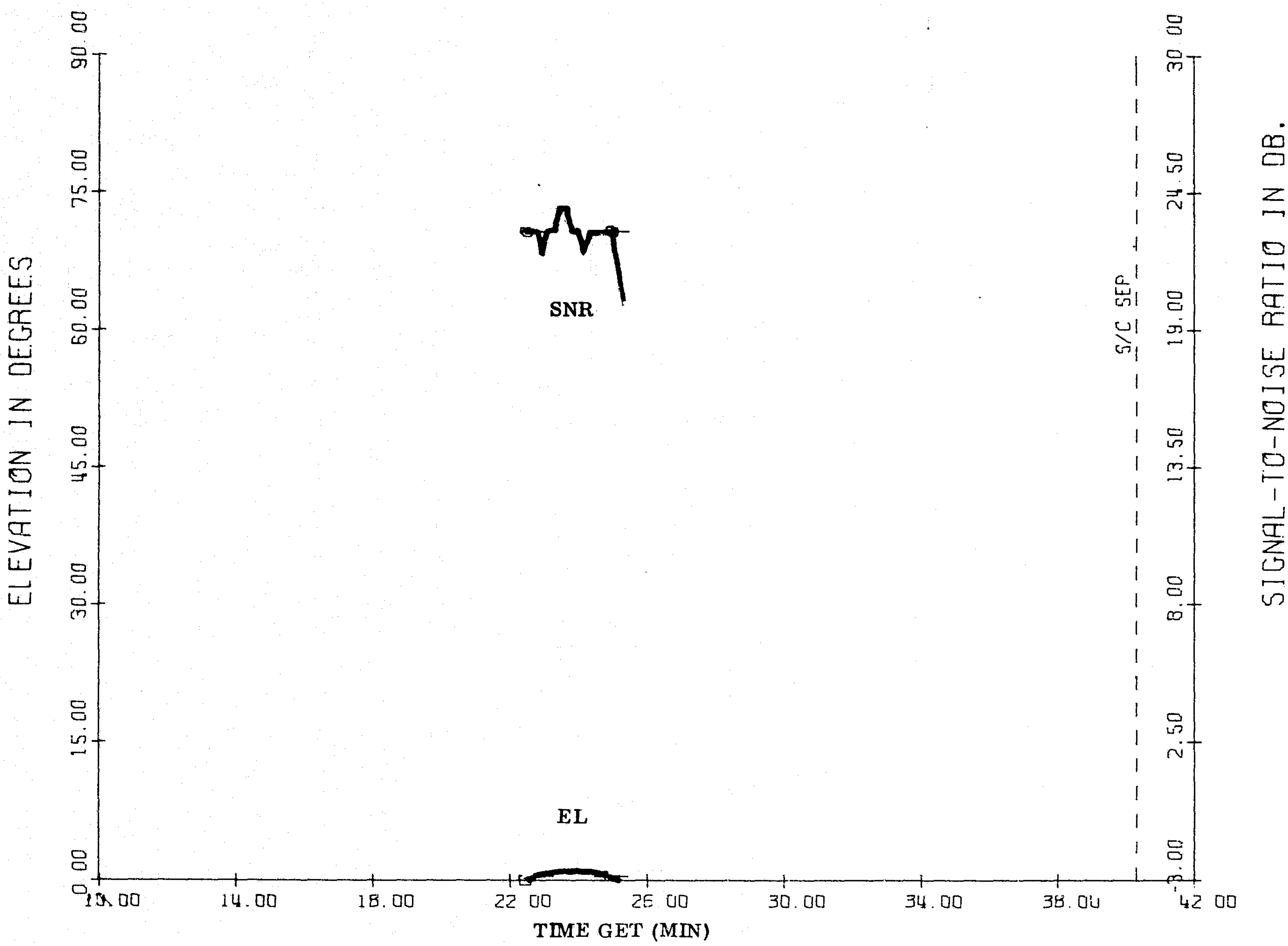


Figure 34. Near-Earth signal levels, ACN 3, FAZ 93 deg, L/V 2202.5 MHz, SNR vs EL

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C-2

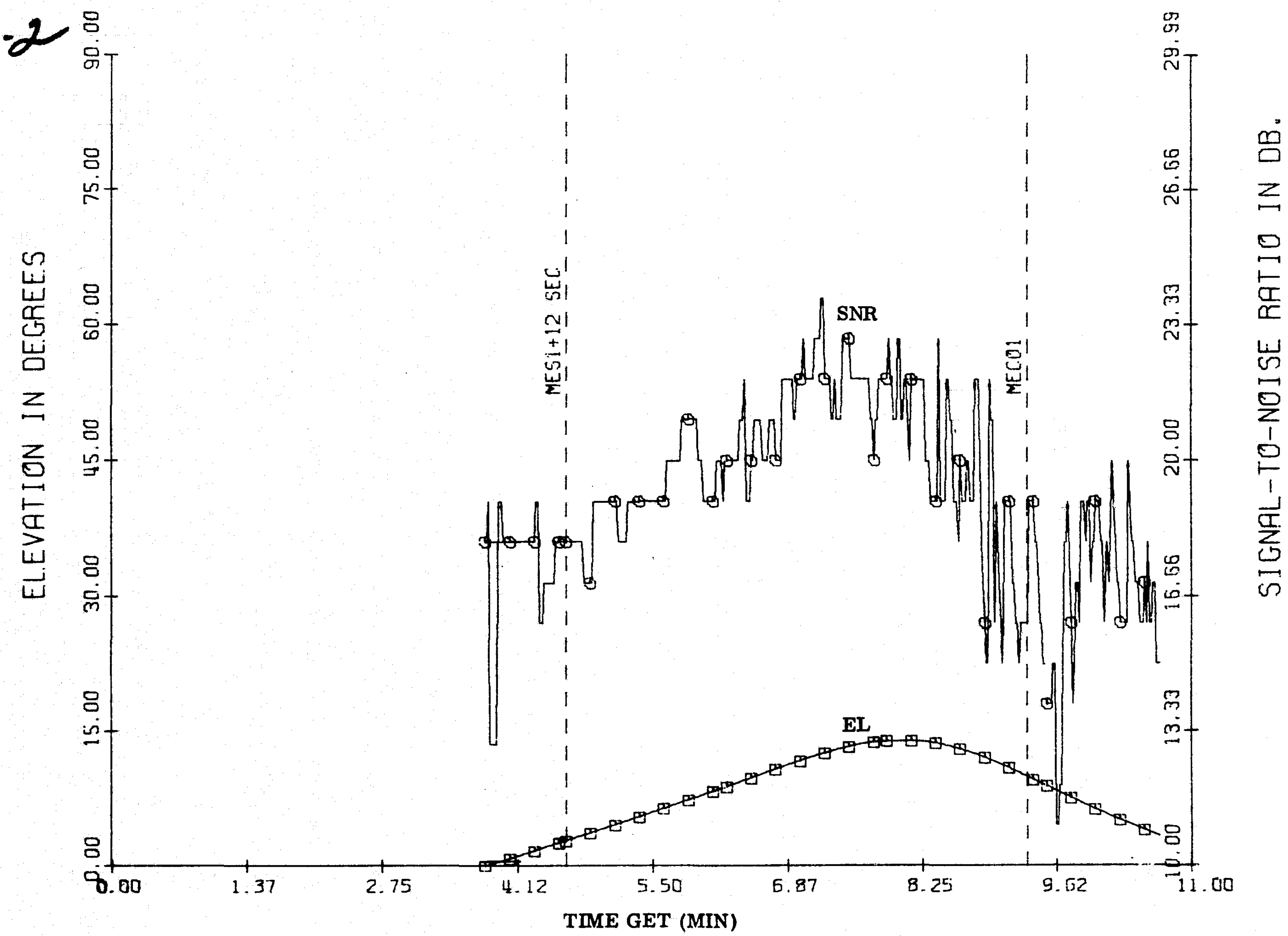


Figure 35. Near-Earth signal levels, BDAQ, FAZ 93 deg, L/V 5765 MHz, SNR vs EL

33-797

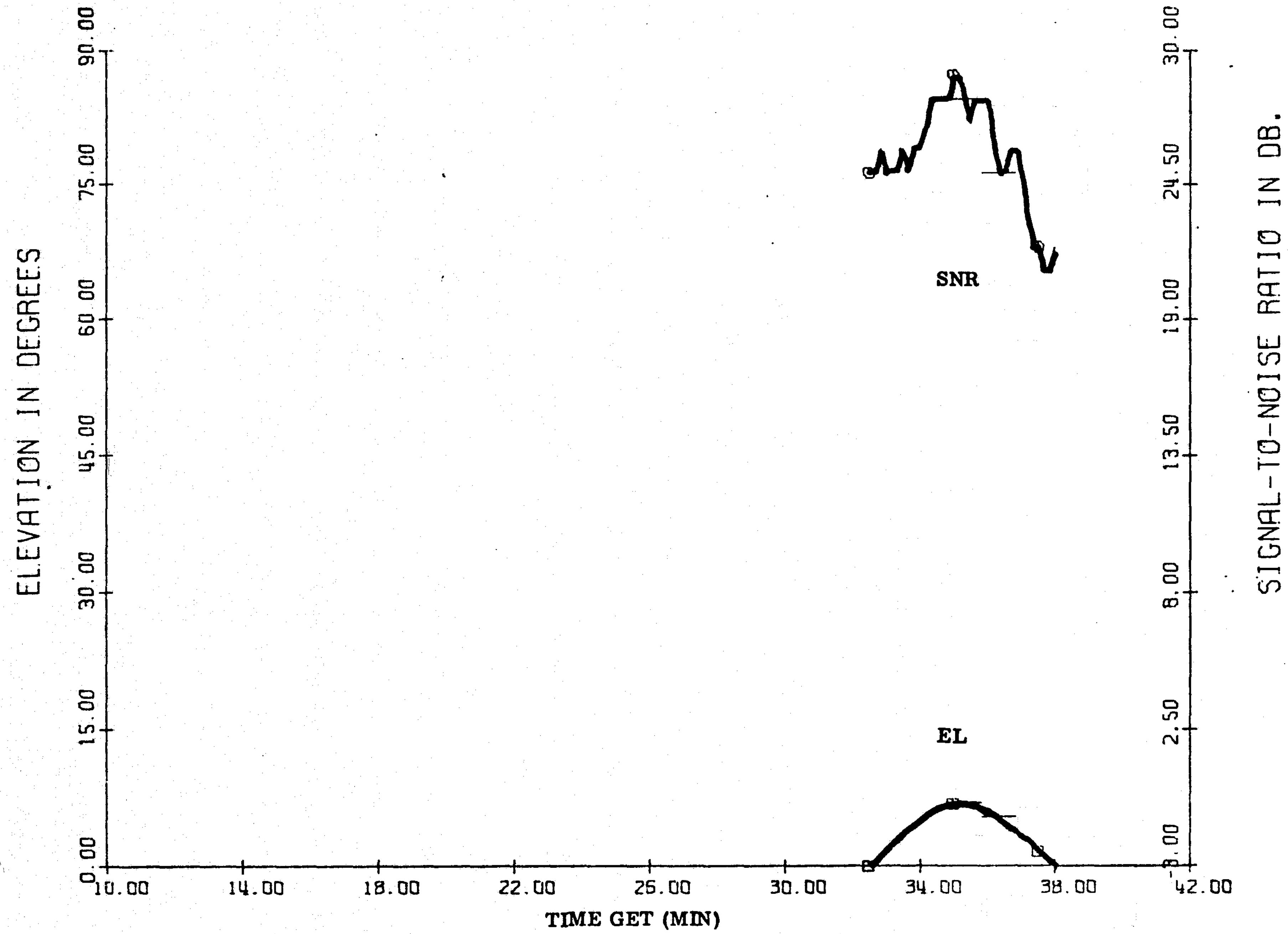


Figure 36. Near-Earth signal levels, BUR 4, TREL 5:48, DLA 5.0 deg, F
AZ 93.0 deg, L/V 2202.5 MHz, SNR vs EL

33-797

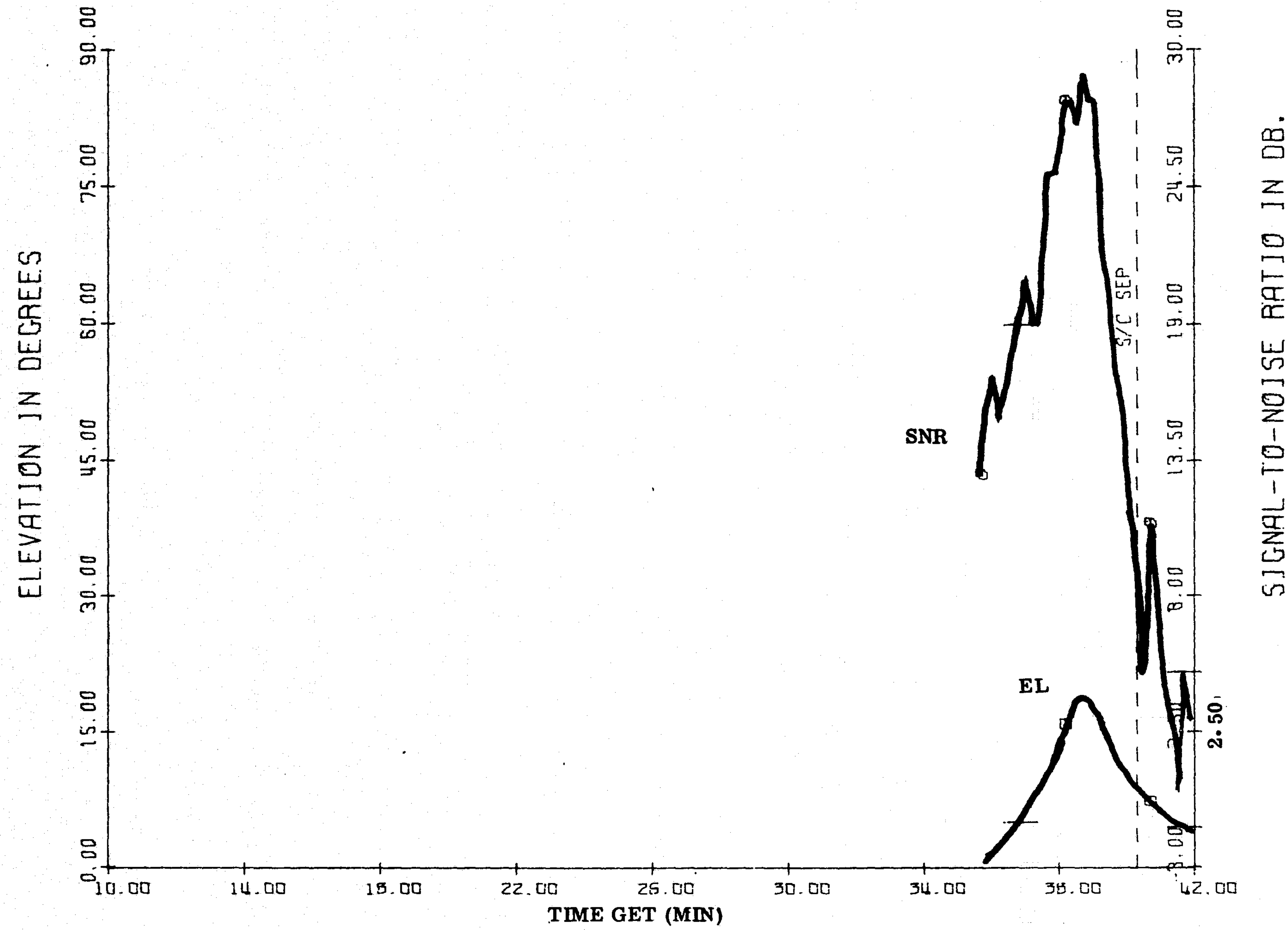


Figure 37. Near-Earth signal levels, TAN 4, TREL 5:48, DLA 5.0 deg, FAZ 93 deg, L/V 2202.5 MHz, SNR vs EL

33-797

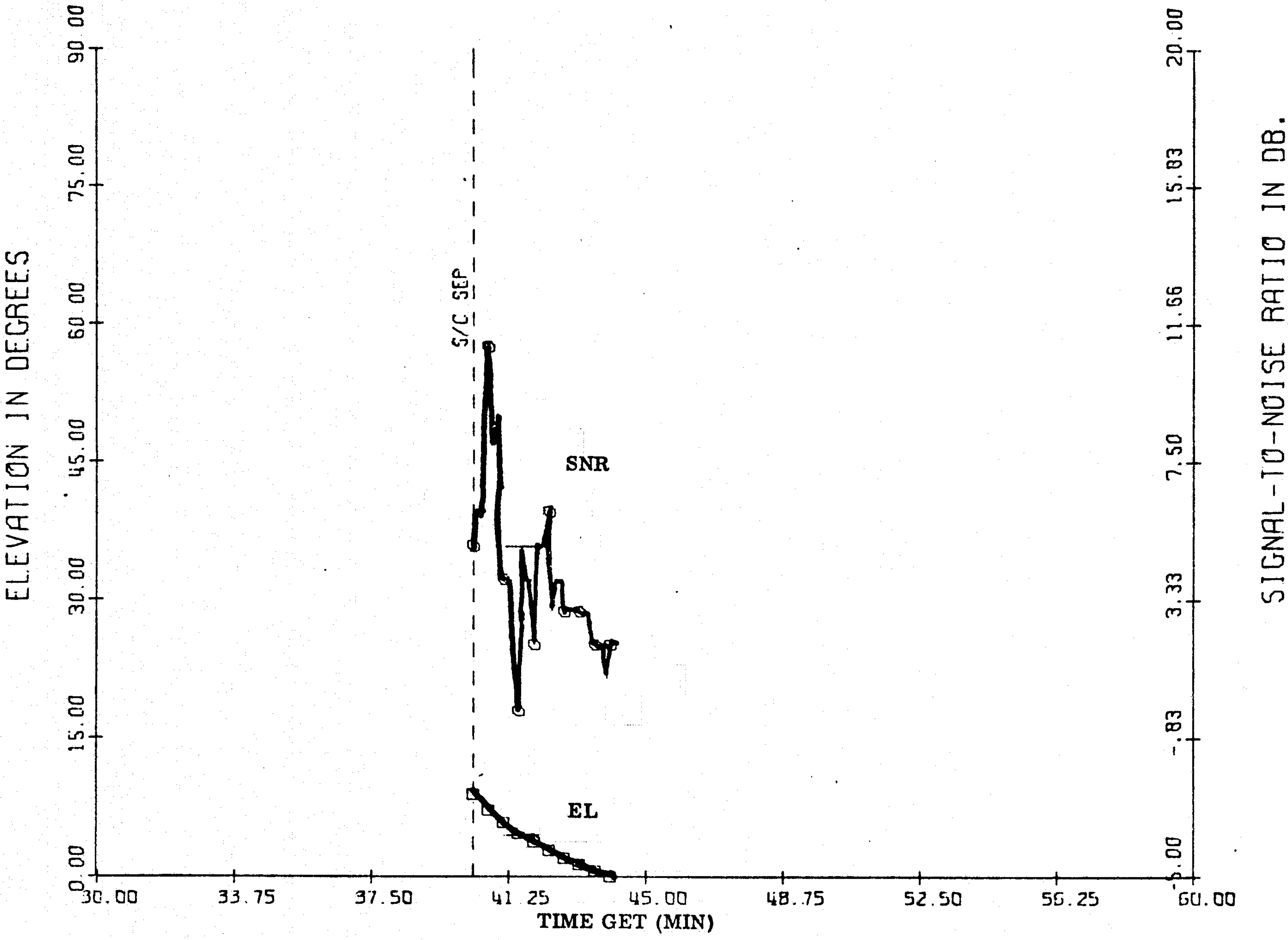


Figure 38. Near-Earth signal levels, TAN 4, TREL 5:48, DLA 5.0 deg, FAZ 93 deg, L/V 2202.5 MHz, SNR vs EL

33-797

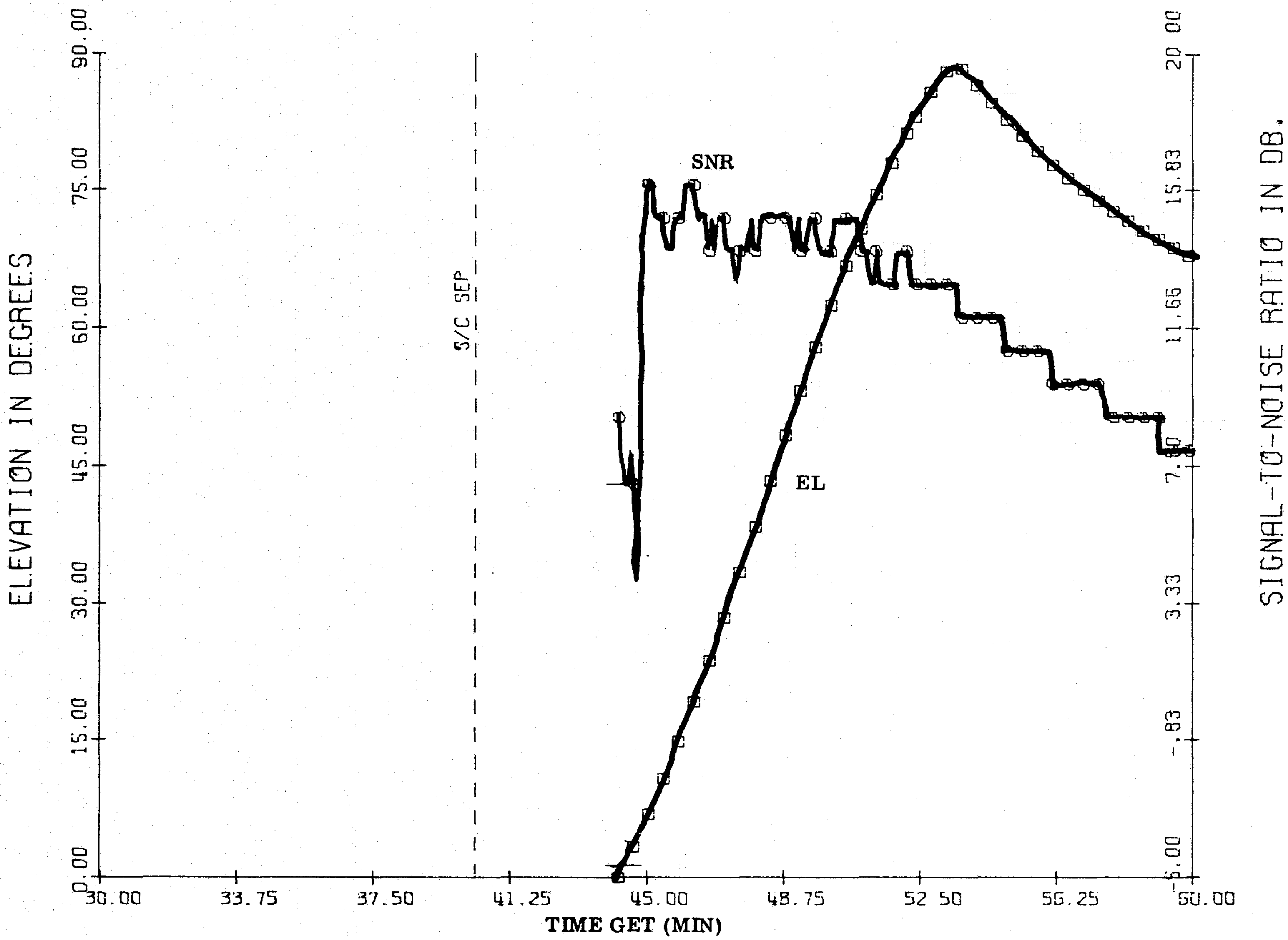


Figure 39. Near-Earth signal levels, CRO 3, TREL 5:48, DLA 5.0 deg, FAZ 93 deg, L/V 2202.5 MHz, SNR vs EL

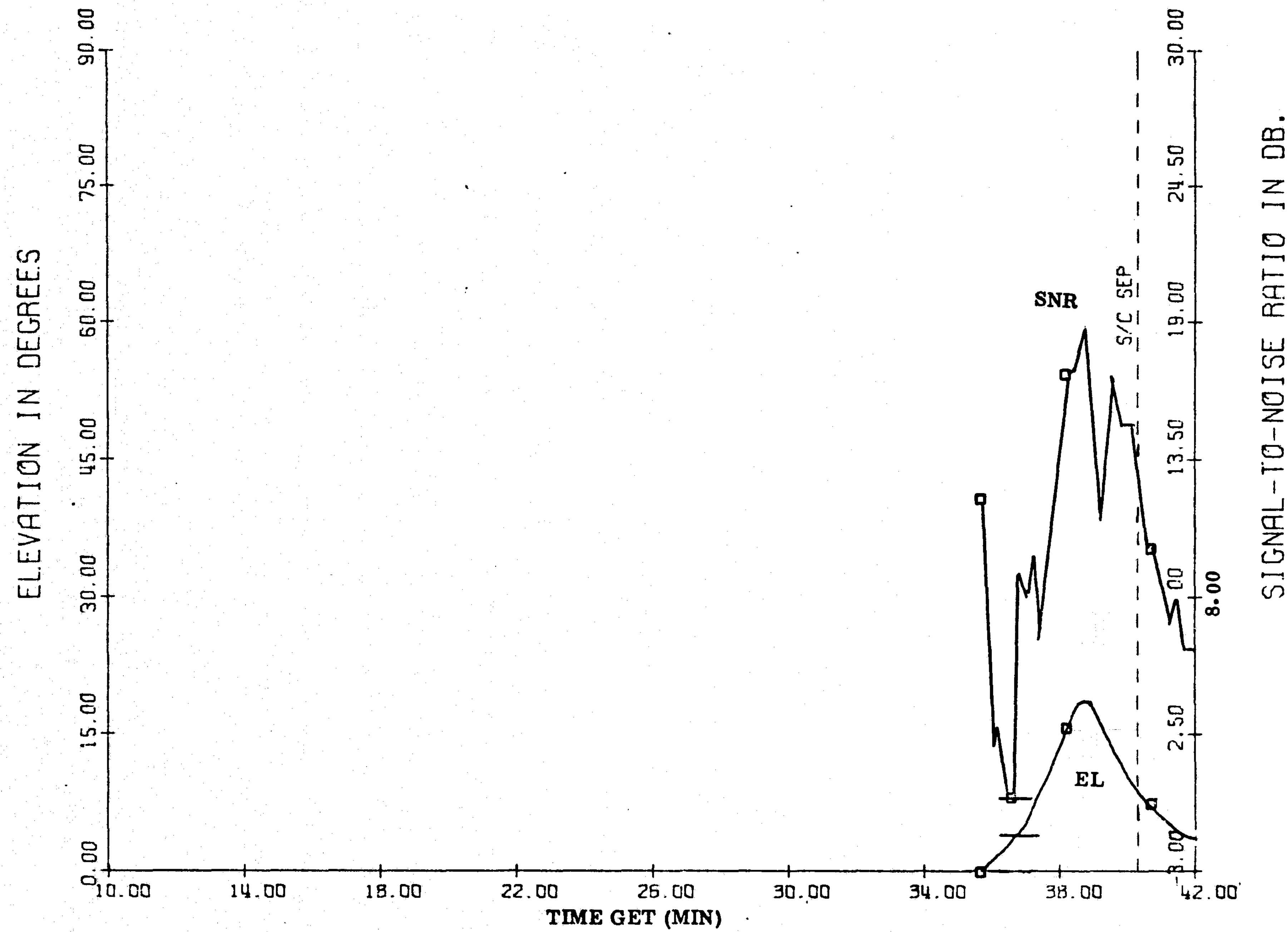


Figure 40. Near-Earth signal levels, TANF, TREL 5:48, DLA 5.0 deg, FAZ 93 deg, L/V 5765 MHz, SNR vs EL

33-797

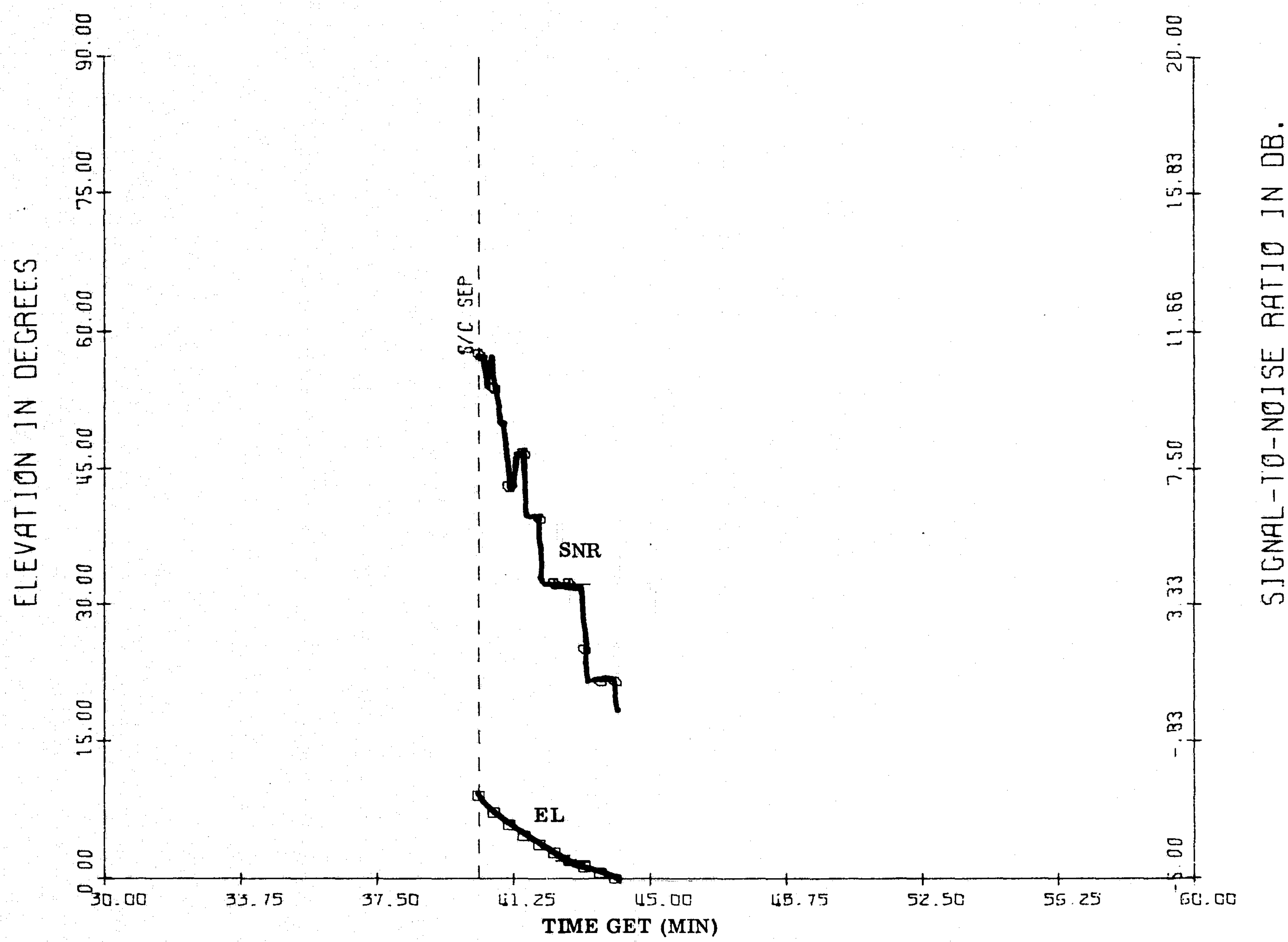


Figure 41. Near-Earth signal levels, TREL, 5:48, DLA 5.0 deg, FAZ 93 deg, L/V 5765 MHz, SNR vs EL

33-797

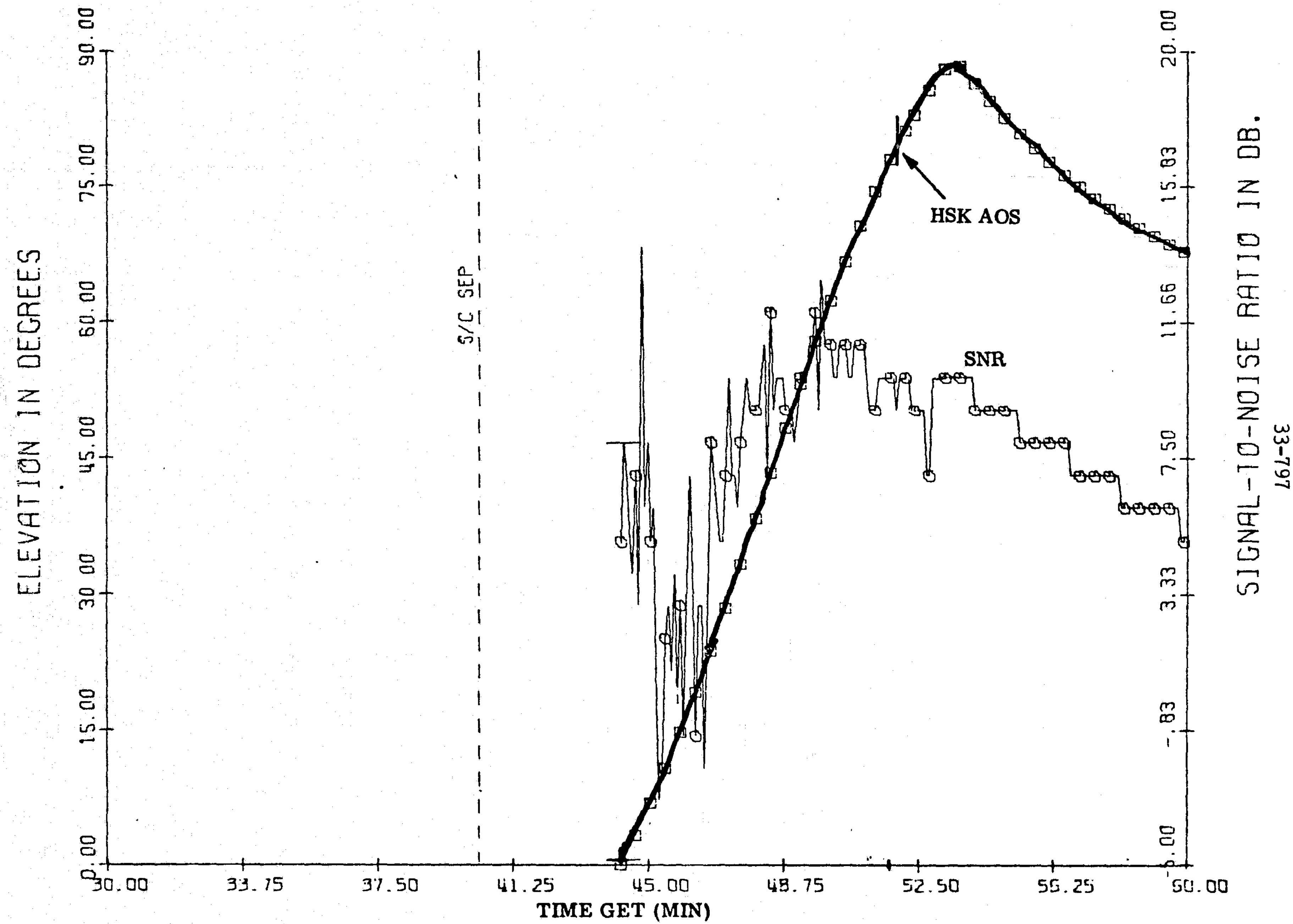


Figure 42. Near-Earth signal levels, CROQ, TREL 5:48, DLA 5.0 deg, FAZ 93 deg, L/V 5765 MHz, SNR vs EL

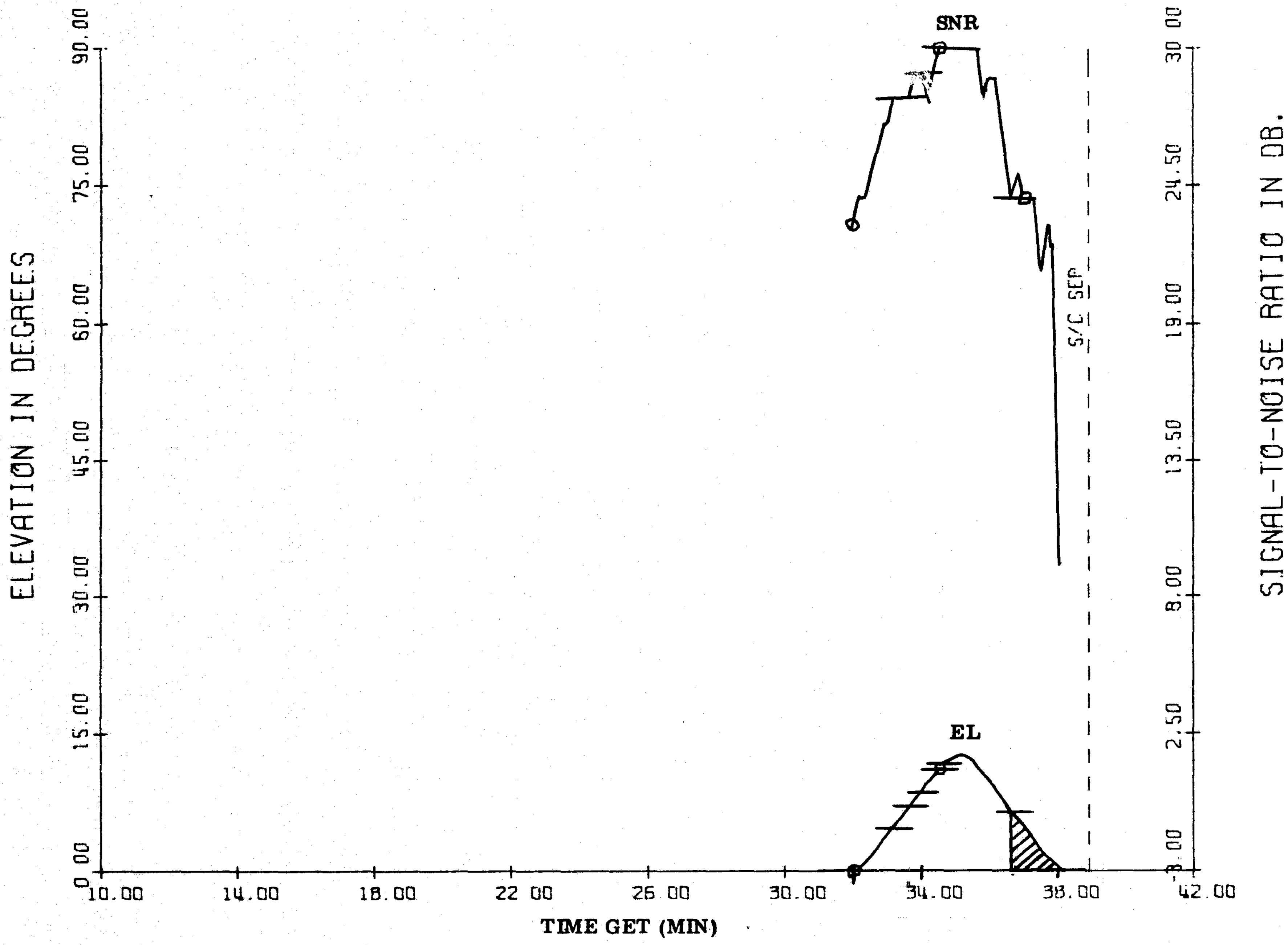


Figure 43. Near-Earth signal levels, BUR 4, TREL 6:13, DLA 5.0 deg, FAZ 93 deg, L/V 2202.5 MHz, SNR vs EL

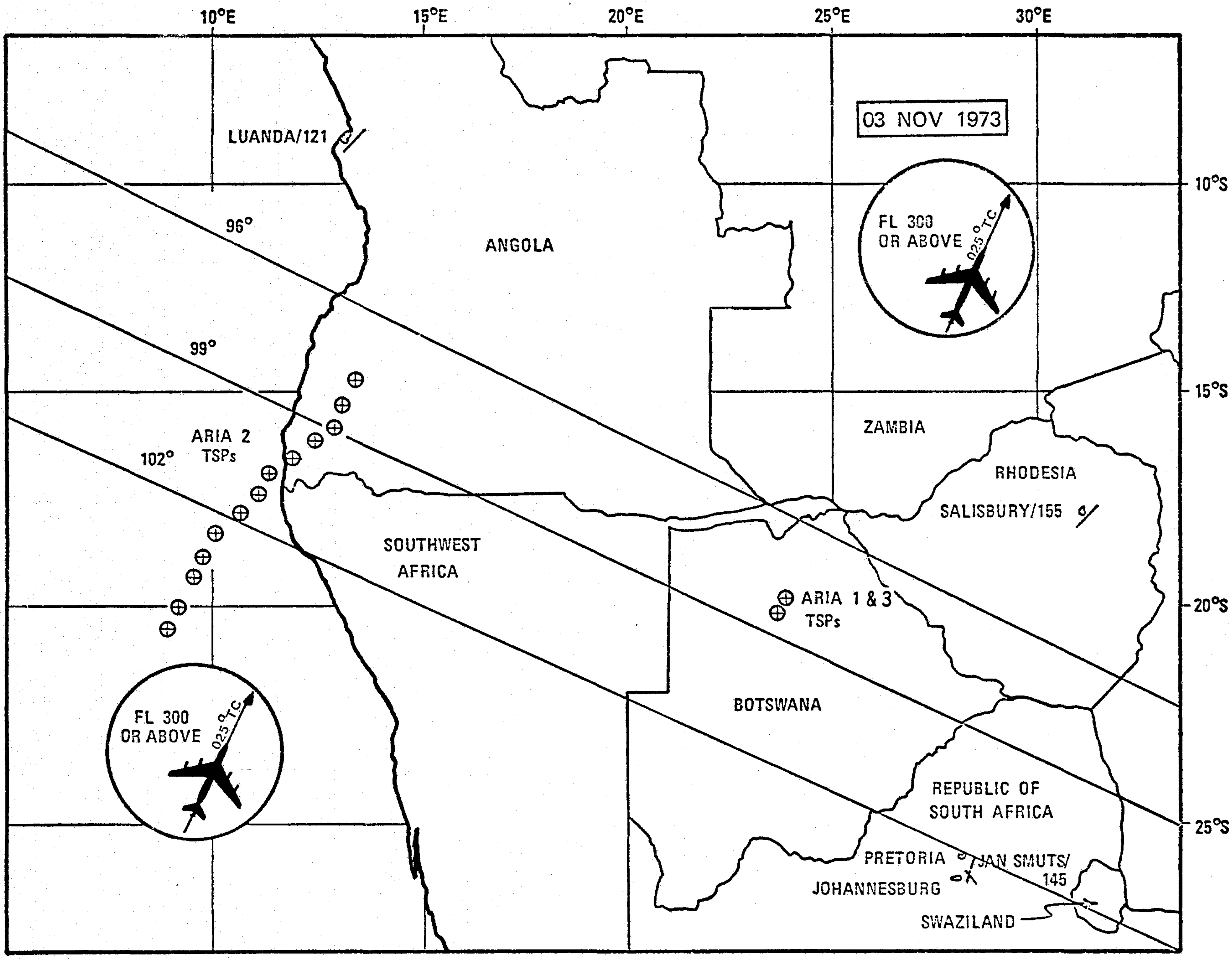


Figure 44. AFETR aircraft coverage plan for MVM'73 launch

3. Near-Earth Data System Implementation and Configuration

This section describes Near-Earth capabilities and configurations which were implemented for the acquisition and handling of MVM'73 telemetry and tracking data. In this case, tracking refers to both radar and radio metric data.

a. Near-Earth Tracking System Implementation and Description. Essentially, no new implementation was required to meet MVM'73 metric data requirements in the Near-Earth Phase. Existing resources were employed, and as indicated in Table 18, C-band pulse radars represented the primary data source. These radars operate in a frequency range of 5400 to 5900 MHz and have peak powers up to 2.5 MW. Time, azimuth, elevation, and range are generated through integration of coded transponders in the Centaur vehicle stage. These data are transmitted to the AFETR Real Time Computing System for processing and computation of tracking station pointing information and vehicle orbits. The Real Time Computing System also uses approximately one hour of spacecraft two-way doppler data from the DSN's initial acquisition station (DSS 42) to generate an early estimate of the spacecraft postinjection orbit. In addition, Centaur telemetered guidance data are received from selected stations and are formatted by the KSC Central Instrumentation Facility in Cartesian inertial form (TXYZXYZ). The Near-Earth's tracking system general configuration and radio metric data flow for MVM'73 are illustrated in Fig. 45. Figure 46 further illustrates the AFETR portion of the tracking system.

Given the described capabilities and configurations, the final estimation of coverage was developed based on such factors as station horizon masks, aspect angles, signal strengths, system characteristics, and past performance. Figure 47 gives the expected coverage during the initial powered flight and that portion of the parking orbit through Ascension station viewing. As indicated, stations through Antigua provide for coverage of the uprange mandatory interval. Ascension provides data during the parking orbit at launch azimuths more southerly than 96 degrees. Figure 48 gives the expected coverage during the interval from launch plus 1680 to 3,480 sec, which encompasses the critical Centaur second burn and blowdown events. In most cases, the 120-sec mandatory interval from MECO 2 plus 10 sec to MECO 2 plus 330 sec is met by Tananarive and supplemented by Carnarvon at the more northerly launch azimuths.

b. Near-Earth Telemetry System Implementation and Description. A significant amount of coordination and new implementation was necessary to achieve telemetry acquisition and real-time transmission capabilities required for the launch vehicle and spacecraft. Table 19 lists the general plan for supporting MVM'73 telemetry requirements. The basic Near-Earth telemetry system configuration is given in Fig. 49. The configurations for spacecraft telemetry from the launch area, AFETR stations, and STDN stations are given in Figs. 50, 51, and 52, respectively. Similarly, configurations for launch vehicle telemetry data are given in Figs. 53 through 55.

Table 18. MVM'73 Near-Earth TDS tracking support

Tracking sites	Centaur C-band beacon	Spacecraft transponder
Merritt Island (ETR 19.18)	X	-
Patrick AFB (ETR 0.18)	X	-
Cape Kennedy (ETR 1.16)	X	-
Grand Turk (ETR 7.18)	X	-
BDA (STDN FPQ-6)	X	-
ANT (ETR 91.18)	X	-
ASC (ETR 12.16)	X	-
TAN (STDN FPS-16V)	X	-
CRO (STDN FPQ-6)	X	-
DSS 42 (JPL DSN)	-	X

Real-time transmission of spacecraft elemetry data from the downrange stations involved the revival of analog bit stream transmission, a technology from earlier missions. Using this method, the stations' tunable PSK demodulators first recover the spacecraft bit stream (33-1/3 bps) from the 88.55-kHz subcarrier using a phased lock loop. The bit stream is then regenerated into a clean rectangular wavetrain by a PCM data decommutator. The regenerated bit stream modulates the IRIG Channel 7 (2.3 kHz) subcarrier oscillator whose output is then transmitted to GSFC. At GSFC, the incoming bit streams are evaluated at the Data Evaluation Computer Center, and two sources are selected for transmission to DSS 71. At DSS 71, the automatic switching unit performs bit stream switching and feeds the received data into the standard DSN telemetry string (symbol synchronizer and telemetry processor) for formatting and transmission to JPL. A large amount of time and effort was needed to make this approach operational since it had not been used in recent years; however, its simplicity had many advantages over a digital system. One should note that the ARIA real-time transmission capability illustrated in some of the referenced figures never actually matured for mission support due to technical problems and funding limitations.

Capabilities for launch vehicle telemetry retransmission varied considerably as a function of station locations, uprange, midrange,

Table 19. General plans for MVM'73 Near-Earth TDS telemetry support

Telemetry support																	
Centaur (2202.5 MHz)																	
Receive and record on tape (analog)	M	R	D		R	R	R	M	D	R	R	M	M	M	M	R	
Real-time retransmission to Bldg AE via CIF	M		D		X		R	M		R			M	M		D	
Data processing/display on site	M	M	D		R	R	R	R	D	R	R		R	R		R	
Spacecraft (2295 MHz)																	
Receive and record on tape (analog)	X		R	M/R	R	R	R	R	NS	D	D	R	M	M	M	M	M
Real-time retransmission to MCCC via DSS 71			R	M/R	R		R	R		D		R	M	M	R	M	
Data processing/display on site				M/R													

Abbreviations:

ARIA	Advanced Range Instrumentation Aircraft		M	Mandatory
CIF	Central Instrumentation Facility		R	Required
DSS	Deep Space Station		D	Desired
KSC	Kennedy Space Center		NS	Not specified
MCCC	Mission Control and Computing Center		X	Added backup support
MIL	Merritt Island STDN Station			

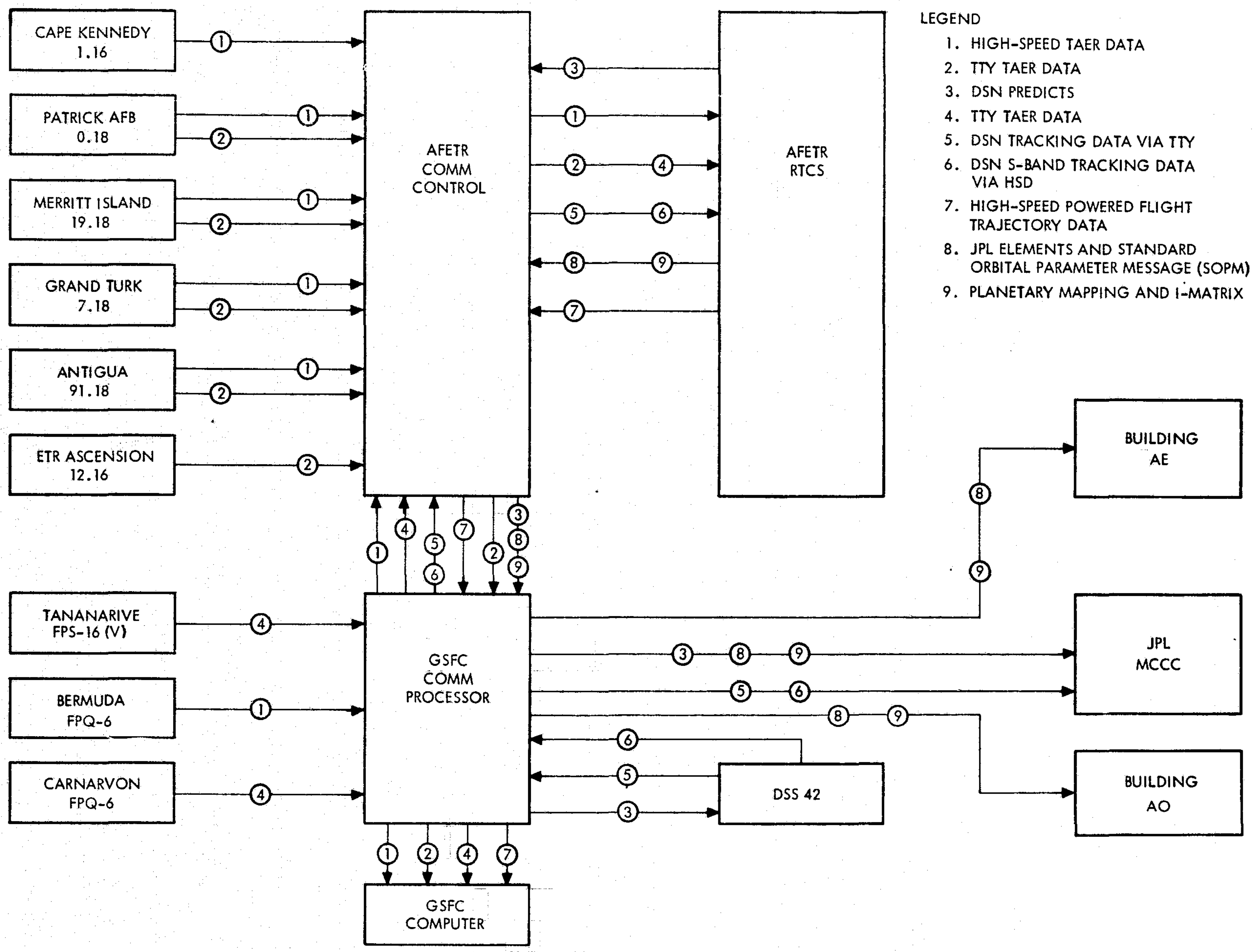


Figure 45. Near-Earth phase tracking data flow

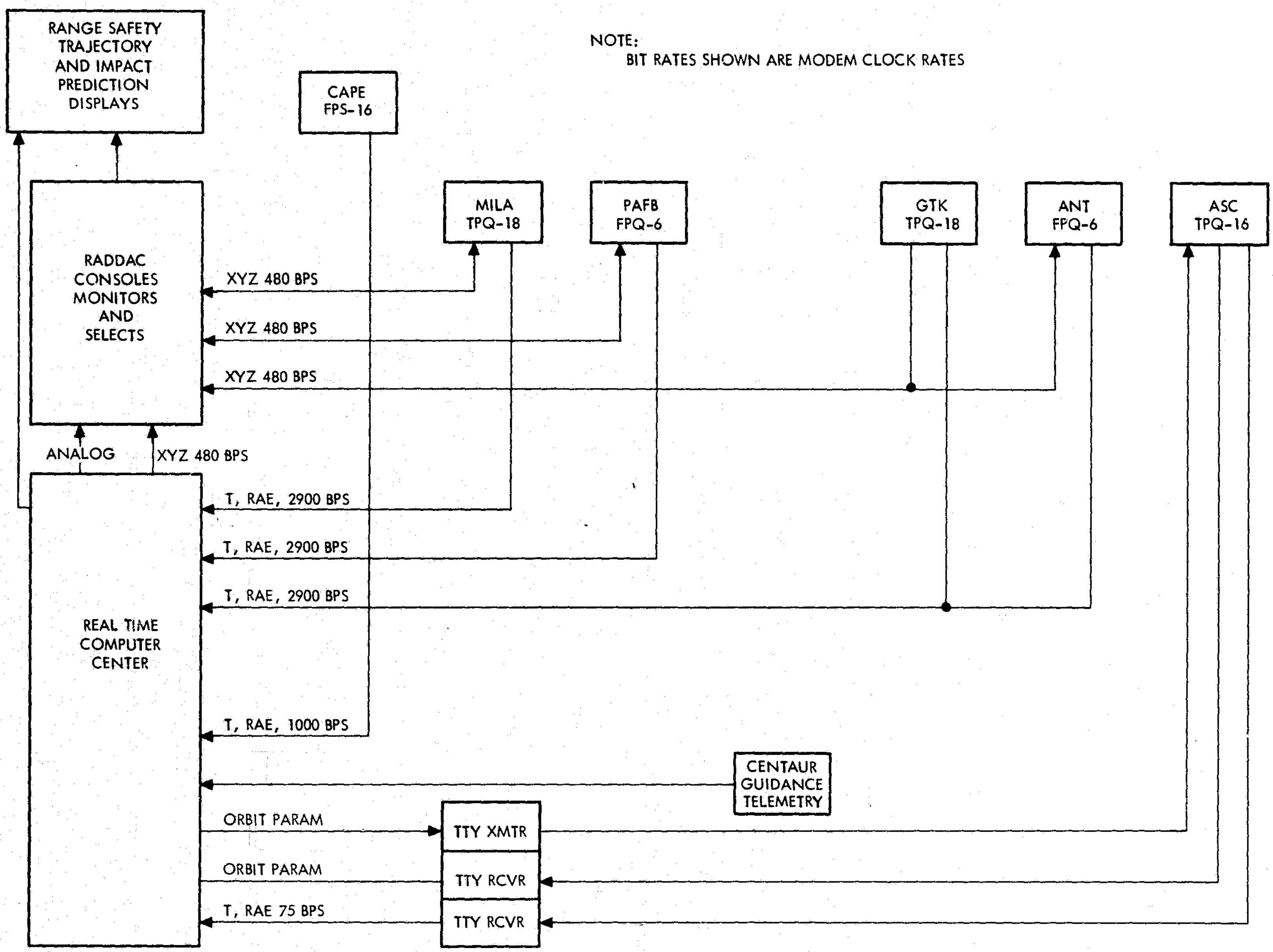


Figure 46. AFETR tracking data system (simplified)

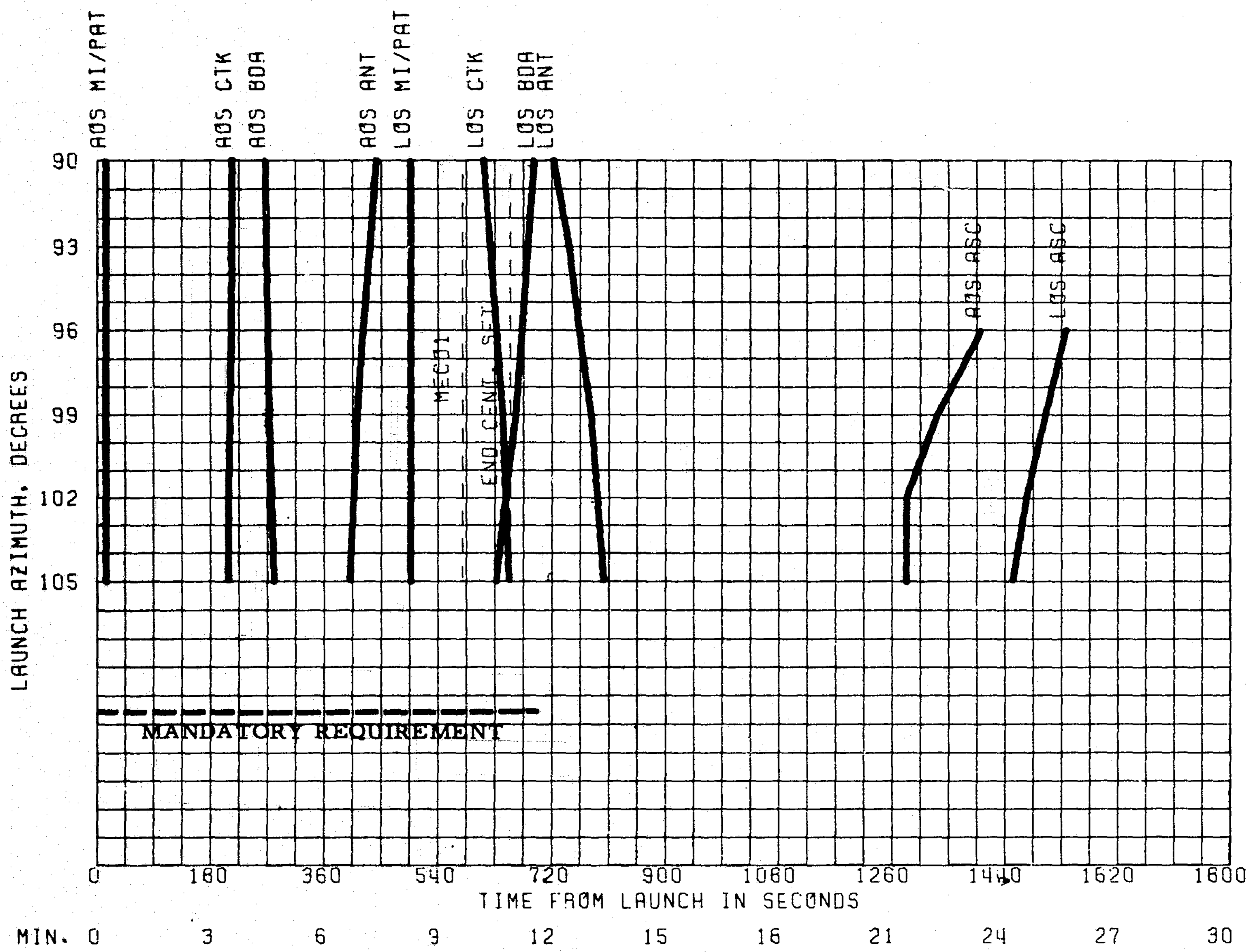


Figure 47. Expected coverage, metric data through ASC

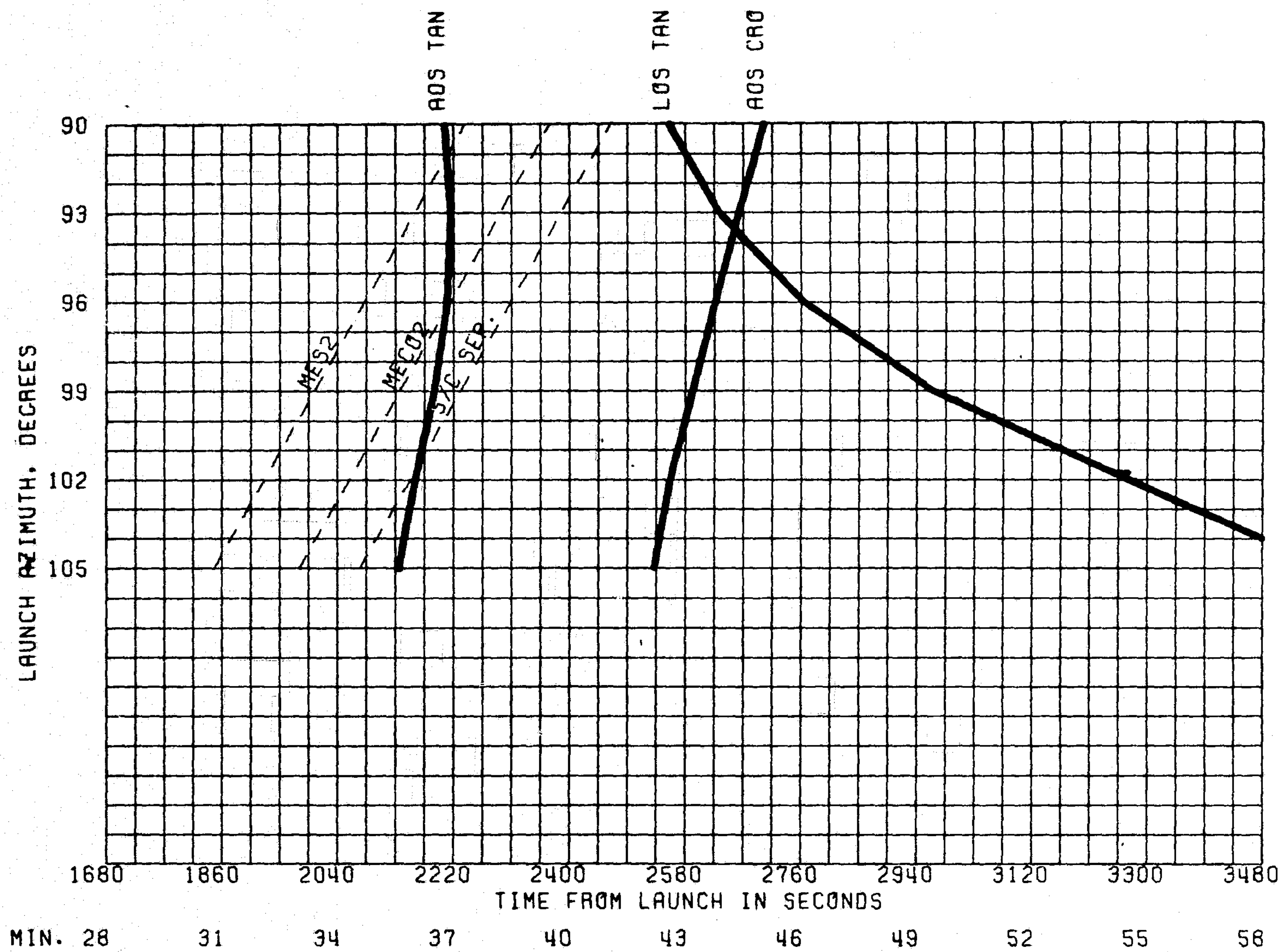
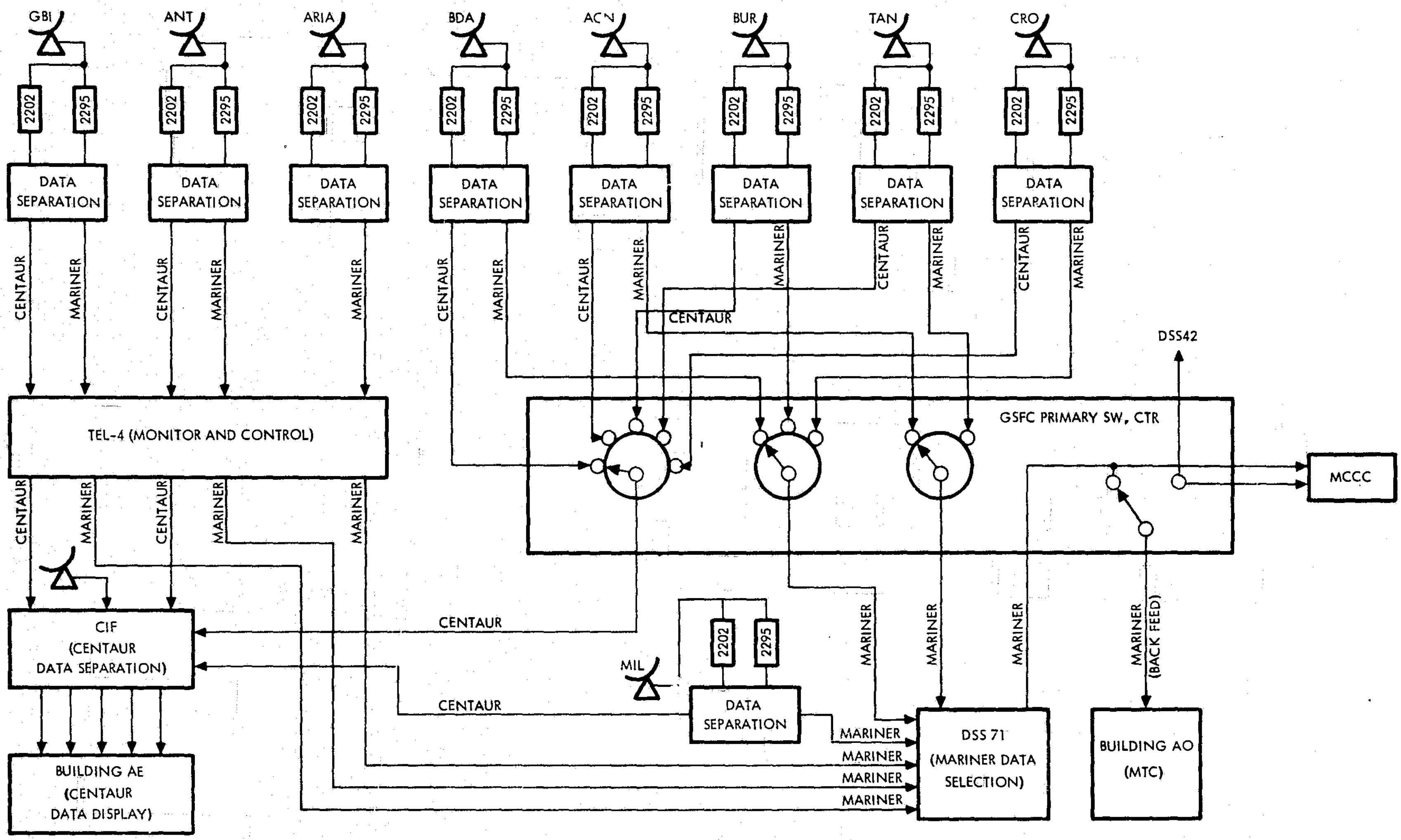


Figure 48. Expected coverage, metric data DLA = 4 deg



LEGEND

ACN - ASCENSION ISLAND, STDN
AE - BUILDING AE, KSC
ANT - ANTIGUA, ETR
ARIA - ADVANCED RANGE INSTRUMENTATION AIRCRAFT, ETR
BDA - BERMUDA, STDN
BUR - JOHANNESBURG, STDN
CIF - CENTRAL INSTRUMENTATION FACILITY, KSC
CRO - CARNARVON, STDN
DSS 42 - WEEMALA DEEP SPACE STATION, CANBERRA, AUSTRALIA, DSN
DSS 71 - SPACECRAFT COMPATIBILITY/MONITOR STATION, CAPE KENNEDY, FLORIDA, DSN
GBI - GRAND BAHAMA ISLAND, ETR
MIL - MERRITT ISLAND, STDN
MTC - MISSION AND TEST COMPUTER
TAN - TANANARIVE, STDN
TEL-4 - MAINLAND TELEMETRY STATION, ETR

Figure 49. Near-Earth phase real-time telemetry transmission system for MVM'73, basic configuration

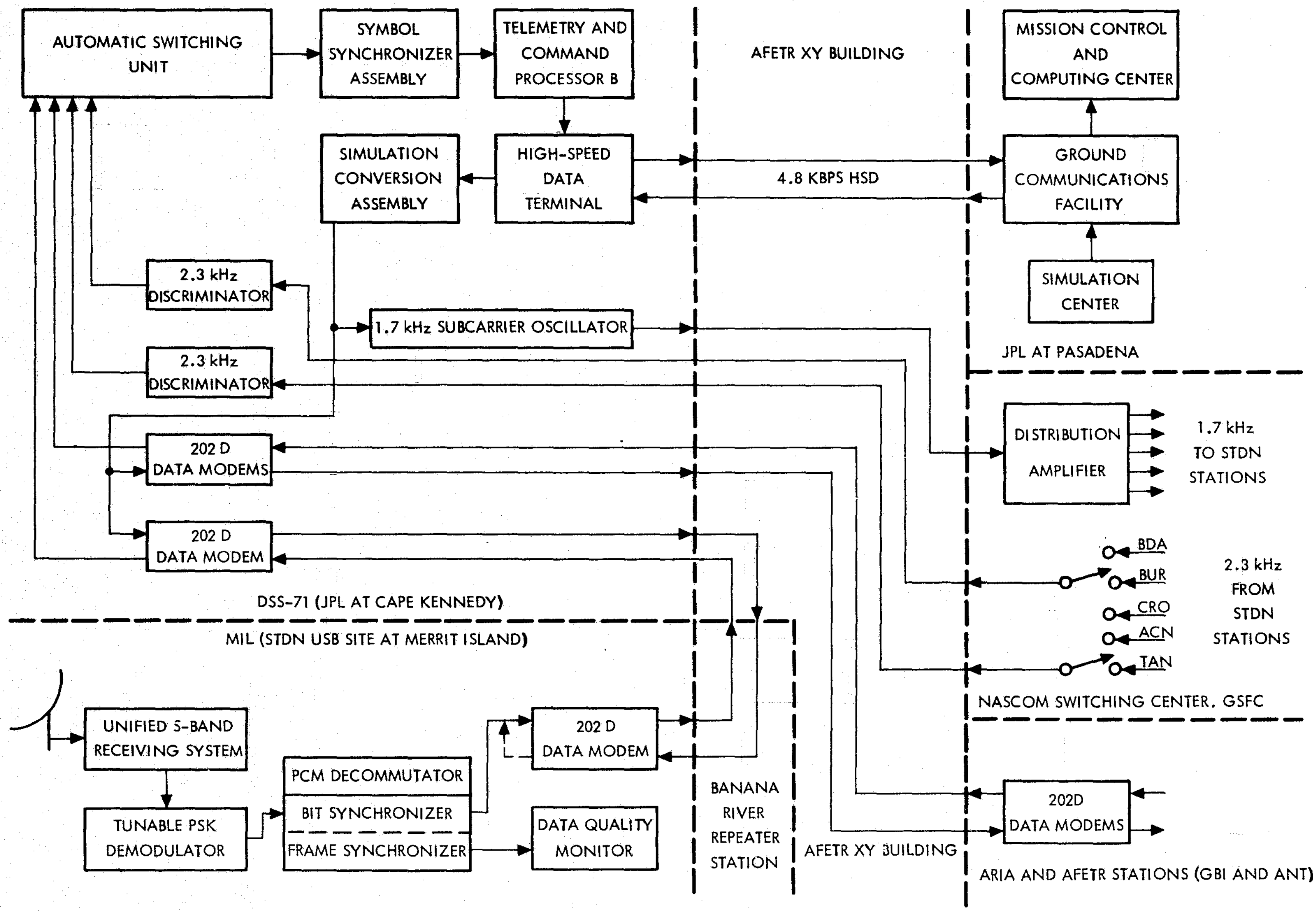


Figure 50. Launch area spacecraft telemetry configuration for MVM'73

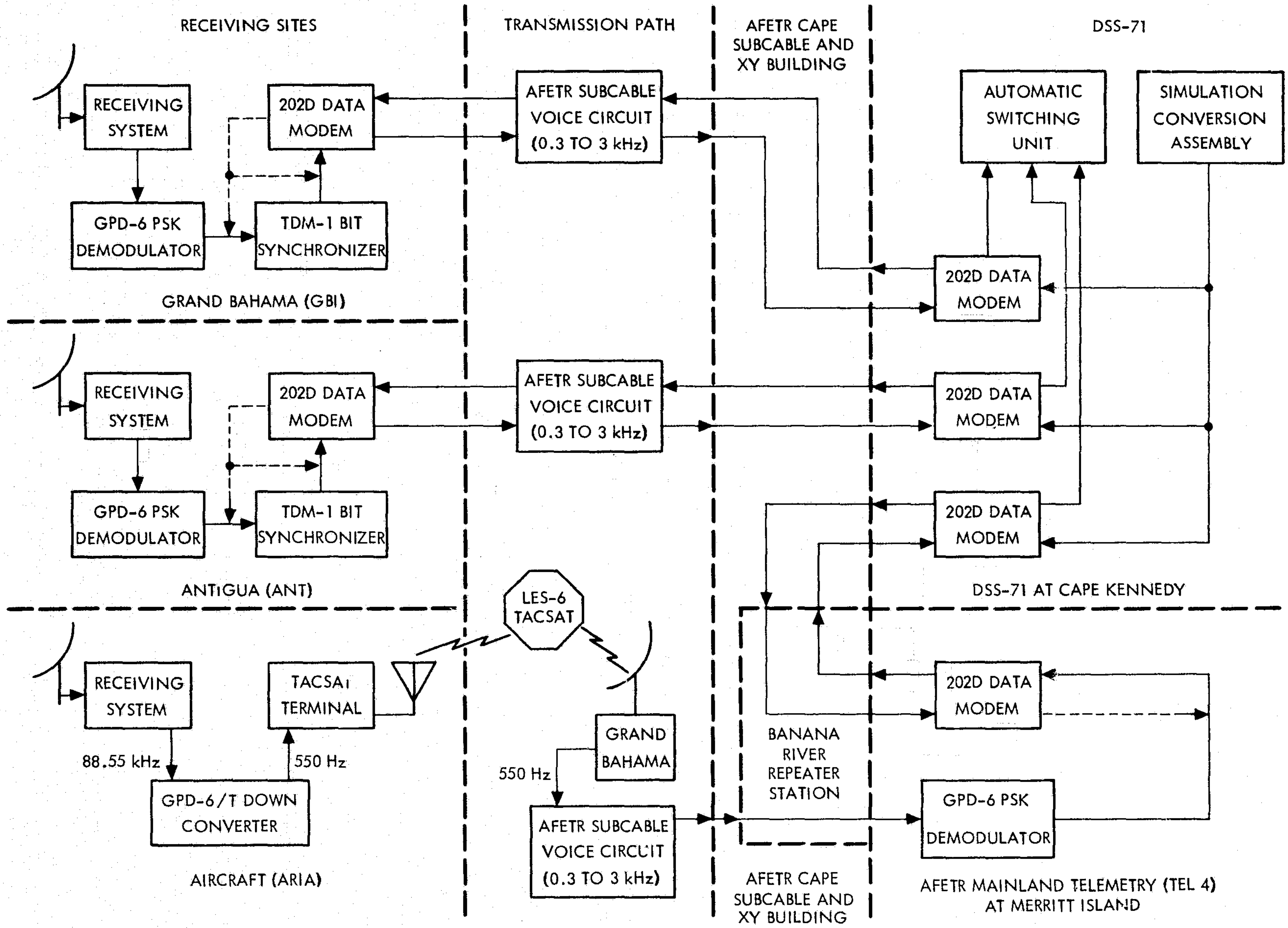


Figure 51. AFETR spacecraft telemetry configuration for MVM'73

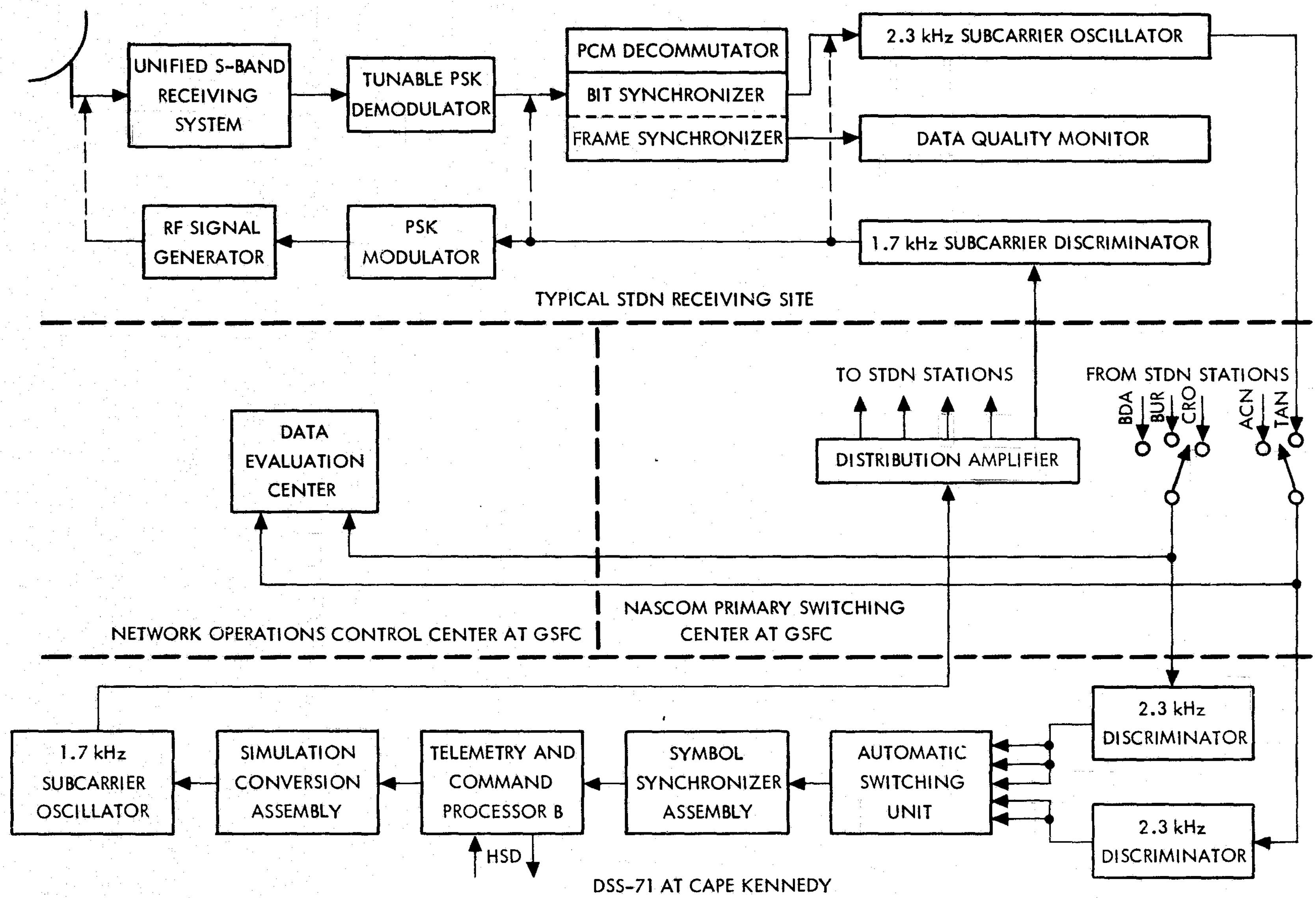


Figure 52. STDN/GSFC spacecraft telemetry configuration for MVM'73

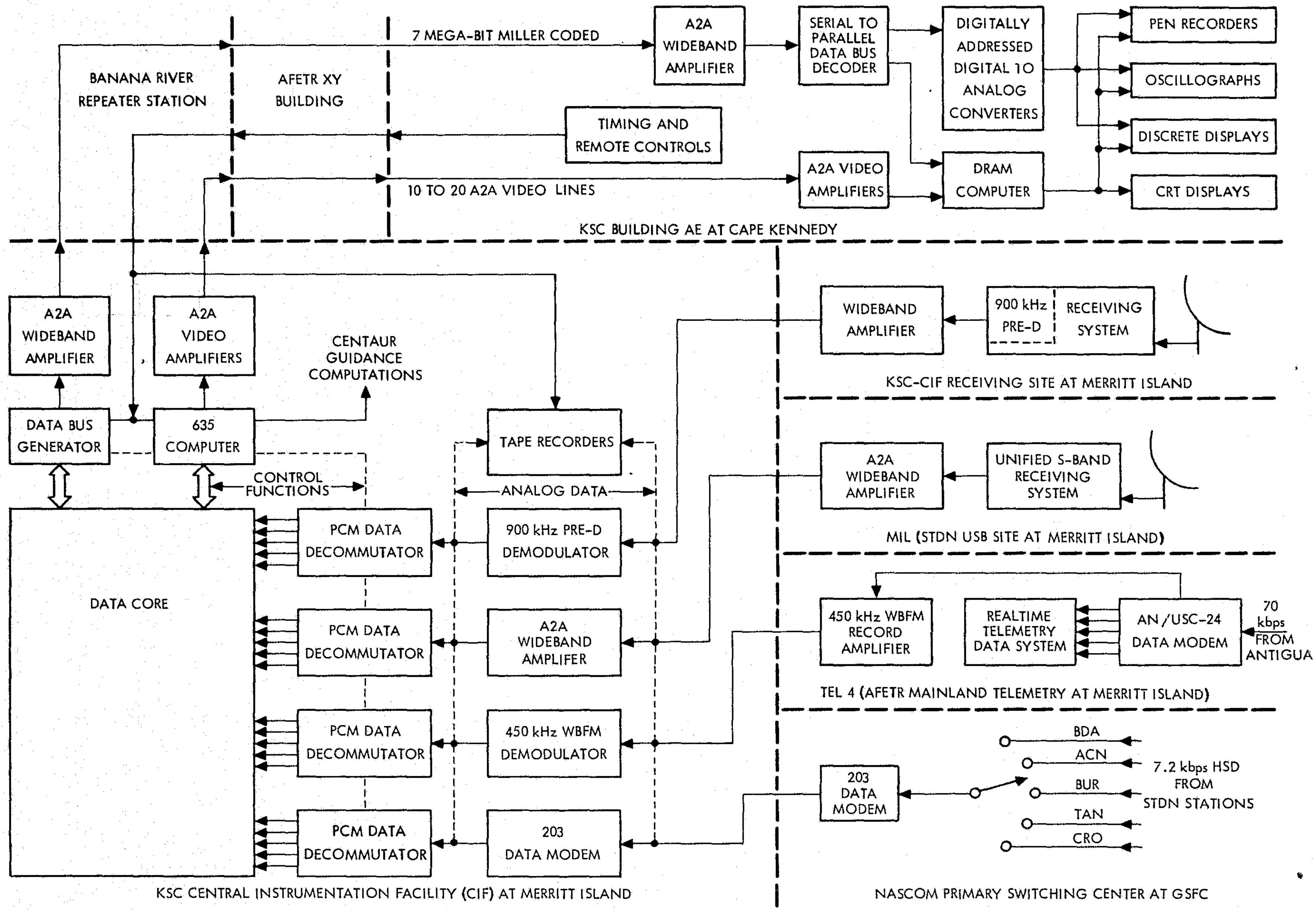


Figure 53. Launch/Area launch vehicle telemetry configuration for MVM'73

33-797

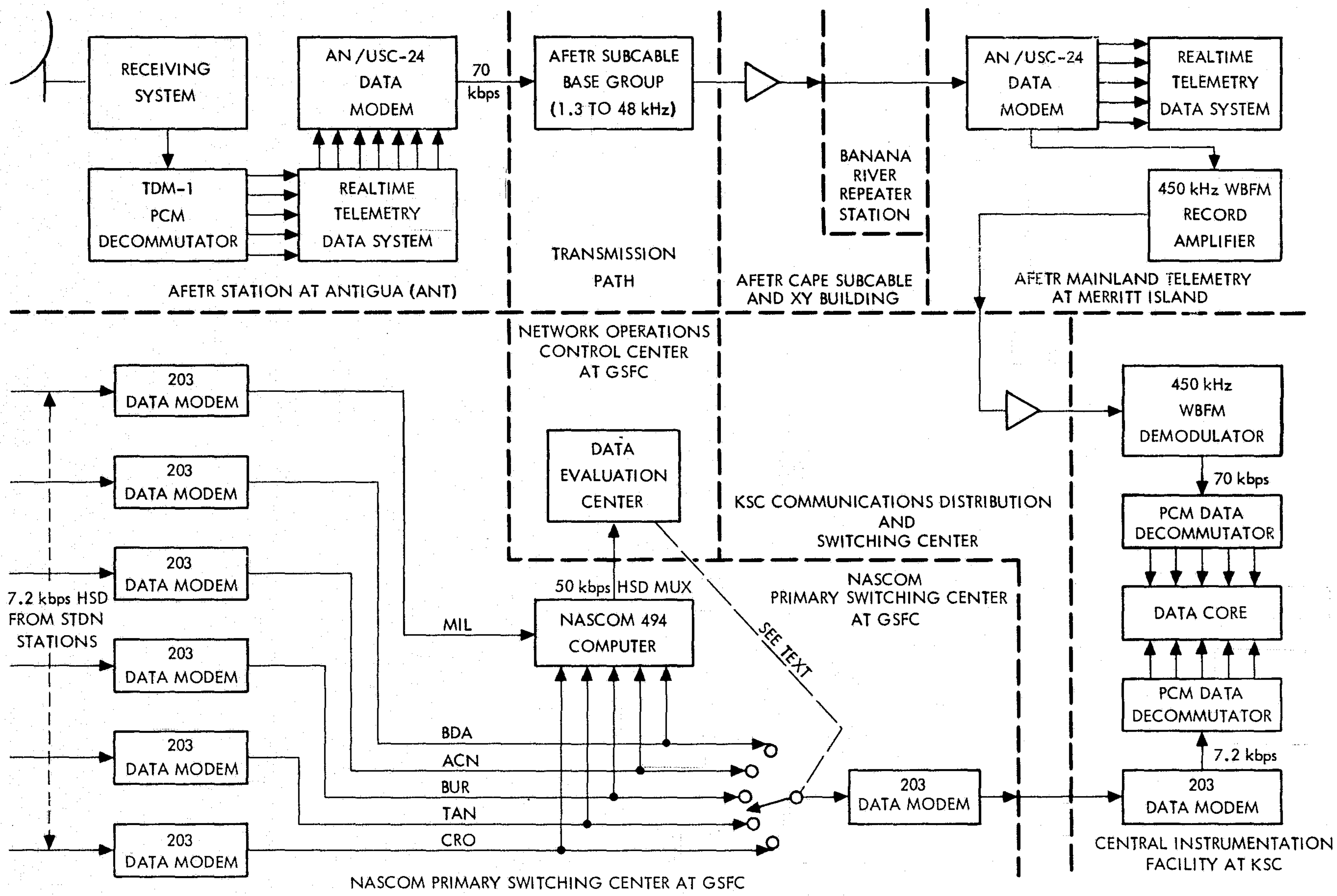


Figure 54. GSFC and AFETR launch vehicle telemetry configurations for MVM'73

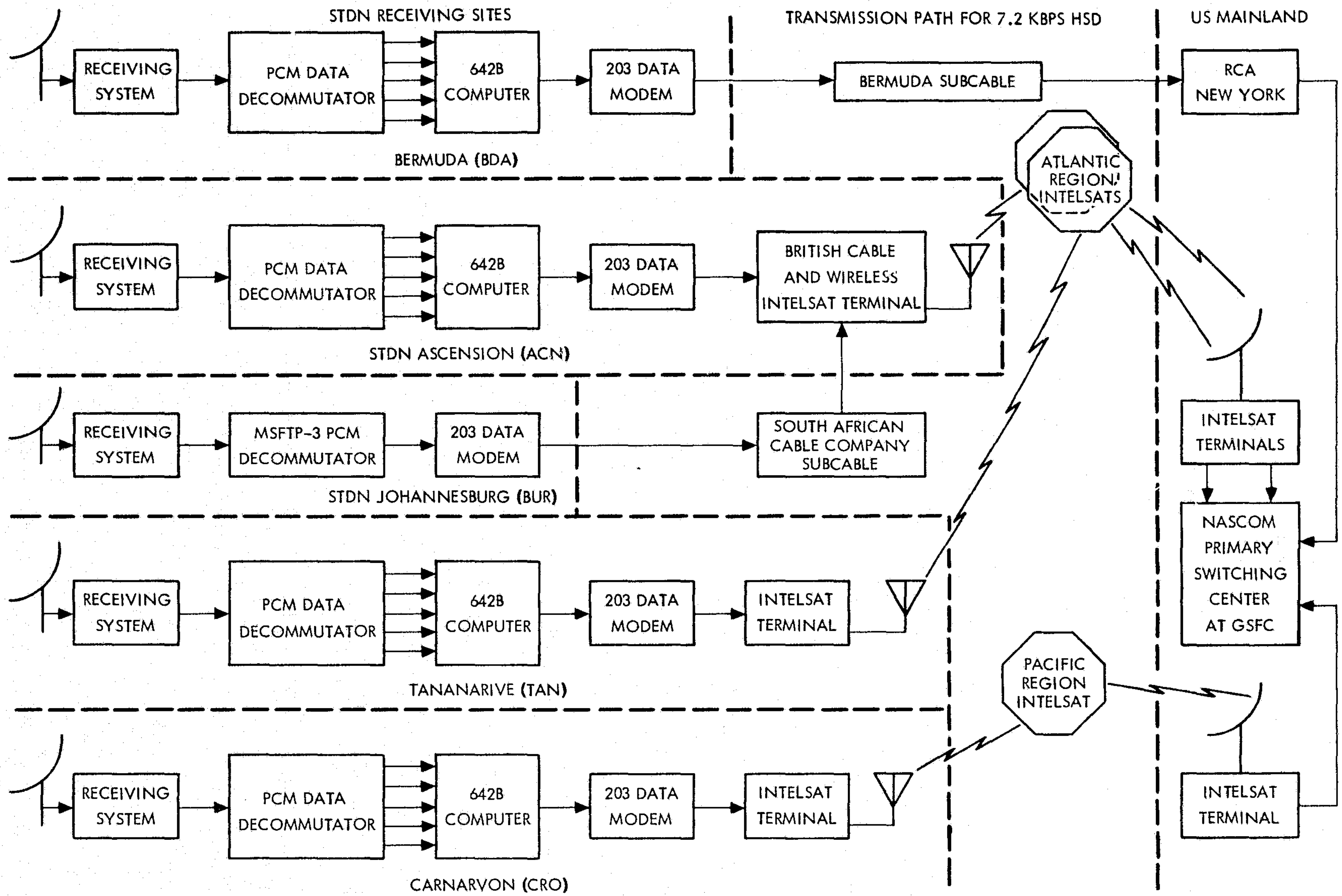


Figure 55. STDN station launch vehicle telemetry configuration for MVM'73

33-797

or downrange. In the launch area, all data were communicated in real-time wherein the KSC Central Instrumentation Facility is the main supporting resource. From AFETR's Antigua station, submarine cables provide for transmission of data up to 70 kbps. STDN stations are capable of transmitting selected portions of received data at rates up to 7.2 kbps.

Coverage of the Centaur second burn posed some particularly difficult problems. Efforts to obtain use of the Vanguard instrumentation ship provided fruitless since this resource was required in the southwestern Atlantic for Skylab Project support during the same time period. The absence of ship support put pressure on the Near-Earth to improve the coverage capabilities of STDN stations at Johannesburg and Tananarive. Electrical stops on these antennas were set well above the mechanical limits for structural safeguard purposes. However, this limit terminated tracking capabilities well above the local horizon, thus foreshortening the possible coverage interval. Negotiations with GSFC resulted in a reduction of the stops to the maximum extent possible consistent with adequate safeguards against antenna damage. Consequently, coverage capabilities were improved.

Based on the described capabilities and configurations, the final estimates for telemetry coverage were made as given in Figs. 56 and 57 for the spacecraft and in Figs. 58 and 59 for the launch vehicle.

c. Near-Earth Operations Control System. The Near-Earth operations control system structure illustrated in Fig. 60 was designed to provide real-time coordination and status reporting required for operational control of the TDS during the Near-Earth Phase of mission operations. Although each Near-Earth supporting agency is responsible for operating and controlling its particular network, the TDS Coordinator provided overall direction through voice contact with the GSFC Network Operations Manager, the AFETR Superintendent of Range Operations (SRO) and Real Time Computing System, the KSC Test Controller, and the Project Chief of Mission Operations and Navigation Team Chief at JPL. The TDS Coordinator to the Mission Director, TDS Manager, and Launch Phase Mission Analyst were available for consultation relative to the state of Near-Earth readiness during the launch countdown.

C. DEEP SPACE PHASE IMPLEMENTATION

This subsection deals with the implementation of tracking and data acquisition capabilities for Mariner 10's deep space phase. As described in Section I, capabilities for this phase were provided by the DSN and NASCOM. Particular attention is given to the DSN's implementation process as well as the resulting configurations of the data systems, which incorporate NASCOM operational communications capabilties. The overall implementation objective was to achieve DSN readiness to support MVM'73 Project operational tests and training by July 1, 1973, and to be operational for mission support prior to the October 15, 1973, launch readiness date.

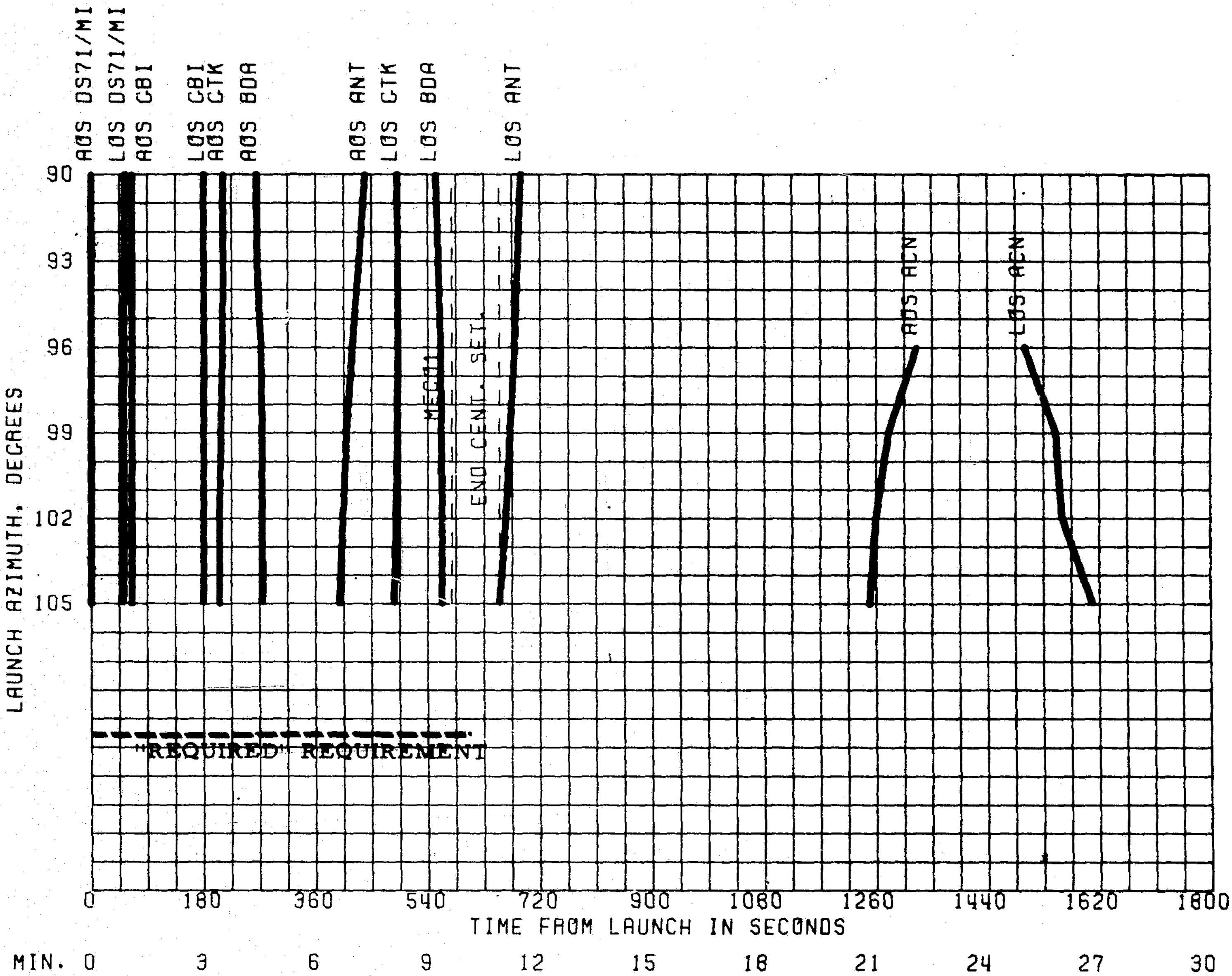


Figure 56. Expected coverage, spacecraft telemetry through ACN

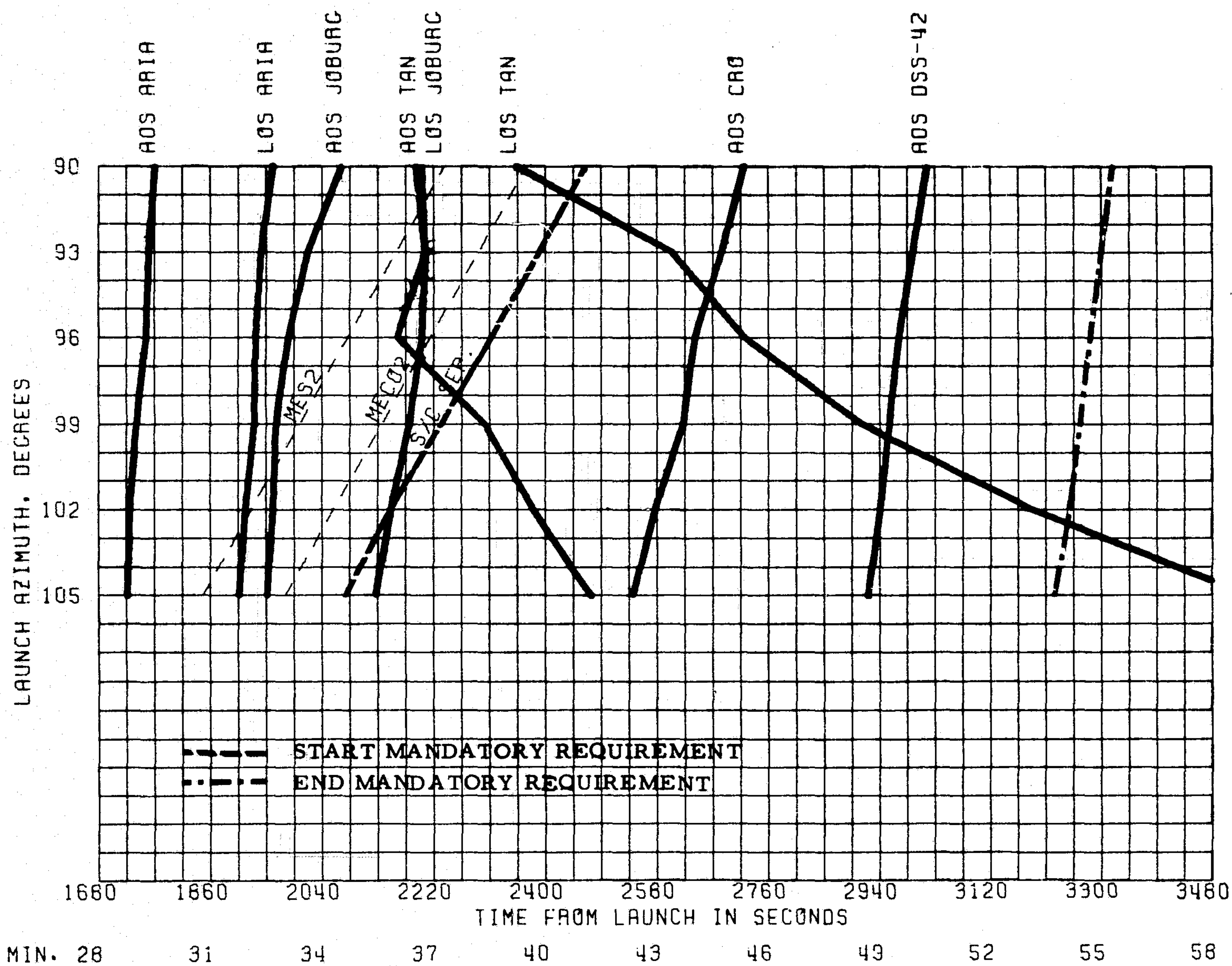


Figure 57. Expected coverage, spacecraft telemetry DLA = 4 deg

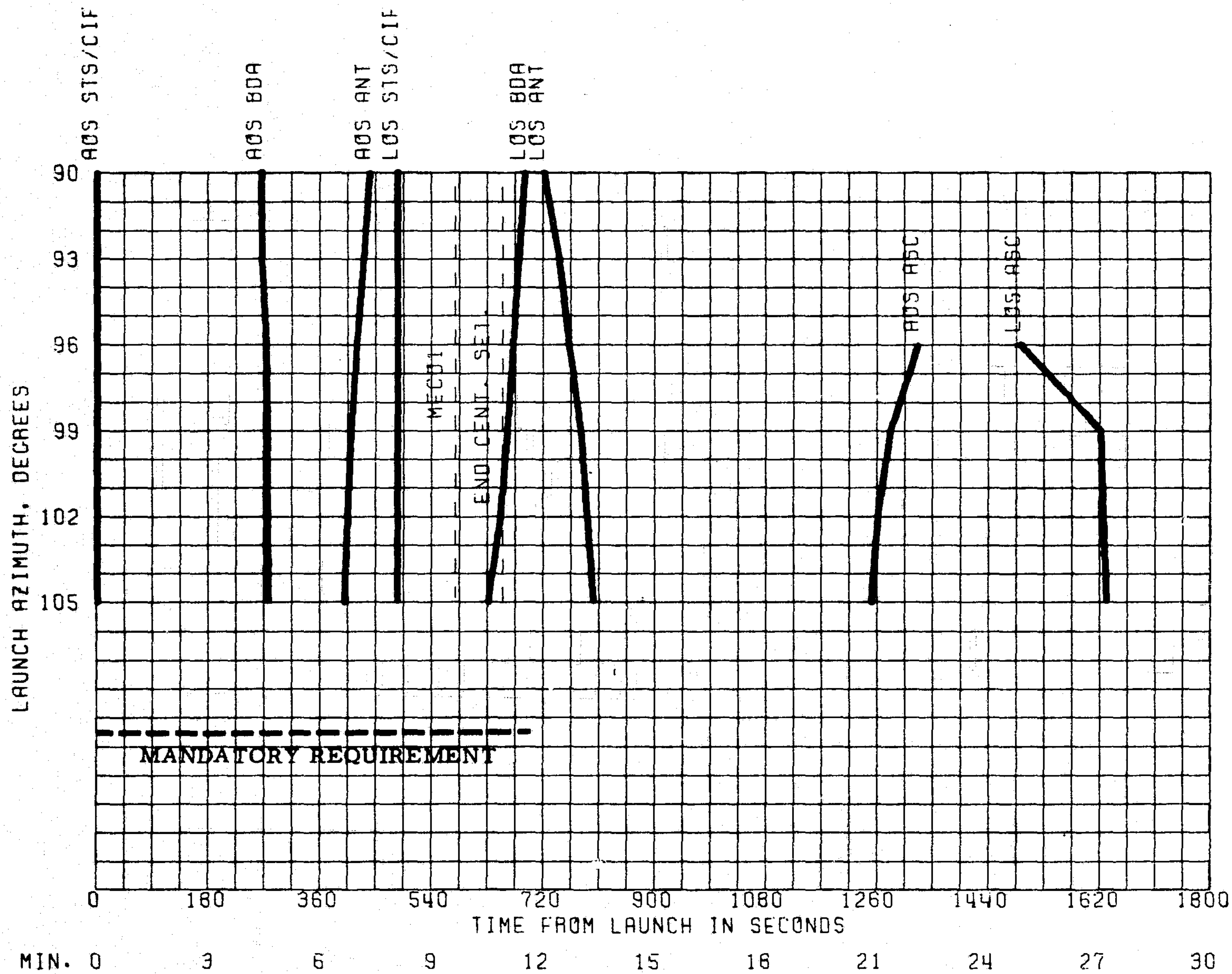


Figure 58. Expected coverage, L/V telemetry through ASC

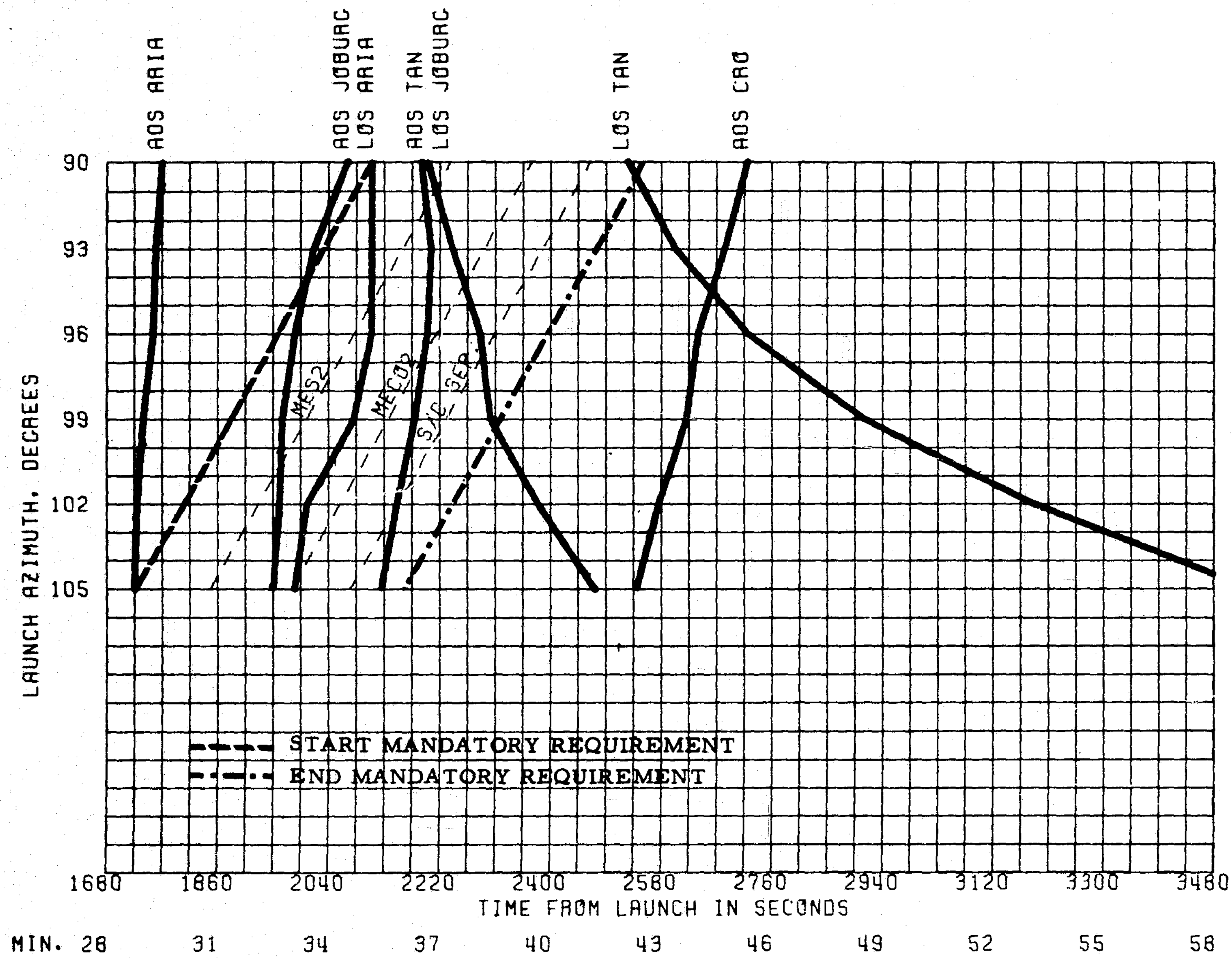


Figure 59. Expected coverage, L/V telemetry DLA = 4 deg

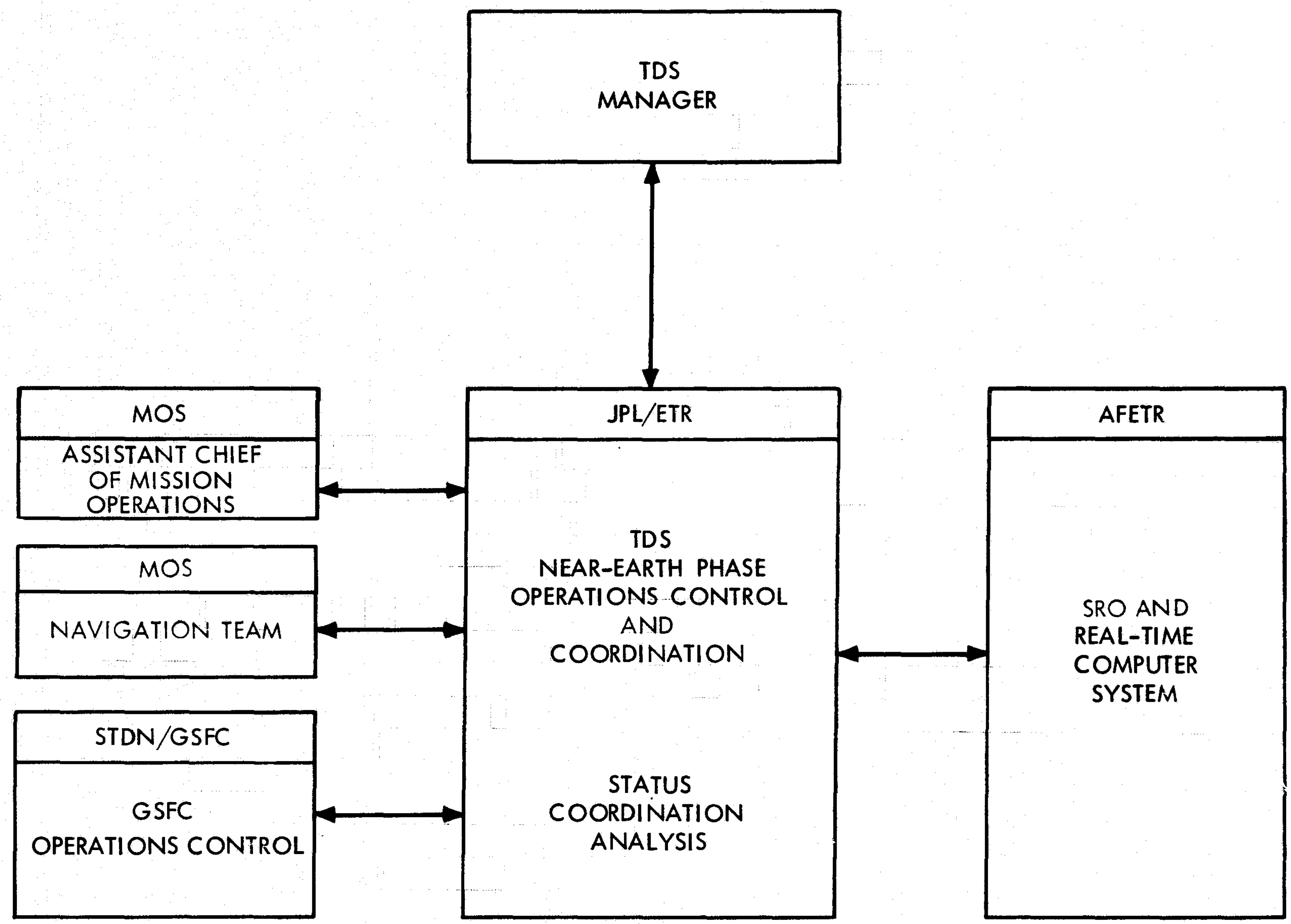


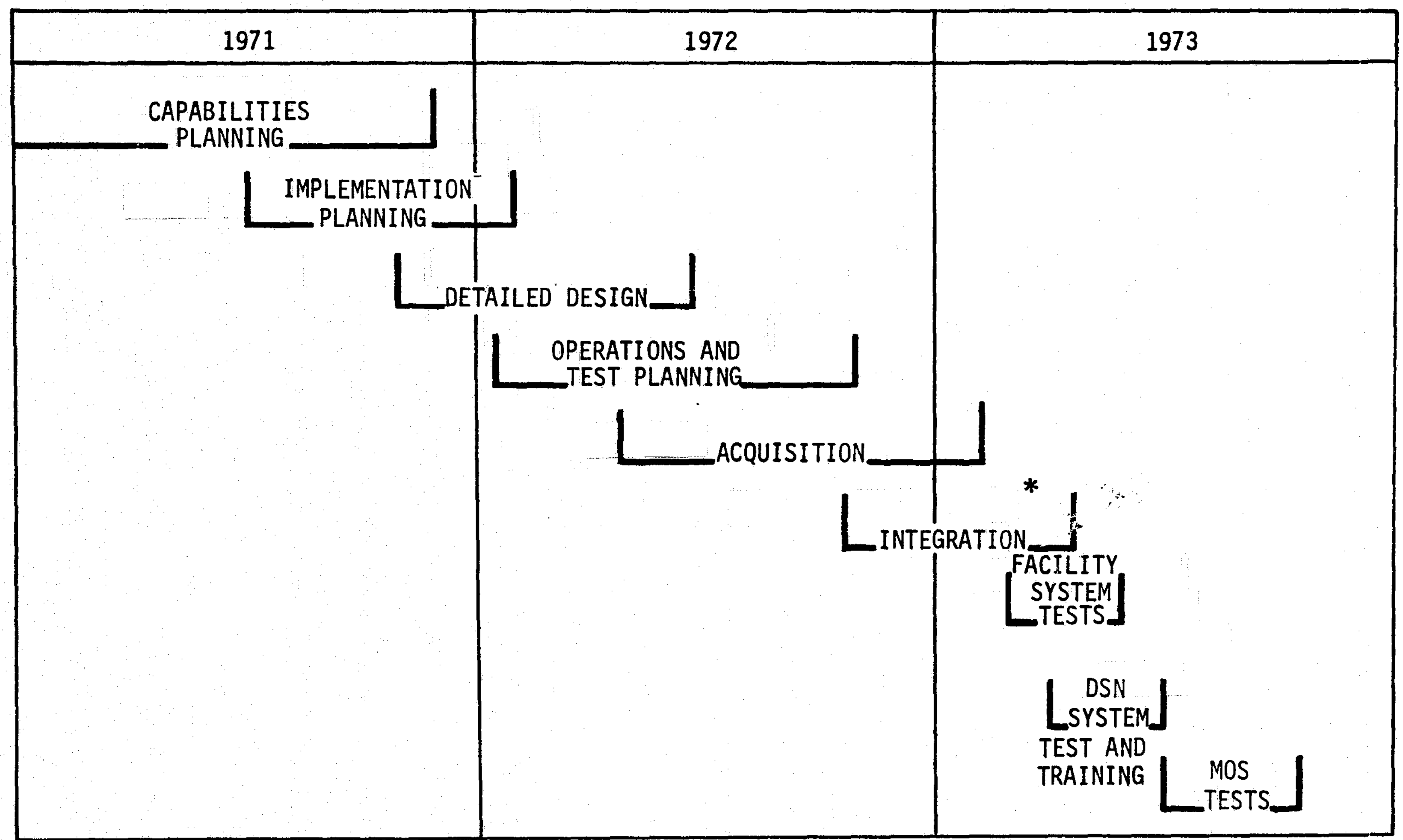
Figure 60. NETDS operations structure

1. DSN Implementation Process

The DSN mission-dependent organization for MVM'73, defined in Section I, accomplished interface engineering and operational support planning between the Flight Project and the DSN multiple mission organization for tracking and data engineering and operations. In accomplishing DSN support capabilities for MVM'73, a systems approach was used, and a comprehensive implementation program was developed which covered the following phases: planning, design, acquisition, installation-integration, testing, and training. The time phasing of these activities is generally illustrated in Fig. 61. The level of detail was greater than any previous program and was such that specific attention could be given to controllable elements of the overall program. The program included a system of formal documents, schedules, and reviews to provide for information communications, decision making, control, and evaluation of progress.

When implementation planning started for MVM'73 in 1971, the DSN consisted of the three facilities and six data systems illustrated in Fig. 62. The Deep Space Instrumentation Facility (DSIF) comprised all of the deep space stations; the Space Flight Operations Facility (SFOF) at JPL included the network-mission data processing and network-mission operations control capabilities; and the Ground Communications Facility, with NASCOM, provided the voice and data transmission capabilities between the DSIF and the SFOF. The six data systems (tracking, telemetry, command, monitor, control, and simulation) cut across the three facilities to provide end-to-end capabilities for the implied data types. DSN implementation activities continued toward this three-facility configuration throughout most of calendar year 1971 in preparation for the joint DSN/Mission Operations System Functional Design Review in December 1971. However, in October 1971, NASA Headquarters redefined the DSN tracking and data acquisition function as follows:

> OSSA and OTDA have been reviewing the planetary mission Operations SFOF/network interface with the view to bringing the program control and budget functions more into line with management responsibilities. The intent has also been to develop an interface that would be reasonably clear in order to simplify technical management, to assure that budgeting requirements of the two offices are well understood, and most importantly to assure all technical and operational requirements are covered.
>
> We have agreed to the following interface which on each side will include management responsibility, funding, configuration control, development, engineering, hardware, software and operations:
>
> OTDA will be responsible for:
>
> Stations
> NASCOM/GCF
> Network control and monitoring
>
> The functions include network scheduling, predicts, network performance monitoring, network validation tests, provision of clean



* ALL SOFTWARE DELIVERED FOR INTEGRATION

Figure 61. DSN implementation sequence and general schedule

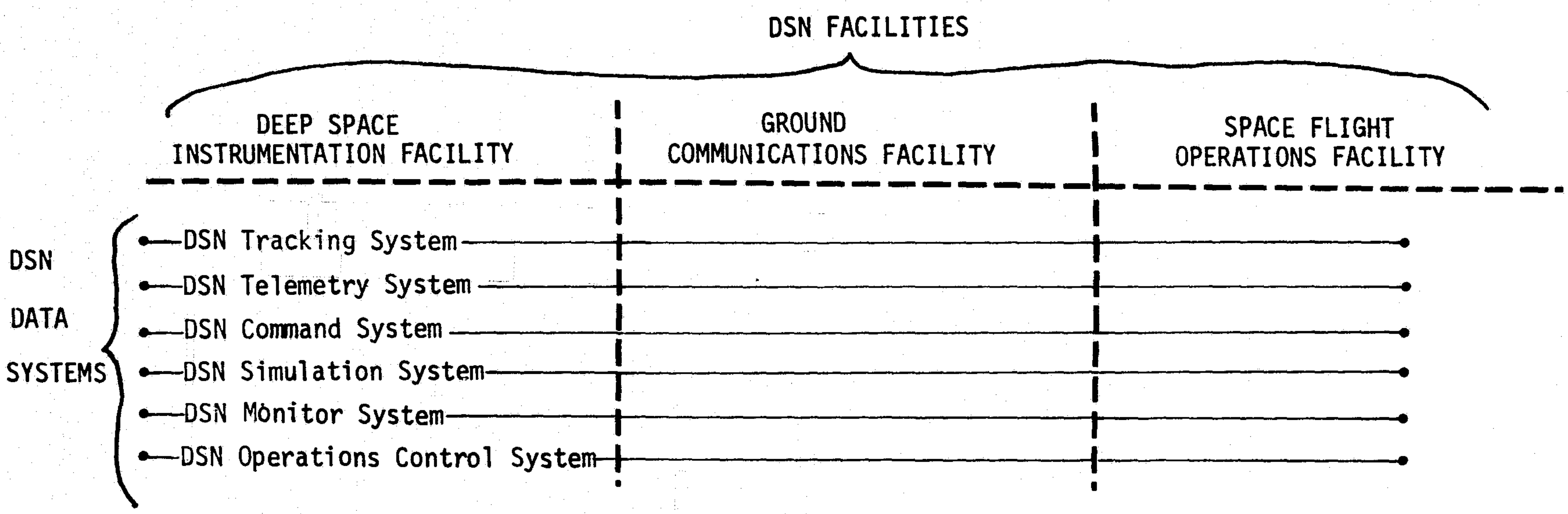


Figure 62. DSN facilities and systems, 1971-1972

(bit synchronized and identified) data streams to mission operations, acceptance of commands from mission operations and transmission to stations and spacecraft, provision of the record of the clean data streams for tracking, telemetry and command to mission operations, as required, and to participate with mission operations in missions simulations.

OSSA will be responsible for:

Mission operations

The functions include spacecraft analysis and control; navigation, engineering, TV and science data processing and display, mission analysis; command generation; sequencing of operational events; mission simulation and data distribution to experimenters. The system should be designed to move to separate hardware for OTDA and OSSA functions to provide for cleaner and more controllable interfaces.

It is requested that JPL proceed expeditiously on plans to carry out the above division of responsibilities and to present us plans for implementation as soon as possible. There will unquestionably be areas needing clarification which we will resolve as they arise.

Budgeting in accordance with the above division of responsibilities will commence in FY 1974. The FY 1972 and 1973 budgets will remain as they are in the two offices with the following provisions:

1. The Mariner/Venus/Mercury Project and the DSN have identified $640,000 in FY 1972 and $1.6 million in FY 1973 of unfunded requirements for software development and computer support. Since we will be in a transition period, OTDA will fund $640,000 in FY 1972 and $400,000 in FY 1973. OSSA will meet the remaining unfunded requirements. It is essential that funding be constrained to the lowest possible budget level. Data processing and computer operating times should be reexamined with all real time processing restricted to the minimum requirements satisfying basic mission objectives.

2. It is requested that JPL make two submissions for the OSSA POP 72-1 and the OTDA FY 1972 WAD summary midyear revision. One of the submissions should structure the FY 1973 budget along present lines and one should separate out and describe those areas of the OTDA FY 1973 budget that would become OSSA responsibilities under the change in the SFOF interface. It is OSSAS and OTDAS plan to use the second FY 1973 presentations as a basis for planning and developing the FY 1974 budget in this area.

John E. Naugle, associate administrator for SS&A
Gerald M. Truszynski, associate administrator for T&DA.

Following this NASA action, the DSN saw significant organizational and technical configuration changes in order to meet the realignment objectives. The new DSN configuration included the previous DSIF and the Ground Communications Facility; however, responsibility for the SFOF's central processing system and mission support areas was transferred to the Office of Computing and Information Systems. To accomplish DSN monitoring, control, and validation activities, a new facility, the Network Operations Control Center (NOCC), was planned to separately accommodate these internal Network functions. This new configuration is illustrated in Fig. 63, wherein the DSN's Ground Communications Facility now represented the primary real-time data system interface with the Flight Project/Mission Control and Computing Center. The Network Operations Control Center was to be established as an "off-line" activity operating in parallel with Mission Operations. The DSN facility concept was also de-emphasized at this time in favor of the Network system and subsystem approaches to implementation. The six Network data systems were reduced to five by a combination of similar functions of the monitor and control systems into one system. The simulation system, which had provided for the generation of mission-simulated data, was redefined as the test and training system, with its scope limited to data generation for DSN internal testing and training purposes. Consequently, DSN interfaces with the Flight Project were greatly simplified from the numerous mission-dependent software interfaces to that of an industry standard communications interface.

These reductions in the scope and complexity of the DSN's responsibilities and the simplified technical interfaces set the stage for significant organizational changes within the DSN's multiple mission engineering and operations organizations, as well as within the DSN's mission interface support organization. Prior to the directed realignment, JPL Division 33 was responsible for both engineering and operations of the DSIF, while Division 91 was responsible for engineering and operations of the SFOF and the GCF. Therefore, GCF engineering and operations functions had to be transferred from Division 91 in order to meet the NASA guideline of maintaining the GCF in the Tracking and Data Acquisition area of responsibility. These required changes provided an opportunity to further reorganize the DSN operations functions. The DSN Operations Office, under the Assistant Laboratory Director for Tracking and Data Acquisition, was established and encompassed the NOCC and GCF operations, as well as DSIF or DSS operations, which were formerly managed by Division 33. This consolidation of all operations functions under one organization also facilitated overall Network and Network system operations concepts and the de-emphasis of facility operations. Consequently, the need for numerous facility operations project engineers on the DSN Interface Team was significantly diminished. The DSN Operations Organizaton established the position of Network Operations Project Engineer to provide the primary interface between the DSN Manager and the Network Operations Organization. The engineering side of the DSN also experienced significant changes during this period. The DSN Systems Engineering Office, under the Assistant Laboratory Director for Tracking and Data Acquisition, was established and encompassed Network engineering and mission interface functions.

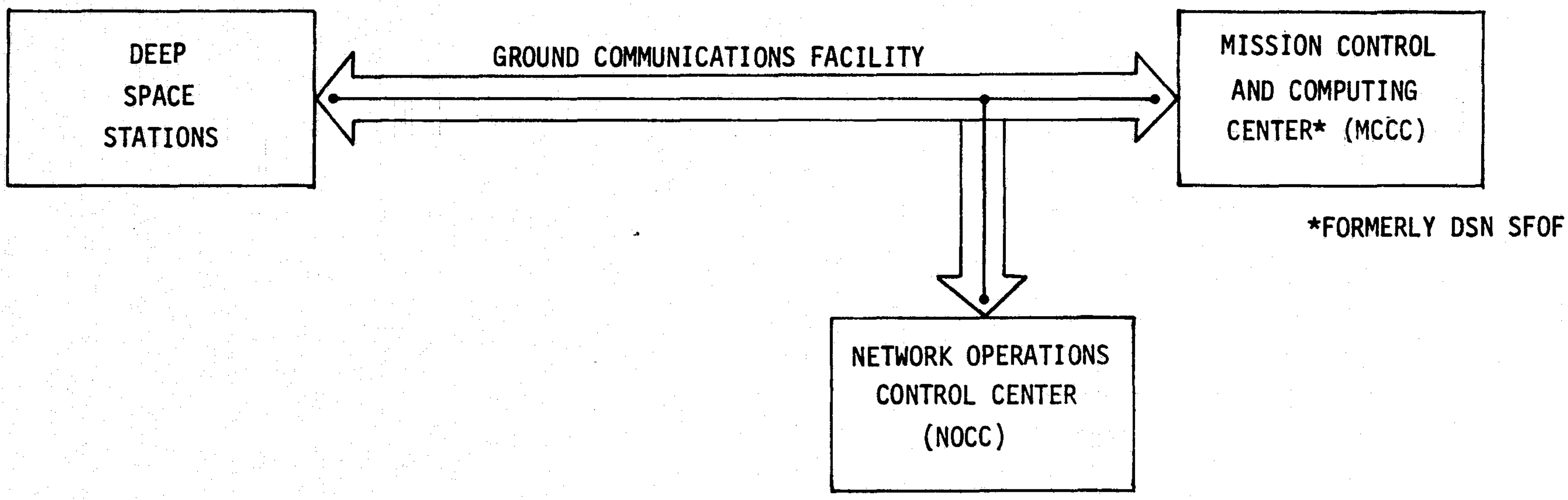


Figure 63. Revised DSN configuration

With these organizational improvements and deletion of the complex SFOF functions, the Mission Interface Organization was examined, resulting in the phasing out of the DSN Project Engineer and Assistant DSN Project Engineer functions. As illustrated in Fig. 64, these changes saw only the TDS and DSN Managers retained, while the Network Engineering and Operations Organizations performed those detailed functions which were previously the responsibility of the numerous Project Engineers in the Mission Interface Organization.

It should be obvious that the DSN implementation and operations support effort for MVM'73 was caught in a difficult transition period between what had been and what was to be. The NOCC would take a number of years to be fully implemented; meanwhile, Network operations and support services had to continue. Detailed and sometimes thorny negotiations were required between the DSN and Mission Control and Computing Center to assure that existing DSN capabilities residing in the central processors would continue until DSN Operations Control Center capabilities came on line. Interim arrangements were numerous. However, close attention to technical capabilities without an excessive concern for organizational boundaries served to provide required functions and services.

Schedules which were developed and their interrelationships are illustrated in Fig. 65. Level 2 represented the Project Master Schedule which was published in the Project Management Report. Level 3 was the Project System schedule and included the TDS schedule. Level 4 was reserved for interface schedules between Project Systems. Level 5 represented the top DSN internal schedule; this milestone schedule and corresponding flow chart are contained in the Appendix. Detailed implementation schedules which responded to the DSN level 5 schedule were the responsibility of the DSN Systems Engineering Organization.

The DSN's capability planning activity was a major element of the implementation process. The activity was designed to identify and validate requirements of assigned flight projects, to deal with requirements which exceeded DSN capabilities, to develop functional requirements for new DSN capabilities, and to define the DSN data systems' configurations for each flight project. Formerly organized as a capability planning team for each flight project, the capability planning activity was redirected as a multiple mission effort to be accomplished as a part of the DSN Systems Engineering Organization. Hence the DSN Mission Interface Support Organization (TDS Manager, DSN Manager, and DSN Project Engineer) served as the primary interface between the MVM'73 Flight Project and the DSN Systems Engineering Organization. Figure 66 outlines the various steps of the capability planning activity.

Each box on the flow chart represents an activity; the responsible person or organization is indicated in the top portion of each box. Based on inputs from the TDA Office, the DSN Systems Engineering Manager provided technical and scheduled guidelines for the implementation activity based on the approved mission set. These schedules were fully coordinated to maintain consistency between Project requirements and on-going DSN development activities. For each flight Project, the DSN Systems Engineers prepared a set of system diagrams indicating

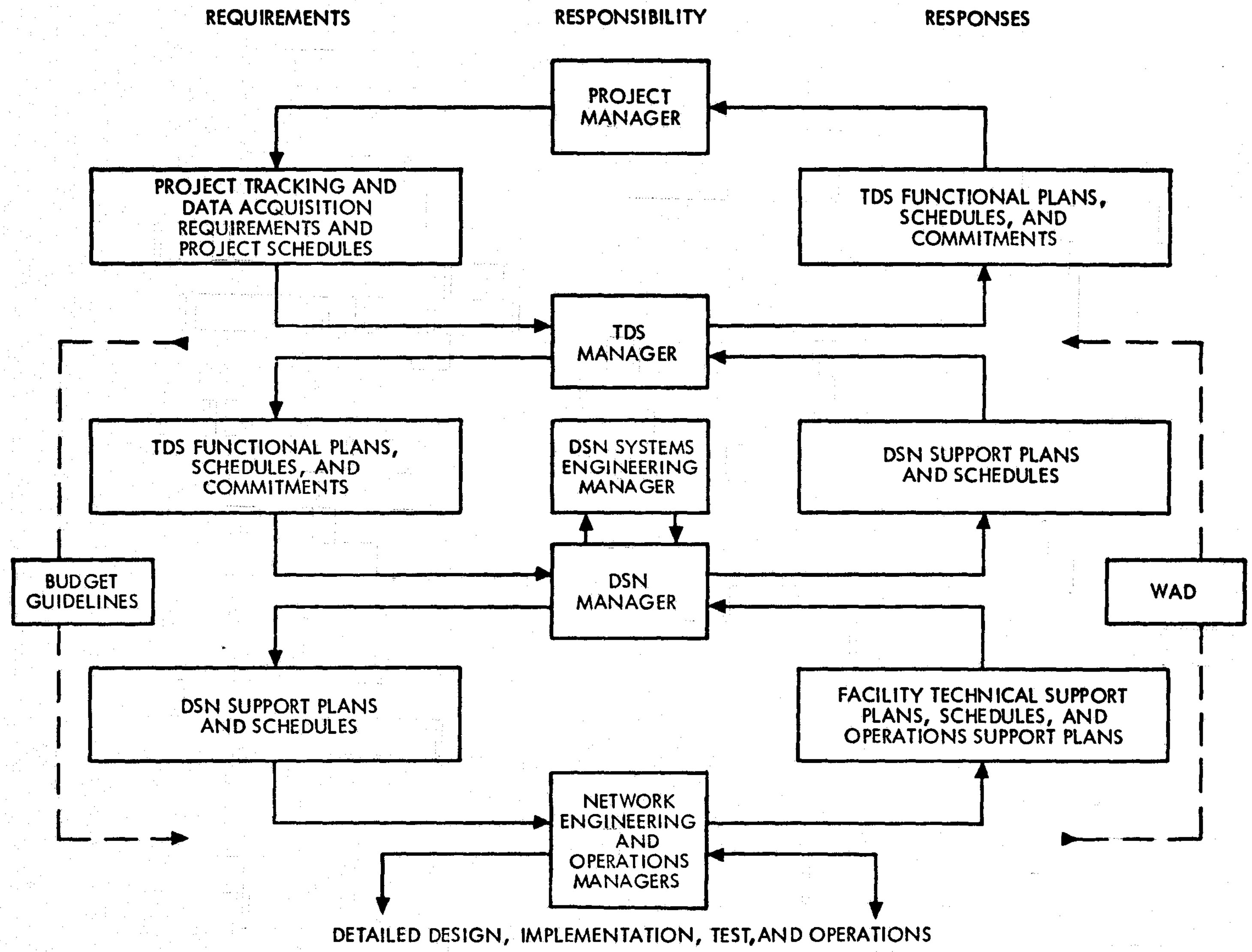


Figure 64. Revised DSN mission interface support process

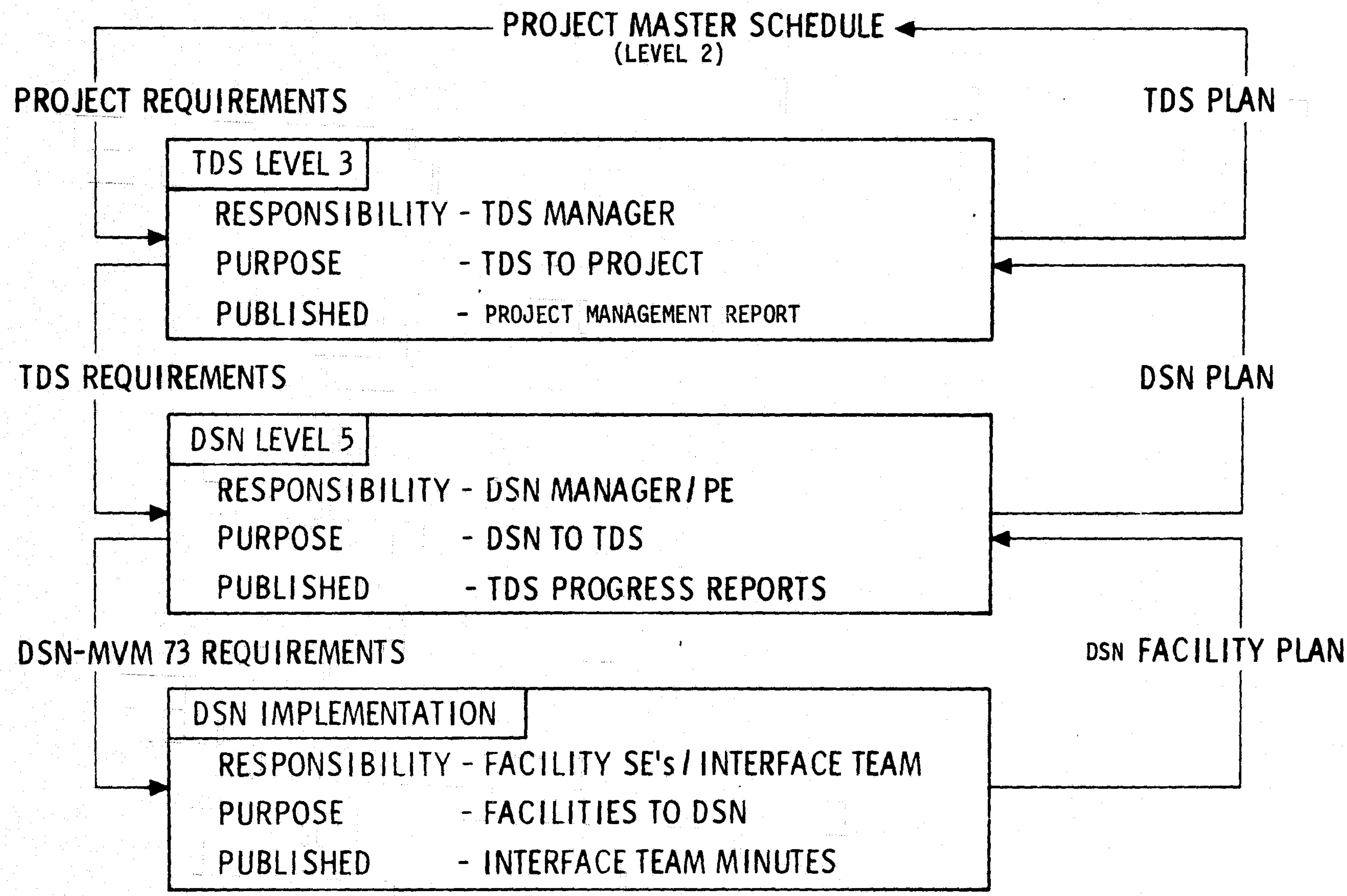


Figure 65. Schedule relationships

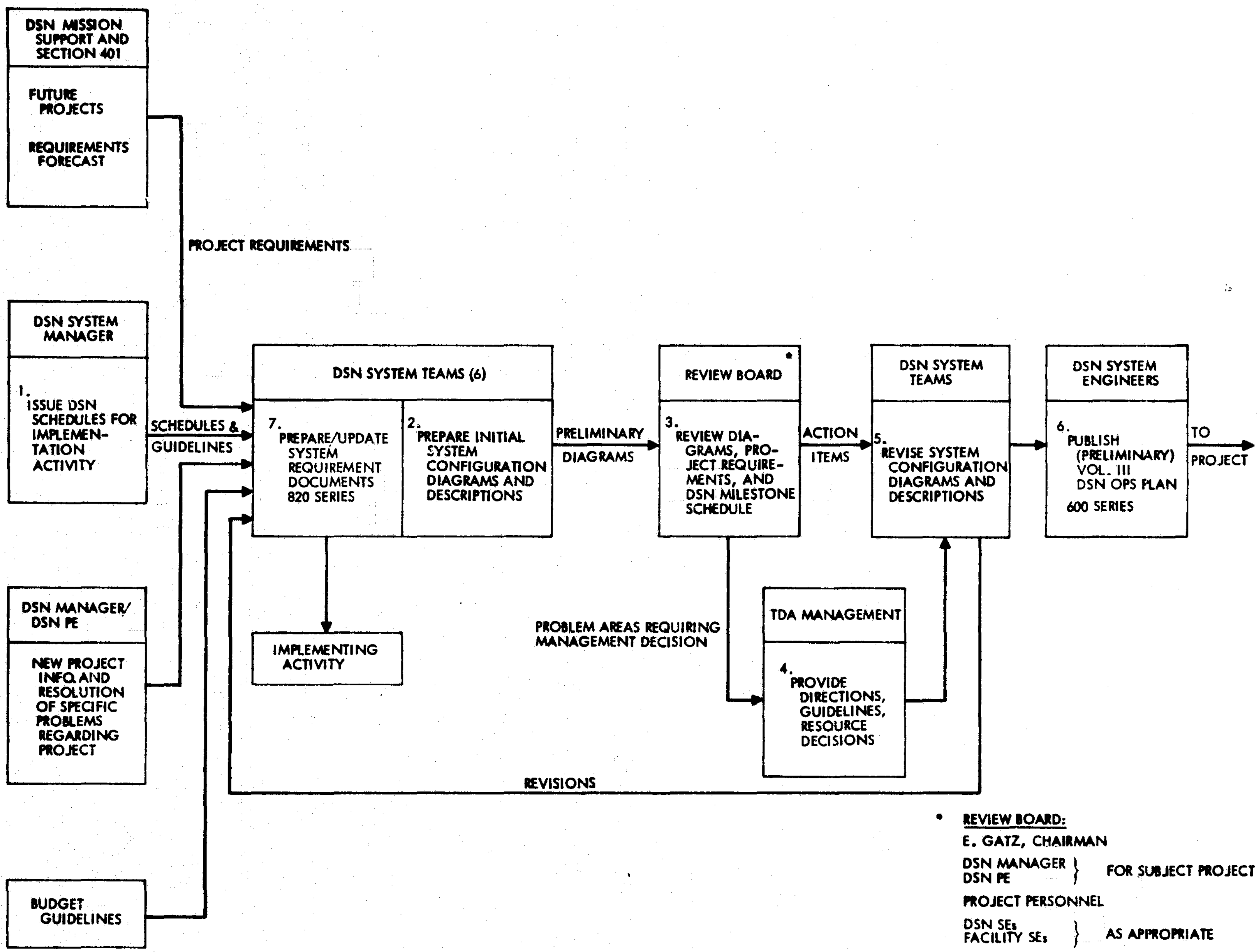


Figure 66. Capability planning activity steps

specific functional performance parameters and configurations applicable to the particular flight project. Inputs for the initial system diagrams were generally derived from the long-range requirements forecast with specific inputs provided by the mission interface support organization. The DSN Manager and DSN Project Engineer for MVM'73 also coordinated any new and special requirements with the DSN System Engineers and participated in the preparation of configuration diagrams. A special review board was convened to review the system diagrams and to determine that all Project requirements had been met or that action was taken to resolve discrepancies. The Board also reviewed the DSN Level 5 milestone schedule for MVM'73 and concurred that the milestones were consistent with DSN implementation plans. DSN System Engineers were responsible for overall conduct of the reviews, and for maintaining integrity of the DSN data systems. The DSN Manager and DSN Project Engineer were responsible for providing the validated Project requirements along with the negotiated capability and scheduled commitments. Project personnel were included on the Board to provide interpretation of Project functions and requirements and, where necessary, to negotiate to gain compatibility between requirements and network capability. Facility managers were represented by the Facility system engineers and were primarily responsible for detailed technical design and implementation schedules. Following the system reviews, the system configuration diagrams were prepared for publication subject to the approval of the DSN Project Engineer for MVM'73.

As was customary on previous projects, a DSN interface team was developed for MVM'73. The primary objective of the team was to achieve DSN operational readiness for MVM'73. Operational readiness was defined to include: (1) definition and documentation of mission-dependent configurations and interfaces, (2) integration of mission-dependent software, (3) publication of operating procedures, (4) operations personnel training, (5) verification of configurations, interfaces, and procedures, and (6) formal transfer of capabilities to the DSN Operations Group. The secondary objective was to assist the DSN Operations Team in accomplishing mission support commitments through proper execution of the DSN operations plan for MVM'73. The interface team was organized and chaired by the DSN Project Engineer for MVM'73. On June 11, 1971, formal assignment of personnel to the team was requested, and assignments were subsequently made, with two exceptions due to budget limitations (see Fig. 5 for listing of team members). The DSN Interface Team normally met once each week and specific responsibilities included the following:

(1) On the basis of validated requirements, DSN commitments, and system capability, accomplish detailed definition and documentation of DSN interfaces with the project.

(2) On the basis of validated requirements, DSN commitments, and system capabilities, accomplish detailed descriptions of facility configurations for MVM'73 and prepare detailed mission-dependent operating procedures to accommodate mission operations,

(3) Document DSN configurations and operational procedures in the DSN Operations Plan for MVM'73,

(4) Prepare integration plans for mission-dependent software,

(5) Design and execute a test and training program to achieve and verify DSN operational readiness and transfer the mission-dependent network configuration to the DSN Operations Group,

(6) Provide quarterly inputs to the TDS Progress Reports for MVM'73 covering accomplishments, plans, and problem areas during the prelaunch phase,

(7) Monitor and evaluate DSN performance during the flight operations phase and produce monthly summaries covering support vs commitments, adequacy of operations plans, deficiencies, recommended changes to configurations and procedures,

(8) Closely monitor facility mission-independent implementation plans to assure availability of resources to meet commitments to MVM'73,

(9) Participate in Project planning and design teams as necessary to maintain coordinated effort between DSN and the Flight Project.

Validation and evaluation of DSN plans and progress for MVM'73 were accomplished by a series of formal reviews. Per agreement with the Project, some of these reviews were conducted jointly with the Mission Operations System; however, prior to such joint reviews the DSN conducted informal internal reviews. A joint Mission Operations System/DSN functional design review was held in December 1971. The primary objective was to ascertain that the DSN's end-to-end functional design properly accommodated the Flight Project requirements.

Since the review followed closely the previously discussed NASA directive regarding separation of support functions, a large amount of uncertainty existed regarding new interfaces and responsibilities for data processing. However, the end-to-end design was satisfactorily presented and the uncertainties were subsequently resolved through a series of meetings with the TDA Office and OCIS. The telemetry and command data handling subsystem software functional design review was held separately in June 1972. The purpose was to review and validate DSIF telemetry and command processor assembly and data decoder assembly software functional design for the MVM'73 time period. This review was the responsibility of the telemetry and command data handling subsystem software development project engineer and was held separately prior to the DSN detailed design review. The DSN detailed design review was held in July 1972, with the primary purpose being to review and validate DSN detailed plans, design, and configurations for MVM'73. This again, was a joint MOS/DSN review, covering an end-to-end description of the ground data system.

The DSN Manager was responsible for the DSN portion of the review. DSN facility representatives to the DSN Support Team presented each facility's design. The review included configuration diagrams, data flow and performance narratives, interface descriptions, unsupported requirements and problem areas, test and training plans, and implementation schedules as well as the summary of the results of the previously held telemetry and command data handling subsystem software functional design review.

The first detailed design review for the telemetry and command data handling subsystem software was held in October 1972. This review followed the preparation of detailed specifications and flowcharts. A DSN implementation progress review was held in February 1973. The second review of the telemetry and command data handling subsystem software detailed design was held in March 1973, following completion of design verification testing in order to evaluate the design in view of test results. DSN test and training readiness reviews were scheduled in January and March 1973. The primary purpose was to review test and training plans and schedules to verify that the preparations for the test and training phase were satisfactory. This was a DSN internal review chaired by the DSN Manager. The review was conducted in two parts: Part one dealt with the facility preparations for software testing and mission-independent integration, testing, and training pertaining to the implementation of new resources. Part two dealt with the facility preparations for mission-dependent testing and training. Presentations included: results of mission-independent test and software acceptance test, mission-dependent test and training plans and schedules, test and training objectives and evaluation criteria, test and training reports, and cross support requirements.

The DSN Operational Readiness Review was held in September 1973, with the purpose of confirming the state of DSN operational readiness to support mission operations test and training based on the results of DSN internal tests. Special attention was given to problem areas, discrepancy reports, and to the preliminary results of DSN spacecraft compatibility tests. Finally, the DSN supported the Project launch readiness review in October 1973. This review verified DSN readiness to support mission operations.

A series of formal reports provided for communication of DSN implementation progress. The DSN Manager made monthly inputs to the Project Management Report which consisted of updates to the Level 3 schedule along with a narrative analysis. The DSN Manager and DSN Project Engineer prepared quarterly tracking and data system progress reports which included a summary of accomplishments, evaluation and performance compared to plans, problem areas, and an update of the Level 5 schedule. Facility status reports were the responsibility of the DSN System Engineering organization and the DSN Operations Project Engineer. These reports were prepared monthly and included an update of the detailed implementation schedule along with the narrative analysis of progress, forecast, problem areas, and justification for changes to the plan. Upon completion of each scheduled test or test phase, the test supervisor was required to prepare and forward a test report to the DSN Manager. These reports included the test title, supervisor, date objectives, acceptance criteria, test configuration, test log, results, comparison of results vs acceptance criteria and objectives, the summary of any problems, and recommendations. Upon completion of each major training course or training phase, facility training supervisors were required to submit training reports to the DSN Manager. These reports included the training course title, dates conducted, objective, trainee names, results, including an evaluation of the trainees' ability to adequately execute the DSN operations plan for MVM'73. In the flight phase, the DSN Operations Organization was required to submit monthly reports to the DSN Manager. These reports were to give an assessment of the support provided vs the commitments and were to include an assessment of the quality and quantity of real-time data delivery as well as the non-real-time data products. A discrepancy report summary, problem evaluation narrative and recommendations for changes and operational procedures or configurations were also required.

All projects are concerned with configuration management and the control of the DSN's configurations during the life of their missions. MVM'73 was no exception. It was agreed that the Project-developed configuration and change control procedures would apply to, but not beyond, the Project-DSN interfaces. These interfaces were defined in the MOS-TDS-MCCC-Spacecraft Interface Control Document. Changes which would have altered controlled interfaces required approval of the interfacing organizations prior to implementation. For all other changes, the DSN employed its internal change control process and no Project approval was required; however, close coordination was the rule regarding internal changes which altered DSN configurations and capabilities as the mission progressed. The applicable controlled interfaces for MVM'73 are listed in Table 20.

2. Network Implementation and Configurations

The remainder of this section provides a summary of the DSN implementation activities which took place to develop required capabilities. Diagrams illustrate the configurations and data flow through the various Network systems. The implementation discussion concludes with a review of the DSN test and training activities which were conducted to complete the implementation process and to achieve mission support readiness.

The deep space stations for MVM'73 consisted of a subnet of 64-m stations and a subnet of 26-m stations as listed in Table 21. Special test stations at JPL and at Cape Kennedy were also used to test and demonstrate the spacecraft interface compatibility with the Network. For the purposes of implementation and planning, each deep space station was considered to consist of the eleven subsystems listed in Table 22. Subsystem assemblies, also listed in Table 22, varied little in regard to name from station to station. However, there were significant differences in quantities, types, and key characteristics of certain assemblies. The annotated flow diagram in Fig. 67 serves as a general reference for correlating and illustrating data handling relationships. Assembly quantity differences between 64-m, 26-m, and co-located stations are given in Table 23. One should note that DSS 14 reflects a significant difference since it was the only station to be equipped with dual frequency assemblies. Implementation in the DSN is authorized through Engineering Change Orders and some 53 changes were approved for MVM'73, as listed in Table 24.

Table 20. Mission operations complex interfaces

MCCCS/TDS interface
1. Command enable/disable messages
2. Command recall request messages
3. Simulated telemetry blocks
4. Simulated tracking blocks
5. Simulation conversion assembly (SCA) control blocks
6. SCA text blocks
7. Tracking blocks
8. Monitor status blocks
9. Teletypewriter (TTY) tracking formats
10. Telemetry blocks - high-speed data
11. Command verification blocks
12. Command confirmation/abort blocks
13. Command recall response blocks
14. Command alarm blocks
15. Telemetry blocks - wide-band data
16. 117.6 kbps input format to word formatter assembly (WFA)
17. 117.6 - WFA electrical input
18. WFA - 230 kbps format
19. WFA - electrical output
20. Digital TCP telemetry original data record (ODR) format
21. Digital DDA telemetry ODR format
22. Building AO electrical output - wide-band and high-speed data
23. GCF high-speed data electrical interface

Table 20 (contd)

MCCCS/TDS interface (contd)
24. High-speed data filler blocks
25. TTY electrical
26. Simulation 28.5 kbps wide-band data telemetry blocks
27. GCF electrical 28.5 kbps wide-band data
28. GCF electrical 117/230 kbps wide-band data
29. Voice interface hardware
30. Wide-band data filler blocks
MOS - TDS interface
1. Applications technology satellite (ATS) ionosphere
2. Weather data digital tape
3. Open-loop receiver digital tape
4. Manual command format
TDS/spacecraft interface
1. RF link boundaries
2. Spacecraft transmit/receive parameters
3. DSIF transmit/receive parameters
4. Combined spacecraft/DSIF parameters

Table 21. Deep space stations configured for MVM'73

Stations	Location
64-m subnet	
DSS 14	California
DSS 43	Australia
DSS 63	Spain
26-m subnet	
DSS 12	California
DSS 42	Australia, co-located with DSS 43
DSS 61	Spain, co-located with DSS 63
DSS 62	Spain
Compatibility test	
CTA 21	JPL
DSS 71	Cape Kennedy, Florida

Table 22. Subsystems and assemblies

DSIF antenna mechanical subsystem
1. Angle data assembly 2. Servo assembly
DSIF antenna microwave subsystem
1. Feed assembly 2. Amplifier assembly 3. Test signal control assembly
DSIF receiver/exciter subsystem
1. Exciter assembly 2. Receiver assembly 3. Open-loop receiver assembly 4. Ranging (modulation-demodulation) assembly 5. Doppler extractor assembly 6. Subcarrier demodulator assembly 7. Test transmitter assembly
DSIF transmitter subsystem
1. Power amplifier assembly
DSIF pre/post detection recording subsystem
1. Occultation recording assembly 2. Analog recording assembly
DSIF telemetry and command subsystem
1. Command modulation assembly 2. Symbol synchronizer assembly 3. Block decoder assembly 4. Telemetry command processor assembly 5. Data decoder assembly

Table 22 (contd)

DSIF telemetry and command subsystem (contd)
6. Digital recording assembly 7. Simulation conversion assembly
DSIF ranging subsystem
1. Digital assembly
DSIF TDS subsystem
1. Angle encoder assembly 2. Doppler-ranging assemblies 3. Recording assembly
DSIF monitor and control/digital instrumentation subsystem
1. Line printer assembly 2. Central processor assembly 3. Recording assembly 4. Station monitor-console assembly 5. Communications buffer assembly 6. Monitor/operations control assembly
DSIF antenna pointing subsystem
1. Central processor assembly
DSIF frequency and timing subsystem

Table 23. DSIF assembly quantity variations

DSS type	RCV	SDA	SSA	BDA	DDA type I	DDA type II	TCP	SCA	CMA	HSDL	WBDL	TTY
Single 64-m DSS 14	2	3	2	2	0	2	2	1	2	1	1	3
Joint 26/64-m total equipment 42/43 and 61/63	4	5	3	2	1	2	3	1	3	2	1	3
Joint equipment allocation 64-m 43 and 63[a]	2	3	1	2	0	1	1	0	1	1	0	1
Shared equipment 26/64-m[a]	0	0	1	0	0	1	1	1	1	0	1	1
26-m 42 and 61[a]	2	2	1	0	1	0	1	0	1	1	0	1
Single 26-m 12, 61, 62	2	2	2	0	2	0	2	1	2	1	0	2

DSS 14 equipment for S/X experiment

X-cone	S/X receiver (block IV)	S/X ranging assembly
X-maser	S/X open-loop receiver	Block IV exciter
X-test transmitter	S/X doppler extractor	100-kW transmitter

[a]Joint equipment allocation

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Table 24. DSN engineering change orders for MVM'73

Item	ECO/subsystem number	Description	Network/DSS(s) requirements
1	72.188(01.0)	SDA-10 MHz notch filter	64-m, 12, 42, 62, 71 and CTA 21
2	72.154(11.4)	SCA-interplex mod	64-m, 12, 42, 62, 71 and CTA 21
3	72.147(11.4)	SCA-HSD tracking data turnaround	12, 14, 62, 71 and CTA 21
4	72.280(29.0)	S/X block up date	14 only
5	72.263(30.4)	SSA selector ch. address in DDA for MVM'73	64-m, 12, 42, 62, 71 and CTA 21
6	71.035 (11.0, 30.0)	Add DDA and HDR	64-m, 12, 42, 62, 71 and CTA 21
7	71.181(11.0)	CMA/TCP noise inhibit	64-m, 12, 42, 62, 71 and CTA 21
8	72.070(11.2)	Increase TCP-SDA interface	43 and 63
9	72.007(29.0)	Change floor plan and block diagram to reflect implementation	43 and 63
10	72.224(51.6)	Add 230 kbps WB at DSS 14 and DSC 10	14 and DSC 10
11	72.269(30.0)	Provide cable from HS/WBDL to DDA patch panel	64-m, 71 and CTA 21
12	72.288(30.5)	SSA/word formatter mod for 117.6 kbps	14 only
13	68.110(01.0)	Zero delay device	14 only
14	67.013(01.0)	Zero delay device	12, 42, 43, 62 and 63

Table 24 (contd)

Item	ECO/subsystem number	Description	Network/DSS(s) requirements
15	72.038(01.0)	Install ranging demodulator assembly	12, 43, 63, 71 and CTA 21
16	72.244(04.0)	TDH/DIS mod. for HSD radio metric data	64-m, 12, and 62
17	73.097(12.0)	FR-1400 VCO modification	64-m, 12, 42, 62, 71 and CTA 21
18	73.096(33.4)	Temporary installation of two FR-1400s for occultation data	14 only
19	73.002(33.0)	Modify CTA 21 occultation digitizing equipment	14 and CTA-21
20	72.250	Interim 28.5 kbps WB-station internal	14 and CTA 21
21	72.146(01.0)	1 MHz bias doppler for PRA	12, 43, 63, 71 and CTA 21
22	72.160(30.4, 30.6)	SSA/DDA couplers-DDA H/R mod	64-m, 12, 42, 62, 71 and CTA 21
23	72.163(30.0)	DDA expansion ROM	64-m, 12, 42, 62, 71 and CTA 21
24	72.165(08.0)	Add 2nd CRT to SMC	14 only
25	72.246(30.4)	TCP interrupt ISW Test	64-m, 12, 42, 62, 71 and CTA 21
26	72.262(30.4)	Add jumper cables to W23 (GND all twisted pairs)	64-m, 12, 42, 62, 71 and CTA 21
27	73.015(37.3)	Install 4th harmonic filter on S-band XMTRS	14 only
28	73.023(11.0)	CMA noise inhibits	64-m, 12, 42, 62, 71 and CTA 21

Table 24 (contd)

Item	ECO/subsystem number	Description	Network/DSS(s) requirements
29	72.037(5.1)	Combine CMD and MON outputs on AB dick printer	64-m, 12, 42, 62 and CTA 21
30	71.068(1.0)	Route CMA CMD mod signal to receiver oscilloscope	64-m, 12, 42 and 62
31	73.038(30.7, 3.0)	Modify ranging sub-system to accommo-date command signal verification while ranging	64-m, 12, 42, 62, 71 and CTA 21
32	73.011(29.0, 16.6)	Add 28.5 kbps WB cables from DDA to DIS	14, 71 and CTA 21
33	73.033(29.0, 16.6)	Replace AIS/REC with PPR	12 and 14
34	72.150(30.6)	Correct noise sensi-tivity problem in BDAs	64-m, 71 and CTA 21
35	72.159(4.0)	VCO counter and sample rate drawer MOD	64-m, 12 and 62
36	72.132(1.0, 29.0)	Add programmed oscil-lators to BLK III exciter/receiver	14 and 43
37	72.244(5.9)	Change monitor and control software to include tracking data processing and out-putting via HSD	64-m, 12 and 62
38	71.154(5.1)	Add pot buffers to DIS to drive HSD and CRT	64-m, 12, 42, 62 and CTA 21
39	73.001(29.0)	Install S/X zero delay device	14 only

Table 24 (contd)

Item	ECO/subsystem number	Description	Network/DSS(s) requirements
40	73.040(11.2, 30.1)	Add GCF block interface to TCP. Install cable W 700 Fm HSD/WB to TCP	64-m, 12, 42, 62, 71 and CTA 21
41	72.292(51.3)	Interface CJM with 3 CH, HSDAs and XDS920/910	64-m
42	73.055(51.3)	Reconfigure CJM and monitor interface	12, 62, 71 and CTA 21
43	72.038(34.3)	Install planetary ranging assembly	12, 43, 63, 71 and CTA 21
44	72.278(30.4)	Add C80 PF capacitor to EBD for 70 bit problem	64-m, 12, 42, 62, 71 and CTA 21
45	72.230(30.0)	CMA switch modification	14 only
46	73.080(30.4)	Correction of WBD cable assembly, J32 and J33 connectors	64-m, 12, 42, 62, 71 and CTA 21
47	73.064(5.9, 11.9, 29.9)	RCV-SDA equipment numbering at conjoint DSS. Correction to TCD and monitor S/W	42, 43 and 63
48	73.105(13.0)	Planetary ranging time modification	12 only
49	73.124	Planetary ranging	12 only
50	72.175	Provide linear 10-mHz output for FR-1400 and station microwave equipment	12 and 14
51	73.059(1.4)	Modify Blk III OLR to provide multimission occultation capability	14 and 43

Table 24 (contd)

Item	ECO/subsystem number	Description	Network/DSS(s) requirements
52	73.066(1.0)	Correct unstable condition in CMD confirmation phase detector	64-m, 12, 42, 62, 71 and CTA 21
53	72.185(11.4)	Modify PMIC mother board to eliminate memory parity errors	64-m, 12, 42, 62, 71 and CTA 21

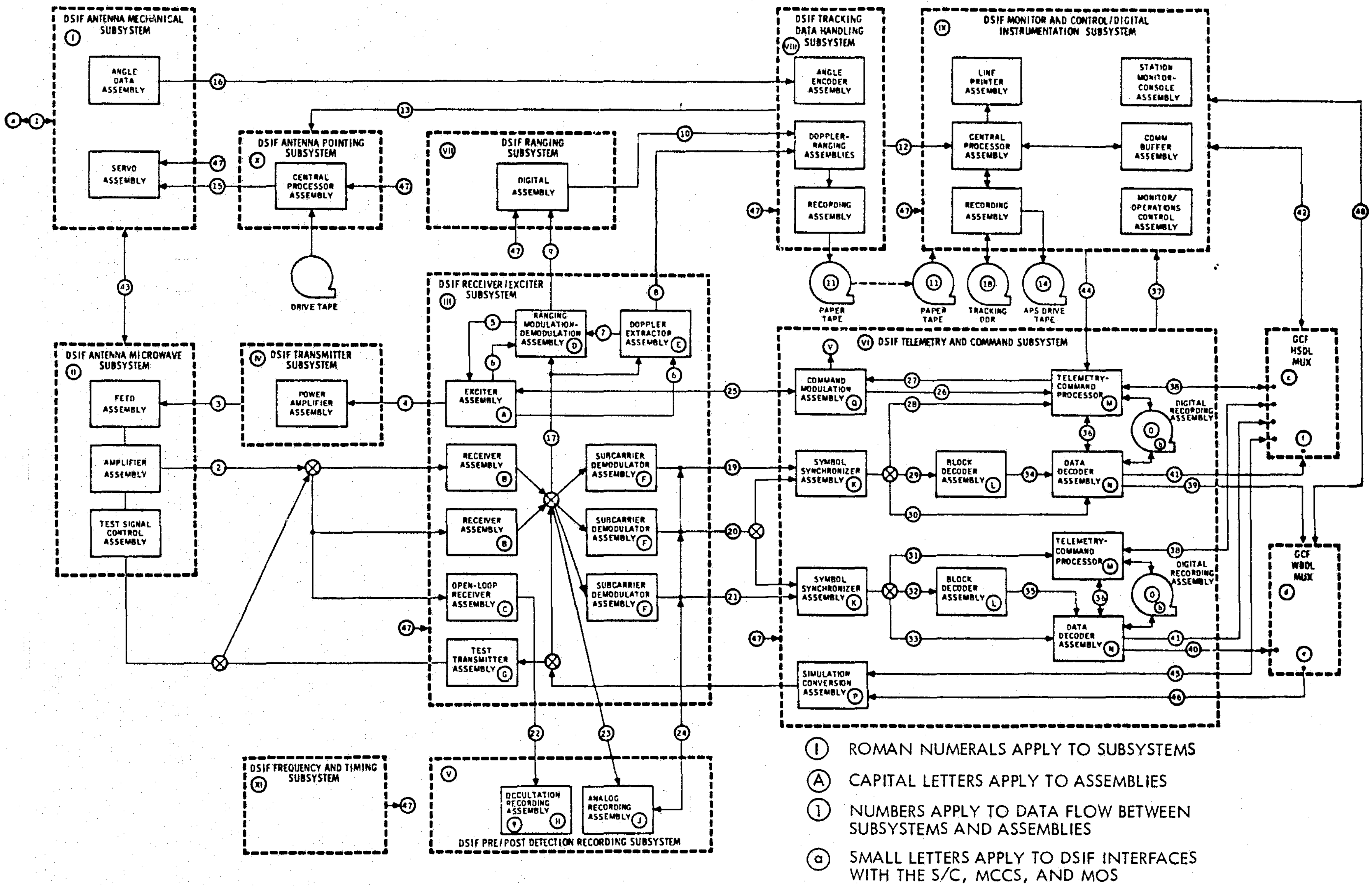

Figure 67. Typical deep space station subsystems and data flow

DATA FLOW FOOTNOTES FOR FIGURE 67
(Sheet 1 of 3)

DATA FLOW	
(1)	S-Band uplink and downlink RF Carrier. Downlink includes interplex modulation, range modulation, and telemetry data modulation
(2)	Amplified S-band reference carrier. Sum channel RF signals containing angle of arrival error, carrier frequency and phase, range code modulation, and telemetry modulation information
(3)	Amplified phase modulated uplink carrier
(4)	Phase modulated exciter carrier
(5)	Block III, S-band range modulation and range code
(6)	Exciter reference frequency
(7)	Block III, S-band doppler, unbiased
(8)	Block III, 1 MHz biased S-band doppler
(9)	Demodulated range and Differenced Range Versus Integrated Doppler (DRVID) information
(10)	Block III, S-band range, and DRVID digital data
(11)	Radio metric data punched paper tape
(12)	Tracking Data Handling Subsystem (TDH) tracking data output to DSIF Monitor and Control Subsystem for formatting (angles, range, DRVID, doppler
(13)	Angle data
(14)	Angle drive tape for Antenna Pointing Subsystem (APS) and predict page print for operations personnel
(15)	Antenna pointing commands
(16)	Angle readouts
(17)	10 MHz Intermediate Frequency (IF) spectrum (non-detected) signal
(18)	Tracking ODR on magnetic tape for non-real-time recall via DSIF Monitor and Control Subsystem (DMC). Includes associated data such as lock status, time, frequency, data condition, and calibration

DATA FLOW FOOTNOTES FOR FIGURE 67
(Sheet 2 of 3)

(19)	Binary telemetry waveform from one subcarrier
(20)	Backup Subcarrier Demodulator Assembly (SDA) output channel to either Symbol Synchronizer Assembly (SSA)
(21)	Binary telemetry waveform from second subcarrier
(22)	Non-detected, modulated carrier spectrum
(23)	Block III receiver 10 MHz IF spectrum signal
(24)	Binary telemetry waveforms from two subcarriers
(25)	Command modulated subcarrier to the exciter. Reference frequency from the exciter
(26)	Detected Command Modulator Assembly (CMA) output for confirm or abort action and status/control information
(27)	Command word bits and control information
(28)	Routing for low-rate data, uncoded, 8-1/3 bps or 33-1/3 bps, first subcarrier
(29)	Routing for coded 490 bps or 2450 bps data first subcarrier or alternate routing of 7.35 Kbps and 22.05 Kbps second subcarrier
(30)	Alternate routing of 117.6 Kbps uncoded data
(31)	Alternate routing low rate, uncoded 8-1/3 bps or 33-1/3 bps
(32)	Routing for 7.35 Kbps and 22.05 Kbps, coded, data. Alternate routing for 490 bps or 2450 bps, coded, data
(33)	Routing for 117.6 Kbps, uncoded, data
(34)	Decoded telemetry data
(35)	Decoded telemetry data
(36)	Control instructions to DDA and response/status information to TCP
(37)	Command/telemetry monitor data, configuration, and status
(38)	Input to TCP: telemetry and command, recall request, enable/disable messages via High-Speed Data Line (HSDL). Output: high-speed data blocks for command verification, recall response, confirm/abort and alarm messages, and low-rate telemetry data

DATA FLOW FOOTNOTES FOR FIGURE 67
(Sheet 3 of 3)

(39) & (40) High-rate telemetry via 1200-bit wideband data blocks

(41) Telemetry (490 bps or 2450 bps) via 1200-bit high speed data blocks

(42) Input to DMC includes DSS predicts, standards/limits, configuration instructions, operational instructions, sequence of events (SOE), and schedules. Output includes high-speed tracking data and station monitor and control data/status

(43) Focused RF signal

(44) Manual command mode enable and display control signals (Actual Command input via TCP/920 keyboard)

(45) Simulated telemetry data from 6050 computer via HSDL

(46) Simulated telemetry data from 6050 computer via wideband data line (WBDL)

(47) Frequency and Timing to other DSIF subsystems

(48) Telemetry data validation loop

DATA INTERFACES*

(a) RF interface

(b) Recorded telemetry data tapes, non-real-time interface

(c) High-Speed System (HSS) interfaces tracking, telemetry, command and monitor data, real-time

(d) Wideband System (WBS) interface, telemetry, real-time

(e) WBS interface, simulated telemetry data

(f) HSS interface, simulated telemetry data

(g) Open-loop recording, nonreal-time

*DSS 14 interfaces with the Project supplied word formatter constitute a special configuration for real-time transmission of 117.6 Kbps to JPL. Also ground weather data (DSS 14) and ionosphere data (DSS 13) are provided by special R&D equipment. These interfaces are not illustrated.

a. Telemetry System Implementation and Configuration. New implementation in the DSN telemetry system for MVM'73 as a function of the requirements given in Section II was associated primarily with the spacecraft's interplex modulation and very high data rates. Twenty-10-MHz notch filters and special alignment procedures were provided to the assigned deep space stations for subcarrier demodulator assembly interplex mode capability modifications. Special coupler modifications were developed between the symbol synchronizer assembly and the data decoder assembly for the handling of high-rate data at the 64-m stations. Furthermore, dual high-density digital recorder assemblies were installed at the data decoder assembly to provide for a deep space station original data record of all high-rate data received. At DSS 14, special steps were taken to implement a capability for real-time transmission of MVM'73's highest data rate of 117.6 kbps. Word formatter assemblies were provided by the Project and were installed by the DSN to serve as an output device between DSS 14's symbol synchronizer assembly and the GCF supergroup communications channel. Special symbol synchronizer assembly/word formatter assembly interface couplers were developed for this purpose.

A major effort was devoted to the development of new telemetry software for the deep space stations' telemetry and command processors and data decoder assemblies. Normally, the TCP could accommodate data rates of 2000 bps or less; however, improvement of existing software permitted MVM'73's 2450-bps rate to be handled at all stations. A second software module was developed for use in the 64-m stations' data decoder assemblies to handle and record all rates above 2450 bps through 117.6 kbps. Since real-time communications of telemetry data from the overseas 64-m stations was limited to the 22.05-kbps rate via a 28.5-kbps circuit, a third software module was developed to accommodate near-real-time transmission of high rates via original data record tape replay at a reduced rate of 28.5 bps. It is noteworthy that the Telecommunications Division's Digital Systems Development Section created and employed various new techniques for managing and controlling the development of these software modules. A significant improvement was realized in the quality and on-schedule delivery of this software compared to efforts on past projects. These procedures are being refined and extended to development of all future DSN software programs.

The 26-m stations were normally configured for the low-rate subcarrier, 88.55-kHz noninterplex mode. The 64-m stations were normally configured for the high- and low-rate subcarriers, 177.1- and 88.5-kHz interplex mode. References to "conjoint stations" pertain to DSS 42/43 and to DSS 61/63, which involves separate but colocated 26- and 64-m antennas sharing a common control room and data handling equipment. The conjoint stations' telemetry configuration is provided in Table 25 and Fig. 68. A special Mercury encounter configuration for DSS 42 and 43 is provided in Fig. 69. The telemetry configuration of DSS 14 is given in Table 26 and Fig. 70. A special DSS 12/14 configuration for Mercury encounter support is illustrated in Fig. 71. The standard 26-m configuration is provided in Table 27 and Figs. 72 and 73. Figure 74 shows the configuration for near-real-time replay of 117.6-kbps data from DSS 43 and DSS 63. Table 28 gives key information which was required to configure station equipment for the various telemetry modes during the mission.

Table 25. Conjoint DSS MVM'73 standard telemetry and command configuration

64-m DSS

Telemetry rate	RCV 1	RCV 2	SDA 1	SDA 2	SDA 3	SSA 1	SSA 2	BDA 1	BDA 2	DDA 1	DDA 2	TCP 1	TCP 2	CMA 1	CMA 2	EXC	20-kw TX	HSDL 1	HSDL 2	WBDL
117.6 kbps	✓	B	✓	B		✓				✓		✓		✓	B	✓	✓	✓	B	✓
22.05 and 7.35 kbps	✓	B	✓	B		✓		✓		✓		✓		✓	B	✓	✓	✓	B	✓
2450 and 490 bps	✓	B		B	✓		✓		✓		✓		✓						B	
33 1/3 and 8 1/3 bps	✓	B			✓		✓				✓		✓	✓	B	✓	✓	✓	B	

26-m DSS

Telemetry rate	RCV 5	RCV 6	SDA 7	SDA 8	SSA 2	SSA 3	DDA 2	DDA 3	TCP 2	TCP 3	CMA 2	CMA 3	EXC	10-kW TX	HSDL 1	HSDL 2
2450 and 490 bps	✓	B	✓	B	B	✓	B	✓	B	✓	B	✓	✓	✓	B	✓
33 1/3 and 8 1/3 bps	✓	B	✓	B	B	✓	B	✓	B	✓	B	✓	✓	✓	B	✓

Note: B = backup.

Table 26. DSS 14 standard telemetry and command configuration, MVM'73

Telemetry rate	RCV 1	RCV 2	SDA 1	SDA 2	SDA 3	SSA 1	SSA 2	BDA 1	BDA 2	DDA 1	DDA 2	TCP 1	TCP 2	CMA 1	CMA 2	EXC 1	EXC 2	20 kW	400 kW	HSDL	28.5 kbps WBDL
117.6 kbps	✓	B	✓	B		✓				✓		✓		✓	B	✓	B	✓	B	✓	B
22.05 and 7.35 kbps	✓	B	✓	B		✓		✓		✓		✓		✓	B	✓	B	✓	B	✓	✓
2450 and 490 bps	✓	B		B	✓		✓		✓		✓		✓							✓	
33 1/2 and 8 1/3 bps	✓	B		B	✓		✓				✓		✓	✓	B	✓	B	✓	B	✓	

Note: B = backup.

Table 27. MVM'73 standard 26-m station telemetry and command configuration (DSS 12 and 62)

Telemetry rate	RCV 1	RCV 2	SDA 1	SDA 2	SSA 1	SSA 2	DDA 1	DDA 2	TCP 1	TCP 2	CMA 1	CMA 2	HSDL
2450 and 490 bps	✓	B	✓	B	✓	B	✓	B	✓	B	✓	B	✓
33-1/3 and 8-1/3 bps	✓	B	✓	B	✓	B	✓	B	✓	B	✓	B	✓

Note: B = backup.

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Table 28. Telemetry configuration table

Spacecraft					Ground			SDA settings			
Data mode	Channel	Data	Mod angle	Record	Inter-plex	Bit rate	Coding	Mod index	Synth	Symbol rate	BW
1	LR	NIS-1	70		No	2450	B/C	11	354200	12-27K	Med
2	LR	NIS-1	70	IM-1	No	2450	B/C	11	354200	12-27K	Med
3	LR	NIS-1	70	NIS-1	No	2450	B/C	11	354200	12-27K	Med
4	LR	NIS-1	16		Yes	2450	B/C	6	354200	12-27K	Med
	HR	IM-1	72			117.6K	U/C	12	708400	56-120K	Med
5	LR	NIS-1	16		Yes	2450	B/C	6	354200	12-27K	Med
	HR	IM-1	72	IM-1		117.6K	U/C	12	708400	56-120K	Med
6	LR	NIS-1	16		Yes	2450	B/C	6	354200	12-27K	Med
	HR	IM-1	72	NIS-1		117.6K	U/C	12	708400	56-120K	Med
10	LR	NIS-1	30		Yes	2450	B/C	9	354200	12-27K	Med
	HR	IM-3	72			22.05K	B/C	12	708400	56-120K	Med
11	LR	NIS-1	30		Yes	2450	B/C	9	354200	12-27K	Med
	HR	IM-3	72	IM-1		22.05K	B/C	12	708400	56-120K	Med
12	LR	NIS-1	30	NIS-1	Yes	2450	B/C	9	354200	12-27K	Med
	HR	IM-3	72			22.05K	B/C	12	708400	56-120K	Med
13	LR	NIS-1	30		Yes	2450	B/C	9	354200	12-27K	Med
	HR	PB-A	72			22.05K	B/C	12	708400	56-120K	Med
14	LR	NIS-2	70		No	490	B/C	11	354200	1200-2700	Med
15	LR	NIS-2	30		Yes	490	B/C	9	354200	1200-2700	Med
	HR	PB-B	72			7.35K	B/C	12	708400	27-56K	Med
16	LR	ENG-A	70		No	2450	B/C	11	354200	12-27K	Med
17	LR	ENG-A	70	ENG-A	No	2450	B/C	11	354200	12-27K	Med
18	LR	ENG-B	41		No	33-1/3	U/C	6	354200	27-56	Med
19	LR	ENG-C	41		No	8-1/3	U/C	6	354200	5.6-12	Med
20	LR	ENG-B	41	IM-1	No	33-1/3	U/C	6	354200	27-56	Med
21	LR	ENG-B	41	NIS-1	No	33-1/3	U/C	6	354200	27-56	Med

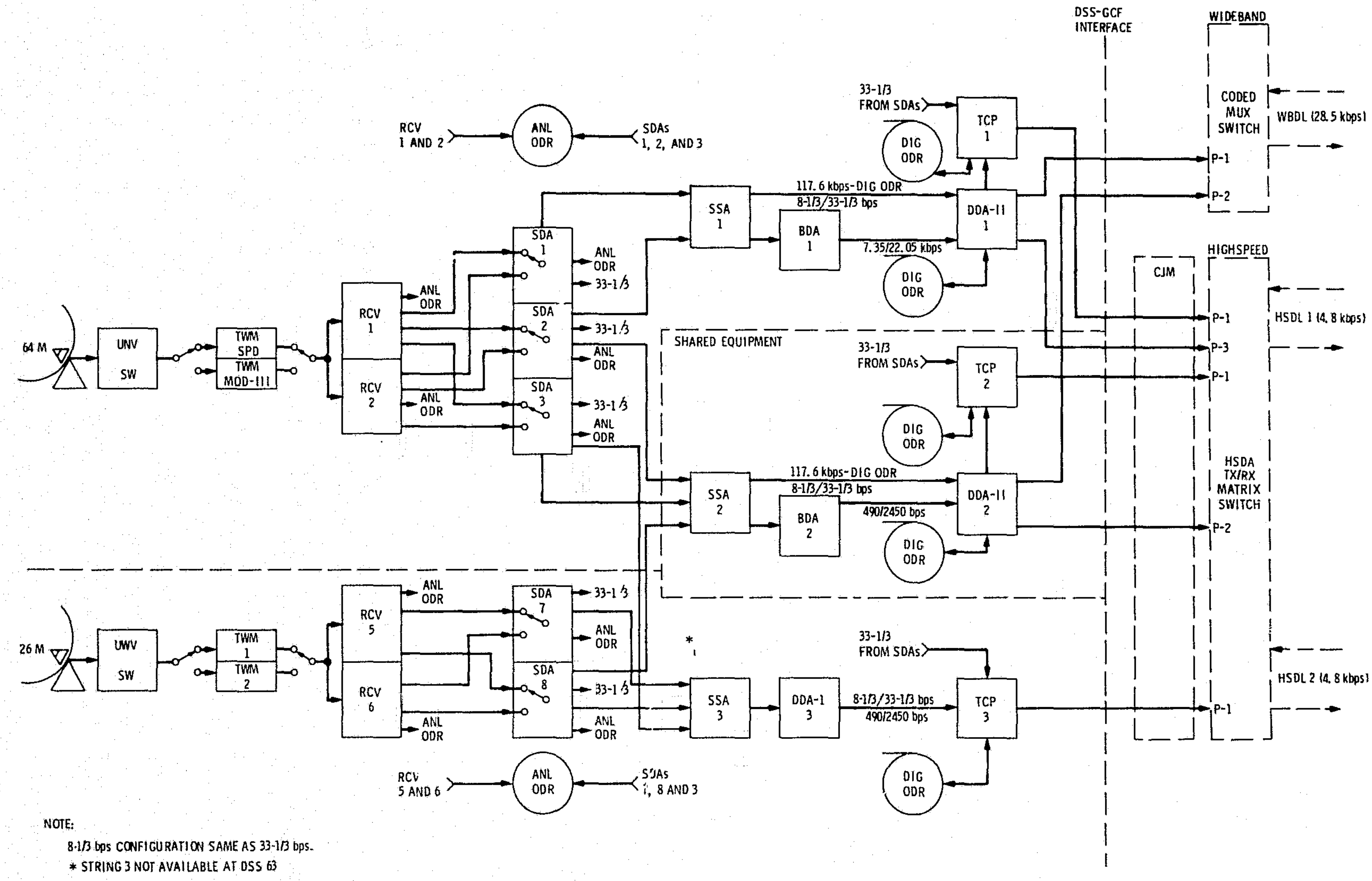


Figure 68. DSN mission configuration, MVM'73 telemetry, 26/64-m conjoint deep space stations

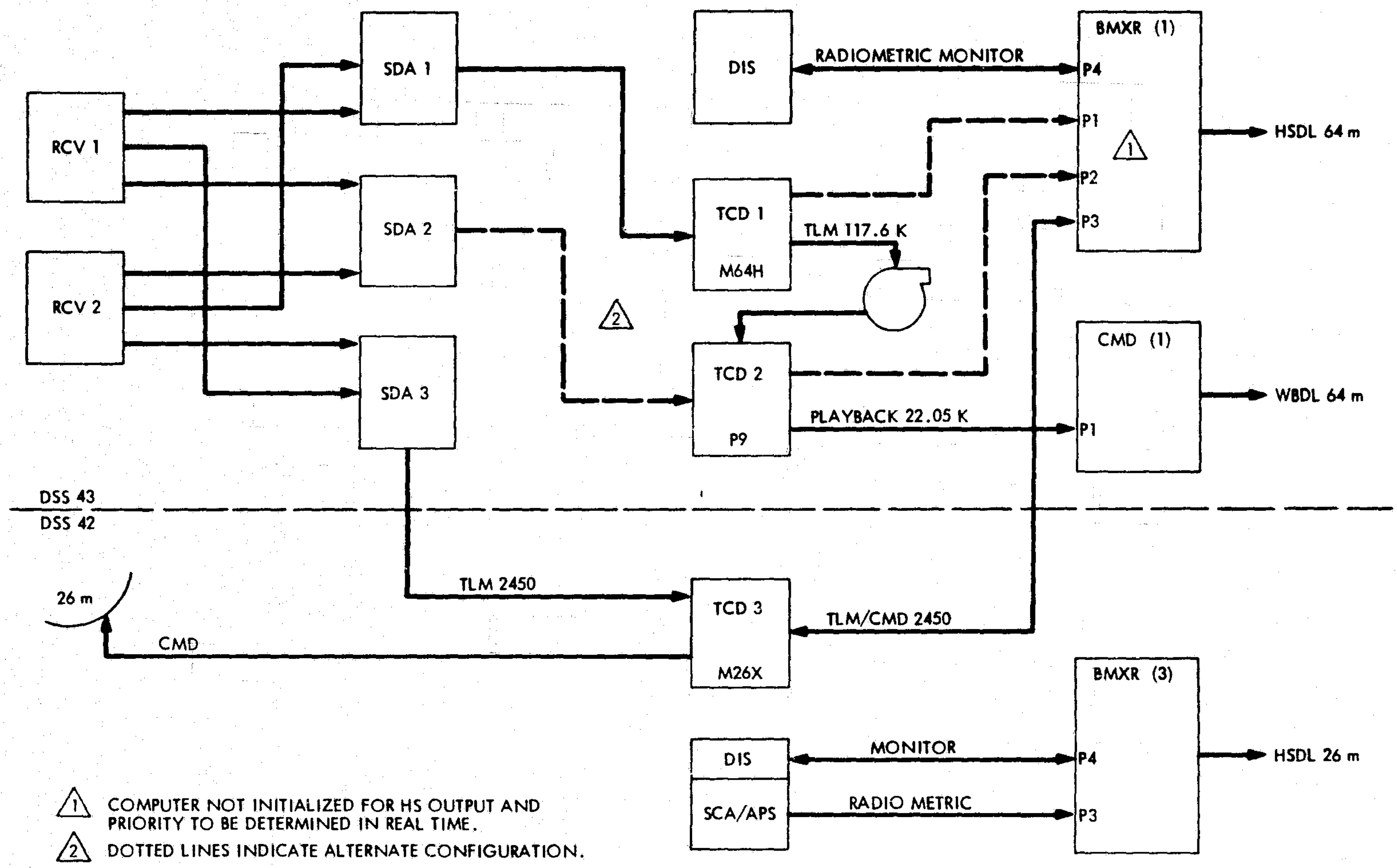
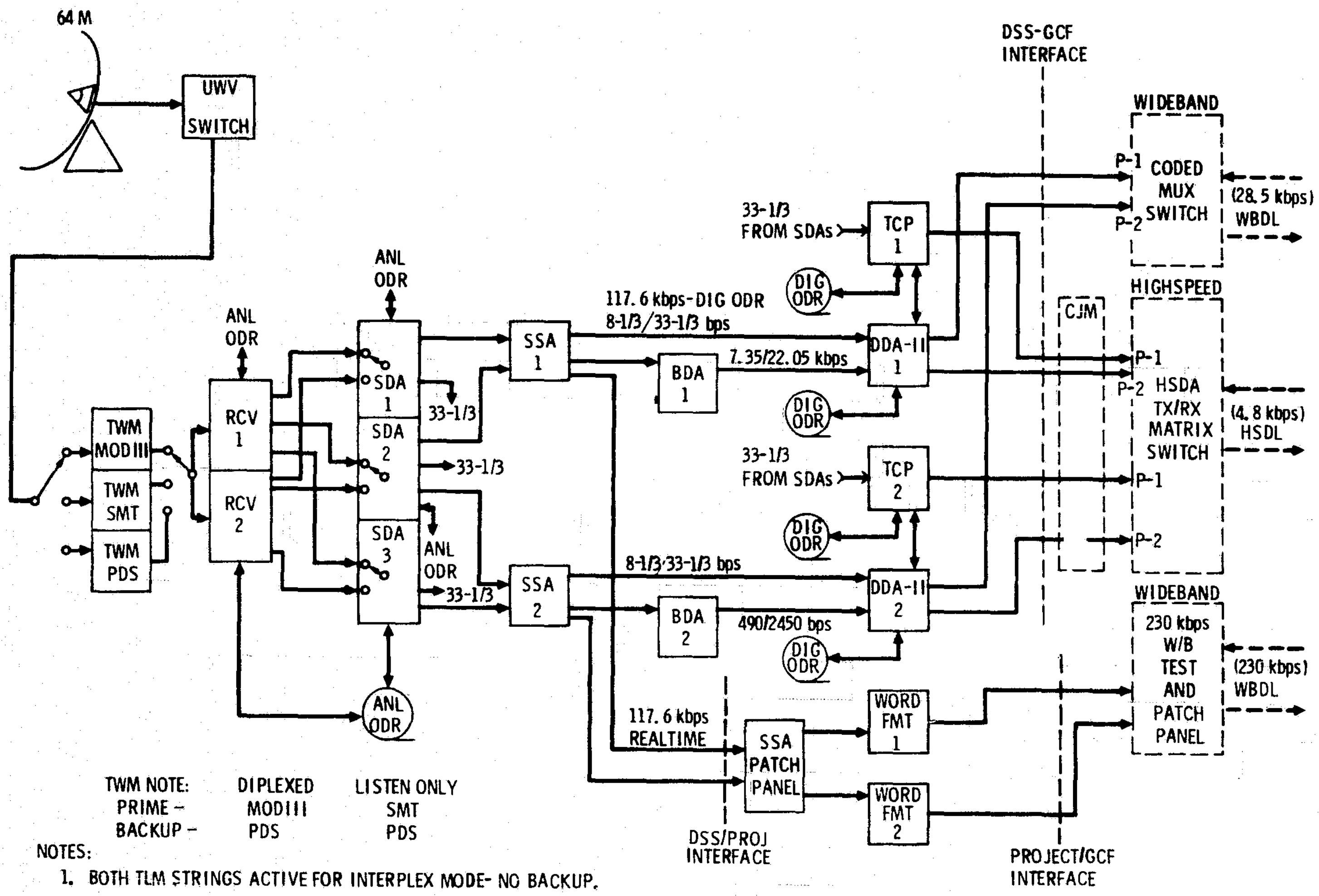


Figure 69. DSN Mercury encounter configuration, DSS 42, 43



TWM NOTE:	DIPLEXED	LISTEN ONLY
PRIME –	MODIII	SMT
BACKUP –	PDS	PDS

NOTES:

1. BOTH TLM STRINGS ACTIVE FOR INTERPLEX MODE- NO BACKUP.
2. 8-1/3 bps CONFIGURATION SAME AS 33-1/3 bps.

Figure 70. DSN mission configuration, MVM'73 telemetry, 64-m DSS 14

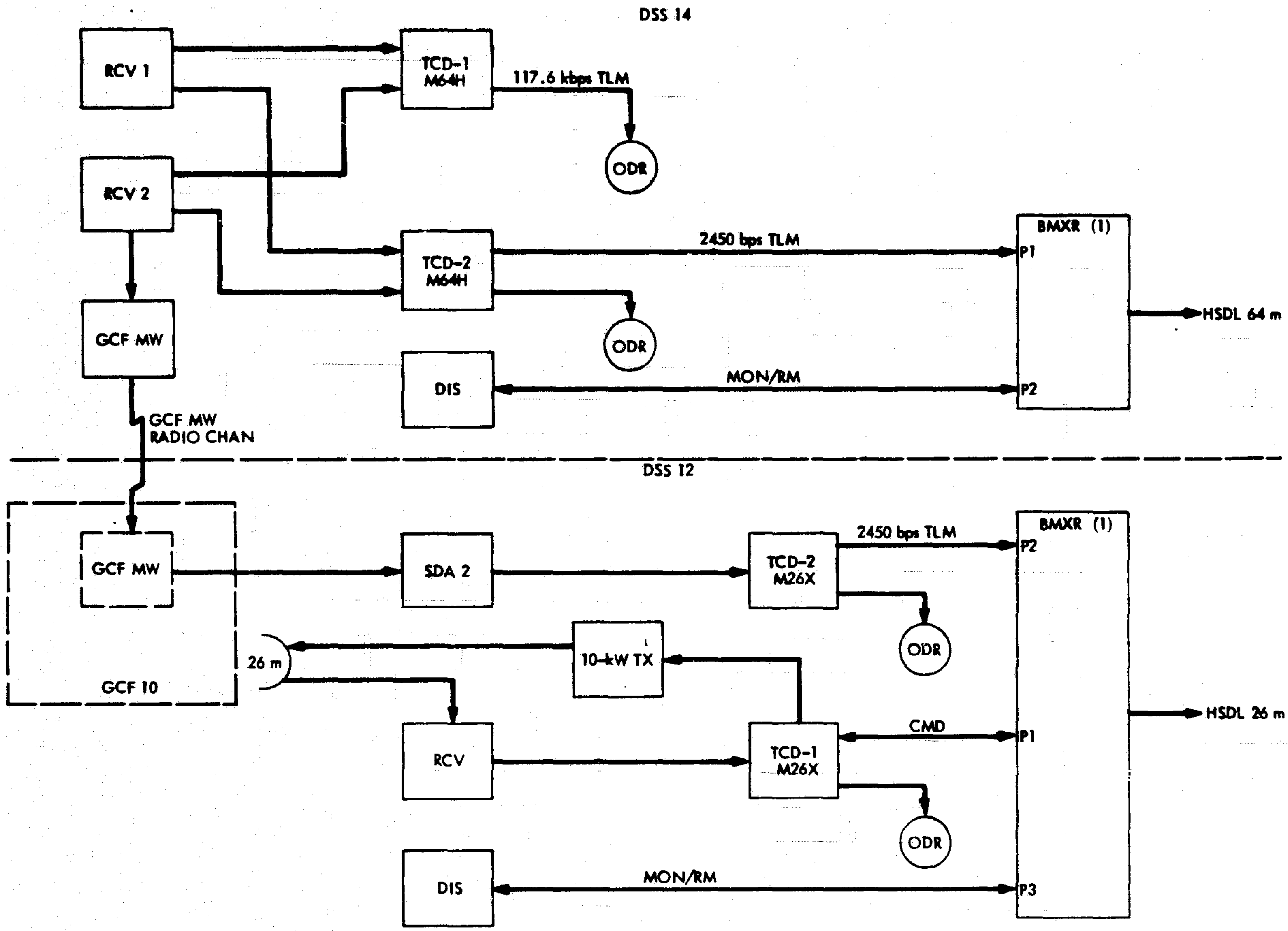
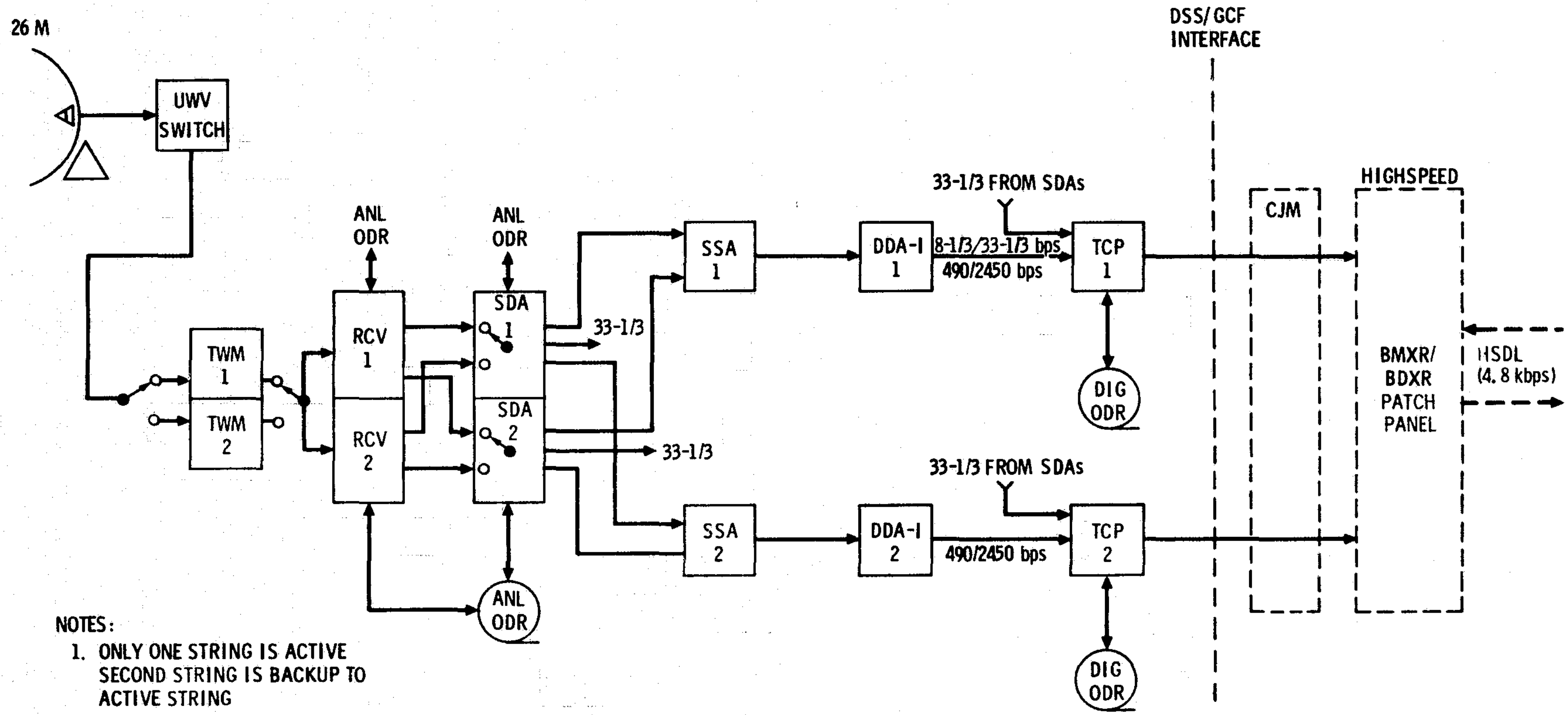
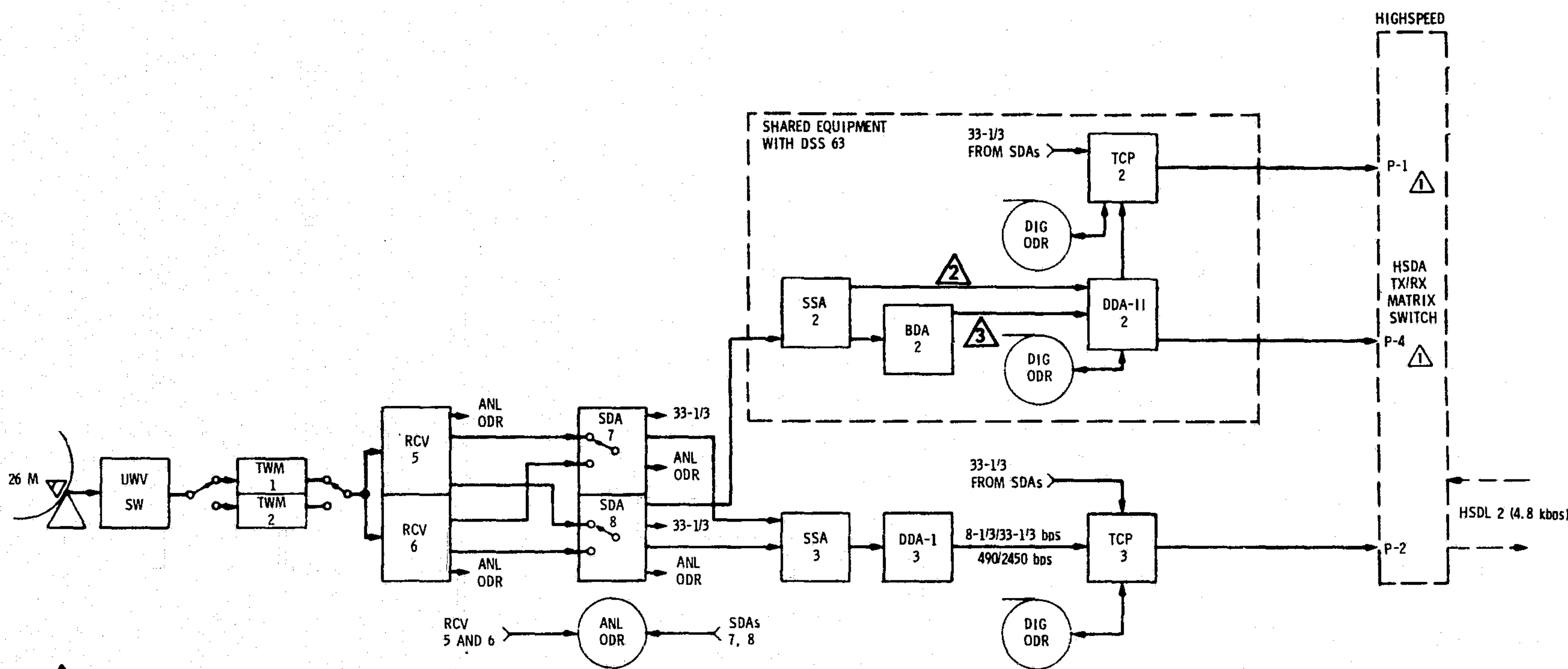


Figure 71. DSN Mercury encounter configuration, DSS 12, 14



NOTES:
1. ONLY ONE STRING IS ACTIVE SECOND STRING IS BACKUP TO ACTIVE STRING
2. 8-1/3 bps CONFIGURATION SAME AS 33-1/3 bps.

Figure 72. DSN mission configuration, MVM'73 telemetry, standard 26-m DSS 12, 62



1 TO BE CONFIGURED TO OUTPUT OVER HSDL 2 (26-m HIGH SPEED DATA LINE)

2 THE FOLLOWING DATA RATES APPLY: 8-1/3, 33-1/3, 490, 2450, 117.6

3 THE FOLLOWING DATA RATES APPLY: 490, 2450, 7.350, 22.05

Figure 73. DSN MVM'73 Mercury III cruise configuration telemetry, DSS 61

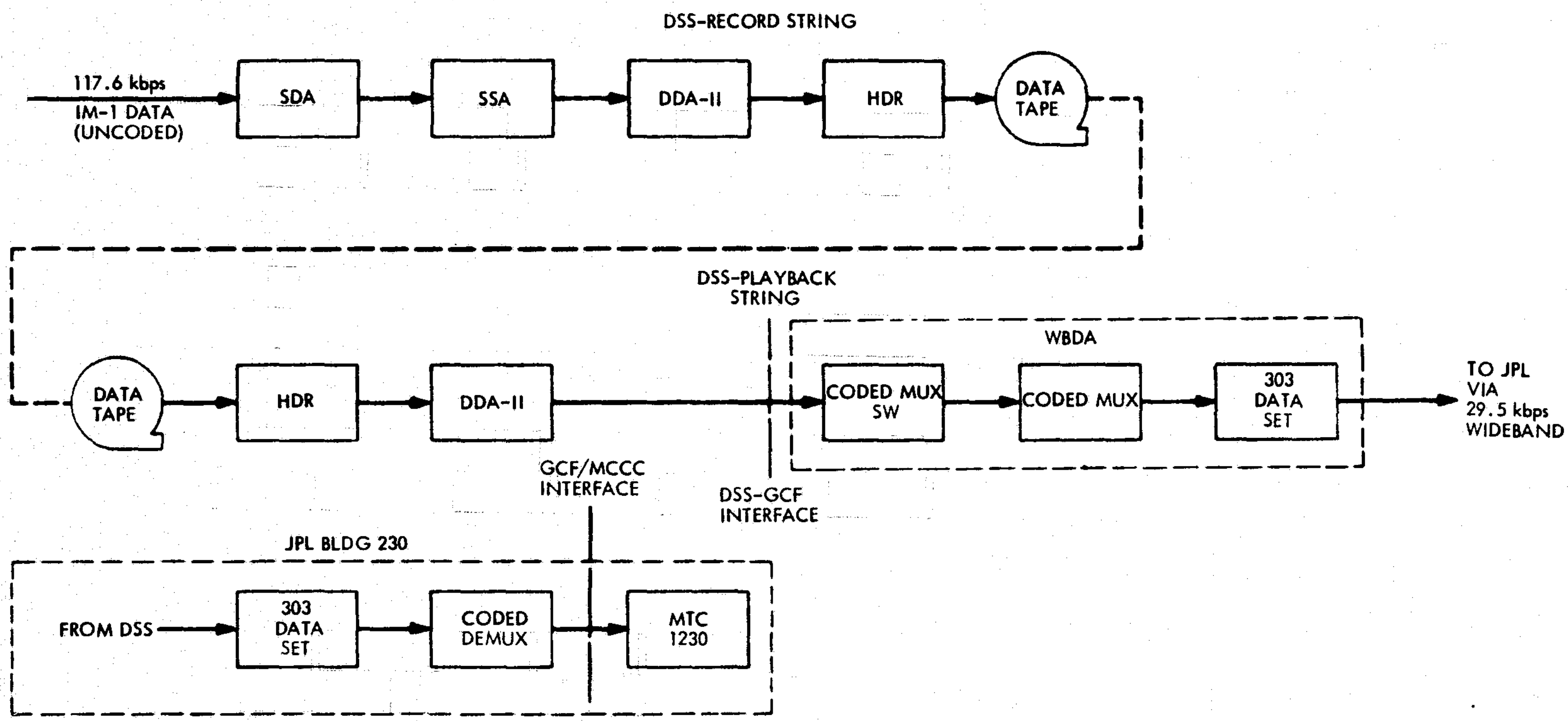


Figure 74. DSN mission configuration, MVM'73 telemetry configuration (117.6 kbps) near-real-time playback, DSS 14, 43, 63

The deep space station receivers normally employed a narrow tracking loop bandwidth for all mission phases except initial acquisition, which utilized a narrow loop configuration. The automatic gain control loop bandwidth was set in the wide mode for initial acquisition and trajectory correction maneuvers and in the narrow configuration for cruise and encounter operations. A telemetry channel bandwidth of 3.3 MHz was selected for both the low- and high-rate subcarriers. Table 29 lists the receiving and transmitting center frequencies and related channel designators. The assigned RF channel for the mission (14A and B) would not accommodate the high doppler offset predicted from aproximately 110 days after launch through the second Mercury encounter. To extend the VCO tuning range to accommodate these offsets, VCO crystals for channel 14+A and +B, as well as 14-A and -B, were required for all MVM'73 supporting stations except DSS 71 and CTA 21. The maximum negative doppler S-band frequency shift was -260 kHz in the downlink and -245 kHz in the uplink during the first Mercury encounter. At the second Mercury encounter, a maximum doppler shift of +270 kHz downlink and +250 kHz uplink occurred.

As illustrated in the various configuration figures, the stations employed analog recorders to recover numerous analog signals. For the telemetry system, both receiver baseband and subcarrier waveforms were recorded to assure preservation of received data in the event of failures in other station equipment. Table 30 summarizes the analog recording configuration utilized at the 64-m stations. One should note that these recorders also were used to record various command, open loop receiver, and station functions. MVM'73 demands on this capability required significant changes in channel assignments and track allocations to accommodate all functions. Table 31 gives the analog recording configuration for the 26-m stations.

b. Command System Implementation and Configuration. Since the MVM'73 spacecraft utilized essentially the same command subsystem as Mariner Mars 71, little change was required in the DSN command system to accommodate MVM'73. Command software, which cohabitates with low-rate telemetry software in the stations' telemetry and command processor, did, however, require rework to gain core utilization efficiencies in order to accommodate MVM'73's 2450-bps telemetry rate. The two-string configuration provided a prime and backup capability for command activities. The conjoint stations, however, had only one backup string shared between the two stations. The system configurations for the various station types are shown in Figs. 75 through 77 and in the previous Tables 25 through 27.

c. Tracking System Implementation and Configuration. Prior to MVM'73, the primary radio metric data types produced by the DSN tracking system were S-band doppler and S-band ranging to lunar distances. These data were transmitted to the Operations Center via low-rate teletype circuits. Since MVM'73 required greater precision in its navigation, additional system capabilities were required to be implemented and included ranging to planetary distances, higher sample rates, and high-

Table 29. MVM'73 receiving and transmitting frequencies

Mode	Channel number	Center frequency of carrier, MHz	Center frequency of VCO, MHz
Block III:			
S-band receiving	14 - A	2294.814815	23.383488
	14.0 A	2295.000000	23.385417
	14 + A	2295.185185	23.387346
S-band transmitting	14 + B	2113.483025	22.015448
	14.0 B	2113.312500	22.013672
	14 - B	2113.141976	22.011896
Block IV:			
X-band receiving	14.0 C	8415.000000	PLO
S-band receiving	14.0 A	2295.000000	PLO
S-band transmitting	14.0 B	2113.312500	PLO

Table 30. FR-1400 recorder configuration for DSS 14, 43, and 63

Track	Data					Mix ratio[a]
	IRIG channel	Function	VCO center frequency, kHz	Deviation percentage ±	Deviation voltage, V	
1		Speedlock (100 kHz/25 kHz)[b] SDA 3 output[b]	Direct 525.0/108.0	30.0	±5	1:1[c]
2	3	RCVR 1 SPE	0.73	7.5	±5	1:1
	4	RCVR 2 SPE	0.96	7.5	±5	1:1
	5	RCVR 1 DPE	1.30	7.5	±5	1:1
	6	RCVR 1 AGC	1.70	7.5	0 to -5	1:1
	7	RCVR 2 AGC	2.30	7.5	0 to -5	1:1
	8	RCVR 2 DPE	3.00	7.5	±5	1:1
		X-band RCVR DPE[d]	13.50	15.0	0 to +5	1:1
	A	Voice	22.00	15.0	±5	1:1
	C	CMA 2	40.00	15.0	±5	1:1
	18	CMA 1	70.00	7.5	±5	1:1
	19	NASA Time	93.00	7.5	±5	1:1
3		RCVR 2 baseband	Direct		e	1:1
4		X-band OLR[b,d]	768.0/192.0	64 kHz/16 kHz	e	1:1
		S-band OLR[b]	128.0/32.0	16 kHz/4 kHz		1:1
		Digitizing tone[b] (320 kHz/80 kHz)	direct			1:1
5		RCVR 2 baseband	Direct		e	1:1
6		Speedlock (100 kHz/25 kHz)[b] SDA 1 output[b]	Direct 525.0/108.0	30.0	±5	1:1[c]
7		Speedlock (100 kHz/25 kHz)[b] SDA 2 output[b]	Direct 525.0/108.0	30.0	±5	1:1[c]

[a]With the exception of the baseband tracks, the input to each recorder track will be adjusted to 28 V peak-to-peak (p-p).

[b]The recording speeds are 60 ips for high-rate telemetry subcarrier (177.10 kHz) and occultation data, and 15 ips for low-rate telemetry subcarrier (88.55 kHz) data. Entries in the form of 525.0/108.0 indicate that the quantity 525.0 will be recorded at 60 ips, whereas the quantity 108.0 will be recorded at 15 ips. Speedlock at 60 ips is 100 kHz and 25 kHz for 15 ips.

[c]The speedlock signal level will be recorded at 10 dB (±0.5 dB) below the normal record levels.

[d]Configuration exceptions:

Track 4 will be used for recording open loop receivers (OLRs).
Block IV RCVRs and OLRs are not available at DSS 63.
Track 4 will be a spare at DSS 63.
Block IV RCVRs and X-band OLRs are not available at DSS 43.
DSS 43 will record S-band OLRs 1 and 2 at 60 ips only.
DSS 14 will record OLR data at 15 ips.
OLR data at 15 ips will be during a cruise phase and will use the 192 and 32 kHz VCOs with the 80 kHz digitizing tone (Ref. Section III, paragraph M-4 of this document).

[e]The baseband tracks will be calibrated during readiness testing (Ref. STP 853-54; 4A-08, Table C-1, operation entitled, "Direct Record Track Evaluation"). At high signal levels, the linear signal level to the baseband tracks will appear to be low. This calibrated adjustment should not be reset from the level that was set during readiness testing.

Table 31. FR-1400 recorder configuration for DSS 12, 42, and 62

Track	Data					Mix ratio[a]
	IRIG channel	Function	VCO center frequency, kHz	Deviation percentage ±	Deviation voltage, V	
1		Speedlock (25 kHz)[b]	Direct			1:1
2	3	RCVR 1 SPE	0.73	7.5	±5	1:1
	4	RCVR 2 SPE	0.96	7.5	±5	1:1
	6	RCVR 1 AGC	1.70	7.5	0 to -5	1:1
	7	RCVR 2 AGC	2.30	7.5	0 to -5	1:1
	A	Voice	22.00	15.0	±5	1:1
	C	CMA 2	40.00	15.0	±5	1:1
	E	CMA 1	70.00	15.0	±5	1:1
3		RCVR 2 baseband	Direct		c	1:1
4		NASA time	93.00	15.0	±5	1:1
5		RCVR 1 baseband	Direct		c	1:1
6		Speedlock (25 kHz)[b]	Direct			
		SDA 1 output	108.00	40.0	±5	1:1[d]
7		Speedlock (25 kHz)[b]	Direct			
		SDA 2 output	108.00	40.0	±5	1:1[d]

[a]With the exception of the baseband tracks, the input to each recorder track will be adjusted to 2.8 volts p-p.

[b]Recording speed is 15 ips.

[c]The baseband tracks will be calibrated during readiness testing (Ref. STP 853-54; 4A-08, Table C-1, Operation entitled, "Direct Record Track Evaluation"). At high signal levels, the linear signal level to the Baseband tracks will appear to be low. This calibrated adjustment should not be reset from the level that was set during readiness testing.

[d]The speedlock signal level will be recorded at 10 dB (±0.5 dB) below the normal record levels.

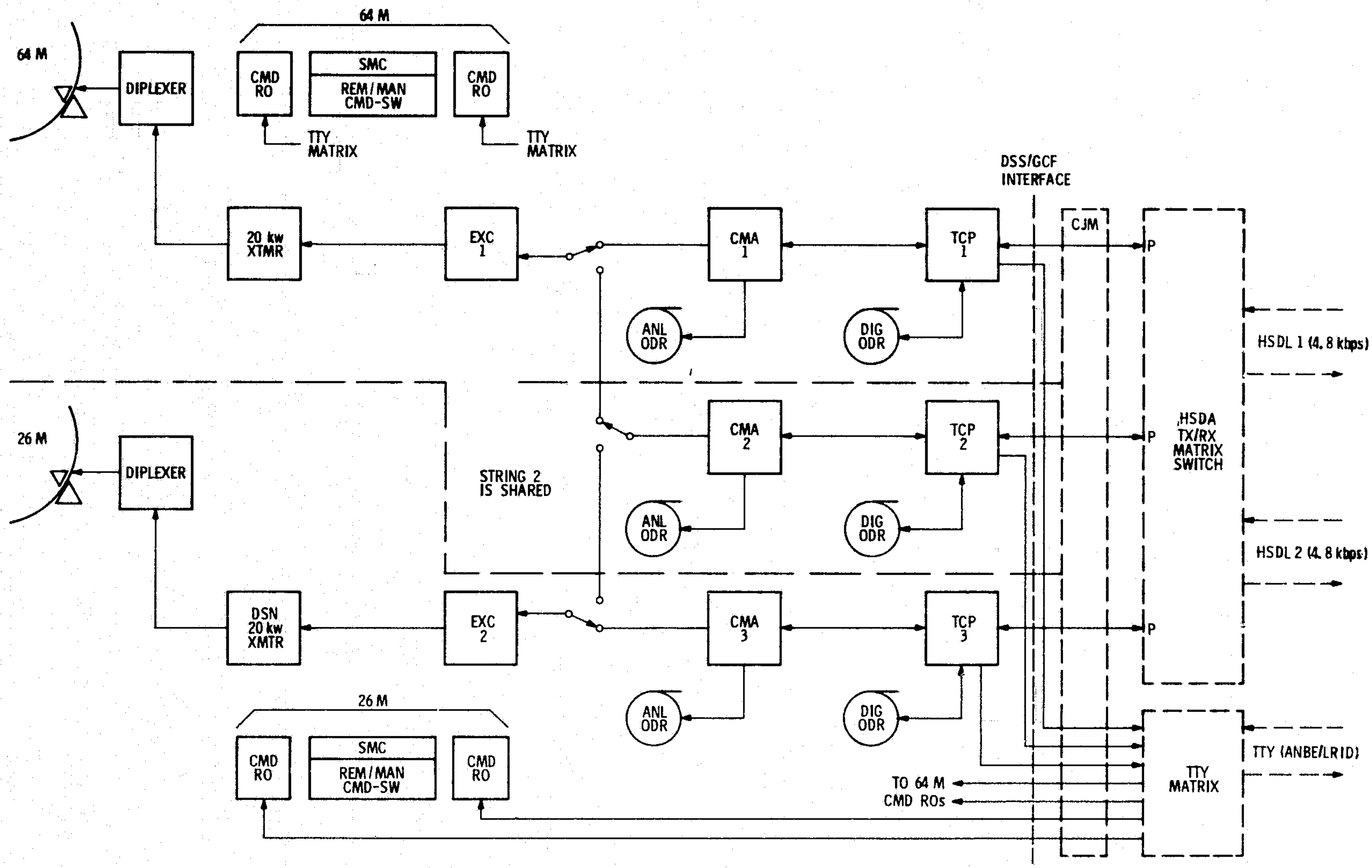


Figure 75. DSN mission configuration, MVM'73 command conjoint deep space stations

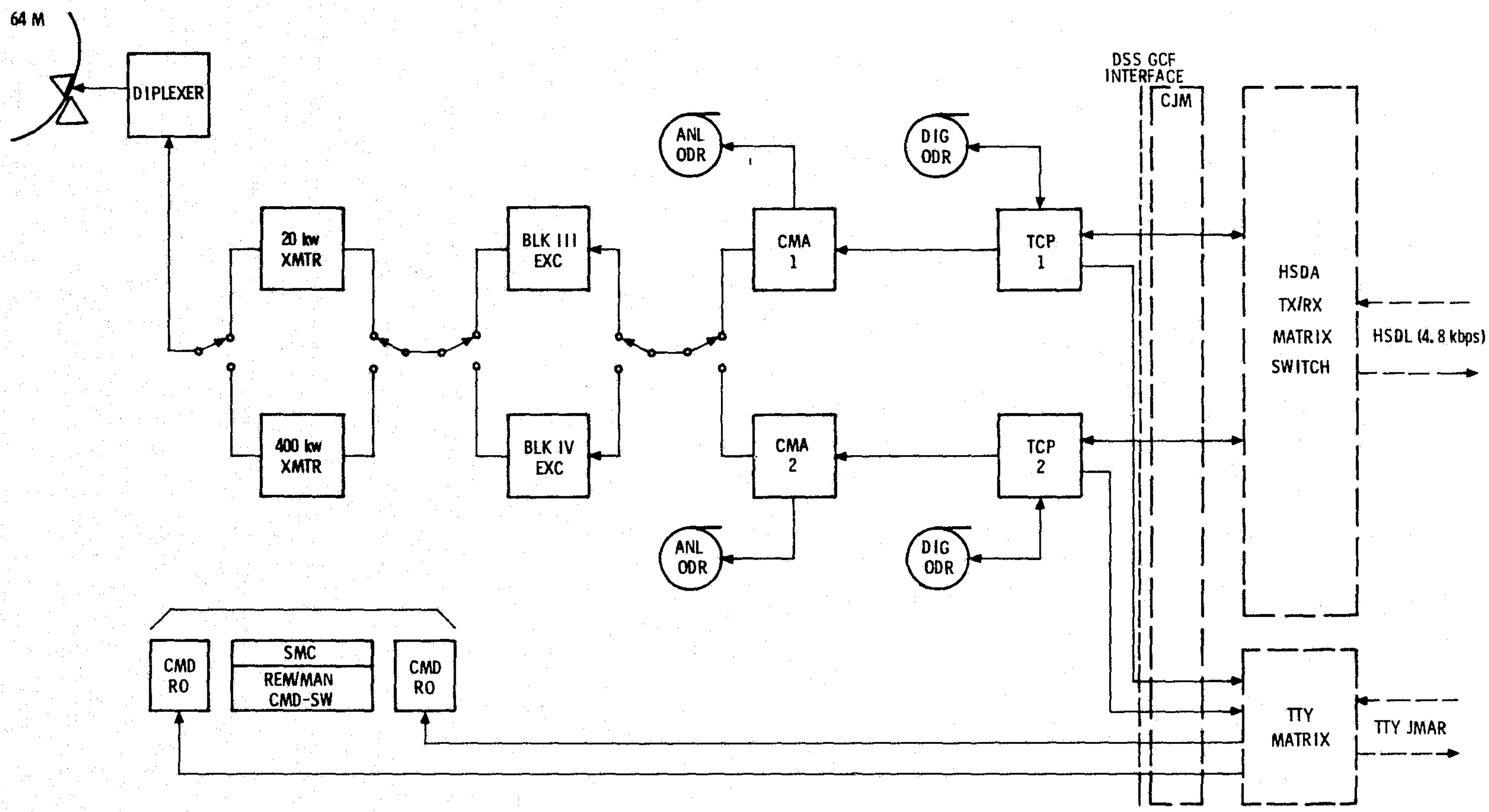


Figure 76. DSN mission configuration, MVM'73 command, DSS 14

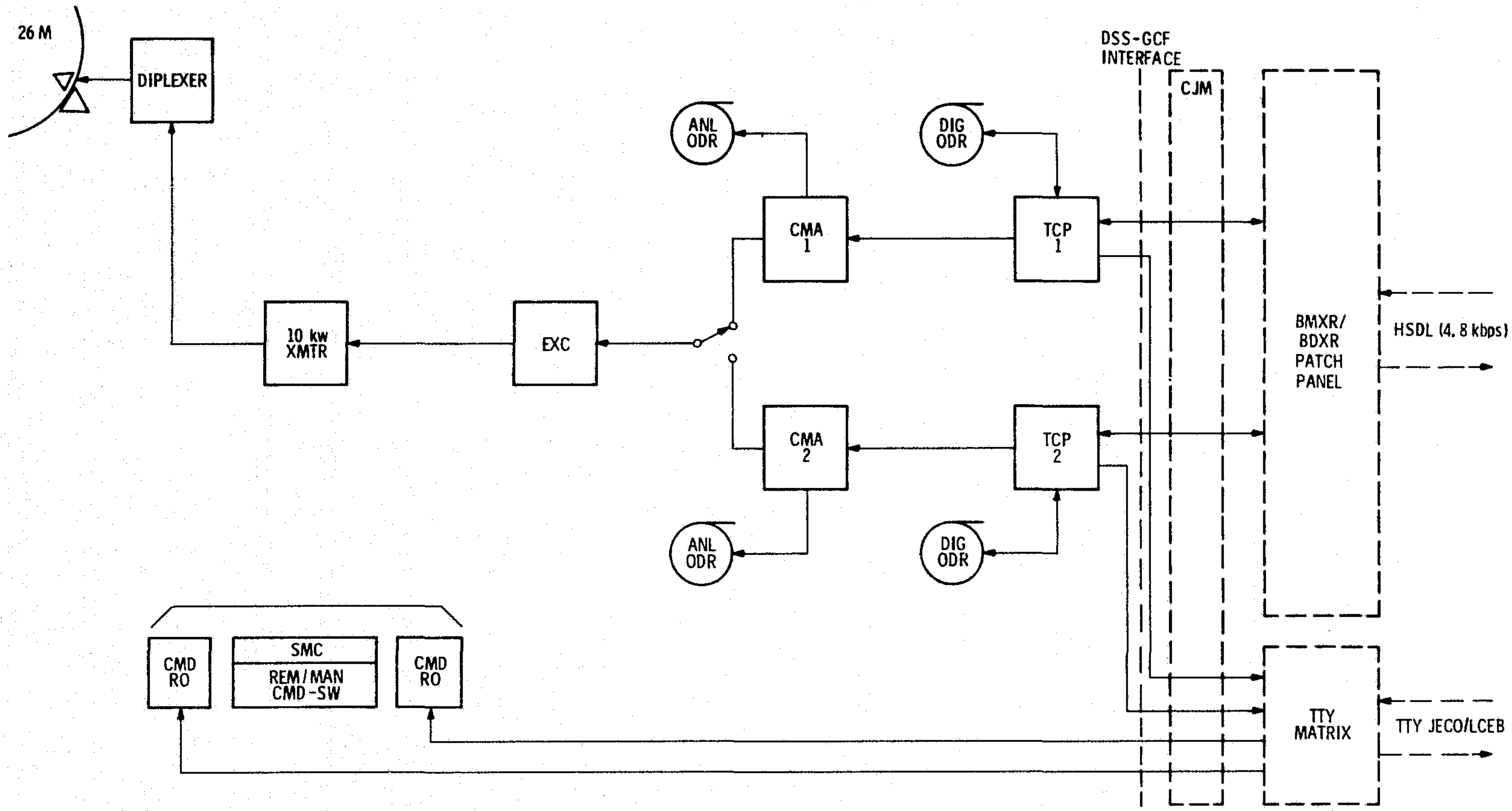


Figure 77. DSN mission configuration, MVM'73 command, standard 26-m DSS 12, 62

speed transmission of data to the users. Planetary ranging assemblies were designed, procured, and installed at the required stations. The existing tracking data handling assembly was modified to interface with the ranging assemblies. To accommodate high-speed transmission of radio metric data from these doppler and ranging assemblies, interfaces were established with the deep space station monitor and control subsystem's XDS 910 computer, wherein radio metric data formatting for digital recording and high-speed transmission was accomplished.

Planetary ranging assembly implementation was on a critical schedule from the start. Delivery from the contractor was not expected until September 1973; consequently, this capability could not be committed for operational use at all stations prior to launch. Negotiations with the Project resulted in an acceptable plan wherein DSS 12 would be operational by October 1973 and DSS 43 and 63 by January 1, 1974. The lunar ranging assemblies' performance capabilities would allow for the required support to be provided until the planetary ranging implementation was completed. Fortunately, these schedules were met in time to meet the higher performance demands resulting from a spacecraft high-gain antenna failure during December 1973.

MVM'73 requirements included the use of dual-frequency (S- and X-band) radio metric data on an experimental basis to develop additional techniques for higher precision navigation. DSS 14 was the DSN's only station to be implemented with the required X-band capabilities to support these mission objectives. Furthermore, this same dual-frequency capability was to serve the Project's radio science occultation experiments at the planetary encounters on an R&D basis. The scope of the implementation was significant and included dual reflex feed, separate feed cones and masers, X-band receivers, X-band test transmitter, doppler extractors-counters, and a special ranging assembly (Mu-II). Although these X-band capabilities were committed on a nonoperational R&D basis, data generated were to be used for operational purposes but not required for meeting primary objectives. Extensive DSN engineering support was required and planned to be made available at DSS 14 throughout the implementation and mission support periods to maintain these equipments in an operable condition.

The tracking system configurations for the various station types are given in Figs. 78 through 81.

d. <u>Monitor and Control System Configuration</u>. The primary implementation in the station monitor and control computer involved the modification of software to include radio metric data formatting and outputting functions in addition to the standard monitor data parameters normally displayed and transmitted to the DSN Operations Center. Problems encountered in installing a new high-speed printer at the monitor computer were never completely solved during the MVM'73 mission. Both computer/printer interface and printer hardware problems persisted throughout the period. Figures 82 through 85 reflect the monitor and control configuration for the various station types.

e. <u>Configuration for Radio Science Occultation</u>. As reported under the tracking system paragraph, significant new capabilities were

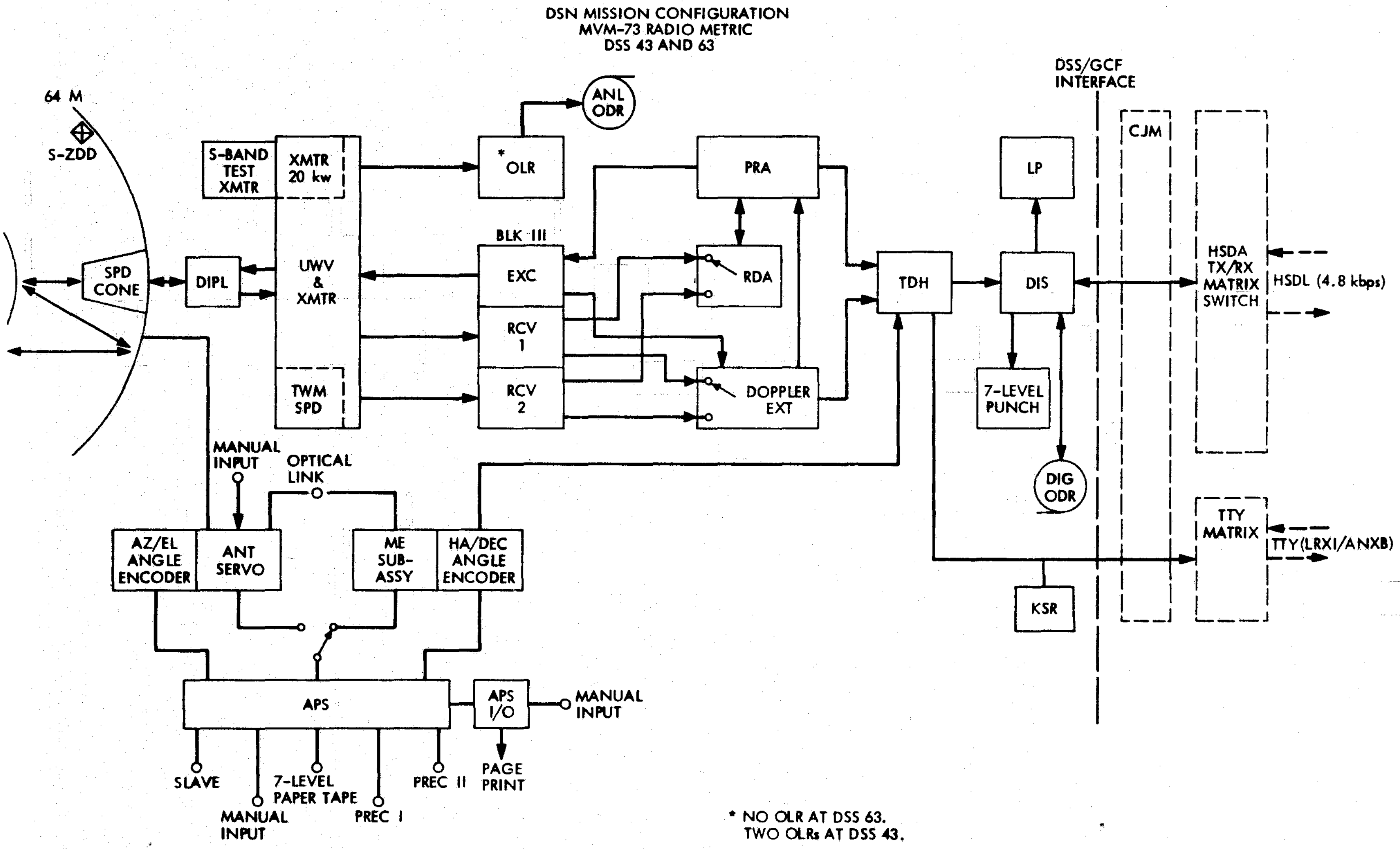


Figure 78. DSN mission configuration, MVM'73 tracking system, DSS 43, 63

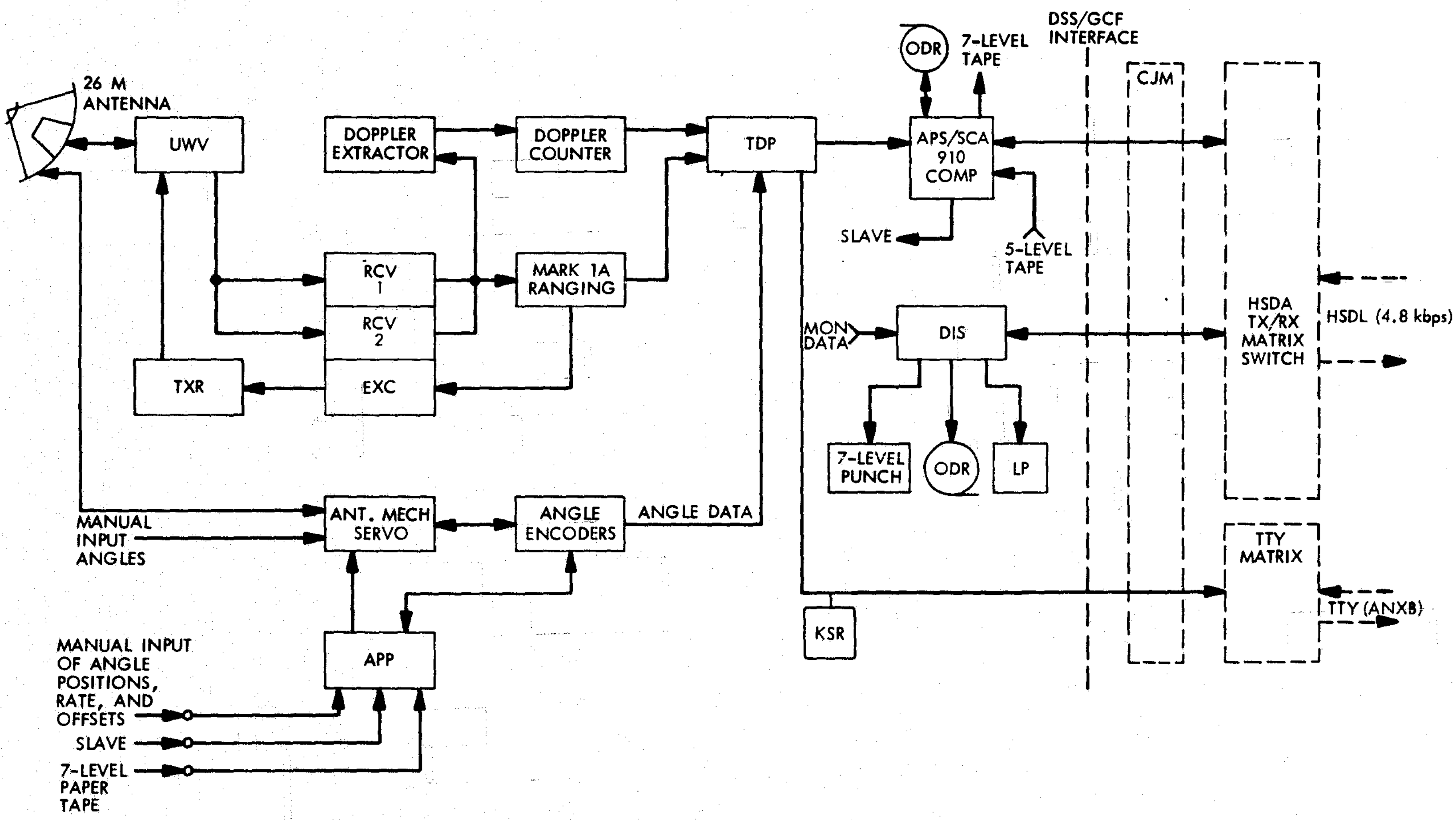
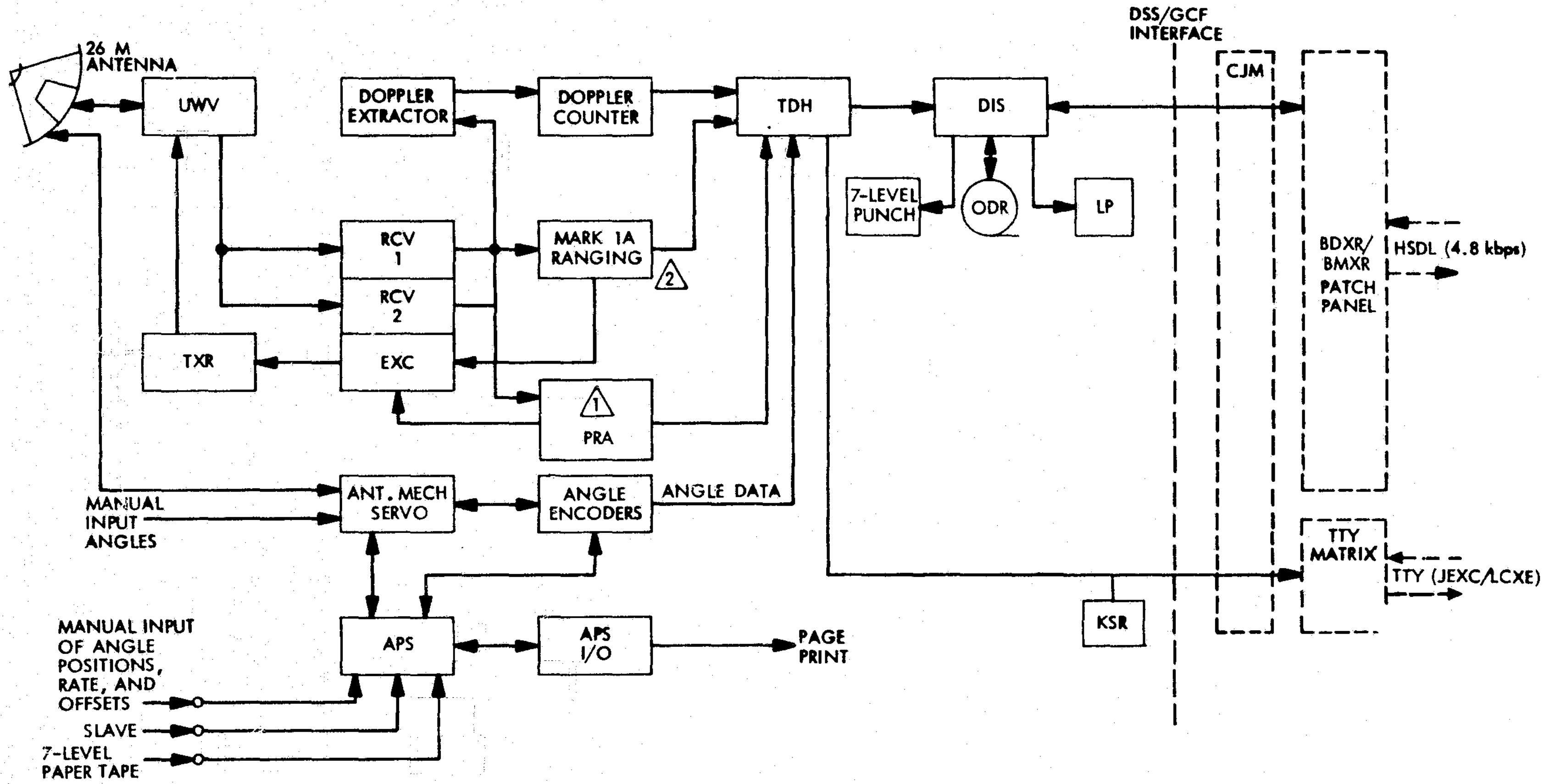


Figure 79. DSN mission configuration, MVM'73 tracking system, DSS 42



(1) PLANETARY RANGING ASSEMBLY (PRA) IMPLEMENTED AT DSS 12 ONLY.

(2) MARK 1A RANGING AT DSS 12 ONLY WILL BE DECOMMITTED AS SOON AS THE PLANETARY RANGING SYSTEM IS OPERATIONAL.

Figure 80. DSN mission configuration, MVM'73 tracking system, DSS 12, 62

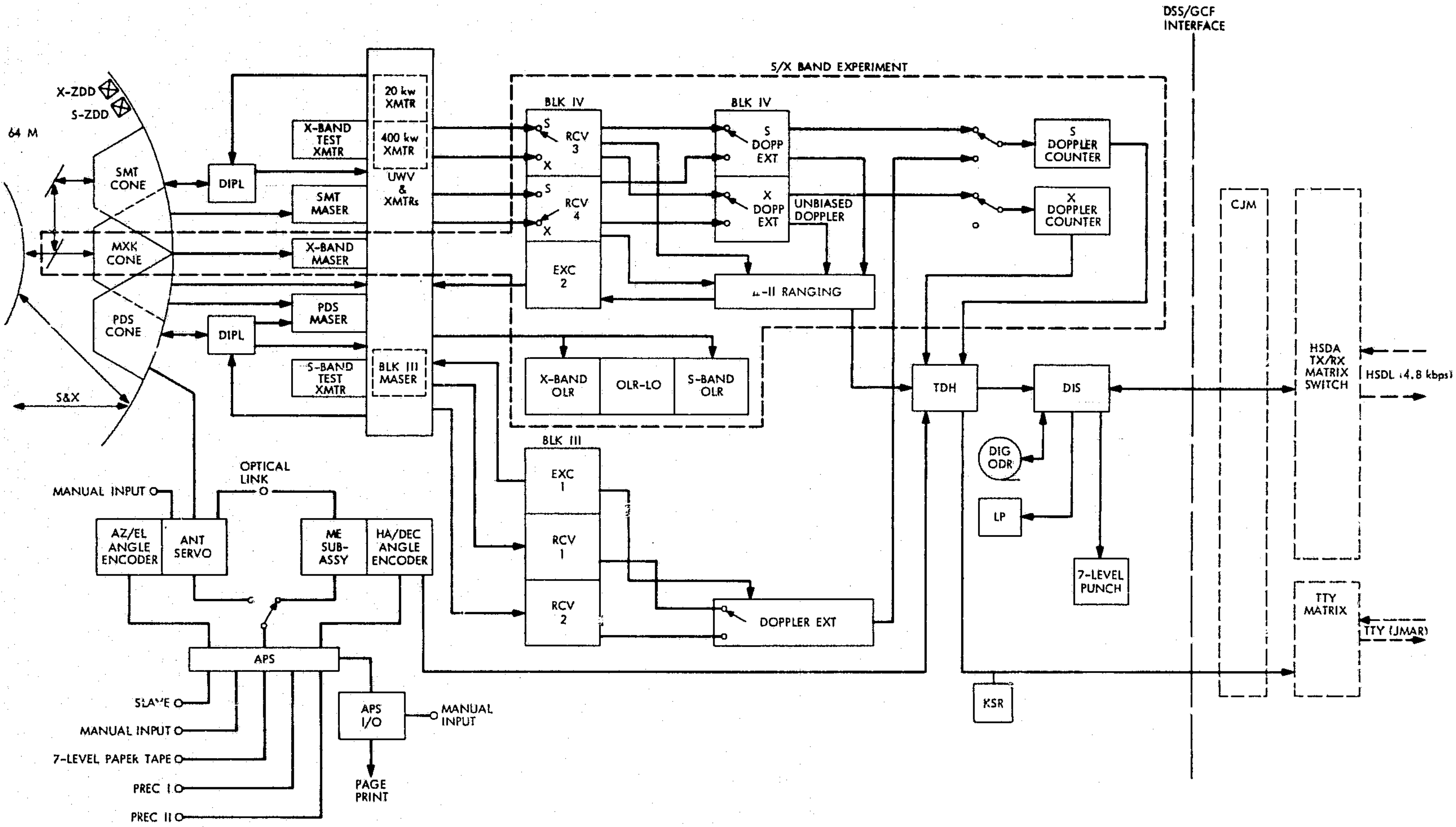


Figure 81. DSN mission configuration, MVM'73 tracking system, DSS 14

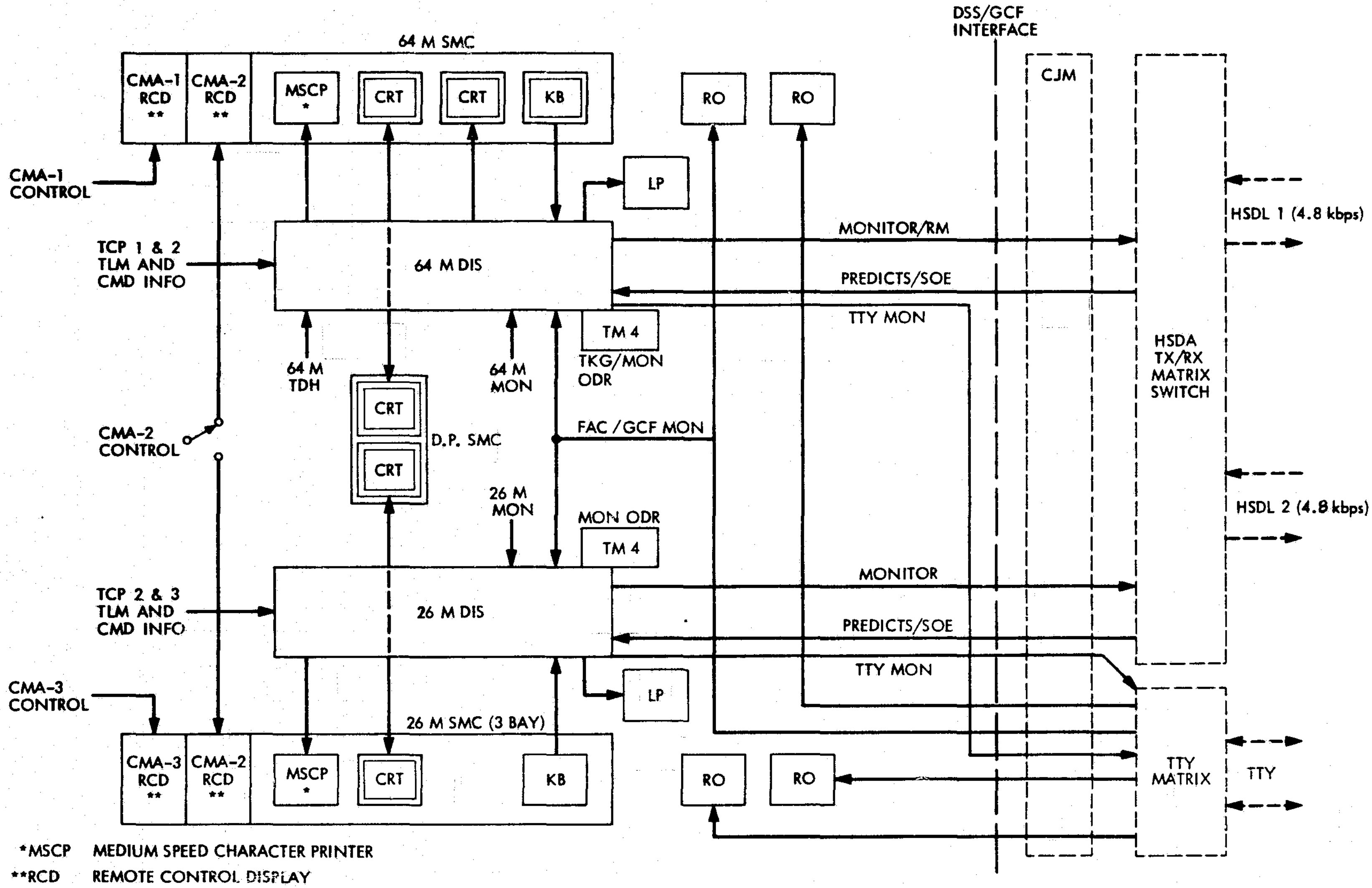
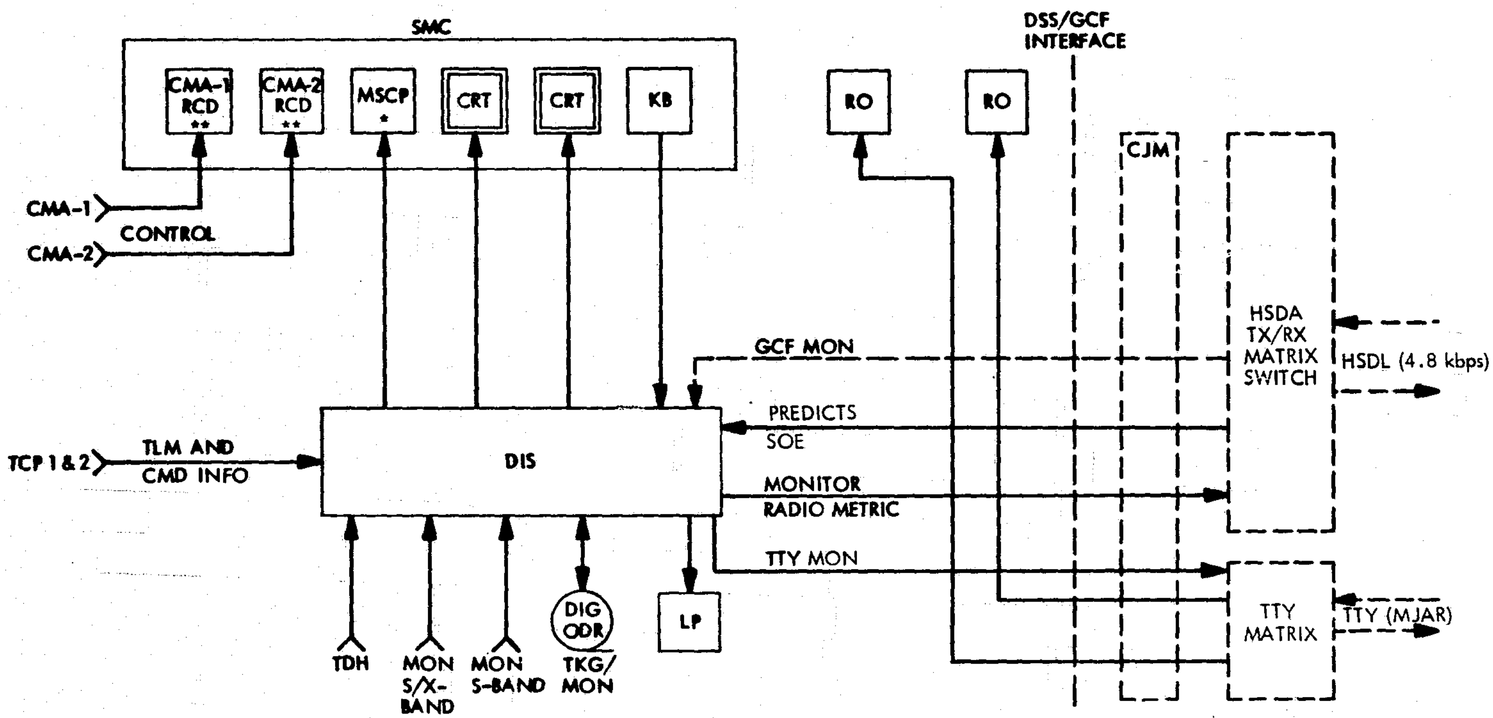


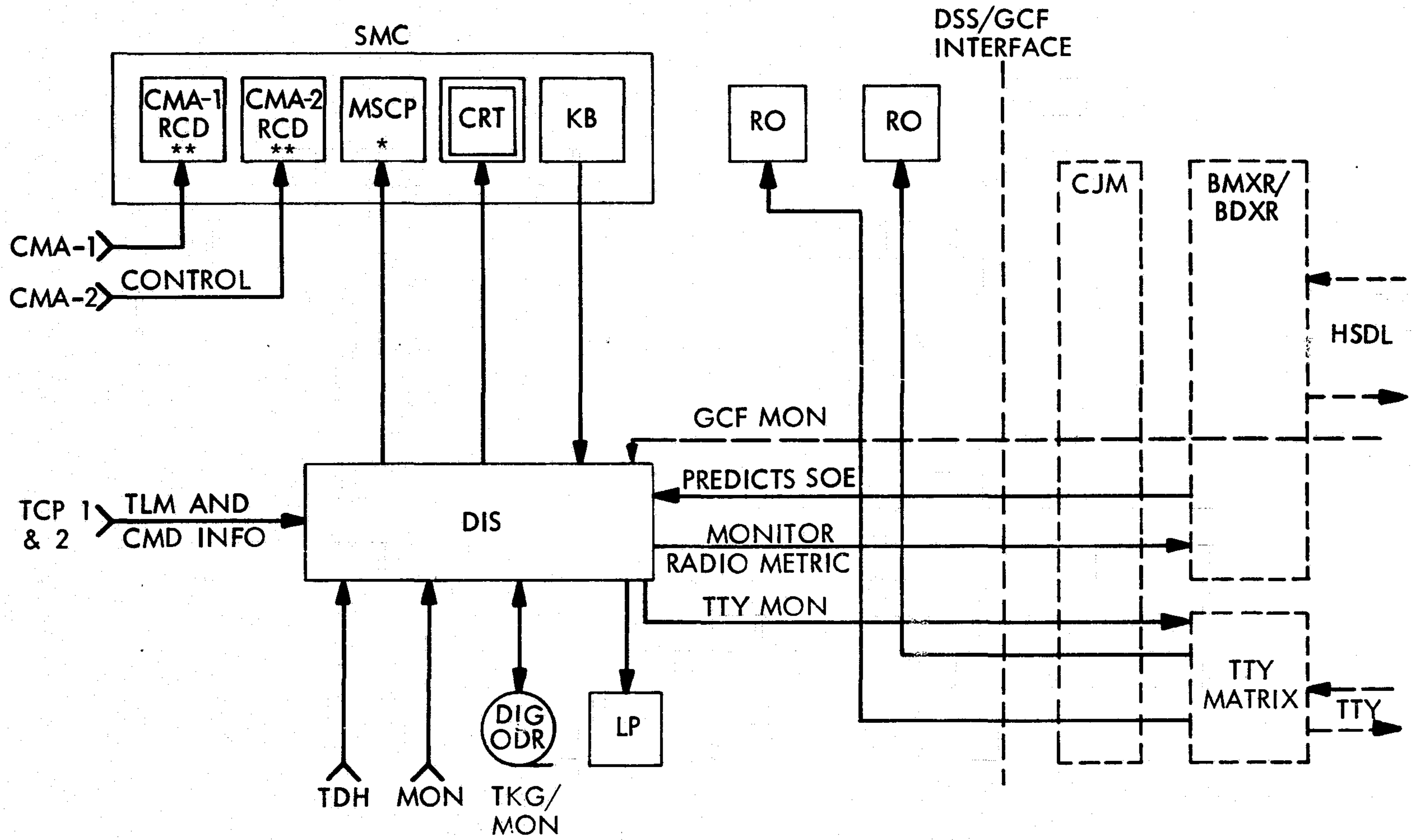
Figure 82. DSN monitor and control configuration, conjoint deep space stations



* MSCP MEDIUM SPEED CHARACTER PRINTER

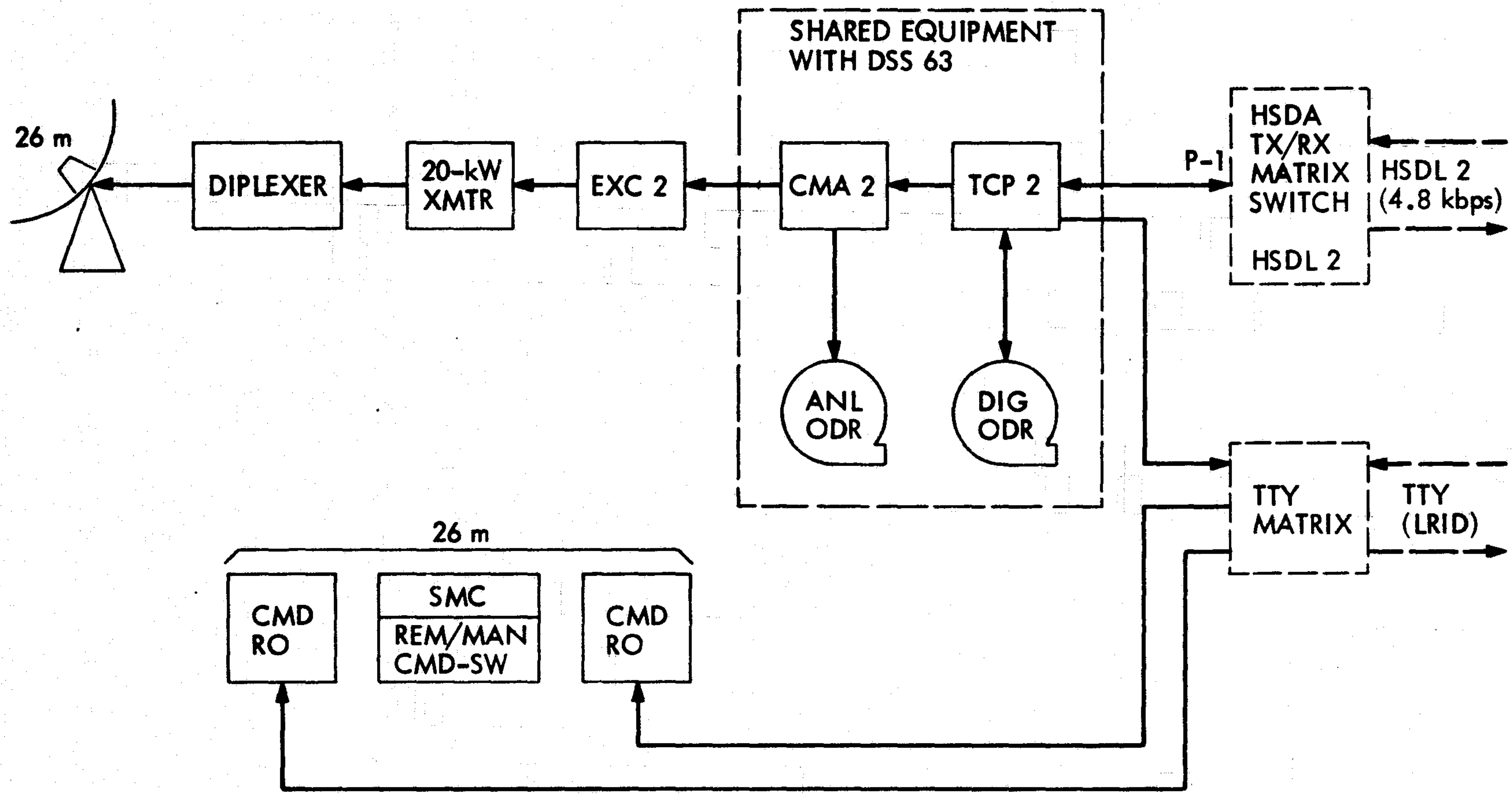
** RCD REMOTE CONTROL DISPLAY

Figure 83. DSN monitor and control configuration, DSS 14



*MSCP MEDIUM SPEED CHARACTER PRINTER
**RCD REMOTE CONTROL DISPLAY

Figure 84. DSN monitor and control configuration, standard 26-m deep space stations



1. CMD CAPABILITY CANNOT BE USED BY MVM WHEN DSS 63 IS IN USE BY OTHER PROJECTS UNLESS STRING 2 IS NOT REQUIRED BY OTHER PROJECTS.

Figure 85. DSN mission configuration, MVM'73 command, DSS 61

implemented at DSS 14 to support the MVM'73 dual-frequency radio science experiment. Implementation of these capabilities continued at DSS 14 up to launch in November 1973. Furthermore, a high level of DSN engineering support was required to continue to troubleshoot and analyze problems encountered during the mission, and such problems were resolved prior to critical occultation periods. Since the occultations for MVM'73 were such to occur during the DSS 14 and 43 view periods, these were the only 64-m stations configured with open loop receiver and the required analog recording capabilities for radio science support. Figure 86 gives the occultation configuration used at DSS 43. Figures 87 and 88 reflect the configurations for DSS 14. Occultation data recorded in analog form were returned to the DSN's CTA 21, wherein the records were digitized prior to delivery to the experimenter. CTA 21's configuration for this operation is given in Fig. 89. The analog recording configuration employed at DSS 14 is listed in Table 32.

f. <u>Ground Communications Facility Implementation and Configuration</u>. Both the previously discussed realignment of TDA responsibilities and MVM'73 requirements led to significant implementation in the DSN's Ground Communications Facility. Prior to the reorganization, the GCF served as the transparent data transmission facility between the DSN's DSIF and SFOF. Following the separation of functions as directed by NASA, the GCF's JPL Central Communications Terminal (GCF 20 or CCT) was established as the primary physical location for the DSN's boundary for communications interfaces with the MCCC/Project mission support areas. The magnitude of the separation task demanded that it be phased throughout the MVM'73 mission period and beyond. Numerous negotiations were required between the DSN and MCCC to assure the continuation of full services as they previously existed until capabilities consistent with the new interfaces could be implemented. Therefore, one may observe in the subsequent configuration diagrams some inconsistencies with the redefined DSN interfaces. The configuration diagrams show the communications as they actually were during the transition period. One should also recognize that the described GCF capabilities between JPL and the DSN's overseas locations are, in fact, provided to the DSN by GSFC NASCOM and by their contract commercial carriers.

GCF implementation for MVM'73 focused on the wideband subsystem for three reasons: (1) for the first time, the Network had three 64-m antennas rather than one, thus giving a high data rate reception capability at all longitudes, (2) MVM'73 spacecraft data rates were higher than any previous planetary mission, and (3) the mission would be designed for maximum science return, meaning that full use would be made of the high rate capabilities. The standard NASCOM wideband capability decided upon for the MVM'73 time period was 28.5 kbps. This would handle MVM'73 data rates in real-time through 22.05 kbps or accommodate near-real-time replay of higher rates at the full line rate. This was considered satisfactory for mission operations. The new wideband capabilities encompassed the 64-m subnet, test stations, various communications terminals, and switching centers and included the implementation of data sets, modems, switches, coded multiplexers, and appropriate interfaces with the station and user equipment.

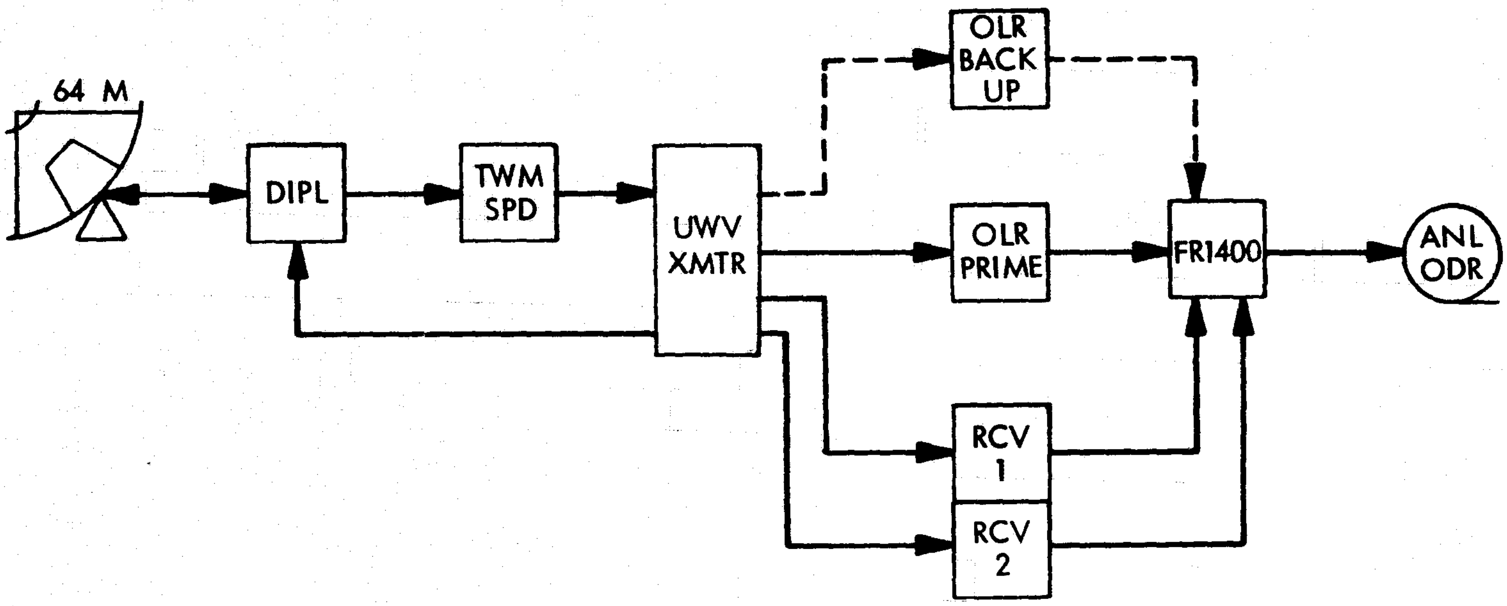


Figure 86. DSN occultation configuration, DSS 43

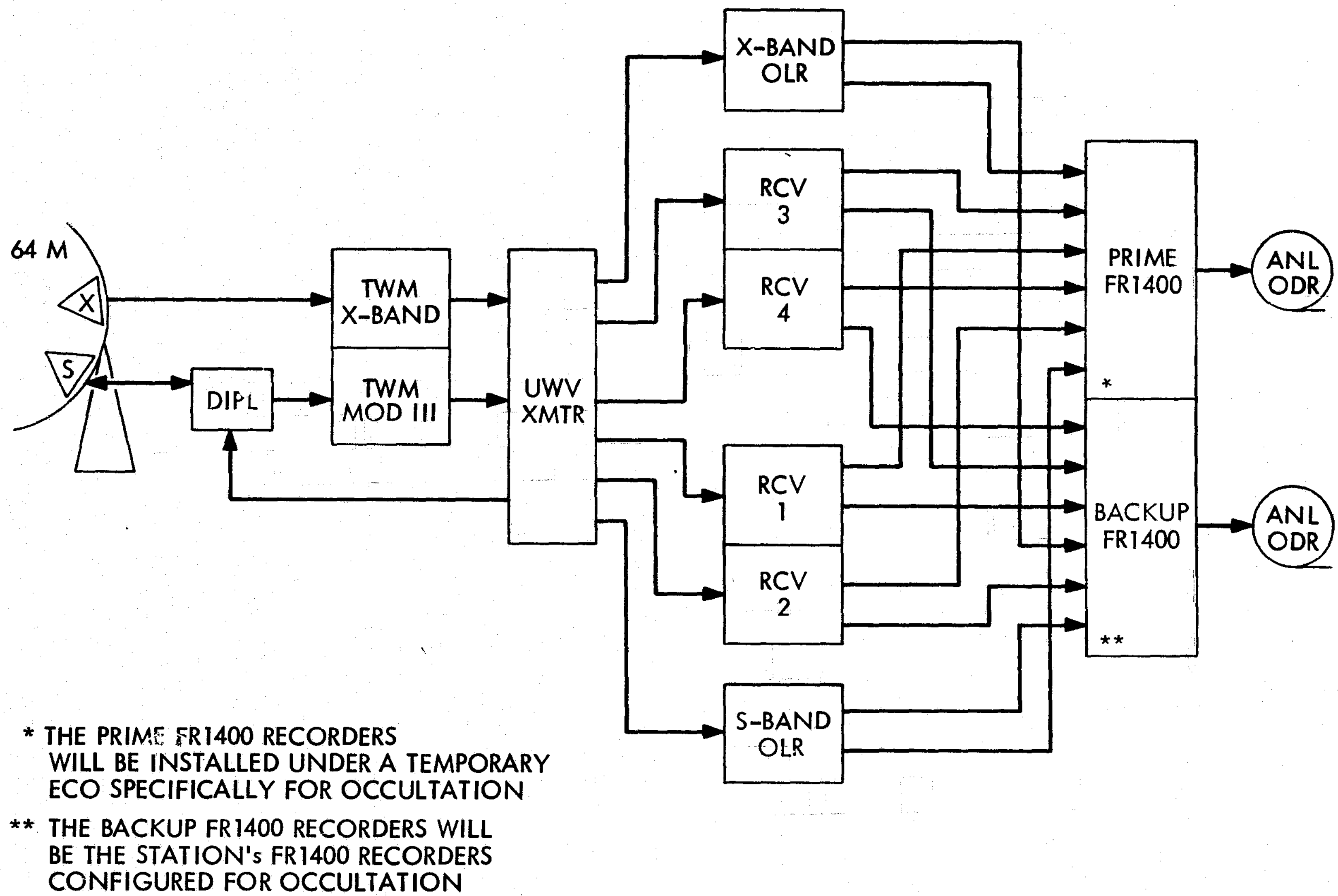


Figure 87. DSN occultation configuration, DSS 14

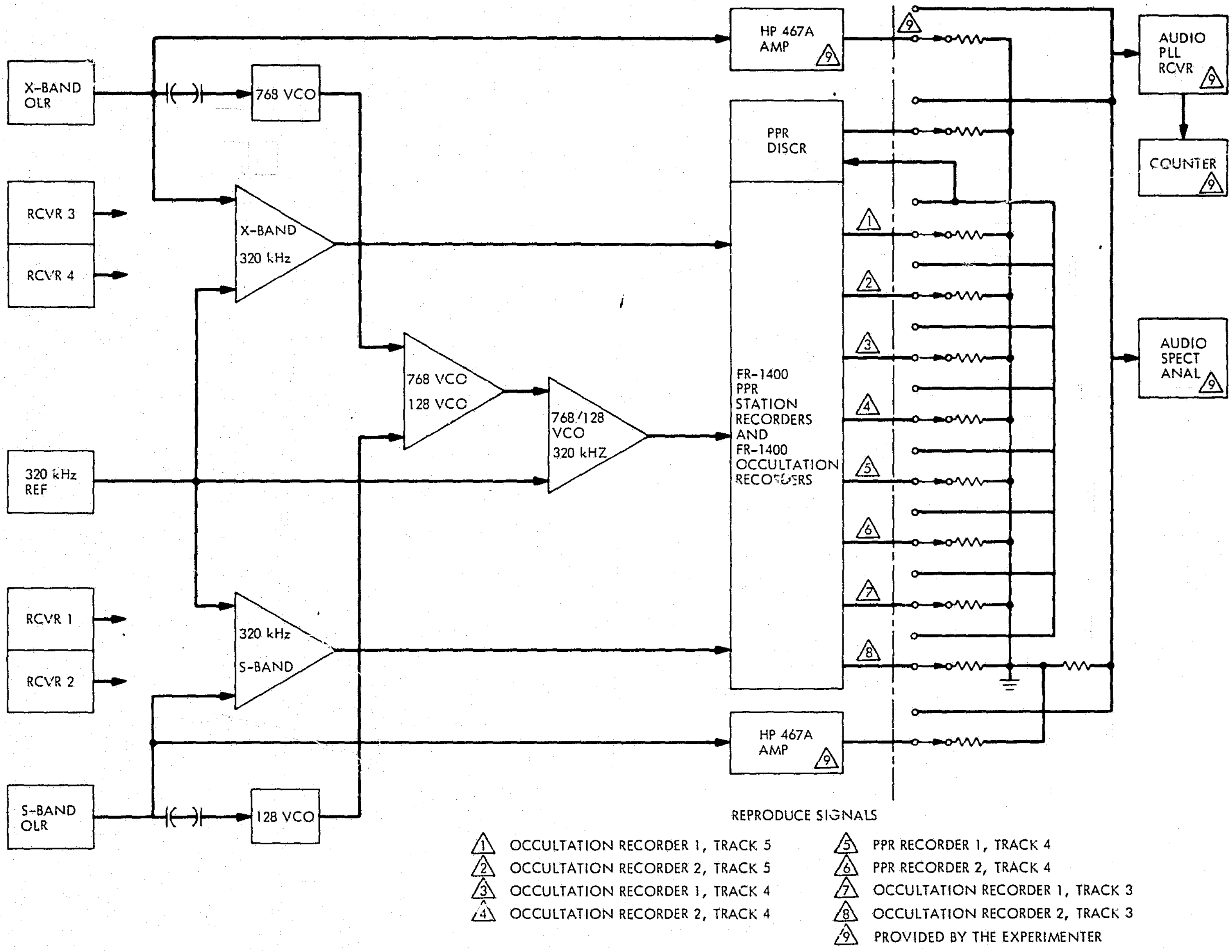


Figure 88. DSN occultation monitoring configuration, DSS 14

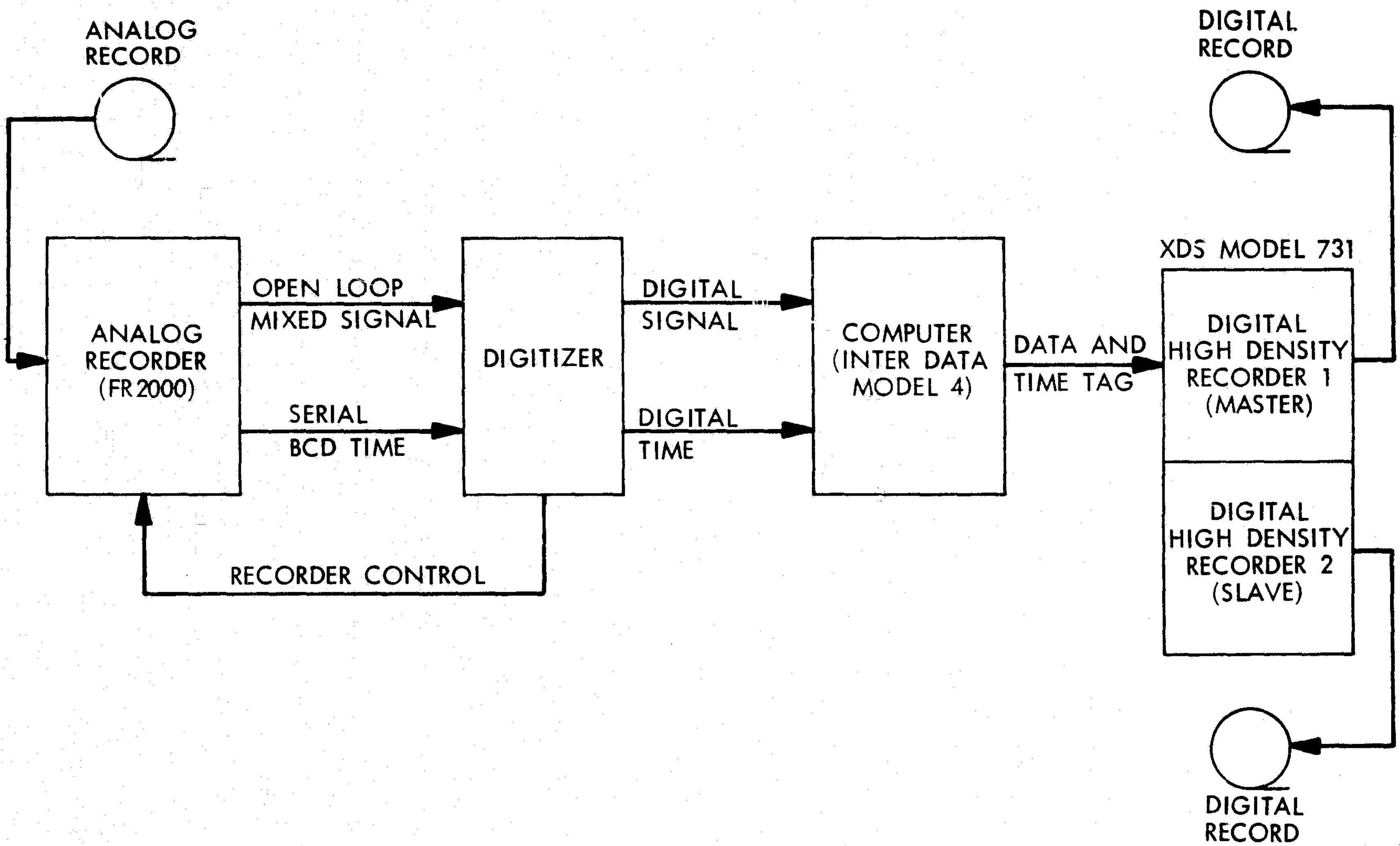


Figure 89. Analog-to-digital recording configuration, CTA 21

Table 32. FR-1400 recorder configuration for DSS 14 only (special recorders for occultation data)

Track	Data					Mix ratio[a]
	IRIG channel	Function	VCO center frequency, kHz	Deviation percentage ±	Deviation voltage, V	
1		Speedlock (100 kHz) For 60 ips	Direct			1:1
2	3	RCVR 1 SPE	0.73	7.5	±5	1:1
	4	RCVR 2 SPE	0.96	7.5	±5	1:1
	5	RCVR 1 DPE	1.30	7.5	±5	1:1
	6	RCVR 1 AGC	1.70	7.5	0 to -5	1:1
	7	RCVR 2 AGC	2.30	7.5	0 to -5	1:1
	8	RCVR 2 DPE	3.00	7.5	±5	1:1
		X-band RCVR DPE	13.50	15.0	0 to +5	1:1
	A	Voice	22.00	15.0	±5	1:1
	C	CMA 2	40.00	15.0	±5	1:1
	18	CMA 1	70.00	7.5	±5	1:1
	19	NASA time	93.00	7.5	±5	1:1
		X-band RCVR AGC	768.00	64/16 kHz	±5	1:1
		X-band RCVR SPE	128.00	64/16 kHz	±5	1:1
3		X-band OLR	Direct			1:1
		Digitizing tone[b] (320.0 kHz)				1:1
4		X-band OLR	768.00/192.0	64/16 kHz	±1	1:1
		S-band OLR	128.00/32.00	16/4 kHz	±1	1:1
		Digitizing (320.0 kHz) tone[b]				1:1
5		S-band OLR	Direct			1:1
		Digitizing tone[b] (320.0 kHz)				1:1
6		Speedlock (100 kHz) For 60 ips	Direct			1:1
7		SDA 2 output	525.00	30.0	±5	1:1

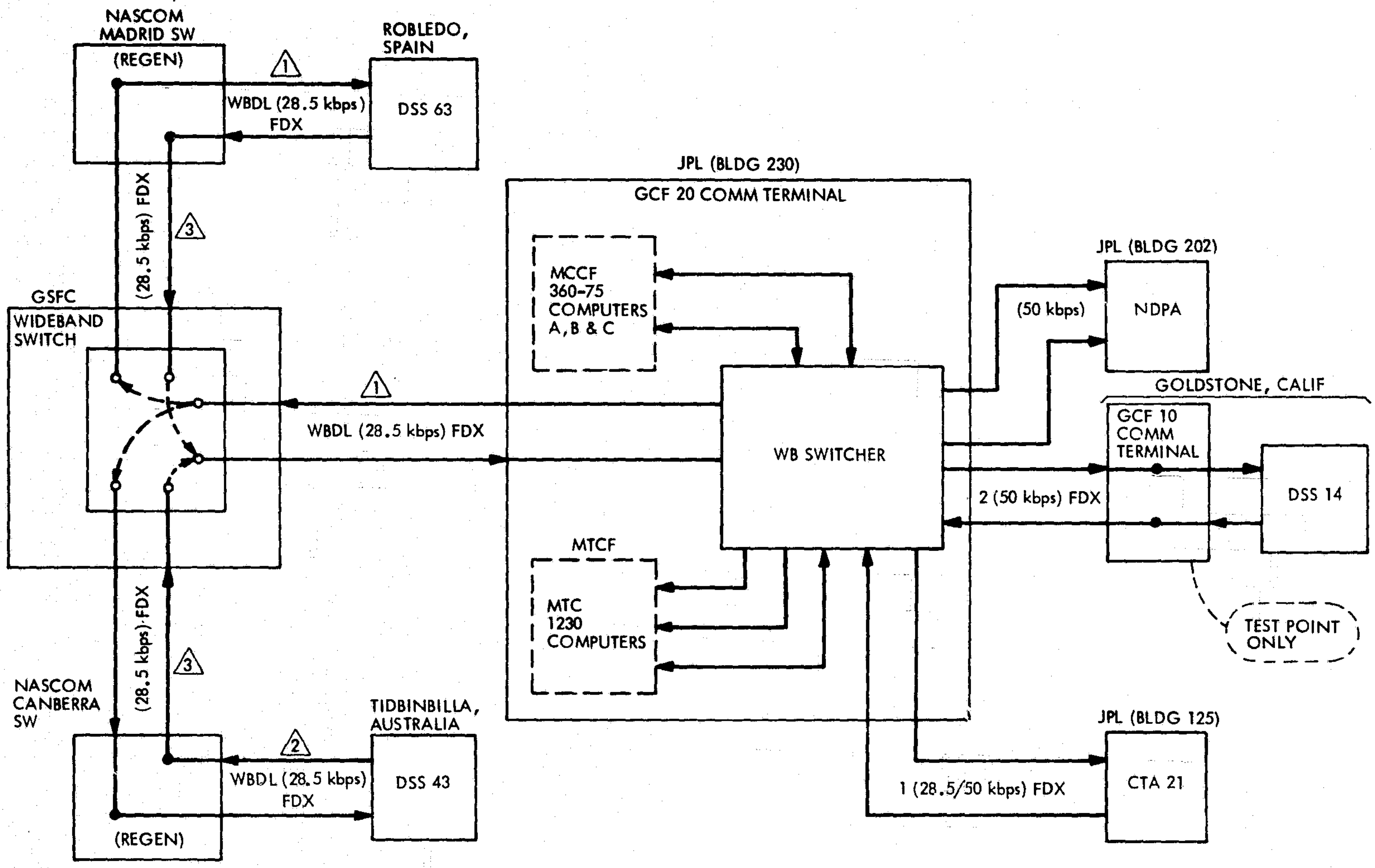
[a]The input to each recorder track will be adjusted to 2.8 V p-p.

[b]The 320.0-kHz digitizing tone input to the recorder will be 0.5 V p-p.

As mentioned in the telemetry system discussion, the possibility of real-time video from Venus and Mercury at 117.6 kbps led to requirements for instant viewing which would not be denied. The Project pressed for real-time transmission of 117.6 kbps from DSS 14 only, and for some months, DSN, GCF, and Project people worked to arrive at a low cost method of providing this service. The station computer capacities could not handle this additional transmission function. Costs and schedules precluded implementation of additional computer and software programs. It was well known that the Project communicated the 117.6-kbps data between the spacecraft and mission test computers during the prelaunch tests through use of the word formatter assembly and serial bit stream transmissions. Technically, the word formatter then could perform a similar function between the station's symbol synchronizer assembly serial bit stream output and the Mission Test Computer (MTC) which would be used by the Project for data processing during flight operations. This required the GCF to provide the necessary super wideband circuit between DSS 14 and JPL via the commercial carrier microwave line. The 230-kbps channel capacity was selected as a function of availability of standard, commercial communications equipment. Although this service worked very well after initial installation problems were solved, it was regarded as a kluge and was unsatisfactory in terms of standard GCF operations. Since these data were not sent in standard GCF block format, no error detection and monitoring capability existed. Test and troubleshooting aids were very limited. GCF operations were conducted in the blind except for user feedback as to the quality of data being delivered.

The overall GCF/NASCOM wideband configuration is given in Fig. 90. Details of wideband capabilities at a typical 64-m station are illustrated in Fig. 91. Figure 92 reflects GCF standard wideband capabilities in the Central Communications Terminal and interfaces with user equipment. Figure 93 details the special super wideband configuration between DSS 14 and the user at JPL.

In addition to wideband services detailed above, standard GCF circuits between each station and JPL included one 4.8-kbps high-speed data line, one 100-wpm teletype, and one operational voice circuit. Figures 94 through 96 illustrate the full complement of communications services for each of the 64-m stations; Figs. 97 through 99 give the same information for the 26-m stations. Figure 100 reflects the communications configuration for a typical 26/64-m conjoint station. Figure 101 shows how use of the GCF intersite microwave capability between stations in the same longitude permitted use of 26-m station data handling equipment as an alternate path for data being received at the 64-m antenna. This particular configuration permitted both of DSS 14's telemetry strings to be configured for high-rate video during the antenna arraying operations for second Mercury encounter. Communications services similar to a 64-m station were also implemented in the DSN test station at JPL as illustrated in Fig. 102. Details of the Central Communications Terminal configuration for high-speed data circuits and interfaces were as shown in Fig. 103. With NASCOM, the GCF also assisted the Project in implementing data circuit capabilities for the transmission of processed data from the mission support computer to remote experimenter locations as shown in Fig. 104.

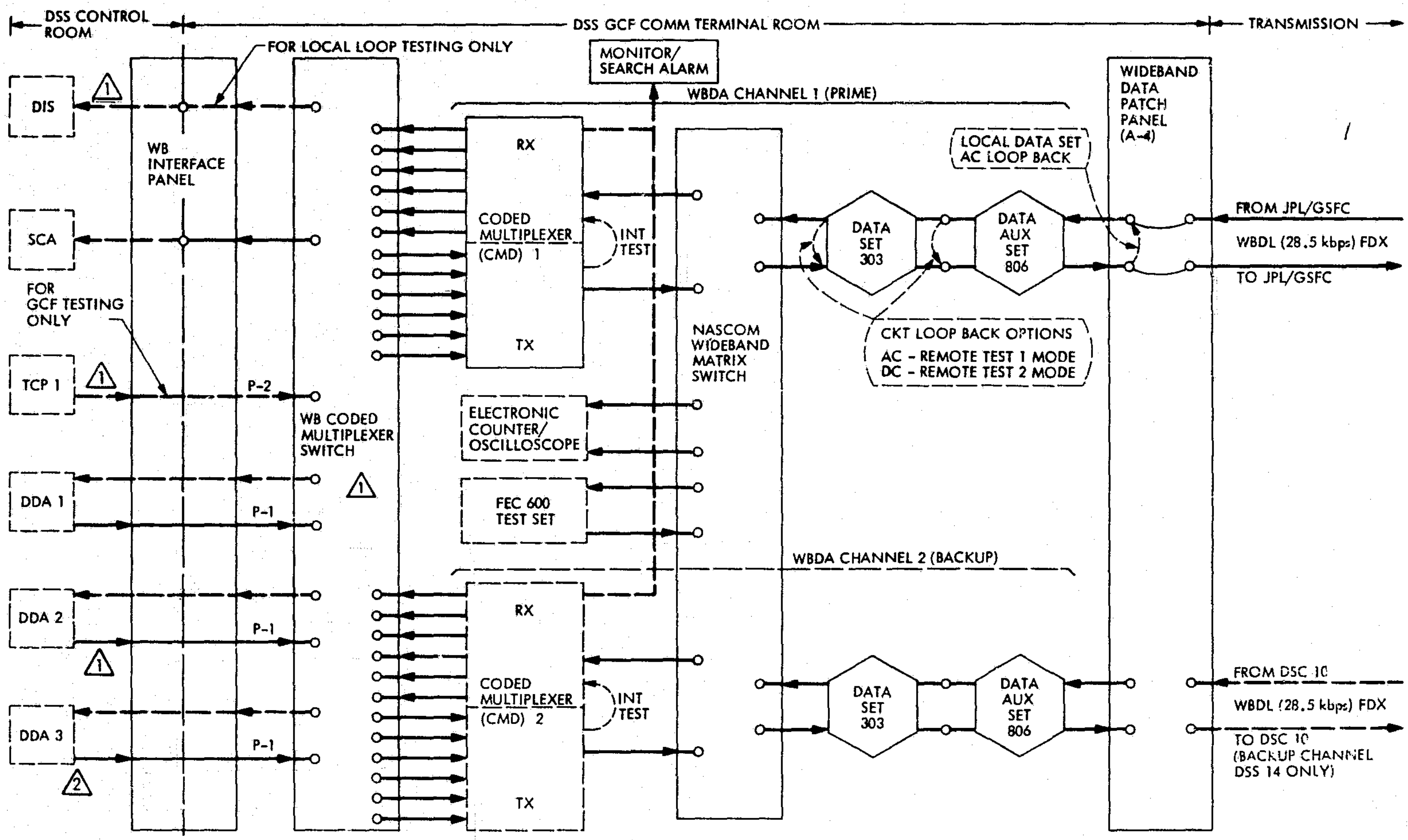


(1) **DSS 63-JPL-GSFC WB CIRCUIT AVAILABLE 3 JAN 75 THRU 26 MAR 75 ONLY. THIS CIRCUIT TO BE SHARED BY MVM-73 AND VK-75 TEST SUPPORT.**

(2) JPL-DSS 43 WB CIRCUIT AVAILABLE VIA GSFC 15 FEB 75 THRU 26 MARCH 75 ONLY.

(3) DSS 63/43 WB CIRCUITS VIA NASCOM FACILITY WILL BE TIME SHARED BY MVM-73 AND STDN ATMOSPHERIC EXPLORER PROJECT.

Figure 90. CF-NASCOM wideband circuit routing/capabilities for third Mercury encounter

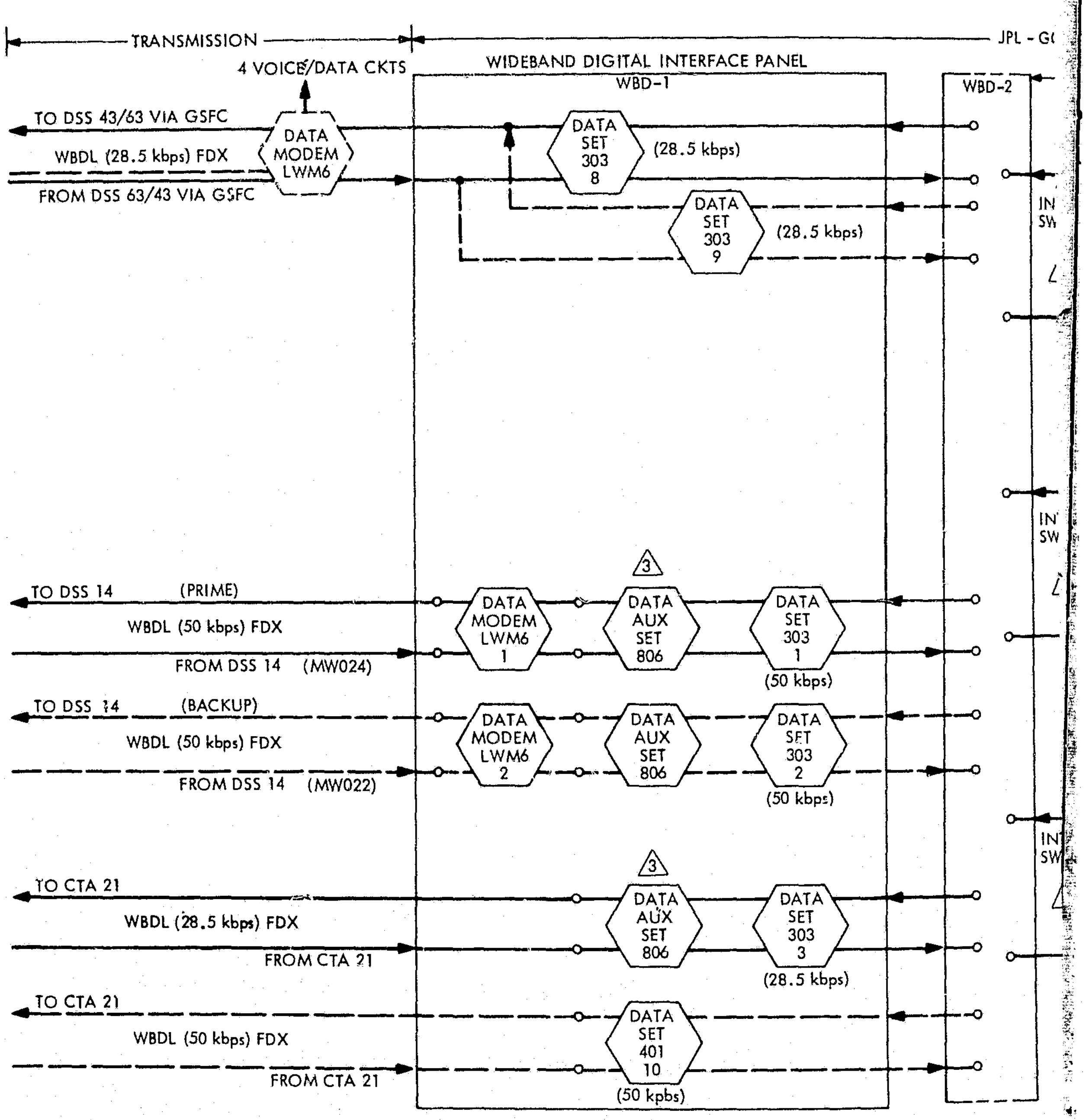


NOTES:

1. DIS AND DDA COMPUTER RX INTERFACES USED FOR LOCAL TEST AND TROUBLE ISOLATION/DATA VALIDATION ONLY.

2. DSS 63 ONLY CONFIG WITH DDA 3 WB INTERFACE.

Figure 91. Typical 64-m DSS, 28.5-kbps wideband data terminal configuration



1. FOR LOOP BACK MODE USE CMD INT TEST SWITCH.
2. GFC 20 TO PROVIDE WB BLOCK ERROR MONITORING AND RECORDING ON TWO WB DATA STREAMS.
3. DATA SETS 1,2,3, AND 10 ARE PATCHABLE TO DSS 14/CTA 21 ONLY.

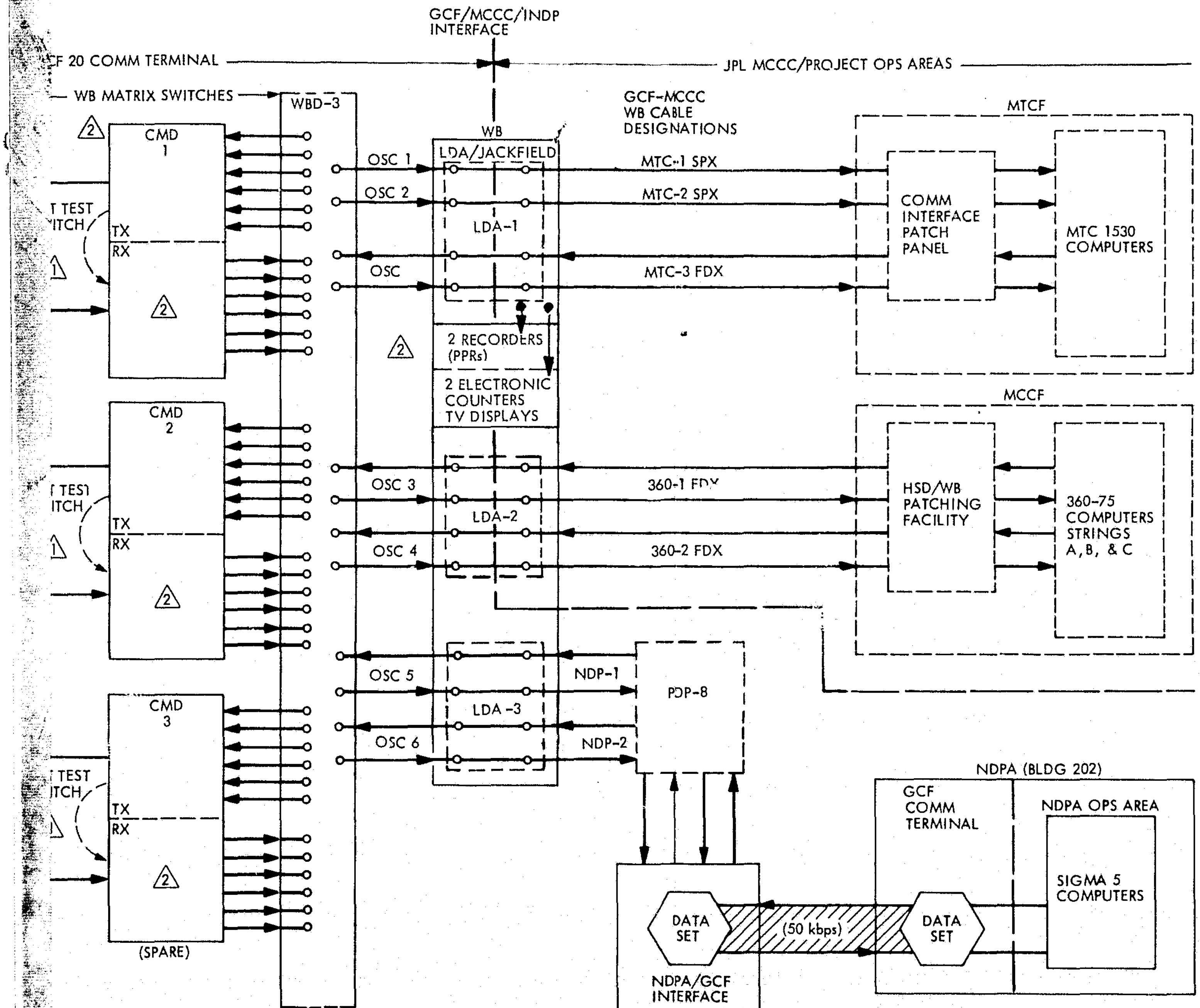
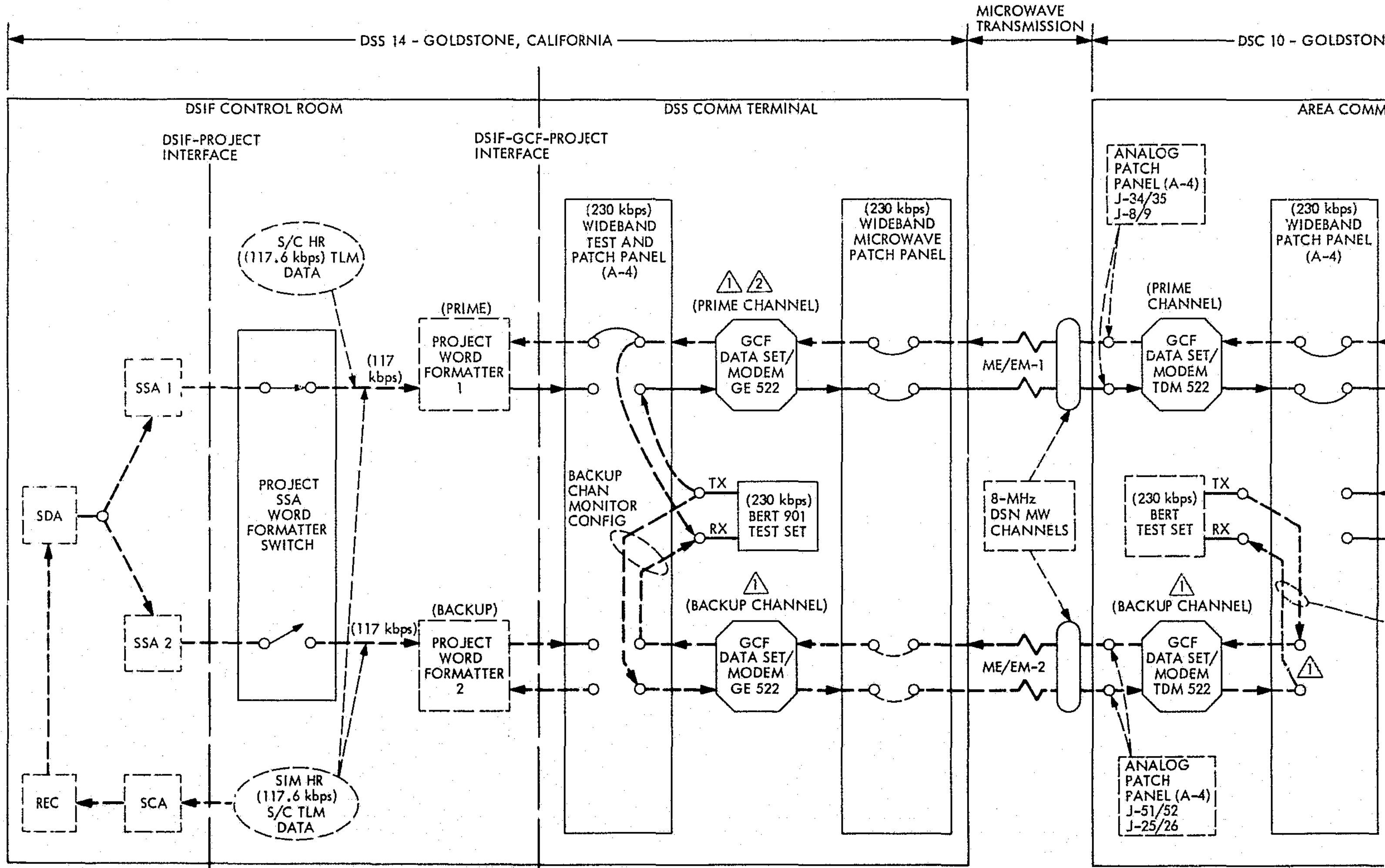


Figure 92. JPL (GCF 20)/MCCC wideband circuit, assembly interfaces

FOLDOUT FRAME 2

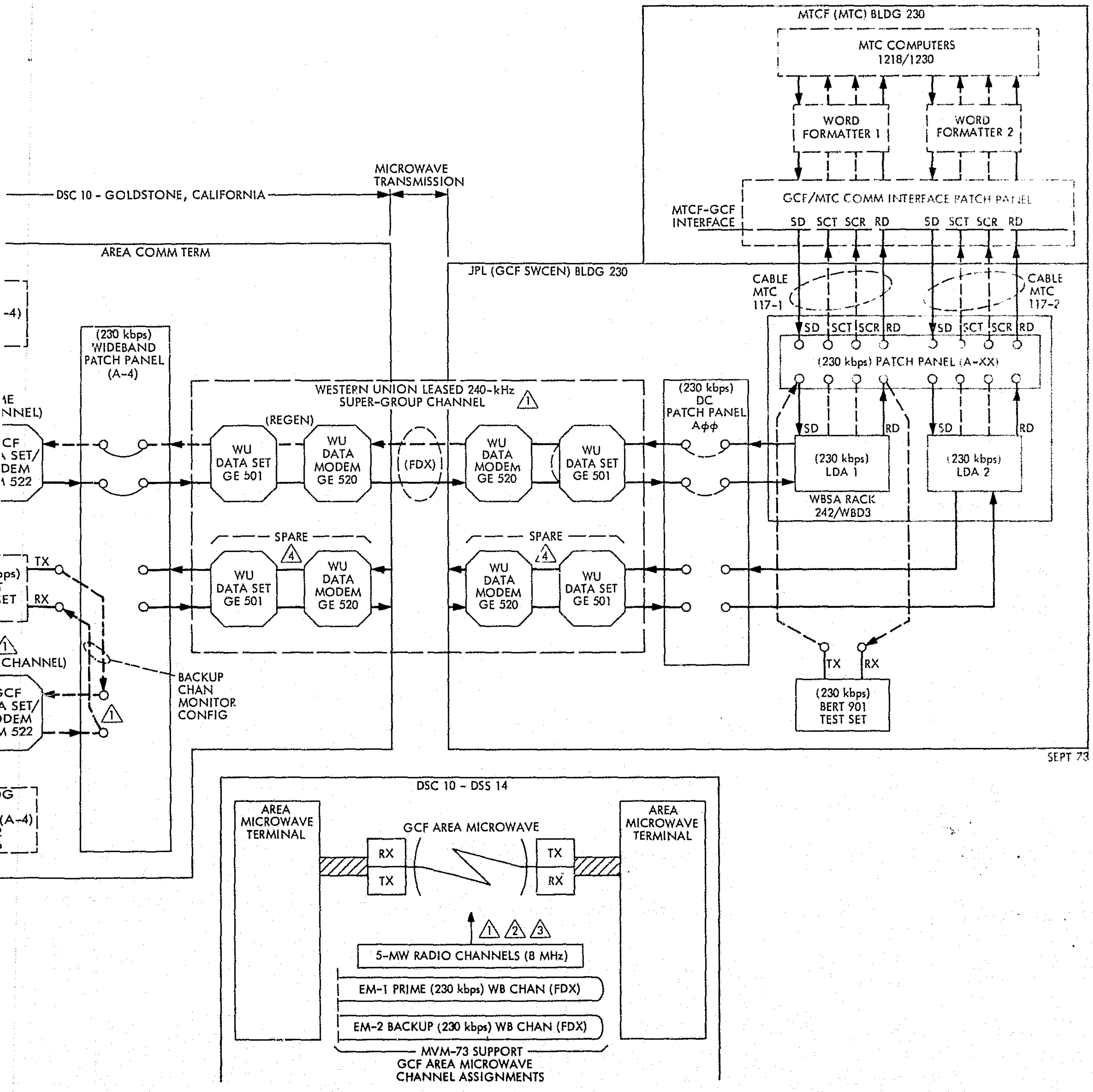
C-3

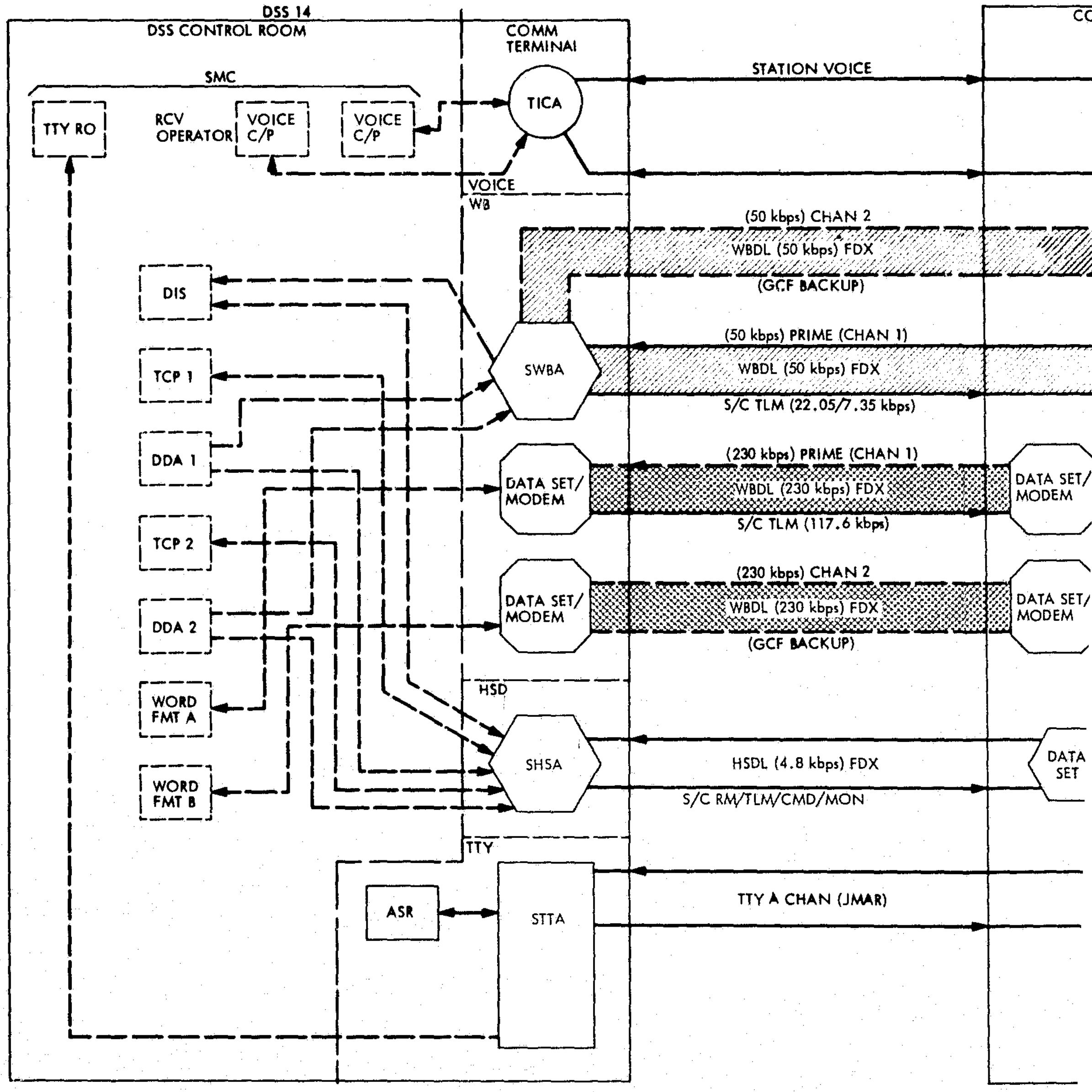


NOTES:

1. ALL GCF CAPABILITIES JPL (GCF SWCEN)-DSC 10 COMM-DSS 14 REQUIRE SCHEDULING VIA THE DSN SCHEDULING SYSTEM. DURING EACH MVM-73 (230.4/117.6 kbps) SUPPORT PERIOD THE GCF WILL AUTOMATICALLY SCHEDULE AND ACTIVATE THE DSN MW BACKUP (230.4 kbps) CHANNEL VIA RADIO CHANNEL EM-2.
2. GCF SWCEN/DSC 10 NORMALLY WILL UTILIZE THE ABOVE GCF AREA MW RADIO/MX-106 CHANNEL ASSIGNMENTS/ROUTING WHEN SCHEDULING DSC 10 - DSS 14 - MVM-73 (230 kbps) SUPPORT.
3. GCF AREA MW RADIO CHANNEL MVM-73 SUPPORT PRIORITY OF RESTORATION IS: EM-1/EM-3/EM-5/EM-4/EM-2.
4. GCF SWCEN AND DSC 10 COMM TERMINAL SUPER-GROUP BACKUP DATA SET/DATA MODEM PATCHING WILL BE PERFORMED BY WU PERSONNEL ONLY AT ANALOG SIDE OF WU MUX EQUIPMENT.

Figure 93. JPL (GCF SWCEN)/MTCF MVM'73 (230/117.6 kbps) Project support wideband circuit, equipment configuration


MTCF (MTC) BLDG 230
MTC COMPUTERS 1218/1230
WORD FORMATTER 1
WORD FORMATTER 2
MICROWAVE TRANSMISSION
DSC 10 - GOLDSTONE, CALIFORNIA
GCF/MTC COMM INTERFACE PATCH PANEL
MTCF-GCF INTERFACE
SD SCT SCR RD
AREA COMM TERM
JPL (GCF SWCEN) BLDG 230
CABLE MTC 117-1
CABLE MTC 117-2
(230 kbps) PATCH PANEL (A-XX)
(230 kbps) WIDEBAND PATCH PANEL (A-4)
WESTERN UNION LEASED 240-kHz SUPER-GROUP CHANNEL
(230 kbps) DC PATCH PANEL Aφφ
(REGEN)
WU DATA SET GE 501
WU DATA MODEM GE 520
(FDX)
(230 kbps) LDA 1
(230 kbps) LDA 2
WBSA RACK 242/WBD3
SPARE
TX
RX
BACKUP CHAN MONITOR CONFIG
(230 kbps) BERT 901 TEST SET
SEPT 73
DSC 10 - DSS 14
AREA MICROWAVE TERMINAL
GCF AREA MICROWAVE
5-MW RADIO CHANNELS (8 MHz)
EM-1 PRIME (230 kbps) WB CHAN (FDX)
EM-2 BACKUP (230 kbps) WB CHAN (FDX)
MVM-73 SUPPORT GCF AREA MICROWAVE CHANNEL ASSIGNMENTS



FOLDOUT FRAME

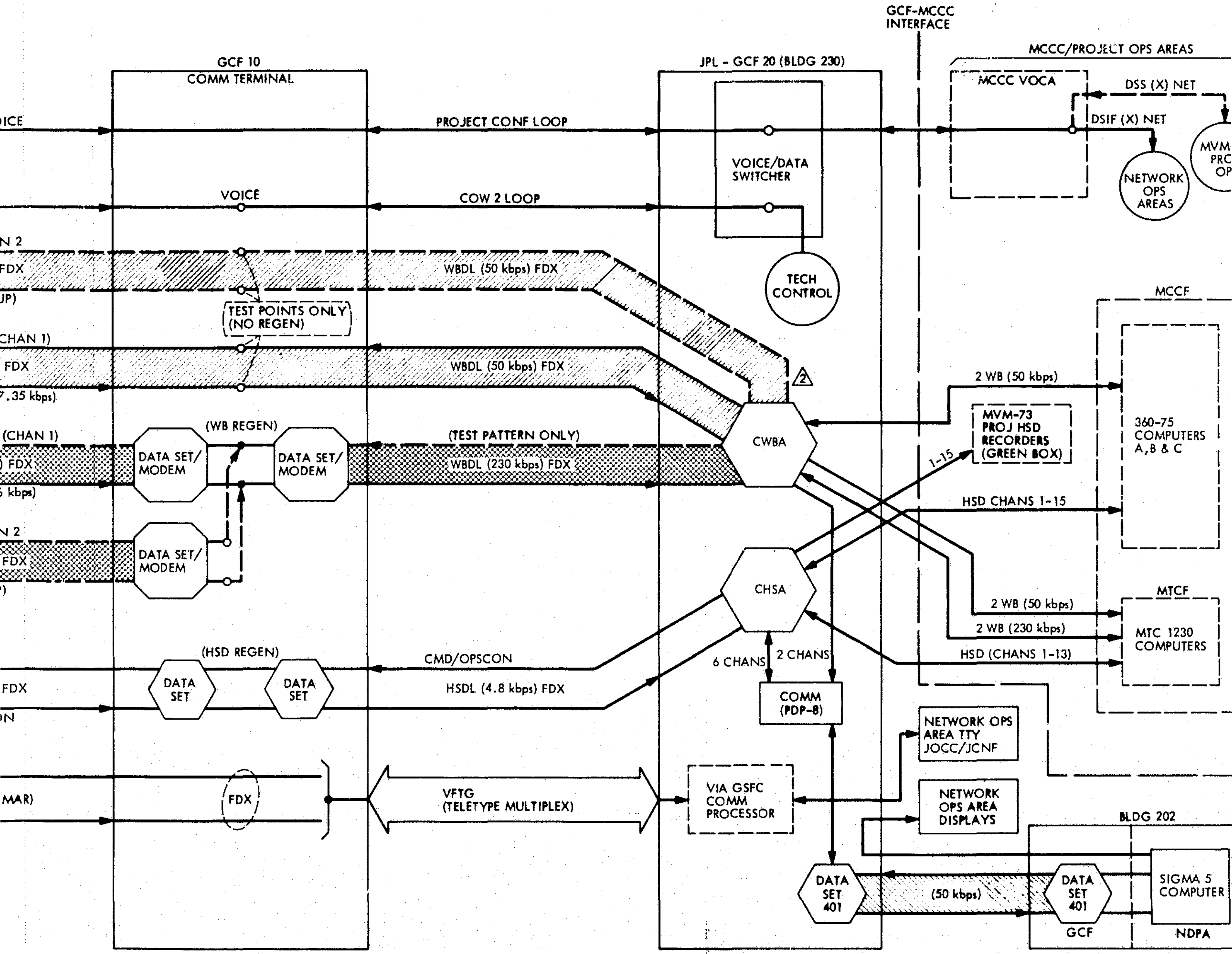


Figure 94. JPL/DSS 14 GCF circuits, data flow configuratio

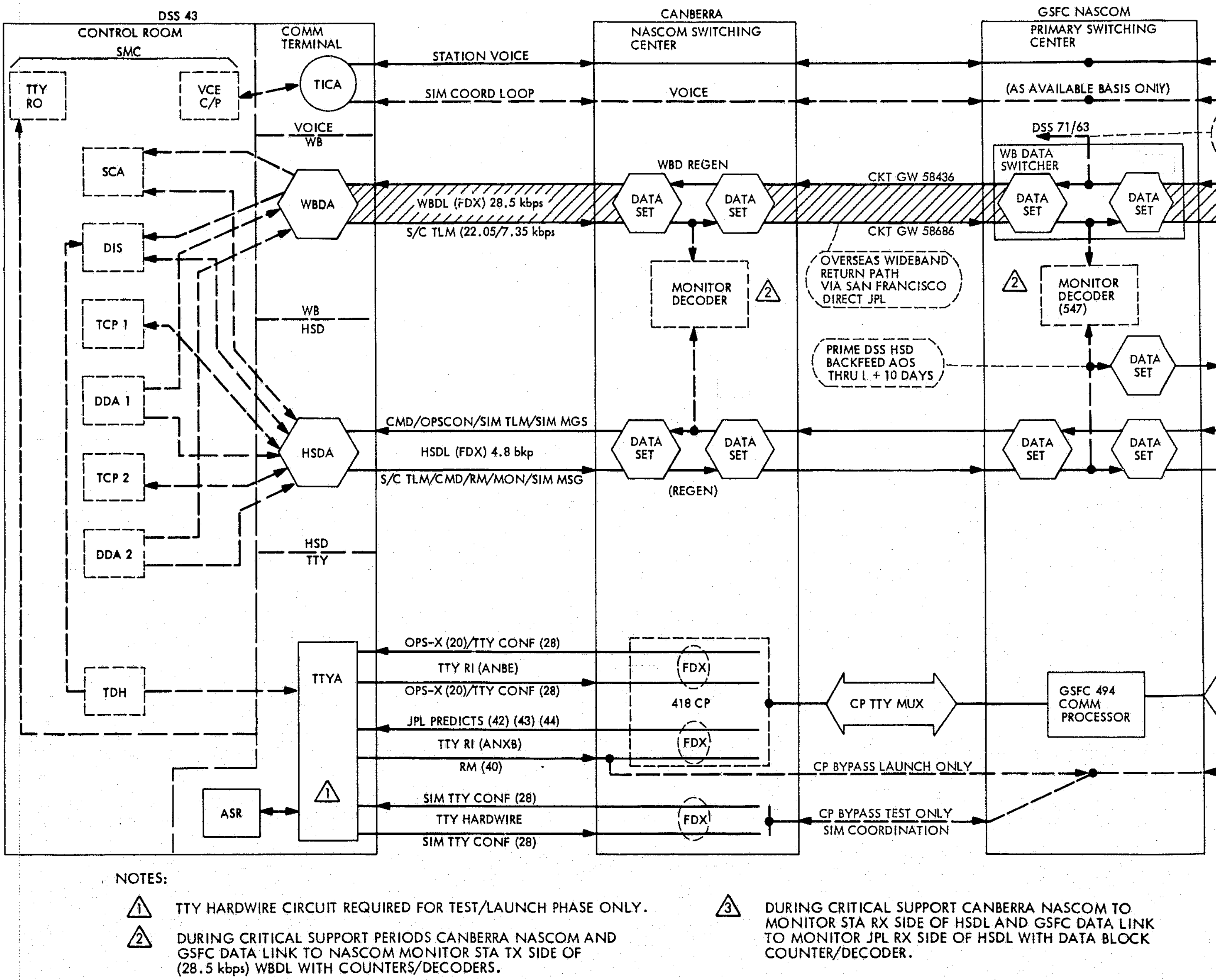
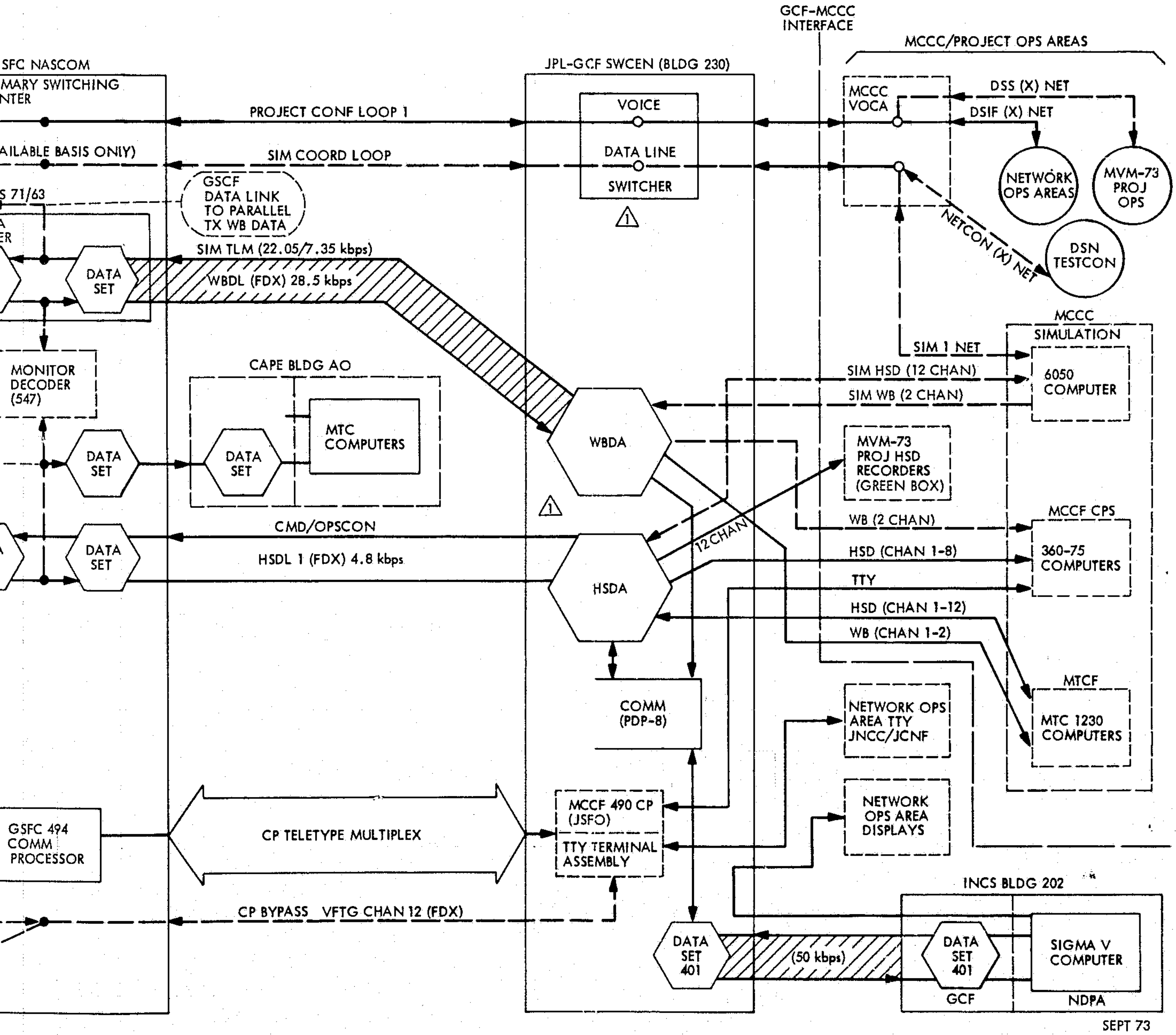


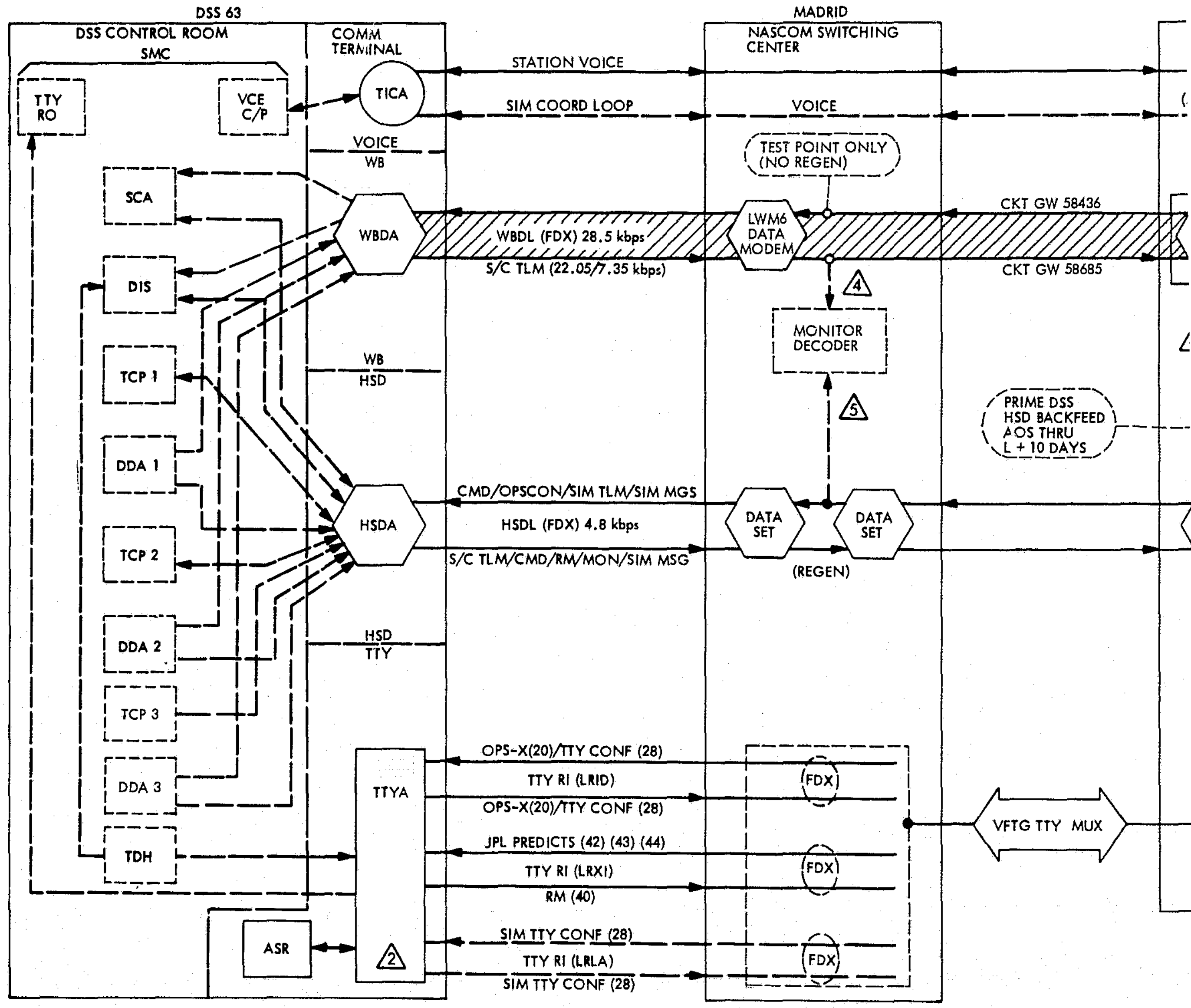
Figure 95. JPL/DSS 43 GCF circuits, data flow configurations

FOLDOUT FRAME 3



ASCOM TO
FC DATA LINK
DATA BLOCK

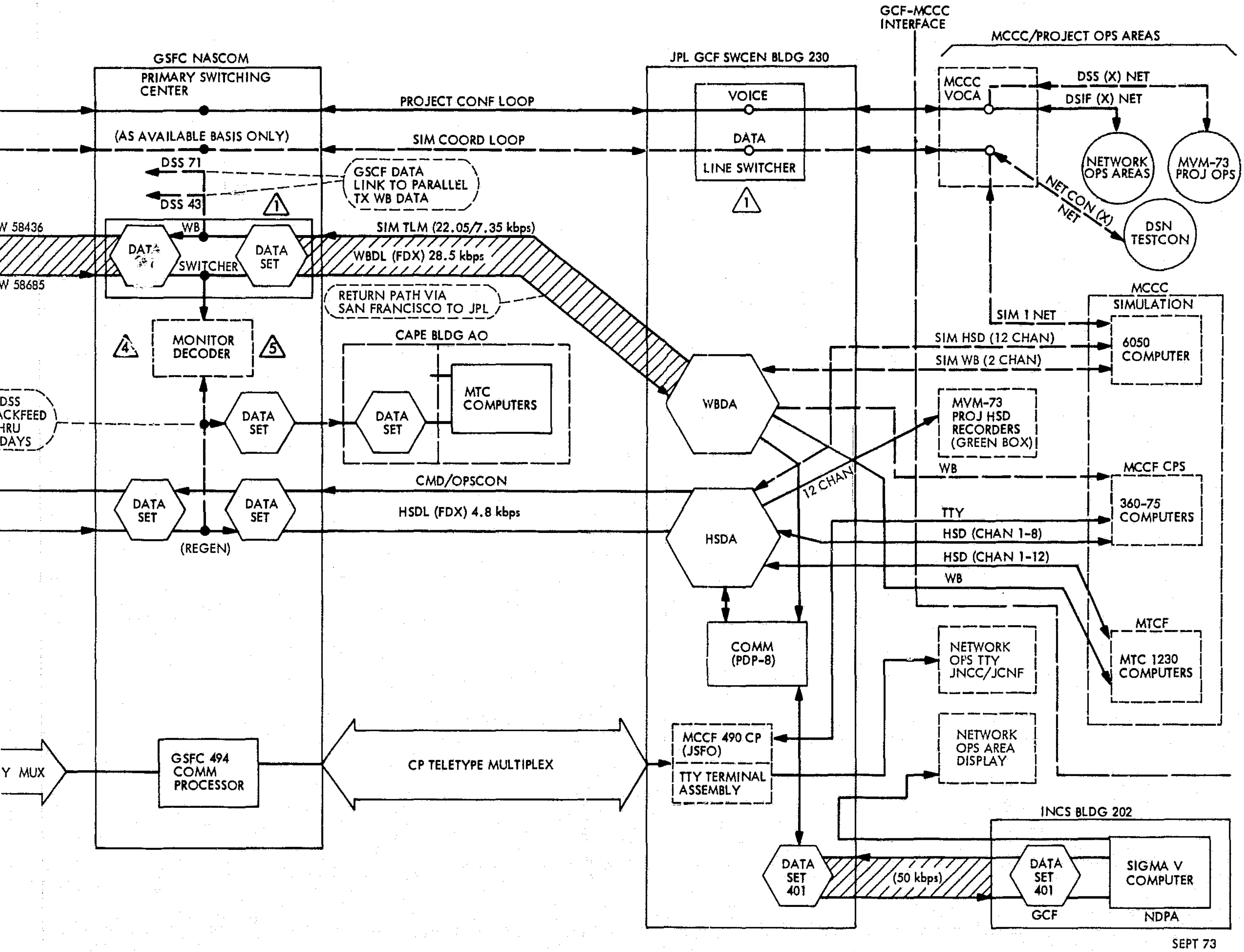
FOLDOUT FRAME 4



NOTES:

1. GSFC DATA LINK TO PARALLEL TX WB SIM DATA STREAM ON REALTIME REQUEST TO ANY TWO OF 3 LOCATIONS (DSSs 43/63/71).
2. TTY L CIRCUIT REQUIRED FOR TA TEST PHASE ONLY.
3. NASCOM PROVIDED (28.5 kbps) WIDEBAND CIRCUIT TO BE SHARED USE WITH STDN NETWORK.
4. DURING CRITICAL SUPPOR
DATA LINK TO PROVIDE D
ING OF THE STA TX SIDE C
5. DURING CRITICAL SUPPOR
DATA BLOCK COUNTER/DE
HSDL AND GSFC DATA LIN
MONITORING OF JPL RX S

FOLDOUT FRAME 1



CRITICAL SUPPORT PERIODS MADRID NASCOM AND GSFC
IK TO PROVIDE DATA BLOCK COUNTER/DECODER MONITOR-
'HE STA TX SIDE OF THE (28.5 kbps) WBDL.

CRITICAL SUPPORT PERIODS MADRID NASCOM TO PROVIDE
)CK COUNTER/DECODER MONITORING OF STA RX SIDE OF
) GSFC DATA LINK TO PROVIDE COUNTER/DECODER
RING OF JPL RX SIDE OF HSDL.

Figure 96. JPL/DSS 63 GCF circuits, data flow configurations

FOLDOUT FRAME 2

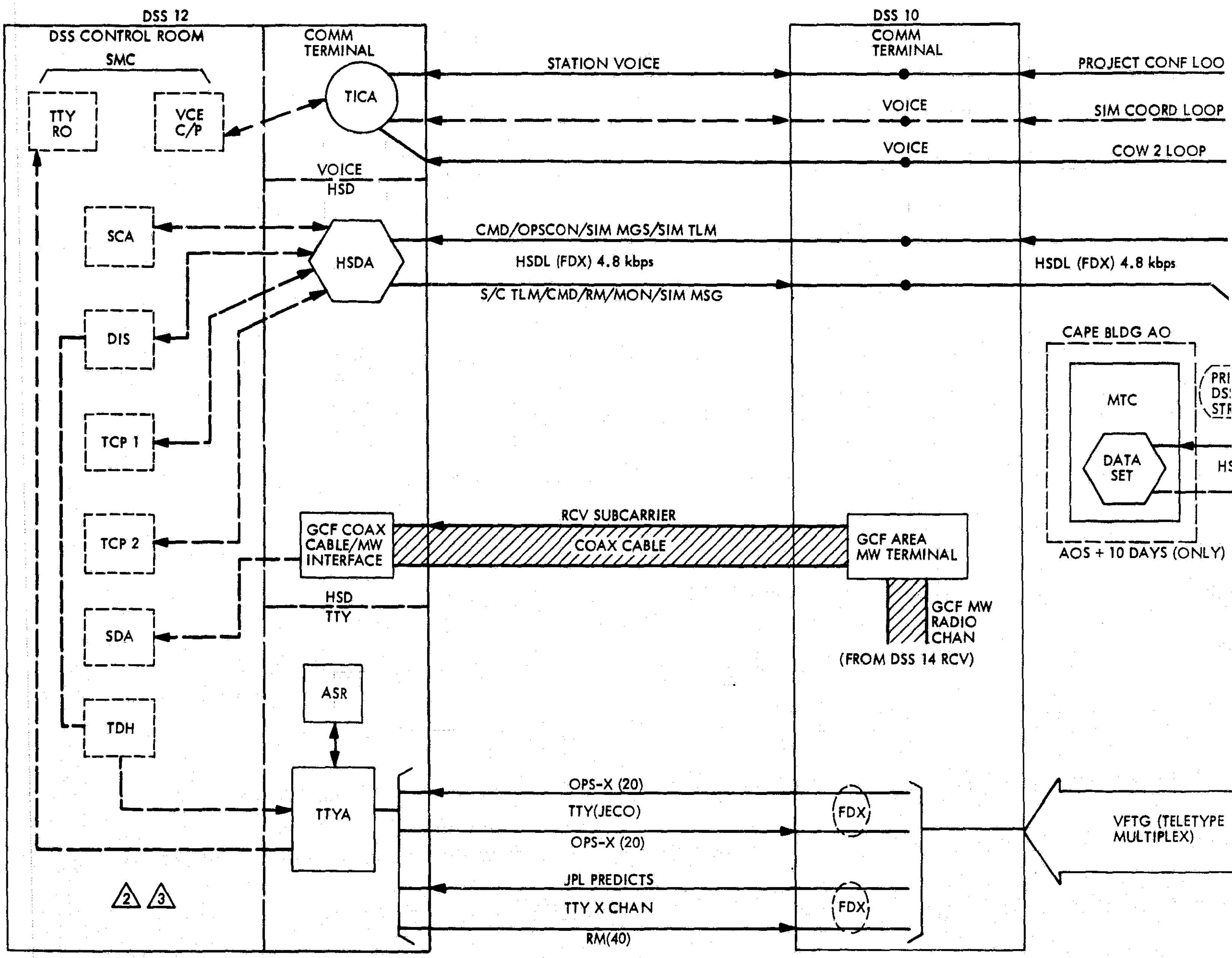
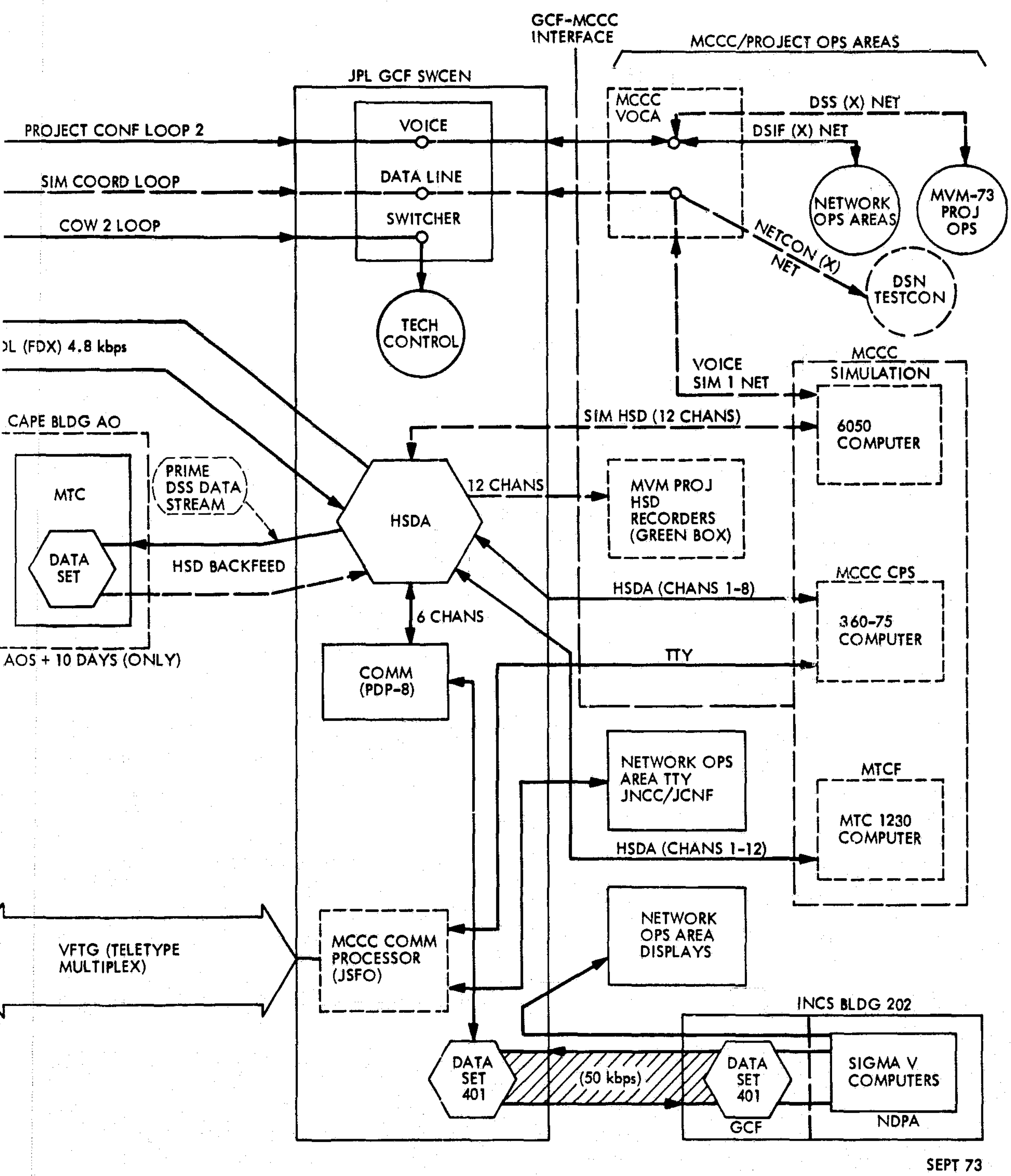
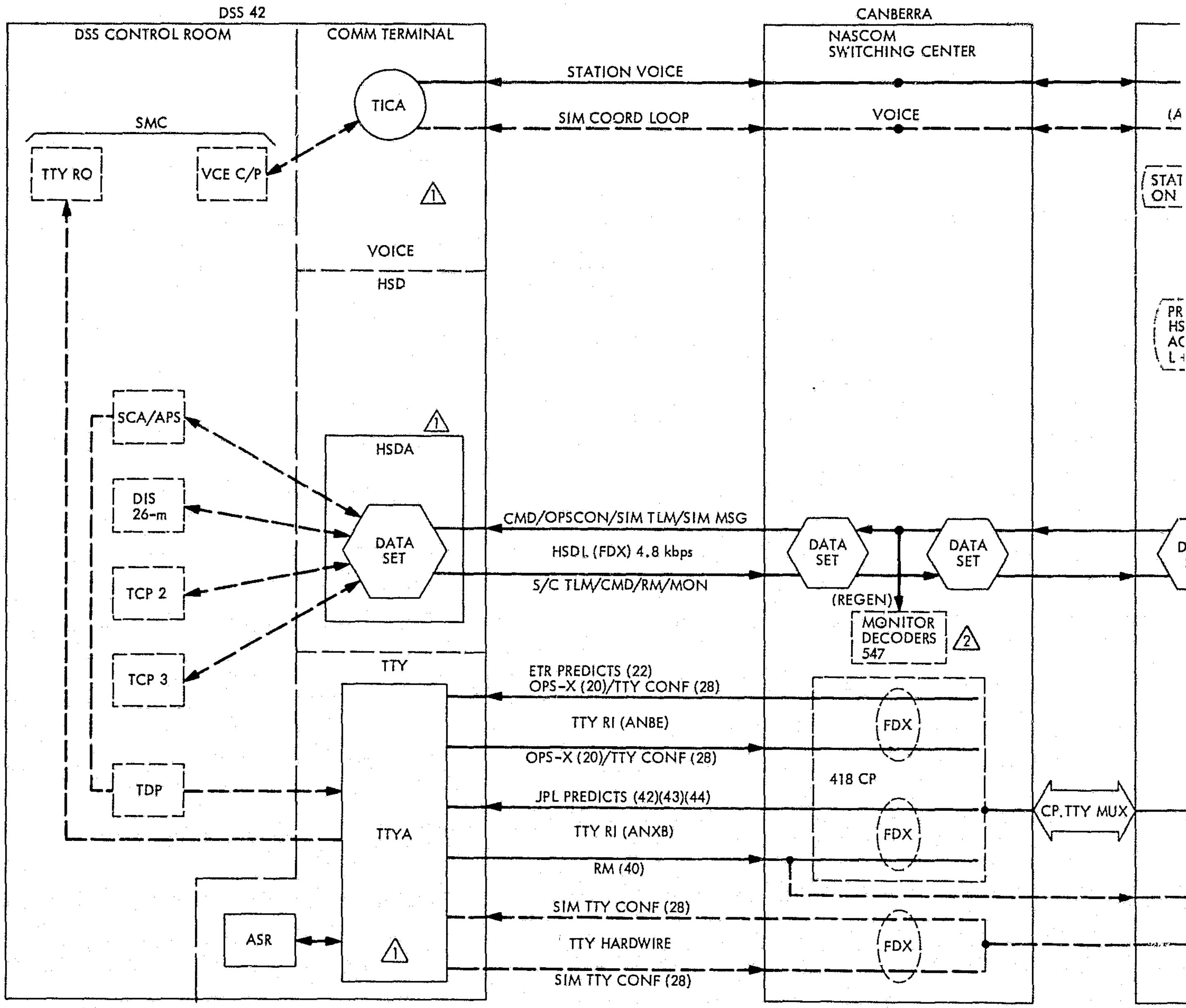


Figure 97. JPL/DSS 12 GCF circuits, data flow configurations

FOLDOUT FRAME 3



FOLDOUT FRAME 4



NOTES:

1. TTY HARDWIRE REQUIRED FOR TEST PHASE ONLY.
2. DURING CRITICAL PERIODS NASCOM SWCEN TO PROVIDE MONITOR DECODERS ON STA SIDE OF HSDL. GSFC DATA LINK TO MONITOR JPL RX SIDE OF HSDL.

FOLDOUT FRAME

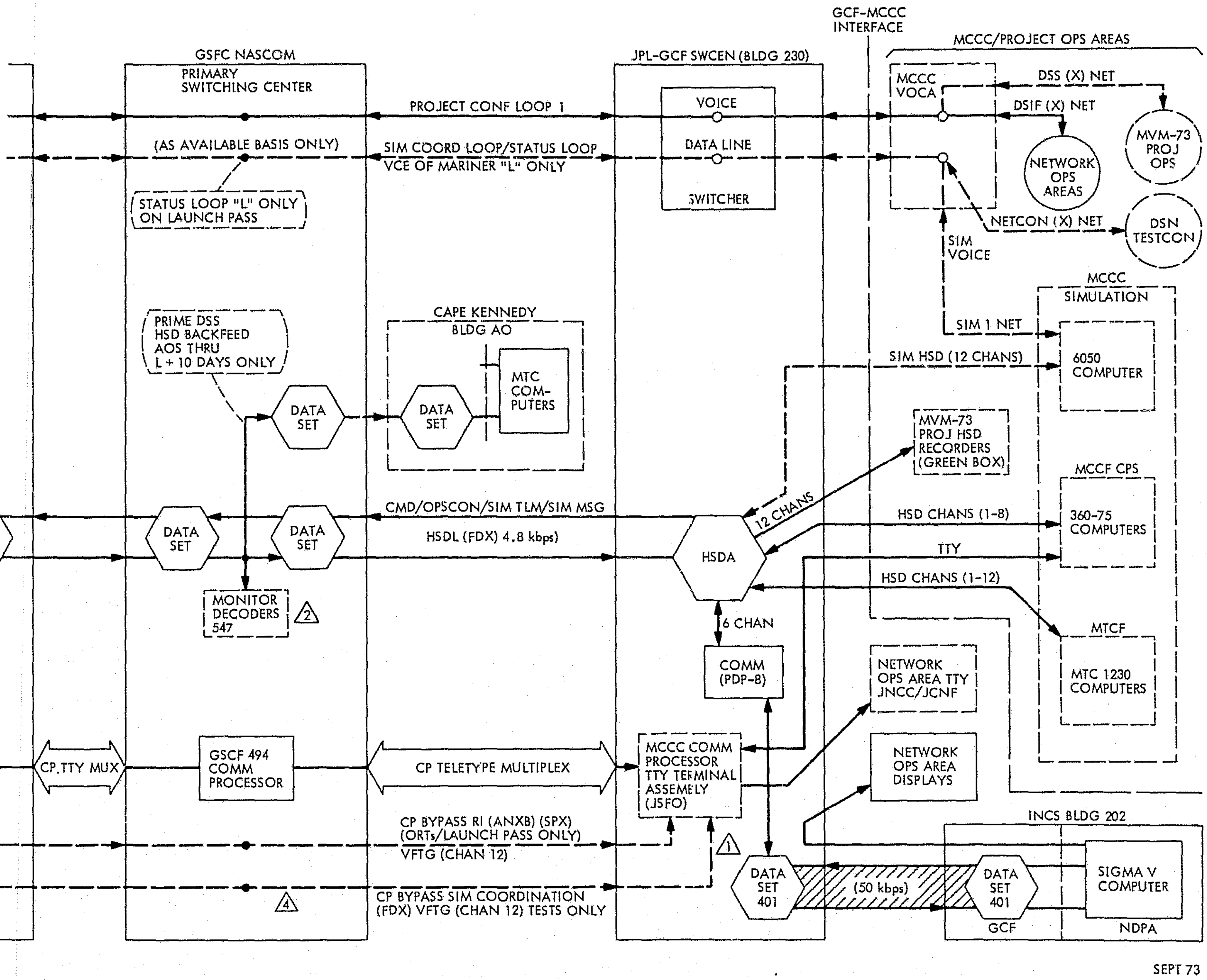
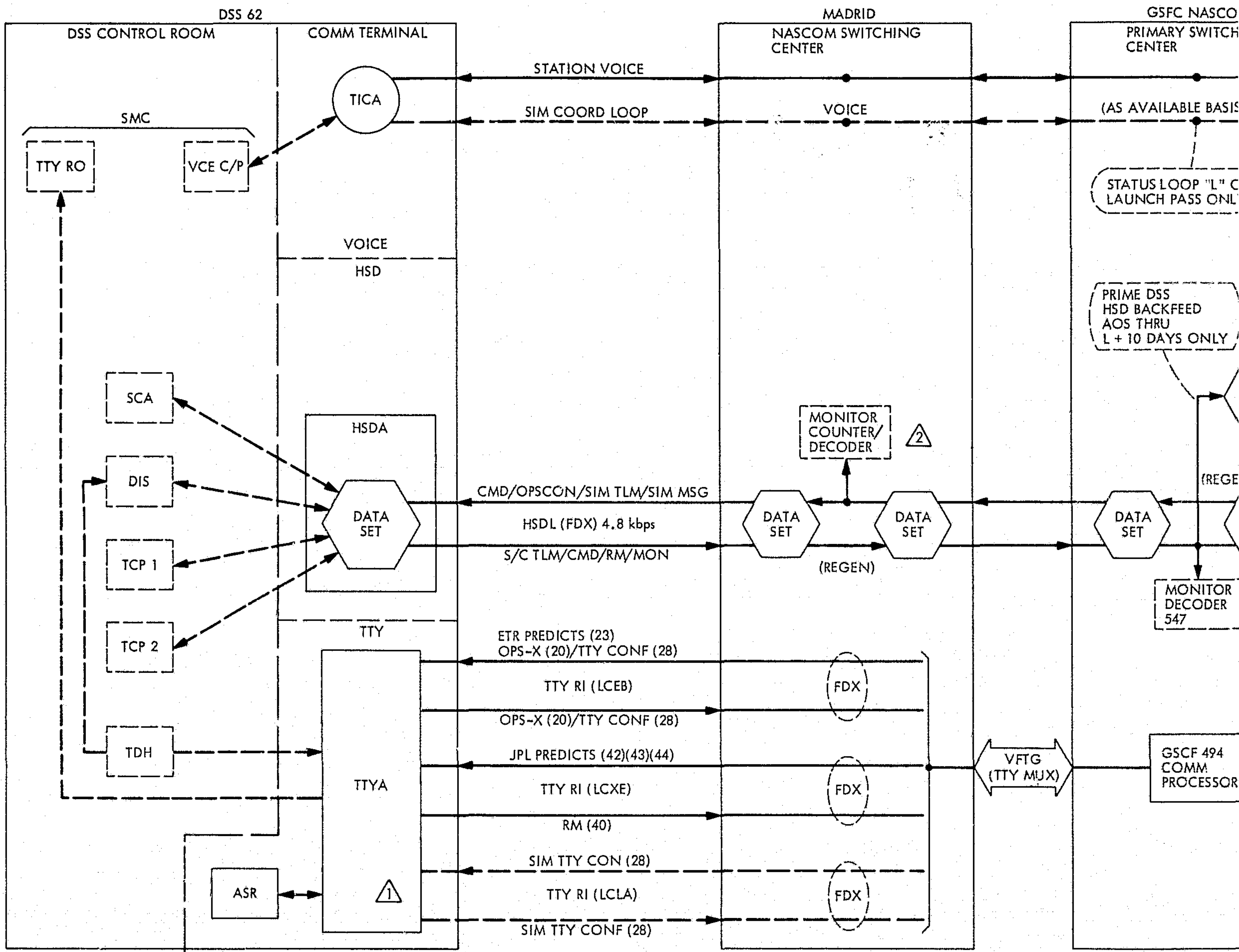


Figure 98. JPL/DSS 42 GCF circuits, data flow configurations

FOLDOUT FRAME 2



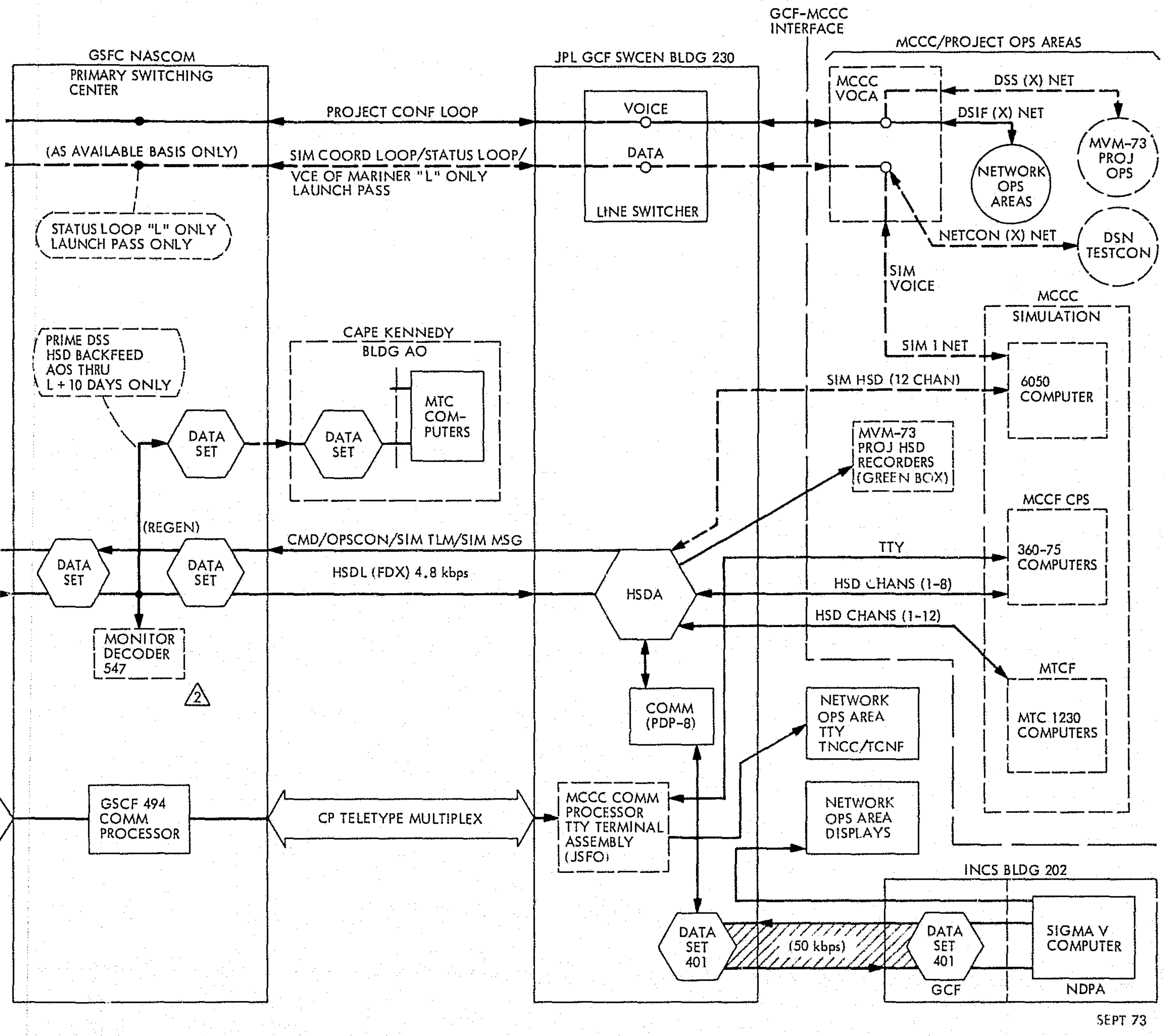
NOTES:

1. TTY RI (LCLA) REQUIRED FOR TEST PHASE ONLY.

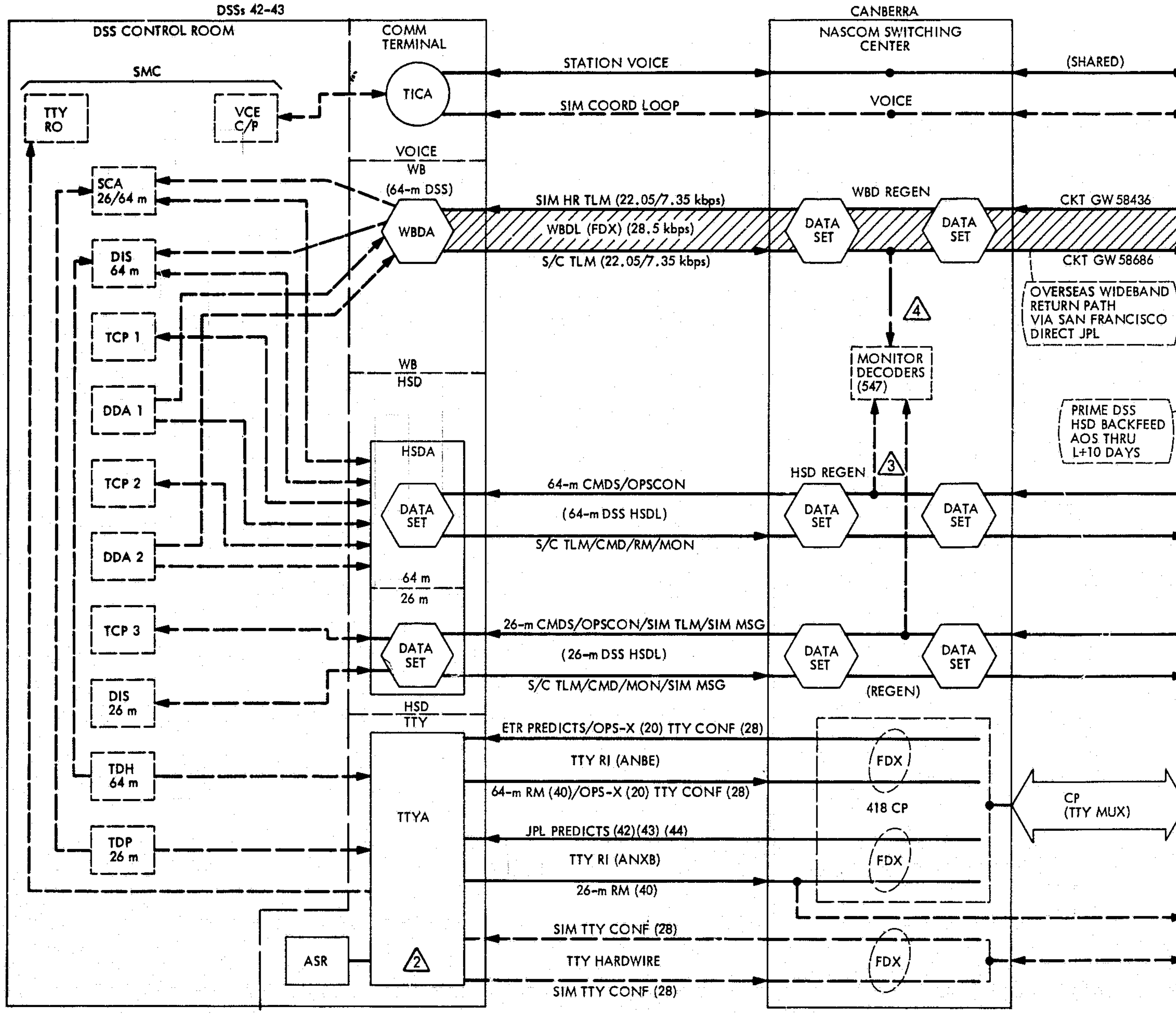
2. DURING CRITICAL SUPPORT PERIODS MADRID NASCOM TO PROVIDE DATA BLOCK MONITOR/COUNTERS DECODER ON STA RX SIDE OF HSDL AND GSFC DATA LINK TO MONITOR JPL RX SIDE OF HSDL.

Figure 99. JPL/DSS 62 GCF circuits, data flow configurations

FOLDOUT FRAME 3



FOLDOUT FRAME 4



NOTES:

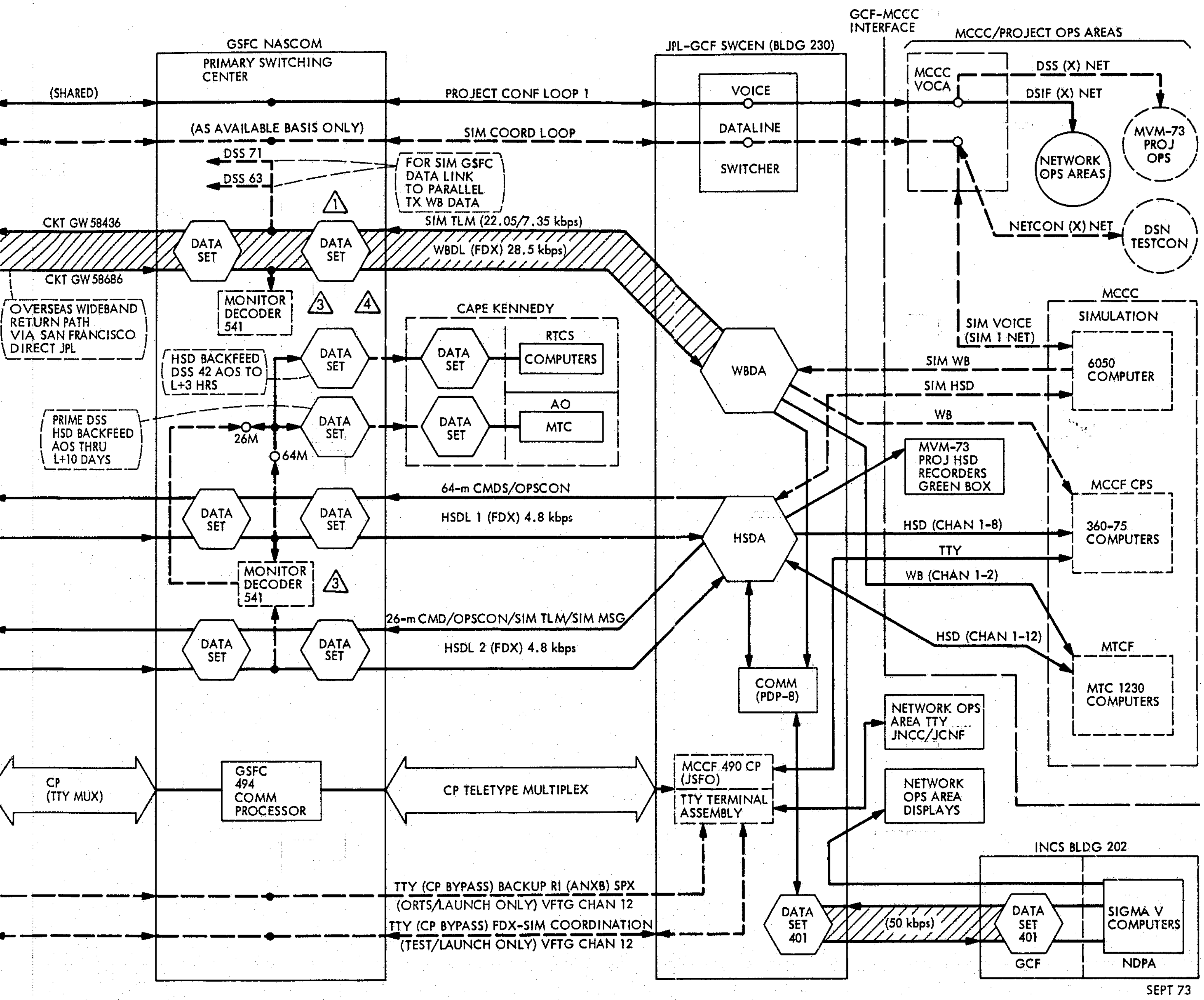
1. GSFC DATA LINK TO PARALLEL TX WB SIM DATA STREAM ON REALTIME REQUEST TO ANY TWO OF 3 LOCATIONS (DSSs 43/63/71) SEE FIG. 145

2. TTY HARDWIRE CKT REQUIRED FOR TEST/LAUNCH PHASE ONLY.

3. DURING CRITICAL SUPPORT PERIODS CANBE STA SIDE OF HSDL AND GSFC TO MONITOR COUNTERS/DECODERS.

4. DURING CRITICAL SUPPORT PERIODS CANBE DATA LINK TO MONITOR STA TX SIDE OF (2 BLOCK COUNTERS/DECODERS.

FOLDOUT FRAME 1



ORT PERIODS CANBERRA NASCOM TO MONITOR
GSFC TO MONITOR JPL RX SIDE OF HSDL WITH

ORT PERIODS CANBERRA NASCOM AND GSFC
OR STA TX SIDE OF (28.5 kbps) WB CKT WITH
ODERS.

Figure 100. JPL/DSS 42/43 GCF circuits, data flow configurations

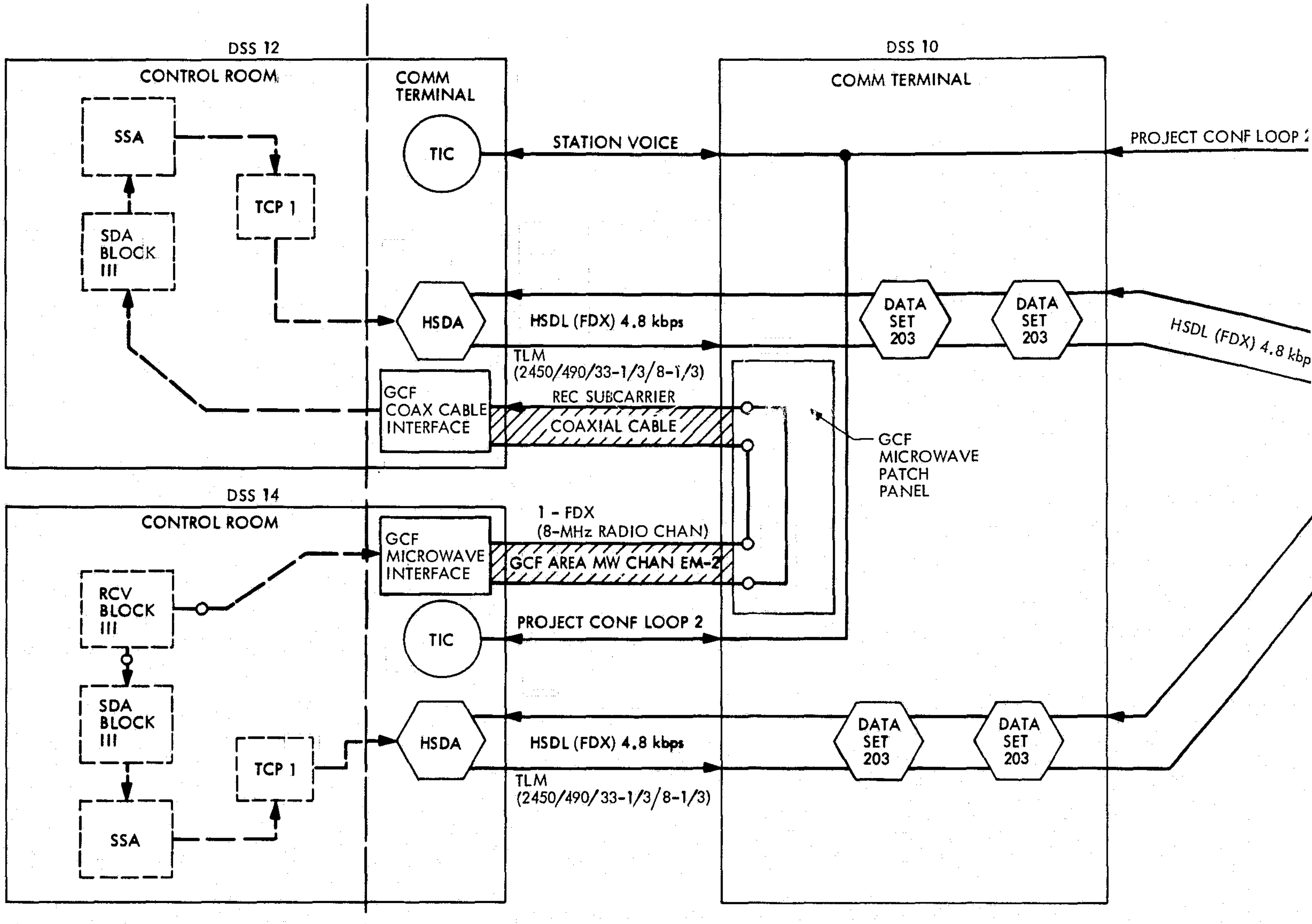
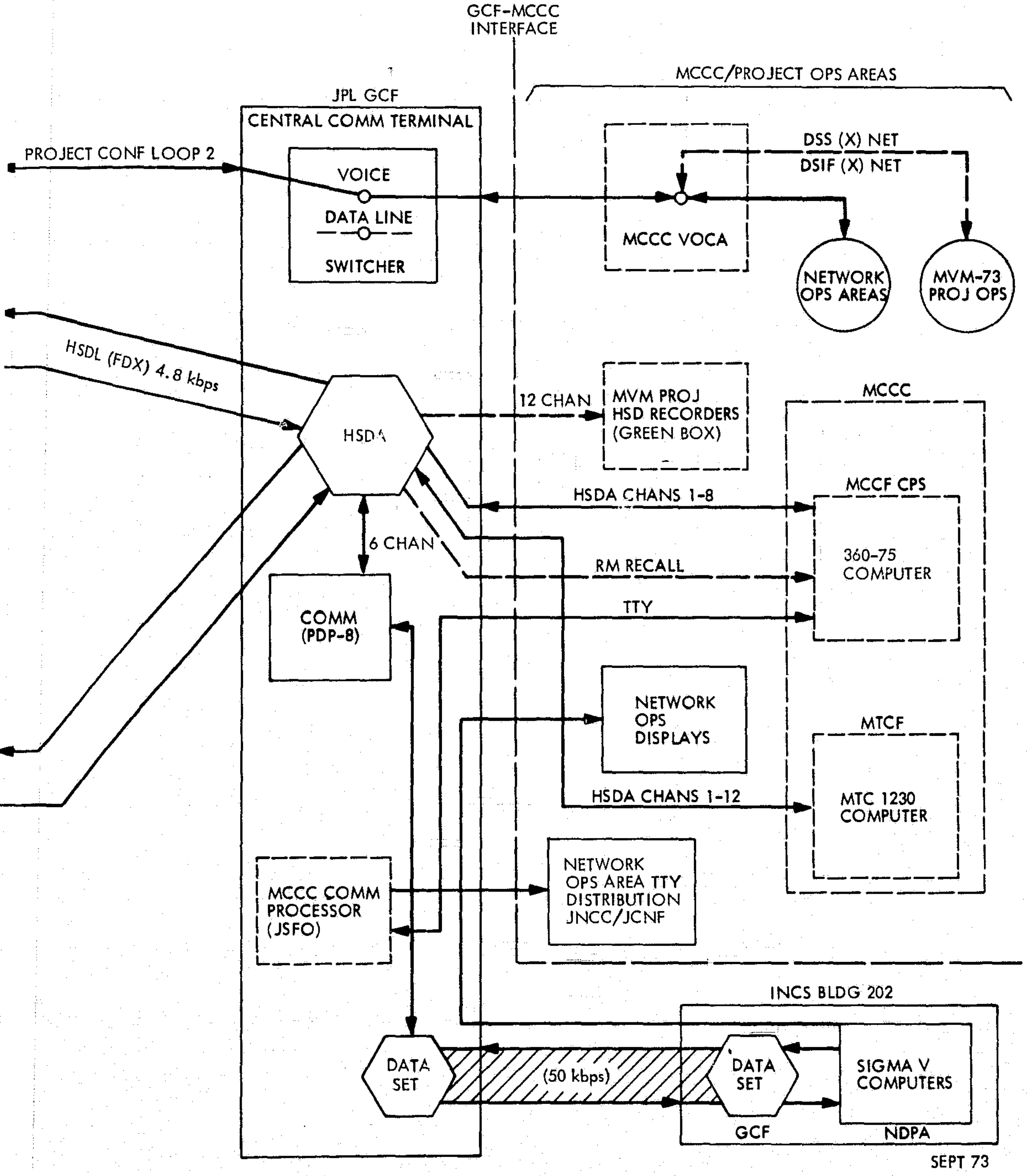
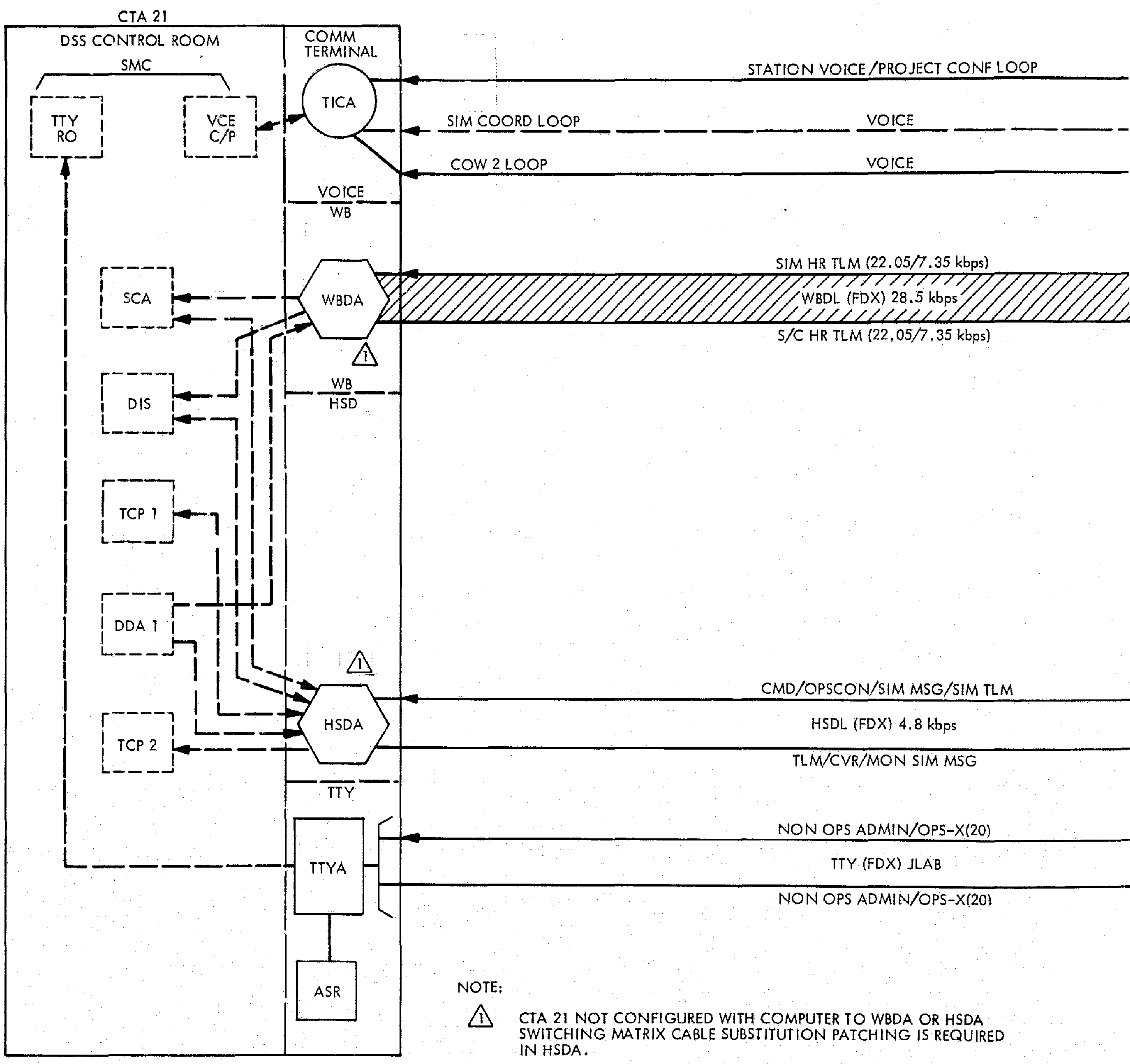


Figure 101. JPL/DSS 12, 14 MVJ cross support GCF circuit configurations

FOLDOUT FRAME 3



FOLDOUT FRAME 4



NOTE:

⚠1 CTA 21 NOT CONFIGURED WITH COMPUTER TO WBDA OR HSDA SWITCHING MATRIX CABLE SUBSTITUTION PATCHING IS REQUIRED IN HSDA.

FOLDOUT FRAME 1

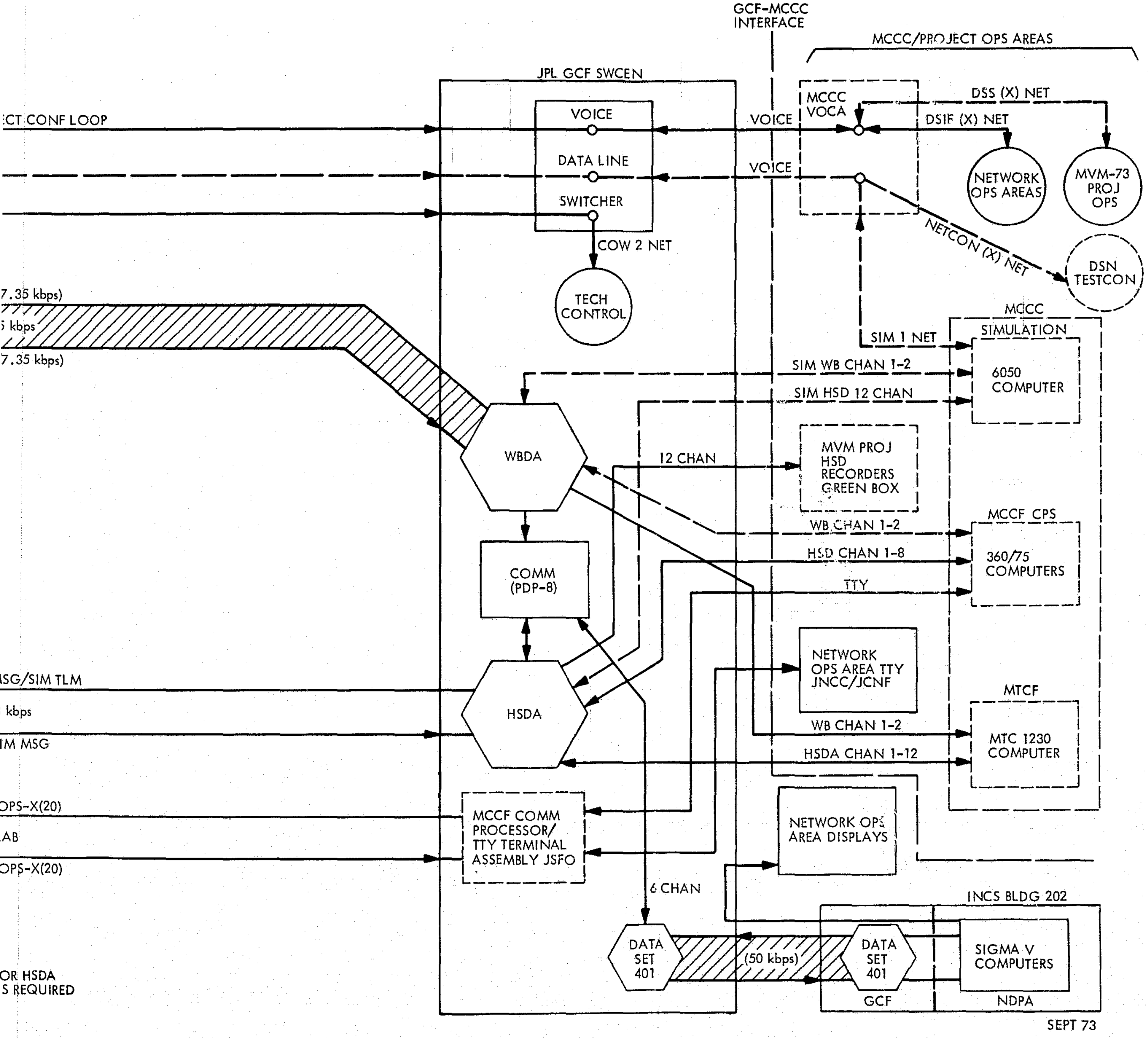
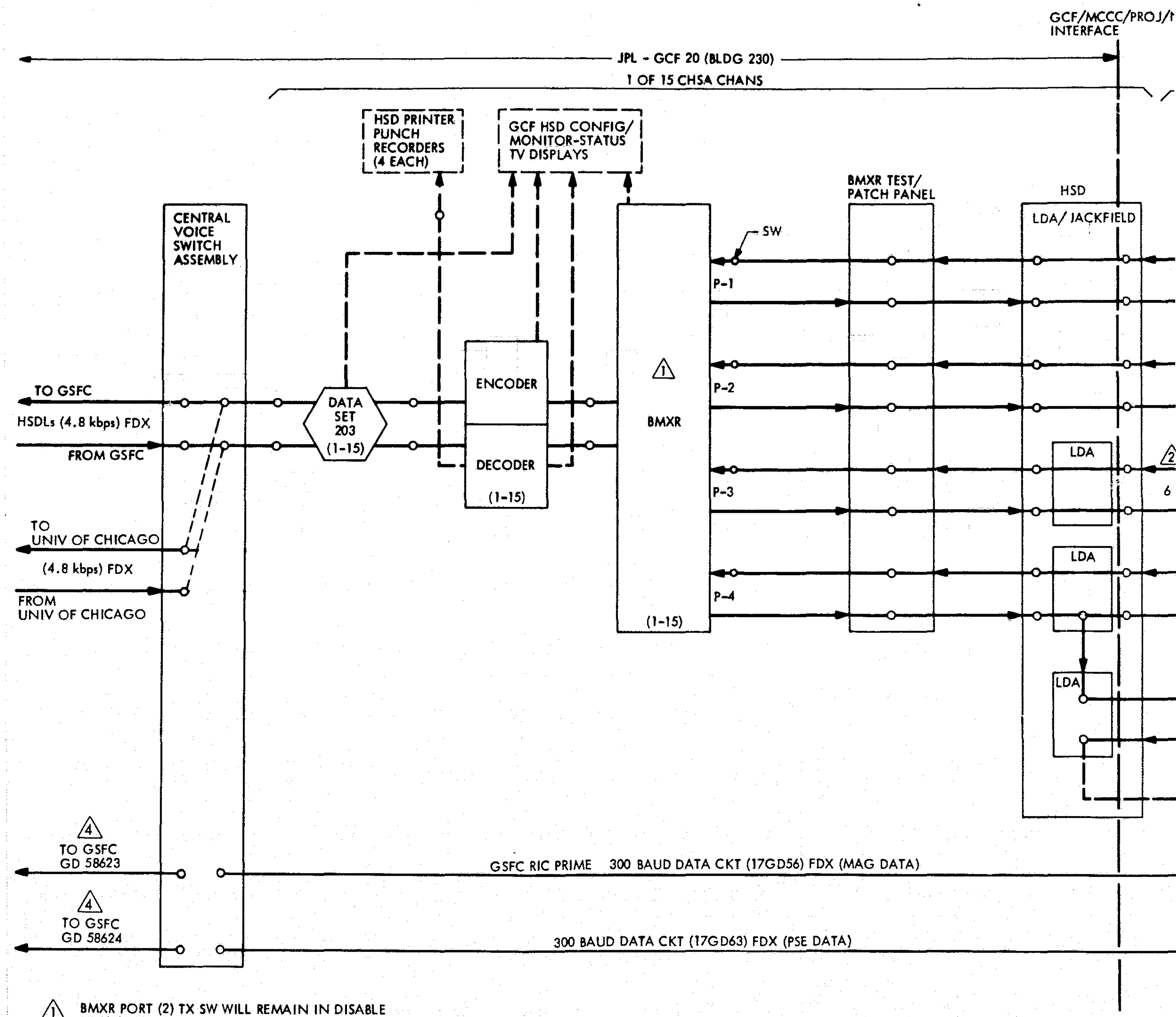


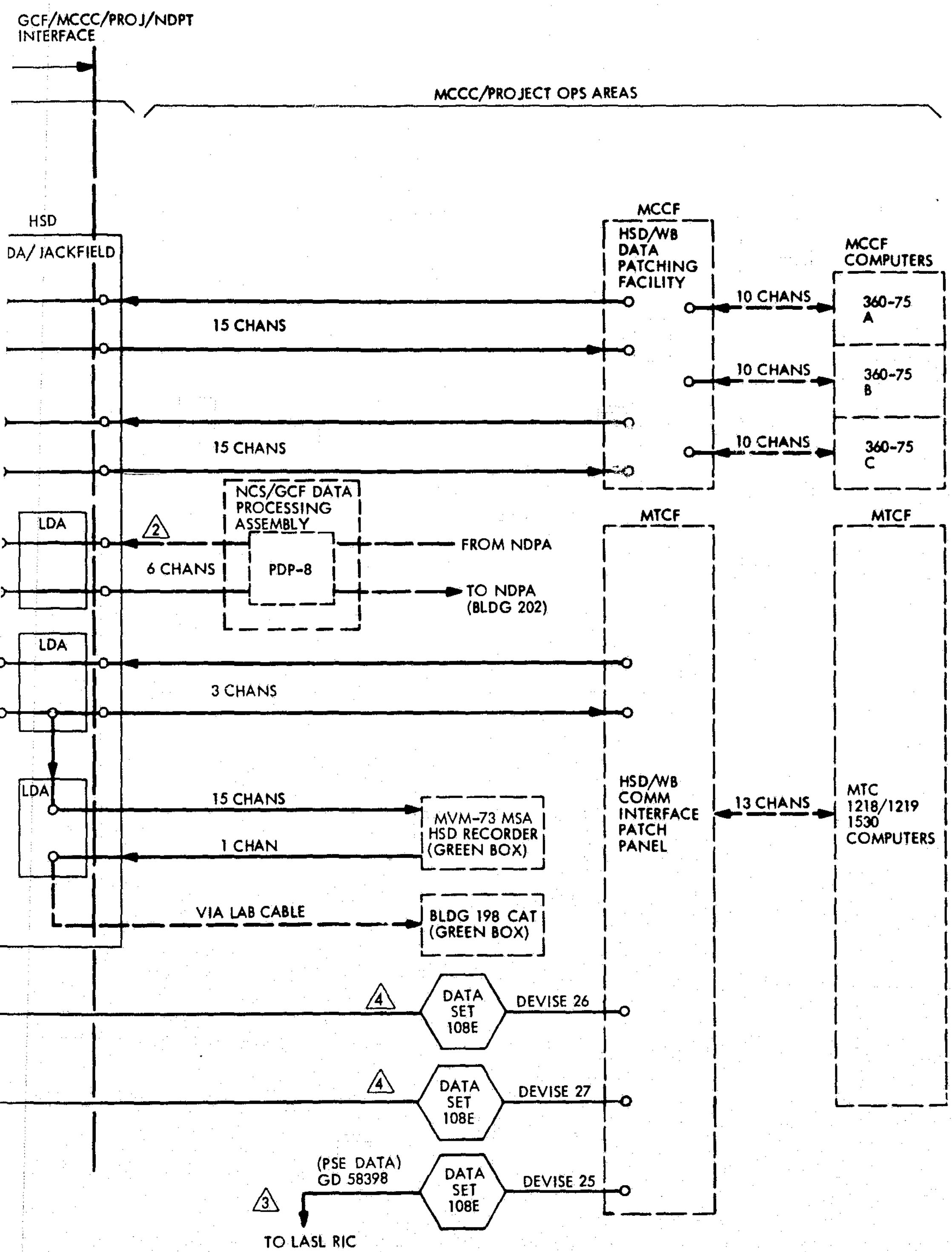
Figure 102. JPL GCF SWCEN/CTA 21 GCF circuits and data flow configurations

FOLDOUT FRAME 2



1. BMXR PORT (2) TX SW WILL REMAIN IN DISABLE POSITION EXCEPT ON REAL TIME REQUEST OF MCCF 360 OPS VIA OPSCON/OPS CHIEF INTERFACE.
2. BLOCK II NDPA (PDP-8) HSD INTERFACE NORMAL THROUGH ON HSD CHANS 1-6 AND PATCHABLE TO 7-15.
3. LASL RIC TO BE REACTIVATED 1 MARCH THRU 31 MARCH 75.
4. 300 BAUD RIC TO BLDG 2 GSFC TO BE REACTIVATED 1 MARCH THRU 31 MARCH 75.

Figure 103. JPL (GCF 20)/MCCC HSD circuit, assembly interfaces, MVM'73 configuration


GCF/MCCC/PROJ/NDPT INTERFACE
MCCC/PROJECT OPS AREAS
HSD
DA/ JACKFIELD
MCCF
HSD/WB DATA PATCHING FACILITY
MCCF COMPUTERS
15 CHANS
10 CHANS
360-75 A
10 CHANS
360-75 B
15 CHANS
10 CHANS
360-75 C
NCS/GCF DATA PROCESSING ASSEMBLY
PDP-8
LDA
FROM NDPA
6 CHANS
TO NDPA (BLDG 202)
MTCF
MTCF
LDA
3 CHANS
LDA
15 CHANS
MVM-73 MSA HSD RECORDER (GREEN BOX)
1 CHAN
HSD/WB COMM INTERFACE PATCH PANEL
13 CHANS
MTC 1218/1219 1530 COMPUTERS
VIA LAB CABLE
BLDG 198 CAT (GREEN BOX)
DATA SET 108E
DEVISE 26
DATA SET 108E
DEVISE 27
(PSE DATA) GD 58398
DATA SET 108E
DEVISE 25
TO LASL RIC

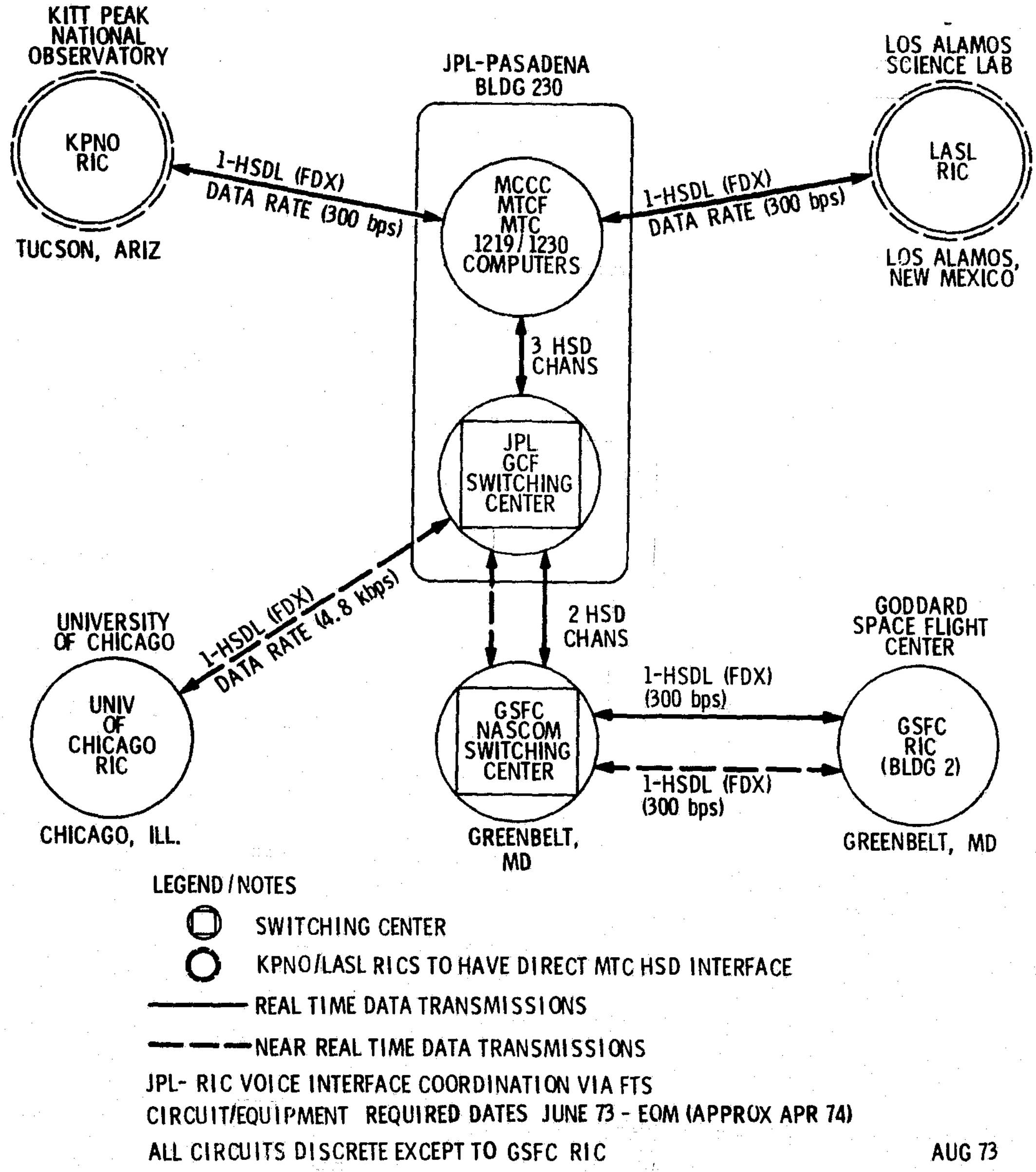


Figure 104. MVM'73 Project RIC locations and GCF-NASCOM support circuit configurations

g. DSN Test and Training. The purpose of the test and training portion of the DSN implementation phase was to achieve full operational readiness of DSN hardware, software, and people to meet mission requirements. A comprehensive test and training program was developed wherein DSN internal testing was integrated with planned Ground Data System and Mission Operations test plans. The relationships of key DSN tests, milestones, and responsibilities are given in Fig. 105. The overall Network test schedule which guided all testing is shown in Fig. 106.

DSN training activities for MVM'73 assumed that most operational functions to be performed were mission-independent in nature and required that on-going training programs continue to maintain an adequate level of trained personnel. Three basic methods of training were employed to achieve proficiency in mission-dependent activities: (1) self-training wherein appropriate documents were studied by operations personnel, (2) classroom training consisting of live lectures and video tape training packages, and (3) on-the-job training which occurred during on-site test and training sessions. Table 33 lists special training packages which were provided for MVM'73 purposes.

Table 33. Training packages applicable to MVM'73 on-site training

Number	Title
101-A2	Telemetry System Functional Description
106-B2	FTS II Operation
107-C2	FTS II Maintenance
108-C2	TM-4 Mechanical Maintenance
109-C2	HDTR Mechanical Maintenance
112-B2	SCA M&O Operational Update
113-A2	Interplex Technical Information
114-A2	TCD Operational Software Functional Description
115-A2	DIS Operational Software Functional Description
116-A2	Wideband Data Link Functional Description

NEW CAPABILITY TESTING (MULTIMISSION TESTS)

FUNCTION ↓ / TEST →	FIRST MODEL DEMONSTRATION (HW ASSY OR SW MODULES)	FIRST STATION SUBSYSTEM/ASSEMBLY DEMONSTRATION	UNIT BY UNIT ACCEPTANCE TEST (HW ONLY)	NETWORK INSTALLATION	SYSTEM PERFORMANCE DEMONSTRATION	MISSION CONFIGURATION TEST (SYSTEM LEVE
COORDINATING AUTHORITY	430 SYSTEM ENGINEER					430 DSN MANAGE FOR PROJECT X
REQUIREMENTS/ ACCEPTANCE CRITERIA	430 SUBSYSTEM ENGINEERS	430 SUBSYSTEM ENGINEERS	422 SUBSYSTEM COE	422 SUBSYSTEM COE / 421 SW COE	430 SYSTEM ENGINEERS	430 DSN MANAGE FOR PROJECT X
TEST PLAN/PROCEDURES	33 CDE	33 CDE	33 CDE	422 SUBSYSTEM COE / 421 SW COE	421 SCOE	421 NOPE
TEST CONDUCT	33 CDE	33 CDE	33 CDE	422 SUBSYSTEM COE / 421 SW COE	421 SCOE	421 NOPE
TEST REPORT	33 CDE	33 CDE	33 CDE	422 SUBSYSTEM COE / 421 SW COE	421 SCOE	421 NOPE
PERFORMANCE EVALUATION	430 SUBSYSTEM ENGINEERS	430 SUBSYSTEM ENGINEERS / 430 SSE 421 SW COE	422 SUBSYSTEM COE	422 FACILITY OPERATIONS MANAGER	430 SYSTEM ENGINEERS, AND 421 NETWORK OPERATIONS MANAGER	430 DSN MANAGE FOR PROJECT X
SUBSEQUENT EVENT	AGREEMENT ON PROCEEDING TO FIRST STATION S/S/ASSY DEMO	AGREEMENT ON PROCEEDING TO NETWORK INSTALLATION	33 CDE TRANSFER TO FACILITY OPERATIONS (422) SUBSYSTEM COE	422 S/S COE TRANSFER TO STATION DIRECTOR * / 421 SW COE TRANSFER TO STATION DIRECTOR *	FACILITIES PLACED UNDER CONFIGURATION CONTROL FOR APPROPRIATE MISSIONS AND RETURNED TO OPERATIONAL STATUS	TECHNICAL PERFORMANCE DEMONSTRATION
MILESTONE NAME	SUBSYSTEM/ASSEMBLY FIRST UNIT DEMONSTRATION; SW ASSY DIV 33 CDE TO 421 SW COE TRANSFER; SUBSYSTEM/HW ASSY DIV 33 CDE TO 422 SUBSYSTEM COE TRANSFER			SUBSYSTEM IMPLEMENTATION COMPLETE		NETWORK SYSTE
MILESTONE SYMBOL	FIRST UNIT DEMO △; SOFTWARE TRANSFER ○			○	◇	□

LEGEND

XXXX (upper half of diagonally divided box)	TEST RESPONSIBILITY FOR HARDWARE
XXXX (lower half of diagonally divided box)	TEST RESPONSIBILITY FOR SOFTWARE
XXX	TEST RESPONSIBILITY INDEPENDENT OF HARDWARE VERSUS SOFTWARE

*	OR GCF AND/OR NCS EQUIVALENT
SSE	SUBSYSTEM ENGINEER
CDE	COGNIZANT DESIGN ENGINEER
COE	COGNIZANT OPERATIONS ENGINEER
SCOE	SYSTEM COGNIZANT OPERATIONS ENGINEER
NOPE	NETWORK OPERAT
OCT	OPERATIONS CON
MOS	MISSION OPERATI
33, 430, 422, ETC	DIVI

Figure 105. Relation of

FOLDOUT FRAME 1

NEW CAPABILITY TESTING (MULTIMISSION TESTS)				MISSION PREPARATION TESTING (SINGLE MISSION TESTS)			
FIRST STATION SUBSYSTEM/ASSEMBLY DEMONSTRATION	UNIT BY UNIT ACCEPTANCE TEST (HW ONLY)	NETWORK INSTALLATION	SYSTEM PERFORMANCE DEMONSTRATION	MISSION CONFIGURATION TEST (SYSTEM LEVEL)	OPERATIONAL VERIFICATION TEST	PERFORMANCE DEMONSTRATION TEST	CONFIGURATION VERIFICATION TEST
430 SYSTEM ENGINEER				430 DSN MANAGER FOR PROJECT X	421 NOPE		
430 SUBSYSTEM ENGINEERS	422 SUBSYSTEM COE	422 SUBSYSTEM COE / 421 SW COE	430 SYSTEM ENGINEERS	430 DSN MANAGER FOR PROJECT X	421 NOPE	421 NOPE	421 NOPE
33 CDE	33 CDE	422 SUBSYSTEM COE / 421 SW COE	421 SCOE	421 NOPE	421 NOPE	421 NOPE	421 NOPE
33 CDE	33 CDE	422 SUBSYSTEM COE / 421 SW COE	421 SCOE	421 NOPE	421 NOPE	421 NOPE	421 NOPE
33 CDE	33 CDE	422 SUBSYSTEM COE / 421 SW COE	421 SCOE	421 NOPE	421 NOPE	421 NOPE	421 NOPE
430 SUBSYSTEM ENGINEERS / 430 SSE 421 SW COE	422 SUBSYSTEM COE	422 FACILITY OPERATIONS MANAGER	430 SYSTEM ENGINEERS, AND 421 NETWORK OPERATIONS MANAGER	430 DSN MANAGER FOR PROJECT X	421 SUPERVISER OCT	421 NETWORK OPERATIONS MANAGER, AND 430 DSN MANAGER FOR PROJECT X	420 DSN OPERATIONS MANAGER
AGREEMENT ON PROCEEDING TO NETWORK INSTALLATION	33 CDE TRANSFER TO FACILITY OPERATIONS (422) SUBSYSTEM COE	422 S/S COE TRANSFER TO STATION DIRECTOR * / 421 SW COE TRANSFER TO STATION DIRECTOR *	FACILITIES PLACED UNDER CONFIGURATION CONTROL FOR APPROPRIATE MISSIONS AND RETURNED TO OPERATIONAL STATUS	TECHNICAL PERFORMANCE DEMONSTRATION	FACILITY PROFICIENCY DEMONSTRATION	NOPE TRANSFER MD CONFIGURATIONS TO OCT; MOS TESTS	CONFIGURATION FREEZE

BSYSTEM/ASSEMBLY FIRST UNIT
MONSTRATION

CDE TO 421 SW COE TRANSFER

/HW ASSY DIV 33 CDE TO 422 SUBSYSTEM COE TRANSFER

SUBSYSTEM IMPLEMENTATION COMPLETE

DSN OPERATIONAL READINESS

MISSION CONFIGURATION COMPLETE

NETWORK SYSTEM PERFORMANCE DEMONSTRATION

FIRST UNIT DEMO △

SOFTWARE TRANSFER ○

○ ◇ □ ▽ ⬠

*	OR GCF AND/OR NCS EQUIVALENT
SSE	SUBSYSTEM ENGINEER
CDE	COGNIZANT DESIGN ENGINEER
COE	COGNIZANT OPERATIONS ENGINEER
SCOE	SYSTEM COGNIZANT OPERATIONS ENGINEER
NOPE	NETWORK OPERATIONS PROJECT ENGINEER
OCT	OPERATIONS CONTROL TEAM
MOS	MISSION OPERATIONS SYSTEM
33, 430, 422, ETC =	DIVISION OR SECTION/ORGANIZATION NO.

Figure 105. Relation of tests, responsibilities, and milestones

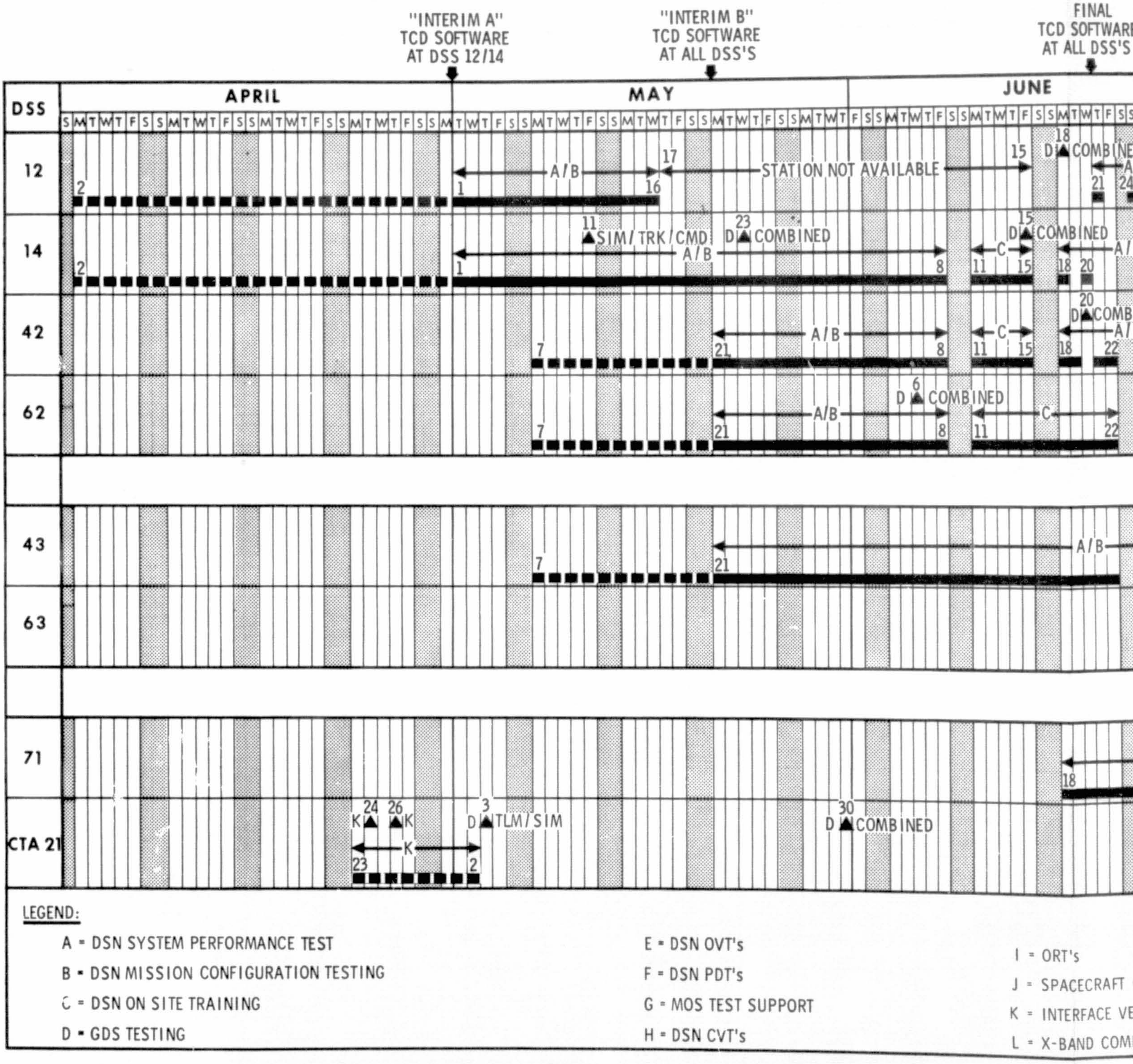
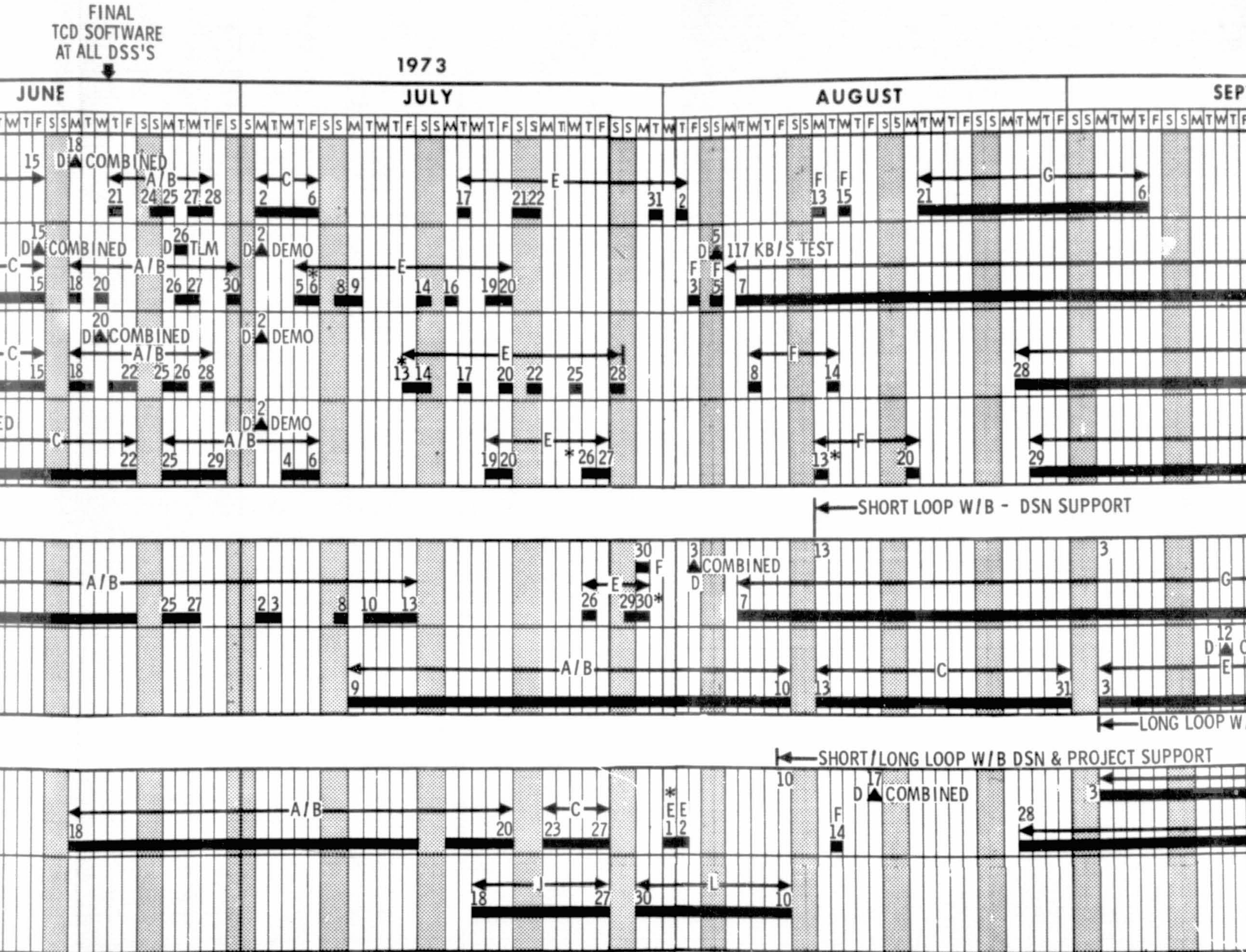


Figure 106. Network test schedule

FOLDOUT FRAME



NOTE:

1. CURRENT
THE NETW

2. * INDICAT

3. ALL PDT'S

4. ** DSS 6

I = ORT's

J = SPACECRAFT COMPATIBILITY TEST

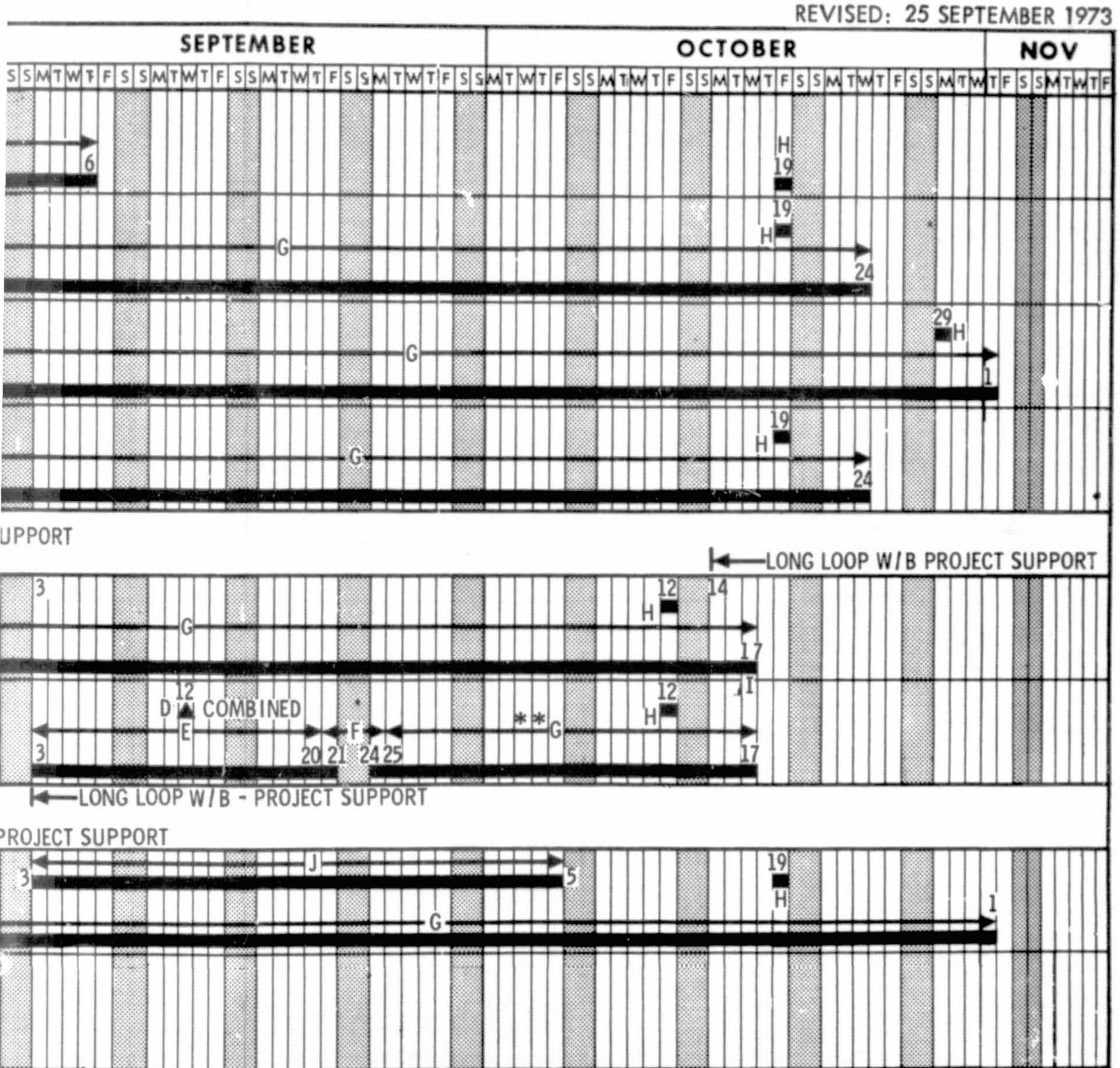
K = INTERFACE VERIFICATION TEST

L = X-BAND COMPATIBILITY TEST

ORIGINAL SCHEDULE

CURRENT SCHEDULE

FOLDOUT FRAME 2



NOTE:

1. CURRENT PLANS FOR DELIVERY OF THE TCD SOFTWARE HAVE REQUIRED COMPRESSION OF THE NETWORK TEST SCHEDULE AND THE COMBINING OF TEST CATEGORIES A AND B
2. * INDICATES OVT'S THAT MAY BE SUPPORTED BY MTC AND OR 6050
3. ALL PDT'S SHOULD BE SUPPORTED BY MTC
4. ** DSS 63 WILL BE SIMULATED IF NOT ABLE TO SUPPORT 25 SEPT THROUGH 5 OCT 1973

FOLDOUT FRAME 2

Operator on-site training consisted of all three training methods. All training at the stations was the responsibility of the Station Director, and established training audit procedures were employed. Reports were submitted twice monthly from May 1973 to October 1973 and weekly during October 1973.

DSN testing for MVM'73 was divided into two categories: (1) testing of new capabilities and (2) mission preparation testing. This division is annotated in Fig. 106 test matrix.

Test and training configurations for the various systems and station types are given in Figs. 107 through 118.

(1) First Model Demonstration Test. This test was usually formed at a factory for hardware or, where convenient, for software. It used a test stimulus for input, and the output was analyzed for correct functional performance. Input/output criteria were established to verify that performance and interfaces were as defined.

(2) First Station Subsystem On-Site Acceptance Test. This test was usually performed at CTA 21 or DSS 71. If the unit under test was an assembly or lower, it was installed normally in its subsystem for testing; if the unit was a subsystem, it was installed and connected normally to all interfacing subsystems. Performance in either case was evaluated and interfaces were verified at the subsystem level. For station-level implementation, or multiple subsystems, a Division 33 Station Project Engineer coordinated all test activities with implementation activities.

(3) Unit-by-Unit Acceptance Tests. These tests were performed by the supplying Cognizant Development Engineer to demonstrate to the Subsystem Cognizant Operations Engineer that all additional units were equivalent to the first unit. This test was applicable to hardware, and was normally conducted at the factory. For software, the intent of this step was realized during the DSN Program Library reproduction of programs and documentation which were demonstrated to the Subsystem Cognizant Operations Engineer during the first station subsystem on-site acceptance test. These tests were intended to be as comprehensive as the first model demonstration and were used to effect a transfer.

At the completion of the test, the subsystem was transferred from the Cognizant Development Engineer to the Subsystem Cognizant Operations Engineer. Software was an exception in that it was transferred to the Software Cognizant Operations Engineer.

(4) Subsystem On-Site Acceptance Tests. These tests were intended to be reruns, by installation location, of the first station subsystem on-site acceptance test. As in that test, the units were installed normally in the subsystem, or the subsystem was normally integrated with interfacing subsystems. These tests were at the subsystem level.

For hardware, the Subsystem COE was responsible for the requirements and acceptance criteria, test procedures, conducting the test, and issuing test reports. For software, the Software COE had equivalent

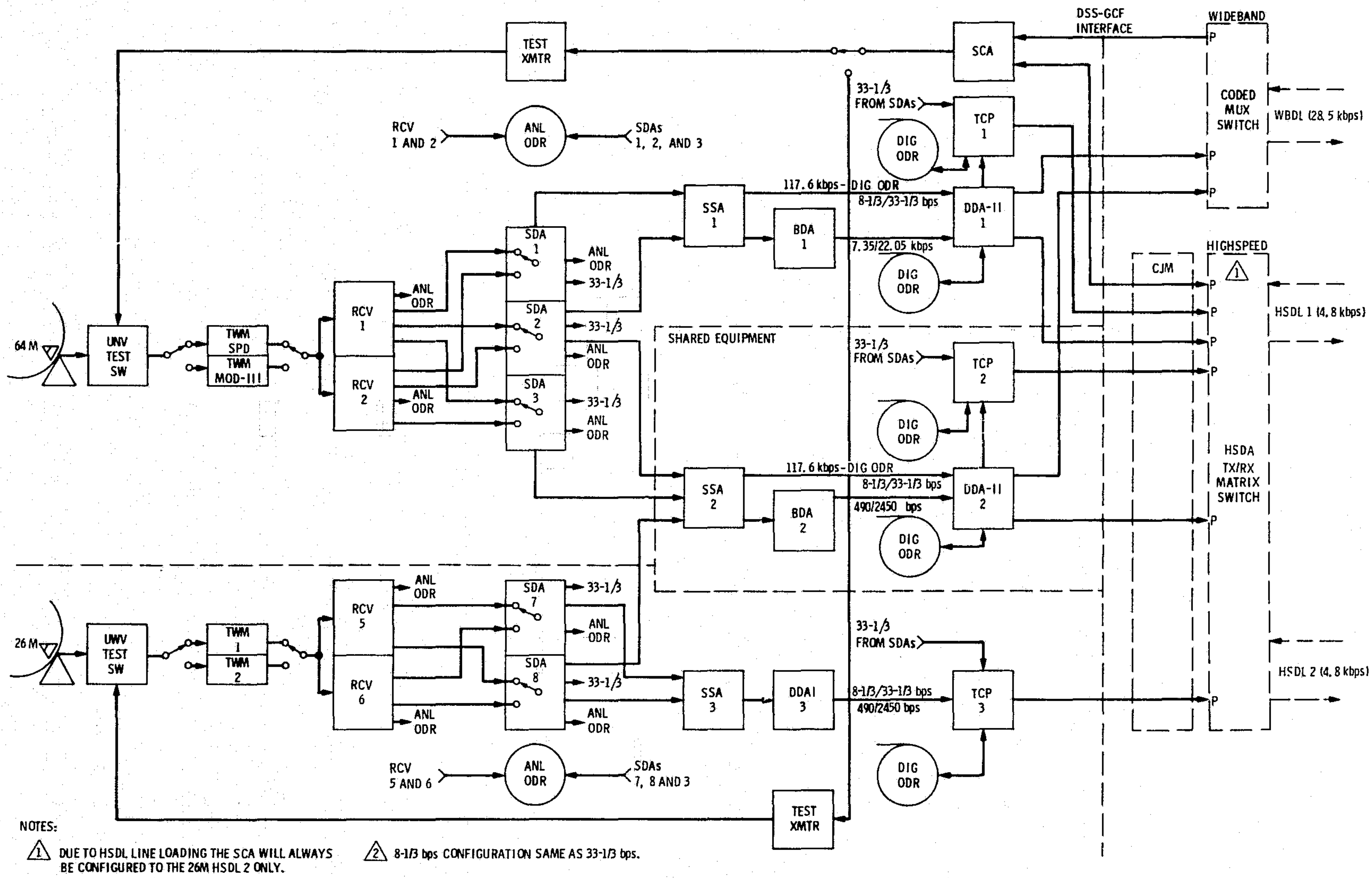
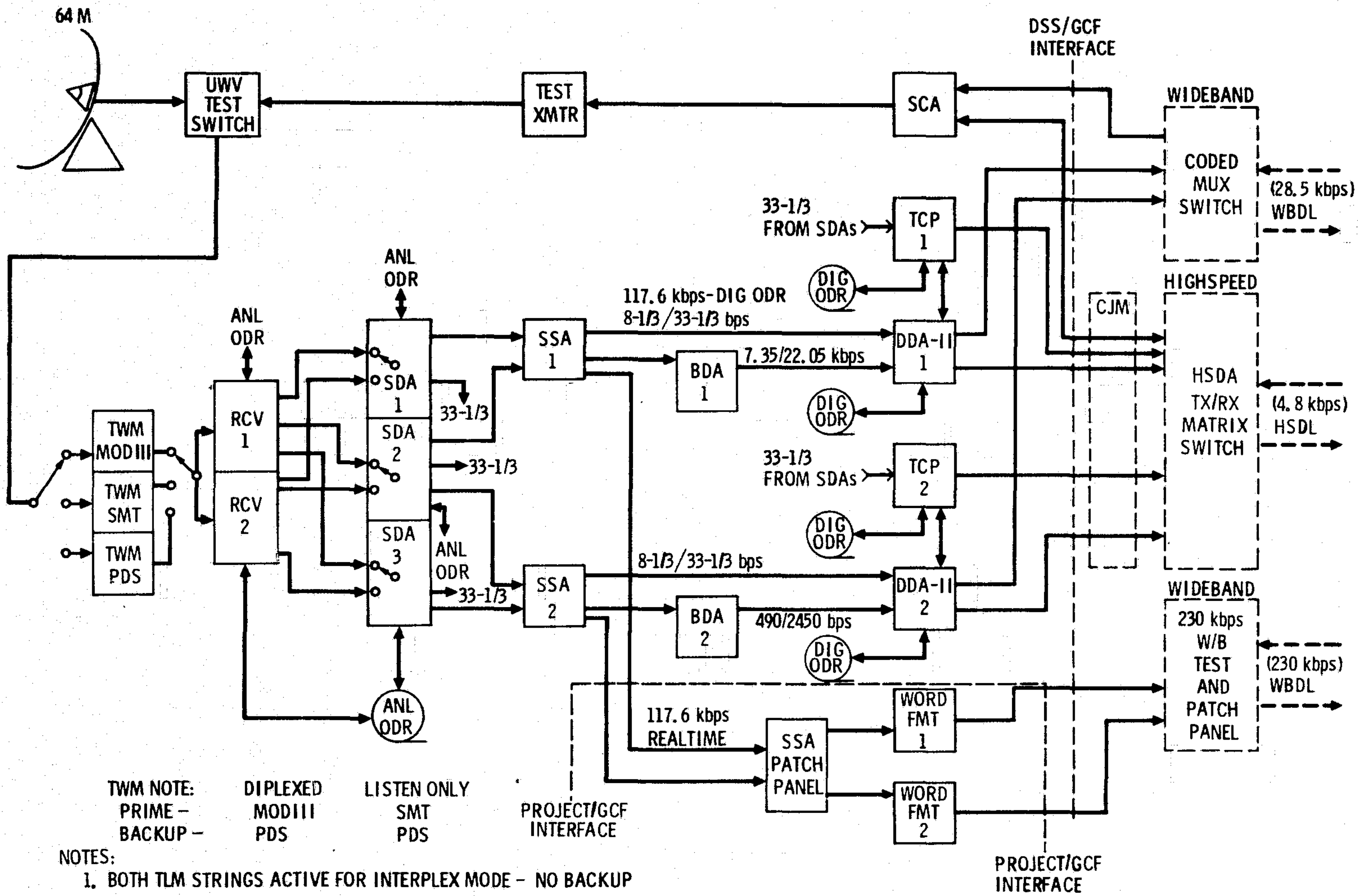


Figure 107. DSN test configuration, MVM'73 telemetry, 26/64-m conjoint deep space stations



NOTES:

1. BOTH TLM STRINGS ACTIVE FOR INTERPLEX MODE - NO BACKUP
2. 8-1/3 bps CONFIGURATION SAME AS 33-1/3 bps.

Figure 108. DSN test configuration, MVM'73 telemetry, 64-m DSS 14

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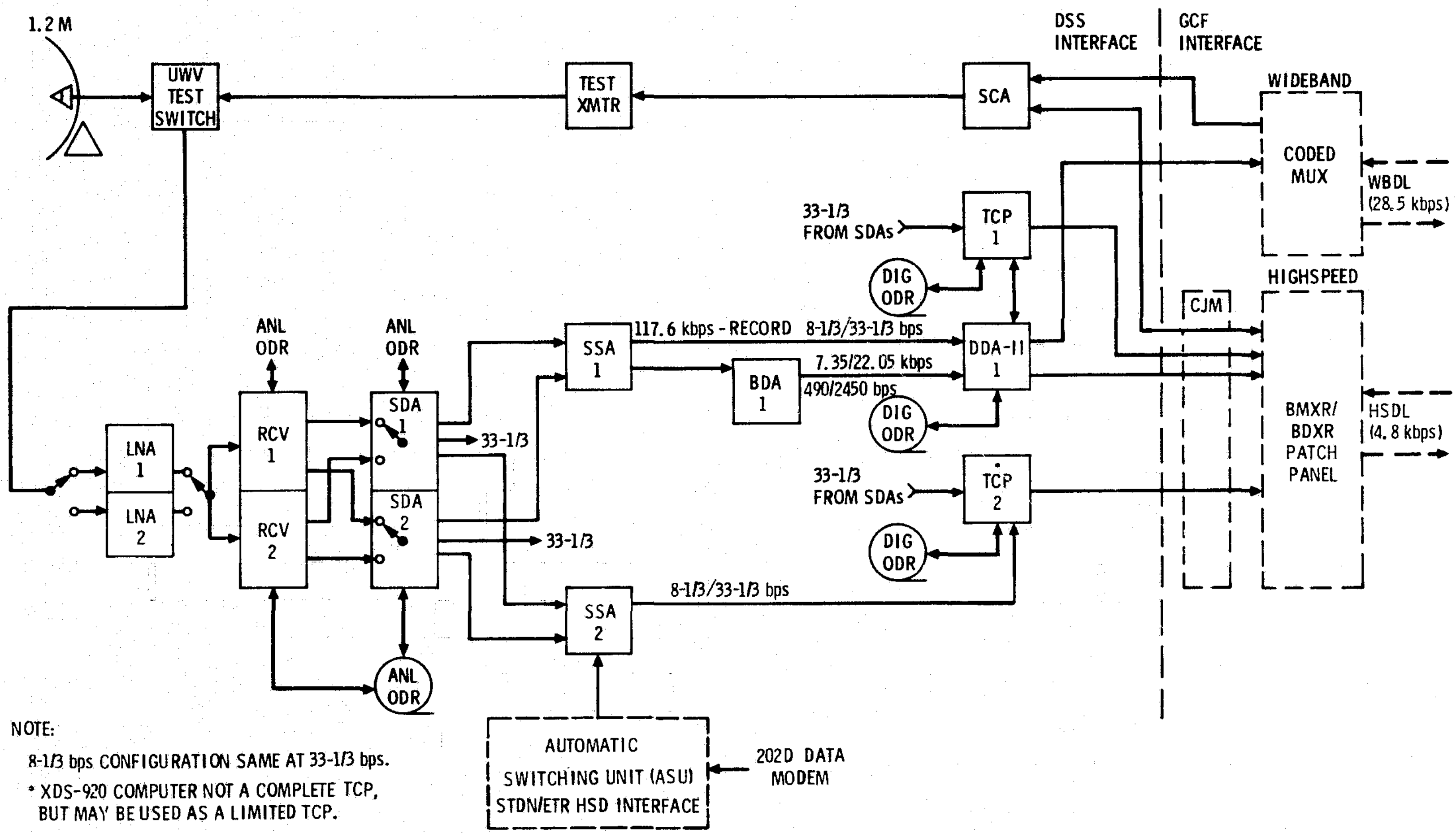
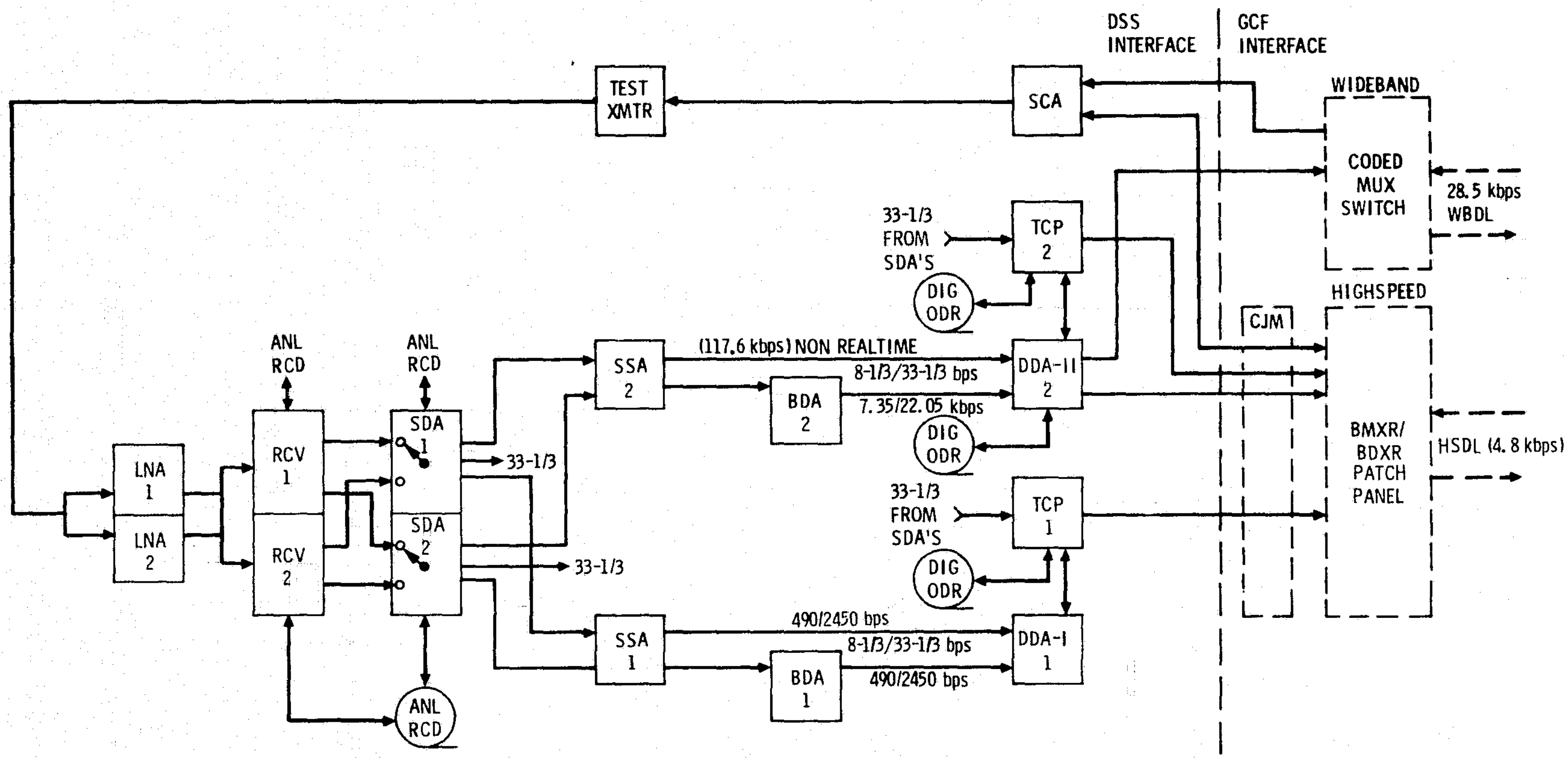


Figure 110. DSN test configuration, MVM'73 telemetry, DSS 71



NOTE:

8-1/3 bps CONFIGURATION SAME AS 33-1/3 bps.

Figure 111. DSN test configuration, MVM'73 telemetry, CTA 21

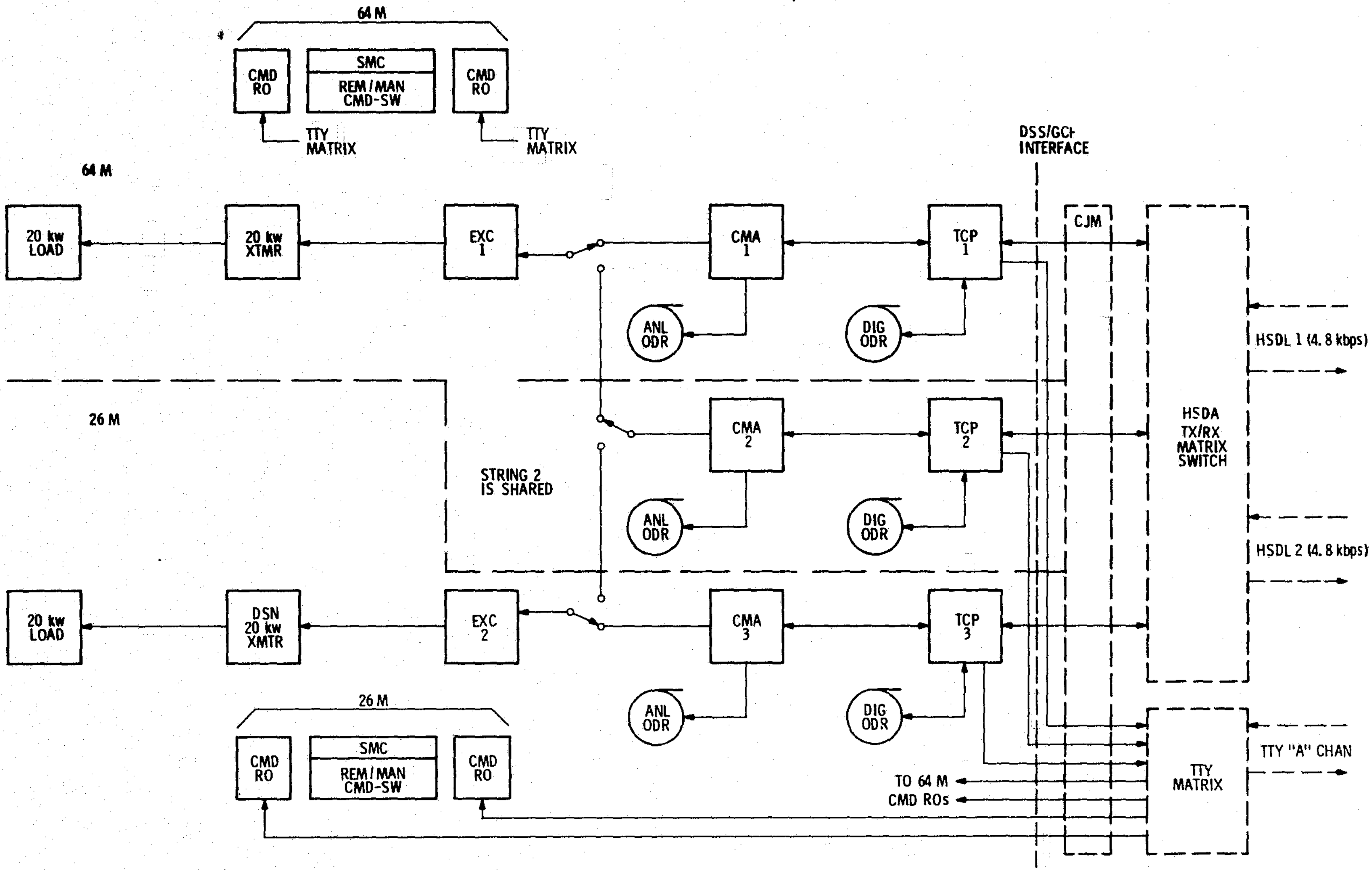


Figure 112. DSN test configuration, MVM'73 command, conjoint deep space stations

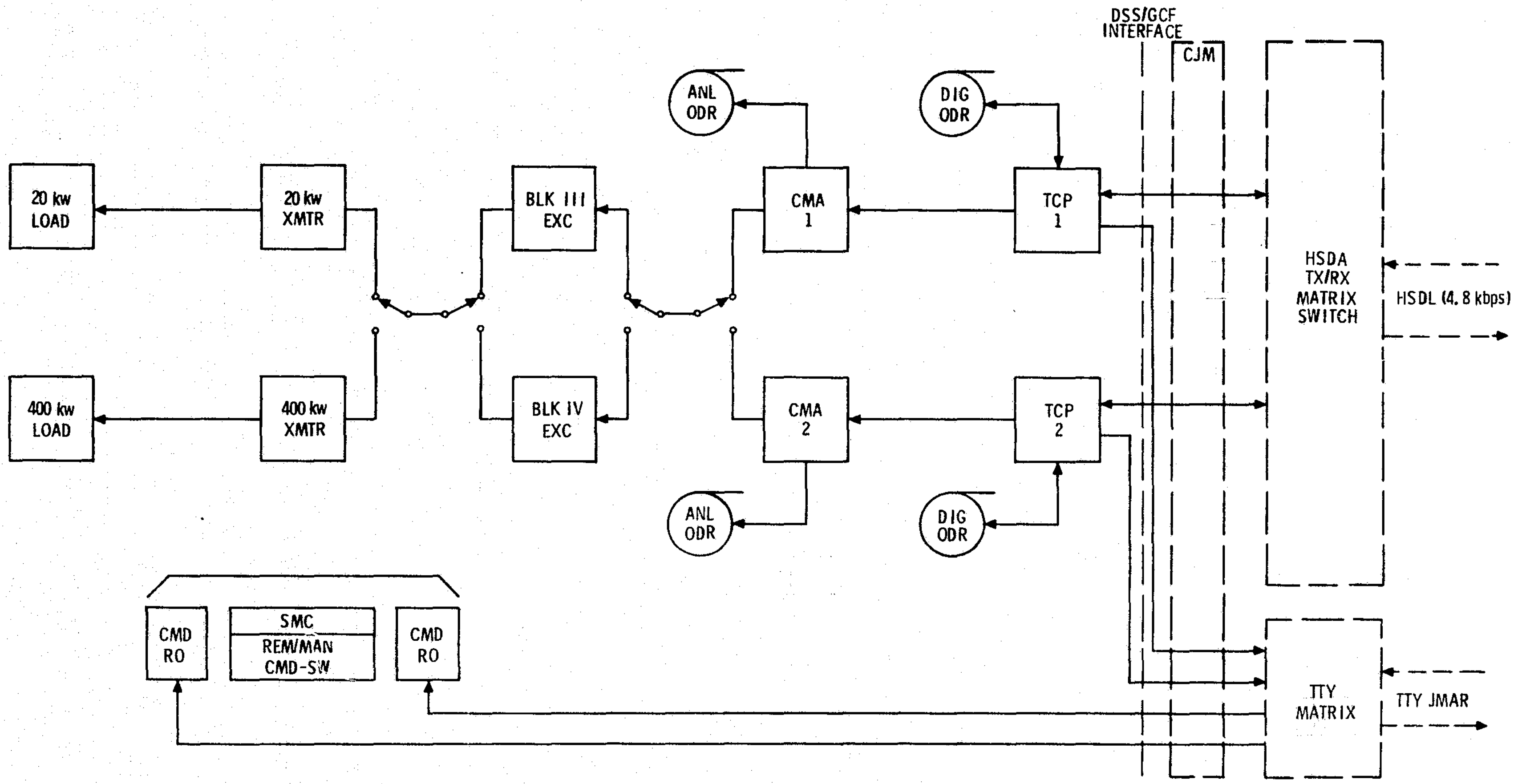


Figure 113. DSN test configuration, MVM'73 command, DSS 14

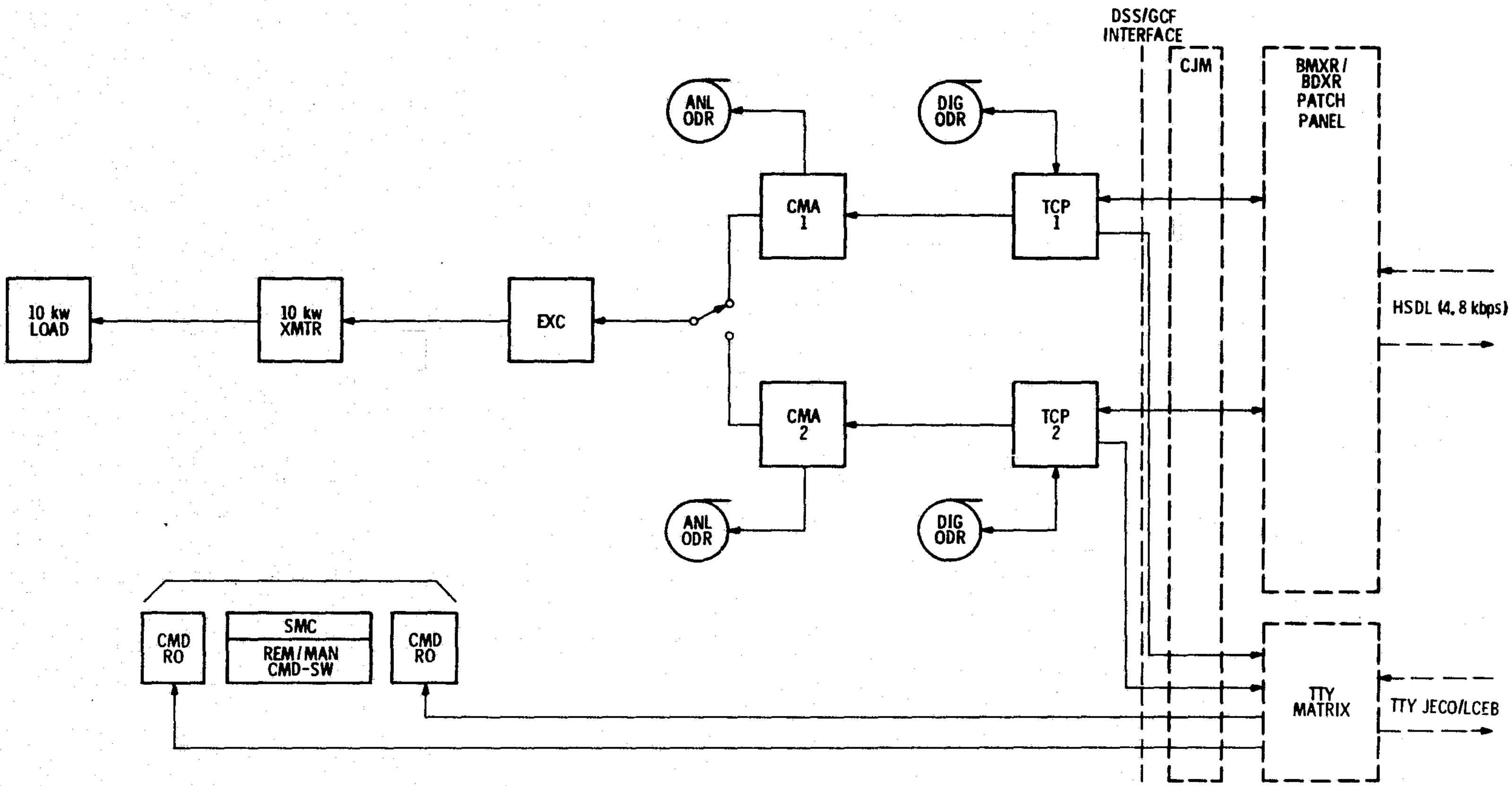


Figure 114. DSN Test Configuration, MVM'73 command, standard 26-m, DSS 12, 62

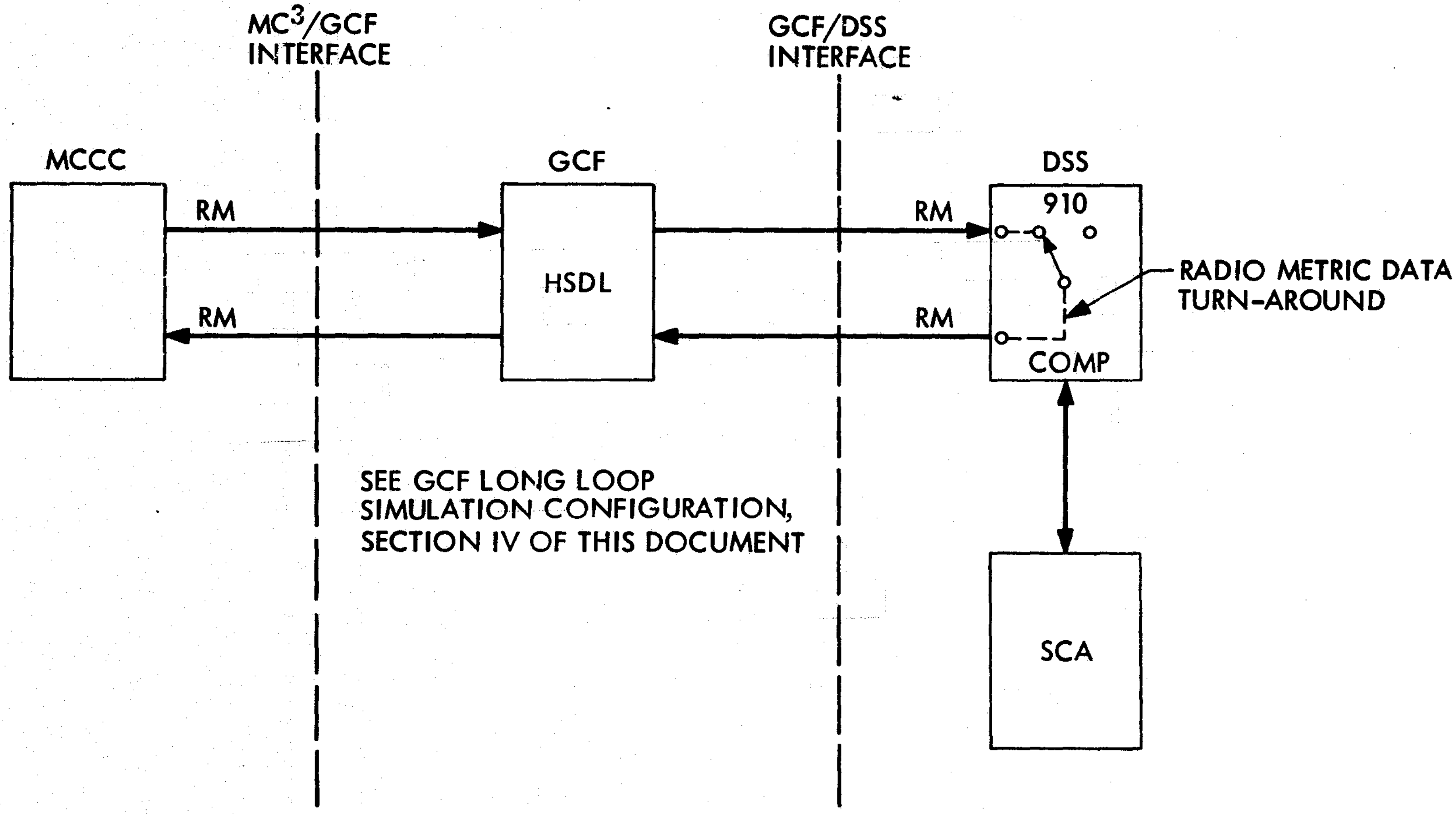


Figure 115. DSN test configuration MVM'73 radio metric data simulation, all deep space stations

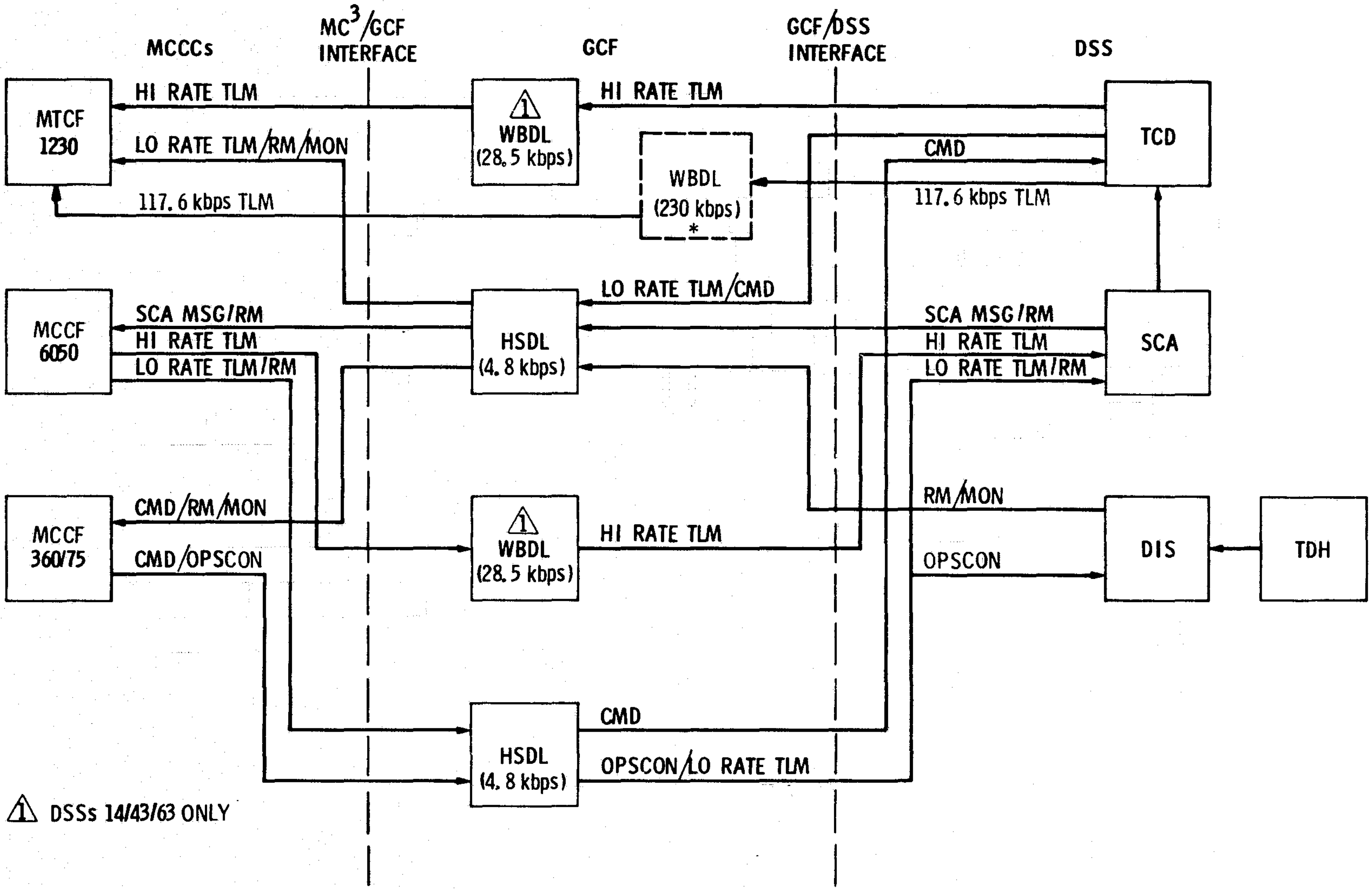
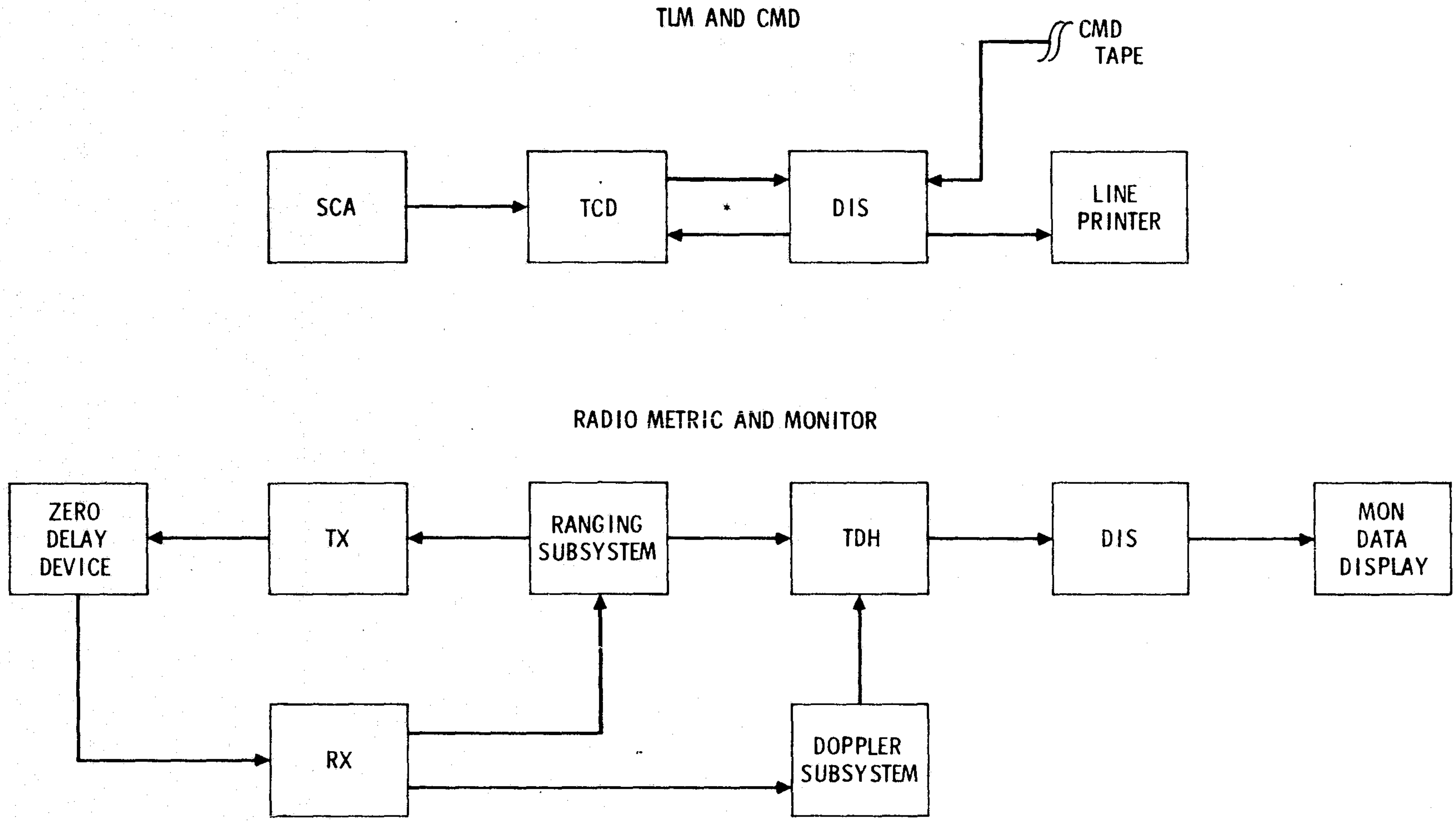


Figure 116. DSN network level tests MVM'73 configuration



* VIA DSS INTERNAL COMMUNICATIONS.

Figure 117. DSS internal test configuration, MVM'73 configuration

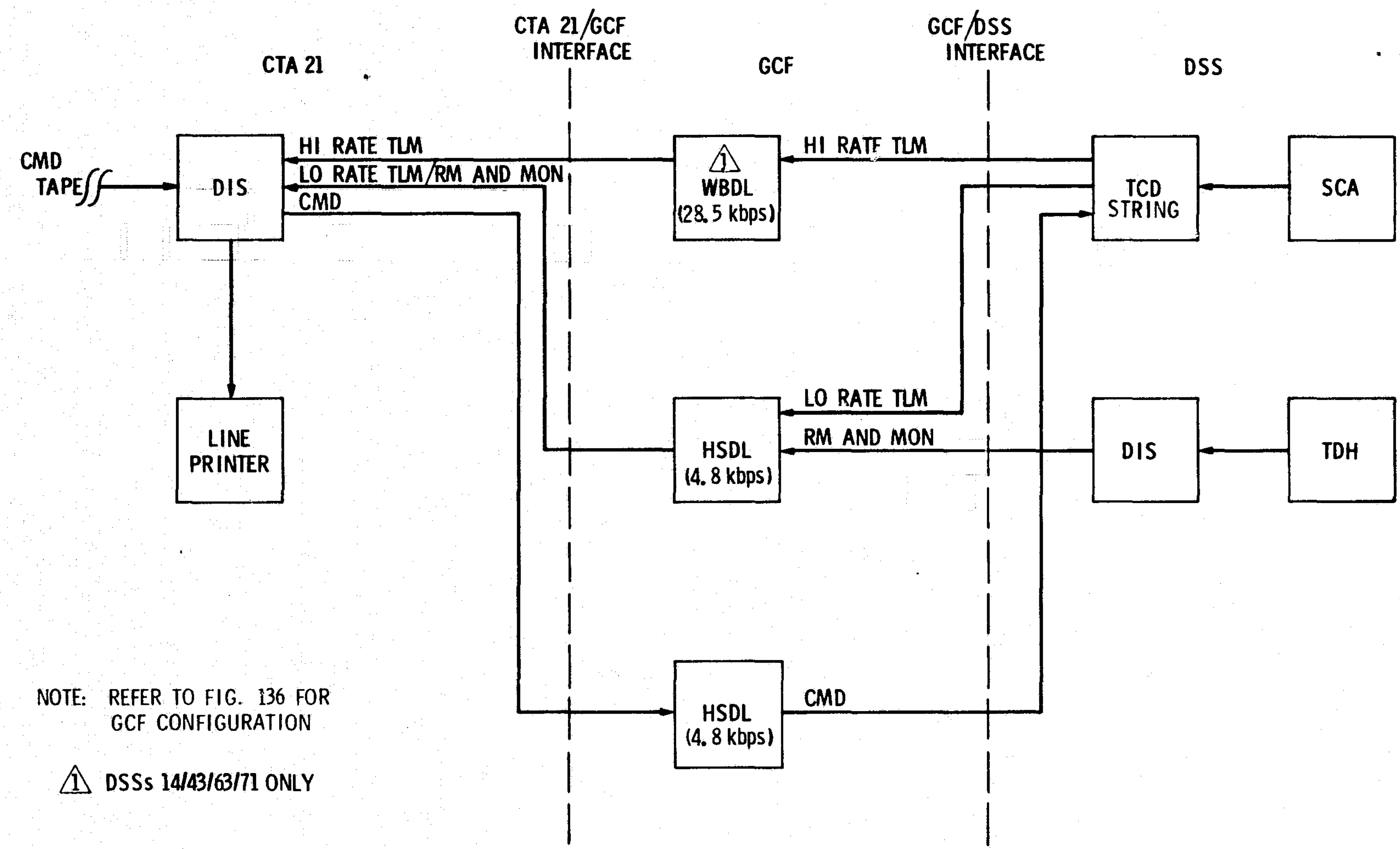


Figure 118. DSN emergency troubleshooting test configuration utilizing CTA 21

responsibility. The performance was evaluated by the Facility Operations Manager against the test requirements and the acceptance criteria; if the performance was satisfactory, the subsystem was transferred from the COE to the Station Director or his GCF equivalent. For station-level implementation, or multiple subsystems, a Station Project Engineer coordinated all test activities with implementation activities.

(5) Network System Performance Tests. These tests were DSN system-level tests. The software was integrated and standard engineering tests were performed in accordance with DSN mission-independent test procedure documents. The requirements and acceptance criteria were obtained from the applicable DSN System Requirements documents. The System COE was responsible for the test procedure, conducting the test, and issuing test reports. The performance was evaluated by the Network Operations Manager, and system performance was documented by the DSN System Engineer. Upon successful completion of these tests, the network was placed under configuration control. Descriptions of this testing for each of the major systems are given below.

(a) Telemetry System Performance Testing. The development of test procedures and test software and the execution of the system performance tests were performed in order to accomplish certain objectives. The overall objective was to guarantee that the Network could meet specified operational capabilities. The system performance tests must verify that the Network configurations and interface requirements are satisfied. They must also evaluate the ability of the Telemetry, Command, Tracking, and Monitor Systems to meet performance requirements.

System performance tests are designed so that they can be used to locate or diagnose system problems. The problems may occur during the installation of new equipment or software, or they may be the result of system failures uncovered during DSN real-time tracking operations. Some of the latter problems are discovered when portions of the tests are used during countdown tests. Use of system performance tests for prepass readiness tests was another objective which required the feature that the test procedure be modular. Thus, the various classes and levels of prepass readiness test can be accomplished by executing the appropriate sections of the procedure.

The modularity feature of the procedure enhances the capability to test modifications which may affect capabilities. Portions of the test procedures are used to perform on-site acceptance testing of both hardware and software. An additional objective of system performance tests was to aid in the training of station personnel. The tests were prepared so that the configurations used were as near as possible to configurations used for real-time tracking of the spacecraft. By using the test procedures, station personnel could gain experience on operating the hardware and software. This experience was particularly valuable when new equipment, configurations, or software had been introduced.

Simulated data is generated in the simulation conversion assembly (SCA). The simulated data called for in the tests is a 2047-bit psuedonoise (PN) sequence; yet fixed pattern data, such as square wave data, may be used if special tests require that the data be recognized and validated by visual inspection. The SCA generates either a single channel or two channels of data, depending on the telemetry mode being tested. In the case of the single channel of data, the SCA modulates the data with a square wave subcarrier. For the two channels, the data channels are modulated with two subcarriers using the interplex scheme. The mod indices of the subcarriers are set by using the wave analyzer at the receiver. The data on the subcarriers phase-modulates a carrier generated in the test transmitter, which is interfaced to the DSN Block III receiver through ambient load and the 20-dB coupler. The test transmitter signal level is adjusted to obtain the required signal-to-noise ratio, which is accurately measured at the Y-factor detector.

The Telemetry and Command Data (TCD) handling software (DOI-5050-OP) resides in the Telemetry and Command Processor (TCP) and in the Data Decoder Assembly (DDA), both of which are small general-purpose computers. The TCD software can be configured to process data using any one of three telemetry channels. For Mariner 10 support the channels are as follows:

<u>CHANNEL 1 (CH1)</u>
Low-rate uncoded (LR UNC) with data rates of
8-1/3 and 33-1/3 bps

This channel interfaces the Subcarrier Demodulator Assembly (SDA) directly to the software internal bit sync loop residing in the TCP. The TCP formats this data, records it as a digital Original Data Record (ODR) and transmits it via high-speed data (HSD).

<u>CHANNEL 2 (CH2)</u>
Medium-rate coded (MR C) at 490 and 2450 bps
Low-rate uncoded (LR UNC) at 8-1/2 and 33-1/3 bps

The data from the DDA is synchronized and detected by the Symbol Synchronizer Assembly. The medium-rate coded data is block-decoded using DDA software. This data is formatted and transmitted to the TCP where it is recorded as an ODR and transmitted via HSD. Low rate data is accepted by the DDA from the SSA. This data is formatted and transmitted to the TCP, where it is handled the same as Channel 1 data.

<u>CHANNEL 3 (CH3)</u>
High-rate coded (HR C) at 22.05 and 7350 kbps
Medium-rate coded (MR C) at 490 and 2450 bps
High-rate uncoded (HR UNC) at 117.6 kbps

The high-rate coded and medium-rate coded data is decoded by the Block Decoder Assembly (BDA). The DDA accepts the high- or medium-rate decoded data from the BDA or high-rate uncoded data from the SSA. This data is formatted and transmitted via wideband data (WBD) lines if it is high-rate coded or via HSD lines if it is medium-rate coded. The formatted data is also recorded on the DDA 9-track high density recorder (HDR), creating an ODR.

The transmitted data blocks (the output of the TCD) are described in detail in Document 820-13, DSN System Requirements, Detailed Interface

Design, TLM-3-5, Telemetry System Wideband and High Speed Data Interfaces. The specifications placed on the telemetry system by these requirements are very important and must be tested.

The TCP has a 24-bit direct transfer interface with the Digital Instrumentation System. The operational Telemetry software uses this interface to transfer initialization, status and calculation messages to the monitor system (See 820-13 - MON 5-4). This interface is tested, but without the DIS monitor operational software.

The DIS is used to process the data for the test using the Telemetry and Command System Test Software (DOI-5049-SP). The data transmitted by the TCP or DDA goes to the station communication center and is normally transmitted to the Mission Control and Computing Center (MCCC). To use the DIS as the processing computer, the DDA or TCP HSD/WBD lines must be patched at the station communication center to the DIS HSD/WBD lines.

The Telemetry and Command Test Program, DOI 5409-SP, resides in the DIS computer. It contains two subprograms - a telemetry subprogram and a command subprogram - both under the control of an executive program. The program interfaces with the TCD string to be tested through the HSD/WBD on-site GCF equipment (station communications center) and the 24-bit monitor interface. By virtue of these interfaces, the TCD and its operational software are tested in an operational environment. That is, the telemetry system test validates data as it is transmitted externally from the TCD system.

The software receives the monitor data, formats it and prints the results selectively on the DIS I/O typewriter or line printer. Due to the greater print speed of the line printer, it is normally used during the tests. The monitor data as displayed are of the Initialization Messages, Status Messages and the Calculation Messages. These messages are validated by visual inspection for correctness and completeness in compliance with 820-13, MON 5-4.

The telemetry data HSD/WBD blocks may be displayed on the line printer for visual inspection, although normal operation consists of permitting the software to output the following:

Standard block header information consisting of source, destination, DDT, UDT, Spacecraft ID and day of the year and the time of the block formation.

Formatted configuration and lock status with receiver AGC or signal level in dBm and the TCD software channel in use.

The bit error rate (BER) or word error rate (WER) measured over a given period; the bit rate and data format.

In the bit error rate test, the data may be either PN or a fixed pattern. The best software synchronizes to the data and does a bit-by-bit comparison. The WER/BER accumulation may be over any chosen interval resulting in a grand summary, while statistics can be displayed as interim summaries at intervals as required.

As the test is being executed, the test software will detect errors and display error messages as follows:

The times between telemetry HSD/WBD blocks are not within specified tolerances.

Excessive bit error or incorrect data type, as evidenced by the inability to achieve sync.

Binary time and multisecond clock differences.

GCF errors.

This telemetry and command test software is an invaluable tool, which has done much to facilitate and ease the execution of the telemetry system performance tests.

The Network Telemetry System Performance Tests for Mariner 10 were executed using the DSN Standard Test Procedure, 853-61; 2A-07, "Telemetry System Performance Test MVM'73 Version." The overall test is divided into three main tests. Each test contains a number of subtests which are modular, so that any test can be run independently. This allows the procedures to be used for prepass readiness tests, trouble-shooting and new equipment or software tests. It also allows for reduced testing when resources so demand. The three tests are the Configuration and Interface Tests, the Telemetry Performance Tests and the Non-Real-Time Capability Tests. These tests all call out a Test Preparation Section as needed. The complete test, two TCD strings, can be accomplished in 40 hours.

(1) Configuration and Interface Tests. The Configuration and Interface Tests are performed on the three telemetry channels (CH1, CH2, CH3). The telemetry operational software and hardware interfaces are tested using all the operational configurations planned for Mariner 10 support. This test contains HSD and WBD interface tests which verify the HSD/WBD blocks. The blocks are verified by inspection of the formatted block headers, configuration and lock indicators which are formatted for ease of interpretation and by the absence of error messages. This section contains a set of TCP-DIS monitor message verification tests which verify that the initialization, status and calculation messages are correct as specified.

(2) Telemetry Performance Tests. The Telemetry Performance Tests determine the capability of the Telemetry System to meet the DSN support requirements (614-15) on the performance. These tests are designed to evaluate telemetry performance at threshold SNRs with CH1, CH2, and CH3 configured in the Mariner support modes.

The test measures the output data word error rate (WER) for coded data and the bit error rate (BER) for uncoded data given an input data signal-to-noise ratio. The results are compared against predicted BER/WER, and if they are within given tolerances the performance is considered to be acceptable. The prédictions are based on available mathematical models of the telemetry system. These models are evaluated using a computer program called the Telemetry Efficiency Program, which is used primarily to generate performance parameters for the telemetry SPTs.

A strong signal test is always executed prior to a weak signal test. The strong signal test is run to detect gross errors in the HSD/WBD blocks which would invalidate the weak signal tests, which take much longer to perform. The strong signal test also confirms the set up configuration and interface.

The weak signal performance tests are run for all operational configurations and data rates. An accurate SNR is set using the Y-factor machine, and the WER/BER is measured and recorded. The SNR calculation is also checked for accuracy.

During the execution of the telemetry performance tests, Original Data Records (ODR) are created to be played back and validated in the Non-Real-Time Capability Tests, with the exception of the ODR for the 117.6-kbps uncoded data mode. Since the WBD lines are limited to a data rate of 28 kbps, it is not possible to perform a telemetry performance test in real-time. Therefore, the data is recorded, then played back at the wideband rate, with an effective data rate of 22 kbps. (This is also normal operational procedure for supporting the 117.6-kbps mode.) Performance data can then be obtained as it was for the other data modes.

(3) <u>Non-Real-Time Capability Tests</u>. The ODRs generated in the performance tests are validated in the third net of SPT tests. These are the Non-Real-Time Capability Tests. In the first part of these tests, the ODR playback demonstration, the digital ODRs are played back using the appropriate playback program, the 7-track playback program (DOI-5041-OP) or the 9-track playback program (P9 module of DOI-5050-OP).

This demonstrates the ability to play back tapes, using both the TCD and the playback software. The HSD/WBD blocks are checked in a manner similar to the configuration and interface tests to insure that the tapes were properly recorded.

In the second part of the Non-Real-Time Capability Tests, analog tape playback demonstration, analog tapes are generated at a specific SNR and then played back. The tape output SNR is obtained and compared against the set SNR. The tape output SNR must be no greater than 1 dB, less than the net SNR.

Execution of Network telemetry system performance tests for MVM'73 was scheduled to begin in May 1973, with a completion date of August 10, 1973. Unfortunately, these dates were not met due to the late delivery of operational software and hardware. The tests were still being executed after the Mariner 10 launch. Yet prior to launch all of the configuration and interface tests had been completed, plus those capabilities which were required for launch. In a number of cases, the system performance tests uncovered station problems, which when corrected by the station personnel, required a rerun of system tests. The station personnel also made recommendations on modifications or corrections of the procedures. Data taken during the tests was transmitted to the Telemetry System Cognizant Operations Engineer for analysis.

All of the configuration and interface tests (including the AGC/DBM and SNR tests) were successfully completed prior to Mariner 10 launch. The telemetry performance tests were not completed. Some of the tests were run, but the results were not within tolerance. These results were accepted since they were nearly in spec, and it was decided that the station resources should not be loaded by further testing except on a best efforts basis.

In some cases, data from the tests was not available. These tests were not completed due to hardware problems which were uncovered prior to or during the tests. Since the tests were run late, many problems were discovered just prior to Mariner 10 launch. The problems could not be corrected due to the Mariner configuration freeze, and then the Pioneer 10 configuration freeze in December 1973. The problems were corrected and the tests were run after the termination of the Pioneer configuration freeze.

(b) Command System Performance Tests. The command system performance test was divided into four main sections: countdown, manual mode, automatic mode, and reliability. The complete testing could be performed in approximately six hours per TCD string.

The countdown section is used as a prepass readiness test that is performed prior to the data transfer test with Network Operations. Using the appropriate TCP operational software, command capability is verified in the manual and remote mode of operations. The modulation index is adjusted and measured. Monitor interface is verified. Both timed and nontimed commands are transmitted.

In the manual mode tests, the same type of testing is performed as in the countdown section. Additional tests are performed on CMA configurations and TCP program manipulation. The ability to record and recover command data from an analog tape is verified.

The automatic tests use the DIS computer to simulate remote command operations. Special test software, as described in the previous section, is used in the DIS to process certain programmed test sequences that can be independently selected by an operator. Each test sequence generates the command data, predicts results, and verifies command data from TCP by utilizing the high-speed data interface to the TCP. These test sequences are processed automatically, and the results are output to the operator. All high-speed data blocks are automatically checked against the 820-13 interface document.

In the reliability tests, the capability to command and to process telemetry in the same computer is demonstrated. Continuous commanding is exercised while processing telemetry at bit rates of 33-1/3, 2450, and 117.6 kbps. Commanding consists of priority commands on 26-sec centers and timed commands on 30-sec centers. The DIS computer is used to generate the command data, to process the command data from the TCP, and to process the telemetry data for errors. This type of testing is performed continuously for four hours per TCD system. An appendix has been added to the reliability section giving the stations the capability to test the PN generators used to generate the PN sync signal. This was developed after detecting bit rate alarms at some stations during the first system performance tests. In this particular test, the 511 bit PN sequences generated by the CMA are processed as a 511-bps telemetry channel. The processed telemetry is checked at the DIS for bit errors in the PN sequence. PN sequences containing bit errors are dumped on a line printer.

The following problems were uncovered and worked to achieve resolution prior to launch:

PSK Data to PN Sync Ratio. A majority of the stations did not have the correct ratio. Analog adjustments within the CMA were made to obtain the correct ratio. The repair depot procedures were changed to reflect the correct ratio adjustments on the CMA analog drawers.

Subcarrier Frequency Alarms and Aborts. Two stations experienced this problem only during reliability testing while processing 2450-bps telemetry. ECO 73-023 was installed in the CMA clock counter interface to eliminate noise problem on TCP pin/pot lines.

Bit Rate Alarms and Watchdog Timer Failures. Stations 12, 42, and 14 experienced this problem. This condition was corrected at Stations 42 and 12 by analog adjustments. However, at Station 14 an emergency ECO was installed as a temporary solution. A permanent solution for all stations is currently being implemented by the Cognizant Operations Engineer. During operations, the bit rate warning limits are narrow to enable detection of bit rate errors caused by PN generator failures.

Exciter Confirmation Phase Detector. Most stations reported excessive dc drifting on the output of the exciter's confirmation phase detector. The drift was more pronounced at some stations. As a result, command confirmation was changed to use the local confirmation within the CMA. During the investigation, a wrong value capacitor that had been installed at the factory was discovered. Installing a capacitor of the correct value enabled the 26-m stations to meet specifications. However, a different problem exists at the 64-m station with the Programmable Oscillator Control Assembly (POCA) installation.

At launch, Stations 12, 14, 62, 63, and 71 had successfully completed and passed all command system tests. Station 42/43 completed and passed approximately 80% of the command system tests; Stations 11 and 51 were not required to perform the tests.

(c) Tracking System Performance Tests. The tracking system performance tests are designed to show the operational readiness of the doppler tracking antenna pointing and ranging systems. The various systems are tested in a manner that closely resembles an actual tracking situation and are based upon mission requirement documents. Successful completion of the test demonstrates that:

(1) Station equipment meets mission requirements.
(2) System interfaces are correct.
(3) Station personnel have established the required degree of familiarity with the committed equipment.

The objectives of the doppler tracking system performance tests were to test exciter jitter (phase errors due to noise or equipment unstability), receiver jitter, doppler resolver and counter, VCO and doppler extractor frequency range, prime and backup time standard stability, and electrical path length variation. All stations passed the doppler tracking system performance tests with only minor problems. Ten sample/sec doppler data was a requirement for MVM'73 that required a new test for the doppler tracking system performance tests. The 10 sample/sec hardware proved to be satisfactory at all stations. The POCA was tested at all 64-m stations to establish compatibility with the tracking system and measure phase stability. The POCA proved to be compatible with the rest of the tracking system, and phase stability specifications were met.

For MVM'73, there were antenna pointing system performance tests only for the 26-m antennas; therefore, the subsystem acceptance test was used as a system performance test for the 64-m antennas until an automated system performance test could be developed. Both tests measured rise and delay time, overshoot, noise, and 3-dB bandwidth and pointing accuracy. All 26- and 64-m stations passed the test. The 64-m stations had a problem in that the low film height alarm kept tripping during tracks. Ths was an alarm indication problem rather than a physical problem and was corrected by an engineering change.

The planetary ranging system performance test was a new test; it was developed for acceptance testing when the new equipment was installed at the station. Prior to launch, only the planetary ranging assembly at DSS 12 had been tested. The DSS 12 planetary ranging assembly met some of the requirements that were put forth by the System Engineer; however, not all of the requirements were tested because excessive test time would be required. For instance, one test required 24 hours of continuous testing for a measure of diurnal drift.

(d) Monitor and Control System Performance Tests. The monitor and control system performance test was designed to establish required monitor function responses to subsystem switch closures, system data from the telemetry, command, and tracking systems, receiver automatic gain control calibration, tracking and telemetry backfeed data, control data from the Network Control System and/or Mission Control and Computing Center. It was also designed to demonstrate specified monitor and tracking original data record processing and tracking system functional throughput. Proper data processing and display were demonstrated on several devices including:

(1) The cathode ray tube used to display any parameter requested and available in the system. This includes color coding status and/or events parameters.
(2) The line printer used to display any parameter available in the system, primarily used for predicts and sequence of events control data and running tabulations of automatic gain control, signal-to-noise ratio, and tracking data pseudoresiduals.
(3) The medium-speed character printer was used as a hard copy display of all events and/or status data appearing on the lower part of the cathode ray tube. It was also used for telemetry and command data that was previously routed to a teletype readout located at the station control and monitor console subsystem. The latest function added was a hard copy printout of all requests accepted when using the cathode ray tube keyboard (echo capability).

Specific functions included the following:

(1) Subsystem switch closures. The subsystem switch closures included lock status and subsystem switch configuration for the receiver/exciter, subcarrier demodulator assembly, tracking data handling, antenna microwave subsystems, telemetry and command data handling subsystem, and Ground Communications Facility.

(2) System data. System data included telemetry signal-to-noise ratios, initialization and lock status, command status, tracking pseudoresiduals, and accountability data.

(3) Receiver calibrations. Receiver calibrations included performing a series of calibrations on all receivers at the tracking stations. This is done by utilizing the calibration software program (DOI-5052-OP), punching a paper tape on the digital instrumentation subsystem and loading this paper tape (calibration coefficients) into the monitor and control operation program (DOI-5046-OP). This allowed voltage data to be converted to dBm.

(4) Tracking Data System (functional throughput). The monitor and control software included control of the interface between the Tracking Data Handling Subsystem and the high-speed data line. This software will format and control the high-speed data output for all tracking data and write an original data record.

(5) Control data. Control data included any test data routed to the line printer, data to the magpak, or data processed through the digital instrumentation subsystem for cathode ray tube display from a facility outside the station. It was primarily to be used for predicts and sequence of events routed to the line printer.

(6) Original Data Record playback. Original Data Record playback consisted of the capability of transmitting data from one facility or computer through the GCF system to another facility or computer from a digital magnetic tape. This data was validated subsequently by dumping the data on a line printer in real-time or by dumping the digital tape on the local line printer that was recorded from the output of the GCF system.

The method of testing the monitor and control system consisted of:

(1) Methodically stepping through all the possible switch settings for each subsystem and observing that these changes were reflected on the station monitor and control console cathode ray tube or line printer in the desired manner. The cathode ray tube or line printer format test tapes will be constructed in such a manner as to observe all the possible parameters for each subsystem within the limits of the cathode ray tube or line printer.

(2) Gathering and displaying system data for analysis and display and correlating the values of the calculated data (i.e., signal-to-noise ratios) utilizing a complete telemetry system with an input from the simulation conversion assembly. This data is calculated in the telemetry and command processor and transferred to the monitor computer through the 24-bit parallel register. The data is then displayed on the cathode ray tube, line printer, and the medium-speed character printer.

(3) Utilizing a calibration curve for receiver automatic gain control and static phase error, compare the known input from the receiver with the display on the cathode ray tube and line printer for each receiver.

(6) Mission Preparation Tests. Testing that was accomplished as described herein included all DSN station hardware and software required to support the mission.

(a) Mission Configuration Tests. These system level data flow tests were to be for the purpose of demonstrating that the network was capable of supporting all data rates, engineering modes, and mission configurations. They were to be the first end-to-end (station to Mission Control and Computing Center) data flow tests designed to verify the system performance demonstration tests covered in preceding paragraphs. Mission configuration was to be considered complete when three successful tests had been accomplished at each station. These tests were to require from 8 to 10 hours to complete by each station. Telemetry, command, tracking, and monitor systems were to be exercised during these tests. Due to late implementation, sufficient test time was not available, and the system performance demonstration test and the mission configuration (system level) tests were combined.

(b) Operational Verification Tests. The purpose of these tests was to provide mission-dependent training for Network operators in the use of hardware and software, using operational procedures specifically for support of MVM'73. The Deep Space Station and GCF mission-dependent operational procedures were used for these tests.

Detailed objectives of these tests were as follows:

(1) Demonstrate that the stations' mission-dependent and mission-independent operating procedures were compatible with software and hardware.

(2) Demonstrate that the Network facility operational interfaces were compatible.

(3) Verify the Network's ability to perform data acquisition and data handling and to provide monitor data and command transmission.

(4) Verify that the stations could operate the on-site simulation system.

(5) Verify that a sufficient number of station and GCF operators and Operations Control Team personnel were adequately trained to support mission operations system tests.

All operational verification tests used the stations, GCF, MCCC, and Operations Control Team as were available. Telemetry was simulated by the use of the stations' simulation conversion assembly, transmitted from the station via the GCF and processed for validation. Command capability was exercised in both the automatic and manual modes. Radio metric data was not normally transmitted to the MCCC except to verify end-to-end configuration capability. Station monitor data was transmitted to the Network Operations Control Area. The sequence of events for these tests simulated portions of the mission such as: launch, cruise, TV calibration, trajectory correction maneuvers, and encounters. Certain of the tests had unscheduled problems inserted into the tests to develop the station's ability to reconfigure using backup command, telemetry, radio metric, and GCF capabilities to meet mission requirements.

Table 34 shows the number of operational verification tests conducted at each station. Each test was conducted over an 8-hour period, including the pre- and post-calibrations. These tests represent approximately 270 hours of testing. It was incumbent upon each station director to arrange his crew manning so that all crews received adequate training. Enough test time was included so that each crew could receive the benefit of at least two 8-hour tests. Also shown on this table is the number of tests in which the long-loop simulation system was exercised. In

Table 34. OVT/PDT summary

DSS	Number OVT	Number PDT	Simulation participation	MTC participation
12	7	1	3	2
14	7	1	1	3
42	6	1	0	0
43	4	1	1	2
62	4	1	2	2
63	4	1	1	1
71	2	1	2	2
Total	34	7	10	12

order to completely train personnel, the MCCC's 6050 computer was required. The number of tests for which the mission test computer facility could be scheduled are also shown in the table. The facility was needed to process the telemetry data, although the high-speed data could be verified via data dumps from the 360-75 computer.

(c) <u>DSN Performance Demonstration Test</u>. The purpose of the performance demonstration test was to verify that operator training was adequate and to demonstrate DSN readiness to support mission operations system testing. The performance demonstration test was essentially an operational verification test with intentional problems inserted into the test sequence to demonstrate the Network's ability to isolate faults and recover from anomalies. Since this was a buy-off test, a higher degree of performance was expected than during the previously conducted operational verification tests. A single, successful 8-hour test was conducted for each station as shown in Table 34. The successful completion of these tests demonstrated DSN operational readiness. At this point, the mission-dependent configurations were transferred to the Operations Control Team.

(d) <u>Configuration Verification Test</u>. The configuration verification test was a single 6-hour test conducted at each 26-m station and at DSS 14 just prior to launch. The objective of the test was to verify each station's ability to properly configure hardware and software to acquire, process, and transmit to the MCCC all required telemetry rates; to process and transmit all required radio metric data sample rates; to receive, process, verify, and confirm command data in both the automatic and manual modes; and to display and transmit monitor data. Upon completion of this test, the 26-m stations and DSS 14 were frozen in configuration and were ready to support the launch/near-Earth operational readiness test.

(e) Initial Acquisition Tests. In order that the initial acquisition would be smoothly accomplished, considerable effort was expended. Three initial acquisition strategy meetings were held to discuss alternative methods and develop an optimum approach. Subsequent to finalizing the initial acquisition strategy, a detailed sequence of events was developed and sent to DSS 42. Prior to launch, the proposed sequence was exercised four times with the Operations Control Team and DSS 42 personnel. During these exercises, the sequence was thoroughly and completely discussed with all personnel involved, particularly with the crew that would be on duty during the actual initial acquisition.

(7) DSN/Spacecraft Compatibility Testing. The initial efforts to establish DSN/MVM'73 spacecraft compatibility consisted of an intensive series of tests to determine the telemetry and command handling subsystem performance for MVM'73 telemetry modes. The tests were performed in late 1971 at the Compatibility Test Station (Cape Canaveral, Florida), the Compatibility Test Area (Pasadena, California), and the Telemetry Development Laboratory (Pasadena, California) utilizing telemetry simulators and test software. Preliminary design tests utilizing MVM'73 spacecraft components were performed at JPL's Compatibility Test Area and Telemetry Development Laboratory during the early part of 1972. These tests were accomplished with telemetry and command data handling software that consisted of modified Mariner Mars 1971 operational software and revised telemetry and command data handling test software.

Phase I of a three-phase test program to establish DSN/MVM'73 spacecraft compatibility was performed with CTA 21 and Telemetry Development Laboratory starting in September 1972. This phase of testing continued through April 1973 and demonstrated design compatibility between the spacecraft telecommunications subsystems and the DSN.

Phase II of the test program was performed with CTA 21 in July 1973. The objective of this series of tests was to establish system design compatibility between the flight spacecraft and the DSN. Operational telemetry and command data handling software was utilized by CTA 21, and the spacecraft was located in the thermal/vacuum facility at JPL.

Phase III compatibility tests were performed at Cape Canaveral between Compatibility Test Station (DSS 71) and both of the MVM'73 flight spacecraft located in the Assembly and Checkout Facility (Building AO), the Explosive Safe Facility (ESF), and Launch Complex 36. The objective of these tests was to verify continued interface integrity and maintenance of compatibility during prelaunch preparations.

Initial tests to determine the telemetry and command data handling subsystem performance for MVM'73 telemetry modes were performed at DSS 71 in September 1971. These tests indicated losses that were higher than predicted for the high-rate modes, and minor operational difficulties with the low-rate modes. These test results prompted an intensive series of tests at the Telemetry Development Laboratory and CTA 21 in an effort to better understand the telemetry and command data handling subsystem performance for MVM'73 telemetry. These tests utilized simulated MVM'73 telemetry, Mariner Mars 71 hardware, and software that consisted of modified Mariner Mars 1971 operational software combined with revised telemetry and command data handling subsystem test software.

Preliminary design tests with spacecraft components were performed at CTA 21 and Telemetry Development Laboratory during the period April through August 1972. This series of tests could not demonstrate subsystem design compatibility because telemetry and command data handling subsystem operational software was not available and the spacecraft components consisted of breadboards. The primary objective of these tests was to provide insight into spacecraft and DSN performance capabilities and to enhance analysis and conclusions derived from compatibility testing.

In September 1972, the three-phase test program to establish DSN/MVM'73 spacecraft compatibility was initiated. Each phase of testing was divided into segments as shown in Fig. 119; the individual tests performed in each phase and segment are shown in Table 35.

(a) <u>Phase I Tests</u>. The objective of tests in this phase was to demonstrate design compatibility between the MVM'73 spacecraft telecommunications subsystems and the DSN.

<u>Flight No. 1 tests</u>. These tests were conducted at CTA 21 on September 29, 1972, utilizing Flight No. 1 spacecraft components and telemetry and command data handling subsystem test software. Although S-band RF interface testing was emphasized, preliminary telemetry and command tests were performed. The use of telemetry and command data handling subsystem test software did not ensure subsystem design compatibility, but did provide a functional test of the DSN and spacecraft hardware.

<u>Flight No. 2 tests</u>. Tests were performed in December 1972 and January 1973, with CTA 21 and the MVM'73 Flight II radio frequency subsystem and modulation/demodulation subsystem. Emphasis was placed on the RF and command interfaces. A total of 18 tests were successfully completed with no anomalies observed. All telemetry tests were performed as functional tests since operational software had not yet been developed.

<u>Command and telemetry tests</u>. Formal compatibility testing was changed to informal software checkout and development testing status. This action was the result of delays in acceptance testing of the operational software and was performed over the time period April through July 1973. Several problems with the software were discovered. Most of these problems were related to the inability to acquire 8-1/3 bps at high signal conditions. Of lesser significance was loss of telemetry and command data handling subsystem program control when selecting a redundant subcarrier demodulator assembly or initialization of 490 bps.

Hardware problems uncovered were a possible alignment problem with the subcarrier demodulator assembly and an interference problem

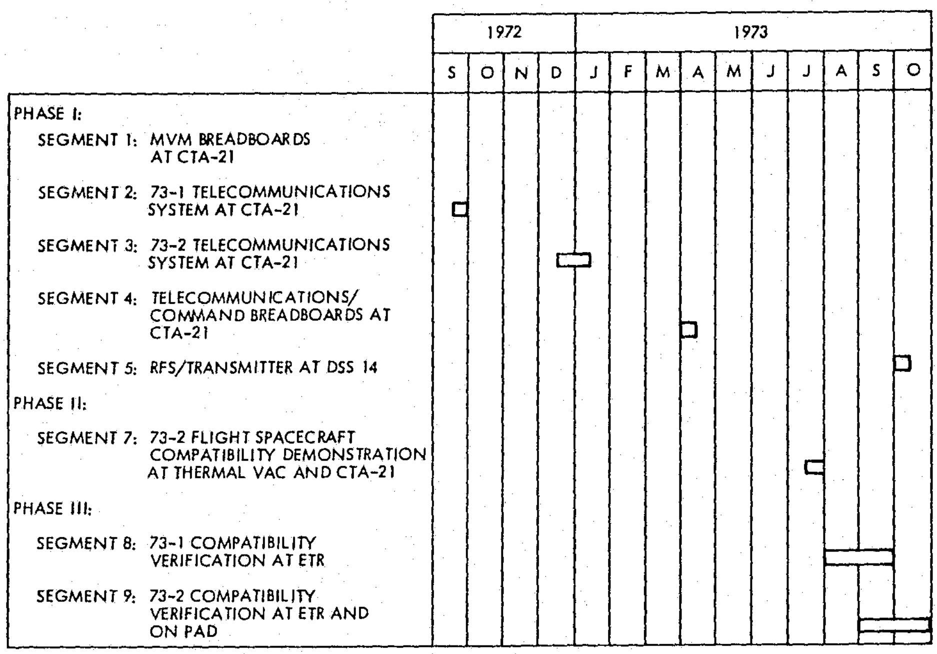


Figure 119. DSN/MVM'73 compatibility test schedule

Table 35. DSN/MVM'73 compatibility test matrix

	Phase											
	I						II[a]			III		
	Segment											
System tests	1	2	3	4	5	6	7a	7b	7c	8	9	10
S-band RF												
Downlink, one-way	X		X									
Uplink threshold, two-way	X		X					X	X	X	X	
Two-way	X		X									
Spacecraft receiver pull-in range	X		X							X	X	
Spacecraft receiver tracking rate and range	X		X							X	X	
Carrier residual 0 jitter	X		X							X	X	
Uplink spectrum analysis	X		X									
Downlink spectrum analysis	X		X							X	X	
Simulated dynamic conditions	X	X	X									
Spacecraft receiver best-lock frequency	X		X					X		X	X	
Auxiliary oscillator frequency	X		X							X	X	
Dynamic acquisition							X					
X-band RF												
Carrier residual 0 jitter					X							
Tracking range and rate					X							
Downlink threshold					X							
Command												
Polarity verification		X	X				X					
Acquisition		X	X				X	X	X	X	X	
Capability under doppler		X	X									
Capability with ranging		X										
Operational capability		X					X	X	X			
Dynamic acquisition							X					
Telemetry												
Functional (strong signal)			X	X						X	X	
Mode 1		X	X	X			X	X				
Mode 2			X	X					X			
Mode 3			X	X								
Mode 4			X	X			X					
Mode 5			X	X				X				
Mode 6		X	X	X			X					
Mode 7			X	X								
Threshold				X								
Mode 1		X		X			X	X	X			
Mode 2				X				X	X			
Mode 3				X					X			
Mode 4				X			X	X	X			
Mode 5				X					X			
Mode 6		X		X			X	X	X			
Mode 7				X				X	X			
S-band ranging												
Acquisition	X		X		X					X	X	
Polarity verification	X		X		X							
Channel delay	X		X		X							
Under doppler conditions	X				X							
X-band ranging												
Acquisition					X							
Polarity verification					X							
Channel delay					X							

[a]Tests 7a, b and c are Sun levels 1, 2 and 4.8, respectively.

using the discrete spectrum from the planetary ranging assembly. With the former problem, one of the two subcarrier demodulator assemblies at CTA 21 would not acquire at the Project-specified Mercury encounter telemetry threshold ST_B/N_0 (0.63 dB).

A special alignment of the subcarrier demodulator assembly was considered to be a resolution to the problem. With the latter problem, the telemetry signal-to-noise ratio estimators in both telemetry channels (22.05/2.45 kbps) indicated an increase in signal-to-noise ratio with the planetary ranging assembly discrete spectrum ranging as opposed to the Mark I-A continuous ranging.

Block IV exciter tests. Block IV exciter (S-band) command capability was established during tests on August 3, 1973, utilizing a flight radio (S/N 006) and the prototype command unit. The S/X-band receiver tests were not accomplished because of the nonavailability of Block IV receiver equipment.

(b) Phase II Tests: Flight No. 2 Spacecraft/CTA 21 Testing. This testing was performed during the month of July 1973 with the spacecraft located in the thermal vacuum chamber. Testing was conducted at various sun levels to simulate: (1) 1.0 Sun, (2) 2.0 Sun, (3) 4.8 Sun, and (4) ambient. Several problem areas were uncovered and are listed below:

(1) The subcarrier demodulator assembly lock indicator would not indicate in-lock at threshold, 5×10^{-2} data bit error rate, for 22 kbps, block coded data.
(2) For some subcarrier demodulator assembly/symbol synchronizer assembly combinations, insufficient subcarrier demodulator assembly correlation voltage was achieved for 22-kbps block coded data to achieve symbol synchronizer assembly lock.
(3) The Mission and Test Computer experienced difficulty in achieving frame sync at threshold for 22 kbps block coded data.
(4) The operational software (DSN Program Library Software No. DOI-5050-OP) would not achieve reliable bit sync lock for 8-1/3 bps at high signal level conditions.

These problems were not resolved during the July 1973 testing at CTA 21, but were given high priority for continued investigation during the Flight No. 1 testing to be conducted at the Compatibility Test Station at Cape Canaveral, Florida. All other objectives of the test plan for Flight No. 2 spacecraft were successfully completed during this phase.

(c) Phase III Tests.

Flight No. 1 compatibility verification tests. This testing was performed at Cape Canaveral on August 26, 1973. The spacecraft was located in Building AO and an RF link was established to the Compatibility Test Station; however, Revision A of the operational telemetry and command data handling subsystem software was not available. Special emphasis was placed on problems uncovered at CTA 21 during Flight No. 2 testing. A summary of the testing and results is as follows:

(1) Command: the DSN/spacecraft command system design was declared compatible. There were no outstanding problems remaining upon completion of this testing.

(2) Telemetry: the subcarrier demodulator assembly and symbol synchronizer assembly lock problems discussed under Phase II testing were tested extensively during this period. A standard alignment of the subcarrier demodulator assembly was performed, followed by a series of acquisition tests at an ST_B/N_0 of 0.63 for 22 kbps coded data.

The subcarrier demodulator assembly/symbol synchronizer assembly combination acquired and performed without difficulty. A decision was made to abandon further tests. Although the telecommunications system was designed to operate at a point below subcarrier demodulator assembly/symbol synchronizer assembly design threshold, there appeared to be no problem in meeting project requirements at Mercury encounter.

(3) Ranging: an interference problem in the telemetry signal-to-noise estimator occurred when the planetary ranging assembly discrete code was applied to the uplink. This problem was manifested by higher-than-normal signal-to-noise ratio printouts. An operational resolution of this compatibility problem was to operate the uplink RF signal at or below -100 dB signal levels.

(4) RF tests: all RF tests were successfully completed and compatibility was declared satisfactory.

Flight No. 2 compatibility verification tests. This test was performed on September 29 and October 23, 1973, at Cape Canaveral. The spacecraft was located in Building AO for the September 22 test, and in Launch Complex 36 for the October 23 test. All testing was performed via an RF link and the launch version (Revision A) of the telemetry and command data handling subsystem operational software was utilized successfully.

Tests performed on September 22, 1973, cleared an outstanding compatibility problem. For the first time, a video picture was sent from the spacecraft to the Mission and Test Computer and fully reconstructed. Data rate for this event was 22 kbps, block coded. The M26X software module was also successfully exercised during this test. All other objectives of testing on this date were successfully completed.

Following completion of these tests, an operational readiness review was held on September 26, 1973, with a report of compatibility status as follows:

(1) Command design compatibility established.
(2) Telemetry design compatibility established with additional testing of DOI-5050-OP-A scheduled for October 23, 1973.
(3) RF design compatibility established.
(4) Ranging design compatibility established with additional operational testing scheduled for October 23, 1973.

On October 23, 1973, final compatibility testing was conducted with the Flight No. 2 spacecraft encapsulated in its launch configuration and located at Launch Complex 36. All compatibility deficiencies encountered during the September 22, 1973, testing were resolved. Therefore, complete compatibility was established for all elements of the spacecraft/DSN interface.

The successful conclusion of the formal DSN/MVM'73 compatibility program enabled the establishment of telecommunications compatibility as evidenced by the successful launch of the MVM'73 spacecraft on November 3, 1973. The importance of the performance of a formal compatibility test program is clearly demonstrated by the problem areas uncovered, verified, and resolved during the DSN/MVM'73 testing.

IV. MISSION OPERATIONS SUPPORT

A. GENERAL

This section summarizes TDS capabilities and resources employed to meet MVM'73 tracking and data acquisition requirements from launch through the end of the extended mission. The near-Earth launch activities are first discussed, followed in turn by the primary mission and the extended mission. A detailed account of each day's activities would fill many volumes; consequently, one will observe that this section deals primarily with mission support highlights associated with critical phases and in-flight problems.

B. NEAR-EARTH PHASE OPERATIONS SUPPORT SUMMARY

1. Launch Countdown

The launch vehicle countdown for MVM'73 was initiated on November 2, 1973, and proceeded satisfactorily without any unplanned holds. The normal built-in holds of 60 min at T-100 min and 10 min at T-10 min were observed. Weather conditions throughout the count were excellent. The opening of the 60-min launch window started at 0545 GMT on November 3, 1973. The spacecraft countdown also proceeded without incident. Countdown of the Near-Earth TDS progressed satisfactorily, with all elements checked out by launch -140 min, with the following exception. During the countdown, when the spacecraft went to the 33-1/3 bps data mode, this data was transmitted from the STDN Merritt Island stations to JPL via DSS 71 to determine if the problem noted during Operations Readiness Test no. 2 was still present, and it was. However, before the second telemetry string at DSS 71 could be initiated to process the STDN Merritt Island data, the spacecraft data mode was changed to 2450 bps, which could not be transmitted by MIL to DSS 71. Since the retransmission of spacecraft data from MIL was not a mandatory requirement, there was no constraint placed on the launch by this anomaly.

2. C-Band Metric Data Coverage

The tracking system of the Near-Earth TDS was configured as described in the previous section to provide metric data for both the launch vehicle and the spacecraft systems. Figure 120 presents the actual coverage provided by tracking the C-band beacon on the Centaur. The intervals of mandatory coverage are indicated. The figure presents the acquisition of signal and loss of signal times only, and each does not necessarily indicate a full interval of good track. Table 36 sets forth the times of the launch vehicle flight events. Mark 12 was not observed because of poor data received at the Building AE Telemetry Laboratory. Uprange radars at Merritt Island, Patrick Air Force Base, Grand Turk, and Bermuda were used to satisfy the requirements for Centaur powered flight data and for range safety. Antigua tracking data were used for a determination of the parking orbit. The computation used

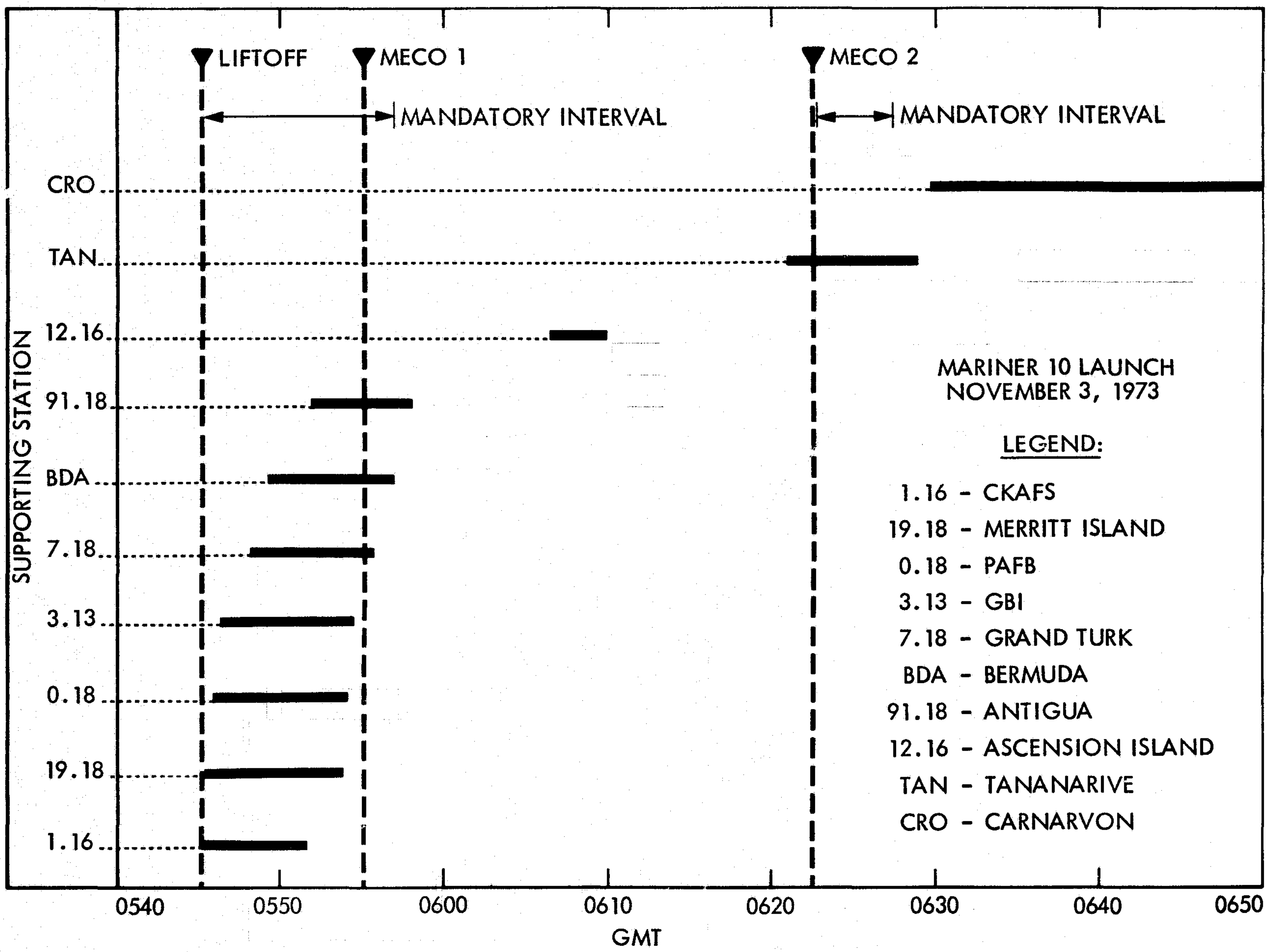


Figure 120. Centaur (AC-34) C-band metric data support

Table 36. Mariner 10 summary of observed mark events

Mark event	Event	Nominal time, GMT	Observed time, GMT	
	Liftoff (2-in. motion)	0545:00.0	0544:59.680	
1	Atlas BECO	0547:17.1	0547:19.0(M)	
2	Atlas Booster Engine Jettison	0547:20.8	0547:22.1(M)	
3	Centaur Insulation Panel Jettison	0548:02.7	0548:04.3(M)	
4	Sustainer Engine Cutoff	0549:13.5	0549:11.3(M)	0549:11.5(B)
5	Atlas/Centaur Separation	0549:15.4	0549:14.8(M)	0549:16.7(B)
6	Centaur Main Engine Start No. 1	0549:25.0	0549:25.9(M)	0549:26.1(B)
7	Nose Fairing Jettison	0549:37.0	0549:37.6(M)	0549:38.2(B)
8	Centaur Main Engine Cutoff No. 1	0554:37.6	0554:33.2(A)	0554:33.3(B)
9	Centaur Main Engine Start No. 2	0620:15.6	0620:14.6(J)	
10	Centaur Main Engine Cutoff No. 2	0622:26.5	0622.26.0(J)	
11	Mariner 10 Separation	0624:01.5	0623:58(T)	
12	Begin Centaur Reorientation	0627:38.5	Missing	
13	Start Propellant Blowdown	0632:36.5	0632:36(C)	
14	End Propellant Blowdown	0636:46.5	0636:46(C)	

A = AFETR/Antigua
B = STDN/Bermuda
M = STDN/Merritt Island
C = STDN/Carnarvon
J = STDN/Johannesburg
T = STDN/Tananarive

high-speed data obtained shortly after Centaur main engine cutoff, MECO 1. The AFETR radar at Ascension Island provided Centaur tracking during the parking orbit, and Carnarvon provided data to compute Centaur post-deflection orbits. Tananarive was the main support station for obtaining post-Centaur main engine cutoff no. 2 data, but the station received a weak signal at horizon and was unable to acquire autotrack; the station had only 210 sec of valid tracking data. The DSN's initial acquisition of the spacecraft was accomplished by DSS 42 at 0634 GMT on November 3, 1973. This station provided two-way S-band doppler data to the AFETR Real-Time Computing System, wherein these data were processed to provide spacecraft orbital elements.

Using data provided by tracking of the Centaur and spacecraft, the Real Time Computing System at AFETR computed (a) S-band acquisition data for use by the STDN and DSN, (b) orbital elements, (c) standard orbital parameter messages, (d) a map to planetary encounter, and (e) the I-matrix. The RTCS also provided acquisition data for the AFETR radars in the form of interrange vectors for Ascension and the real-time acquisition bus for those stations on the sub-cable. High-speed acquisition data was provided to Bermuda. Orbital parameters were computed from post-MECO 1 and MECO 2 C-band data, postdeflection maneuver C-band data, and spacecraft tracking data from the initial acquisition site. A summary of the RTCS's computed orbital elements is provided in Tables 37 and 38. B-plane Venus map solutions are presented in Table 39. The RTCS also computed and transmitted nominal predicts in the minus count for Carnarvon, DSS 42, and DSS 62. Three real-time sets were transmitted in the plus count.

3. Centaur Telemetry Coverage

The telemetry system of the Near-Earth TDS was configured and described in the previous section to provide telemetry data transmitted from the launch vehicle and spacecraft systems. Figure 121 presents the actual Centaur telemetry support provided by the Near-Earth TDS. The intervals of mandatory coverage are indicated. Launch area support was provided by tracking the Centaur at the Central Instrumentation Facility at Kennedy Space Center. The data was processed and transmitted to Building AE, Vehicle Telemetry Laboratory, for evaluation. Real-time vehicle performance was analyzed, and flight event readouts were provided. Real-time transmission of Centaur telemetry data to the Kennedy Space Center was hampered by periodic fading of the microwave communications circuits in the northern Florida area. These problems occurred approximately from 0612 to 0619 GMT and from 0625 to 0632 GMT. The data lost during these fadeouts was later retransmitted from the acquiring stations.

Table 37. RTCS orbital computations for Mariner 10

Type	Data source	Time of computation (L+min)	Quality of solution	Remarks
Centaur parking orbit	Antigua	L+18	Fair	Low elevation angle at Antigua
Theoretical Centaur transfer orbit	Antigua	L+22	Fair	
Actual Centaur transfer orbit	Tananarive	L+50	Fair	Station late acquir-ing. Data started 16 deg going down
Centaur post-deflection orbit	Carnarvon	L+101	Good	
Spacecraft orbit	DSS 42	L+190	Good	High-speed data

Table 38. Mariner 10 orbital parameters from RTCS computations

Parameters	Centaur parking orbit	Centaur theoretical transfer orbit	Centaur actual transfer orbit	Centaur postdeflection orbit	Spacecraft orbit
Epoch time, GMT	05 55 54.7	06 22 29.7	06 22 27.9	06 41 00.0	06 22 27.9
Earth-fixed sphericals					
Radius, km	6562.7799	6591.3201	6590.1714	1182.3430	6587.6308
Latitude, deg	23.2616	-23.5584	-23.4615	-22.5594	-23.3619
Longitude, deg	304.9014	41.6708	41.4613	115.9574	41.0804
Velocity, km/sec	7.3745	11.3955	11.3793	8.7611	11.3834
Path angle, deg	00.0825	3.9622	3.5631	48.4996	3.3701
Azimuth angle, deg	108.6189	107.9066	108.0828	68.8937	108.1615
Eccentricity, deg	00.00138	1.30069	1.30048	1.31345	1.30133
Inclination, deg	28.8636	28.90410	28.9231	28.9185	28.8883
C_3	-60.7518	18.6369	18.2326	18.9730	18.2846

Table 39. RTCS Venus mapping computations

Data source	Time of computation, min	Time of closest approach, GMT (M,D,Y,H,M,S)	B TC,[a] km	B RC, km
Tananarive C-band	L+70	2-6-74; 0046:50.6	-191,850.1	-40,911.585
Carnarvon C-band[a]	L+111	2-4-74; 1208:25.1	569,068.30	-28,507.199
DSS 42	L+203	2-5-74; 2112:52.6	-97,999.808	3,524.2995

[a]Map on Centaur postdeflection maneuver.

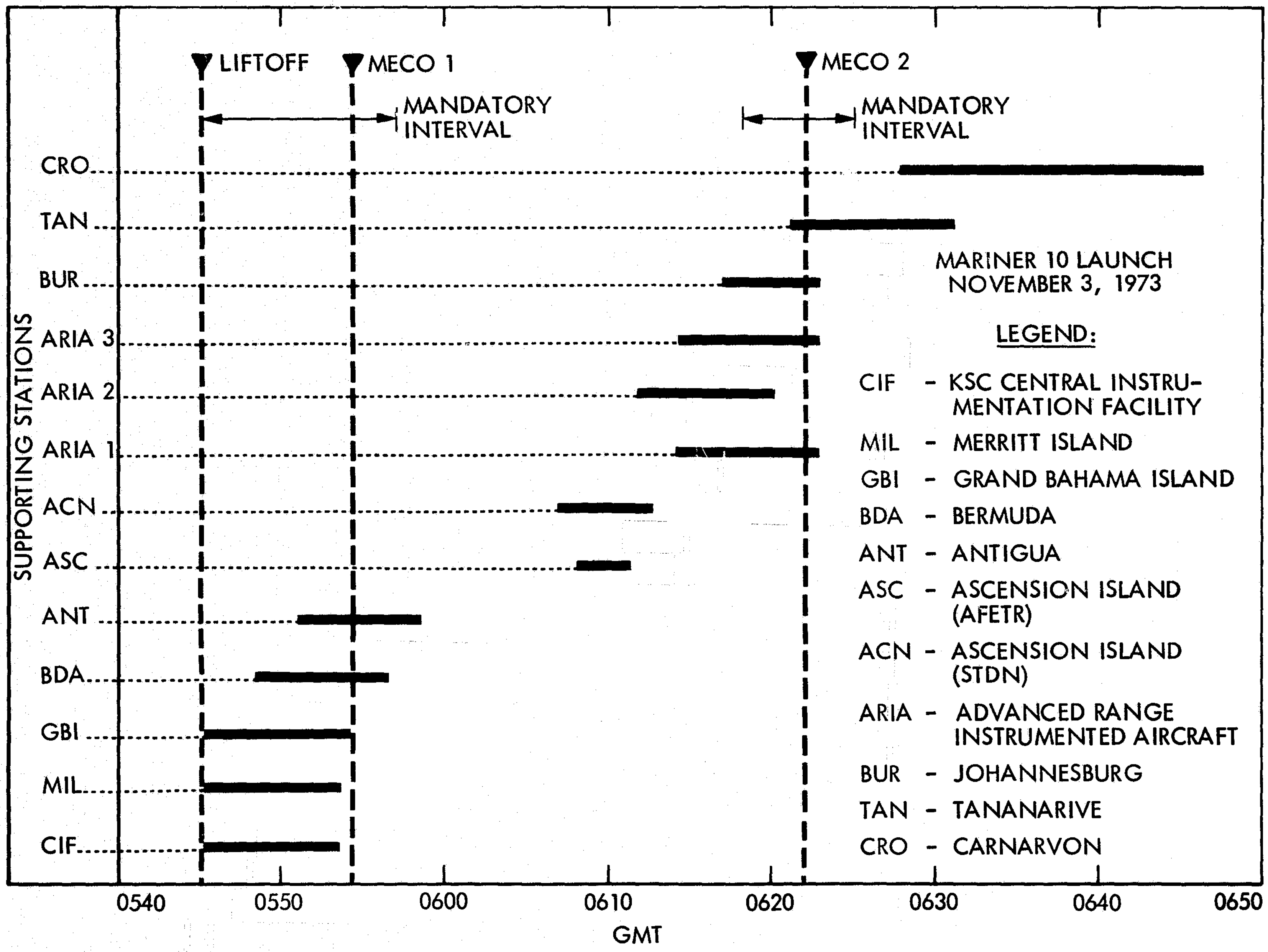


Figure 121. Centaur (AC-34) telemetry support

Centaur telemetry data was recovered at Antigua and transmitted via the AFETR sub-cable to the Kennedy Space Center Central Instrumentation Facility. The Goddard Space Flight Center stations at Bermuda, Ascension, Johannesburg, Tananarive, and Carnarvon retransmitted selected data to the Central Instrumentation Facility. At acquisition of signal, Tananarive reported trouble acquiring PCM lock, and consequently did not see the appearance of Mark 10. A delayed lock was achieved at 0623:58 GMT. The supporting aircraft received and recorded Centaur data as planned. The 10 support positions for the three aircraft used to support Atlas/Centaur telemetry recovery were as illustrated in the previous section. Aircraft 1 and 3 staged out of Johannesburg, while Aircraft 2 staged out of Capetown.

4. Spacecraft Telemetry Coverage

Figure 122 presents the actual Mariner 10 telemetry support provided by the Near-Earth Tracking and Data System with the interval of mandatory coverage indicated. Also indicated are the intervals of real-time transmission of data received at DSS 71 and retransmitted to JPL. This transmission was affected by the microwave phase mentioned in the preceding Centaur telemetry coverage paragraph both on the circuits to DSS 71 and from DSS 71 to JPL. None of the Near-Earth stations were requested to retransmit their data following the pass. As planned, real-time transmission was terminated when the spacecraft data rate changed from 33-1/3 to 2450 bps. Spacecraft telemetry data was processed and retransmitted in real-time from Kennedy Space Center, AFETR, and GSFC stations as indicated in Fig. 122. Grand Bahama and Antigua recovered spacecraft data was transmitted directly to DSS 71, which processed the data for retransmission to JPL. Data recovered by the aircraft was retransmitted via the LES-6 satellite to the AFETR telemetry station.

5. Near-Earth Performance Evaluation

Except for a brief time interval when Tananarive had problems acquiring the Centaur C-band signal, the mandatory requirements placed on the Near-Earth TDS were supported. Goddard Space Flight Center investigated the cause for late autotrack and found indications of station antenna pointing problems and antenna misalignment. A detailed report on the problem, including corrective action taken, was published by GSFC in March 1974. The AFETR Real Time Computing System accepted high-speed radio metric data from the DSN for the first time on the MVM'73 mission. This data was used as an input source for generating spacecraft orbital elements and a Venus map for the navigation team at JPL. The orbital elements and map from this data were the most accurate of the solutions available during the first four hours of the mission; see Fig. 123 for results of the early B-plane maps.

Overall telemetry support provided for the launch and early flight was considered good. Postlaunch analysis of launch vehicle data indicated that tapes provided by the range aircraft were very good. Loss of data in real-time due to circuit phase did not affect the conduct of

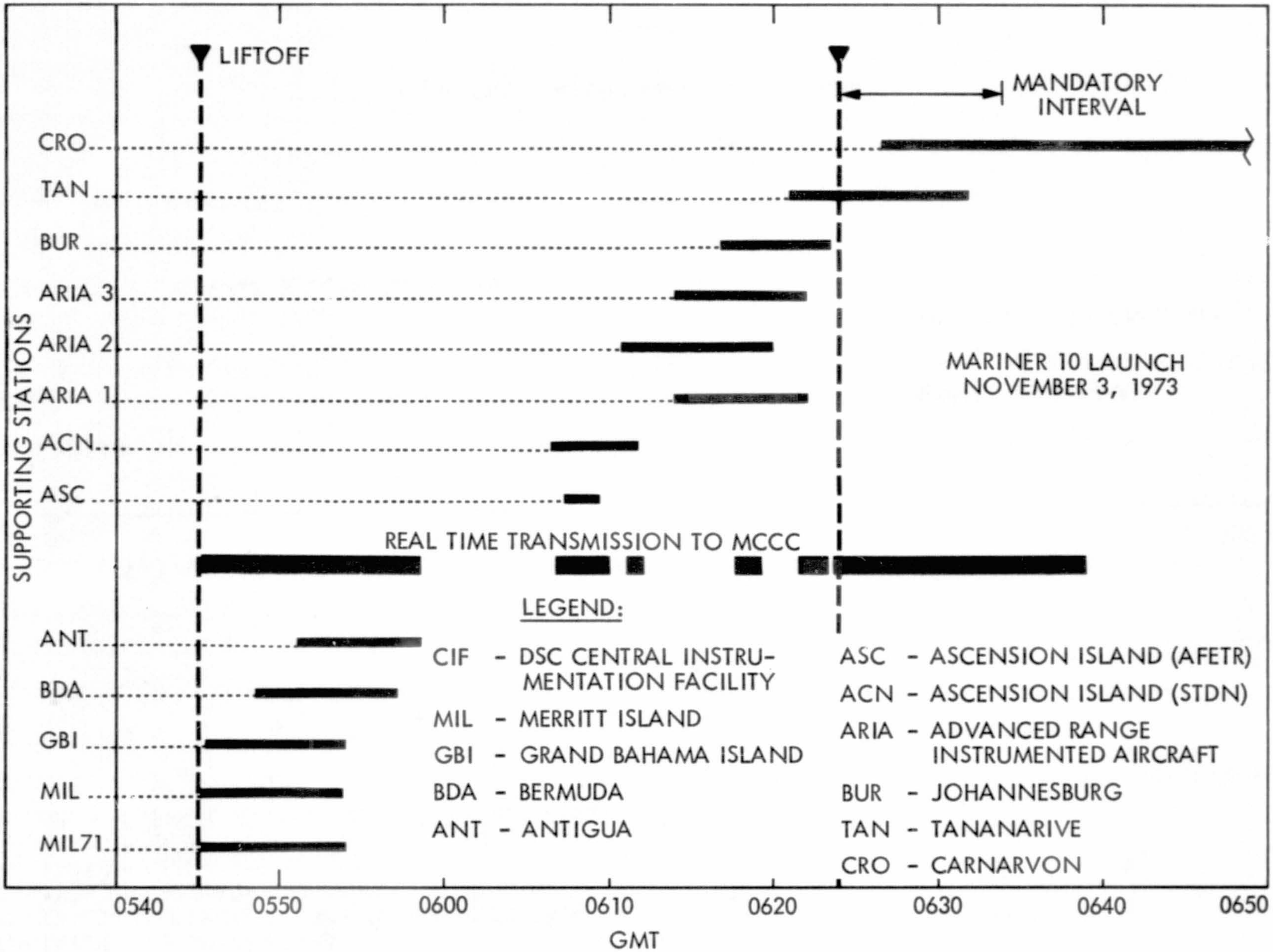


Figure 122. Mariner 10 telemetry support

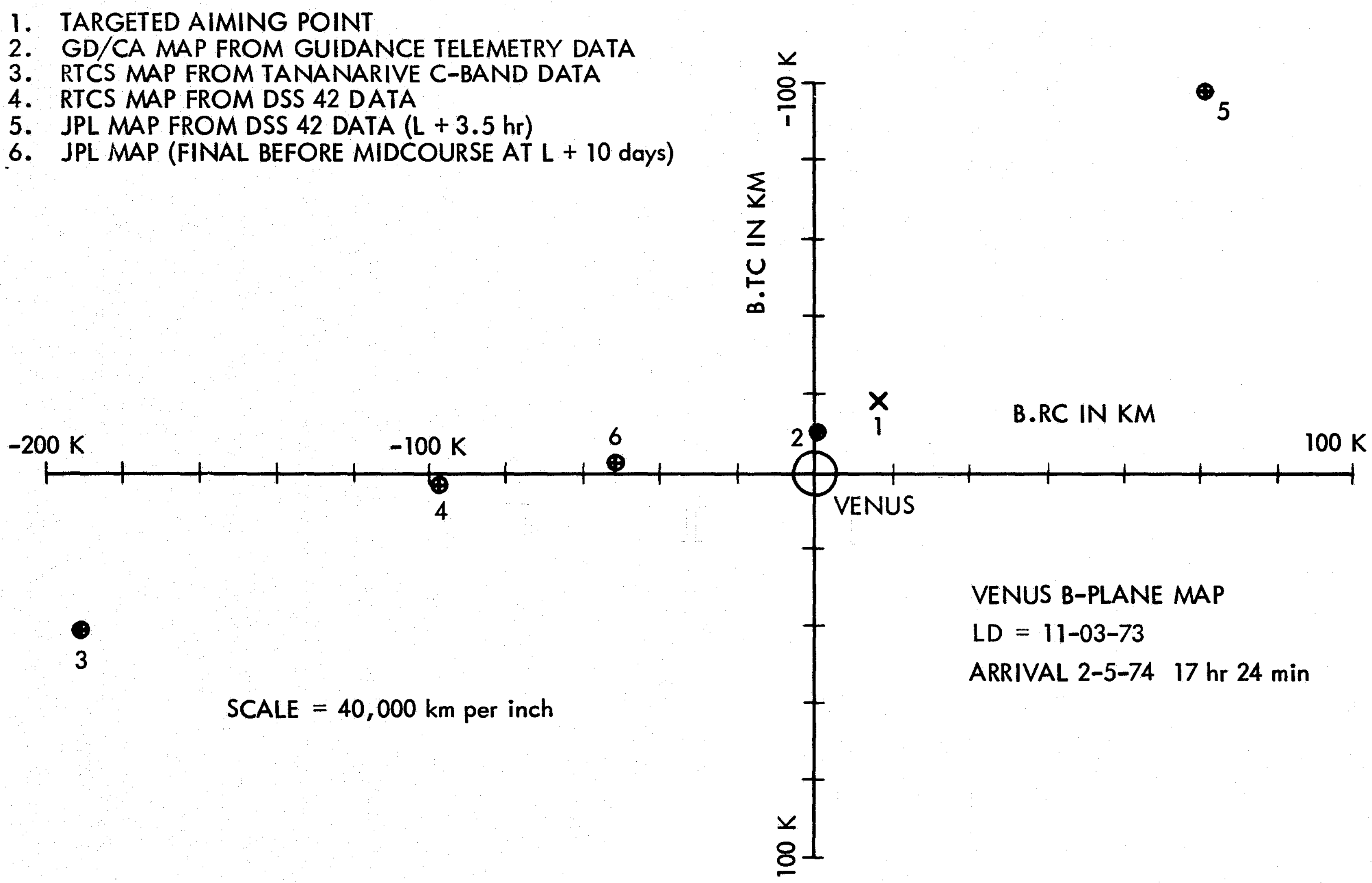


Figure 123. MVM'73 early B-Plane maps

the mission. Removal of the digital instrumentation subsystem from DSS 71 for installation elsewhere in the Deep Space Network left the station without the capability to monitor either the spacecraft serial bit stream or high-speed data blocks transmitted to JPL. The only data quality indication available on site was frame-sync detection on incoming bit streams by the automatic switching unit. During the last operational readiness test and during the launch countdown, the mission operations system reported that data in certain words was erratic and sometimes erroneous when received from Near-Earth Phase stations through telemetry string number 2 at DSS 71. Data transmitted directly through telemetry string number 1 was normal. The Near-Earth TDS did not receive a clear and concise statement of the problem, though inquiry was made. Consequently, the following independent courses of action were considered imperative to preclude recurrence of this and some of the problems on subsequent missions: (1) the mission operations system would be requested to provide a telemetry engineer to operate with the Near-Earth TDS telemetry coordinator, and (2) DSS 71 should be provided with a data quality monitor on the outgoing data blocks.

This was the first mission in which the Near-Earth TDS was to interface directly with the mission operations system rather than with the DSN. This operational interface worked satisfactorily for the metric data delivered from the Real Time Computing System to the JPL navigation team and to the reporting of countdown status. However, it was less than satisfactory for coordinating the delivery of spacecraft telemetry data in real time. Since DSS 71 is part of the DSN, its role and support in the Near-Earth TDS for the delivery of Near-Earth Phase data to the mission operations system was not properly appreciated by all members of the DSN and MOS. A suitable interface between the Near-Earth TDS and the mission operations system ground data system engineer for the prelaunch test and launch was lacking. Evaluation of the quality of data was relegated to the DSN telemetry analyst even when spacecraft team members reported the data received was invalid.

C. DEEP SPACE NETWORK OPERATIONS SUPPORT

1. General

Combinations of DSN resources described in the previus section were employed to meet MVM'73 tracking and data acquisition requirements from initial acquisition on November 3, 1973, through the end of the extended mission in March 1975. This high activity period saw the DSN struggling to meet the heavy flight support demands of the Pioneer, Helios, and MVM'73 projects as well as the high-priority, concurrent implementation for the Viking project. Although far from trouble-free, the overall support provided was regarded as excellent and was so recognized by the MVM'73 Project and by NASA program managers. The resulting wealth of scientific and precision navigation data directly reflects the professionalism and dedication of the Deep Space Network people who supported this mission.

The discussions in this section give a rather detailed coverage to the primary mission phase while the extended mission phase is generally handled in a summary fashion. The subject is treated chronologically; each major paragraph addresses an identified subphase of the mission. Table 40 provides a more detailed summary of key mission events for the entire mission, and Figs. 124 and 125 put these events on a time line and gives the associated DSN station coverage for the prime mission. This data is provided here as a general summary and as a ready reference for the discussions which follow.

2. DSN Operations Organization

The DSN Operations Chief was delegated the required authority by the DSN Operations Manager for conducting the overall direction and control of the DSN Operations and was responsible to the DSN Operations Manager for effectively exercising this authority in the discharging of his responsibilities. The DSN Operations Chief was responsible for the overall direction of DSN operations and specifically responsible for proper operation of DSN resources committed to the MVM'73 Project. In this operational capacity he acted as a single point of contact between the Project and the DSN. The DSN Operations Chief was also the controlling interface for the Network with the Mission Control and Computing Center. The DSN operations control system provided the mechanism for controlling the operations of DSN facilities and systems in support of all flight projects. Operations control was effected by the DSN mission-independent operations organization headed by the Network Operations Chief. The DSN Operations Team for MVM'73 basically was that subset of the DSN mission-independent operations organization which at any given time supported the MVM'73 Project. The organizational structure of the DSN operations team is illustrated in Fig. 126. The organization and interrelation of specific functions are illustrated in Fig. 127.

Table 40. Mission summary

Item	Date, GMT	Comment
Launch	11/3/73	05:45 GMT
Spacecraft separation	11/3/73	06:23 GMT
Sun acquisition	11/3/73	07:09 GMT
TV optic heater failure	11/3/73	PFR No. 5001
CC&S update U-0.1	11/3/73	
Vega acquisition	11/4/73	
Earth/Moon TV calibrations	11/4,5/73	Three Earth and four Moon calibrations were successful
CC&S update	11/5/73	
PSE power on and scanning	11/5/73	System normal except for SEA count, PFR No. 5007
UVS earth slews	11/6/73	
Earth/Moon TV calibrations	11/6/73	4th Earth and 5th Moon TV calibration
RCM No. 1	11/6/73	
CC&S update	11/7/73	
Pleiades star picture	11/7/73	
PSE/SEA troubleshooting	11/7/73	
CPT calibration	11/8/73	
PSE/SES turnon and low scan	11/8/73	
Partial RCM	11/9/73	
Earth/Moon TV calibration	11/9 73	5th Earth and 6th Moon TV calibration; excellent TV data obtained
CC&S update	11/10/73	

Table 40 (contd)

Item	Date, GMT	Comment
TCM No. 1	11/13/73	Manuever successful
RCM No. 2 (first POR)	11/21/73	PFR No. 5013
RCM No. 3	12/7/73	Second POR; PFR No. 5017
First indication scan platform sticking	12/18/73	Occurred during UVSAG scan, PFR No. 5019
RCM No. 4	12/19/73	No POR during 8th roll maneuver
HGA anomaly	12/25/73	Drop in RF power, thought to be in feed and temperature-dependent; PFR No. 5020
HGA healed	1/3/74	HGA feed temperature increasing
HGA failure	1/6/74	
Spacecraft switched to backup power system (POR 3)	1/8/74	PFR 5021
Kohoutek observation	1/16/74	TVS and UVA observations
TV heaters on	1/17/74	
TCM No. 2	1/21/74	Performance good
RCM No. 7 (8 rolls)	1/28/74	Oscillation at end of roll sequence
CC&S Venus encounter load	1/29/74	
Venus CA	2/5/74	
CC&S Venus FE load	2/6/74	
DSS tape recorder	2/9/74	Tape recorder stuck; PFR No. 5-23 and 5025
CC&S load	2/12/74	Enable RCM No. 8
Gyro test	2/14/74	Investigate structural oscillation

Table 40 (contd)

Item	Date, GMT	Comment
Loss of Canopus	2/18/74	Numerous bright particles are causing occasional loss of Canopus acquisition
CC&S load	2/23/74	Enable RCM No. 9
HGA healed	3/4/74	Downlink gain up 6 dB; close to predict
Spacecraft placed in roll drift mode	3/9/74	Conservation of attitude control gas
Loss of Canopus	3/11/74	Bright particle
Gyros on (POR 5)	3/16/74	
TCM No. 3 (POR 4)	3/16/74	Successful
-X solar panel	3/16/74	Differential solar panel currents; PFR 5027
First FE TV and UVS	3/23/74	Excellent data
Mercury diameter experiment	3/28/74	
CC&S in control of Mercury Encounter for 32 hr	3/28/74	
Mercury CA 90-W power increase	3/30/74	PFR 5031
XTX transmitter	3/30/74	Output dropped to 0 DN. Several days of diagnostic tests revealed XTX output erratic, PFR 5032
LGA	4/8/74	Last pyro squib operated properly. LGA to Extended Mission configuration
DSS on/off toggle	4/28/74	Possibly due to power anomaly on 3/30/74
Spacecraft perihelion	4/5/74	Closest approach to the Sun

Table 40 (contd)

Item	Date, GMT	Comment
TVs off	4/11/74	
Begin Extended Mission	4/15/74	Began routine use of DSS (tape recorder) to obtain data during DSN tracking gaps. Some DSS cycling controlled by CC&S routines. Beginning in May, tape recorder playbacks were suspended due to poor link performance as a result of increasing range to the spacecraft.
CC&S load for Extended Mission	4/16/74	
TCM No. 4A/B	5/9,10/74	TCM performed on back-to-back days due to propulsion constraints. CC&S parameters were reloaded between maneuvers.
Superior conjunction Period	5/24/74 Start 6/6/74 Conj. 7/20/74 End	Performed dual-frequency S/X-band science experiments
TCM No. 5	7/2/74	TCM provided precise navigation to Mercury-2 aim point. Last successful use of onboard tape recorder.
MAG and CPT	7/5/74	First mag calibration and flips and CPT calibration after superior conjunction. Calibrations performed on weekly basis when possible
UVSAG slip cal. and scan eng. test	7/22/74	Performed to support Mercury-2 encounter preparation
PSE/SES status check	8/5/74	Checkout of the response of the channeltrons
DSS tape failure	8/14/74	Tape recorder not slewing properly; tape motion sluggish, appeared to be stuck past parking window

Table 40 (contd)

Item	Date, GMT	Comment
Subreflector, antenna off-point, and dichroic reflector test	8/12/74	Performed in preparation for Mercury-2 encounter. Telecom/DSN preparing for antenna arraying at Goldstone during this period
Mag sensitivity check	8/19/74	Check out of mag performance degradation
DSS failed	8/29/74	DSS test performed, tape motion obtained but stuck again during test; unable to move tape again
MCCC OVT	9/9/74	Verified readiness of facility
Array test: DSS 14, 12, 13	9/11/74	Verified array concept and performance using 117.6-kbps data from the spacecraft
GDS test: DSS 14, 43	9/11/74	Checkout of the DSN stations for encounter operations
Array test: DSS 14, 12, 13	9/12/74	Further verification and performance measurement
CC&S load, U-260, EM-2 encounter sequence	9/13/74	Full load (about 500 words) of the CC&S requiring approximately 10 hr of continuous ground commanding
GDS test: DSS 63	9/15/74	Checkout of DSS 63 for 22.05-kbps sequences
TV and UVSAG on	9/16/74	Science instruments turned on
Array test: DSS 14, 12, 13	9/16/74	Final array test prior to encounter
GDS test: DSS 14	9/16/74	GDS supergroup test to validate ability to receiver 117.6 kbps in real-time at MCCC
Optical navigation	9/17/74	Perform optical navigation sequences via ground commands every 3 hr

Table 40 (contd)

Item	Date, GMT	Comment
F/E TV mosaic UVSAG	9/17/74	73 km F/E TV mosaic and UVSAG slews
Optical navigation	9/18/74	Two sets of optical navigation sequences to obtain planet/star relative geometry pictures
Real-time TV mosaics	9/18/74	Data mode 4 (117.6 kbps) with filter wheel stepping followed by UVSAG slews
Jupiter TV pictures and UVSAG slews	9/19/74	First pictures of Jupiter taken by Mariner spacecraft for TV calibration purposes followed by UVSAG slews of Mercury
TV mosaic	9/20/74	Final F/E 117.6-kbps TV mosaics prior to encounter
UVSAG step and drift	9/20,21/74	UVSAG step and drift sequence to obtain slow scans across the EM-2 hr and after closest approach from EM-2 +2 hr to EM-2 +7 hr
CC&S control	9/21/74	Begin onboard computer control of the encounter sequence
UVSAG slews	9/21/74	Performed from EM-2 -7 hr to EM-2 -7 hr and after closest approach from EM-2 +2 hr to EM-2 +7 hr
Encounter TV	9/21/74	Primary encounter pictures were obtained for EM-2 +2 hr; pictures received were of excellent quality, providing new coverage of the south pole region. The antenna array technique used for the first time during this encounter made possible the receipt of full frame pictures at acceptable bit error rates. Ranging was off during encounter. The CC&S sequence terminated at EM-2 +2 hr

Table 40 (contd)

Item	Date, GMT	Comment
UVSAG step and drift	9/22/74	UVSAG data obtained during outgoing encounter similar to the incoming sequence
TV mosaic	9/22/74	Final outgoing F/E TV mosaic to complement the corresponding incoming mosaic
Optical navigation	9/22/74	Final three optical navigation sequences followed by TV and UVSAG off
CC&S load, U-28.0	9/23/74	Onboard computer programmed for cruise functions such as HGA pointing, solar panel tilts, Canopus cone steps
Acquisition lost	10/5/74	Loss of Canopus due to particle
Acquisition lost	10/6/74	Loss of Canopus due to particle, difficulty reacquiring without using major portion of remaining A/C gas. Decision to stay in roll drift mode, thereby demonstrating practicality of this technique
CC&S load, U-28.2	10/28/74	TCM No. 6 maneuver sequence and FDS reprogramming
TCM No. 6	10/30/74	First TCM performed with rolling spacecraft; maneuver consisted of stopping at proper roll angle and performing pitch-burn-pitch CC&S controlled sequence; then return to roll drift mode
1 year in flight	11/3/74	Mariner 10 was launched 11/3/73 at 05:45 GMT
NIS-2 using LGA mag RCM NIS C/O		During spacecraft closest distance to Earth, data mode 13 was used to obtain low-rate NIS data over the LGA with the spacecraft in the roll drift mode

Table 40 (contd)

Item	Date, GMT	Comment
Aimpoint selection	12/74-1/75	Meetings were held to determine best aimpoint for science. SSG selected high north latitude darkside pass as close as possible with primary emphasis on magnetic field measurements
CC&S load, U-28.6	2/10/75	TCM No. 7 maneuver sequence loaded for another pitch-burn-pitch maneuver strategy similar to TCM No. 6
TCM No. 7 aborted	2/12/75	Uncertainties in Canopus identification made aborting mandatory
TCM No. 7	2/13/75	Executed as planned; entire maneuver sequence was retargeted and implemented by working around the clock. Spacecraft remained in roll drift mode before and after CC&S controlled maneuver.
EM-3 sequence preparation	12/74-2/74	Varying aimpoint selection created the need for developing several Mercury-3 encounter sequences. The sequence was very sensitive to pointing due to the close approach
CC&S load, U-28.8	3/6/75	Small CC&S load to perform TCM No. 8 sunline maneuver
TCM No. 8 sunline	3/7/75	Executed as planned. Performed to provide assurance of not impacting; created need for another complete iteration through sequence software
EM-3 encounter load part 1	3/8/75	Due to multiple project demands of DSN stations MVM'73 was forced to use one pass per day; consequently it was elected to uplink the encounter load in 3 parts using DSS 63

Table 40 (contd)

Item	Date, GMT	Comment
EM-3 encounter load part 2	3/9/75	
EM-3 encounter load part 3	3/10/75	
Canopus acquisition	3/3 to 3/15/75	Tremendous difficulties in acquisition are attributable to a series of problems
TV sequence and NIS checkout	3/15/75	F/E TV in edit mode was obtained. Mag and PSE C/O sequences were performed
CC&S load to tweak encounter sequence	3/15/75	Redefinition of the aimpoint from OD after performing TCM No. 8 created the need for a final restructuring of certain parts of the encounter sequence
Mercury-3 encounter	3/16/75 22:39:24 GMT	Closest approach was about 327 km above the surface. Primary objectives of obtaining critical NIS data were achieved. The highest resolution pictures of Mercury were obtained, although optimum TV data was not achieved because the TV edit mode was used because station was not able to receive Imaging 1 data at the required bit error rate
TV color mosaic and TV off	3/17/75	Outgoing F/E TV mosaic was performed with filter wheel stepping. This obtained the data required for preparing a color mosaic. Following the mosaic the TVS was turned off.
UVSAG slit calibration and astronomy	3/17/75 to to 3/20/75	The UVSAG slit was calibrated and several UVS astronomy sequences were performed with good results.
End-of-mission	3/24/75 12:21:00 GMT	Spacecraft attitude control gas was depleted. Radio subsystem was turned off using DC-55.

Table 40 (contd)

GLOSSARY OF TERMS

A/C	attitude control
CA	closest approach
CC&S	Central Computer and Sequencer
CPT	Charged particle telescope
DC	direct command
DN	data number
DSN	Deep Space Network
DSS	Deep Space Station
EM	Encounter Mercury
FE	far encounter
GDS	Ground Data System
GMT	Greenwich Mean Time
HGA	High-gain antenna
LGA	Low-gain antenna
MAG	magnetometer
MCCC	Mission Control and Computing Center
NIS	nonimaging science
OD	orbit determination
OVT	Operations Verification Test
PFR	Problem Failure Report
POR	power on reset
PSE	Plasma Science Experiment
RCDR	recorder
RCM	roll control maneuver

Table 40 (contd)

GLOSSARY OF TERMS (contd)

RF	radio frequency
TCM	trajectory correction maneuver
TV	television
UVS	ultraviolet spectrometer
UVSAG	ultraviolet spectrometer - airglow
XTX	X-band transmitter

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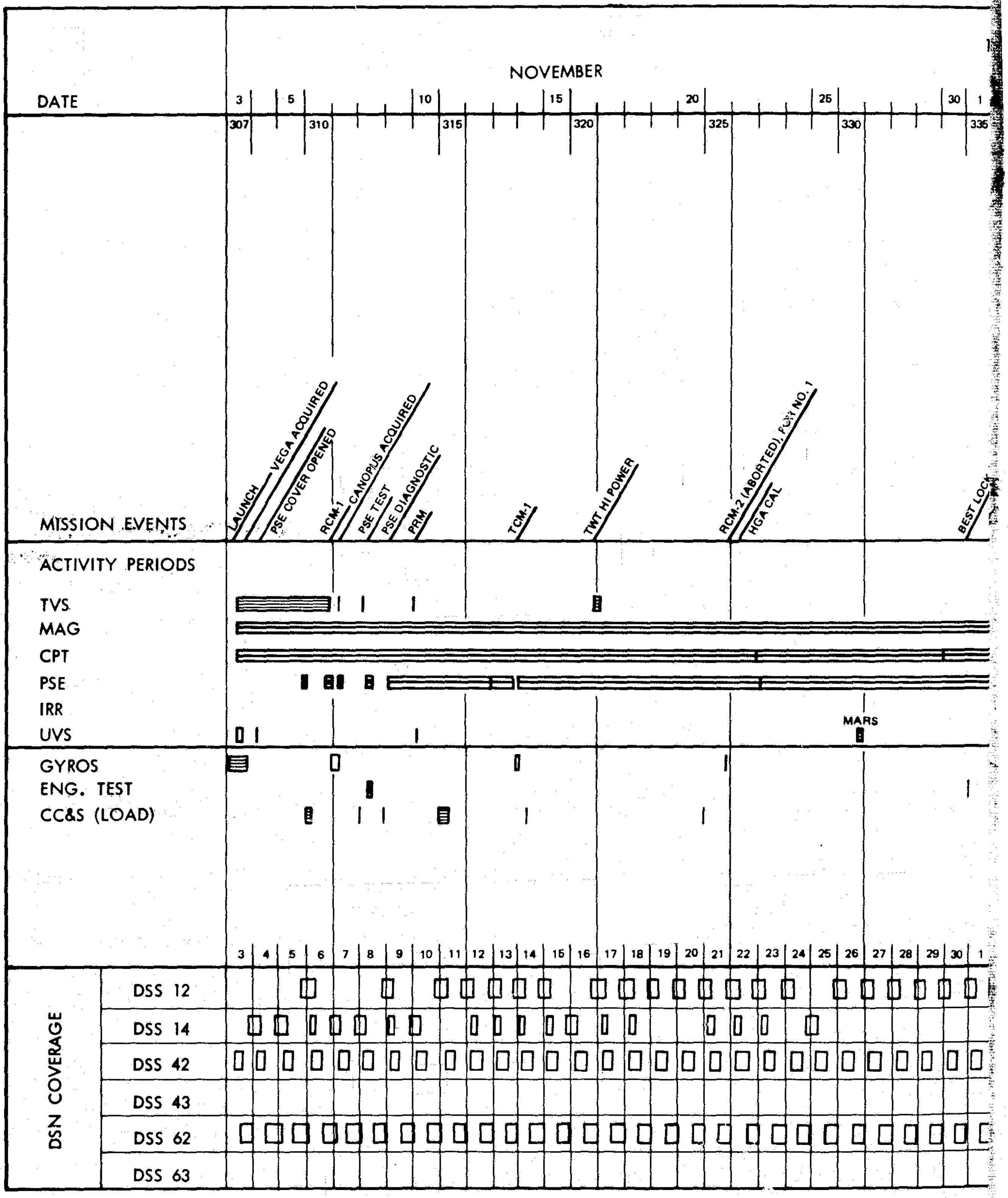

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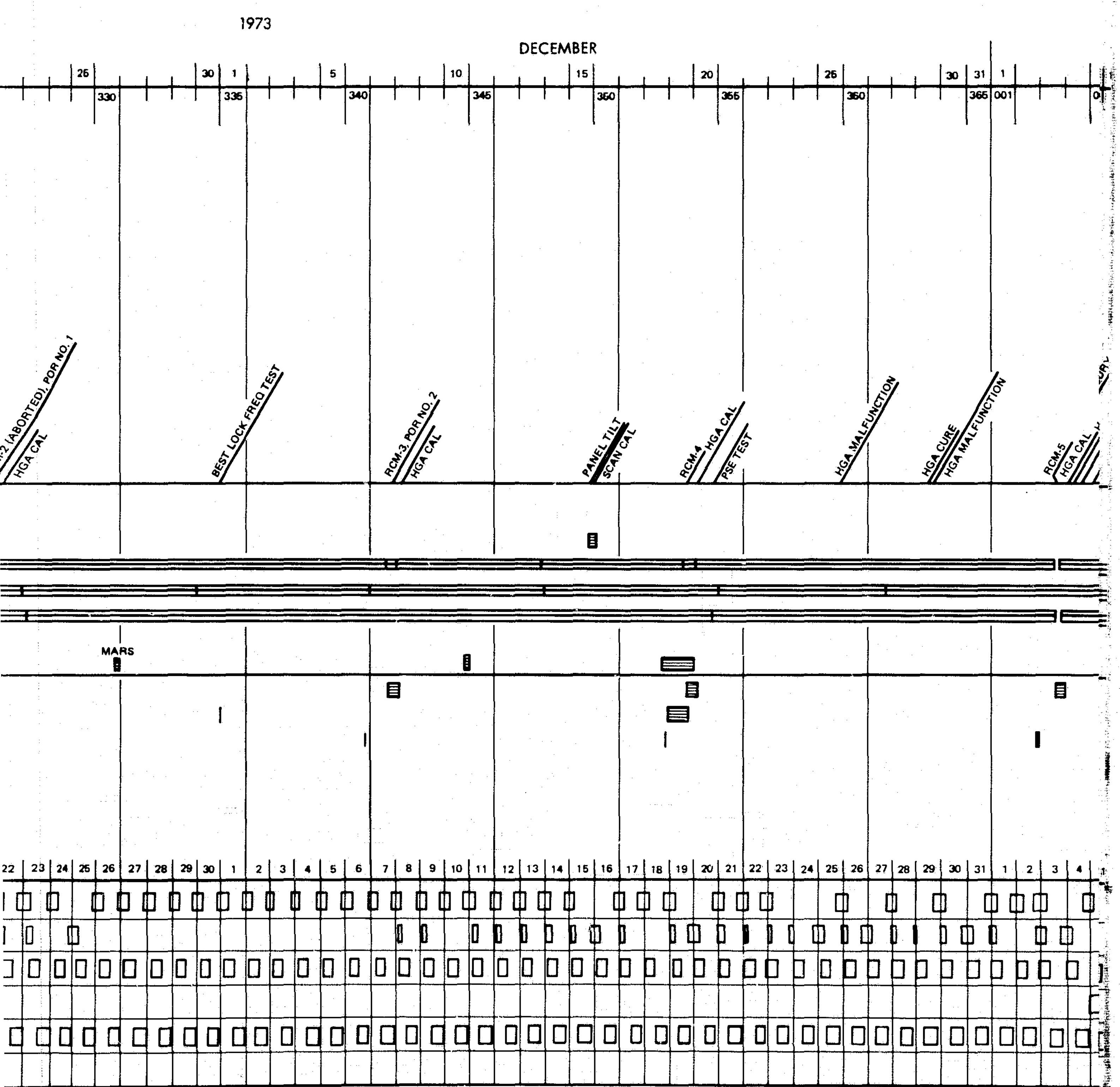

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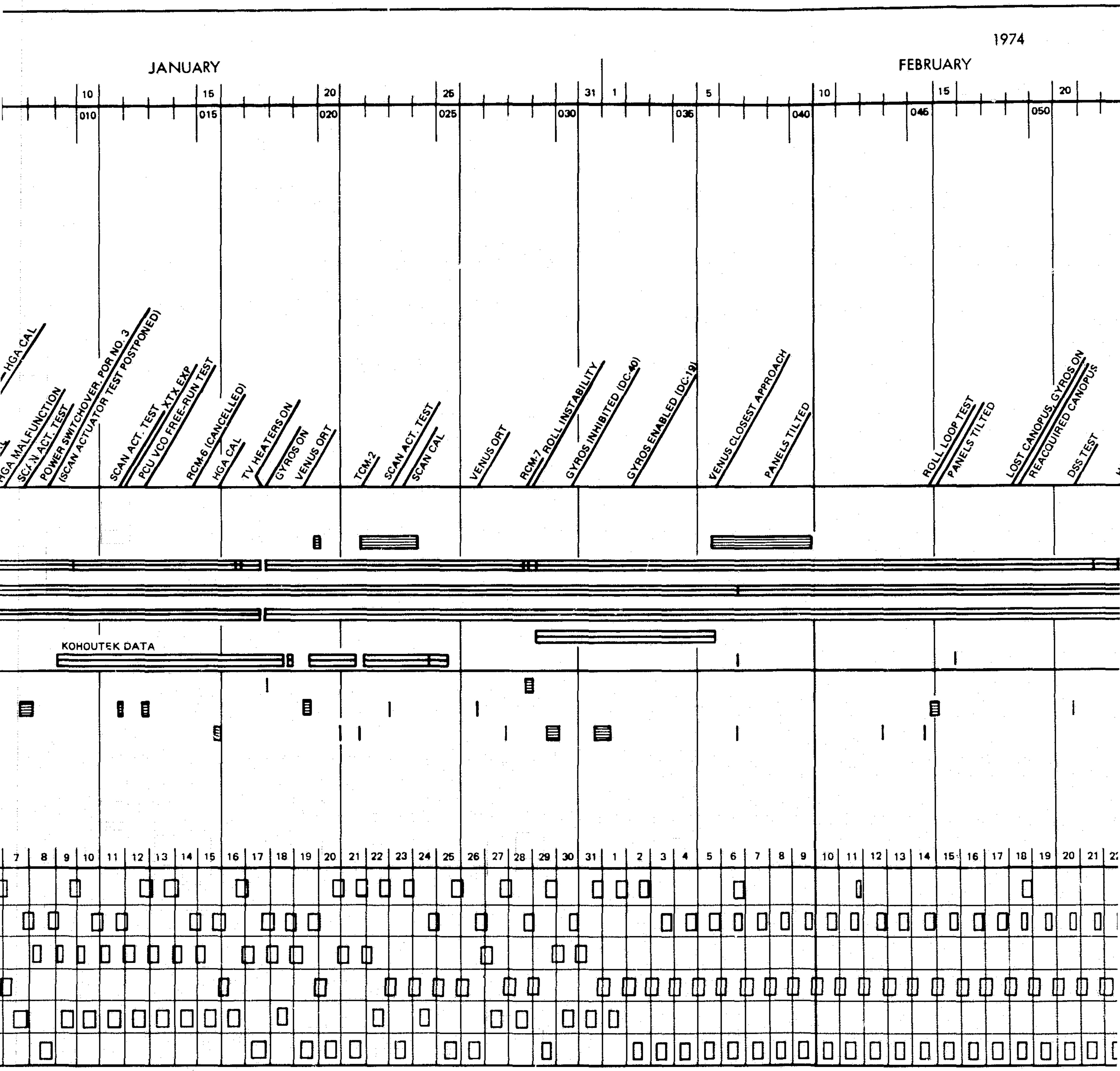

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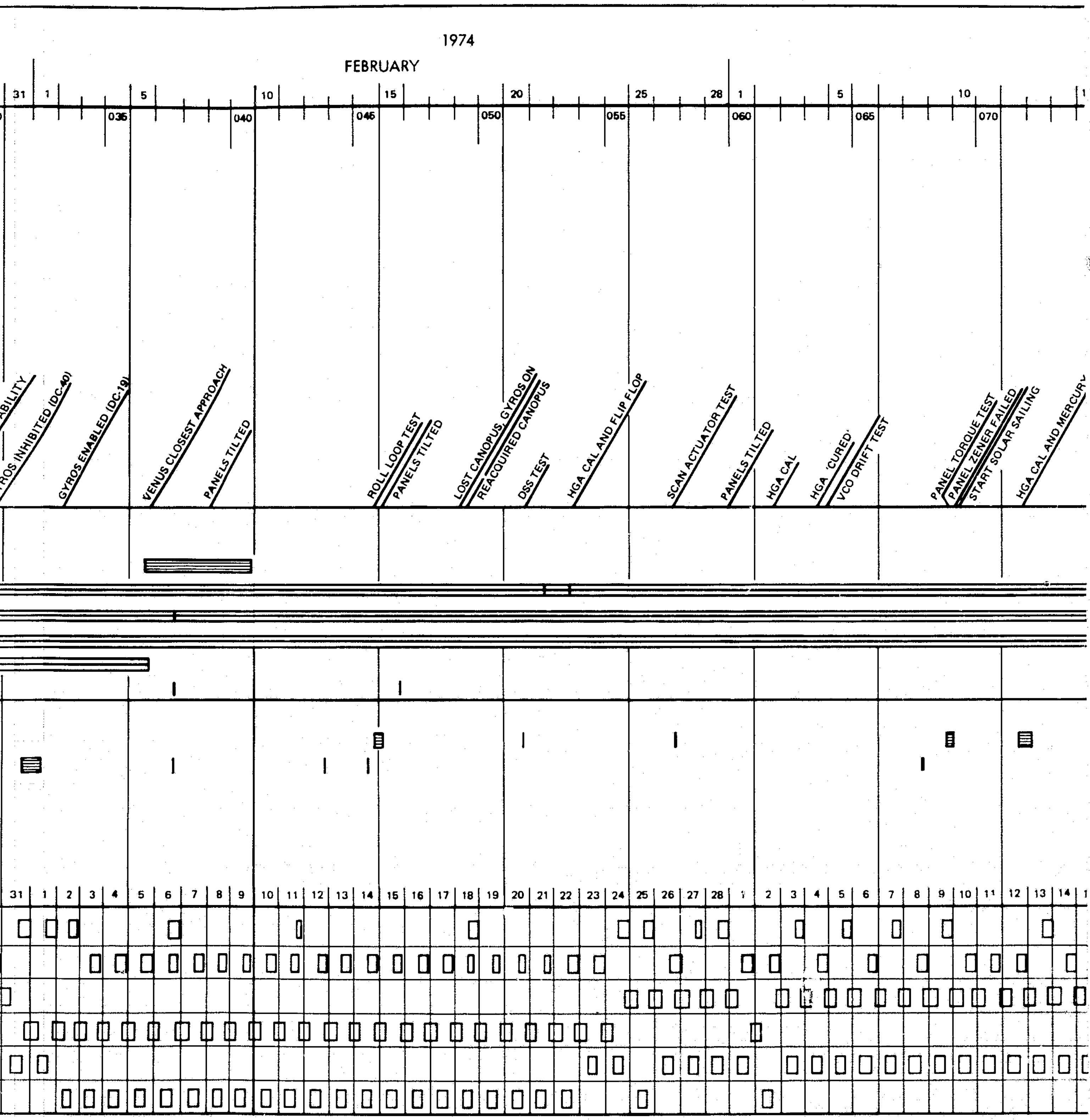

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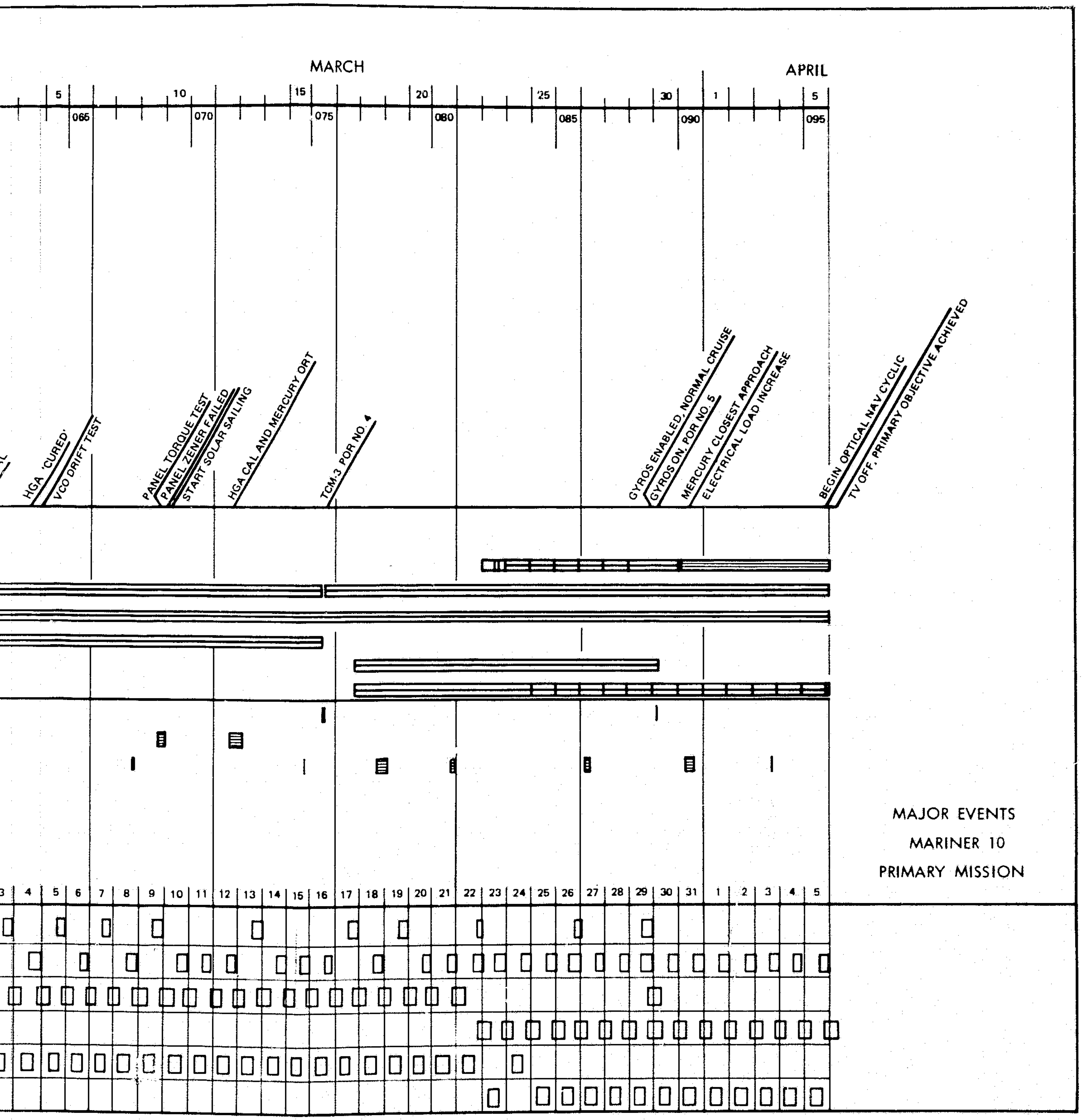

Figure 124. Major events, Mariner 10 primary mission

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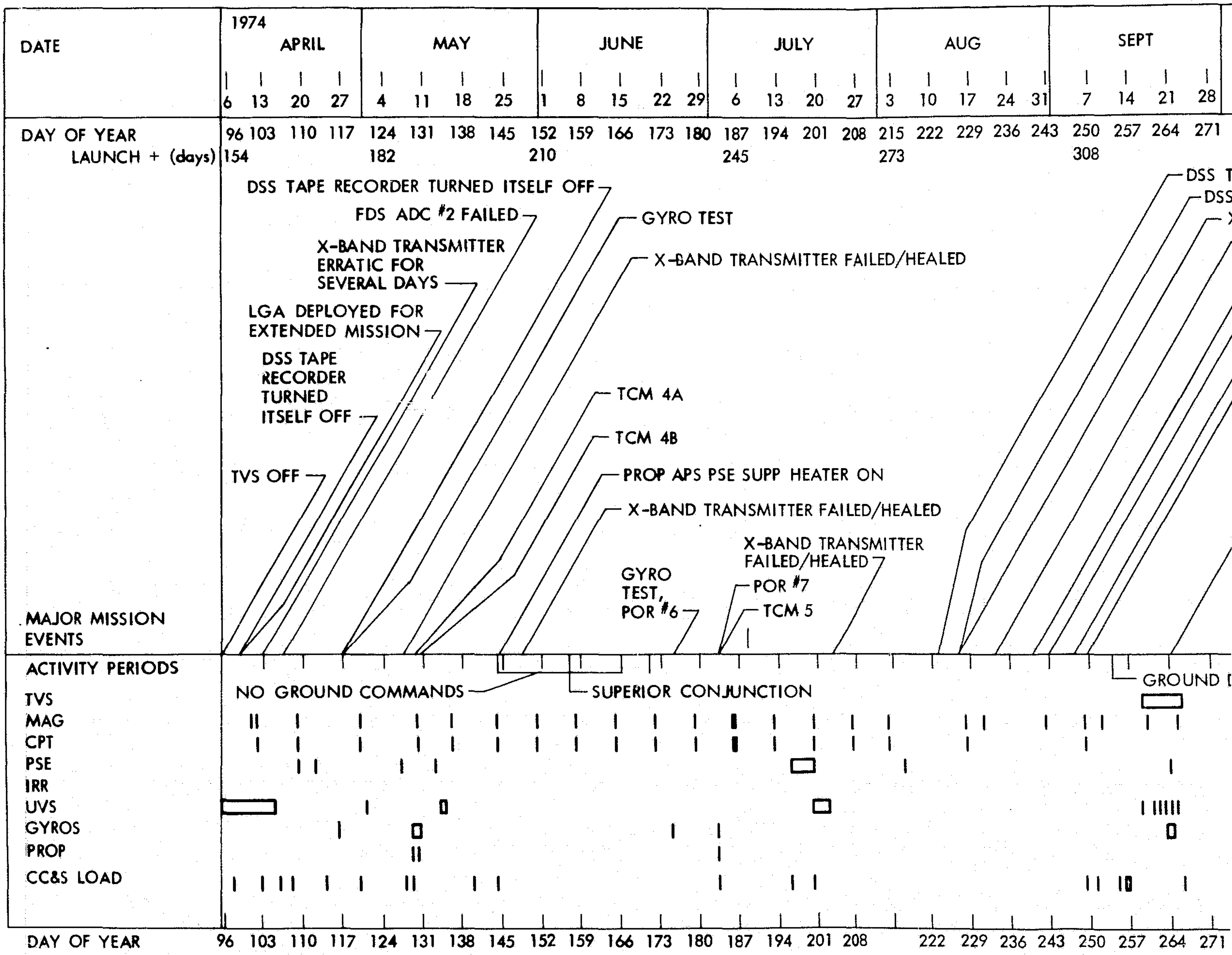

Figure 125. Major mission events time line

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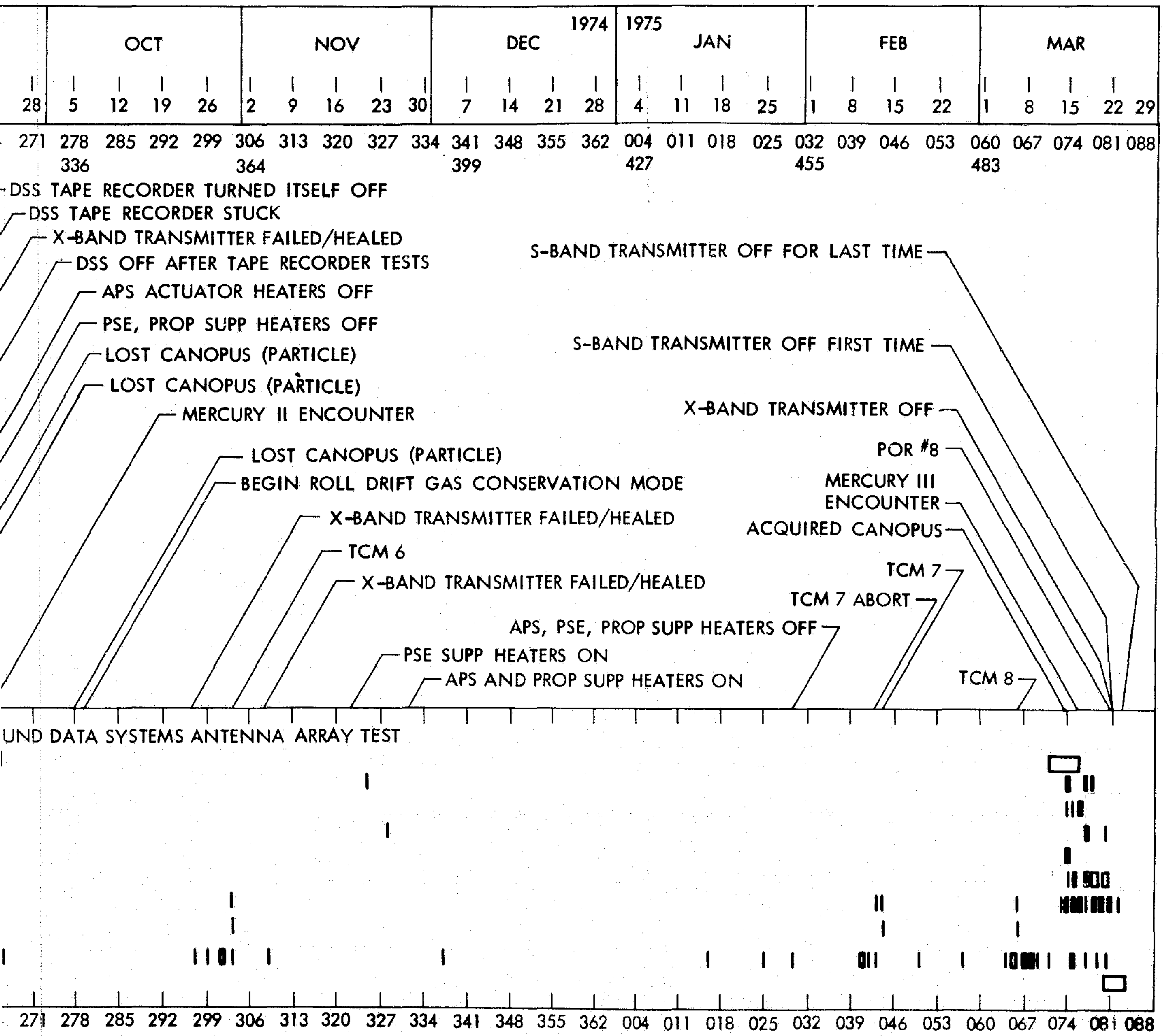

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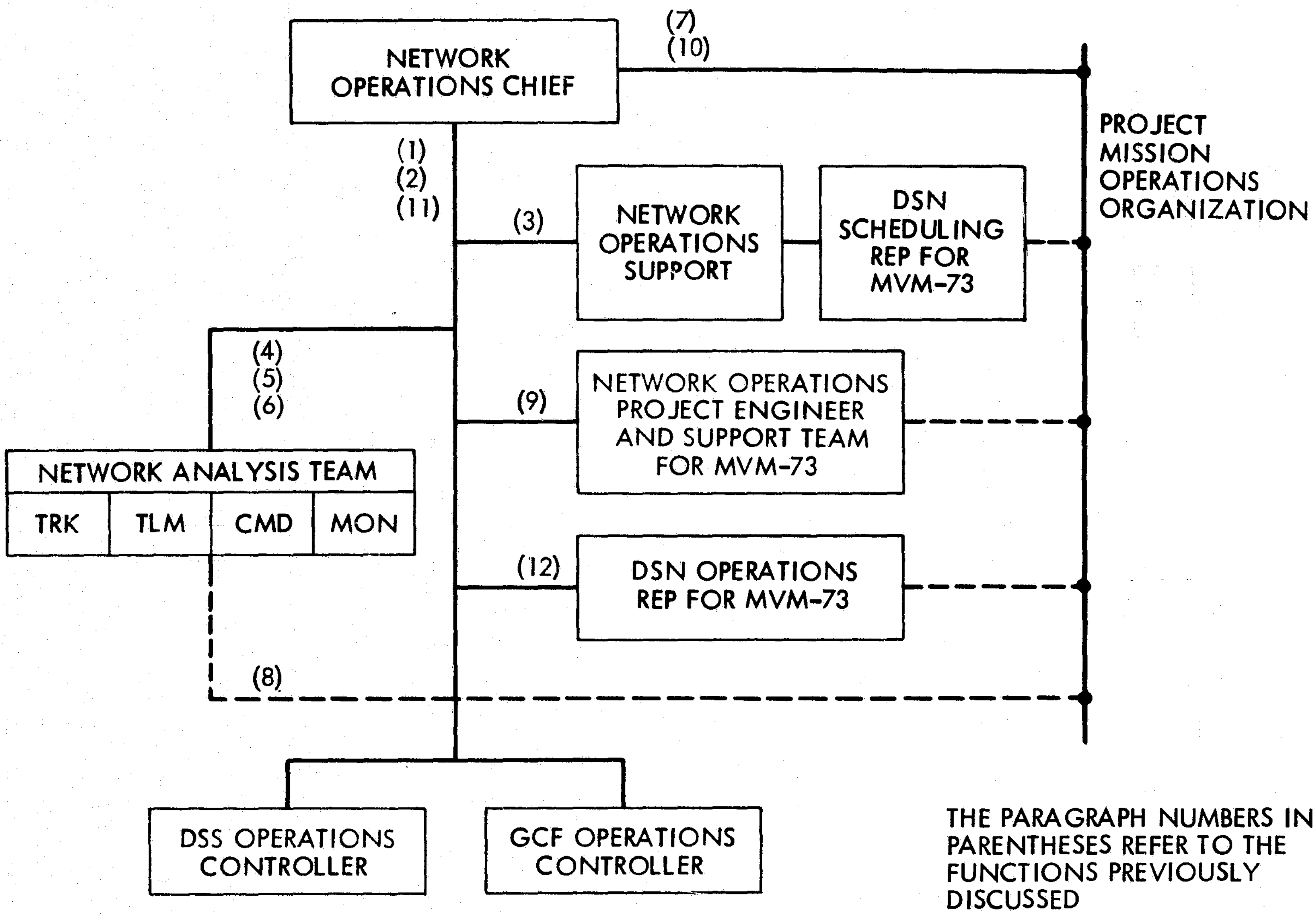


Figure 126. DSN operations team organization

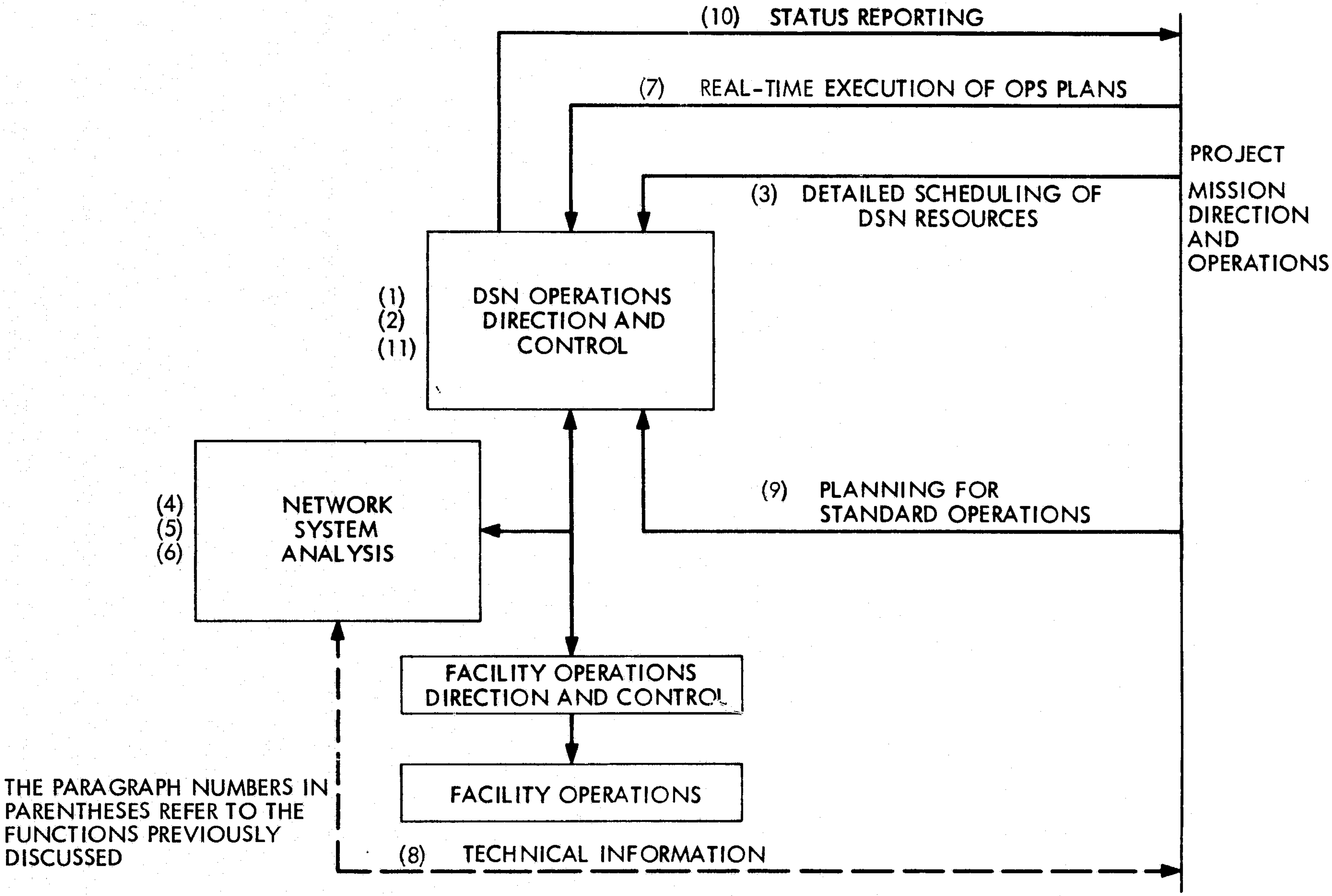


Figure 127. Organization of functions, DSN operations team

a. DSN Operations Control Team Functions. Under the direction of the DSN Operations Chief, the Operations Control Team performed the following functions:

(1) Directed and controlled the operations of committed DSN elements in accordance with the DSN Standard and Mission-Dependent Operations Plans in response to mission directions from the MVM'73 mission operations organization.

(2) Exercised DSN configuration management and control to assure the continued compatibility of the documented DSN/Project interfaces.

(3) Allocated and scheduled DSN resources for MVM'73 support in accordance with commitments, priority guidelines, and real-time requirements.

(4) Provided real-time monitoring and analysis of radio metric and telemetry data being delivered to the user.

(5) Provided real-time analysis and verification of accurate DSN handling of command data provided by the Project.

(6) Provided DSN failure detection recovery and reporting.

(7) Provided the simplified, direct, authoritative interface between the DSN operational elements and the MVM'73 Chief of Mission Operations for the execution of approved operations plans.

(8) Directed exchange of technical information between the DSN and Project mission operations teams.

(9) Planned for nonstandard or adaptive operations requiring revisions to DSN Operations Plans.

(10) Maintained and reported current operational status of DSN elements to the DSN operations system.

(11) Generated DSN sequence of events.

(12) Provided daily detailed standard planning and coordination of DSN support with the Project sequence of events.

b. Operational Roles.

(1) DSN Operations Representative. A DSN representative was appointed for the MVM'73 Project utilizing the DSN. His primary function was to represent the mission-independent DSN operations organization to (1) the Network Operations Project Engineer (NOPE) and his DSN Support

Team, and (2) the Flight Project Chief of Mission Operations and his Mission Operations Team.

Responsibilities are defined for the periods before and after formal transfer of operational responsibility from the NOPE to the DSN OC. This transfer will nominally occur approximately three months prior to launch. Responsibilities before operational transfer are as follows:

(1) Provide liaison between the NOPE and DSN Operations Chief.

(2) Act as operations advisor to the DSN Support Team.

(3) Flag conflicts between planned activities and DSN operational capabilities and assist in resolving these conflicts.

(4) Review integration schedules prepared by the Support Team and ensure that all milestones are in agreement with DSN operational implementation schedules.

(5) Interpret DSN operational philosophy, capabilities, and requirements to other DSN/TDS elements and to flight project mission operations teams.

Responsibilities after operational transfer are as follows:

(1) Act as DSN operations advisor to the Flight Project Mission Operations Team.

(2) Participate in mission operations planning meetings, flag conflicts between planned activities and DSN operational commitments, and assist in resolving these conflicts.

(3) Coordinate planned activities with the DSN operations organization and transmit necessary instruction and information to the DSN Operations Chief.

(4) Act as operations advisor to the NOPE in planning and developing support for nonstandard operations.

(5) Provide Sequence of Events (SOE) inputs necessary for flight project support, to the DSN scheduling group.

(2) <u>DSN Scheduling Representative</u>. Each major project that uses the DSN will be assigned a scheduling representative by the DSN scheduling unit. A description of the duties and responsibilities of the scheduling representative are as follows:

(1) Schedule, within the framework of the DSN Allocation System, all project activities and Project-related DSN activities from the early Network configuration testing, nominally launch minus 6 months, until the end of the operational mission, and for the duration of extended mission operations, if any.

(2) Following the completion of DSN Performance Demonstration Tests, interface with the DSN Operations Representative for all special operational scheduling requirements and for Project-related DSN Operations Control Team scheduling requirements.

(3) Interface with the supervisor of the DSN scheduling unit for overall and Project-related ground rules, priorities, and constraints.

(3) Operations Control Team.

(a) Network Operations Chief. As head of the Operations Control Team, the DSN Operations Chief directs and coordinates the activities of the Real-Time Network Analysis Team, DSS Operations Controllers, GCF Operations Controller, and Real-Time Scheduling, Discrepancy Reporting, and Network Information Control (NIC) in the real-time operation of committed resources. He coordinates the isolation of equipment or procedural problems and any required corrective or contingency actions. The DSN Operations Chief controls the real-time configuration of the DSN and resolves any conflicts in the use of DSN resources that arise during periods of operational support. He is responsible for the coordination of end-to-end systems data flow. He is also responsible for keeping the flight projects advised of DSN status.

(b) DSS Operations Controller. The DSS Operations Controller provides real-time direction and control of DSS operations. He controls committed DSS resources and the real-time configuration of DSS equipment and procedures. He also provides facility status to the DSN Operations Chief.

(c) GCF Operations Controller. The GCF Operations Controller directs and controls the operations of the GCF in real-time. He coordinates circuit requirements with NASA Communications Network (NASCOM) and controls the real-time configuration of the GCF. He also provides facility status to the DSN Operations Chief.

(d) Network Analysis Team. Members of the Network Analysis Team (NAT) provide real-time Tracking, Telemetry, Command, and Monitor Systems analysis. During low-activity periods, some analysis functions may be accomplished by the on-duty DSS Operations Controller.

The NAT responsibilities include:

(1) Analyzing the operational effectiveness of the DSN systems against prescribed limits.

(2) Informing the DSN Operations Chief of data system performance status.

(3) Isolating causes of anomalies to specific facilities.

(4) Supporting facility operations and troubleshooting.

(e) Tracking System Analyst. The real-time Tracking System Analyst (NAT Track) determines the performance of the Tracking System and recommends corrective action in case of failure or substandard performance. He is also responsible for the generation of tracking predictions and providing real-time recommendations in support of spacecraft acquisitions and tracking. He provides a real-time technical interface with the Project navigation area and Project Telecommunications Analyst.

(f) Telemetry System Analyst. The real-time Telemetry System Analyst (NAT Telemetry) determines the performance of the Telemetry System and recommends corrective action in case of failure or substandard performance. He is also responsible for providing real-time recommendations to isolate the problem in the case of any nonstandard acquisition. He provides a real-time technical interface with the Project Telecommunications Analyst. He determines real-time data outages and availability of data on the Original Data Record (ODR).

(g) Command System Analyst. The real-time Command System Analyst (NAT Command) is responsible for monitoring and analyzing the operation of the DSN Command System. He is responsible to the Network Operations Chief for defining, isolating, and recommending solutions to problems that occur in the DSN Command System. In addition to this monitoring function, the Command System Analyst generates and transmits the standards and limits, configuration, and test commands utilized at the Deep Space Stations. The Command System Analyst determines the real-time data outages and coordinates any required playback from the DSS digital ODR. He provides a real-time technical interface with the Project Command Team.

(h) Monitor System Analyst. The Monitor System Analyst (NAT Monitor) provides the capability for sensing certain characteristics of the various elements of the DSN and for processing and displaying these data for use by the Network operations personnel. Monitor data is used for determining status and configurations, for guidance in directing DSN operations, for furnishing alarms of nonstandard conditions, and for analysis of data provided to the Project.

The Monitor System Analyst is responsible for the following tasks:

(1) Maintain continuous operational control of the Monitor System.

(2) Monitor and analyze the performance of the Monitor System.

(3) Gather and validate standards and limits for all DSN systems.

(4) Maintain continuous interface with the Network Operations Chief.

(5) Perform computer input/output (I/O) functions necessary for the support of system operation.

(6) Participate in system tests and analyze results.

(7) Maintain system logs and records.

(8) Generate pass folder and transfer to NIC.

(9) Generate postpass reports.

(4) Network Operations Support. Network operations support is responsible to the DSN Operations Chief for the direction and coordination of real-time operational support functions that are performed by elements of the DSN Scheduling and Discrepancy Reporting Group. These functions include 7-day scheduling and discrepancy reporting. The information flow for preparing Network Operations Reports is illustrated in Fig. 128. The DSN Manager, Network Operations Project Engineer, and other DSN members of the support team served as advisors to the operations team during the operational phase of the mission.

3. DSN Operations Support, November 1973

For the period from November 3, 1973, to December 1, 1973, the primary support activities included DSS 42's initial acquisition of Mariner 10 following its separation from the launch vehicle, DSS 14's acquisition of 117.6-kbps telemetry data from the Earth-Moon TV calibrations during the first four days of the mission, high command activity for the postlaunch update of the spacecraft central computer and sequencer, and the first trajectory correction maneuver.

DSS 42 acquired the spacecraft signal in a one-way mode at approximately the predicted time; however, there were some difficulties in the two-way acquisition. Analysis of the events and data during the time period indicated that DSS 42 achieved two-way lock on a cross modulation product at about 3450 Hz off the main carrier frequency. There was a total delay of about 10 min and 48 sec from the time of lock on the cross-modulation product until good two-way lock was achieved.

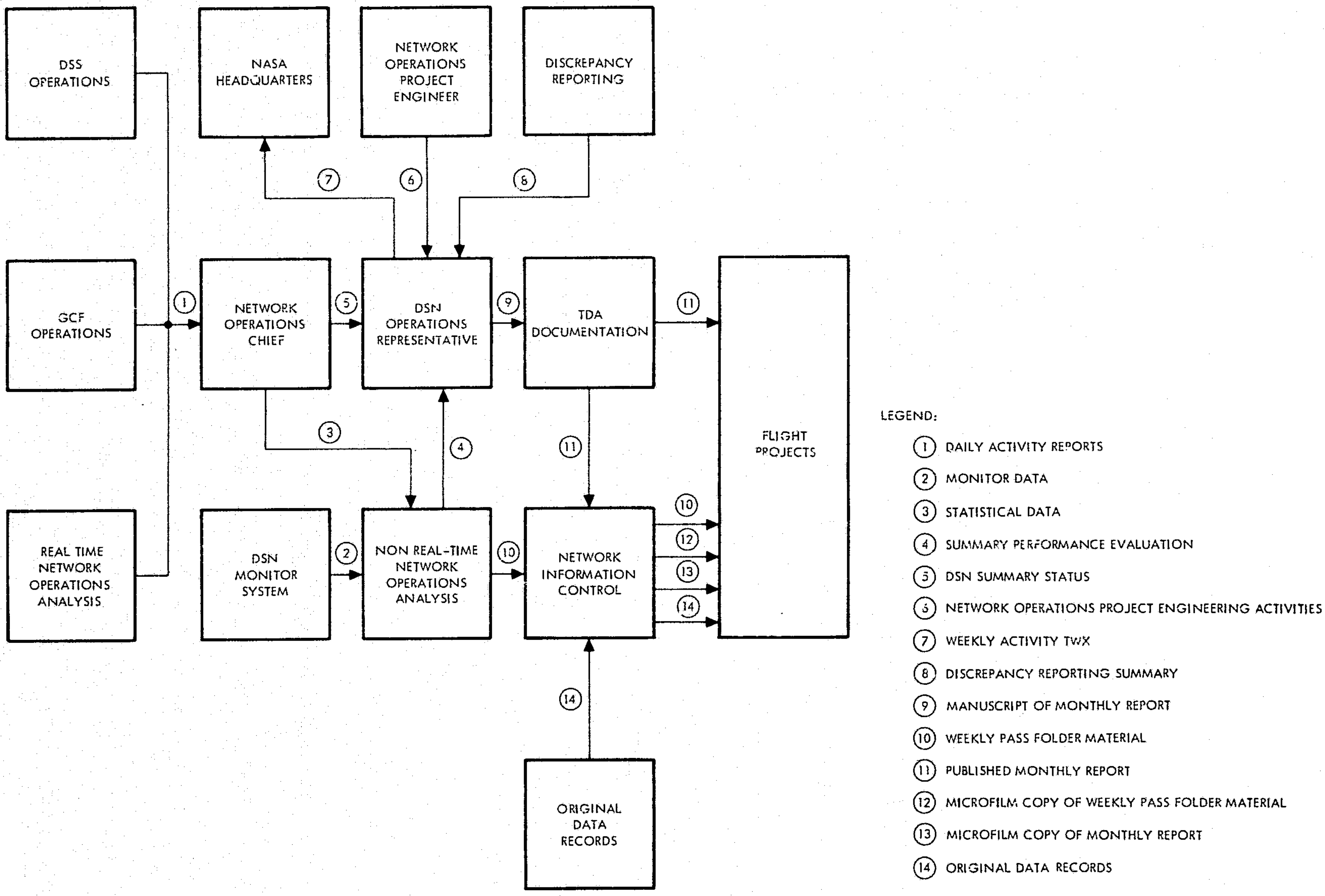


Figure 128. Information flow for DSN operational activity reporting

This delay was the result of slow detection of the problem, slow reaction, slow communication and implementation of corrective action, slow tuning, and an unavoidable delay of about 4 min, the optimum time to achieve good two-way after locking on a cross-modulation product. The results of this analysis have resulted in the development of techniques which should help avoid a similar problem in other launch situations. Nominal good two-way data was expected at launch plus 53 min 50 sec. However, actual good two-way data was achieved at launch plus 64 min 30 sec. At launch plus 53 min 42 sec, two-way lock was achieved at the S-band carrier frequency plus 3450 Hz (postlaunch testing with the actual spacecraft disclosed the existence of a cross-modulation product at 3450 Hz). Apparently, the cross-modulation product was brought into existence at launch plus 53 min 4 sec when the spacecraft went from 33-1/3 to 2450 bps. Slow detection of the off-carrier situation is illustrated in Fig. 129, and the station tuning rate is given in Fig. 130.

Table 41 directly provides some key DSN data for the November 1973 period, and other information of interest may be derived from the table. Since the format of Table 41 appears in subsequent discussions of each mission period, time is taken here to define each entry in some detail. Item 1 refers to the tracking passes provided during the stated period. From this, one can readily see the total number of Deep Space Station tracks provided, and how these tracks were allocated among the 26- and 64-m stations. However, a word of caution is needed in that all tracking passes listed were not of equal duration. Anytime a Deep Space Station acquired data from Mariner 10, a tracking pass was logged, whether the pass was of 30-min or 12-hr duration. Three tracking passes of some 9 to 10 hours each are required to produce continuous spacecraft coverage, including sufficient station overlap for transfer of uplink control and downlink acquisition. Therefore, a minimum of 28 full passes from each longitude, or a total of 84 full passes, were necessary to meet Mariner 10's requirements during this 28-day period. Table 41 shows that 95 passes were actually provided. The 28 passes from each of DSS 42 and 62 were then full passes. The total of 39 passes provided from the California longitude was then a combination of full and partial or split passes.

Item 2 of Table 41 is simply a cumulative sum of the tracking passes for the mission from initial acquisition through the date of the table. Item 3 gives the number of hours each station spent tracking Mariner 10 during the defined period. This information helps define the average tracking pass length. From this, one can see that the tracking hours provided in the California longitude were not much greater than that of Spain, although California had significantly more passes logged. The reasons for two short passes from two Deep Space Stations in the same longitude rather than one long pass from one station are significant. Each longitude has only one 64-m Deep Space Station, and the combined Mariner 10 and Pioneer 10 mission requirements exceeded that which could be provided by one 64-m antenna if support were continued to be given in a full pass mode. Fortunately, however, many requirements could be met through a foreshortened 64-m pass. Consequently, a shared-pass or split-pass technique was developed and refined during the Mariner 10 mission to help resolve the 64-m Deep Space Station

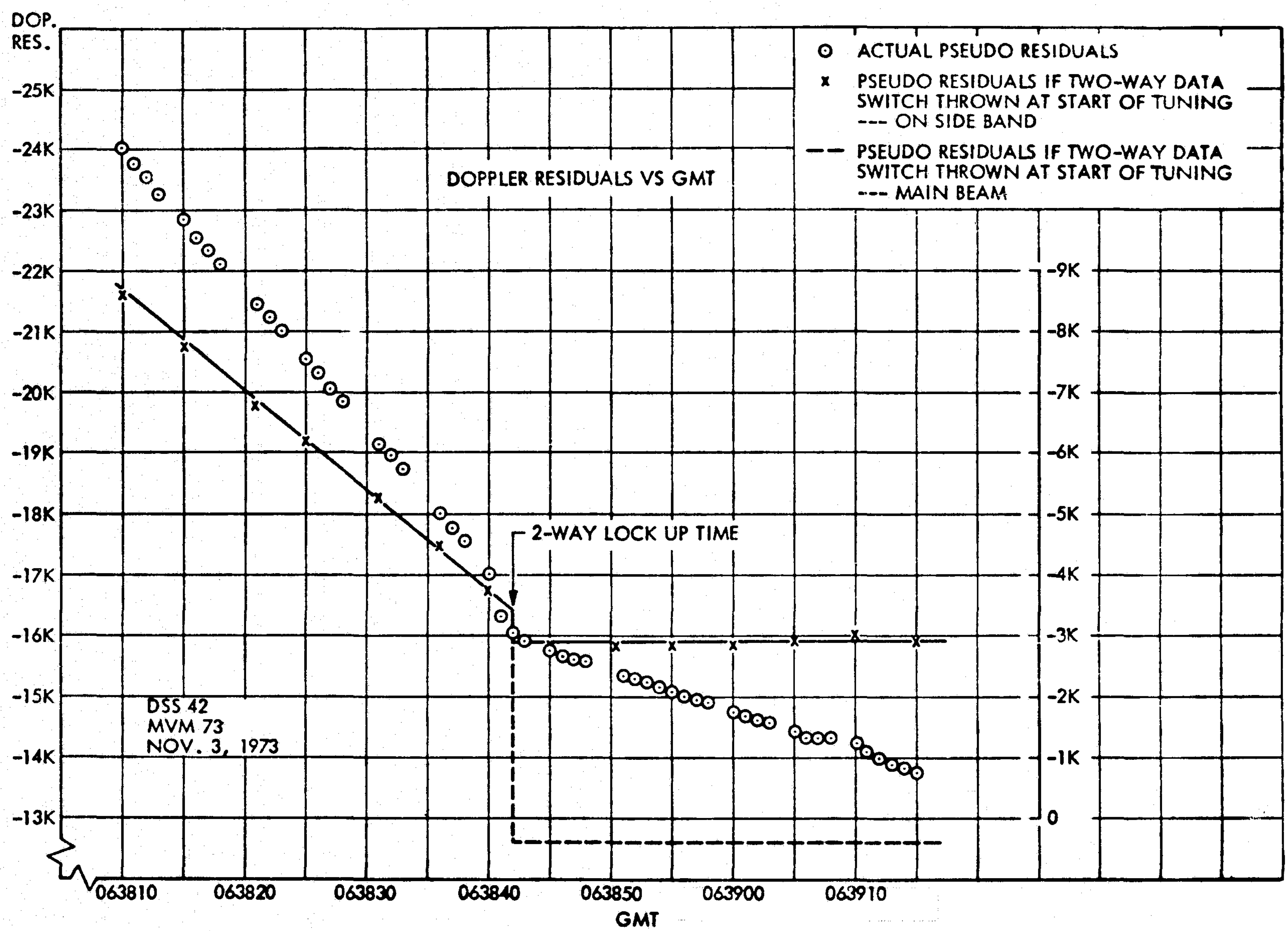


Figure 129. Slow off-carrier detection

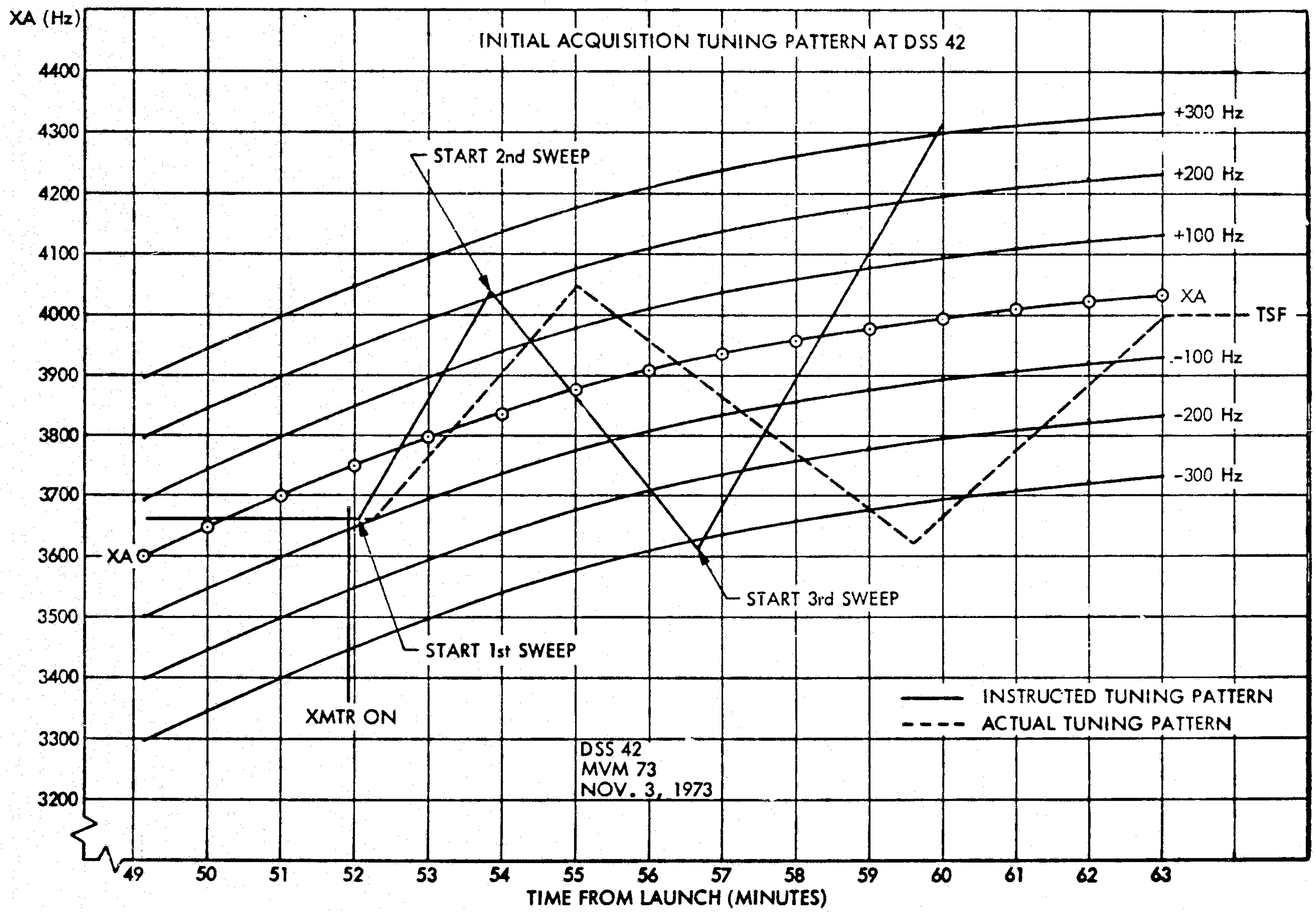


Figure 130. Slow station tuning

Table 41. DSS operations summary: November 3 - December 1, 1973

Item	California		Australia		Spain		Network totals
	DSS 12	DSS 14	DSS 42	DSS 43	DSS 62	DSS 63	
1. Tracking passes this period	20	19	28	0	28	0	95
2. Cumulative passes	20	19	28	0	28	0	95
3. Tracking hours this period	192	119	271	0	303	0	885
4. Cumulative tracking hours	192	119	271	0	303	0	885
5. Commands this period	1772	293	210	0	181	0	2456
6. Cumulative commands	1772	293	210	0	181	0	2456
7. Command aborts this period	1	0	0	0	0	0	1
8. Cumulative aborts	1	0	0	0	0	0	1

support conflicts which seemed to be ever present. Figure 131 reflects a typical Mariner 10/Pioneer 10 coverage sharing plan for DSS 14 and the resulting station transfer sequences required to accomplish the shared tracking. In this mode, Pioneer 10 would start out on DSS 14, while Mariner 10 was on DSS 12. As soon as possible after Pioneer 10 rise over DSS 43, its tracking would be transferred from DSS 14, thus allowing Mariner 10 to transfer from DSS 12 to DSS 14 for a track of some 4 or 5 hr. Operationally, the sharing mode was difficult to execute since it required rapid station reconfigurations and alterations to DSN standard practices regarding configuration control; however, it did result in satisfactory support for both flight projects. Item 4 of Table 41 gives the cumulative tracking hours for the mission through the date of the table.

Information regarding command transmission activities is given in items 5 through 8 of Table 41. Item 5 gives the number of commands sent to the spacecraft during the period; item 6 reflects the sum of commands transmitted from launch. Item 7 lists the number of commands aborted due to DSN command system problems, and item 8 maintains a running total of all aborts from launch. The one abort shown was the result of a detected error in the command bit rate. One abort in 2456 commands reflected a highly reliable command system performance which was maintained throughout the mission.

Beginning with the first California pass after launch and continuing through the first six days of the mission, DSS 14 was utilized to acquire 117.6-kbps video data during the Earth-Moon calibration sequences. This data was transmitted in real-time to the mission operations center via the configuration described in Section III. Except for a brief period during the first trajectory correction maneuver when the cruise data rate was lowered to 33-1/3 bps, all stations supported continuous acquisition of the nonimaging science and engineering data at 2450 bps. As expected in any continuous operation, the DSN experienced some problems and equipment failures; however, none had significant impact on mission operations or data recovery. During November 1973, the DSN telemetry system saw 0.43 hr of downtime in which real-time telemetry data was not delivered out of a total of 885 total tracking hours. This represented a real-time throughput in excess of 99.9% wherein the data quality was excellent.

Extensive radio metric data was generated and delivered to the Project in preparation for the first trajectory correction maneuver and for defining the spacecraft's post maneuver orbit. Ranging data from the overseas 26-m stations' Mark I-A lunar ranging device and from DSS 12's planetary ranging assembly was generally good. Doppler noise levels and residuals were well within the predicted values. The first trajectory correction maneuver was conducted on November 13, 1973, as planned. Since reorientation of the spacecraft for the maneuver precluded communications via the spacecraft high-gain antenna, DSS 14 support was required to accommodate communications via the spacecraft low-gain antenna. During the maneuver sequence, DSS 14 utilized a transmitter power of 10 kW. Figure 132 gives a plot of expected vs actual uplink AGC during the maneuver, and Fig. 133 provides the

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
NOVEMBER 1973			M	M	S M_V	M	M	S V	M	S V	S V	S M_V	S M_V	S M_V	M	S M_V	S M_V	S V	S M_V	S M_V	S M_V	S M_V	S V	M	S M_V	P	(P) (M_V)	P	P	P
DECEMBER 1973	P	P	P	P	P	(P) (M_V)	(P) (M_V)	P	P	(P) (M_V)	S	S M_V	S M_V	S M_V	M	S M_V	(S) M_R	S M_V	M	S M_V	S M_V	S M_V	(S) M_R	M	S M_V	M	S M_V	(S) M_R	S M_V	M

P = PIONEER FULL PASS

M_V = MVM'73 SHARING

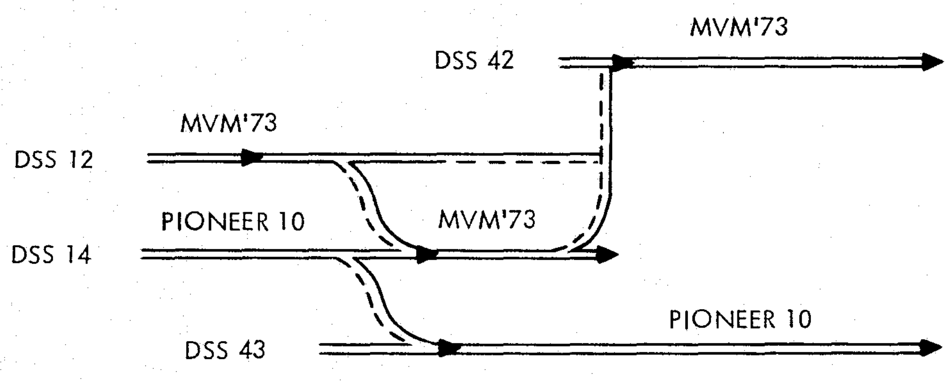
◯ = TO BE RESOLVED

M = MVM'73 FULL PASS

V = VIKING MARS RADAR SHARING

S = SHARED PASS WITH PIONEER 10

M_R = MVM'73 VENUS RADAR



TYPICAL SHARING SEQUENCE FOR A DAY

Figure 131. Pioneer 10/MVM'73 sharing plan for DSS 14

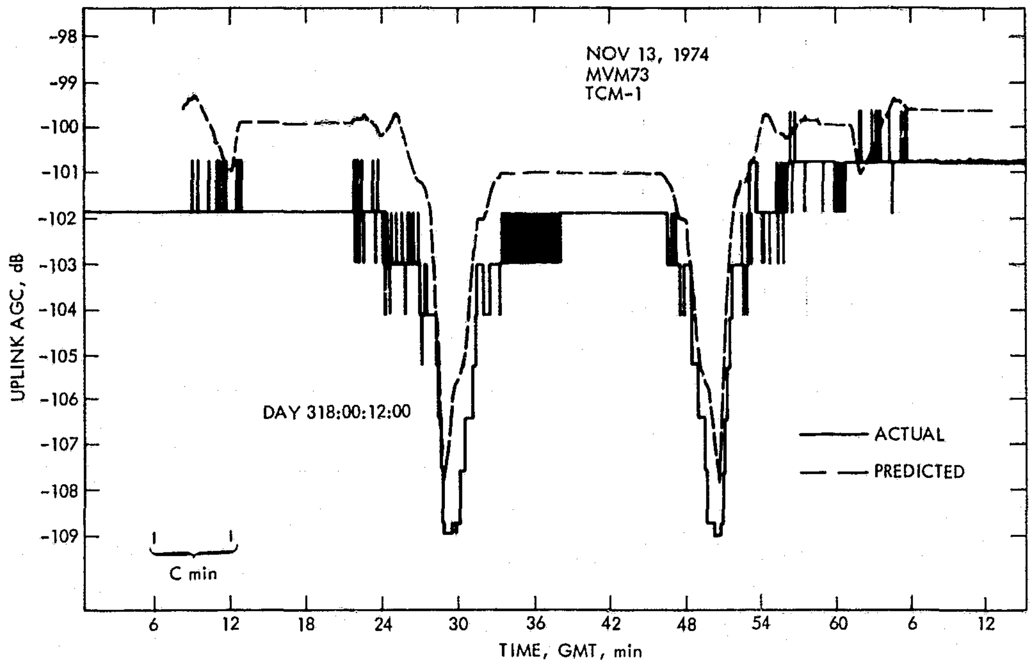


Figure 132. Uplink AGC expected vs actual

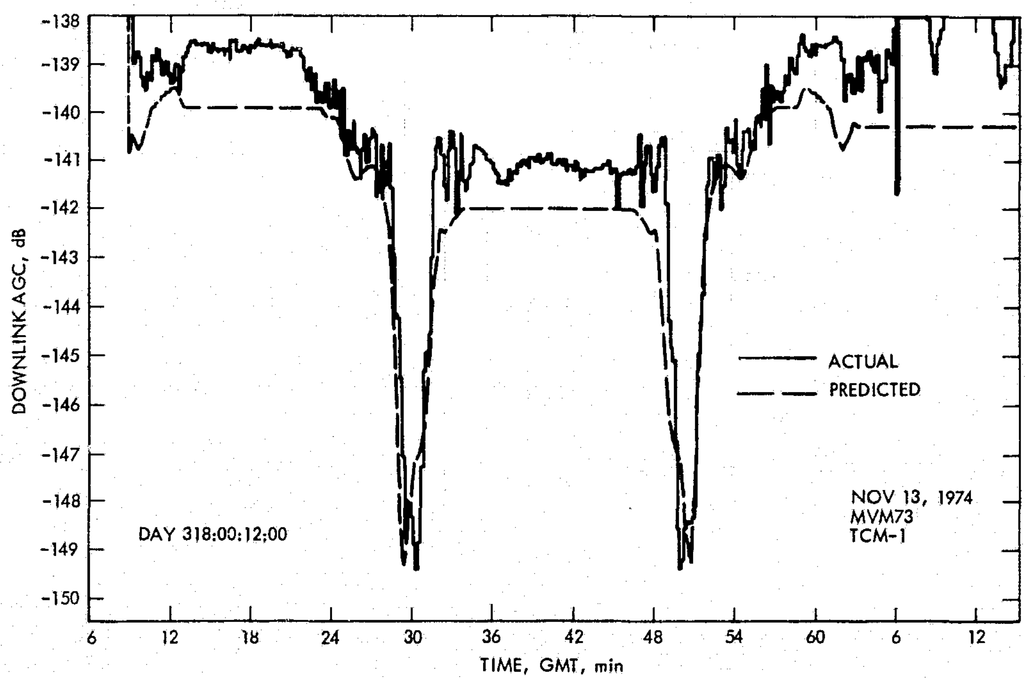


Figure 133. Downlink AGC expected vs actual

expected vs actual downlink AGC.[1] The two nulls in the curves were due to the spacecraft's pitch turn moving the Earth vector near the low-gain antenna bicone zero degree point. Actual AGC followed the predicted very closely. The larger deviations which occurred before the first roll and at the end of the unroll were due to the high-gain antenna pointing at Earth. The high-gain antenna boresight gain and the circulator switch isolation produced a higher effective radiated power along the high-gain antenna boresight than that from the low gain antenna when in the low-gain antenna transmit configuration. This produced large interferometry deviations when the spacecraft was in this mode and geometry. Downlink ST_B/N_0 was also considered a critical observable for evaluating radio link performance during the maneuvers. Figure 134 gives a plot of expected vs actual ST_B/N_0, which reflects a small deviation.

Near the end of the period, on November 21, 1973, the first spacecraft problem occurred which had an effect on DSN operations. This problem was known as a power-on reset, wherein the spacecraft power subsystem would, after apparently sensing a low voltage condition at the power bus, switch out certain power users and then reset itself. This automatic action caused the flight data subsystem to switch from its normal 2450-bps noninterplex, single-channel mode to a different data mode having the interplex configuration. Consequently, the Deep Space Stations would lose subcarrier lock, thus interrupting data acquisition. To minimize the DSN's response time and the resulting data loss during power-on resets, special procedures were developed for configuring the station subcarrier demodulators and for handling of the backup analog data records.

4. DSN Operations Support, December 1, 1973 - February 1, 1974

The primary, planned mission event for the two-month period of December 1, 1973, to February 1, 1974, was trajectory correction maneuver number 2, along with preparations for Venus encounter. However, things were not to remain that simple. In January 1974, the comet Kohoutek provided unique observation opportunities, and additional spacecraft problems required significant revisions to network support plans. The DSN was severely stressed and hard pressed to keep abreast of these changing events.

As reflected in Table 40, this period saw the continuation of power-on resets. Further, on December 25, 1973, the spacecraft high-gain antenna experienced some partial failure, resulting in a drop of observed RF power. The high-gain antenna was observed to experience a number of fail/heal/fail cycles during this period. Degradation of the downlink varied from 2 to 6 dB below the design value, and the resulting signal polarization was linear rather than the normal circular.

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[1] A significant portion of the radio link analysis data presented throughout this section was provided by the Project's Telecommunications Analysis Group of the Mission Operations Team.

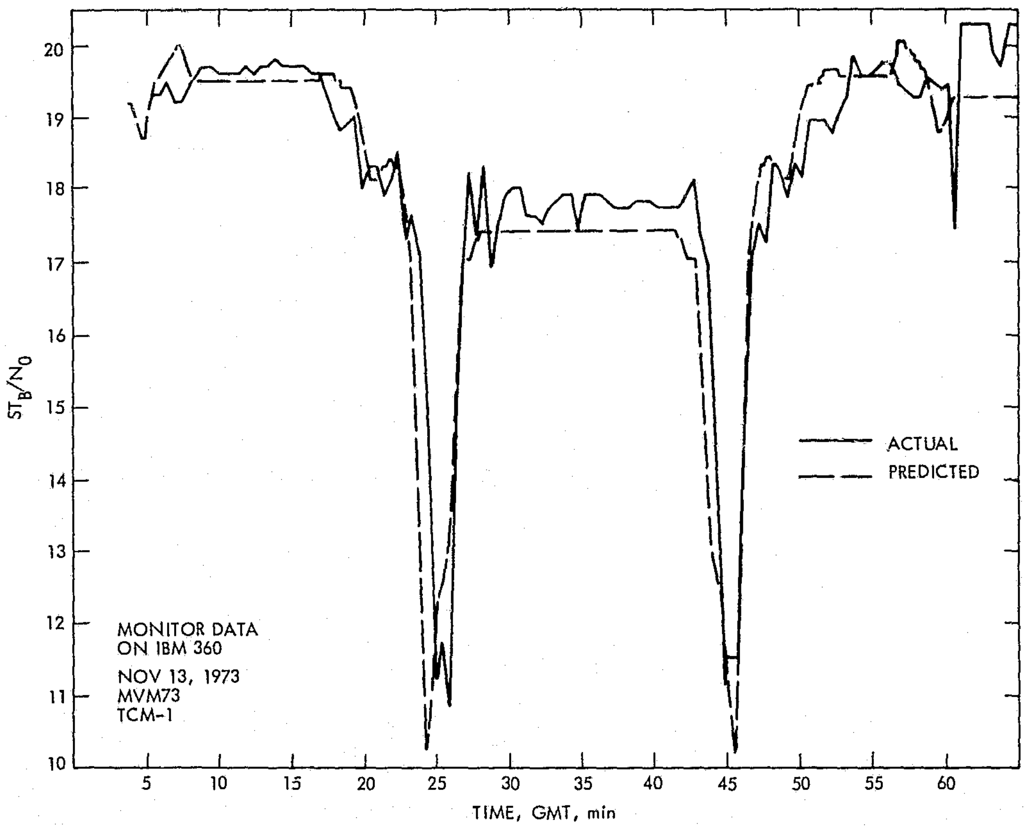

Figure 134. Downlink ST_B/N_0 expected vs actual

At this telecommunications link performance, 26-m subnet reception of 2450-bps telemetry at the required bit error rate of 1 in 10^4 or less was marginal. Approximately 3 dB of the high-gain antenna loss was attributed to the cross polarization between circular polarization of the Deep Space Station antennas and the nearly linear polarization of the spacecraft. In response to the Project's request, and to meet Mercury TV experiment objectives, the DSN initiated emergency action to provide, ship, and install linear polarization equipment at each of the three 64-m stations. This task was planned to be completed shortly before Mercury encounter. The high-gain antenna problem also precluded continued ranging support from the 26-m station lunar ranging device because system threshold had been reached. Support plans had called for this ranging capability to continue through January 1974; fortunately, implementation of the planetary ranging capability at the 64-m stations was completed at about this time and was able to accommodate ranging even with the spacecraft degraded telecommunications link performance. Doppler residuals and noise computed by the DSN through the residual program indicated that doppler data continued to be normal.

Preparations for trajectory correction maneuver number 2 were well under way in early January 1974 to support a planned mid-January burn. However, the occurrence of a spacecraft emergency on January 8, 1974, interrupted and delayed completion of the maneuver sequence. The spacecraft emergency resulted from a failure in the spacecraft's primary power chain and its automatic switch to the backup power chain. A power-on reset also occurred at the time of the power chain switchover. The effect on the DSN was a momentary receiver out-of-lock and loss of telemetry lock since the spacecraft went from 2450 bps noninterplex to 2450 bps, 22.5-kbps dual subcarrier interplex mode. Rapid action by Network operations and DSS 63 minimized the telemetry outage to about 5 min. Deep Space Station analog and digital original data records were sent to JPL to help in the analysis of this problem.

The second trajectory correction maneuver was scheduled for January 19, 1974, and then again slipped to January 21, 1974, as additional spacecraft power constraints had to be factored into the sequence. These changes required the DSN to make significant corresponding adjustments to Network plans and schedules. During one particular week, 68 real-time schedule changes were necessary to realign Network support for Mariner 10, Pioneer 10 and 11, and Earth-based Radio Science. The correction maneuver was finally executed, and excellent support was provided by DSS 12 and 14. DSS 12 support was scheduled concurrently with DSS 14 so that DSS 12 could provide uplink support while DSS 14 operated in a listen-only mode as a means of improving data acquisition capabilities. Data was received at a 33-1/3 bps rate; however, during the actual burn the spacecraft data rate was increased to 2450 bps and was recorded at the spacecraft for later playback. The 2450-bps data was below 0 db ST_B/N_0 and was not obtained in real-time; however, carrier lock was maintained. The spacecraft power problem also required that the maneuver be performed with the spacecraft TWT operating at low power with transmission via the low-gain antenna. The cone angle at the start of the maneuver was 163 deg, and at the engine burn, the attitude was 123 deg. These cone angles translated into a low-gain antenna performance uncertainty of ±2.4 and ±1.7 dB, respectively. In addition to the normal uncertainties of low power on the TWT, modulation angles, DSS receiving antenna gain, and ST_B/N_0 would produce a composite uncertainty of ± 5.3 dB at the burn attitude. The plot of actual vs predicted ST_B/N_0 in Fig. 135 shows the deviation to be -1.3 dB at 33-1/3 bps. The data plot reflects a time shift from the predicted data due to the use of a maneuver orientation prediction which was generated well in advance of the actual maneuver time.

At the end of the roll calibration maneuver on January 28, 1974, the spacecraft's roll gyro experienced some severe oscillations which resulted in excessive use of spacecraft attitude control gas. The impact of this nongravitational force on the spacecraft trajectory was uncertain, and again revisions to the DSN's tracking coverage plan were required. Additional radio metric ranging data was necessary to help determine the effects on the Venus aimpoint and the possible need for an additional correction maneuver prior to Venus encounter. None was shown to be necessary since the gas perturbations apparently moved the spacecraft toward rather than away from the desired aim point.

Concurrently with these critical events, the Project and the DSN pushed on with some planned experiments. Using DSS 14, an X-band telemetry data experiment was conducted wherein data was modulated on the uplink ranging channel. The spacecraft turned this data around much like the ranging code on the S/X-band downlink. Therefore, DSS 14 then used the Block IV receiver to acquire the S/X-band signal containing telemetry data, thus giving a measure of the X-band frequency performance for telemetry transmission. This experiment was conducted on January 11 and again on January 15, 1974.

A second experiment, called the simultaneous interference tracking technique, was conducted on December 15, 17, and 21, 1973. In this experiment, two Deep Space Stations were utilized to track the spacecraft simultaneously, with each transmitting an uplink signal, one slightly offset from the other. The resulting prime and interfering signals were detectable on the downlink such that each station had the appearance of tracking the spacecraft in a two-way mode. This technique showed significant promise for reducing current uncertainties and error sources over that of the normal three-way doppler mode.

Table 42 provides key station data for this two-month period. An increase in 64-m subnet coverage for Mariner 10 over that of the previous month is reflected, a part of which was attributed to the described spacecraft problems. However, 26-m passes still number twice that of the 64-m stations. Since only 62 full passes were required to provide continuous coverage during this two-month period, it is again seen that the split pass strategy was extensively used in the California longitude and to some extent between California and Australia. The average length of the DSS 14 passes was only about 6 hr.

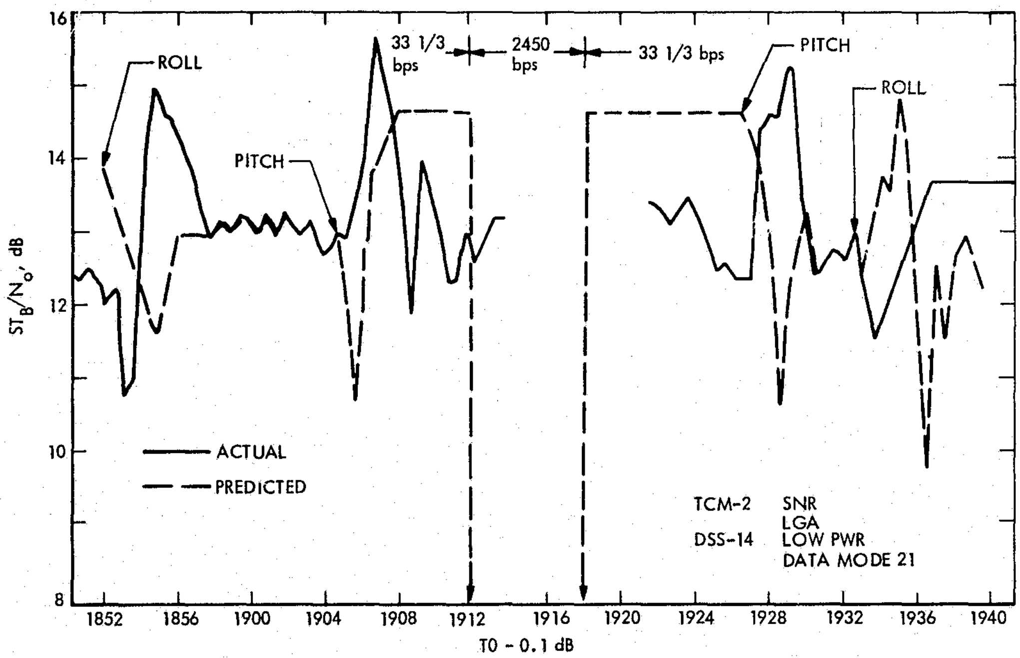

Figure 135. ST_B/N_O actual vs predicted

Table 42. DSS operations summary: December 1, 1973 - February 1, 1974

Item	California		Australia		Spain		Network totals
	DSS 12	DSS 14	DSS 42	DSS 43	DSS 62	DSS 63	
1. Tracking passes this period	41	44	59	11	48	15	218
2. Cumulative passes	61	63	87	11	76	15	313
3. Tracking hours this period	363	272	433	105	437	129	1739
4. Cumulative tracking hours	555	391	704	105	740	129	2624
5. Commands this period	1994	1304	260	167	380	109	4214
6. Cumulative commands	3766	1597	470	167	561	109	6670
7. Command aborts this period	0	4	0	0	0	0	4
8. Cumulative aborts	1	4	0	0	0	0	5

Command activity was again high, with the total exceeding 4000 command transmissions. Four command aborts, one in December 1973 and three in January 1974, all at DSS 14, raised some concern regarding the effect ongoing implementation was having on the reliability of command operations. The first abort occurred on pass 43 when the transmitter kicked off due to a heat exchanger problem; Discrepancy Report 0582 was written. On January 15, 1974, DSS 14's transmitter again failed during the CC&S update, causing a command abort on message No. 079-05. The station had no alarm indication prior to the abort. Loss of command detector lock and reacquisition resulted in a 20-min delay to the Project command sequence; DR 0639 was written. Again the transmitter failed at DSS 14 during the CC&S update on January 17, 1974, causing another abort on message 104-02. Delay of the commanding sequence extended to 29 min, and Discrepancy Report 0645 was written. On January 26, 1974, DSS 14's transmitter was turned on 20 sec late during the acquisition sequence, and the result was that the programmed oscillator control assembly started tuning at the proper time and was above XA at the transmitter turn-on. Consequently, turn-on of command modulation was also late, causing an abort of a scheduled DC-6 direct command. Commanding was delayed 28 min and Discrepancy Report 0664 was written.

To complete the heavy support load picture for this period, recognition is given to the Network's activities in planning and conducting a comprehensive set of Venus encounter readiness tests during the last half of January 1974. Both the 26- and the 64-m subnets were fully checked out. Following the tests, a DSN Venus encounter readiness review was held, and it was determined that the DSN was in a high state of readiness for the upcoming critical operations.

5. DSN Operations Support, February 1974 to Venus Encounter

Beginning February 1, 1974, DSS 14, 43, and 63 configurations were frozen for the duration of the Venus encounter operations. The encounter sequence was supported in a highly successful manner, with closest approach occurring on February 5, 1974. Table 43 provides a detailed list of encounter activities which were of interest of the DSN. Table 44 summarizes key Deep Space Station tracking and command activities. The total of 106 passes for Mariner 10 saw increasing use of the 64-m subnet as planned during encounter. In this case, more than two-thirds of the passes provided were from the 64-m subnet. Command activity was moderate, with one abort occurring at DSS 12 due to a transmitter-off alarm. No transmitter failure was involved, however. Rather the exciter loop short button had been accidently bumped, causing the problem.

During the February 1974 period, the DSN Telemetry System experienced some 1.78 hr of total downtime, which resulted in a real-time loss of data giving a reliability of 99.81%. Data lost in real-time was subsequently recovered from backup data records. Analysis of Mariner 10 downlink residuals consisted of some 90 observations, with a mean of 0.7 dB, a variance of 0.3 dB, and a standard deviation of 0.5 dB. Of these values, 70% had variations of less than 1 dB from predicted, and 24% had variations of less than 0.3 dB from predicted. The statistical "mode," i.e., the most often observed value, was found in the decile representing 0.4 to 0.5 dB. DSN analysis of Mariner 10 signal-to-noise ratio residuals consisted of 90 observations with a mean of 0.9 dB and a variance of 0.5 dB, and a standard deviation of 0.7 dB. Of these values, 57% had variations of less than 1 dB from predicted, and 16% had variations of less than 0.3 dB from predicted. The statistical "mode," i.e., the most often observed values, was found in the decile representing 0.7 to 0.8 dB. Downlink AGC and SNR residuals for this critical period are shown in Figs. 136 through 141.

The DSS 14 to JPL Supergroup Communications channel worked exceptionally well in handling the real-time transmission of 117.6-kbps video telemetry data. However, the "cheap and dirty" nature of this communications link posed some problems for DSN Operations during prepass checkout. Unfamiliarity with the Project-provided word formatter assembly at DSS 14 and the inability to monitor the serial data stream at various points in the circuit made problem isolation difficult. These problems should be considered in the design of high-rate data circuits for future missions.

The prime telemetry mode at Venus encounter was the dual-channel 117.6-kbps/2450-bps configuration. The high-rate channel was used for imaging and the low-rate was the timed multiplex of nonimaging science and engineering modulation interplexed with the high-rate data. A detailed comparison was made of uplink AGC, downlink AGC, and low-rate signal-to-noise ratio. One should remember that, at this stage of the mission, the high-gain antenna was still in a failed condition, and after careful in-flight measurements, the Venus encounter low-rate data was compared with preflight test data showing the high-gain antenna performance having a degradation of 3.9 dB. Figures 142 through 150 show the results of these comparisons at DSS 14 on the day of Venus encounter. Tables 45 and 46 list the deviations for all stations.

Table 43. Venus encounter sequence of events

Time, GMT	Activity
Day 36 2/5/74	
16:21	Start Venus TV (dark limb). Picture every 42 sec
16:49	First TV picture showing lighted portion of planet (twilight cusp)
17:04	Closest approach to Venus: 5792 km (3600 miles). Range to Earth: 45 million km (28 million miles). Venus' disc is about 75% illuminated
17:09	Enter occultation. Slew high-gain antenna in "tear drop" pattern to track planet limb (radio science data). Record 36 TV frames and other science on tape recorder No "real-time" TV
17:30	Exit occultation. Resume real-time high-rate TV
18:08	Helium scan of planet by ultraviolet spectrometer (UVS) (about 7 min)
18:20	Start planet strip photography, 163 frames in six strips. Average resolution one kilometer
19:00	Turn off infrared radiometer (IRR)
20:15	Ultraviolet spectrometer airglow scan of Venus for hydrogen. About 12 min
20:25	Start TV mosaic, 238 frames (UV filters), average resolution: 3 km
21:30	Transfer tracking from Goldstone to Canberra. End JPL receive pictures at 42-sec intervals. Begins 3-3/4 min intervals. (Spacecraft to Earth data rate remains at 117 kbps, but station to JPL relay at 22 kbps)
23:06	Second UVS airglow hydrogen experiment. About 6 min
23:12	Start TV mosaic, 180 frames (UV filters), average resolution: 4-1/2 km
01:20	Start full planet TV mosaic (UVs and orange filters), 169 frames, average resolution: 5.7 km

Table 43 (contd)

Time, GMT	Activity
03:16	Start full planet TV mosaic (UV and UV polarizing filters), 169 frames, average resolution: 7 km
05:15	Start full planet TV mosaic, 169 frames (UV and orange filters), average resolution: 8 km
00:00	Transfer tracking station from Canberra to Madrid. Pictures obtained to this point: approximately 1200. Of the total, about 470 received at Goldstone and transmitted directly to JPL; 700 received at Canberra, 150 of which relayed to JPL via wideband data lines; 36 frames stored on spacecraft tape recorder.
Day 37 2/6/74	
19:15	Madrid tracking. Start TV mosaic, 64 frames (UV and UV polarizing filters) average resolution: 8.9 km
08:00	TV mosaic, 64 frames, UV and orange, 9.3 km resolution
08:45	TV mosaic, 64 frames, UV and UV polarizing, 9.7 km resolution
09:30	TV mosaic, 64 frames, UV and blue filters, 10.2 km resolution
10:15	TV mosaic, 64 frames, UV and orange, 10.7 km resolution
11:00	TV mosaic, 64 frames, UV and minus UV filters, 11.2 km resolution
11:40	TV mosaic, 64 frames, UV and UV polarizing, 11.6 km resolution
12:25	TV mosaic, 36 frames, UV and blue, 12 km resolution
12:50	TV mosaic, 36 frames, UV and orange, 12.3 km resolution
13:15	Conclude Venus near-encounter TV. Pictures obtained to this point: approximately 1740. Of the total, about 710 relayed to JPL from all three tracking stations; about 1000 recorded on magnetic tape at Canberra and Madrid; 36 recorded on board Mariner

Table 43 (contd)

Time, GMT	Activity
13:20	Playback 36 TV frames and other science data recorded on spacecraft 20 hr earlier. Readout time: 2 hr, 17 min. (Spacecraft computer was updated during this period for execution of 16 days of far encounter TV.)
14:45	Transfer tracking Madrid to Goldstone
15:40	Real-time TV, one picture every 42 sec, about 40 frames
16:20	Start second playback of encounter tape from spacecraft. Readout time: 2 hr, 17 min
16:50	Charged particle telescope calibration 20 minutes.
17:01	Venus encounter plus one day. picture count: approximately 1800, 800 of which received in real-time at JPL
18:20	First of 10 daily Ultraviolet Spectrometer far encounter scans. 20 min
18:40	Complete second playback of Venus near encounter taped TV frames
18:40	Begin far encounter TV cyclics record playback of 36 frames
Day 38 2/7/74	
02:35	Start 18 frame cyclics
Day 44 2/13/74	End Venus encounter TV

Table 44. Venus encounter: February 1 - March 1, 1974

Item	California		Australia		Spain		Network Totals
	DSS 12	DSS 14	DSS 42	DSS 43	DSS 62	DSS 63	
1. Tracking passes this period	18	20	9	24	15	20	106
2. Cumulative passes	79	83	96	35	91	35	419
3. Tracking hours this period	153	142	101	275	130	162	963
4. Cumulative tracking hours	708	533	805	380	870	291	3587
5. Commands this period	1067	417	0	716	13	72	2285
6. Cumulative commands	4833	2014	470	883	574	181	8955
7. Command aborts this period	1	0	0	0	0	0	1
8. Cumulative aborts	2	4	0	0	0	0	6

33-797

Table 45. RF link performance comparison, 117.6/2.45 kbps at Venus

Station	Predict (HGA-3.9), corrected for T_s AGC/117.6/2.45 SNR	Actual AGC/117.6/2.45 SNR	Deviation
DSS 14	-136.6/7,6/12.9	-136.0/6.8/12.3	+0.6/-0.8/-0.6
DSS 43	-136.6/7.8/13.2	-137.6/7.1/11.6	-1.0/-0.7/-1.6
DSS 63	-136.7/7.3/12.6	-136.7/7.4/13.2	0.0/+0.1/+0.6
DSS 12	-144.6 13.3	-143.3 14.9	+1.3 +1.6
DSS 42			
DSS 62	-144.7	-143.3	+1.4

Table 46. RF link performance comparison 22.05/2.45 kbps at Venus

Station	Predict (HGA-3.9) corrected for T_s AGC/22 SNR/2.45 SNR	Actual AGC/22 SNR/2.45 SNR	Delta
DSS 14	-137.8/13.3/18.0	-138.0/13.5/18.1	-0.2/+0.2/+0.1
DSS 43	-137.8/13.5/18.2	-137.6/13.3/18.1	+0.2/-0.2/-0.1
DSS 63	-138.2/12.8	-138.8/12.9	-0.6/+0.1
DSS 12	-146.7 /6.1	-144.8 7.9	+1.9 +1.8

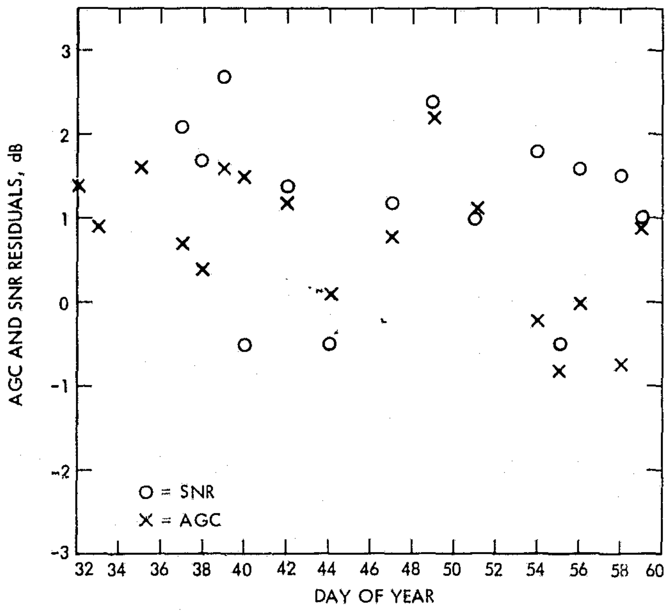

Figure 136. DSS 12 residual data plot

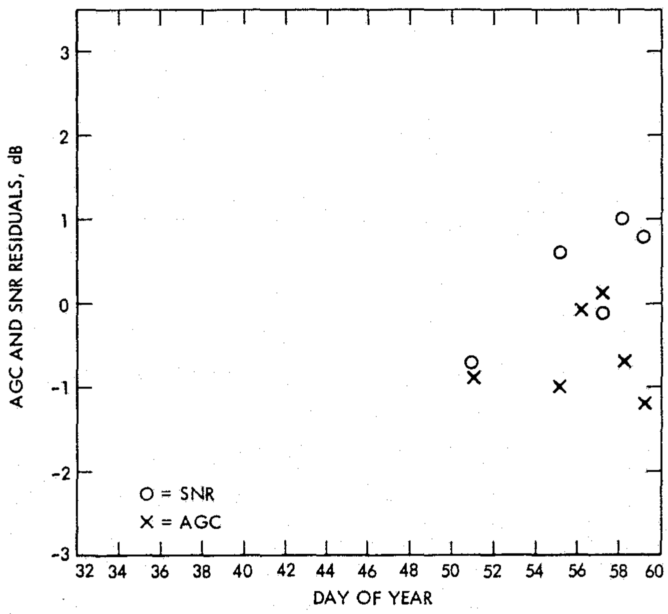

Figure 138. DSS 42 residual data plot

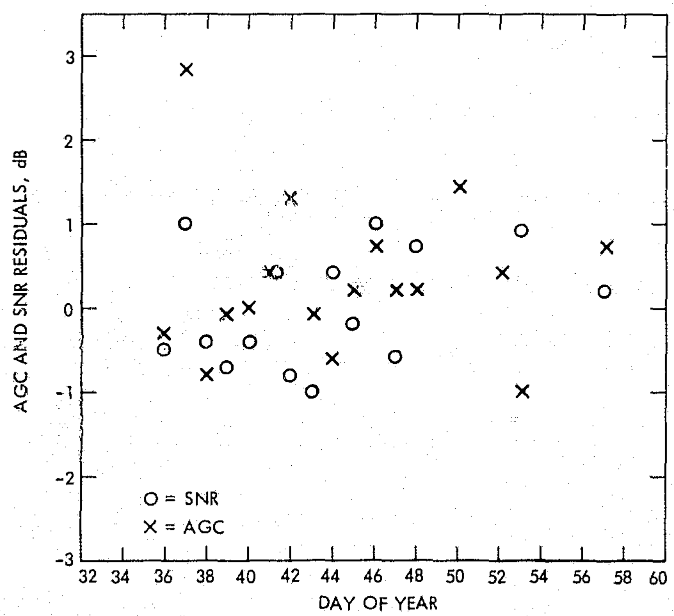

Figure 137. DSS 14 residual data plot

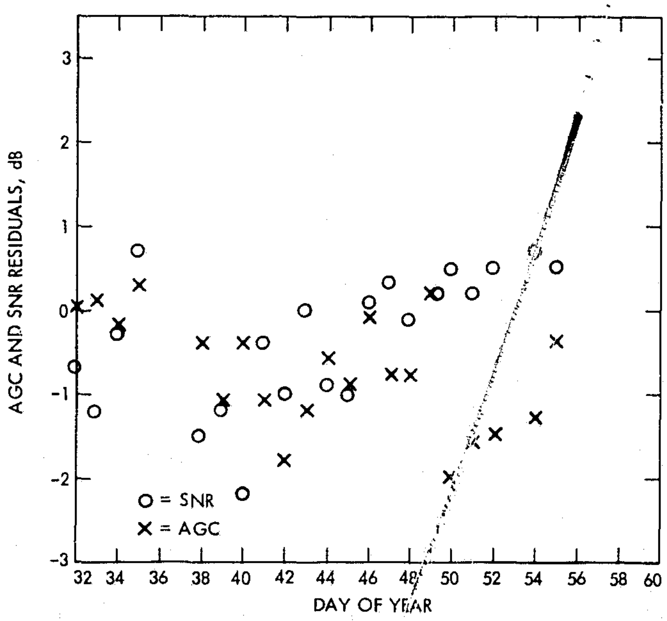

Figure 139. DSS 43 residual data plot

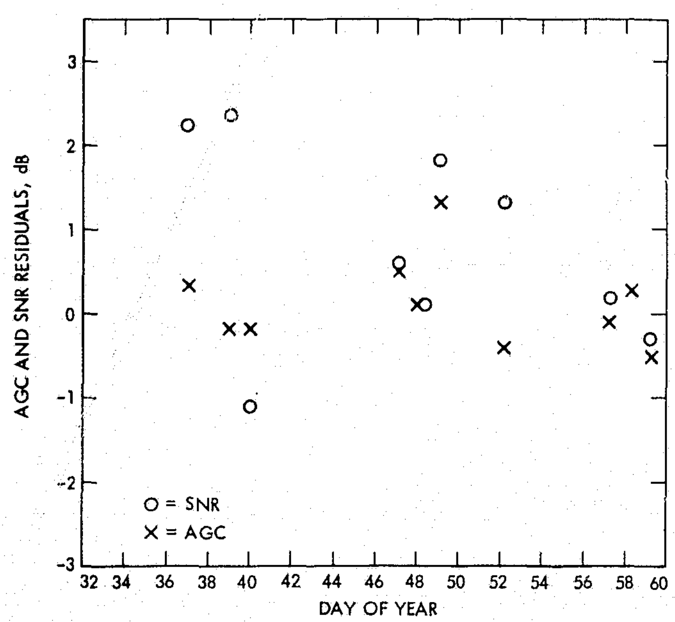

Figure 140. DSS 62 residual data plot

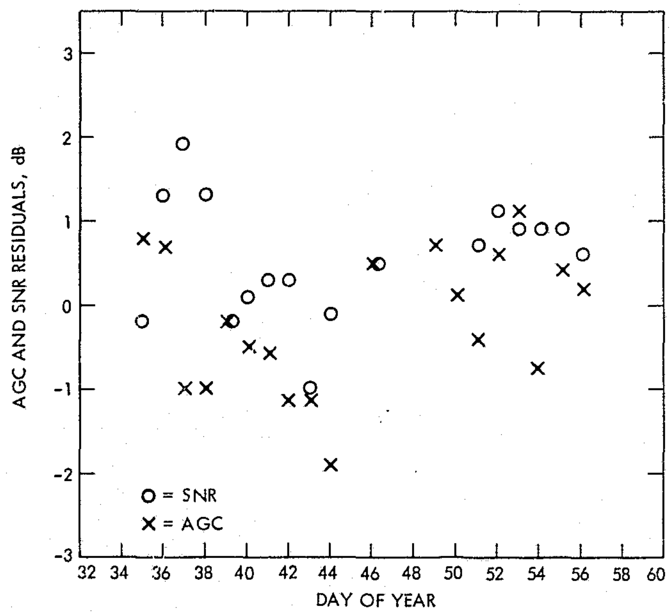

Figure 141. DSS 63 residual data plot

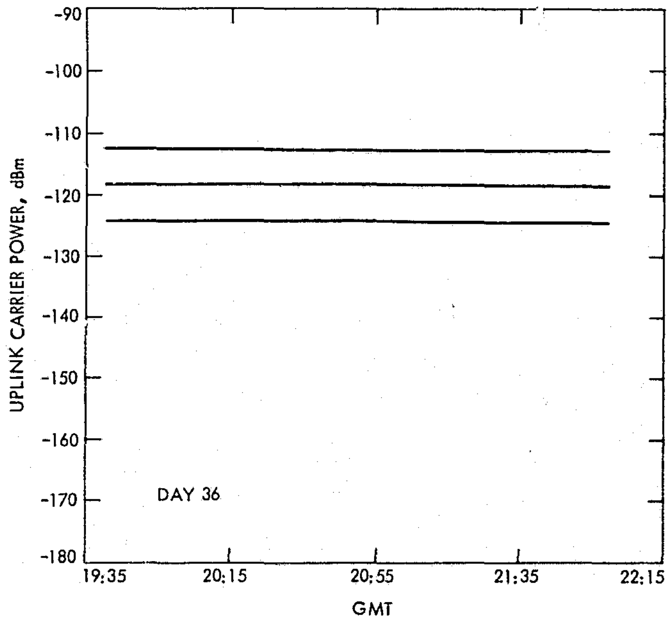

Figure 142. Comparison analysis, uplink carrier power

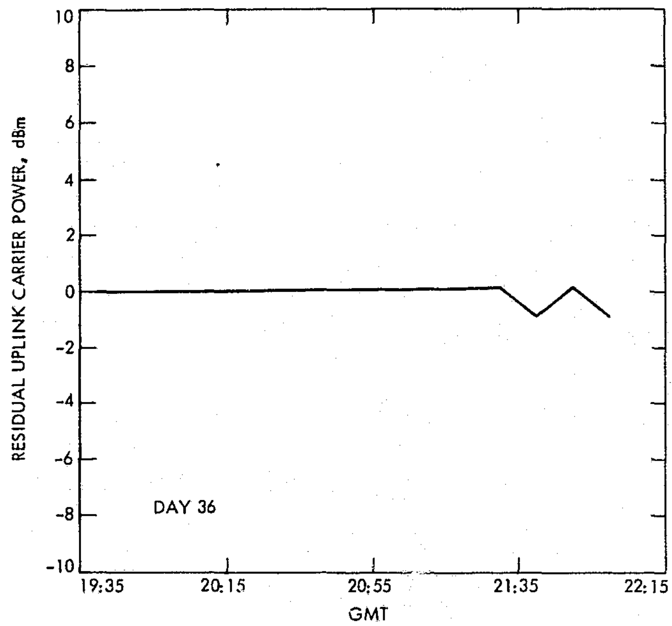

Figure 143. MVM'73 comparison analysis, residual uplink carrier power

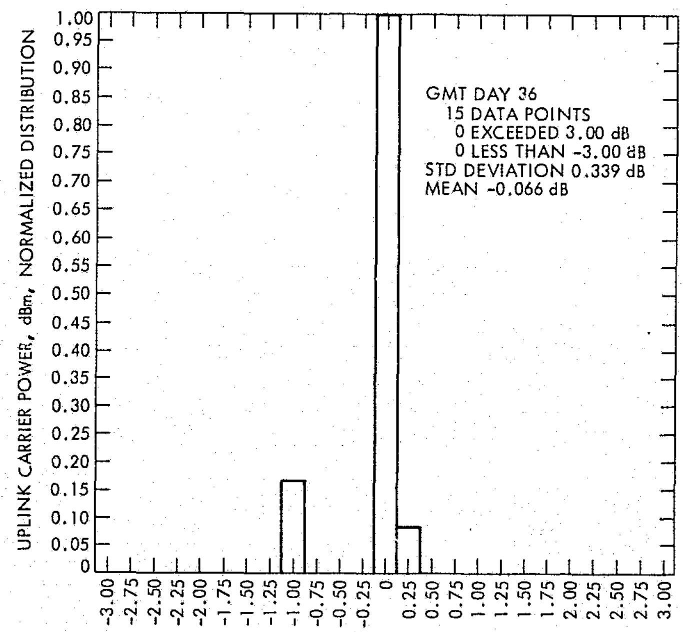

Figure 144. MVM'73 histogram, uplink carrier power

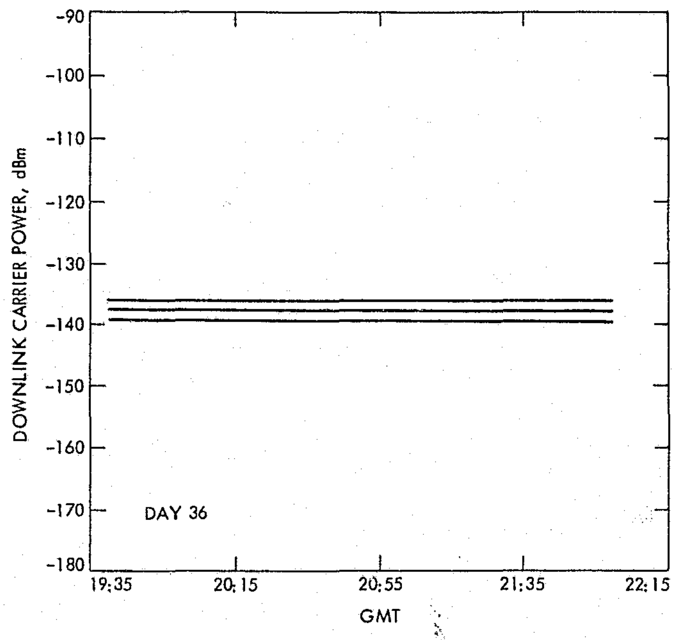

Figure 145. MVM'73 comparison analysis, downlink carrier power

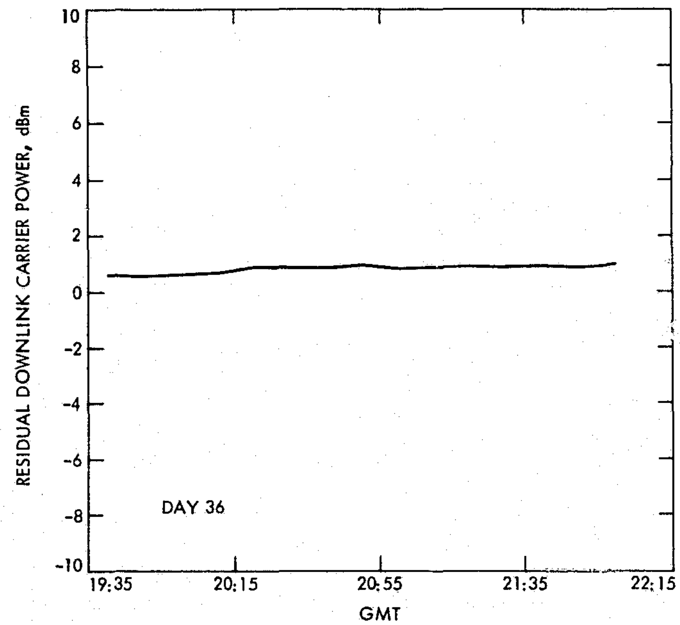

Figure 146. MVM'73 comparison analysis, residual downlink carrier power

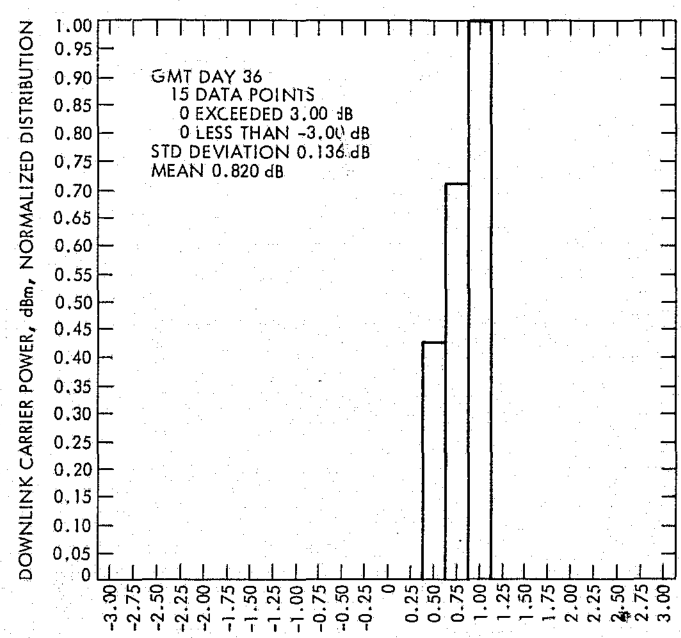

Figure 147. MVM'73 histogram, downlink carrier power

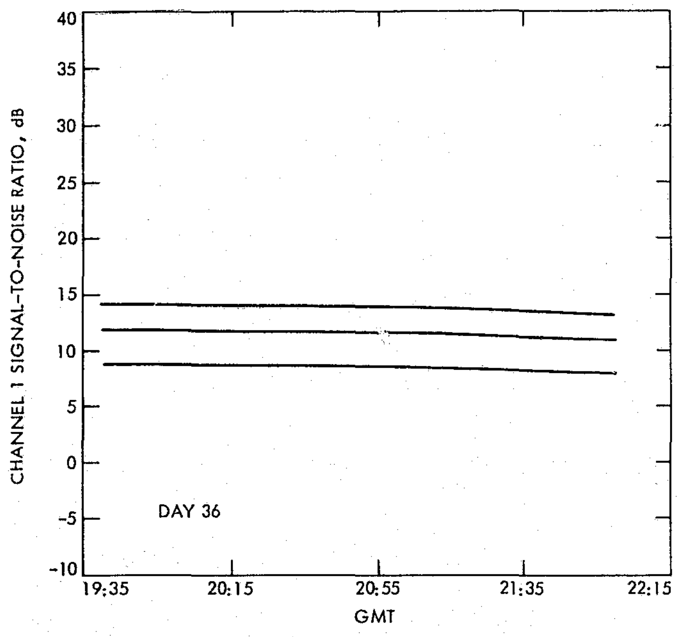

Figure 148. MVM'73 comparison analysis, channel 1 signal-to-noise ratio

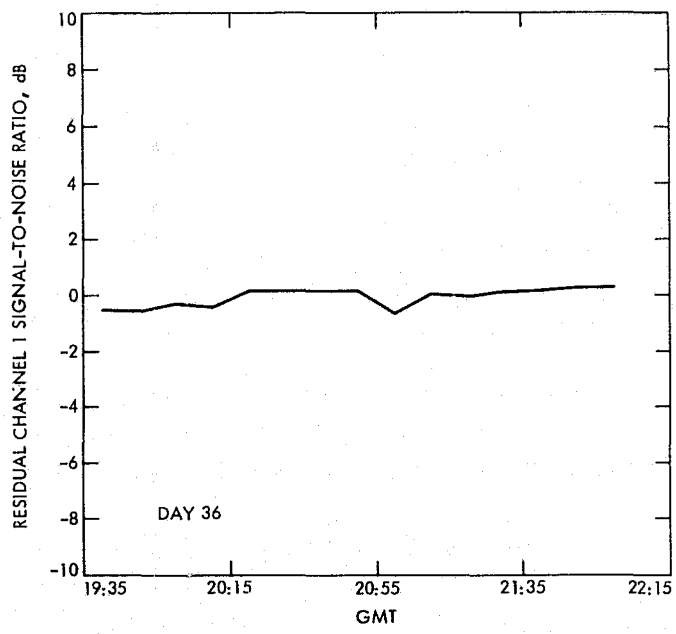

Figure 149. MVM'73 comparison analysis, residual channel 1, signal-to-noise ratio

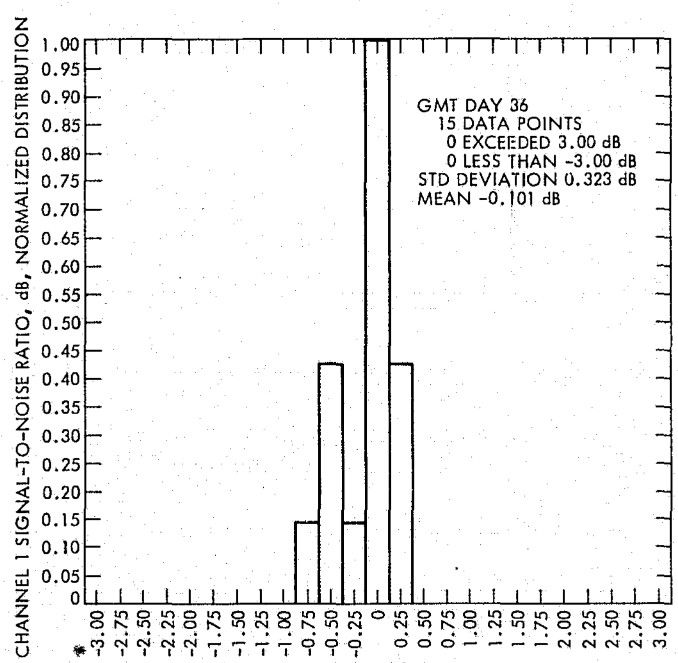

Figure 150. MVM'73 histogram, channel 1, signal-to-noise ratio

Shortly prior to Venus encounter, ground and flight test data eventually showed that the spacecraft auxiliary oscillator had a frequent one-half cycle offset when operating in the one-way mode. Instability of this nature would have masked Venus atmospheric effects on the RF signal, thus severely degrading radio science occultation results. It was determined that proper auxiliary oscillator performance could be obtained in the two-way mode, but to do this required use of the newly implemented 100-kW transmitter at DSS 14 to gain adequate link performance. Furthermore, the Venus near-encounter sequence had been planned to be conducted in a one-way, listen-only mode to enhance performance for high-rate video acquisition. The decision was made in favor of radio science support, and the DSN with the Project had to develop a new two-way, 100-kW sequence between February 1, 1974, and Venus encounter on February 5, 1974. Detailed planning and coordination continued until Venus encounter minus 1 day. The fact that the DSN operations organization and DSS 14 people were able to execute this demanding, last-minute sequence in a near flawless manner is a tribute to their professionalism and willingness to attempt new things in the interest of mission objectives. The following excellent account of these activities was produced by A. Berman and G. Spradlin of the DSN Operations Analysis Group.

On February 5, 1974, at 17:01:04 GMT (spacecraft time), the Mariner 10 spacecraft reached closest approach to the planet Venus. Closest approach activity was visible only to the Goldstone complex, thus limiting participation to DSS 14 (the prime site) and DSS 12 (the backup site), and was noteworthy from a tracking system standpoint in that it marked the first use of the Block IV S- and X-band receiver (at DSS 14) during a critical phase of a planetary encounter. Briefly described, the Block IV receiver is a quadruple conversion superheterodyne, phase-locked receiver capable of S- and/or X-band operation. Increased capabilities of the Block IV receiver over the Block III receiver are as follows:

(1) Improved single-pass phase and modulation delay stability.

(2) Increased receiver sensitivity.

(3) Increased modulation bandwidth.

(4) Programmable oscillators.

(5) S- and X-band operation.

(6) Automatic control capability.

(7) More efficient packaging.

(8) Increased reliability.

For the Venus encounter, the mode used at DSS 14 consisted of the Block III exciter as the transmitter, with one Block IV receiver at S-band with a coherent ratio of 240/221 and the other Block IV receiver at X-band with a coherent ratio of 880/221. Combined with the two Block III receivers, this made a total of four receivers at DSS 14. Each of these receivers was equipped with a digital controlled oscillator (DCO), which had to be programmed separately. The DCOs were still relatively new, having been used only once previously in a critical encounter phase (Pioneer 10 Jupiter encounter, December 5, 1973) and so remained a vital area of concern. Besides the task of supplying DCO-level predictions manually from JPL to DSS 14 for four separate receivers, the Block IV receivers posed an additional problem in that both the S- and X-band doppler data are interleaved into the same pseudo-residual stream. Since the doppler residuals for S- and X-band data are radically different (by a factor of 11/3), near-real-time interpretation of doppler residuals at the NOCA during periods of rapidly changing residuals, such as those occurring at planetary encounters, is made extremely difficult. Finally, an important factor of the Venus encounter was the extremely large refractive effect of the Venusian atmosphere during the period between geometric enter and exit occultation (at its peak, this refraction amounted to approximately 13 kHz, two-way S-band). This refractive effect evidenced itself very strongly during the pre-encounter tracking operations planning phase in three areas:

(1) As the signal refraction increased, its attenuation increased and, as no information existed regarding the accuracy of the attenuation data, uncertainty arose as to when lock would drop and when spacecraft uplink and downlink would be reacquired.

(2) No information was available regarding the accuracy of the atmospheric doppler predictions, thus impacting the selection of an acquisition sweep range.

(3) The DSN Prediction Program does not model planetary atmospheric refraction, so the refraction predictions had to be manually factored into otherwise computerized prediction data for the various encounter strategy studies.

The original uplink tuning strategy called for both enter and exit occultation to occur in the one-way mode. However, several days before encounter, additional testing of the spacecraft auxiliary oscillator disclosed an unacceptable short-term instability, so the decision was made to enter occultation in the two-way mode. This decision immediately introduced a complication with the usage of the open-loop receivers. It was quite conceivable that the uplink could be lost one RTLT or more before loss of the downlink, and that part of the open-loop data would be two-way and part one-way (this happened, and will be amplified in a later section). To avoid possibly losing the one-way segment of data (since the bandwidth of the open-loop receivers is limited), it was desirable to see if the one- and two-way downlinks could be forced to be the same frequency at the time of expected two-way/one-way transition. This was accomplished as follows, where

D1	=	one-way downlink
D2	=	two-way downlink
TSF	=	track synthesizer frequency (transmitted frequency)
XMT REF	=	spacecraft best lock
TFREQ	=	spacecraft auxiliary oscillator
XA	=	spacecraft best lock, including doppler
$\dot{r}$	=	spacecraft range rate
c	=	velocity of light
R	=	received time
T	=	transmitted time

$$D1_R = 96\frac{240}{221}TSF_R - TFREQ(1 - \dot{r}/c) + 10^6$$

$$D2_R = 96\frac{240}{221}TSF_R - 96\frac{240}{221}TSF_T(1 - 2\dot{r}/c) + 10^6$$

By requiring $D1_R = D2_R$, the equation becomes

$$-TFREQ(1 - \dot{r}/c) = -96\frac{240}{221}TSF_T(1 - 2\dot{r}/c)$$

or

$$TSF_T = \frac{221}{96(240)}TFREQ(1 - \dot{r}/c)(/1 - 2\dot{r}/c)$$

Now for $1 \gg \dot{r}/c$

$$(1 - \dot{r}/c)/(1 - 2\dot{r}/c) \approx (1 + \dot{r}/c)$$

so that

$$TSF_T \approx \frac{221}{96(240)}TFREQ(1 + \dot{r}/c)$$

Furthermore,

$$XA_T = XMT\ REF(1 + \dot{r}/c)$$

so that one finally arrives at the necessary condition upon the transmitted frequency

$$TSF_T \approx \frac{221}{96(240)} TFREQ \left\{ \frac{XA_T}{XMT\ REF} \right\}$$

Whether this condition is feasible for any given spacecraft depends on the values of TFREQ and XMT REF; in this case it was feasible, but would cause the spacecraft to be left approximately 80 Hz (at VCO level) above XA at approximately the time of loss of uplink at enter occultation. However, this immediately impacted the uplink acquisition strategy at exit. In general, the spacecraft is left at XA at enter occultation (because one has the best chance of knowing where the spacecraft is at exit), and then a simple sweep around XA at exit is performed to reacquire the uplink. Since the spacecraft was being left quite far from XA, one would have to calculate (rather imprecisely) where the spacecraft had drifted to, and then perform a much wider sweep because of the uncertainties introduced by the spacecraft drift. The calculations were as follows:

$$TSF - XA \text{ (at approximately drop lock)} \cong 80 \text{ Hz}$$

$$\Delta t \text{ (from drop lock to reacquisition)} \approx 1200 \text{ sec}$$

Mariner 10 receiver relaxation constant

$$t_0 \approx 3600 \text{ seconds}$$

so that the drift back to best lock would be

$$\Delta = \Delta_0 e^{-\Delta t/t_0}$$

$$\cong (80 \text{ Hz}) e^{-1200/3600}$$

$$\cong 57 \text{ Hz}$$

Therefore, it was decided to execute a two-way acquisition sweep of (XA + 60 Hz) ±60 Hz. This sweep successfully acquired the spacecraft and this subject will be dealt with in greater detail later in this report. The uplink frequency strategy is detailed in Fig. 151; Fig. 152 describes the one- and two-way doppler during the occultation period.

A fast reacquisition of the downlink by the closed-loop receivers at exit occultation was a prime goal, and it was here that the heaviest impact of the large Venusian atmospheric refraction was felt. Given the large uncertainties in signal strength and doppler as a function

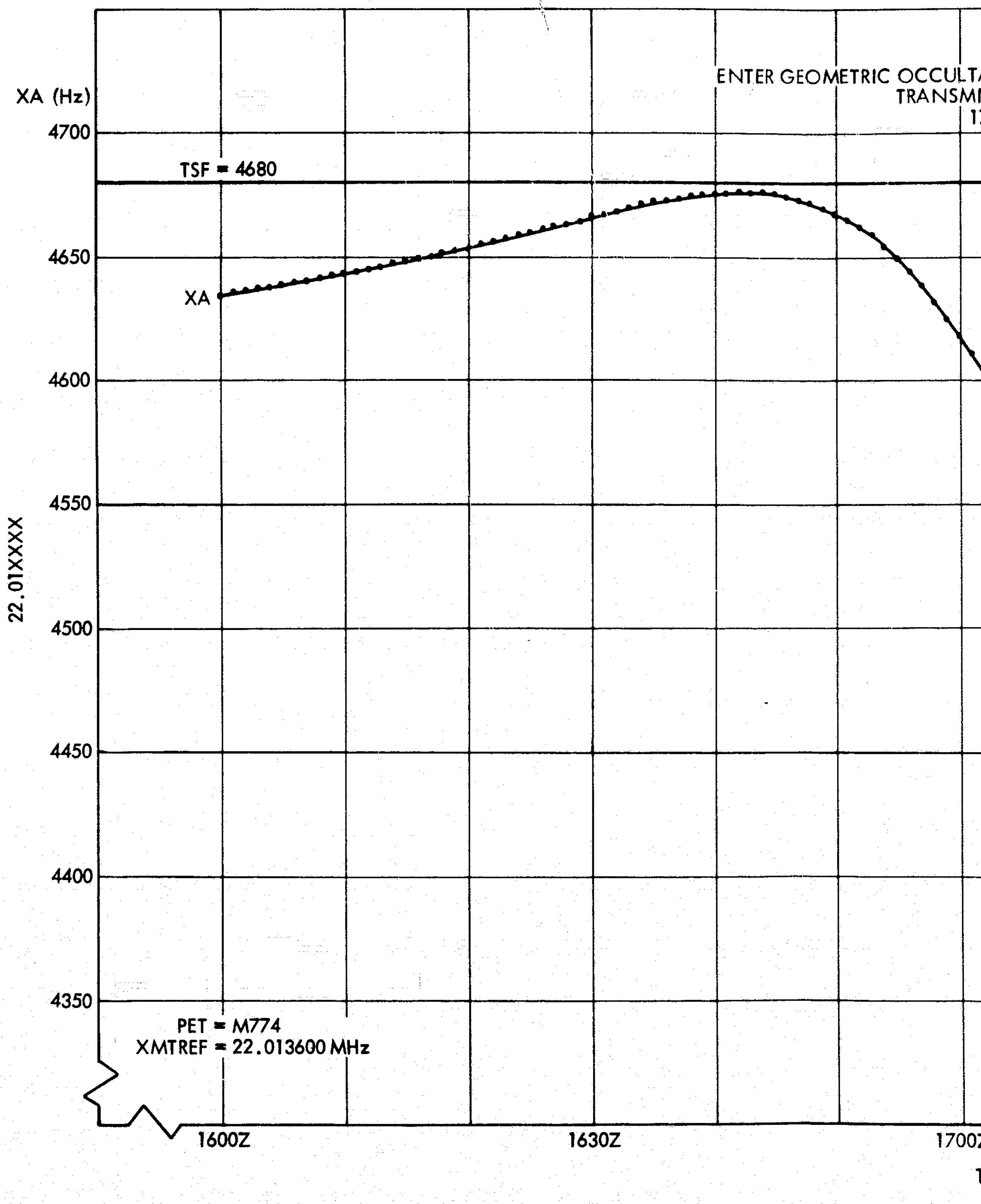

Figure 15

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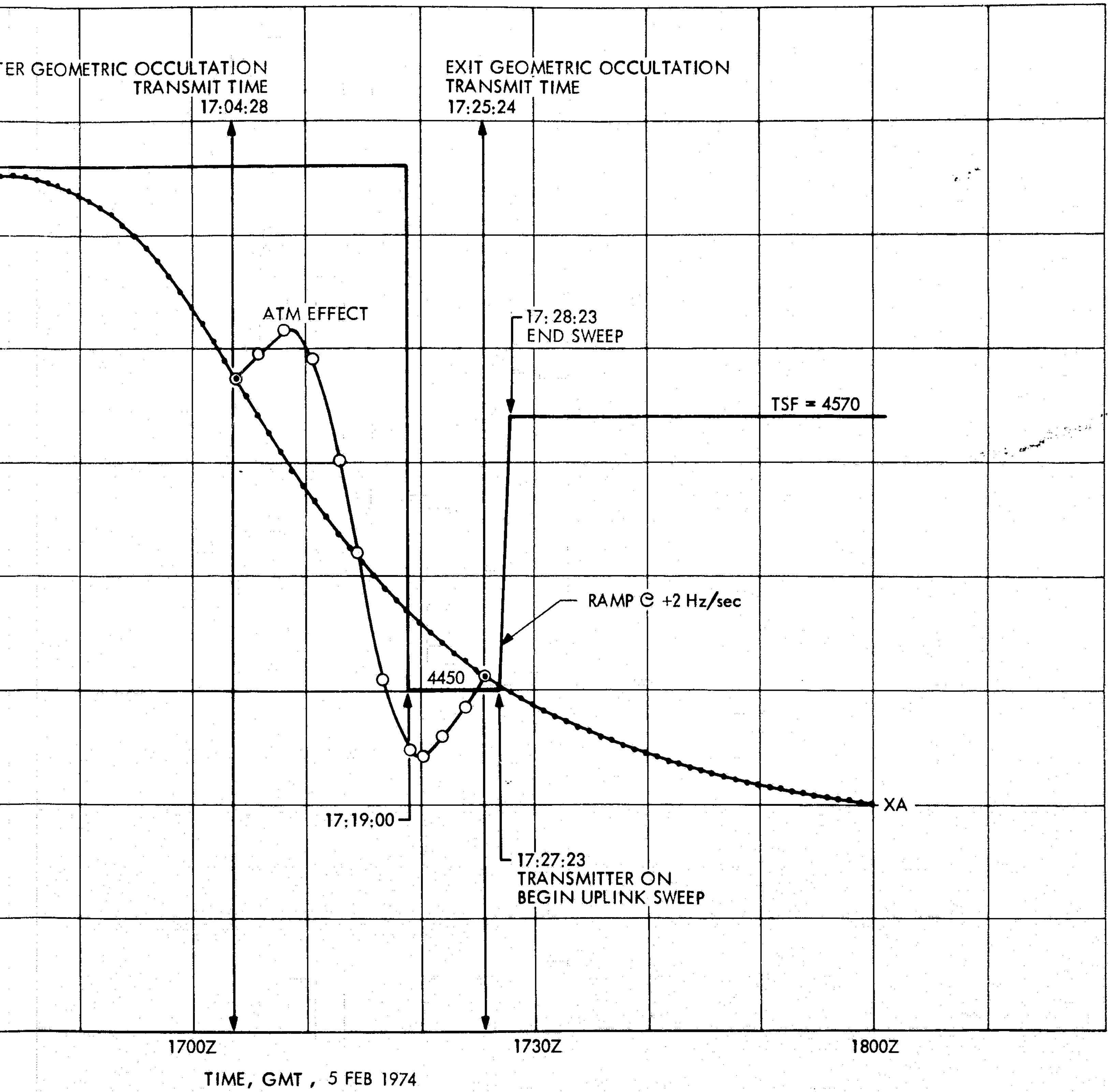

Figure 151. Ground transmitter VCO frequency and tuning pattern for Venus encounter, DSS 14

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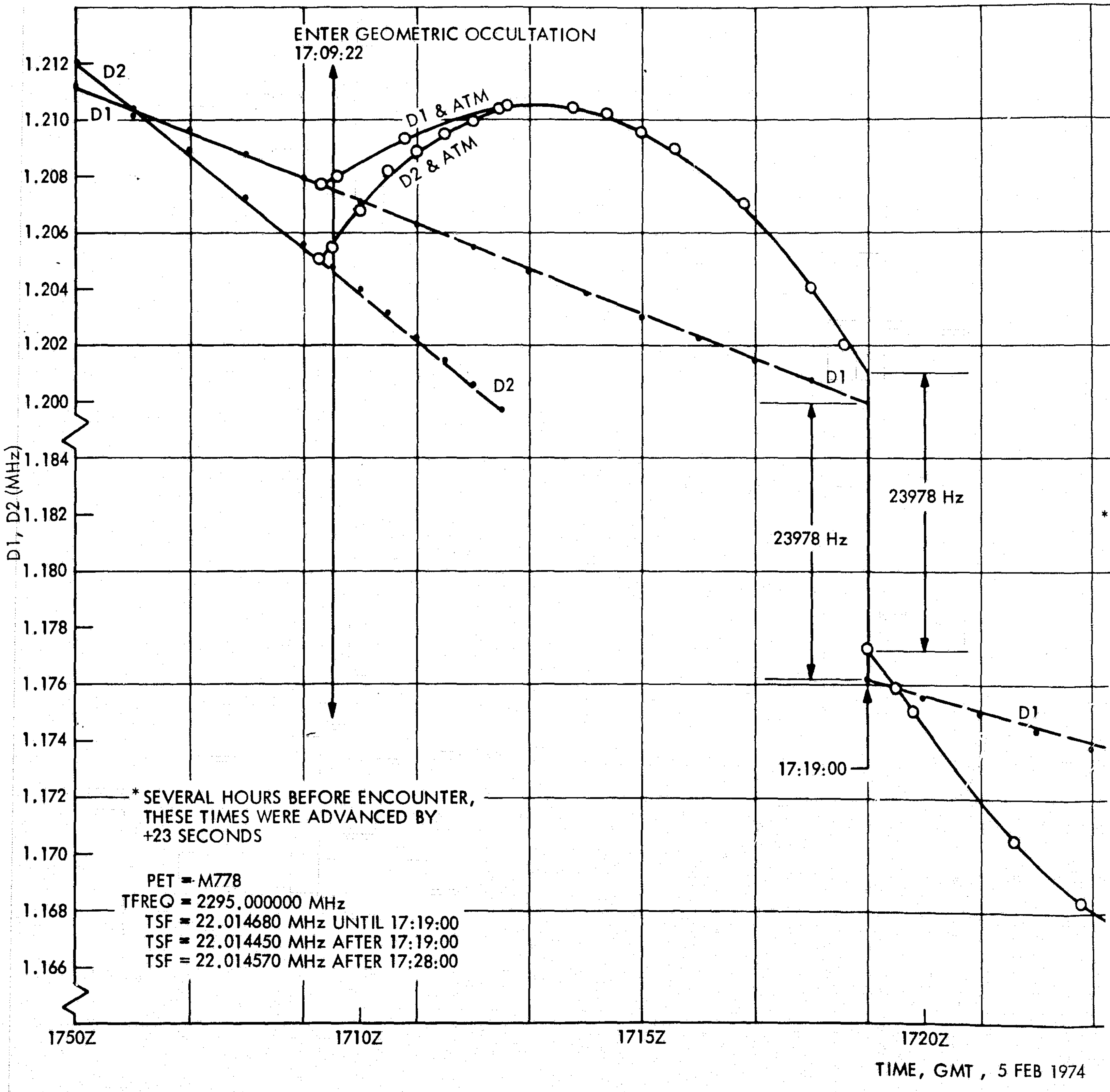

Figure 152. D1 and D2 plus atmospheric correction for Venus encounter, DSS 14

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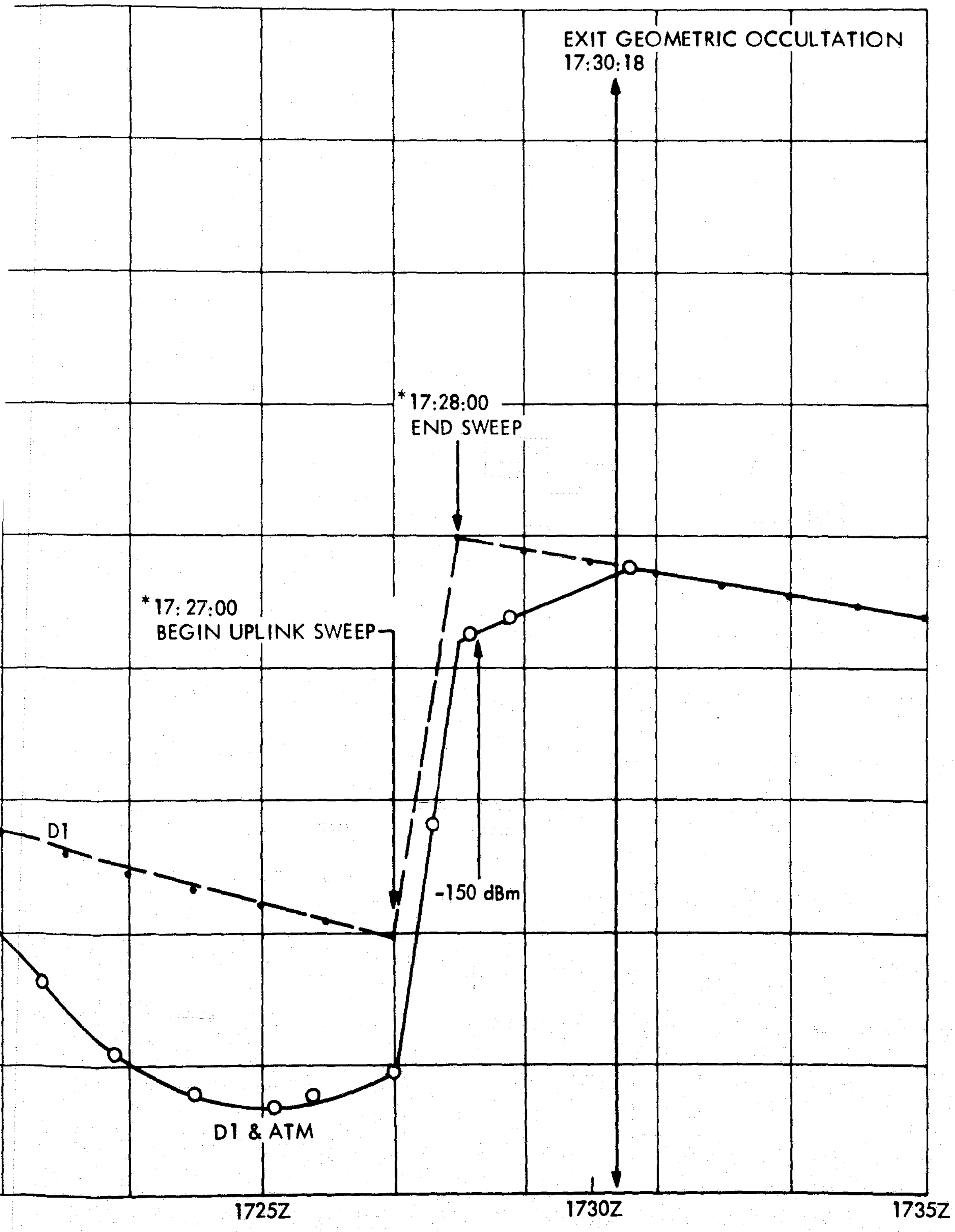

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of time, the DCO automatic acquisition mode was an obvious choice. The selection of sweep rate and sweep range, however, was a far more difficult problem.

This was the situation. A signal would emerge at threshold (~-175 dBm) and slowly, over a period of minutes, increase to its full unrefracted value (~-130 dBm). To acquire at a very low signal strength, one must greatly lower the sweep rate, but in so doing, the sweep takes much longer to sweep through the uncertainty band, thus lowering the chances of rapid acquisition. The Radio Science Occultation Team finally decided on choosing a sweep rate which would be conservative for a signal strength of -150 dBm, and after considerable testing at DSS 14, the value of ±1000 Hz/sec was chosen, in conjunction with a tracking loop filter setting of 100 Hz (wide). A sweep range of D1 -3000 Hz to D1 +5000 Hz was selected, where D1 was the predicted one-way doppler (with atmospheric refraction included) at the time of predicted -150 dBm downlink signal strength. This sweep range was selected because it covered the expected uncertainties from all sources as well as allowing for the increasing doppler if reacquisition of the downlink was not as rapid as had been expected.

Information regarding atmospheric refraction of doppler was provided by G. Fjeldbo of the Tracking and Orbit Determination Section. This data was made available as a plot of the expected X-band doppler shift due to atmospheric refraction superimposed upon the nominal transparent planet X-band doppler curve. Postencounter analysis of the doppler residuals as computed by the IBM-360 Pseudoresidual Program reveals that these atmospheric corrections were quite accurate. The Pseudo-residual Program computes doppler residuals by subtracting from a received actual doppler data point a value obtained from the IBM-360 Predicts Program. Since these predicts do not contain atmospherically refracted doppler corrections, the doppler residuals directly reflect the magnitude of the doppler shift due to the atmosphere of Venus, as well as trajectory and frequency inaccuracies. A plot of the doppler residuals computed by the Pseudoresidual Program on data received from the Block IV S-band receiver during the enter occultation period can be seen in Fig. 153. Superimposed on the plot of this data is a plot of predicted atmospheric effect. As can be seen from Fig. 153, biases due to trajectory and/or frequency inaccuracies were very small (note the period prior to encountering the atmosphere), and the computed doppler residual compares very favorably with the predicted doppler shift due to the atmospheric refraction.

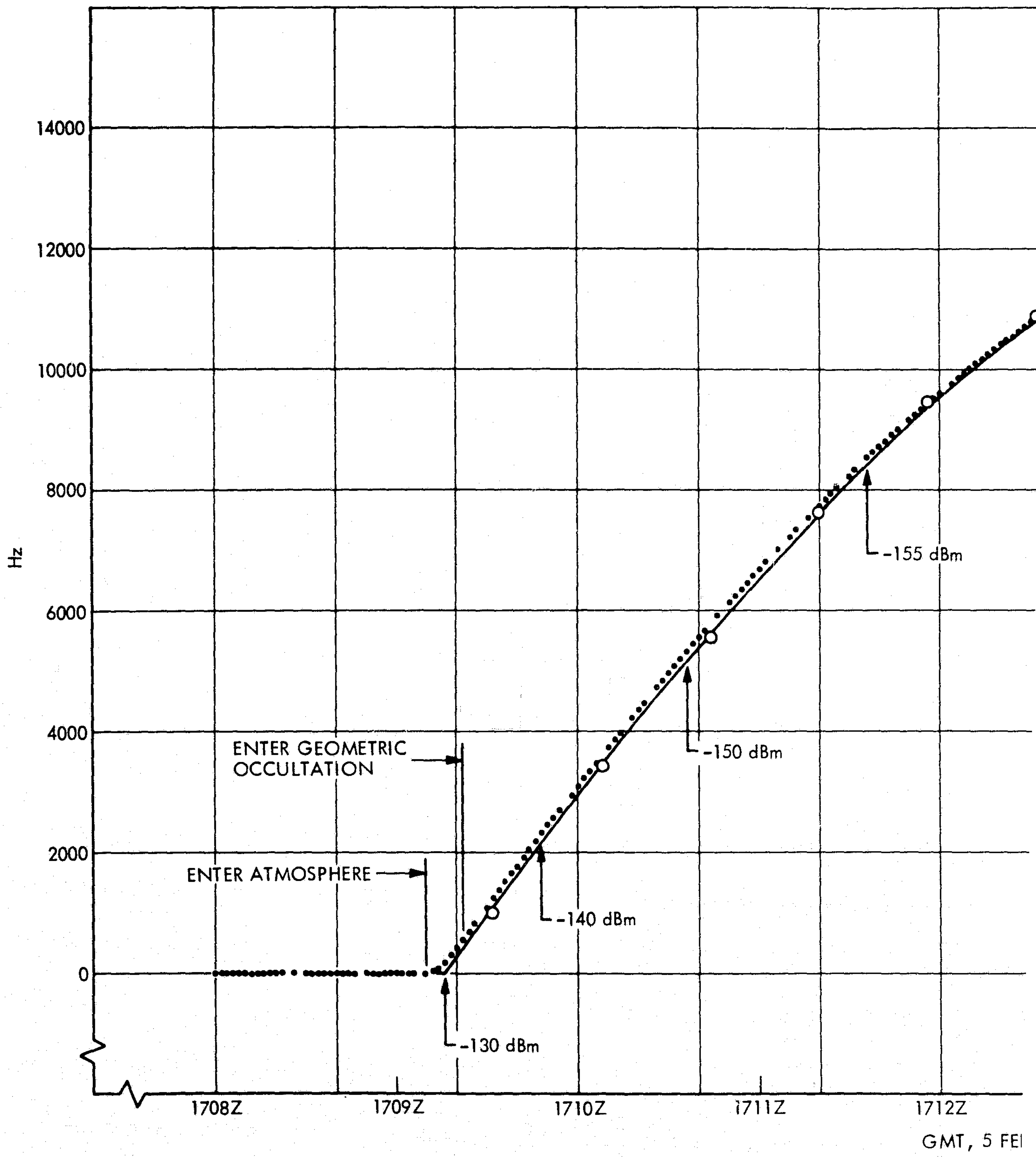
Referring to Fig. 153, it can be seen that two-way lock with the spacecraft was maintained for approximately 6 min beyond geometric occultations. At that time the spacecraft, being unable to maintain lock on the uplink, began transmitting, using the on-board auxiliary oscillator. With the out-of-lock condition, the Block IV S-band receiver began to drift, unexpectedly resulting in the receiver locking to the auxiliary oscillator-generated downlink. The Block IV S-band receiver maintained one-way lock for approximately 40 sec before the signal became too weak to sustain receiver lock. The offset that can be seen between the predicted one-way doppler residuals and the actual values indicated on the plot is the result of inaccuracy in predicting the spacecraft auxiliary oscillator frequency, this difference being approximately 580 Hz.

Following the loss of receiver one-way lock, the Block IV S-band receiver again began to drift as a result of the receiver VCO being stressed off nominal rest frequency. Figure 154 is a plot of the doppler residuals during the period of receiver drift. By fitting a curve through these points it was determined that the receiver time constant was approximately 690 sec. This compares reasonably with a theoretical (assuming the narrow, 30-Hz, tracking loop filter) receiver time constant of approximately 650 sec. The exponential drift of the receiver and the relatively long time constant indicate that the Block IV receiver loop was not shorted (which would have immediately removed the stress) and that the tracking loop filter in use was 30 Hz (resulting in the relatively long time constant). It should be noted that it had been planned to switch to the wide (100-Hz) tracking loop filter following loss of lock, but that apparently during the excitement and confusion resulting from the unexpectedly lengthy ground receiver lock at enter occultation, this SOE item was not executed. Had the switch to the wide (100-Hz) tracking loop filter taken place, the receiver time constant would have been reduced to approximately 35 sec. At loss of one-way lock, the receiver VCO was stressed approximately 15.7 kHz (S-band) off nominal rest frequency. During the approximate 465 sec the receiver was allowed to drift, this stress had decayed to approximately 8 kHz off receiver VCO rest frequency. During this interval, the receiver DCO was being set up for reacquisition of the spacecraft as it emerged at exit occultation.

The receiver tuning pattern executed by DSS 14 can be seen in Fig. 155. The data points plotted are the doppler residuals as computed by the Pseudoresidual Program, but modified such that zero represents the predicted one-way doppler. The acquisition search can plainly be seen to be in the wrong frequency region (due to failure to short the VCO). However, even if the search had been in the correct frequency region, acquisition would have been precluded by the incorrect tracking loop filter setting.

After several minutes of sweeping, the data indicates that DSS 14 altered the sweep pattern and did cross the expected lockup frequency. However, since the tracking loop bandwidth had not been changed to the prescribed wide (100-Hz) tracking loop filter, the sweeps were too fast for the receivers to acquire the downlink. After several minutes of searching in the widened sweep pattern, DSS 14 did acquire the downlink. This occurred at approximately 17:28:58 GMT and as is apparent from the plot, only after the sweep rate had been reduced (to approximately one third) to a rate compatible with the still-in-use narrow (30-Hz) tracking loop filter. It should be noted at this point that the Block III prime and backup receivers, using the correct tracking loop filter, an identical sweep region, and with the receiver VCO stress removed, acquired at approximately 12:26:00 GMT.

The Block IV X-band receiver acquired the two-way downlink at approximately 12:40:58 GMT. Due to the intensified effort to lock the Block IV S-band receiver and the complications introduced due to



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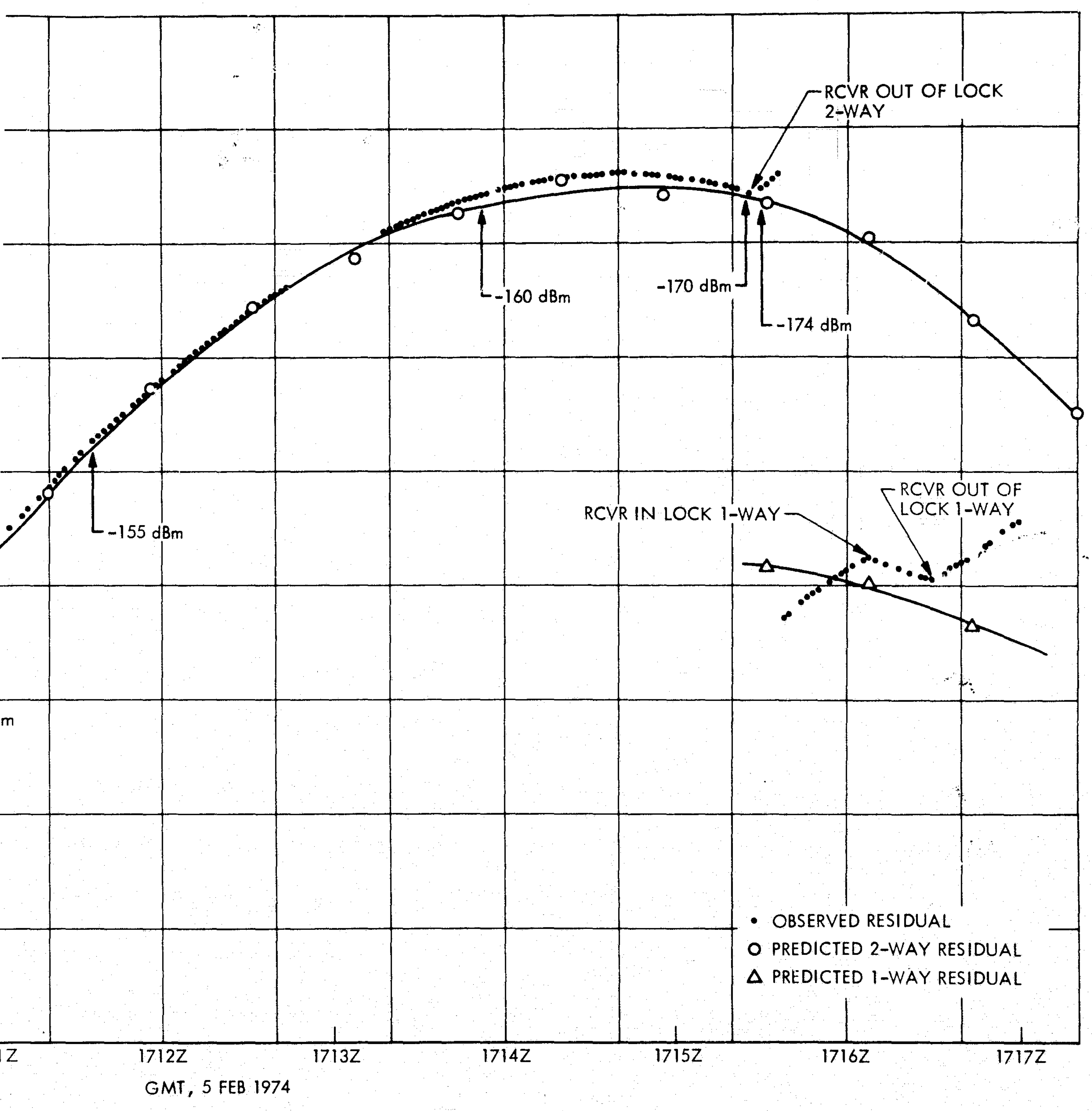

Figure 153. Venus encounter, enter occultation doppler residuals, actual and predicted, DSS 14, Block IV, S-band

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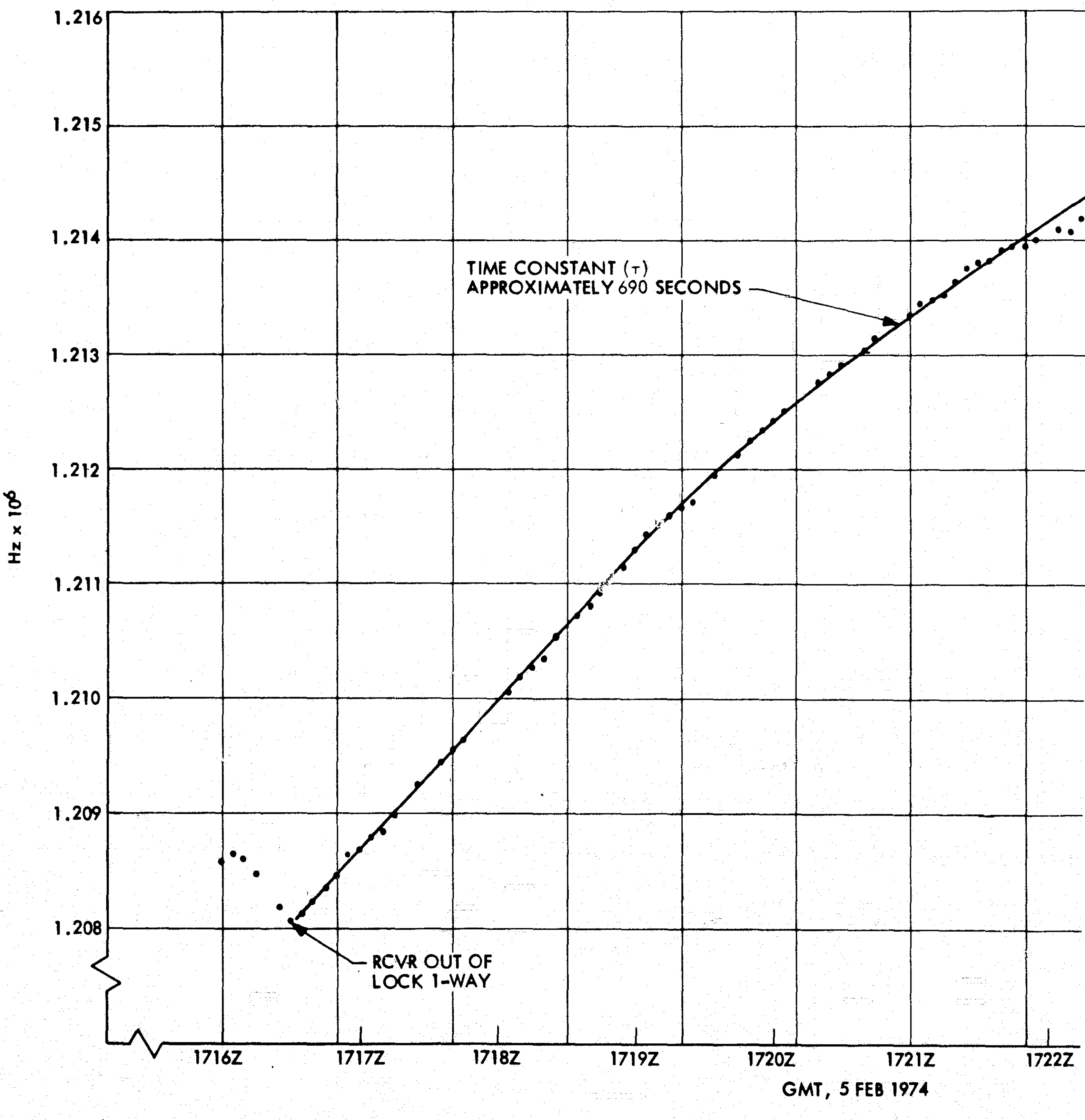

Figure 154. Venus occultation, receiver stress relaxation, DSS 14, Block IV, S-band

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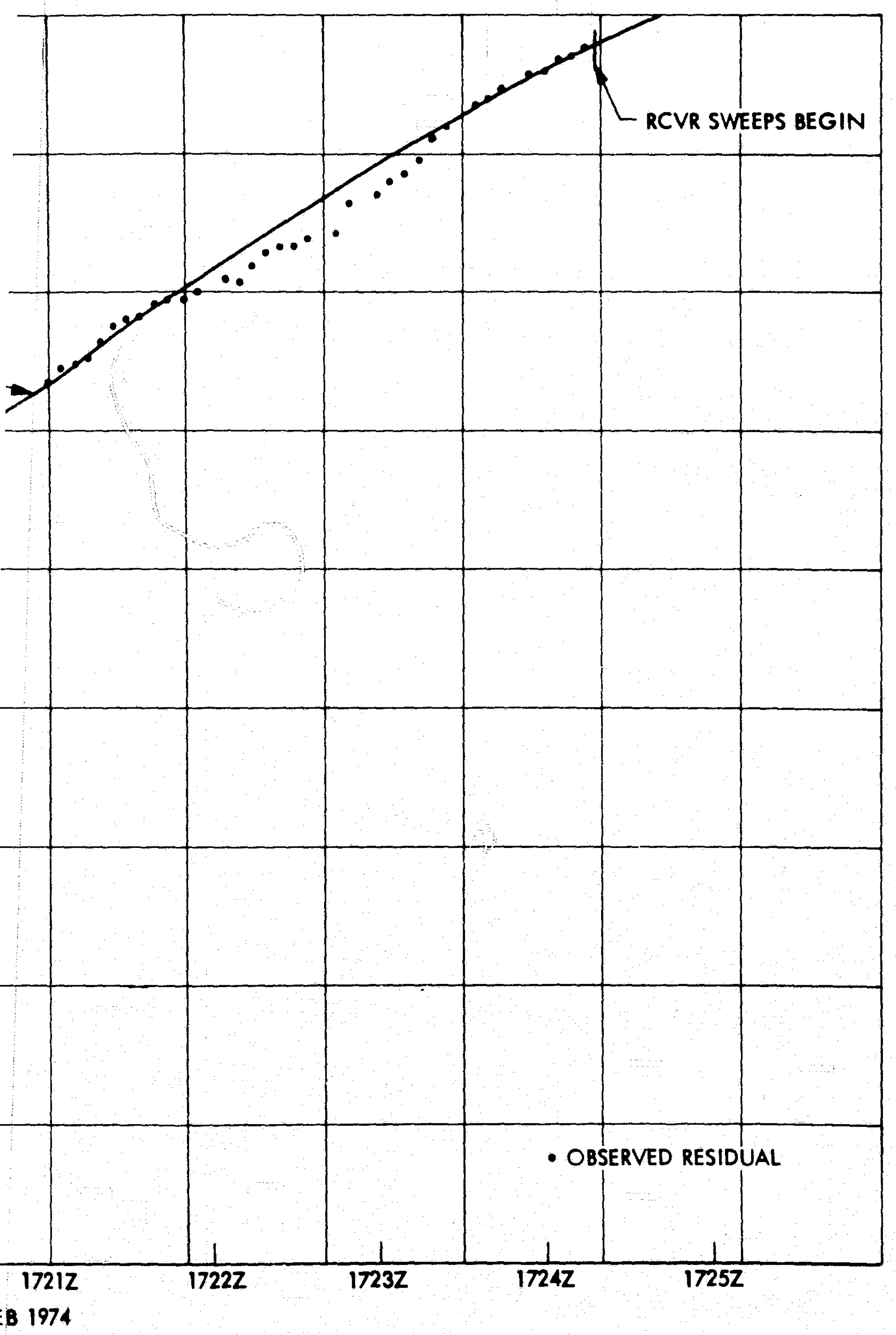

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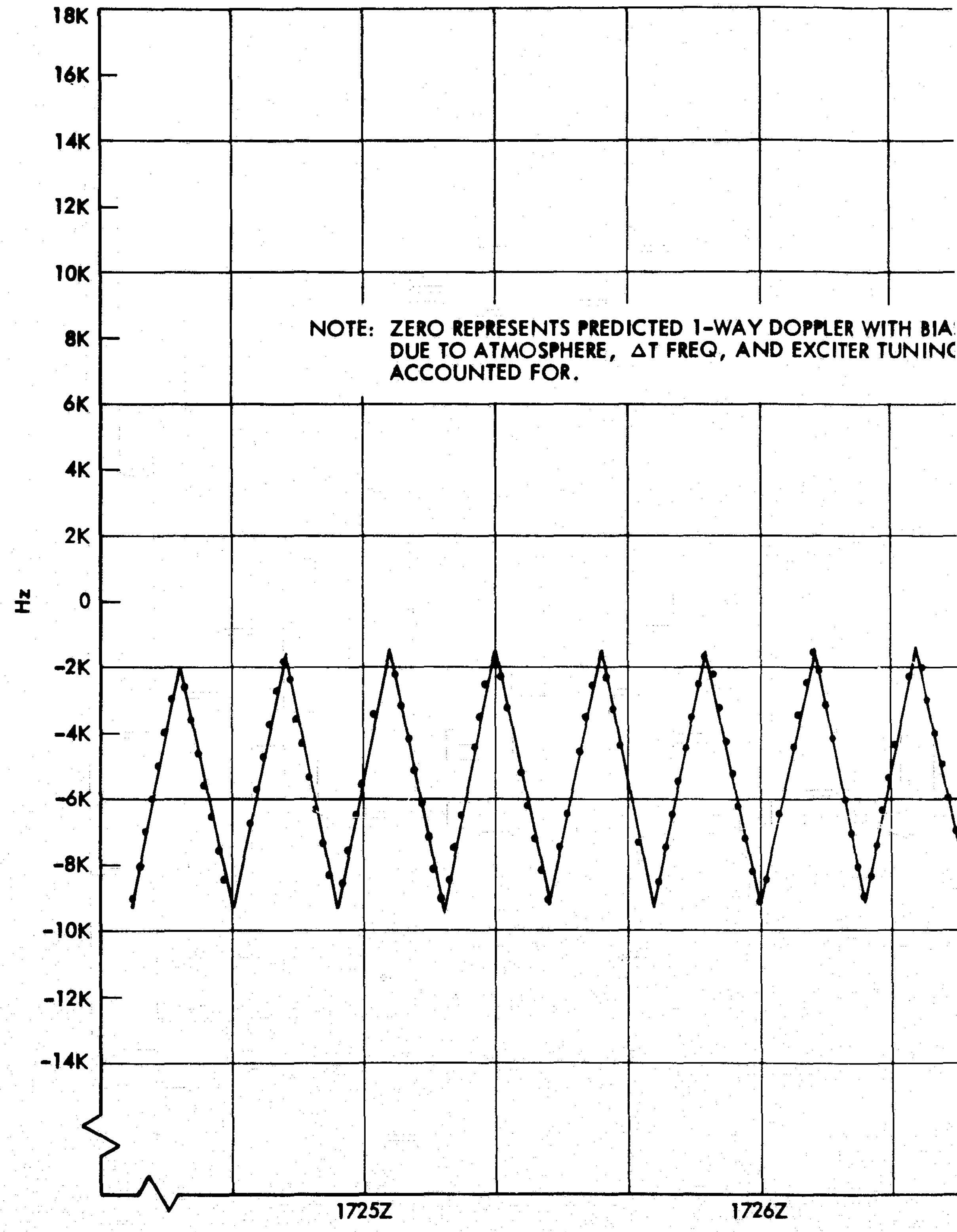

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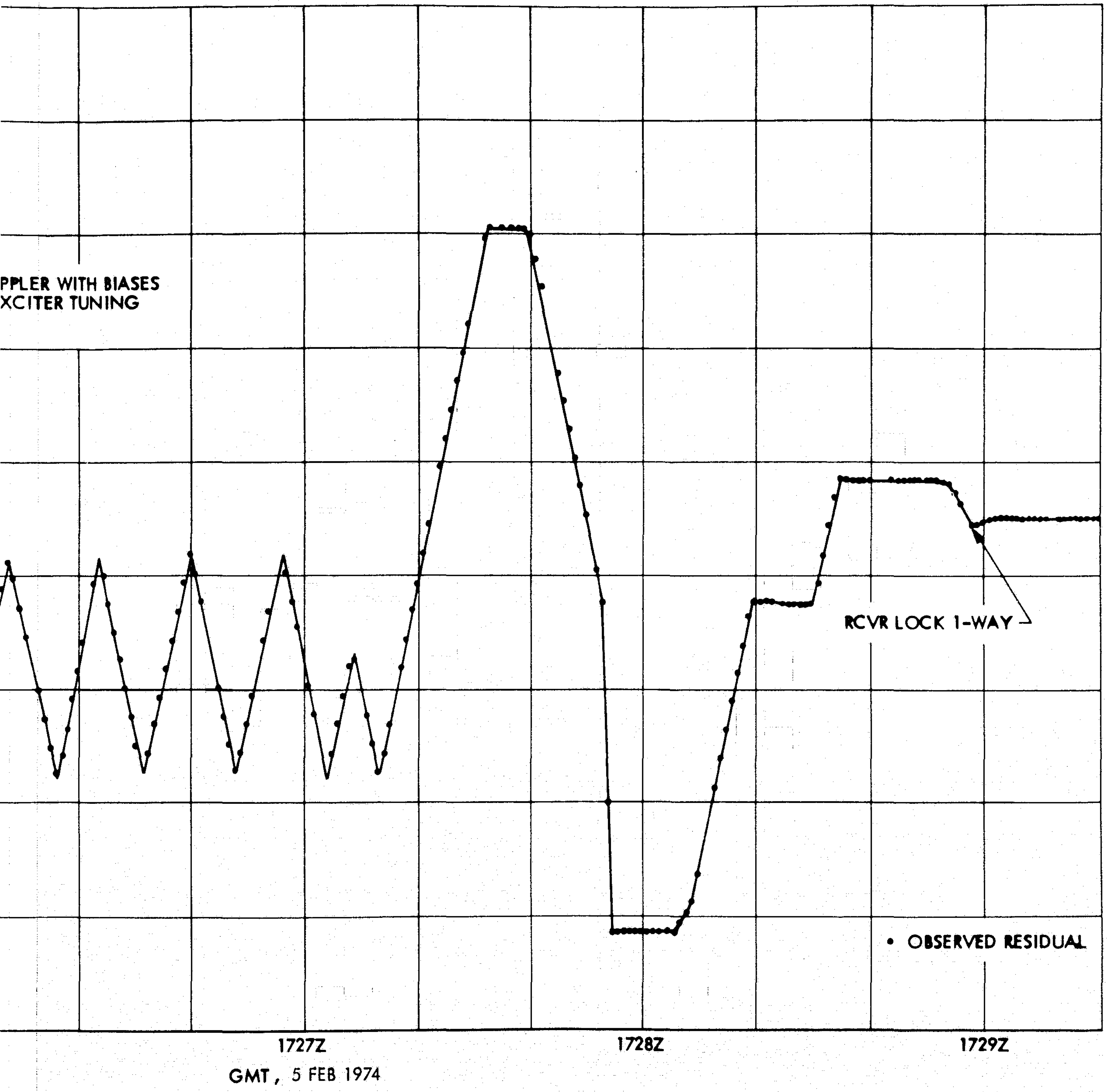

Figure 155. Venus exit occultation, tuning pattern, DSS 14, Block IV, S-band

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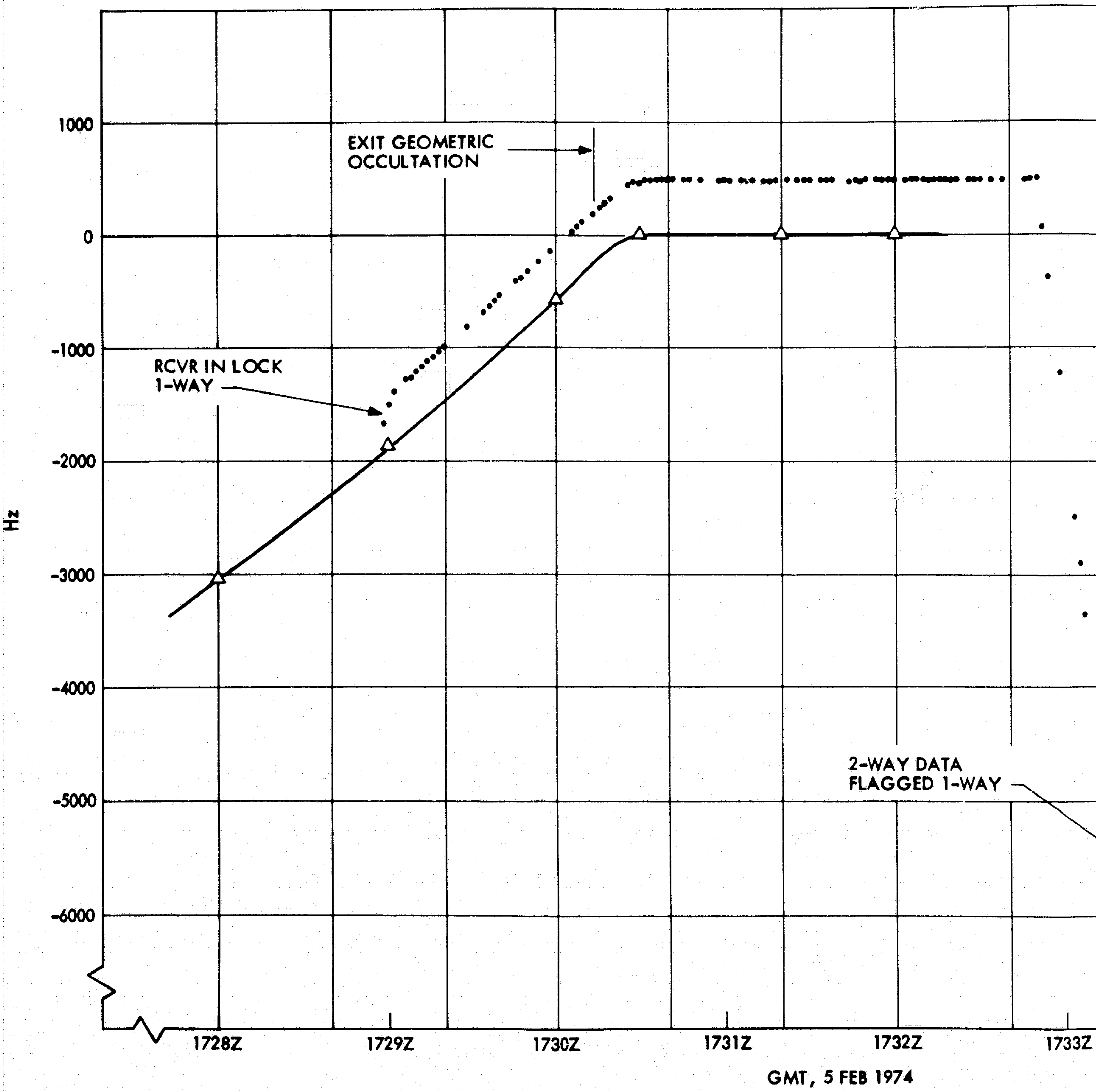

Figure 156. Venus encounter, exit occultation doppler residuals, DSS 14, Block IV, S-band

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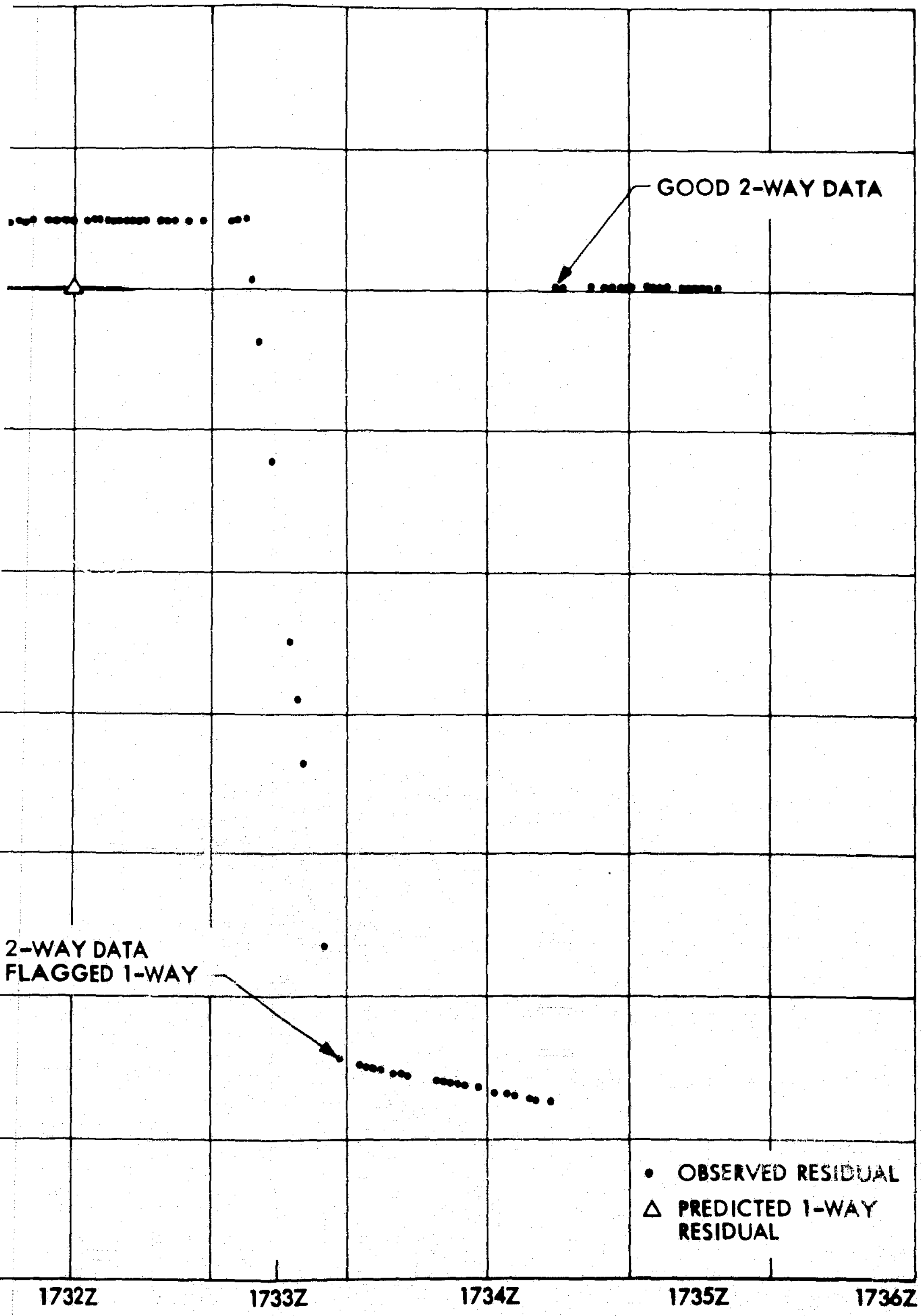

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the differences between the S-band and X-band receivers, the lockup of the X-band receiver was delayed until some time after lock of the S-band receiver had been achieved.

The doppler residuals seen in Fig. 156 are of the exit occultation period. Again it can be seen that the predicted residuals and the actual residuals reflect the effects of atmospheric refraction, with the offset being due to the previously mentioned inaccuracy in the predicted auxiliary oscillator frequency.

At approximately 17:32:50 GMT, the downlink switched from the one-way to the two-way doppler mode. This switch occurred without loss of lock as the one-way doppler and two-way doppler were nearly equal at this time. As mentioned in an earlier section, the uplink frequency at the expected loss of signal time at enter occultation was chosen to cause the one- and two-way doppler frequencies to be as close together as possible to optimize the open-loop receivers. To demonstrate that the one- and two-way doppler frequencies were also nearly equal at the time of the two-way acquisition, it is necessary to determine how far off the spacecraft nominal rest frequency (XA) the spacecraft receiver was when loss of two-way lock occurred at enter occultation. From Fig. 153 it is apparent that the spacecraft dropped the uplink at approximately 17:15:28 GMT ground received time or about 12:10:34 GMT ground transmit time. The value of XA at this time, corrected for atmospheric refraction, was 22014595.6 Hz. The transmitted frequency (TSF) at the time the spacecraft dropped the uplink was 22014680.0 Hz. Therefore, at loss of two-way lock the spacecraft receiver was stressed off XA by +84.4 Hz.

During the out-of-two-way-lock period, the spacecraft receiver drifted back toward XA. Using the equation that describes this relaxation, the spacecraft rest frequency at two-way reacquisition time can be determined as follows:

$$\Delta = \Delta_0 \text{ (at start of drift) } e^{-\Delta t/t_0}$$

where

Δt = period of drift

t_0 = spacecraft receiver time constant

Δ = actual spacecraft receiver frequency - XA

Since the spacecraft dropped lock at 17:10:34 GMT and reacquisition occurred at 17:27:56 GMT (ground transmit time), Δt = 1042 sec. From spacecraft measurements,

$$t_0 \approx 3600 \text{ sec}$$

Therefore,

$$\Delta \approx (84.4 \text{ Hz})\, e^{-(1042/3600)}$$

$$\Delta \approx 63.2 \text{ Hz}$$

Since the predicted XA at this time was

$$XX = 22014448.8 \text{ Hz}$$

the expected spacecraft best lock frequency (XA_A) at this time would be

$$XA_A \approx XA + \Delta$$

$$\approx 22014448.8 \text{ Hz} + 63.2 \text{ Hz}$$

$$\approx 22014512.0 \text{ Hz}$$

The actual transmit frequency (TSF_A) at the spacecraft reacquisition time is found as follows:

$$TSF_A = TSF_1 + (\text{ramp rate}) \times (\text{time})$$

where

$$TSF_1 = \text{preramp TSF} = 22014450.0 \text{ Hz}$$

$$\text{Ramp rate} = 2 \text{ Hz/sec}$$

$$\text{Time} = 32.8 \text{ sec}$$

Thus,

$$TSF_A = 22014515.6 \text{ Hz}$$

The difference between the expected lock-up frequency and the actual lock-up frequency is:

$$\approx TSF_A - XA_A$$

$$\approx 22014515.6 \text{ Hz} - 22014512.0 \text{ Hz}$$

$$\approx 3.6 \text{ Hz (at VCO level)}$$

thereby indicating good agreement between expected and actual. Finally, using the equation developed earlier to determine the transmitted frequency (TSF_B) that forces the one and two-way doppler frequencies to be equal, we have as follows:

$$TSF_B = \frac{221}{96(240)} TFREQ \left\{ \frac{XA}{XMT\ REF} \right\}$$

where

$$TFREQ = 2294999220.0 \text{ Hz}$$

$$XA = 22014448.8 \text{ Hz}$$

$$XMT\ REF = 22013600.0 \text{ Hz}$$

Thus

$$TSF_B = 22014513.2 \text{ Hz}$$

The difference between the one- and two-way doppler frequencies at two-way reacquisition time is found to be:

$$= 96\frac{240}{221}\left\{TSF_A - TSF_B\right\}$$

$$= 96\frac{240}{221}\left\{22014515.6 - 22014513.2\right\} \text{ Hz}$$

$$= 251 \text{ Hz(S-band)}$$

With so small a difference between the one- and two-way doppler frequencies, the switch from the one-way mode to the two-way mode occurred without loss of lock. Within 60 sec the station had been informed of this condition and had thrown the two-way data mode switch. This can be seen in Fig. 156 at approximately 17:34:20 GMT, at which point the two-way residuals reflect only biases due to prediction inaccuracies.

Table 47 provides a summary of the receiver lock status for the DSS 14 Block III prime and backup and Block IV S-band and X-band receivers during Venus occultation. The in/out of lock times are derived from Monitor AGC data.

Table 47. Summary of DSS receiver events

Event	Ground received time (GMT Feb 5 1974)
Enter atmosphere[a]	17:09:10
Enter geometric occultation[a]	17:09:23
Block IV X-band out-of-lock	17:10:45
Block III prime and backup out-of-lock	17:14:58
Block IV S-band out-of-lock (two-way)	17:15:35
Block IV S-band out-of-lock (one-way)	17:16:30
Block III backup in-lock	17:25:48
Block III prime in-lock	17:26:03
Block IV S-band in-lock	17:28:58
Exit geometric occultation[a]	17:30:17
Exit atmosphere[a]	17:30:28
Two-way[a]	17:32:50
Block IV X-Band in-lock	17:40:58

[a]These are best estimates from actual encounter data.

Table 48 presents the accuracies of (as compared to the actual data at encounter) the last four orbital determination solutions as provided for encounter planning. Probe ephemeris tapes (PETs) M778 and M774 were provided several weeks prior to encounter, while PETs M781 and M780 were provided during the last days before encounter. In all cases the residuals provided represent the Δ between the referenced PET and the final observed doppler and time. Two generalizations (at least for this encounter) can be formulated here:

(1) The 3σ uncertainties provided by the Navigation Team for encounter planning were approximately 1500 Hz (S-band, two-way) for doppler and 40 sec for time events. Using the four referenced solutions, the navigation-provided uncertainties would have to be considered quite conservative, which is as it should be.

(2) There is a noticeable improvement between the PETs (M778 and M774) provided weeks ahead of the encounter vs those (M781 and M780) provided in the last days before encounter. However, there is, for instance, no clear cut improvement in going from M780 to M781 (the final PET provided). Therefore, the idea of changing many tracking parameters in the last hours before an encounter might be considered more of a possible, but unlikely contingency, rather than a planned for and totally expected procedure.

Table 48. Accuracy of orbit determination solutions generated prior to Venus encounter

Time	Observed doppler, Hz	Change from observed, Hz			
		PET M781	PET M780	PET M778	PET M774
1600 Z	1214895.35	-2.5	-3.65	-11.52[a]	-11.07[a]
Closest approach	1214073.47	+3.1	+74.42	+72.55[a]	+88.16[a]
Enter occultation	1204820.21	-4.1	-10.38	-45.23[a]	+58.56[a]
Exit occultation	1191292.72	-33.8	-13.61	+7.37[a]	+63.79[a]
1800 Z	1167523.96	-41.2	-11.93	+33.94[a]	+88.00[a]
Time (ground observed)	**Event**	**Change from observed, sec**			
17:03:31.344	Closest Approach	+3.656	+1.126	+3.226	+3.816
17:09:22.585	Enter Occultation	-0.585	+0.415	+4.415	+6.415
17:30:16.842	Exit Occultation	+1.158	+2.158	+2.158	+6.158

[a]PETs M778 and M774 were based upon solutions generated prior to the gas leak.

In summary, tracking operations during the Venus encounter phase were extremely successful on balance, especially in light of the considerable difficulties posed by the confluence of new equipment at DSS 14 (Block IV receivers) and the large uncertainties associated with the Venusian atmospheric effects on telecommunications. The one minor problem during this phase was the late acquisition by the Block IV receivers at exit occultation, which is explained in large part by the unexpectedly lengthy lock at enter occultation and a degree of unfamiliarity with the new equipment. Furthermore, the late acquisition entailed no loss of data since (1) the DSS 14 Block III receivers locked up extremely early in the exit occultation, successfully receiving all spacecraft data, and (2) the DSS 14 open-loop receivers successfully acquired data during both enter and exit occultation, thus satisfying radio science requirements.

DSS 43 and 63 acquired and made digital original data records of significant amounts of the 117.6-kbps video data during the spacecraft's approach to and departure from Venus encounter. Selected intervals of this data were relayed to the mission operations center in near-real-time via tape replay at the wideband live rate of 28.5 kbps. At this time, and again when the original data records were received at JPL for Project processing, a problem was discovered in the recorded data. Although all the data was recorded on the original data record, some tapes contained scrambled data wherein "older" and "newer" data were interleaved in a repetitive pattern. The Mission Control and Computing Center, using special processing techniques, was, however, able to recover the video frames from tapes which exhibited this problem. DSN engineering support was requested to help analyze the problem. Special tests were planned to be conducted at CTA 21 and DSS 14, but at this time the effort was given a rather low priority since 117.6 kbps would not be possible at Mercury encounter due to the spacecraft high-gain antenna problem. This problem is discussed further in the section dealing with March 1973 - Mercury Encounter.

On February 17, 1974, the spacecraft lost Canopus lock and consequently its roll position reference. A spacecraft emergency was declared by the Project because of the potential excessive use of attitude control gas when the spacecraft was under gyro roll control. With the spacecraft in this mode, 64-m station support was required to minimize data loss caused by the spacecraft high-gain and low-gain interferometry effects. A decision was made to terminate DSS 63 tracking of Pioneer 11 and to rapidly reconfigure for Mariner 10 support. The emergency condition was terminated on reacquisition of Canopus. Anomalies such as this which exerted nongravitational forces on the spacecraft necessitated the significant changes to the tracking support schedule during this period. A new radio metric data generation technique, near-simultaneous ranging, was developed and applied as an important navigation tool throughout the remainder of the Mariner 10 mission. Closely spaced range points taken from the different longitudes during their short period of mutual viewing of the spacecraft proved to be valuable in resolving the navigational uncertainties when dealing with short arc solutions. An example of the complex schedule arrangements necessary to support near-simultaneous ranging is illustrated in Fig. 157.

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6. Mercury Encounter: March 1974

March 1974 proved to be the most dynamic and critical period of this rather eventful mission. This period saw the correction of one spacecraft problem and the occurrence of other problems requiring the DSN to again rapidly respond with appropriate changes in plans, procedures, configurations and schedules. DSN preparations for trajectory correction maneuver 3 and for Mercury encounter were completed, however, and support was provided in an outstanding manner.

During early March 1974, the DSN gave priority to preparations for the third trajectory correction maneuver and to the development of final sequences of events for Mercury encounter. Trajectory correction maneuver 3 was planned to occur over DSS 14 on March 16 and the encounter television sequence was planned around a 22.5-kbps data rate, rather than 117.6 kbps, due to the spacecraft antenna feed problem. However, two events during the first week in March 1974 required significant changes to these near-final arrangements.

In tracking the Earth throughout the flight, the spacecraft high-gain antenna feed went from a sun-illuminated position into a shadowed position on December 25, 1973, and the partial failure was observed. On March 4, 1974, the antenna feed exited the shadow position back into sunlight and the high-gain antenna problem went away. This, of course, reopened the possibility of real-time 117.6-kbps video operations at Mercury encounter. Further, on March 6, 1974, the spacecraft lost lock on the reference star Canopus, and gyros automatically came on to provide attitude stability. However, the roll gyro began oscillating and resulted in high consumption of attitude control gas. Gas usage effects on the orbit were such to shift the third trajectory correction maneuver from DSS 14 to the DSS 43 viewperiod. Further orbit refinements again shifted the maneuver to occur over DSS 63.

These problems and changes resulted in a heavy unanticipated replanning load at the time when plans should have been in the final stage for the approaching encounter with Mercury. Revival of the 117-kbps TV sequence required development of special telecommunications link performance measurement tests, changes to planned deep space stations configurations, and schedule negotiations to accommodate Mariner 10 and Pioneer during encounter.

Orbit uncertainties due to nongravitational forces required development and execution of special procedures for generation of simultaneous doppler and near-simultaneous ranging data to accurately refine the orbit following the third correction maneuver. Furthermore, to preclude excessive gas consumption during any future loss of Canopus, the spacecraft was placed into a free-drift mode using solar pressure on the solar panels as an assist to attitude stabilization. In this mode, automatic gyro turn-on was inhibited. Consequently, loss of Canopus would result in the spacecraft's high-gain antenna drifting off the Earth line and would require 64-m deep space station support for reacquisition. Therefore, special arrangements were negotiated with the Pioneer Project, and new DSN procedures were developed wherein one telemetry string at the 64-m stations would always be configured for immediate Mariner 10 support.

The introduction of these late but necessary changes shortly before the critical encounter period caused a great deal of DSN concern regarding the ability of the network to avoid operational errors which would be detrimental to the primary mission objectives. DSN operations planners and advisors gave close support during this high risk situation to help assure that required results were achieved.

On March 7, 1974, the DSN conducted a special review of various discrepancy areas in the network, particularly those which represented continuing problems and those with a potential to impact Mercury encounter support. The discrepancy report review board consisted of representatives of DSN Operations and Engineering. Following is a summary of significant items discussed:

The recently implemented planetary ranging capability soon logged a number of discrepancies. Many of the problems were traceable to a lack of operational experience which significantly improved with time. However, error dispersion continued to be larger than anticipated, and frequent biases and offsets were observed between station passes. DSS 63 exhibited a rather consistent 20-m bias. Consensus was that this ranging performance would meet Mariner 10 navigation requirements and that ranging assemblies should not be perturbed by any rework prior to the end of mission. Recommended areas for on-going study included (1) recalculation and verification of 64-m antenna Z height, (2) check for timing errors as a possible cause, (3) resurvey the DSS 63 site location, and (4) evaluate calibration accuracies using the zero delay device as a function of antenna angle position.

DSS command subcarrier frequency and bit rate error alarms occur periodically and account for a large percentage of open discrepancy reports in the system; 30 were open at the time of the review. It is important to note that these are alarms, not aborts. The DSN had experienced only one command abort for Mariner 10 due to an erroneous bit rate. Standard practice is to set the subcarrier frequency alarm limit tighter than the project abort limit; e.g., alarm at ±0.2 Hz, abort at ±-0.3 Hz deviation. Analysis of DSS analog tape readouts disclosed that some 80% of bit rate error alarms were false alarms resulting from bit rate detection circuitry errors rather than actual bit rate errors. When these alarms occurred, they usually cleared immediately and normal commanding was resumed. Infrequently, the alarms persisted, requiring switch to the backup command string. In either case, short delays have had little or no effect on mission operations since Mariner 10 is an automated spacecraft. However, concern increased with the number of spacecraft emergencies requiring critical ground command activity. Two approved engineering change orders, which would have corrected a block counter interface problem, were available for implementation. However, it was decided that installation would be delayed until after Mercury encounter. Also, a widening of the subcarrier frequency tolerance could have been easily accommodated during prepass initialization instruction, but the Project requested that the present alarm limits be maintained.

Although installation of new selector channels and other modifications significantly improved the data decoder assembly performance, problems continued throughout the network. A number of discrepancies were grouped into two categories: data decoder assembly external and data decoder assembly internal.

The data decoder assembly external category included those events involving decoder assembly halt and alarms. These problems were very intermittent and were usually cleared in less than 10 min by reinitialization or reload of the decoder assembly. Specific cause analysis was difficult due to the lack of data. Deep Space Stations need to dump the decoder assembly memory when a halt or alarm occurs in order to get useful trouble shooting data; however, most projects are reluctant to approve an additional 15- to 20-min data outage while this is done. Postreview coordination with the MVM'73 resulted in an agreement and procedures for data decoder assembly memory dumps as required when critical Project data were not being handled.

The data decoder assembly internal category included those discrepancies involving bit errors, improper data sequences, and timing errors. Telemetry data timing errors were resolved by special operational procedures involving front panel restart when timing errors were observed. Of more concern was the mixing of data in the decoder assembly through a linear combination of bits. This was observed in some of the Venus encounter digital original data records as previously mentioned. All bits were recorded but were out of sequence in a systematic interleaving pattern. It was suggested that this was an initialization procedure problem. Actions were assigned for a special testing to verify the specific cause and to develop a solution. Since return of the spacecraft telecommunications link to normal gain and polarity again made real-time 117-kbps data possible at Mercury encounter, priority attention was now given to this problem. Special tests were conducted at DSS 14 and at CTA 21 to determine the cause of the data being out of sequence. As suspected, the problem was operationally induced and could be corrected by changes in operational procedures. To avoid having prepass countdown simulated data on the record delivered to the Project, the original procedure called for loading of virgin tapes following completion of station countdown activities. This apparently left the data decoder assembly pointers out of phase with the high-density recorder tape position. The high duty cycle at 117 kbps then apparently resulted in a linear combination of bits in about 25% of the test cases. Reinitialization of the data decoder assembly following loading of the new tape was required to avoid this problem. Special operational instructions to this effect were issued to the Deep Space Stations. No further indications of this problem were observed in the Mercury encounter data.

With normal spacecraft telecommunications link performance restored, a number of special in-flight tests were planned and conducted to make precision measurements of the signal strength, signal-to-noise ratio, and the spacecraft antenna polarization in order to confirm proper operation of the high-gain antenna system and to provide confidence that the 117-kbps TV sequence could be adequately supported at Mercury encounter. Uncertainty as to whether the high-gain antenna would remain healed further impacted support planning, and the DSN continued with its effort to implement linear polarization capability in the 64-m subnet. This capability was completed by mid-March as planned. Utilizing DSS 14 and DSS 63, special telecommunications link performance tests were initiated on March 12, 1974, and continued through March 27, 1974. The mandatory telemetry requirement for Mercury encounter was 22.05 kbps with an error rate of less than 5 bits in 100. The goal was 117.6 kbps with an error rate of less than 3.33 bits in 100. Both required the simultaneous transmission of the second channel at 2450 bps with an error rate of less than 1 bit in 10^4.

During the preliminary analysis of measured data, it became apparent that, if the supercooled masers at DSS 14 and 43 could achieve and maintain a noise temperature of 13.5 K and if spacecraft telecommunications performance stayed at the designed value and if other Deep Space Station performance was normal, 117.6-kbps data at Mercury was, indeed, achievable. Obviously the difference between success and failure, in terms of acceptable bit error rate, was measured in a few tenths of a dB. The first telecommunications link performance test was conducted on March 12, 1974, using DSS 14 and DSS 43 configured for minimum noise temperature operations, using the supercooled, low-noise masers. At the time, the spacecraft had some attitude control difficulties which placed the spacecraft high-gain antenna boresight off Earth by a significant amount. However, this effect was calculable and only added a small residual uncertainty. The procedure followed involved moving the ground antenna off track to produce a synthetic attenuation of the signal from the spacecraft without modifying the noise temperature conditions at the station. The ground antenna offsets were designed for approximately -2, -3, and -4 dB from the current link conditions. This eliminated, to a large extent, the dependence on absolute values and predicts and substituted the range distance increase from the test time to encounter which automatically included all nonlinear effects at these signal-to-noise ratios. The additional range increase to Mercury would produce a 3.5 dB decrease in received signal level; therefore, a plot of bit error rate as a function of dB down from current conditions would indicate the expected error rate at encounter within the uncertainty of the measurement of the data points.

Since precision measurement of the telecommunications link performance to the required tenth of a dB resolution was beyond the capability of the current system, it was decided to use the video histograms as a measure of the bit error rate and to convert this data to a signal-to-noise ratio value. To accomplish this, the spacecraft television system was turned off and the flight data system was commanded to interrogate the television at the 117.6-kbps rate. This produced a black picture with a slight amount of residual noise at the spacecraft. The flight data system quantifies the elements of the picture into 8-bit binary pixels. This is then biphased-modulated on a high-rate subcarrier, interplexed with the low-rate stream and modulated on the downlink carrier.

The end result, after reception, demodulation, synchronization, and dequantization is either a picture or a histogram of the decimal values of each pixel. From the histogram, it was now possible to measure the total link bit error rate and to eliminate the residual spacecraft noise since spacecraft noise existed in the least significant bits and link noise existed uniformly on all bits. As many bits as possible were utilized to maximize the confidence level in the measurements. Strong signal tests had indicated that only the two least significant bits would be affected by peak residual noise. This was checked by plotting the derived error rate as a function of the number of bits used and correlating this with the total number of bits per picture used to calculate the error rate. Figure 158 gives an example of this plot for one particular picture and illustrates that using the two least significant bits (bits 7 and 8) in the calculation increases the total error rate due to the spacecraft residual noise. The bits used for link error rate measurement were the six most significant bits.

The result of the above testing was a set of points cross-correlating bit error rate and dB decrease in signal. Since dB decrease is related to range increase, which is in turn related to time by the trajectory, one may now plot bit error rate vs time as is illustrated in Fig. 159. In this figure, time is deliberately set from right to left to correspond to a loss in dB. The 1-sigma elipses are signal-to-noise ratio estimates converted to error rate in the ordinate and carrier level estimate deltas in the abscissa, together with the tolerances. The histogram error rates are plotted as points. As can be seen, the expected error rate at encounter was 3.8 in 100, while the TV experiment goal was 3.33 in 100. But there still were several considerations that were not yet included. During the subject testing, the elevation angle of the Deep Space Station peaked at 37.5 deg. However, at encounter it would peak at 42 deg. This would result in an approximate 0.1-dB improvement in the encounter operations. Second, the tests were conducted on rather short notice and station personnel had little opportunity to fine-tune or closely calibrate station equipment; therefore, it was expected that, at encounter time, ground performance would be even better than that exhibited during the test due to the conduct of special countdowns prior to Mercury.

These short 10-minute in-flight performance evaluation tests which were conducted prior to Mercury encounter are listed in Table 49. Plots derived from data taken by DSS 14 are given in Fig. 160 and for DSS 43 in Fig. 161. On March 20, 1974, a decision was made to switch spacecraft exciters. This was in response to the celestial mechanics and radio science teams' analysis of the oscillator's phase noise spectrum. This action also caused a switch to a different telemetry phase modulator in the spacecraft which, according to preflight test data, could provide a potential improvement of 0.1 dB. On March 27, 1974, just two days before encounter, the Project requested a final error rate predict for the encounter pass at Goldstone. The value given by the Spacecraft Telecommunications Group was 2.29 bit errors in 100, the equivalent signal-to-noise ratio was 3 dB at 17 hours 18 minutes 59 seconds on March 29, 1974. Actual encounter measurements, including the design predict of October 18, 1972, the preflight predict of October 4, 1973, and the in-flight predict of March 27, 1974, are given in Fig. 162. The mean deviation over the 2-1/2 hours at encounter was 0.2 dB from preflight data and 0 dB from in-flight data. Figures 163 through 174 are selected plots of downlink carrier and ST_B/N_0 residuals at 22.05 kbps at DSS 63, 43, and 14. Figures 175 through 177 are plots of ST_B/N_0 residuals at 117.6 kbps from DSS 14 configured in a listen only mode.

Although the telecommunications performance tests continued until encounter, standard DSN encounter readiness tests were completed by mid-March 1974. The DSN Operations Status Review for Mercury Encounter was conducted on 24 March 1974. The purpose was to evaluate the final status of encounter preparations and to review potential problem areas. The review was comprehensive in that it covered test and training, documentation updates, encounter time lines, occultation strategies, configurations, configuration freeze plans, data shipment plans, staffing, and discrepancy report status. All items exhibited a satisfactory readiness posture for the start of encounter operations.

As planned, the March period saw an increasing use of the 64-m subnet for Mariner 10 support, including the third trajectory correction maneuver and the encounter. However, the Pioneer Project tracking requirements limited the configuration freeze for Mariner 10 to an 8-day period around encounter rather than the desired 20-day period. Table 50 summarizes key DSS tracking pass and command activities. Slightly over half of 112 total passes were provided by the 64-m subnet, and the total number of passes again reflects the split pass strategy and the simultaneous scheduling of DSS 12 and 14 and DSS 42 and 43 to achieve the encounter "listen only" mode at the 64-m stations, while permitting commanding from the 26-m stations. Command activity was high, reflecting 5362 commands during the period, with two aborts occurring at DSS 43, as a result of the failure of bits to verify in the confirmation sequence.

During the March period, the DSN telemetry system experienced some 6.46 hr of downtime, causing real-time data loss and giving a reliability of 99.1%. Data lost in real-time was subsequently recovered from backup data records. DSN analysis of Mariner 10 downlink residuals consisted of 72 observations with a mean of 0.8 dB, a variance of 0.4 dB, and a standard deviation of 0.6 dB. Of these values, 61% had variations of less than 1 dB from predicted and 20% had variations of less than 0.3 dB from predicted. The statistical mode was found in the decile representing 0.3 to 0.4 dB. The analysis of Mariner 10's signal-to-noise ratio residuals consisted of 72 observations with a mean of 0.9 dB, a variance of 0.5 dB, and a standard deviation of 0.7 dB. Of these values, 57% had variations of less than 1 dB from predicted and 22% had variations of less than 0.3 dB from predicted. The statistical mode was found in a decile representing 0.2 to 0.3 dB. Downlink AGC and SNR residuals are shown in Figs. 178 through 183.

Starting on March 23, 1974, the Mercury encounter sequence listed in Table 51 was supported by the DSN in a highly successful manner with no significant problems. The Network's performance in the acquisition and handling of the dual 117.6-kbps and 2450-bps data streams from near-encounter exceeded performance expectations. The Network Operations Analysis Group (A. Berman and G. Spradlin) again produced the following detailed account of Mercury near-encounter operations.

Table 49. 117.6-kbps tests

		Mean SNR deviation from predicts, dB	
Day, 1974	Exciter	DSS 14	DSS 43
March 12	1	-0.5	
March 13	1		+0.2
March 20	1	-0.4	
March 22	2	+0.0	
March 24	2		+0.3
March 25	2		+0.1
March 26	2	+0.0	+0.4
March 27	2		-0.1
March 28	2	+0.5	-0.1
Encounter			
March 29	2	+0.2	+0.1

Table 50. Mercury encounter: March 1 - April 1, 1974

Item	California		Australia		Spain		Network totals
	DSS 12	DSS 14	DSS 42	DSS 43	DSS 62	DSS 63	
1. Tracking passes this period	17	23	16	22	21	13	112 passes
2. Cumulative passes	96	106	112	57	112	48	531 passes
3. Tracking hours this period	112	206	179	221	192	112	1022 hr
4. Cumulative tracking hours	820	739	984	601	1062	403	4609 hr
5. Commands this period	544	2178	588	840	1061	151	5362 commands
6. Cumulative commands	5377	4192	1058	1723	1635	332	14,317 commands
7. Command aborts this period	0	0	0	2	0	0	2 aborts
8. Cumulative aborts	2	4	0	2	0	0	8 aborts

Table 51. Significant Mercury encounter events

Date (1974)	GMT	Event
March 21	14:30-18:30	U-16.2 CC&S update to reconfigure a portion of computer memory to provide 117-kbps data at close encounter
	19:00-10:45	Near simultaneous ranging in support of navigation
	11:40-13:40	Magnetometer flips and calibration and charged particle telescope calibration
March 22	16:00-17:00	DSS 14 bit-error-rate-test
	19:00-10:45	Near simultaneous ranging
	08:30	TV subsystem on for checkout
March 23	11:00	TV light flood and beams on in Edit Mode 1 (skip-slide) and begin imaging phase function measurement. This will return the first Mercury pictures.
	19:00-10:30	First far encounter daily TV and UVSAG science sequence
	10:00-10:30	DSS 43 link performance measurements
March 24	19:00-10:30	Second TV and UVSAG daily science sequence
	10:00-10:30	DSS 43 link performance measurement
March 25	19:00-10:30	Third TV and UVSAG daily science sequence
	10:00-10:30	DSN 43 link performance measurement
March 26	15:00-17:00	U-16.4 E_m-3 day CC&S update to incorporate latest navigation estimates for fine tuning the encounter sequence
	19:00-10:30	Fourth TV and UVSAG daily science sequence. Note: This sequence will utilize 117-kbps data mode

Table 51 (contd)

Date (1974)	GMT	Event
March 26	19:10-08:10	Special GCF circuits to GSFC checkout with 117 kbps data
	10:00-10:30	DSS 43 link performance measurement
March 27	19:00-10:30	Fifth TV and UVSAG daily science sequence
	10:00-10:30	DSS 43 link performance measurement
March 28	19:00-10:30	Sixth TV and UVSAG daily science sequence
	11:00-14:30	Mercury diameter experiment
	16:30	Begin 32-hr close encounter Mercury sequence under CC&S control. (Note: Spacecraft closest approach occurs March 29 at about 08:46 GMT.)
March 29	20:46	Mercury closest approach
March 30	20:20-21:15	Mercury diameter experiment
March 31	02:00	Begin daily outgoing for encounter TV sequences
	17:30-24:00	Mercury satellite search
April 1	08:22-14:07	Mercury satellite search
April 4	18:00-23:14	Optical navigation
April 5	15:07-21:36	Optical navigation
	23:01	Terminate outgoing TV sequence

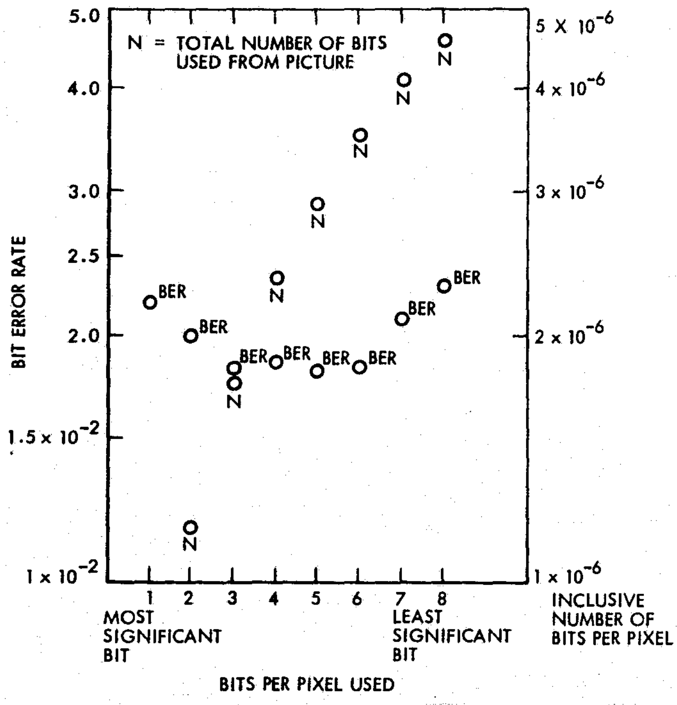

Figure 158. Bit error rate from picture 0129955, March 12, 1974, vs number of bits per pixel used

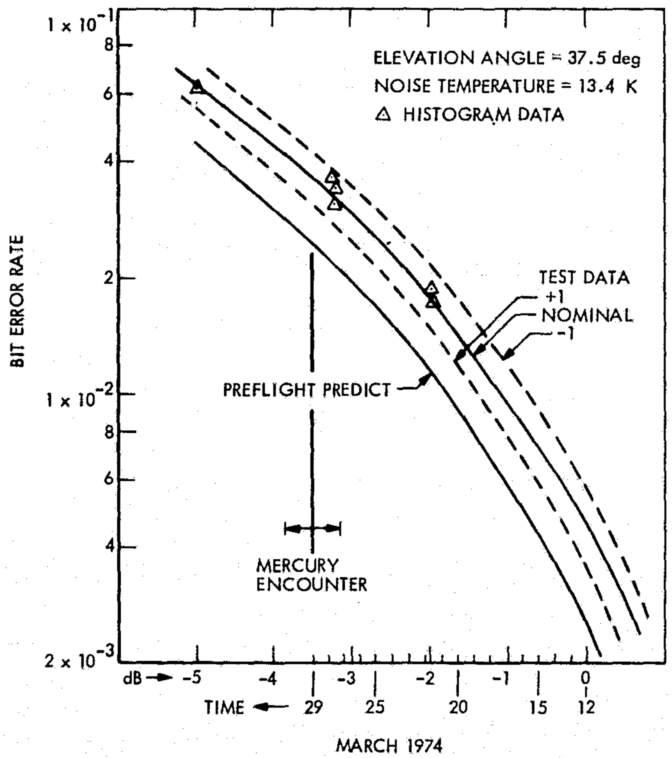

Figure 159. Goldstone 117.6-kbps test bit error rate, March 12, 1974

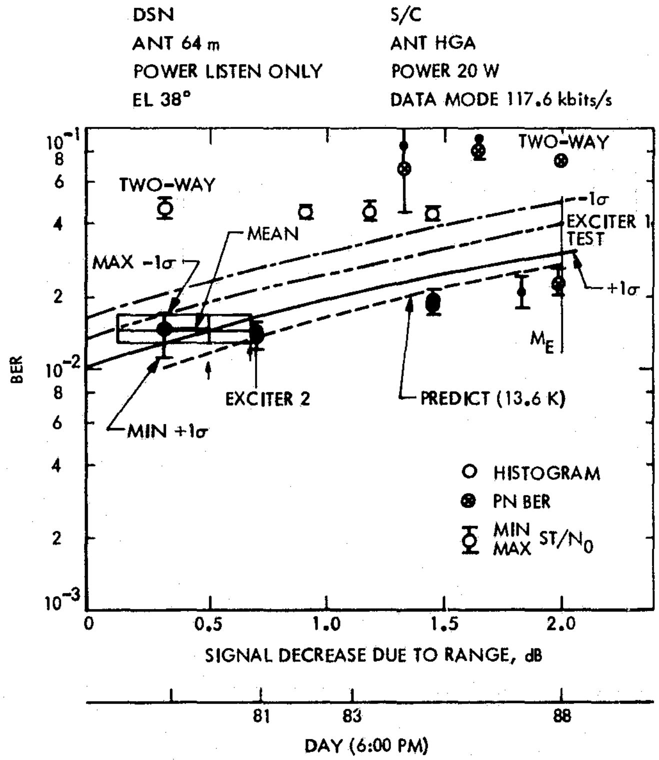

Figure 160. One- and two-way 117.6 kbps tests at DSS 14

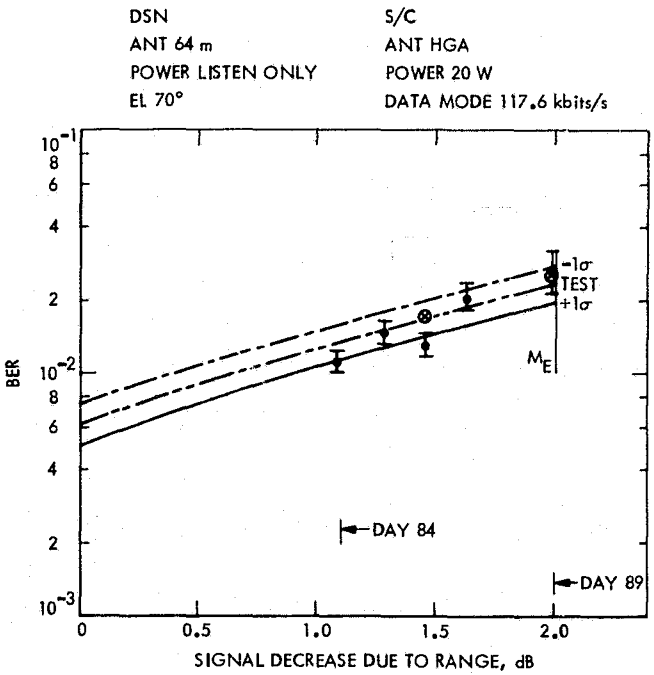

Figure 161. One-way 117.6-kbps tests at DSS 43

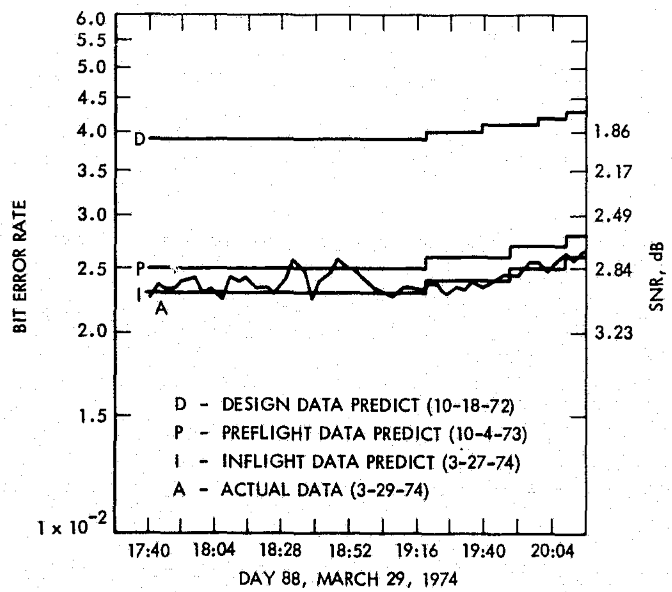

Figure 162. Bit error rate at Goldstone, March 29, 1974, at 117.6 kbps compared to predicts

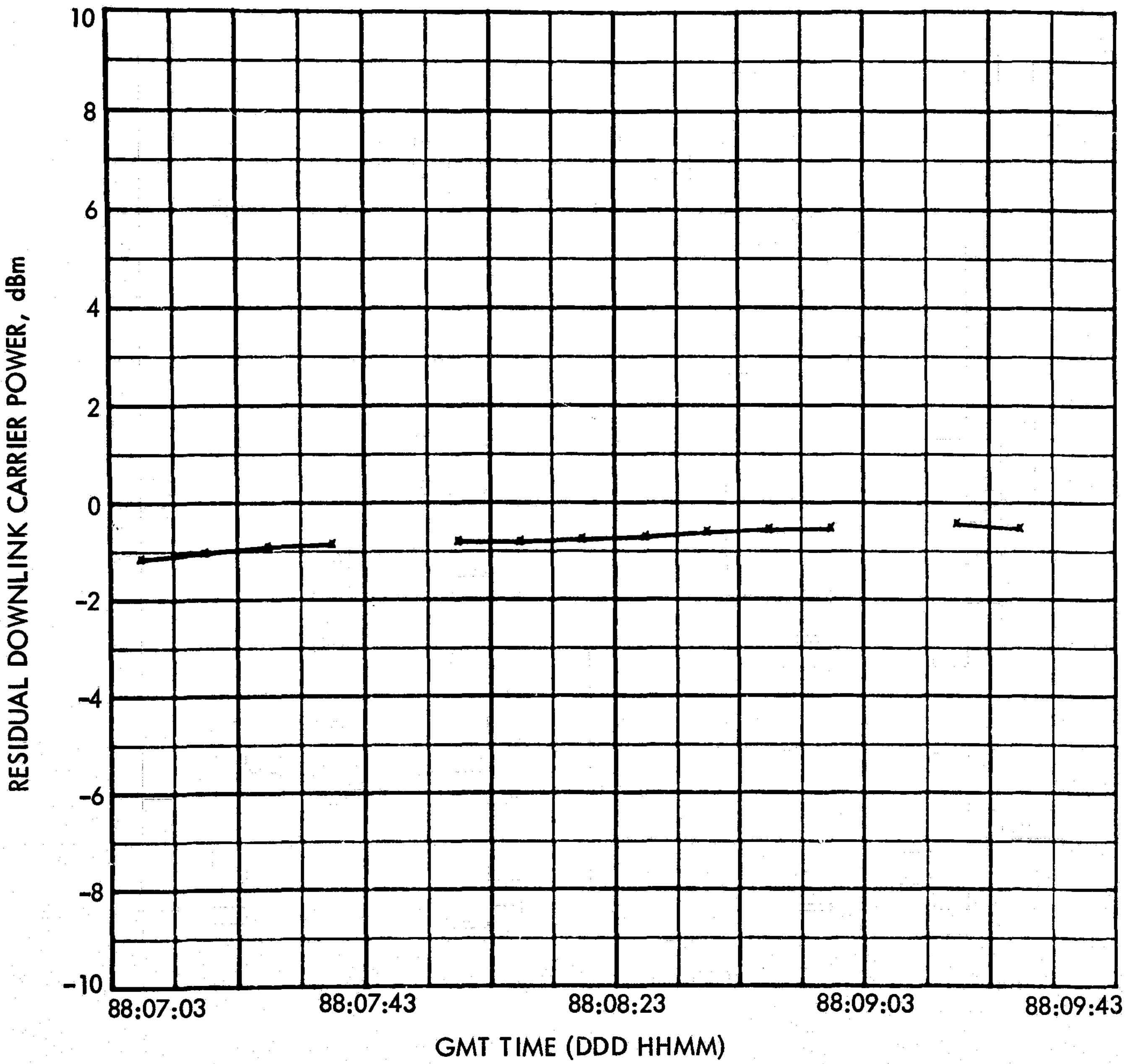

Figure 163. MVM'73 comparison analysis, residual downlink carrier power

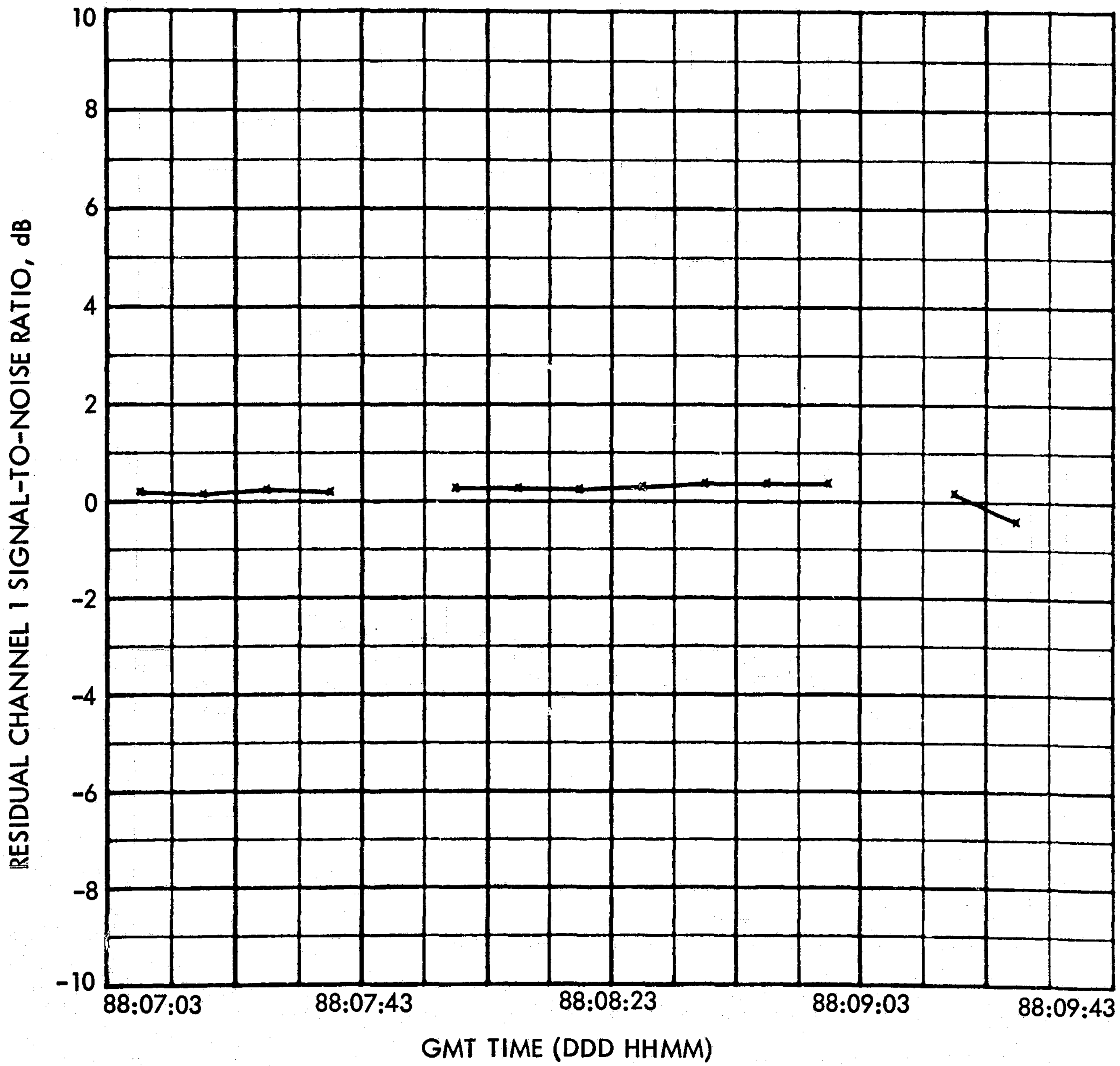

Figure 164. MVM'73 comparison analysis, residual channel 1, signal-to-noise ratio

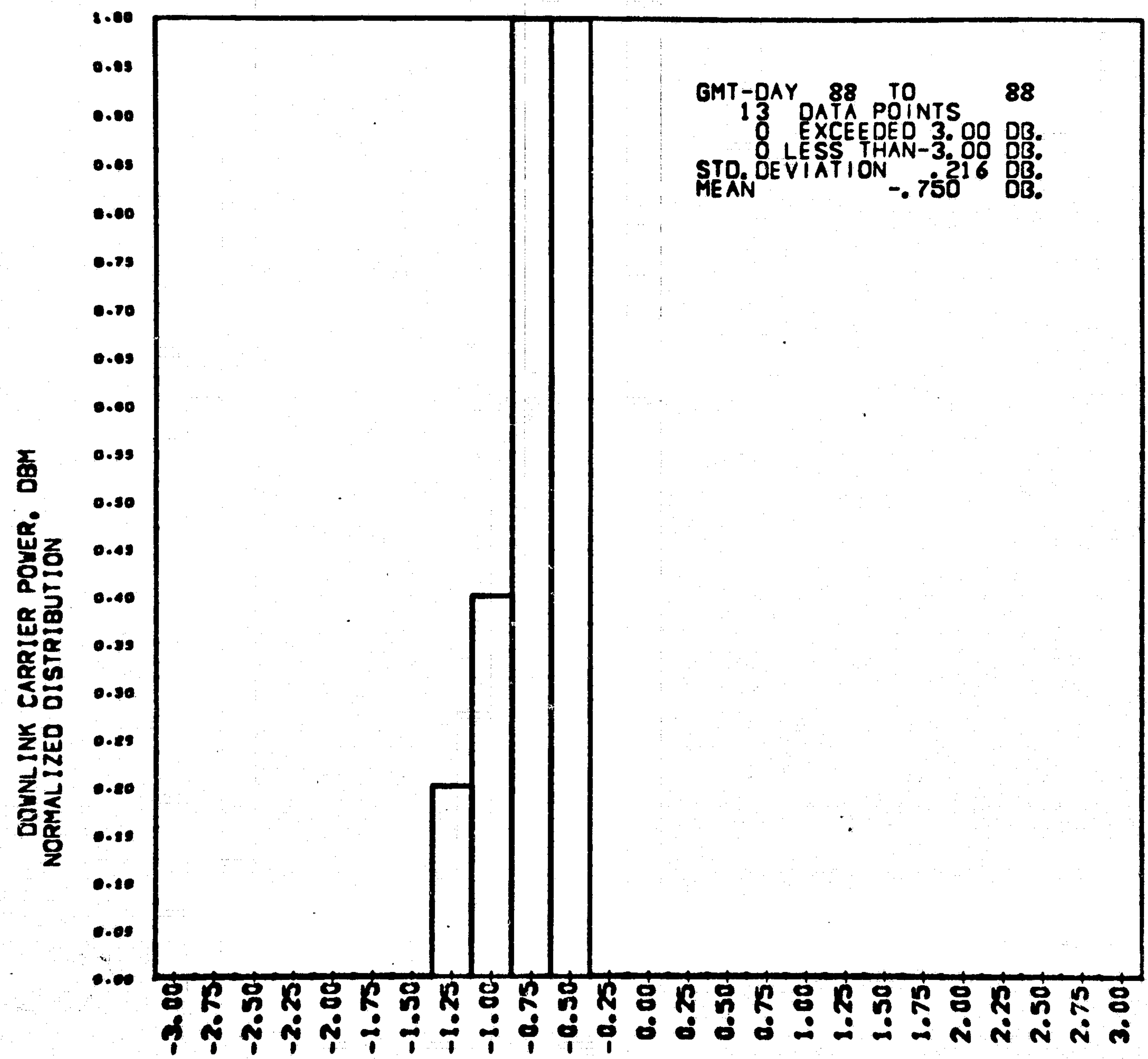

Figure 165. MVM'73 histogram, downlink carrier power

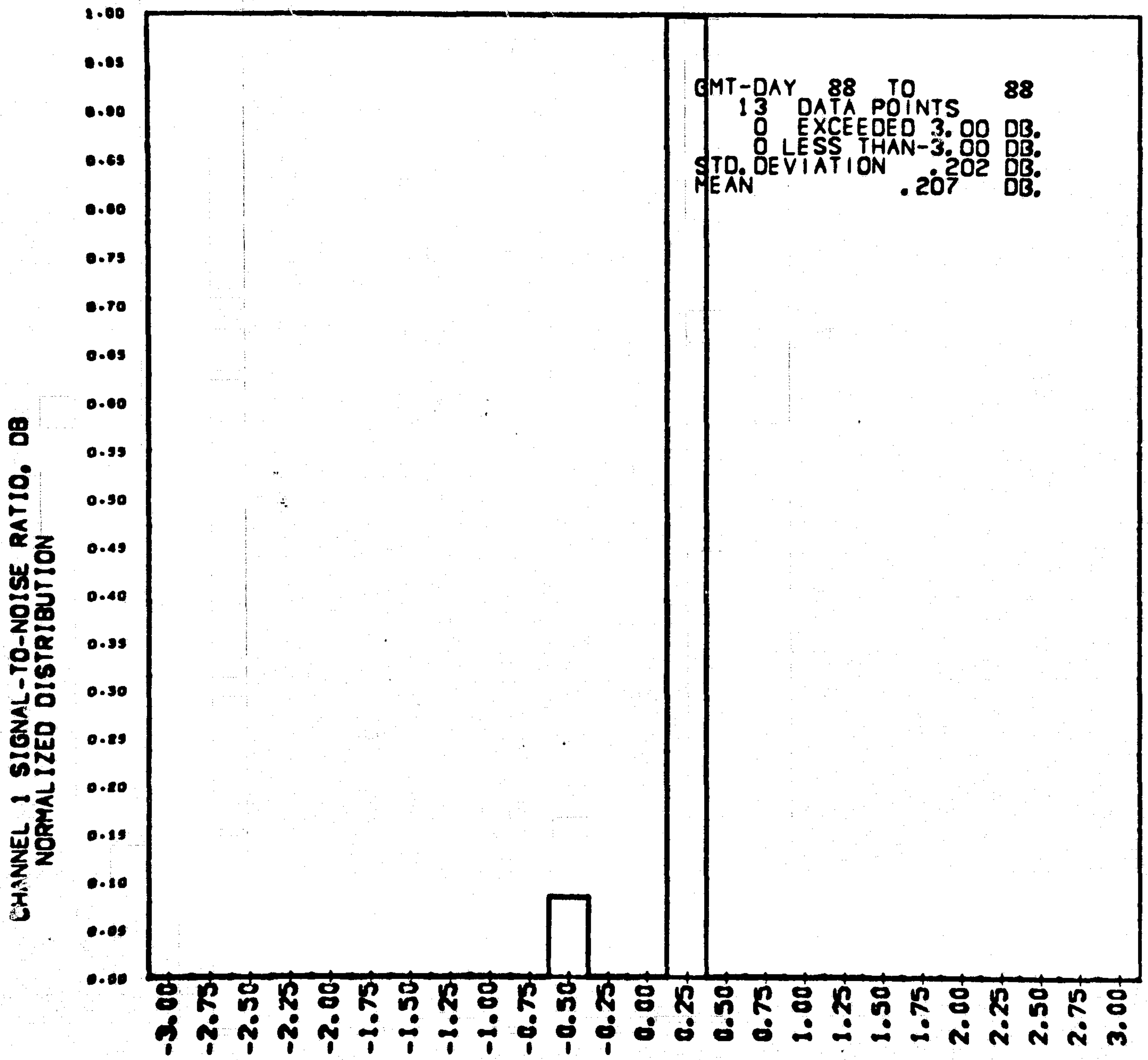

Figure 166. MVM'73 histogram, channel 1 signal-to-noise ratio

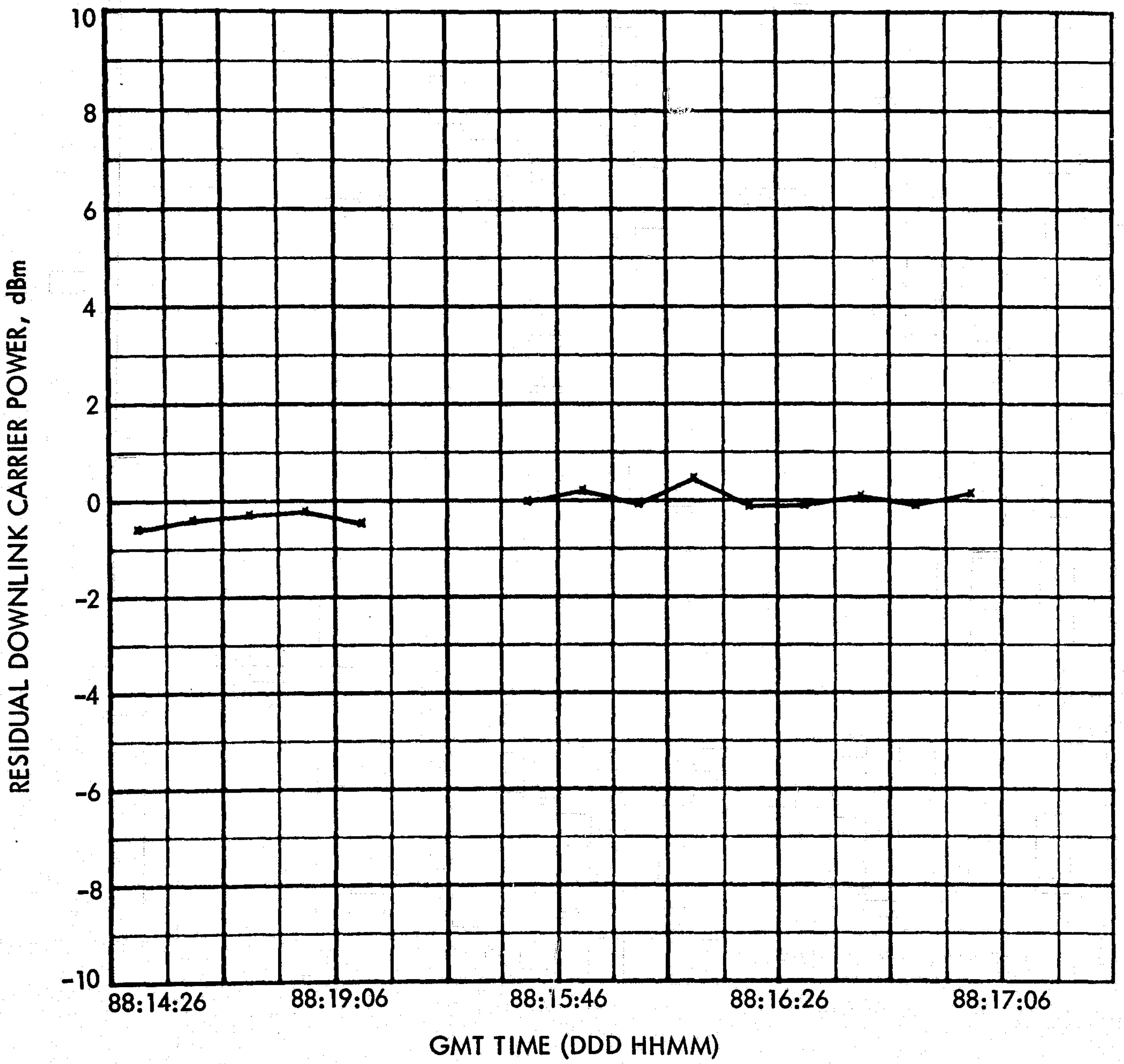

Figure 167. MVM'73 comparison analysis, residual downlink carrier power

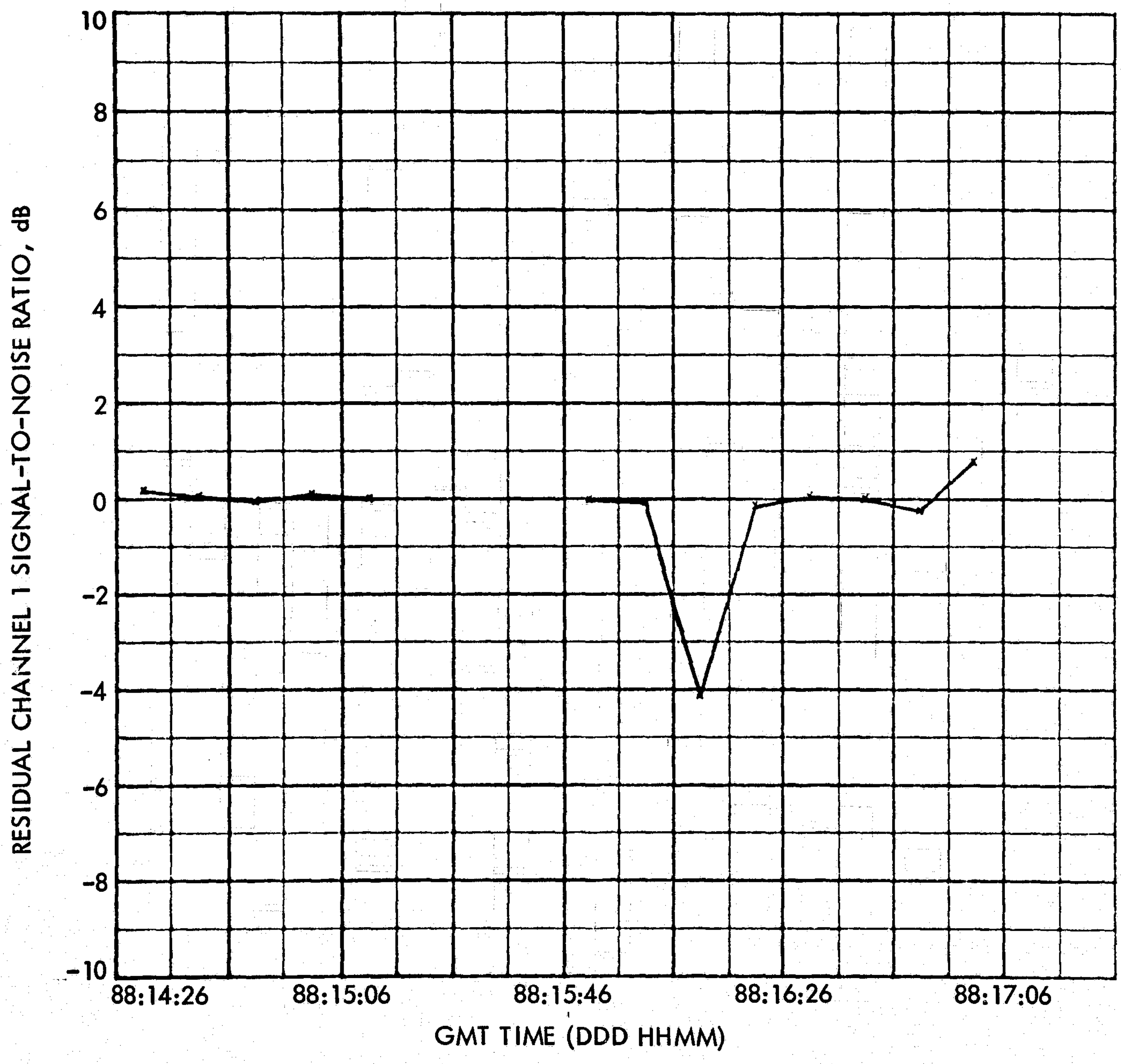

Figure 168. MVM'73 comparison analysis, residual channel 1, signal-to-noise ratio

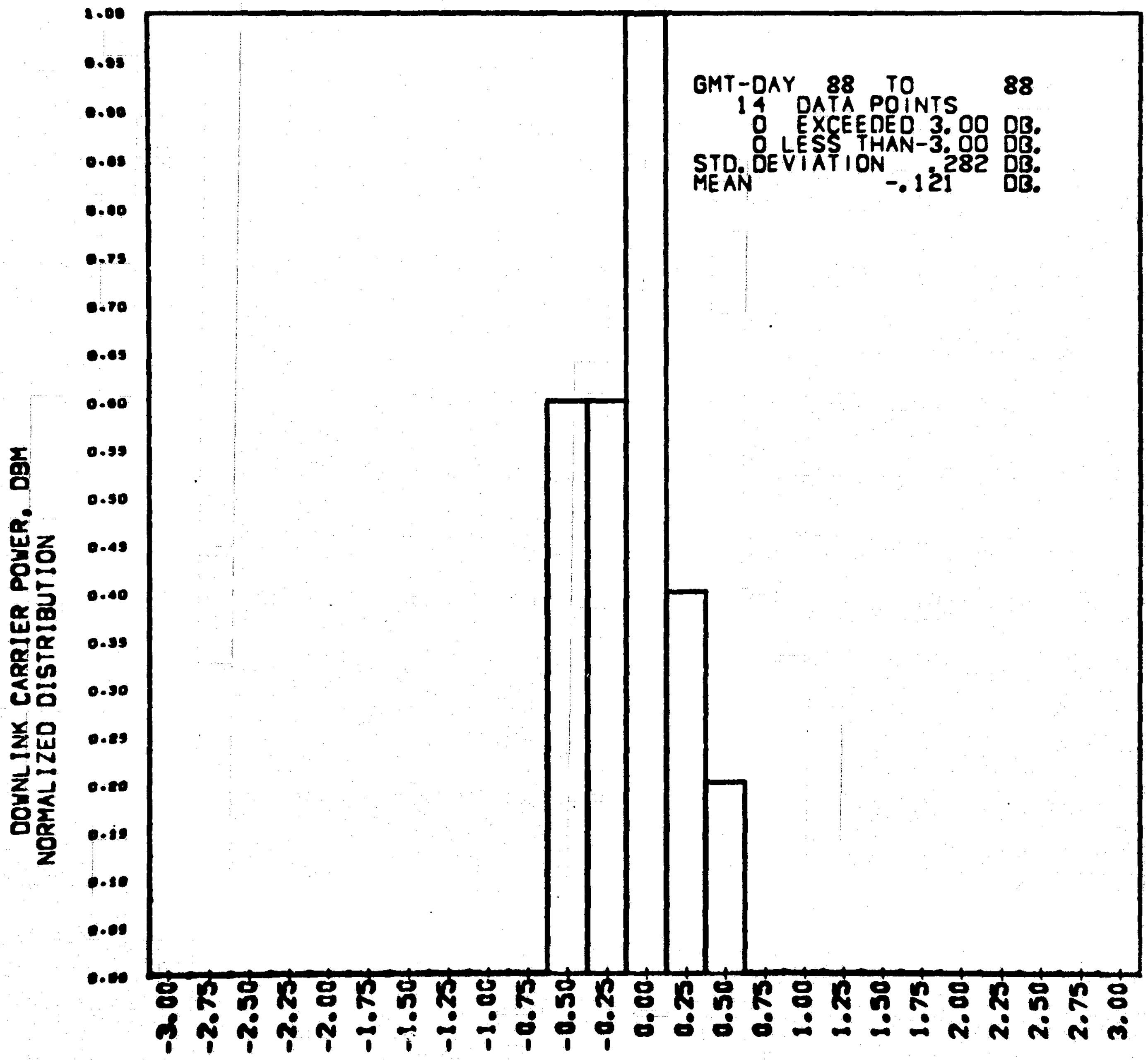

Figure 169. MVM'73 histogram, downlink carrier power

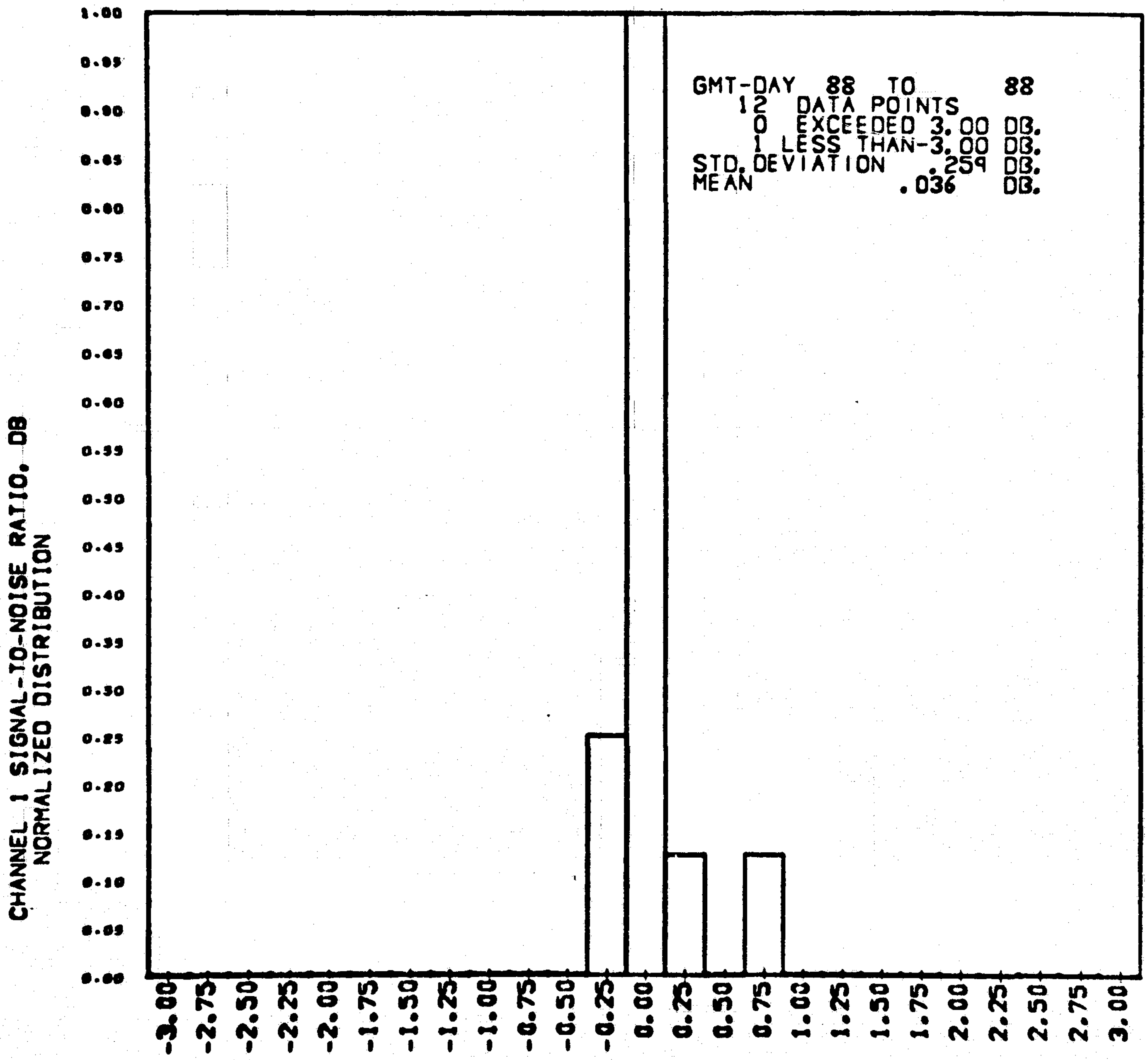

Figure 170. MVM'73 histogram, channel 1, signal-to-noise ratio

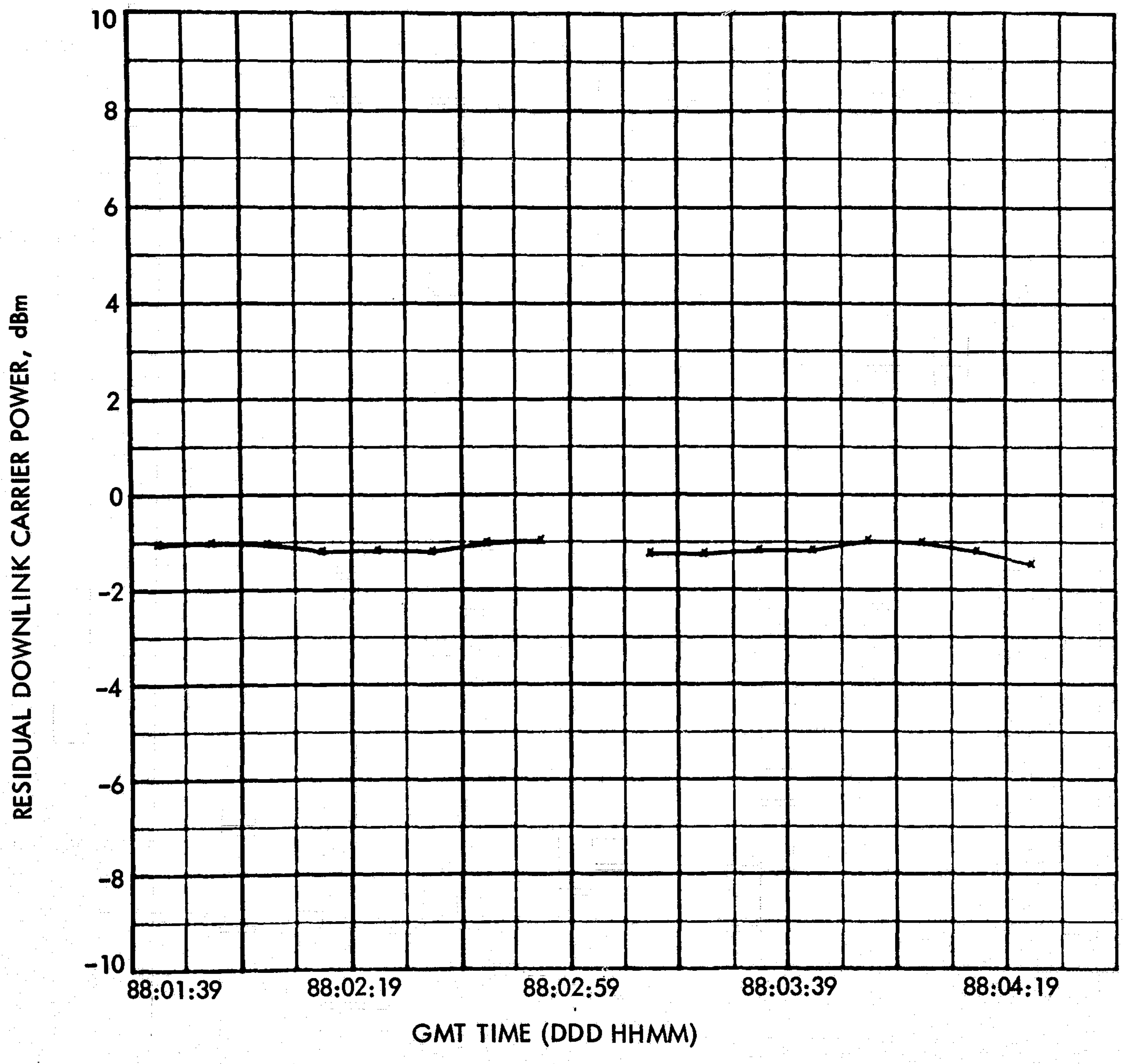

Figure 171. MVM'73 comparison analysis, residual downlink carrier power

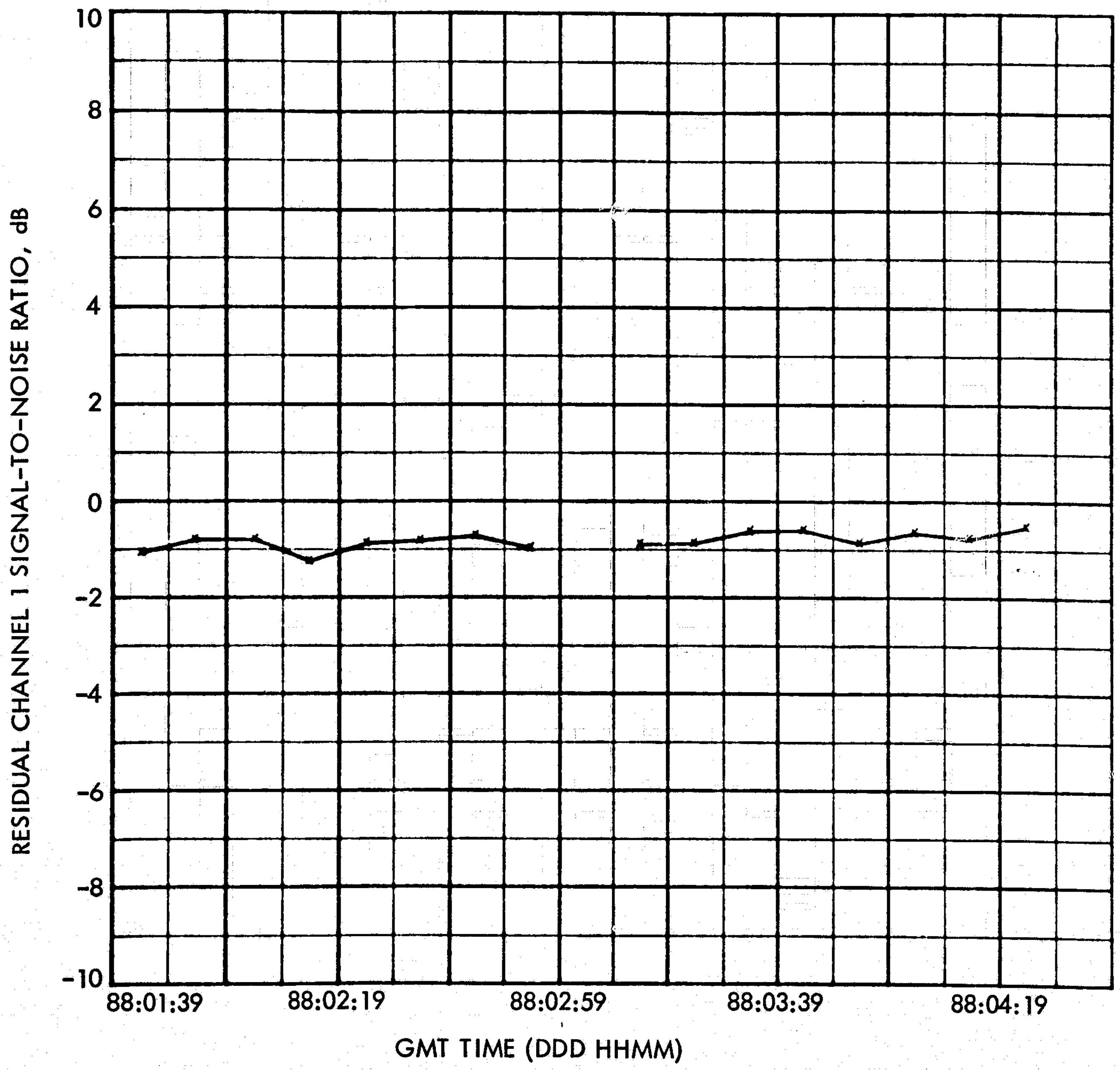

Figure 172. MVM'73 comparison analysis, residual channel 1 signal-to-noise ratio

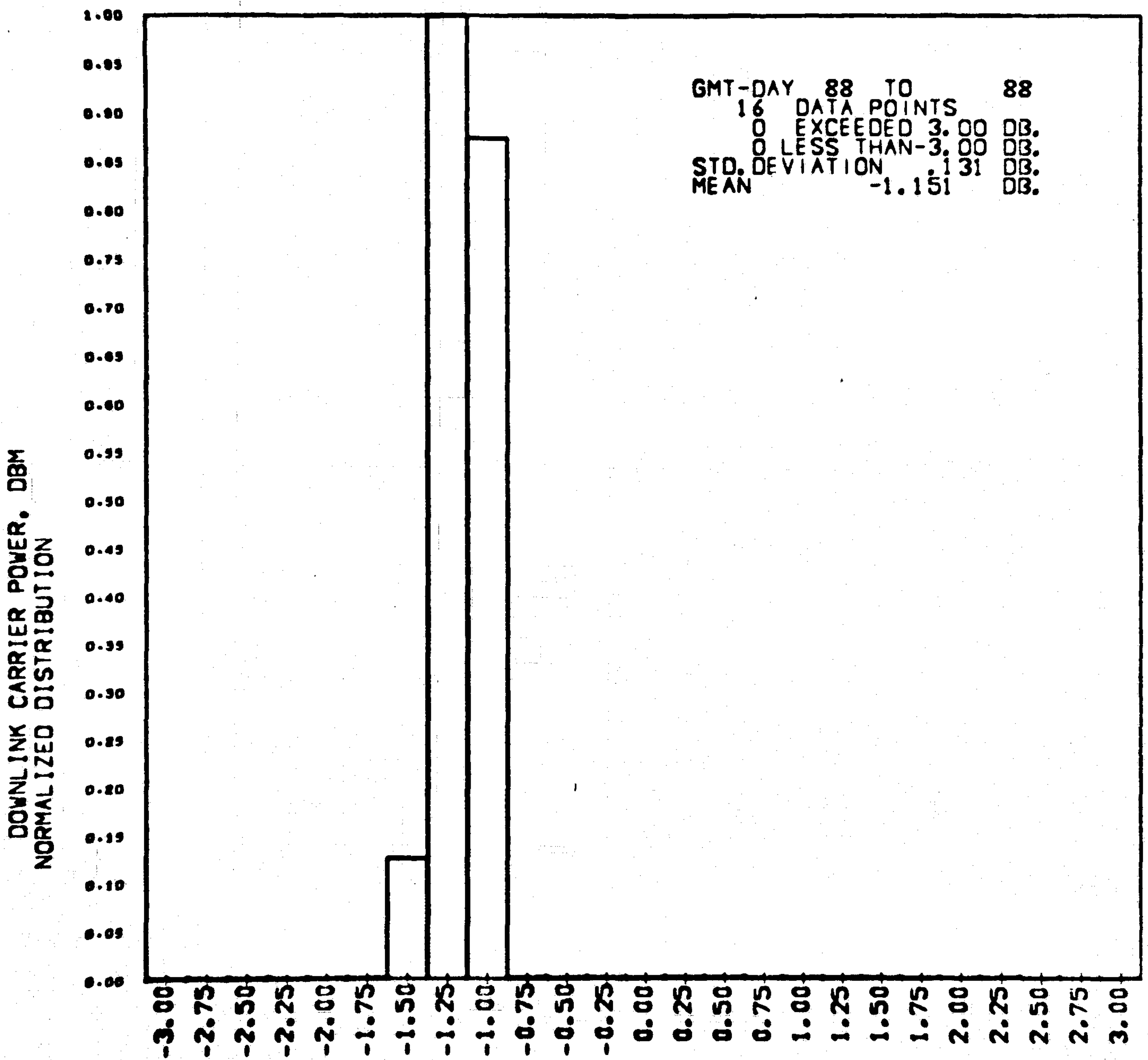

Figure 173. MVM'73 histogram, downlink carrier power

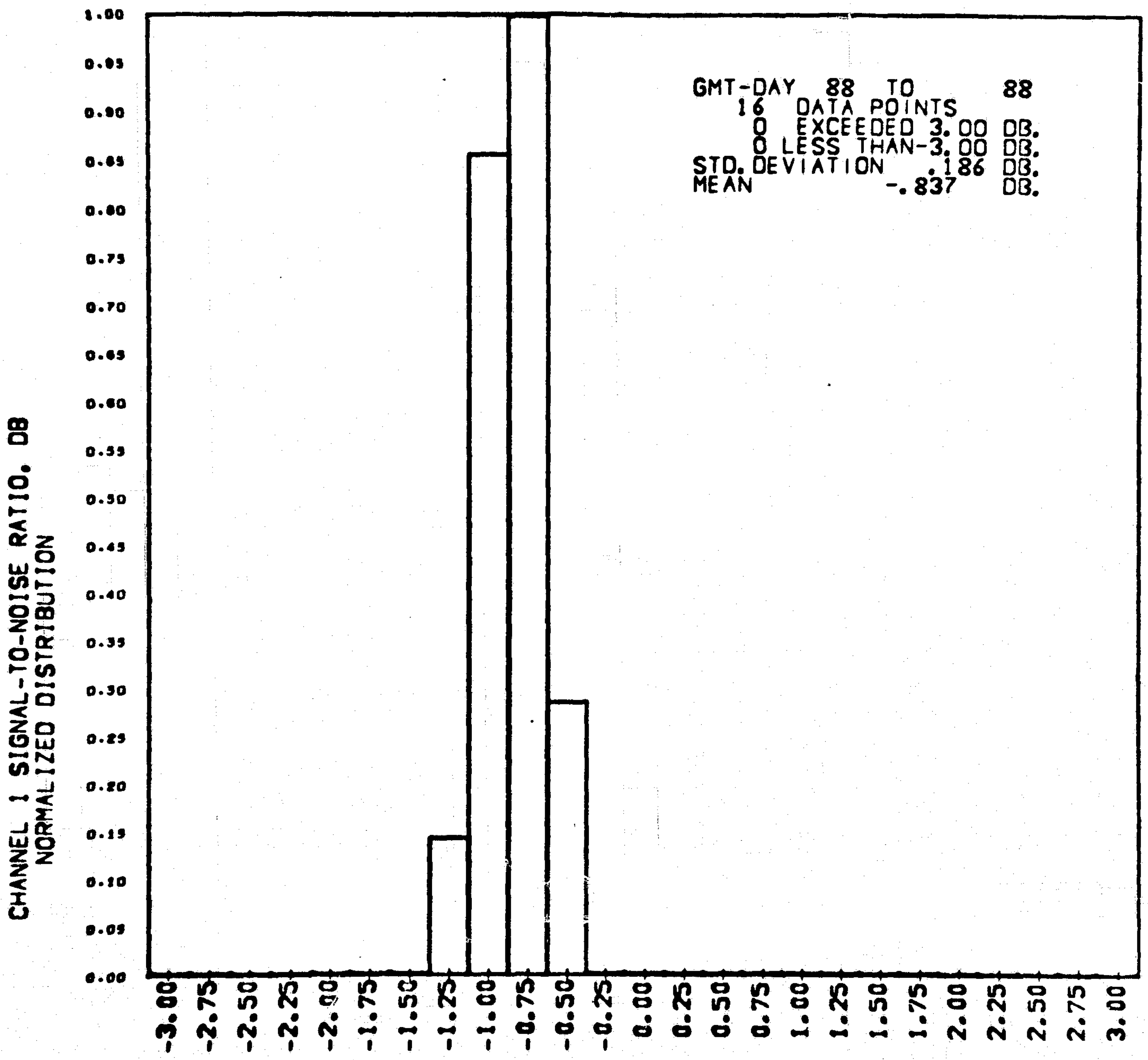

Figure 174. MVM'73 histogram, channel 1, signal-to-noise ratio

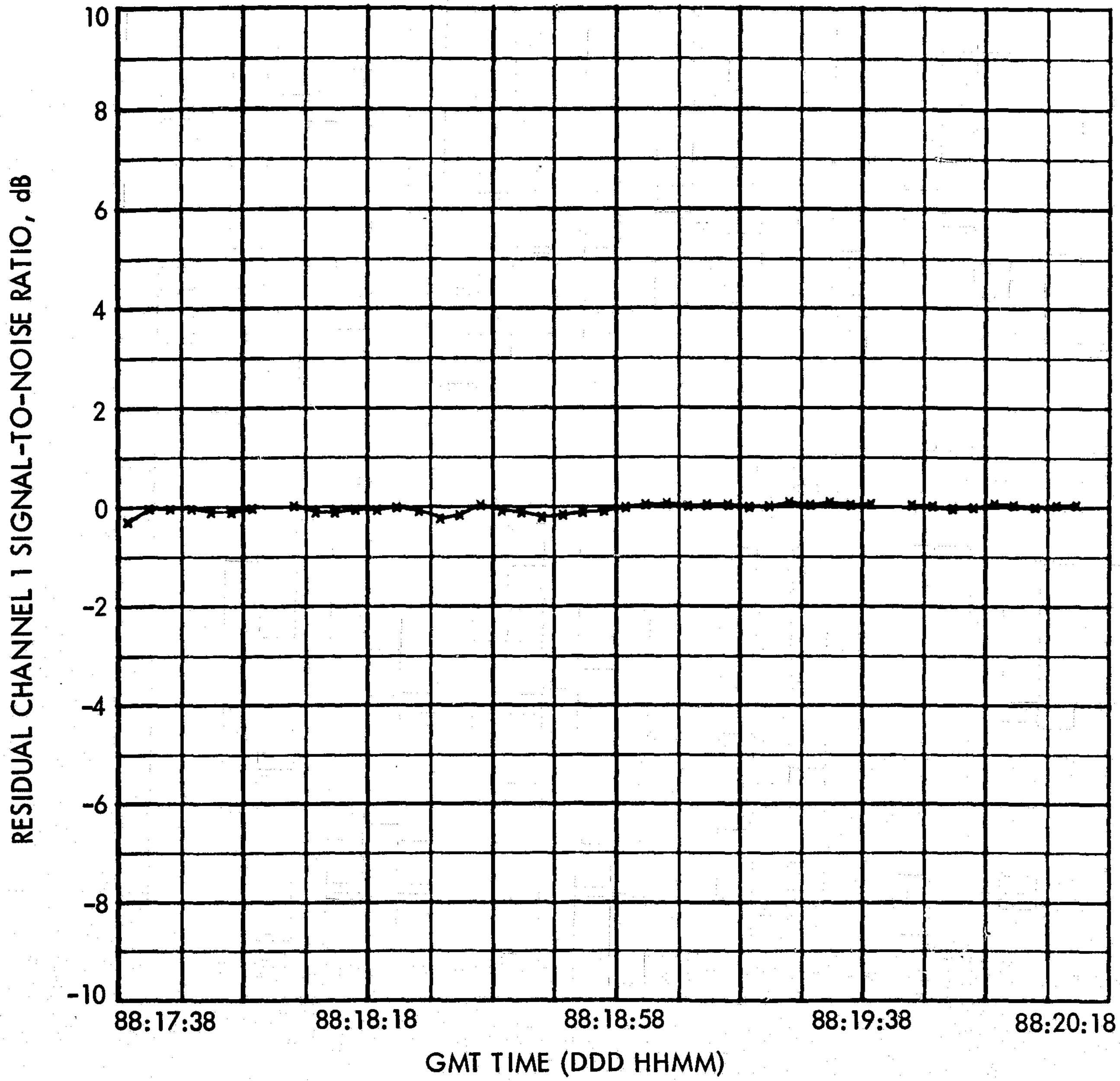

Figure 175. MVM'73 comparison analysis, residual channel 1 signal-to-noise ratio

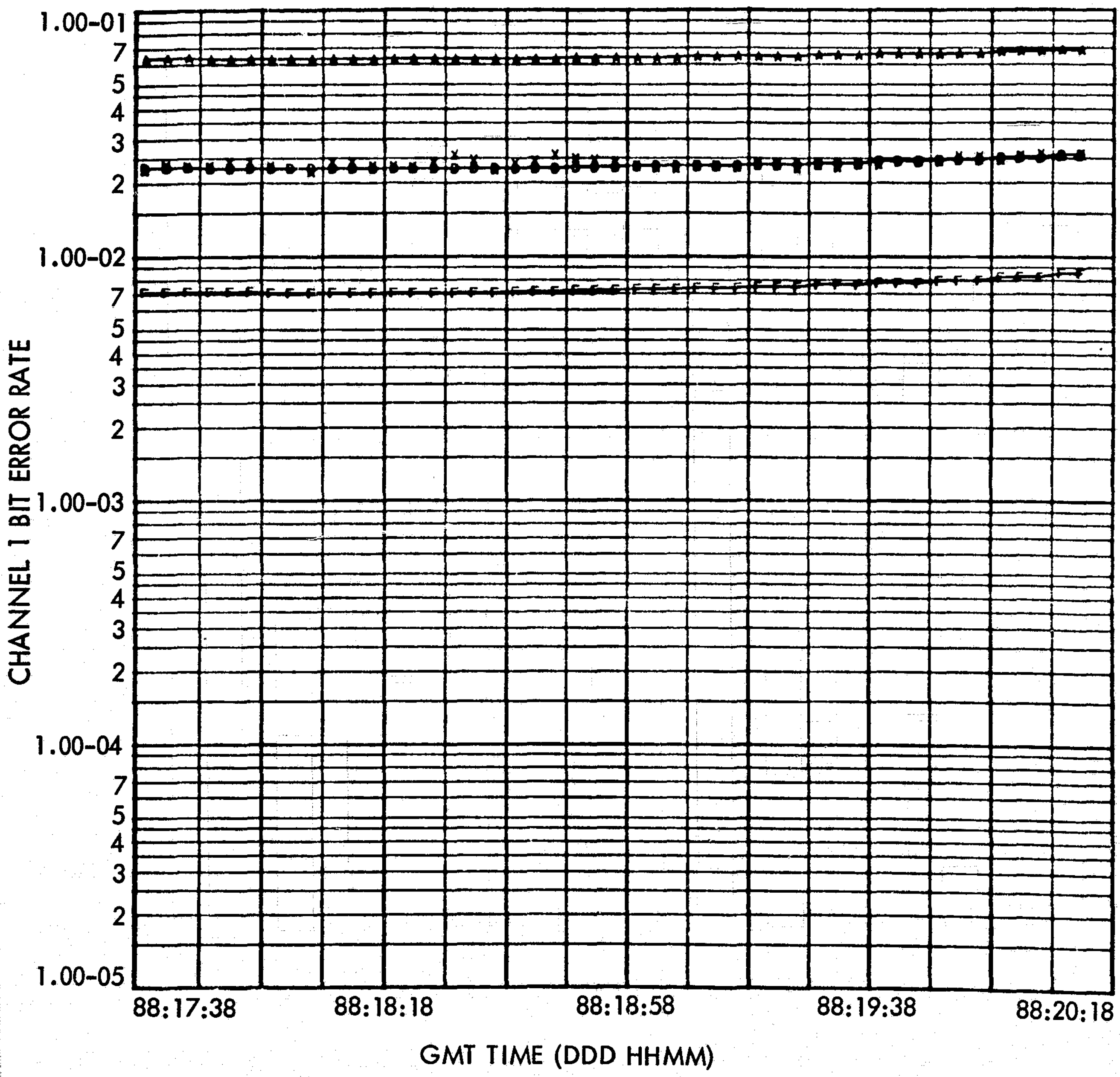

Figure 176. MVM'73 comparison analysis, channel 1 bit error rate

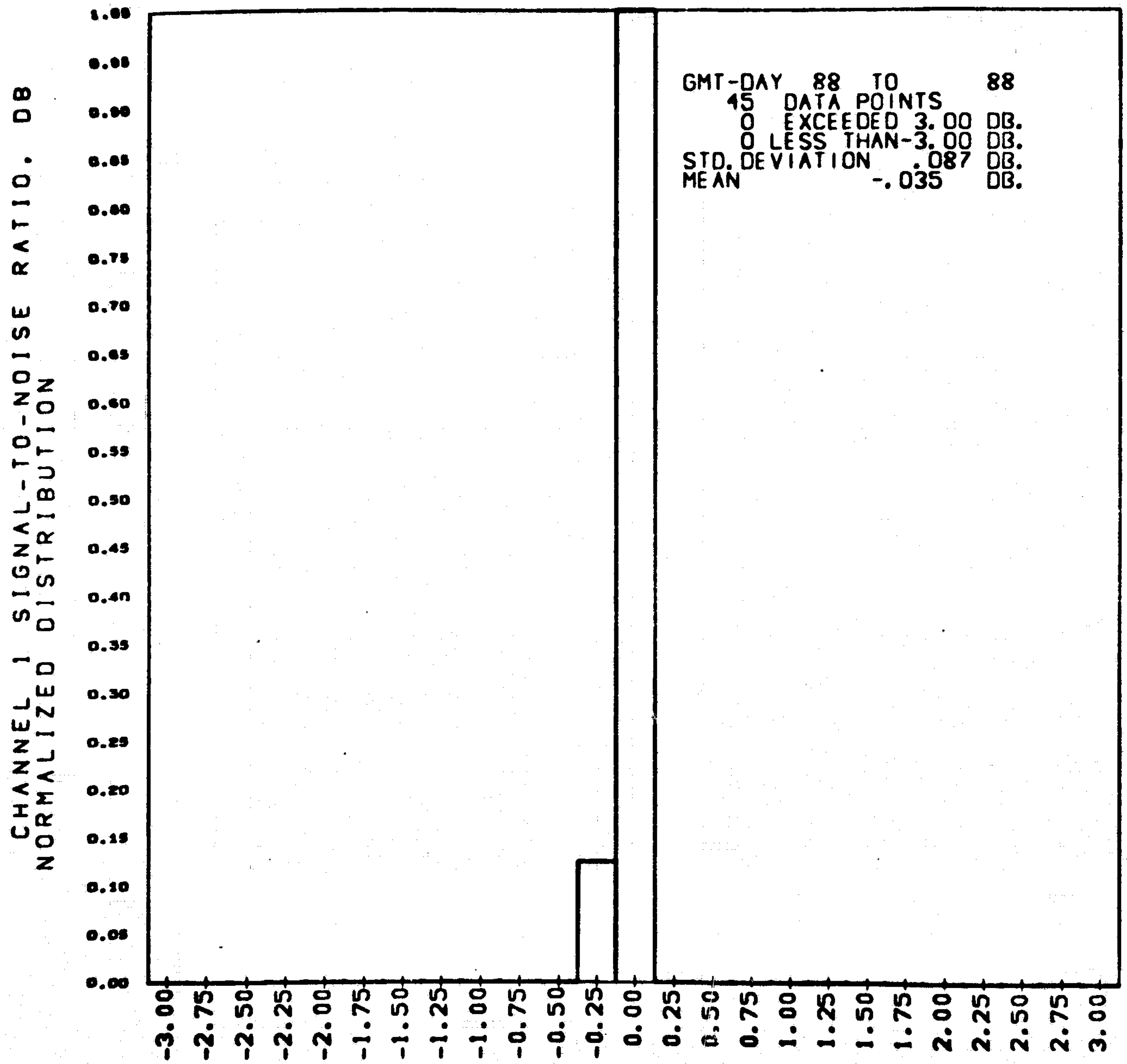

Figure 177. MVM'73 histogram, channel 1 signal-to-noise ratio

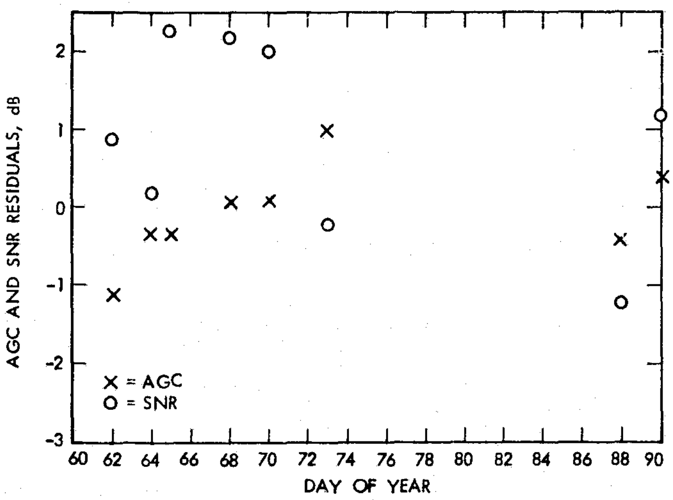

Figure 178. DSS 12 residual data plot

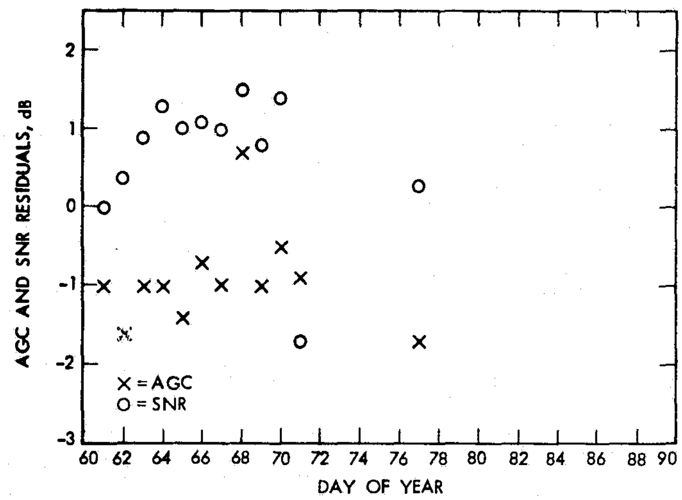

Figure 180. DSS 42 residual data plot

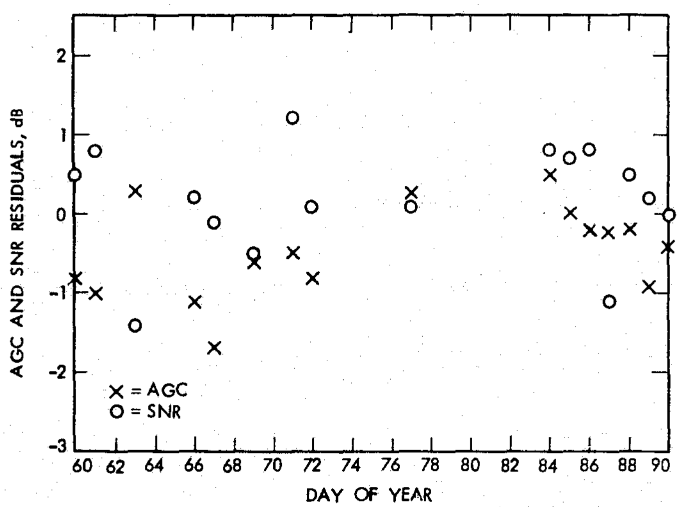

Figure 179. DSS 14 residual data plot

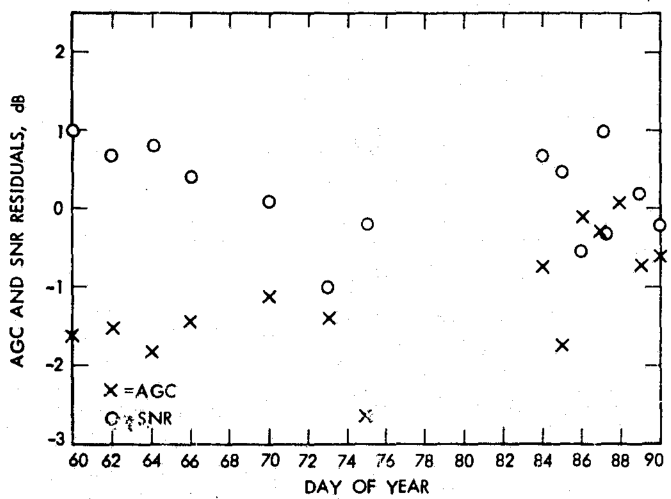

Figure 181. DSS 43 residual data plot

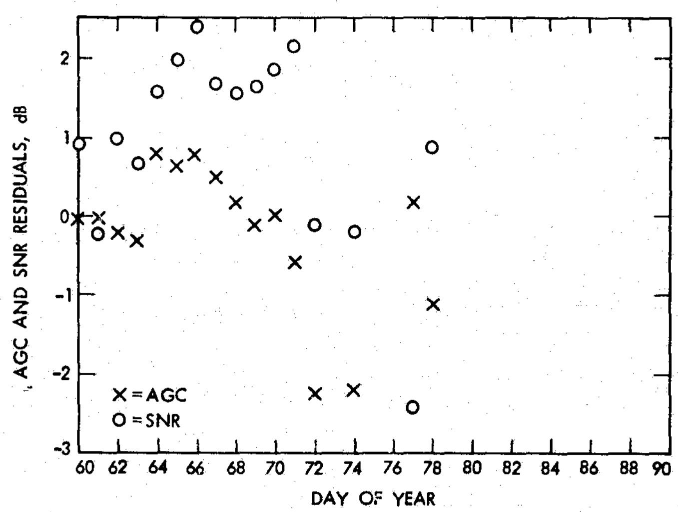

Figure 182. DSS 62 residual data plot

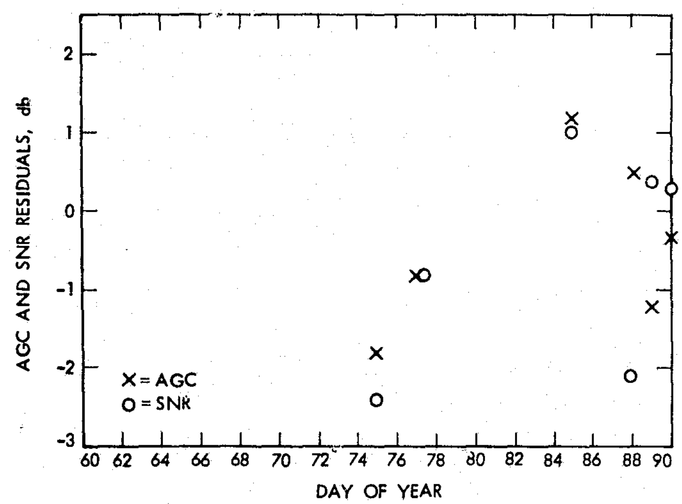

Figure 183. DSS 63 residual data plot

On March 29, 1974, at 20:46:31.9 GMT (spacecraft time), the Mariner 10 spacecraft reached closest approach to the planet Mercury. This encounter was simultaneously visible to both the Goldstone and the Australian complexes, thus allowing prime participation by two 64-m deep space stations, DSS 14 and DSS 43. Significant elements of the configuration at the stations during the encounter included the Block IV S- and X-band receivers at DSS 14, and the digitally controlled oscillators and open-loop receivers at both DSS 14 and DSS 43. The following combination of circumstances, the first two of which are common knowledge and whose positive effects were anticipated, contributed to improving tracking operations results:

(1) Mercury has essentially no atmosphere, thereby greatly reducing the signal refraction and the corresponding uncertainties in the doppler at enter and exit occultation.

(2) The mass of Mercury is relatively small, thereby inducing only a small perturbation in the near-encounter doppler.

(3) Although the block IV receivers and the digitally controlled oscillators were relatively new, considerable operational experience with them had been obtained in the previous four to six months, and especially during the Pioneer 10 Jupiter and Mariner 10 Venus encounters.

The initial uplink tuning strategy chosen by the Radio Science/ Occultation Team was to have the spacecraft in the two-way mode at both enter and exit occultation. More specifically, it was hoped that acquisition of the uplink at exit occultation could be effected within 2 sec of the actual spacecraft emergence. The only possible way to accomplish this goal would be to hit the spacecraft receiver with (very close to) the receiver best-lock frequency (with doppler = XA) at the time of emergence. Factored into the probability of success of this attempt were the uncertainties in doppler at emergence and uncertainty in the spacecraft nominal (no doppler) best-lock frequency. Additional spacecraft receiver data received and analyzed by the Radio Science/ Occultation Team at approximately encounter minus 24 hr indicated a substantial possibility that the uplink acquisition plan at emergence would not succeed. Therefore, an uplink acquisition "insurance" sweep, which had been proposed some weeks earlier by the DSN Network Operations Analysis Group, was adopted and scheduled at approximately exit occultation plus 7 min. The final uplink tuning strategy, seen in Fig. 184, was as follows:

(1) Spacecraft to enter occultation in the two-way mode with ground transmitted frequency (TSF) to be equal to predicted XA at enter occultation.

(2) During occultation, ground transmitter to be snapped to a TSF equal to predicted XA of exit occultation.

(3) Approximately 7 min after exit occultation, the ground transmitter to be swept approximately ± 45 Hz (at VCO level) about predicted XA.

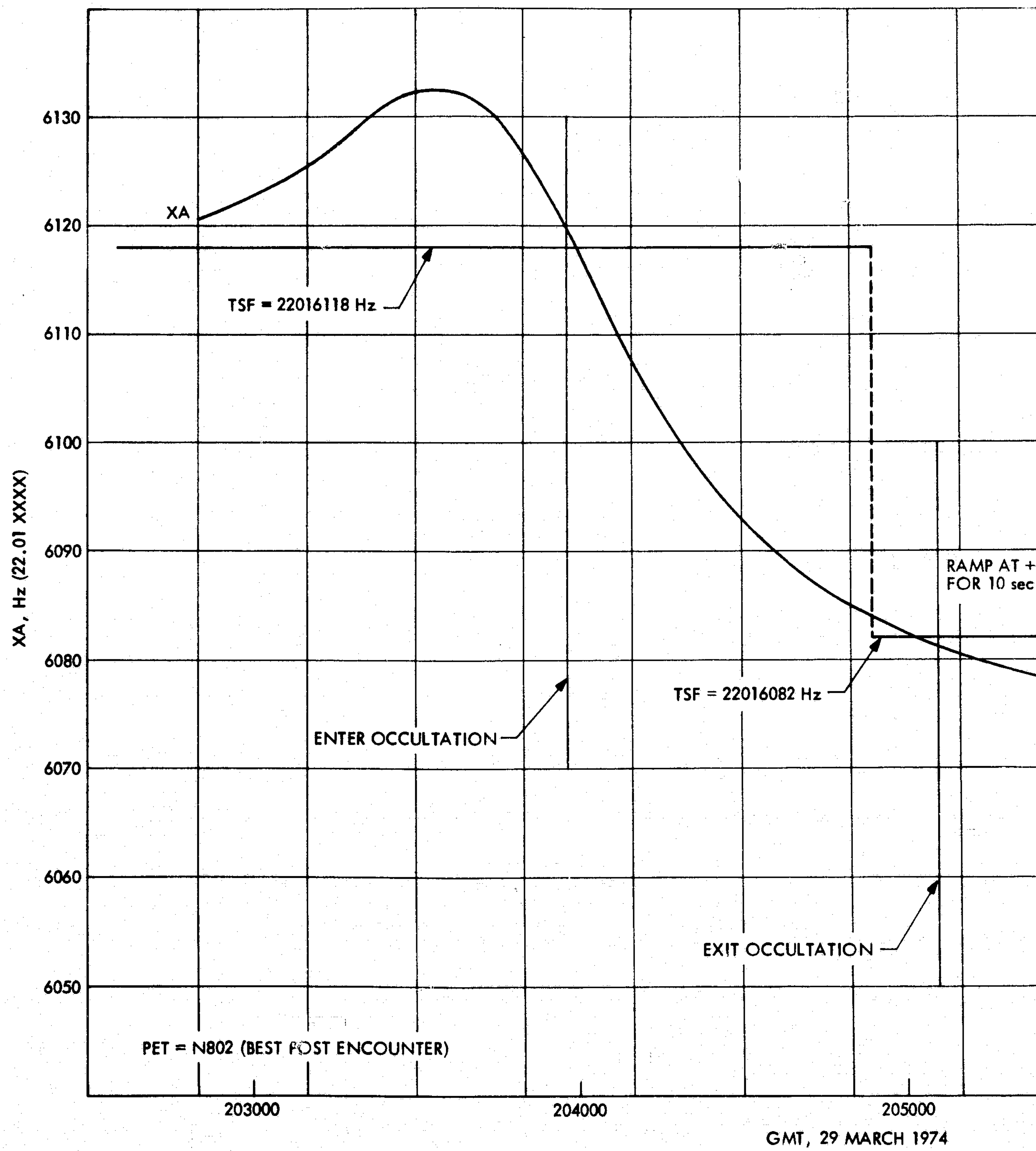

Figure 184. XA and exc

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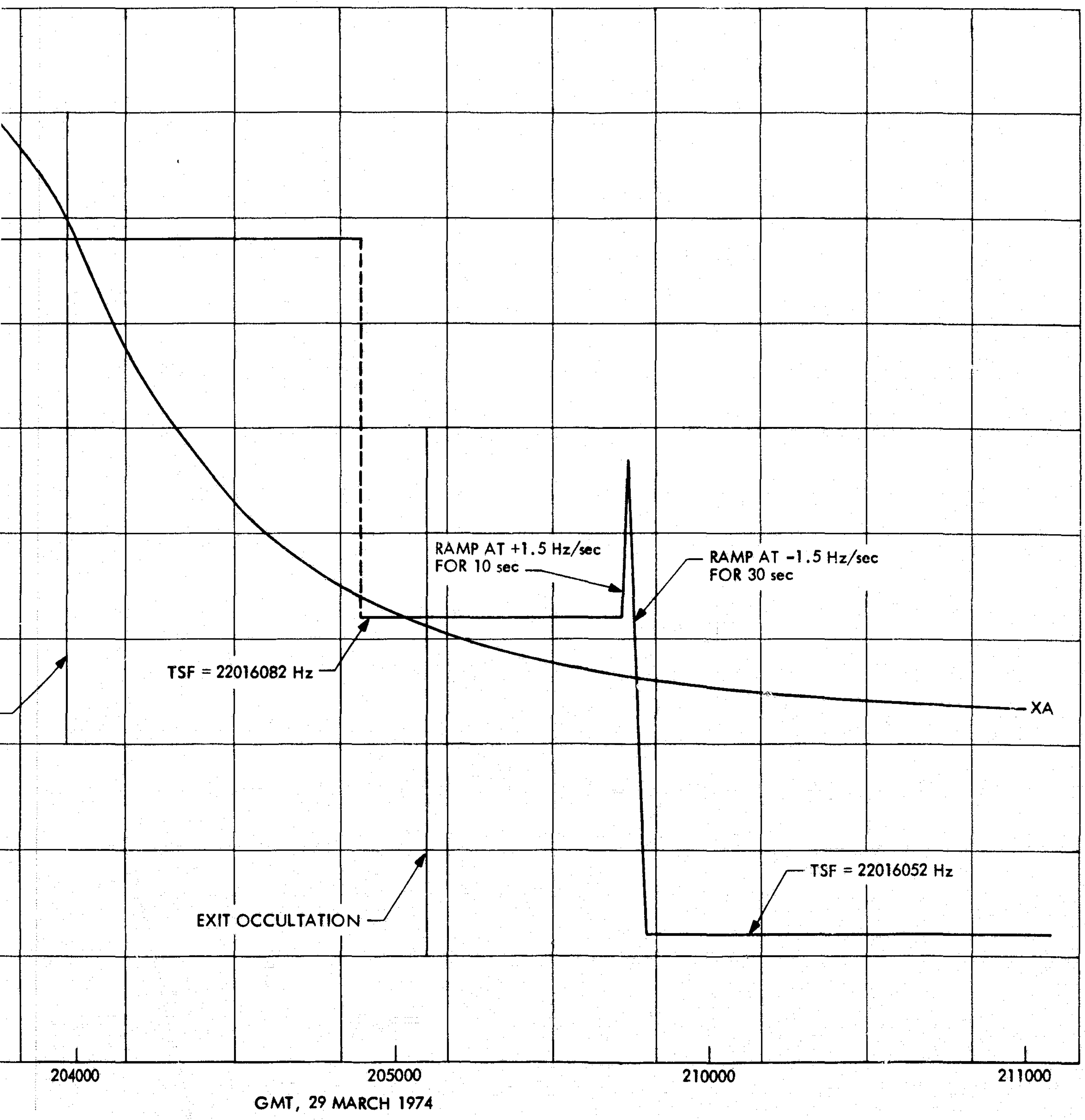

Figure 184. XA and exciter tuning pattern for Mercury Encounter, DSS 14

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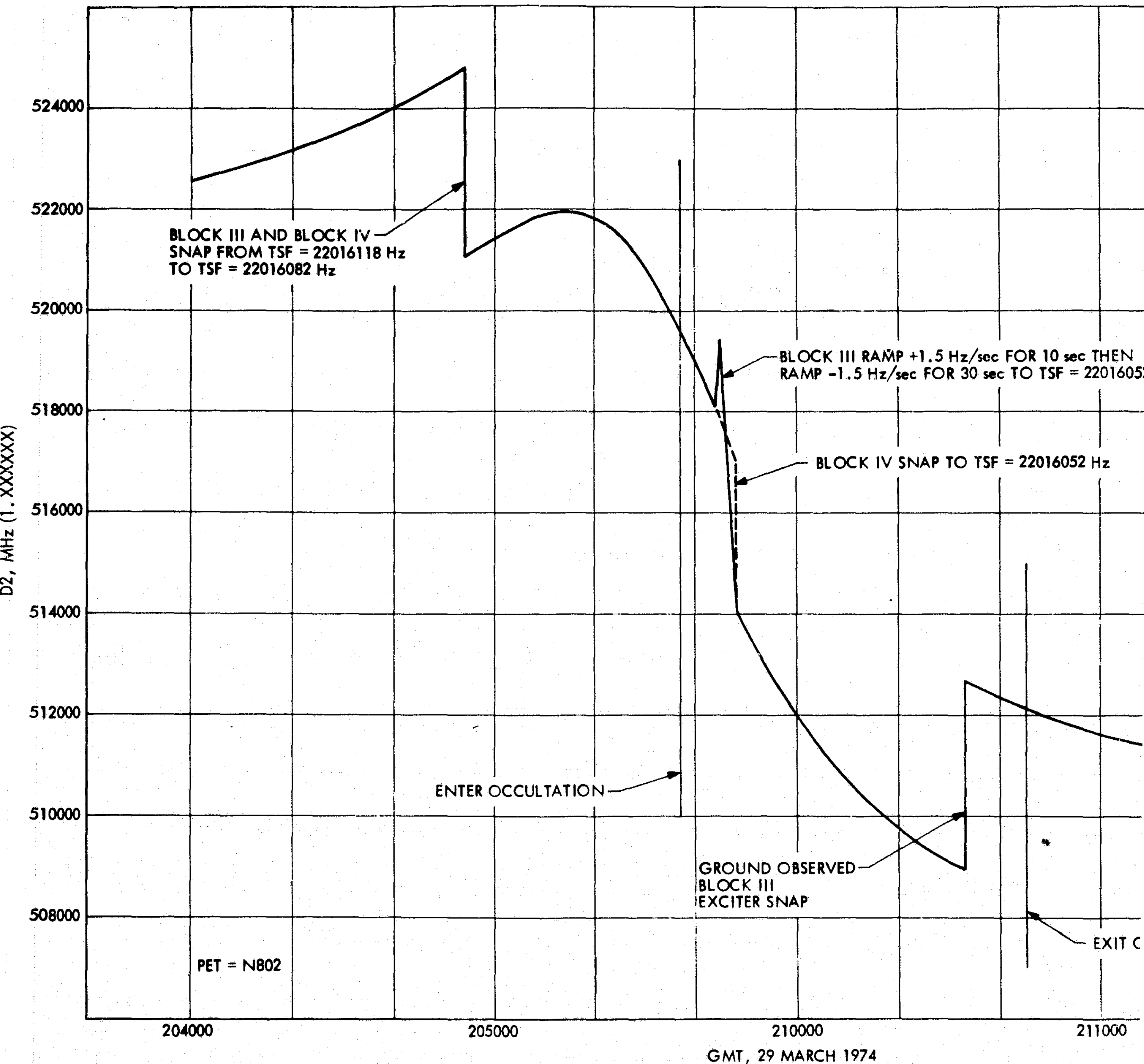
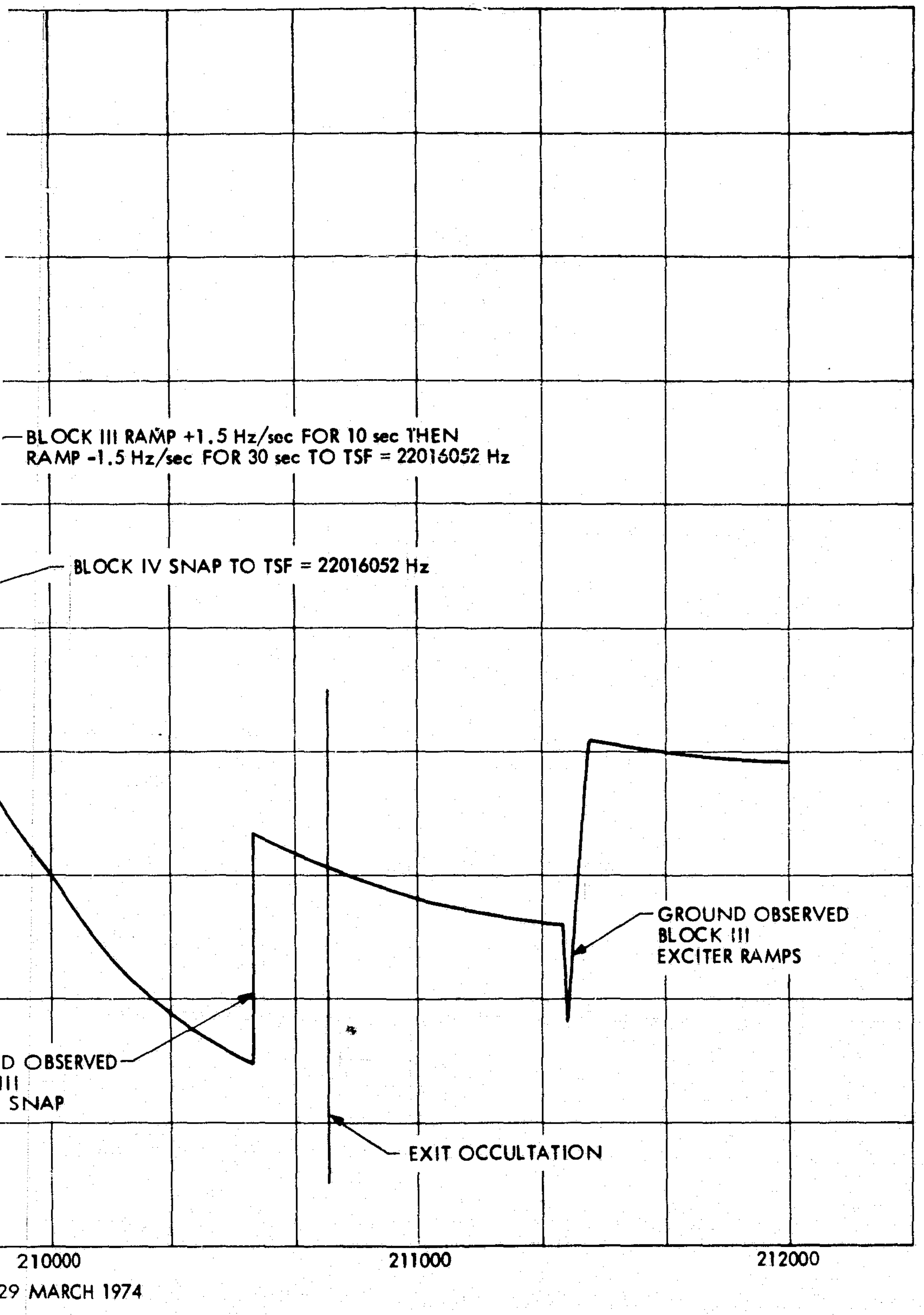


Figure 185. S-band D2 at Mercury encounter, DSS 14

FOLDOUT FRAME 3



FOLDOUT FRAME 4

The effects of uplink tuning as seen in the downlink two-way doppler are presented in Fig. 185. The values used for enter and exit transmitted frequency (= predicted XA) were, respectively:

$$(XA_P)_{EN} = 22.0161180 \text{ MHz}$$

$$(XA_P)_{EX} = 22.0160820 \text{ MHz}$$

Analysis of probe ephemeris tape (PET) N802 ("best" postencounter PET) shows the actual XAs to be:

$$(XA_A)_{EN} = 22.0161197 \text{ MHz}$$

$$(XA_A)_{EX} = 22.0160813 \text{ MHz}$$

yielding a difference between transmitted and actual (trajectory difference only) of:

$$XA_{EN} = (XA_A - XA_P)_{EN} = +1.7 \text{ Hz}$$

$$XA_{EX} = (XA_A - XA_P)_{EX} = -0.7 \text{ Hz}$$

Based on the above (trajectory) differences, one would expect that the attempt to acquire the uplink quickly and without tuning would have a high probability of success. The best trajectory estimates of the occultation times (PET N802) were:

Enter occultation = 20:56:12 GMT

Exit occultation = 21:07:33 GMT

Substantiating the above are the event times as recorded by the open loop receivers (and supplied by A. Kliore, Section 391):

Enter occultation = 20:56:11.69 GMT

Exit occultation = 21:07:33.03 GMT

One-way/two-way transition = 21:07:43.55 GMT

It is therefore concluded that the uplink was acquired approximately 10.5 sec after emergence of the spacecraft. Although this acquisition time exceeded the goal of a 2-sec acquisition considerably, it very adequately fulfilled the broader goal of locking the uplink quickly and without tuning.

Because of the planned attempt to acquire the uplink at exit occultation without tuning, it was particularly desirable to know the enter and exit occultation XA's to the highest degree possible. Figures 186 and 187, respectively, show the enter and exit occultation XA's vs time. The various probe ephemeris tapes were received over the last several weeks prior to encounter and in the following order (chronologically):

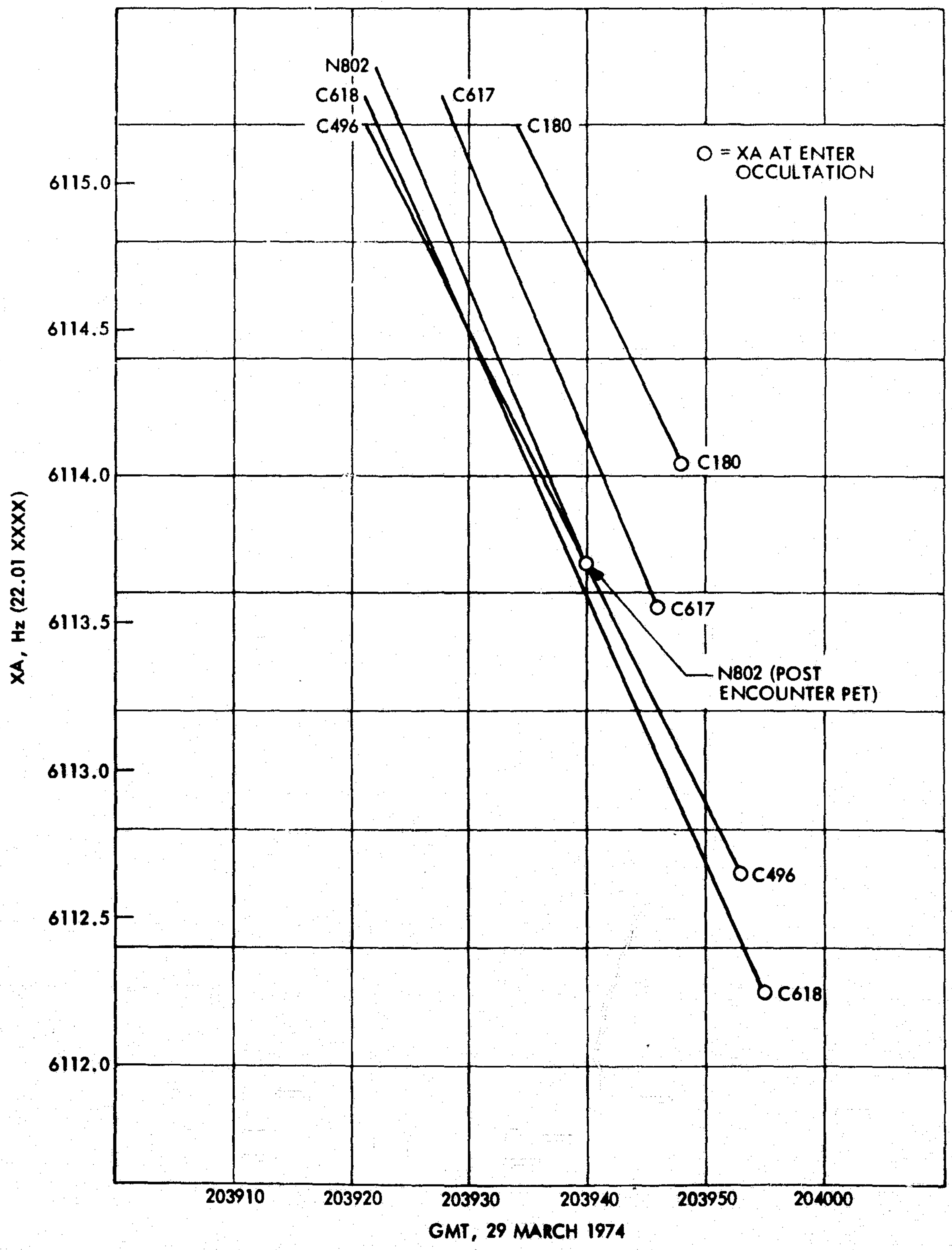


Figure 186. Enter occultation XA for pre-Mercury encounter orbital solutions

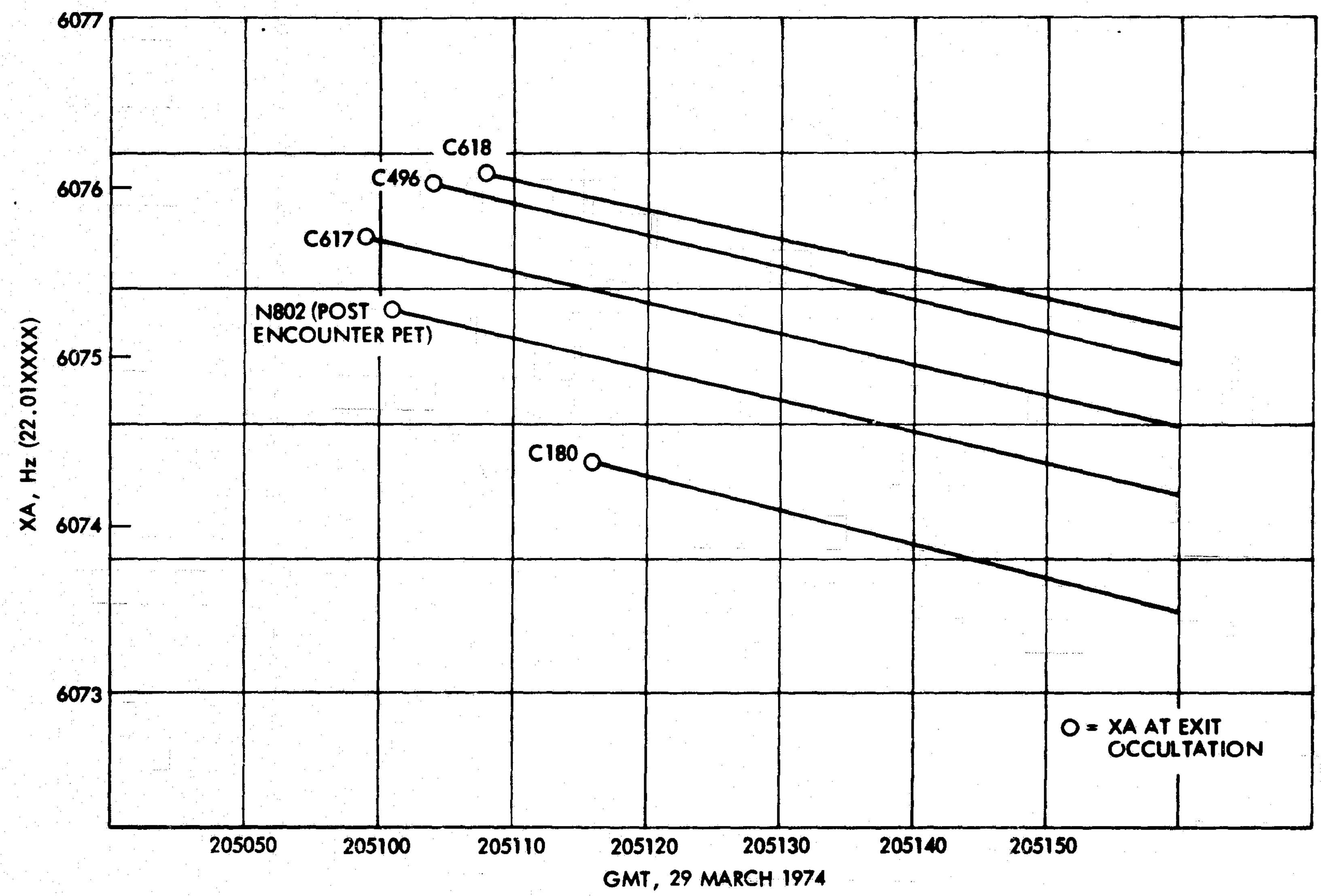


Figure 187. Exit occultation XA for pre-Mercury encounter orbital solutions

PET No.

C180
C496
C617
C618 (actually used for the encounter)

N802 ("best" postencounter solution)

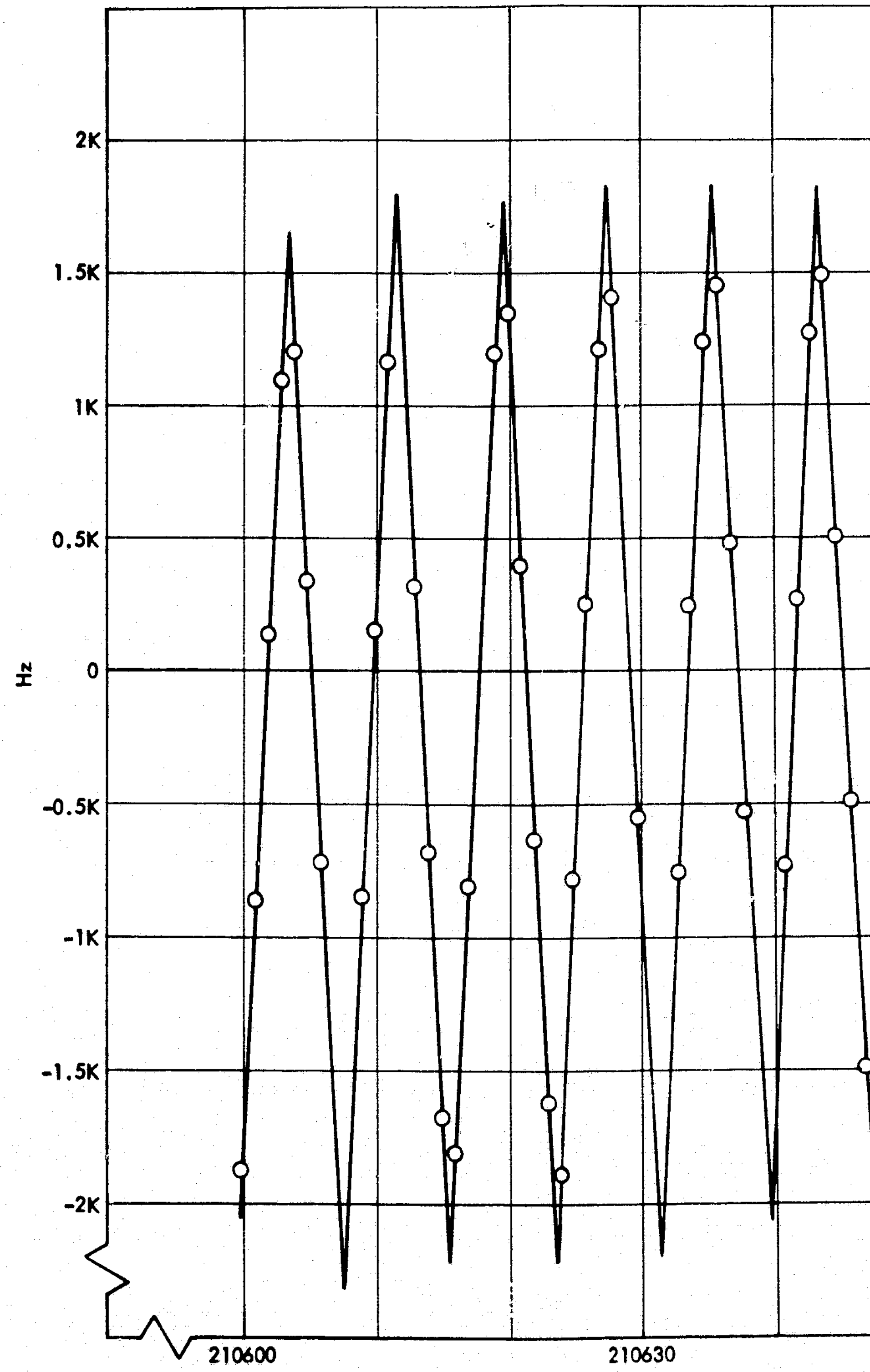
During Venus encounter, it was suggested that the practice of holding off the selection of final critical phase tracking operations parameters (event times and frequencies) until a final orbit determination solution is received in the last hours before an encounter is unwarranted and risks operational errors due to hasty implementation. Similarly, this data substantiates that conclusion as there is no clear-cut progression in accuracy (to the actual) among the PETs received.

As in the two previous critical phase encounters (Pioneer 10/Jupiter and MVM/Venus), it was decided that the digitally controlled oscillators would be used in the acquisition mode (ACQ MODE). The sweep rate selected was ±1000 Hz/sec (S-band), in combination with the following:

Tracking loop bandwidth	= 152 Hz (Block III)
	100 Hz (Block IV)
Sweep range	= ±2000 Hz (DSS 14)
	±3000 Hz (DSS 43)

At both stations the Block III backup receiver was swept for one-way operation while all other receivers were swept for two-way (DSS 14) or three-way (DSS 43). During the approximately 10.5 sec of one-way data following exit occultation and prior to uplink acquisition, neither backup Block III receiver locked (note that this data was recorded on the open loop receivers). However, both prime S-band receivers at DSS 14 and DSS 43 locked to the two-way (DSS 14) or three-way (DSS 43) downlink at the very first time possible. Figures 188 and 189 show the exit occultation acquisitions for DSS 14 and DSS 43, respectively. As can be seen in each case, ground receiver lock was achieved at the very first zero (predicted doppler) crossing after the two-way/three-way downlink signal appearance (21:07:43.55 GMT). One interesting point to note is that the receiver VCO stays shorted continuously during the ACQ MODE on the Block IV receiver, but drifts during the ACQ MODE on the Block III receiver; this is clearly seen in Fig. 188 (Block IV) vs that seen in Fig. 189 (Block III). The linear drift seen in Fig. 188 is that due to doppler.

Table 52 provides a summary of important spacecraft and station events (all in ground received time) during the Mercury encounter occultation phase.



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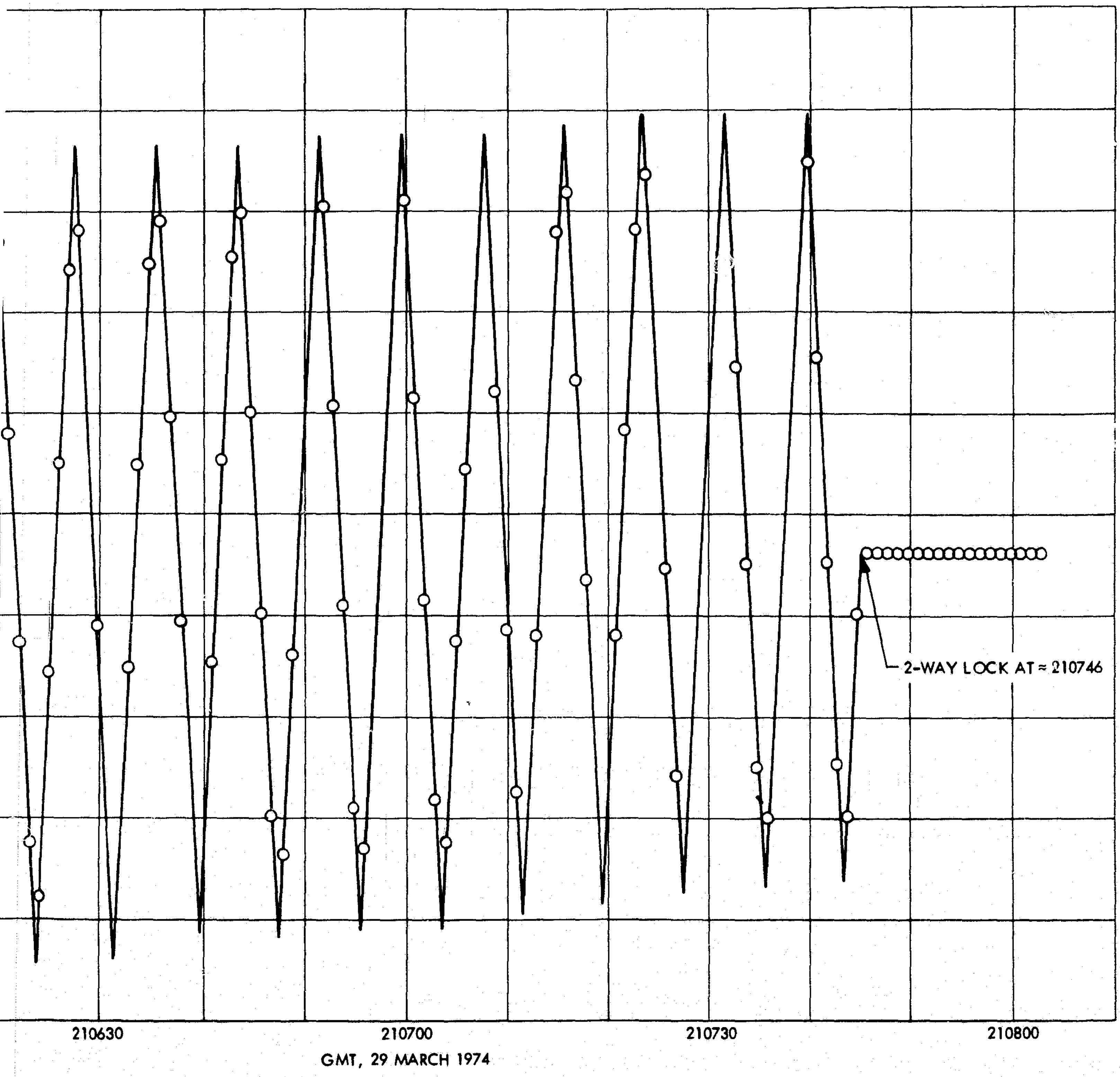

Figure 188. Acquisition tuning pattern, Mercury exit occultation, Block IV S-band receiver, DSS 14

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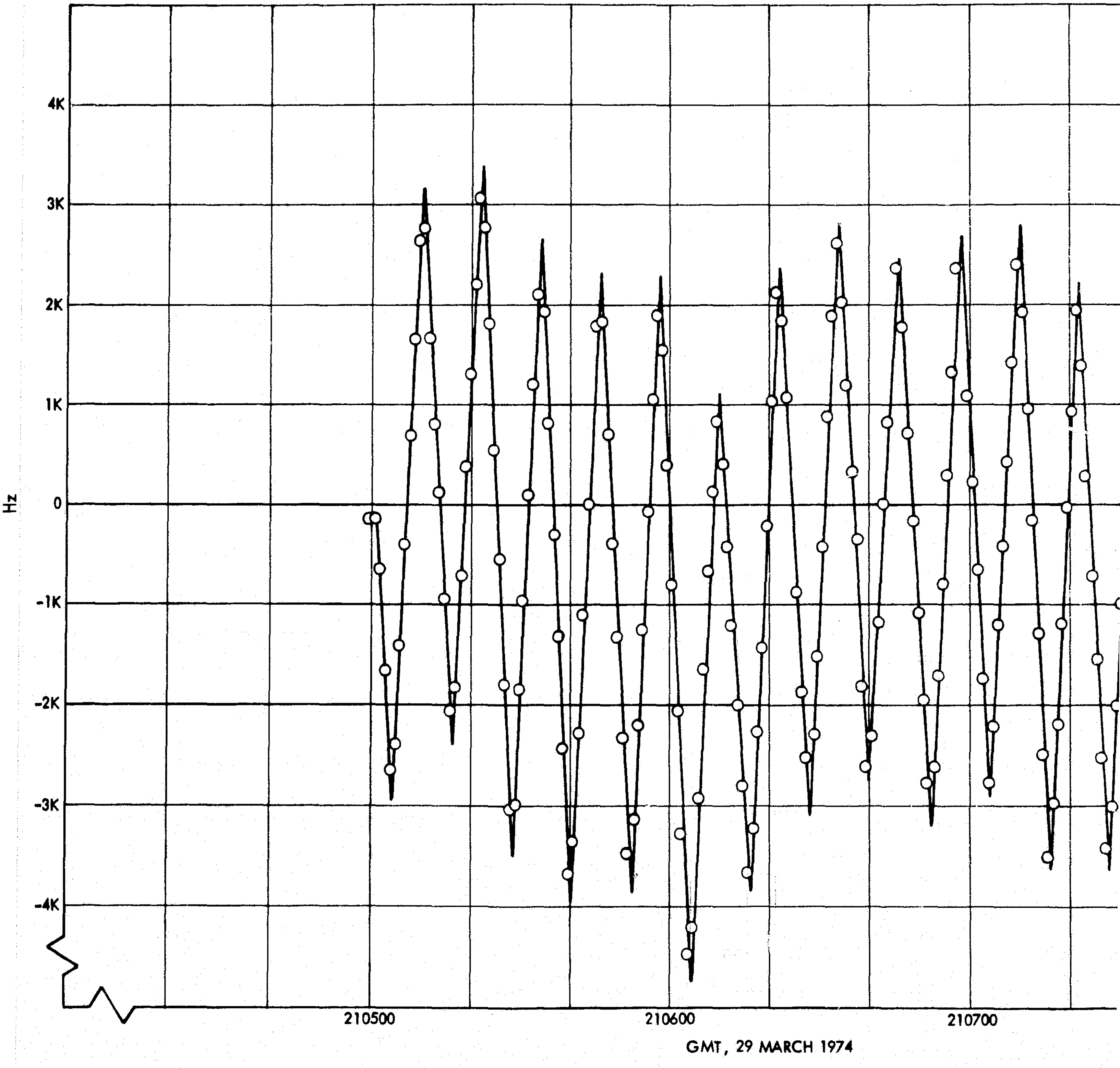

Figure 189. Acquisition tuning pattern, Mercury exit occultation, DSS 43

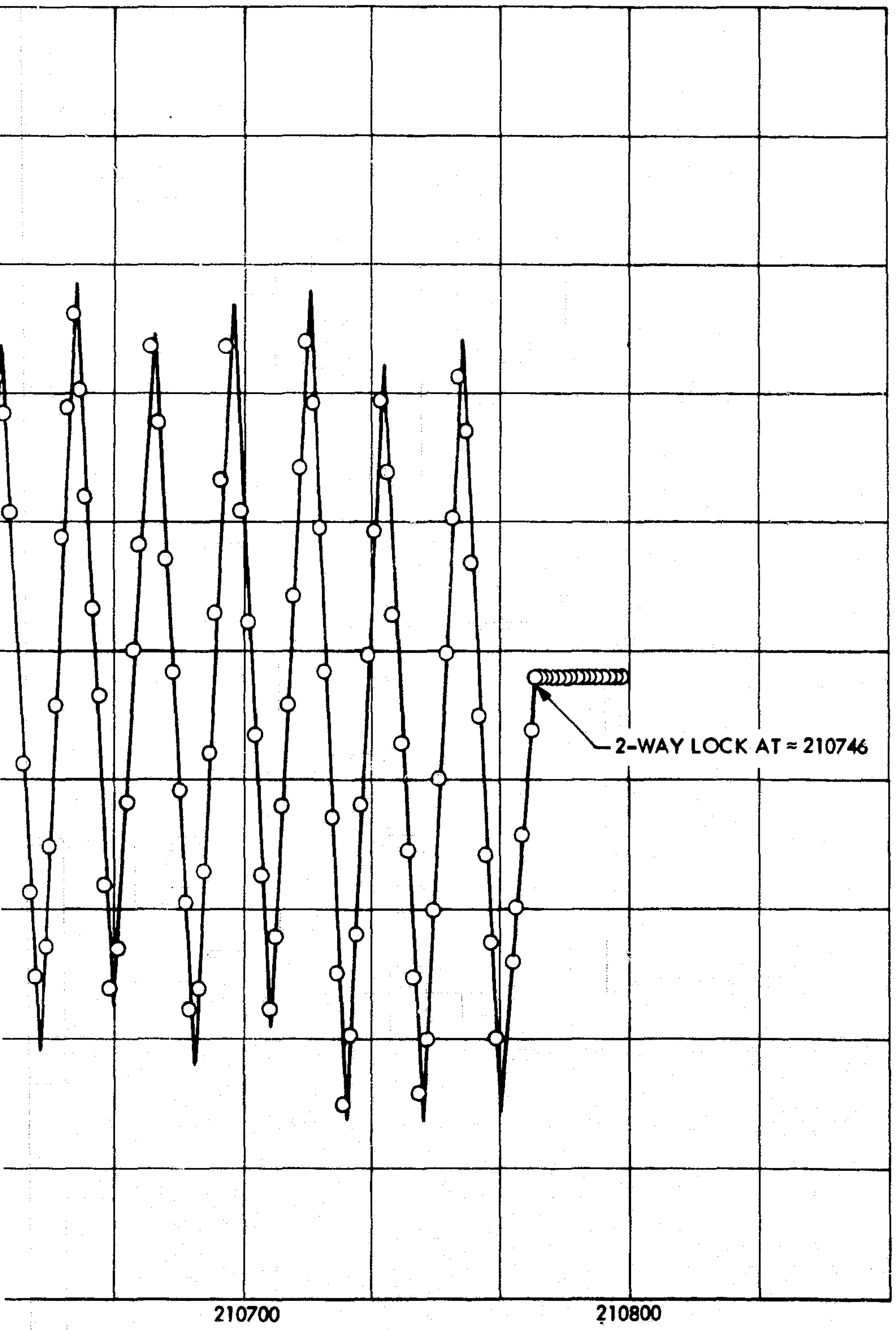

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Table 52. Spacecraft and DSS events during Mercury encounter occultation

Event	March 29, 1974, GMT (ground received time)
Enter occultation	20:56:11.69
DSS 43 drop lock	20:56:12
DSS 14 S-band Block IV drop lock	20:56:12
DSS 14 X-band Block IV drop lock	20:56:12
Exit occultation one-way	21:07:33.03
Downlink one-way to two-way	21:07:43.55
DSS 43 acquire downlink	21:07:46
DSS 14 S-band Block IV acquire downlink	21:07:46
DSS 14 X-band Block IV acquire downlink	21:09:56

Tracking operations during Mercury encounter were extremely smooth and resulted in a highly successful encounter. Factors which simplified and contributed to the success of tracking operations were:

(1) Lack of any substantial Mercurian atmosphere.

(2) Small gravitational effect of Mercury on the spacecraft.

(3) Far greater experience with the DCOs and Block IV S- and X-band receiver operations than in the previous two planetary encounters.

The most difficult operation was the attempt to acquire the uplink almost immediately upon exit with no tuning, and although the most optimally desired goal of a 2-second-or-less acquisition was not met, the broader goal of a very rapid acquisition of the uplink with no tuning was very soundly fulfilled. One should note that the outgoing Mercury encounter sequence was modified to support an additional spacecraft anomaly investigation and a search for a Mercury satellite. This required additional tracks from DSS 12 and 62, causing some gaps in coverage for the Pioneer spacecraft. On March 31, 1974, at the start of an outgoing TV mosaic sequence, a spacecraft power subsystem problem occurred which resulted in large power dissipations in the spacecraft bus. One of the resulting effects was intermittent reduction of the X-band transponder output power by 27 dB and the development of sidebands on the S-band carrier. A special effort was carried out at DSS 14 to detect these sidebands and to analyze their character. This activity essentially marked the end of the very successful MVM'73 primary mission. The approved extended mission, carrying Mariner 10 through two more successful encounters with the Planet Mercury, is the subject of the remainder of this section.

7. Extended Mission Cruise and Superior Conjunction: April-September 1, 1974.

April 1974 marked the beginning of the Mariner Venus/Mercury 1973 Extended Mission Project. At the outset it is noted that the numbers of Deep Space Network people and resources devoted to Mariner 10 were greatly reduced during the extended mission. Consequently, detailed DSN operations data and its analysis for reports of this nature simply were not produced beyond July 1974. Data which reflects DSN performance was, however, taken from appropriate Project reports produced by various elements of the Spacecraft Telecommunications and Mission Operations Teams in order to supplement the general DSN data which was available.

Only after completion of the primary mission was any significant Project or DSN attention given to extended mission planning. This late start, combined with the number of required critical events and the occurrence of additional spacecraft problems, again placed a heavy load on DSN planners during the short five-month interval discussed in this paragraph. Detailed planning was, however, satisfactorily accomplished in advance of each major event, including trajectory correction maneuver No. 4, solar superior conjunction, and correction maneuver No. 5. First priority was given to supporting the Project in planning for trajectory correction maneuver No. 4. The primary concern in the Deep Space Network was in arranging for required 64-m deep space station support once the date and time of the fourth maneuver were fixed. The Project had many factors to consider (spacecraft constraints, science return, encounter aim point, and third Mercury encounter) before finalizing the correction maneuver design.

On April 26, 1974, the DSN supported a special spacecraft gyro test to determine if the roll axis oscillation would occur with solar panels and the scan platform set in the planned maneuver configuration. No oscillations resulted. Also, spacecraft propulsion subsystem thermal constraints precluded one engine burn of the required duration; therefore, the maneuver was planned to be conducted in two parts. Part A of the fourth maneuver was completed on May 9, 1974; a plot of downlink AGC is given in Fig. 190. It was pointed out that real-time telemetry data would not be possible during the maneuver unless the spacecraft high-gain antenna was adjusted to point at Earth. However, the Project opted to give up this data in order to maintain the high-gain antenna in the April 26, 1974, test configuration during the actual correction maneuver. This data would be recorded on the spacecraft recorder for playback following the maneuver.

The primary mission had enjoyed essentially continuous tracking coverage from November 3, 1973, through the end of the primary mission via a combination of 26- and 64-m deep space stations. This level of support could not be continued throughout the extended mission due to the higher priorities of other flight projects and of DSN implementation requirements for Viking. Basically, the plan was for Mariner 10 to receive approximately two-thirds continuous coverage by a combination of full or partial passes each day. The daily coverage gap would normally occur over the Australian longitude since each of these stations was planned to be down for upgrade and repair, in a serial manner, throughout the extended mission. Therefore, it was planned that Mariner 10 would record nonimaging science data during coverage gaps and then play these data back via a 7.35 kbps dump during the next scheduled 64-m pass. During the very first such coverage gap on April 16, 1974, the analog-to-digital converter in the spacecraft flight data subsystem apparently failed, causing a loss of 50 of the 134 analog engineering measurements. This spacecraft problem, unlike some others, had no direct affect on the Deep Space Network. However, it did affect mission operations and indirectly resulted in increased requirements for network support.

Since the Canopus intensity function had been lost, recognition that the star was acquired now depended upon a priori knowledge of the approximate roll position of the spacecraft as a function of the received signal strength from the high-gain or low-gain antennas. Telemetry on the pointing direction of the high-gain antenna had also been irretrievably lost; therefore, future pointing of the antenna depended on use of the high-gain antenna pattern and its calibrations performed during the primary mission. Concerns were raised regarding the wisdom of the partial coverage plan, but circumstances dictated a continuation of this mode. Unfortunately, the spacecraft was not long in putting

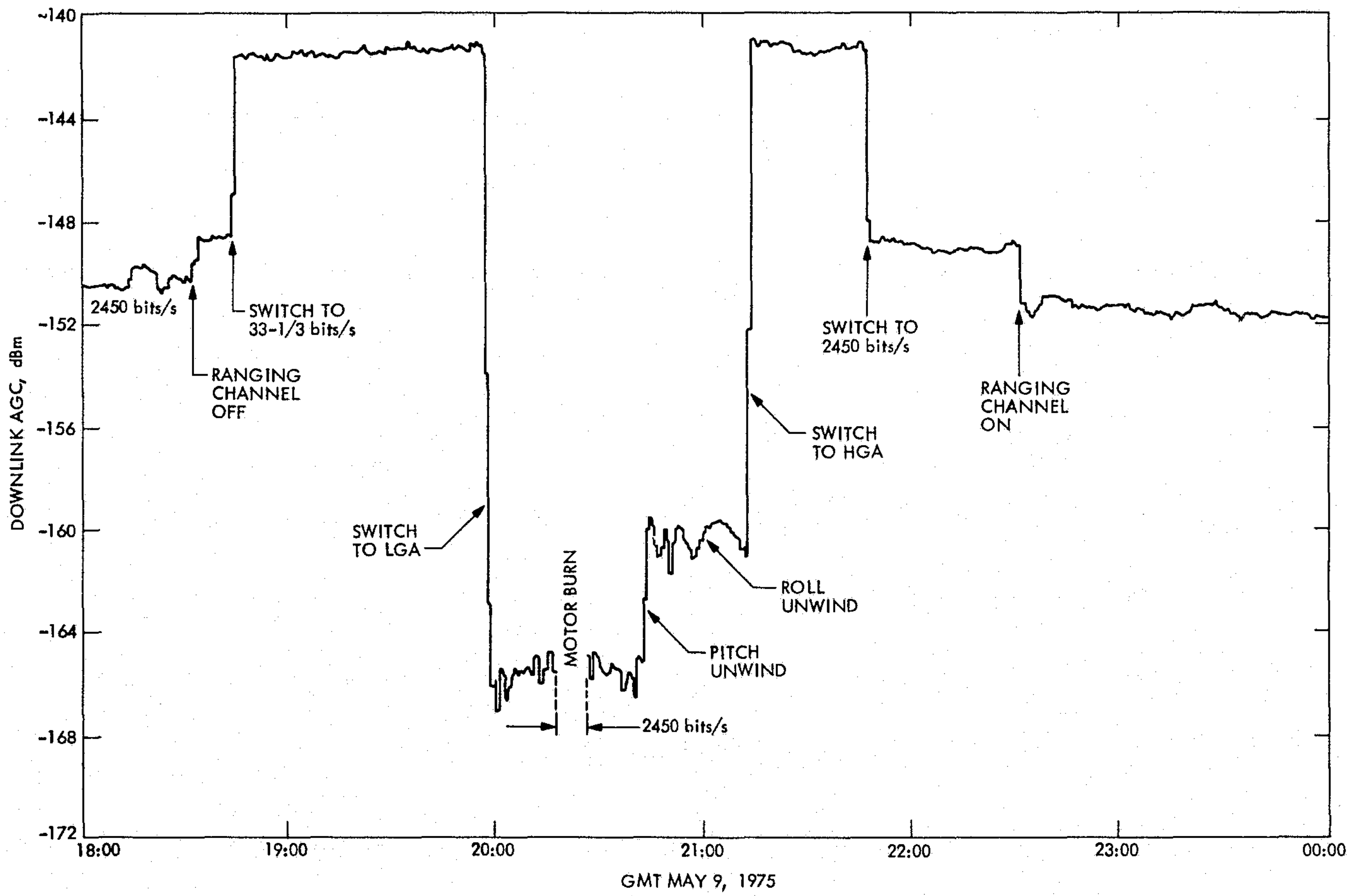


Figure 190. TCM 4A downlink AGC

an end to the recorder playback plan. On August 14, 1974, the spacecraft recorder was to serve as the data source for a ground telemetry test; however, no tape start occurred. It appeared that the recorder tape was stuck in the parking window and could not be freed. Troubleshooting continued through 19 August. Some tape movement was achieved, but it then apparently became permanently jammed. The recorder was declared inoperable and turned off on August 21, 1974. This, of course, meant complete loss of cruise science and engineering data during Deep Space Network coverage gaps and, of more concern, the increased potential for loss of critical event data, even while tracking, due to inadequate telecommunications link performance or failures at the deep space stations. As a result of this loss, the DSN gave added attention to redundant configurations and backup recordings to assure recovery of data on Earth.

At the time of solar superior conjunction on June 6, 1974, the dual-channel S-band and X-band radio signals emanating from mariner 10's high-gain antenna passed within 1.67 deg of the Sun's surface as viewed from Earth. Effects of the solar corona's electron cloud on these signals were recorded at DSS 14 using open loop receivers and the R&D Block IV closed loop receivers. Primary effects of the solar corona on the radio signals were scintillation and differential S/X-band phase delay. Mariner 10 was the first space mission in which an X-band signal was used to probe the Sun's environment. In addition, dual-channel S/X-band ranging data was gathered. Data quality remained good despite low signal strength and high noise conditions. The influence of the Sun's coronasphere upon the range values became increasingly significant as the date of superior conjunction approached. Differences between S- and X-band range as large as 3.6 microsec were noted due to corona effects. The maximum time delay expected when the S-band frequency was used on both the uplink and downlink signals was about 11 microsec, whereas with S-band used in the uplink only and X-band in the downlink, the maximum delay was about 6 microsec. The reason for the difference in the delays was that the coronal effects had an inverse square dependence on the radio frequency, and the X-band frequency is 11/3 the S-band frequency.

Mariner 10 solar superior conjunction activities occurred during the period May 24 through June 21, 1974. Recovery of dual-frequency S/X-band doppler data, range, and open loop receiver data types was required. In addition, it was desired that calibration tracks be provided beyond the stated intervals. Since Mariner 10 provided the first opportunity for spacecraft dual-frequency analysis of solar corona and gravity effects, the DSN gave considerable emphasis to arranging proper support at DSS 14. Originally, DSS 14's Block IV S/X-band receiver was scheduled for removal and rework in preparation for Viking test support in mid-June 1974, following superior conjunction on June 6, 1974. The expanded observation period required negotiation of the removal date and was subsequently set for July 1, 1974. Support by the special Block IV receiver troubleshooting team was planned to continue in effect until July 1, 1974.

Telecommunications performance during this period was influenced by the Sun-Earth-probe angle, the level of solar activity, and the communications modes used. A plot of the Sun-Earth-probe angle during this period is shown in Fig. 191. Typically, during solar conjunction the bit error rate increased as the Sun-Earth-probe angle decreased with no total loss of data during the entire period. Also, usable two-way S-band doppler and S-band ranging were received, although the doppler noise level greatly increased. X-band ranging and doppler were of little use due to the multiplication factor in the noise on the X-band downlink.

Plots of downlink AGC and SNR are given in Figs. 192 and 193. In the first figure, the circled dots represent the mean of the AGC over 15-min periods each day, with the receiver in the wide loop bandwidth. If there were more than one such 15-min period on a given day, the AGC's were averaged. Dots surrounded by triangles are similar AGC's when the receiver was in narrow loop bandwidth. The rest of the data shows that the narrow loop bandwidth produced an indicated AGC about half a decible higher than the wide loop bandwidth. The bottom half of the figure shows the 33-1/3 bps cruise mode signal-to-noise ratio. Data obtained with the wide loop bandwidth is designated by a circle and the narrow bandwidth by a triangle.

The minimum Sun-Earth-probe angle for solar superior conjunction occurred on June 5, 1974. The maximum downlink AGC degradation occurred two days later on June 7, 1974, and the maximum signal-to-noise ratio degradation occurred on June 10, 1974. However, AGC variations during the week centered on June 5 was less than 0.5 dB and signal-to-noise ratio variations were less than 1 dB, since the Sun-Earth-probe angle was changing very slowly. The standard deviation is indicated by the vertical line centered on the dot for each day. The reason for the extreme change in the AGC variation on June 6 relative to the other days nearby is not known unless the station digital instrumentation subsystem AGC smoothing factor was set differently on that one day. The signal-to-noise ratio standard deviation on June 6 is only slightly larger than that on nearby days.

Figure 192 provides data only for the wide loop bandwidth. Once the Sun-Earth-probe angle had increased to 3 deg, there was a single DSS 14 pass weekly in which the 33-1/3 bps cruise mode was available. The data on days 182 and 189 (July 1 and 8, 1974) is interesting. A solar flare of intensity 1 occurred on 4 and 5 July, and high to very high solar activity occurred during the entire week. A large scatter but small degradation occurred on the indicated S-band AGC. The degradation of the signal-to-noise ratio was larger on July 1 than on July 8, but the scatter was more than twice as much on July 8 than on July 1. After the July 8 observation, the Sun entered a quiet period of activity. By the time the Sun-Earth-probe angle was 6 deg, the scatter in the data seemed to show that conditions were back to the way they were before the Sun had a perceptible effect on the downlink.

Because of various spacecraft problems during the mission, the X-band transmitter was not operating normally at all times. However, the degradations discussed in this paragraph are believed to be due mainly to the solar effects and not the X-band transmitter anomalies. Figure 194 is a summary of DSS 14's Block IV receiver AGC from the X-band downlink. Immediately apparent is the great difference between

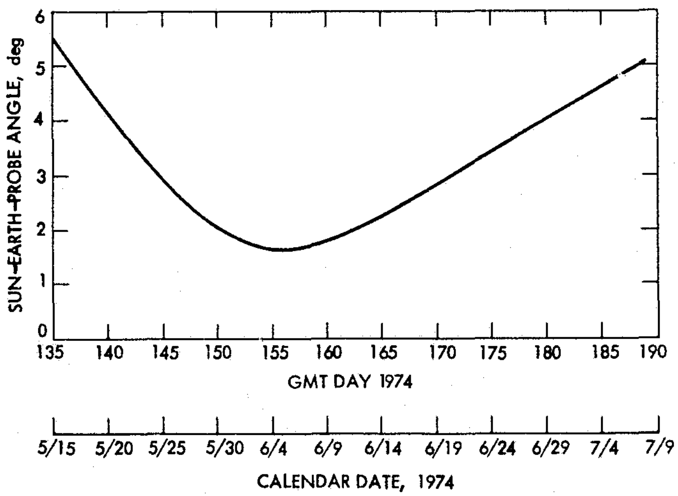


Figure 191. Sun-Earth-probe angle

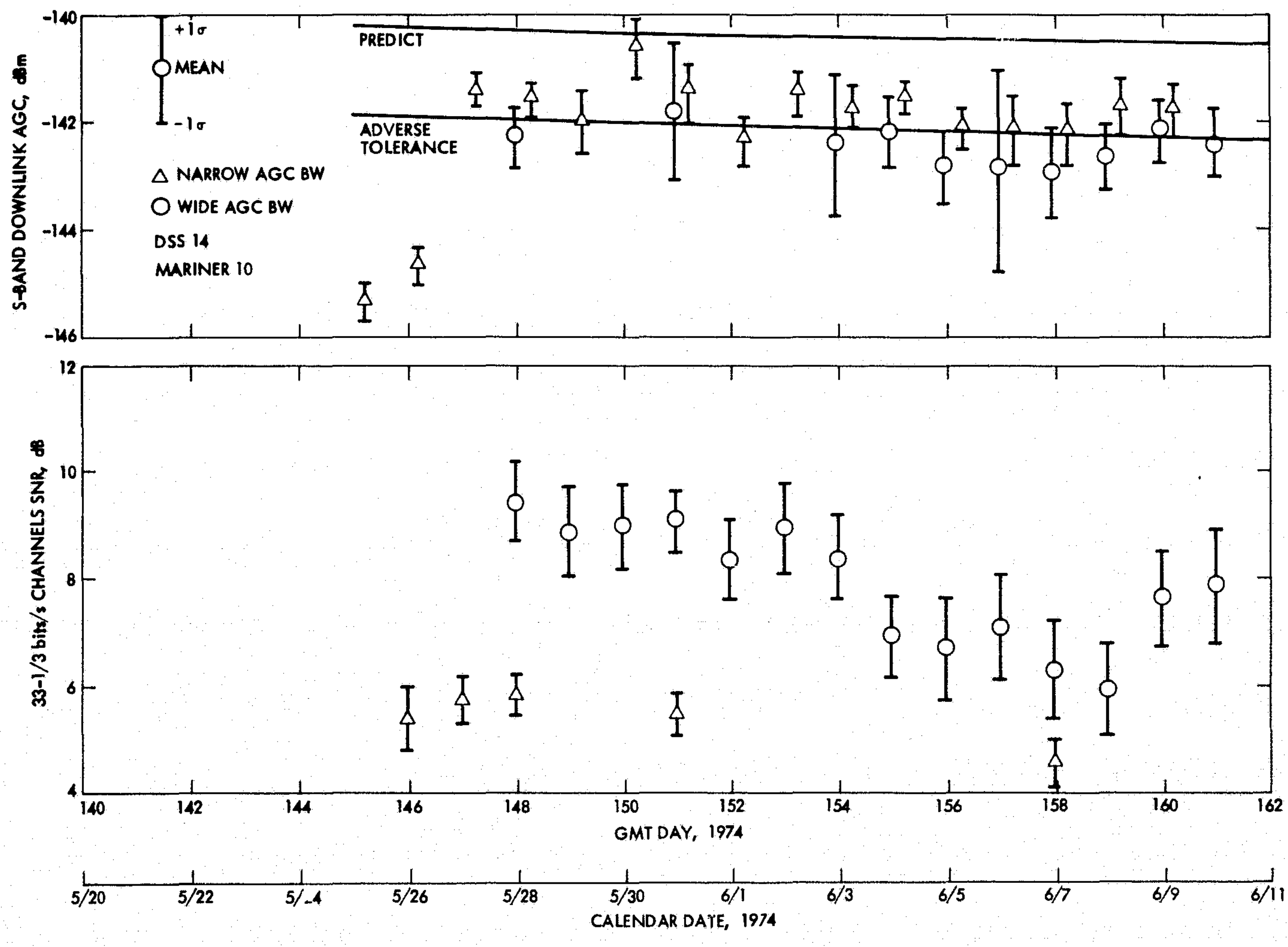


Figure 192. 33-1/3 bits/s SNR and AGC, May 22 to June 11, 1974

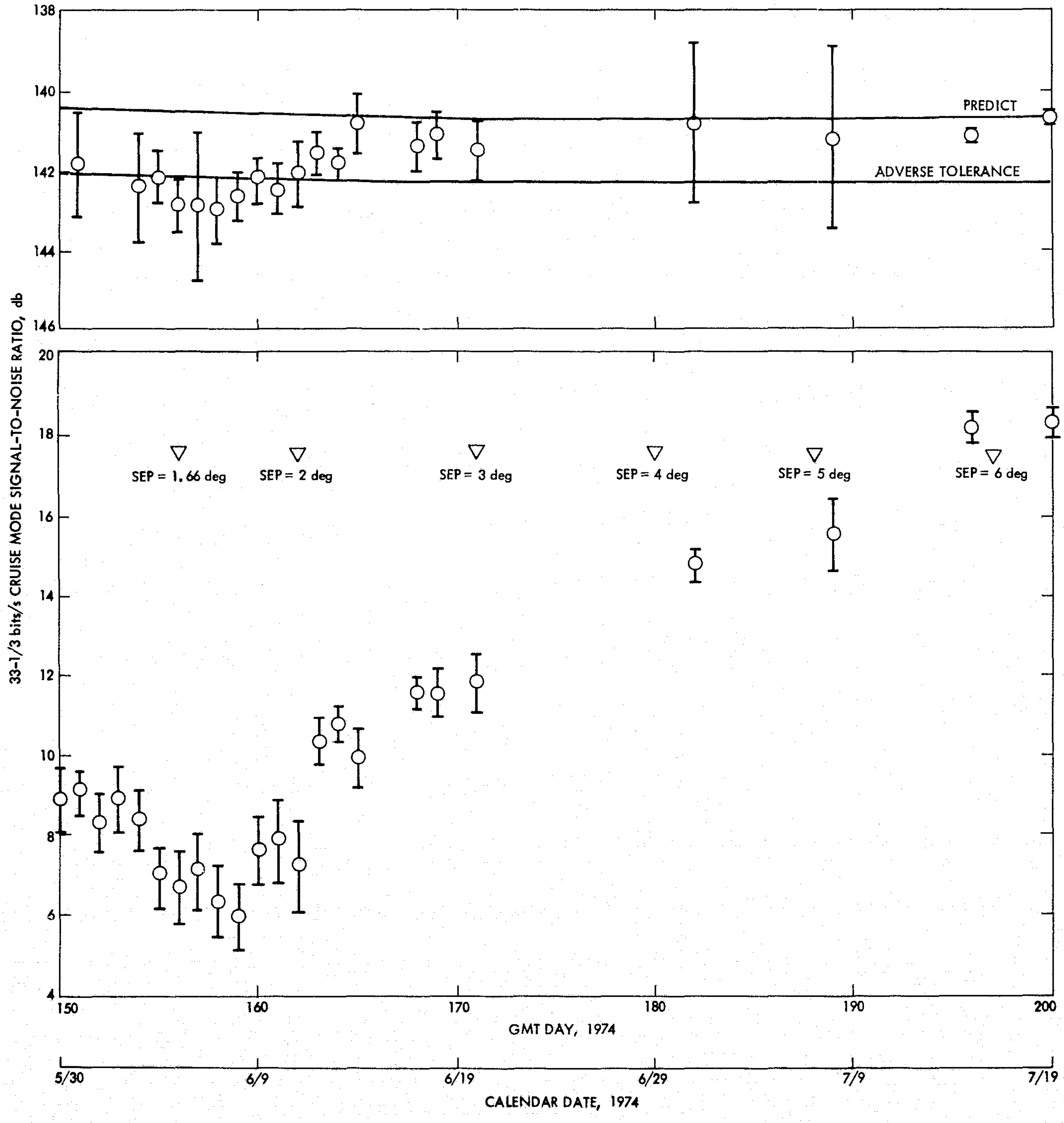


Figure 193. 33-1/3 bits/s SNR and AGC, June 19-29, 1974

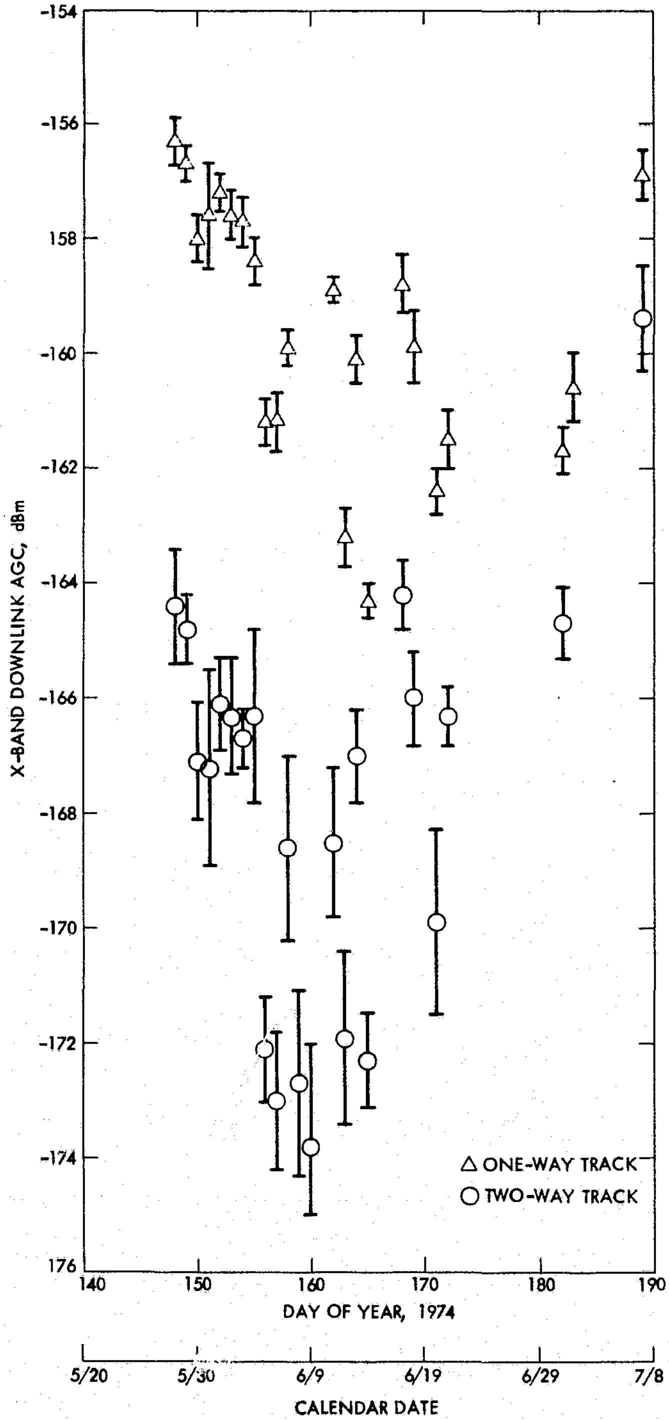


Figure 194. X-band downlink AGC mean and standard variation

the one-way and the two-way signatures. Compared to two-way, the one-way AGC has a much higher mean and a much lower standard deviation. The degradation in two-way AGC is caused by the effects of solar activity on the S-band uplink. Phase jitter in the spacecraft S-band receiver is multiplied by the factor 11/3rds before being applied to the X-band downlink carrier. The spacecraft S-band receiver can follow to some degree the phase transients; however, the ground receiver has much less success in following the phase transients which have been multiplied by 11/3rds.

A significant accomplishment during Mariner 10's solar superior conjunction was the reception of spacecraft telemetry through the period. Therefore, the effects on the S-band link could be deduced directly by analysis of the telemetry data. Figure 195 shows the solar effects on the uplink were significant. There were some bit errors introduced in the downlink telemetry; however, most of the data points shown lie within the range of -128 to -136 dBm and are considered, therefore, to be valid. On the day shown, May 29, 1974, the Sun-Earth-probe angle was 2.2 deg and the amplitude fluctuations on the uplink AGC were about 8 dB peak-to-peak. Figure 196 gives a plot of DSS 14's 100-kW uplink AGC mean and standard deviations for the entire period. However, the use of DSS 14's 100-kW transmitter was terminated prior to the end of all solar effects due to implementation commitments to other flight projects. When comparing the uplink and downlink AGC plots for this period, it should be noted that the respective measurement quantizations are quite different. The uplink AGC measurement is taken from the spacecraft telemetry stream and each data number equals a quantization of approximately 1 dB. The downlink AGC measurement is received in the DSN monitor block data and each data number equals a quantization of -0.016 dB. Therefore, a greater scatter is seen in the uplink AGC ata.

In parallel with superior conjunction activities, the DSN assisted the Project in planning support for the fifth trajectory correction maneuver. The correction maneuver occurred on July 2, 1974, over DSS 14 and was preceded by a gyro roll test on June 24, 1974. To avoid possible impact on DSS 14's support for the maneuver, the planned removal of the Block IV receiver was renegotiated to occur on July 5 rather than July 1, 1974.

DSN tracking support for the April 1974-September 1974 period is summarized in Table 53. Of the 348 passes provided, 191 were from the 64-m subnet and 157 from the 26-m subnet. The 64-m subnet coverage was greater than originally planned and reflects the increased need due to spacecraft problems and navigation demands. Of the 3076 tracking hours provided, 1781 were from the 64-m subnet and 1295 were from the 26-m subnet. It was expected that Mariner 10 could receive only about two-thirds of full coverage during the extended mission. During this 154-day period, some 4312 tracking hours would have been required to provide full, overlapping coverage. Since 3076 tracking hours were provided, one sees that Mariner 10 realized some 71% of the full coverage, which was slightly in excess of the plan. Although not shown in the table, DSS 61 also provided two telemetry acquisition passes for a total of 13 hours near the end of this period. The one command abort out of 3679 commands continued to reflect highly reliable operation of the DSN command system.

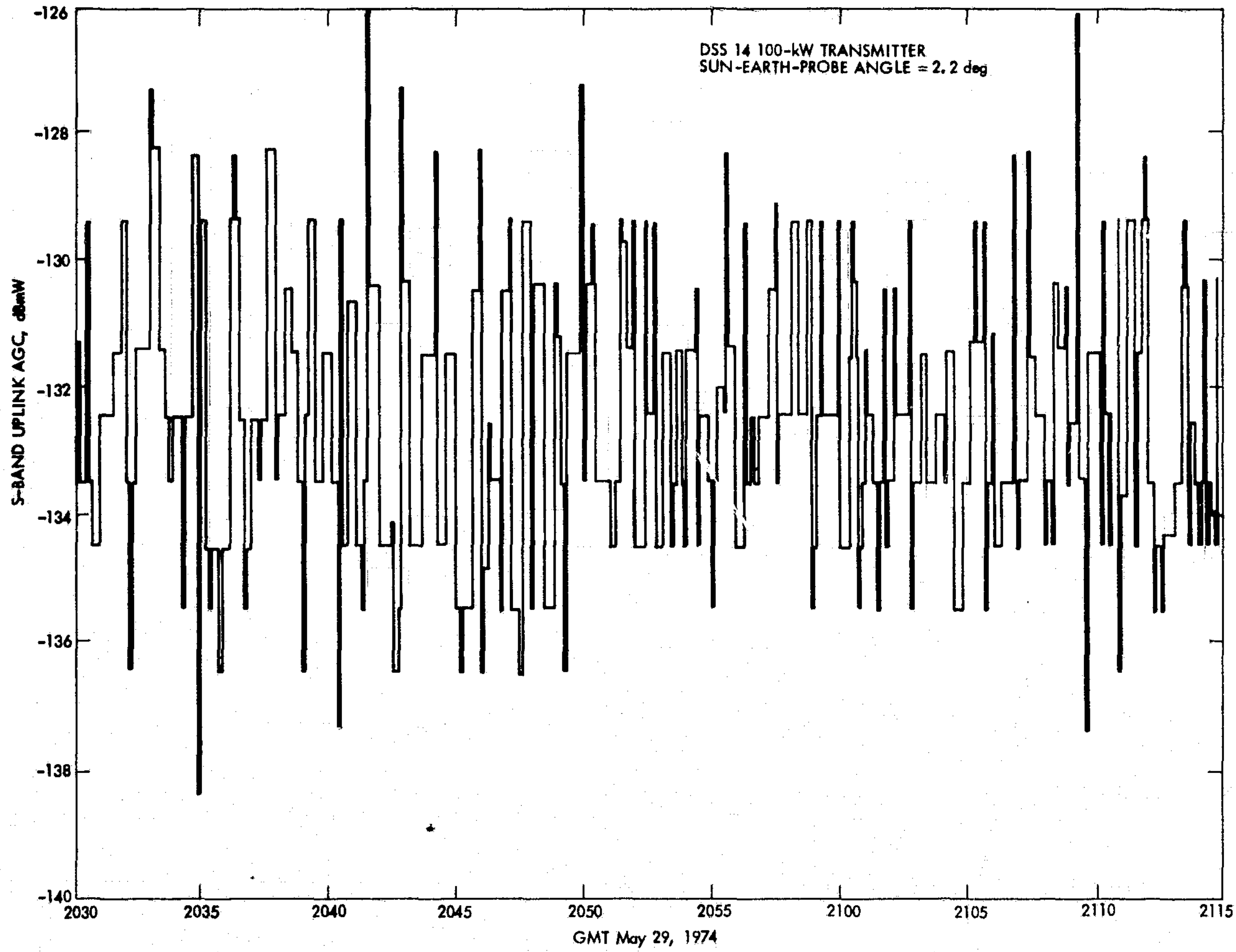


Figure 195. S-band uplink AGC

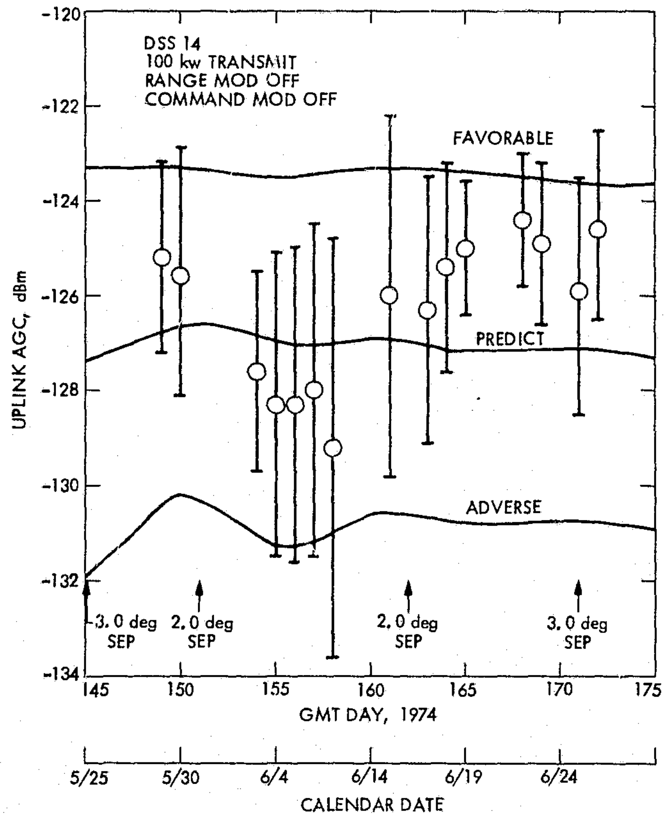


Figure 196. Uplink carrier power mean and standard variation

Table 53. DSN tracking support: April 1 - September 1, 1974

Item	California		Australia		Spain		Network totals
	DSS 12	DSS 14	DSS 42	DSS 43	DSS 62	DSS 63	
1. Tracking passes this period	56	85	34	30	67	76	348
2. Cumulative passes	152	191	146	87	179	124	879
3. Tracking hours this period	415	721	255	230	625	830	3076
4. Cumulative tracking hours	1235	1460	1239	831	1687	1233	7685
5. Commands this period	20	1867	326	380	0	1086	3679
6. Cumulative commands	5397	6059	1384	2103	1635	1543	18,121
7. Command aborts this period	0	1	0	0	0	0	1
8. Cumulative aborts	2	5	0	2	0	0	9

8. Second Mercury Encounter: September 1974

Following the Project's decision in May 1974 regarding the second encounter aimpoint, detailed encounter support plans were able to rapidly progress. Initially, the second encounter differed in two significant ways from the first encounter: (1) the second encounter would be a Sun-side pass having no solar or Earth occultations with emphasis on additional TV coverage of Mercury, and (2) the Earth-spacecraft distance would be greater than that at first encounter, resulting in the telecommunications link being 1 dB lower in regard to received signal level. The aimpoint difference, in fact, made second encounter planning easier for the DSN than that for first encounter since there were no occurrences of radio science occultation and rapid signal reacquisition requirements. The spacecraft could be continuously tracked in its pass by the planet in a "listen only" mode. However, the lower signal levels, due to the increased distance, posed some critical questions and support considerations. Would real-time 117-kbps video still be possible at Mercury II? Or would the reduced 22-kbps rate be necessary to stay above the maximum allowable bit error rate of 1 in 30? Could some improvement in the DSN deep space stations be implemented to regain the "lost" dB?

Telecommunications link analysis indicated that the bit error rate would be, at best, 1 in 20 and somewhat worse during much of the encounter pass at 117 kbps. It appears as if TV experimenters had a choice between a large number of TV frames of poor quality or a small number of high quality. In June 1974, engineers of the DSN's Communications Systems Research Section proposed that deep space station antenna arraying and signal combining techniques might be employed to gain 0.6 to 0.7 dB. The feasibility of this approach was pursued in a number of meetings, and the decision was made to implement an arrayed antenna capability for Mercury second encounter. It was understood that data via this source would be provided on an engineering experiment basis in parallel with the standard configuration at DSS 14.

The data system configurations for the antenna arraying experiment is given in Fig. 197. In this configuration, it should be noted that DSS 13 is not normally a flight support station; however, it was employed as one of the arrayed stations to take advantage of its lower system temperature. The arraying called for a three-station array of two 26-m and one 64-m antennas (DSS 12, 13, and 14), all operating in a listen only mode. The receiver baseband output from DSS 12 and 13 was microwaved to DSS 14 for the arraying experiment. DSS 14's receiver No. 2 baseband output was microwaved to the Goldstone Area Communications Terminal and looped back to DSS 14 via the microwave link to introduce a signal delay nearly equivalent to that of DSS 12 and 13. The signal combiner device, located at DSS 14 at the microwave interface, received the parallel input from the microwave subsystem from DSS 12, 13, and 14 in the form of baseband signals. The signal combiner correlated and phased the signals providing a combined output to DSS 14's subcarrier demodulator assembly in the beta string for processing and real-time transmission to JPL, as well as recording on the DSS original data record. In addition, DSS 14's receiver No. 1 was configured normally with its output to the alpha telemetry string for processing and digital

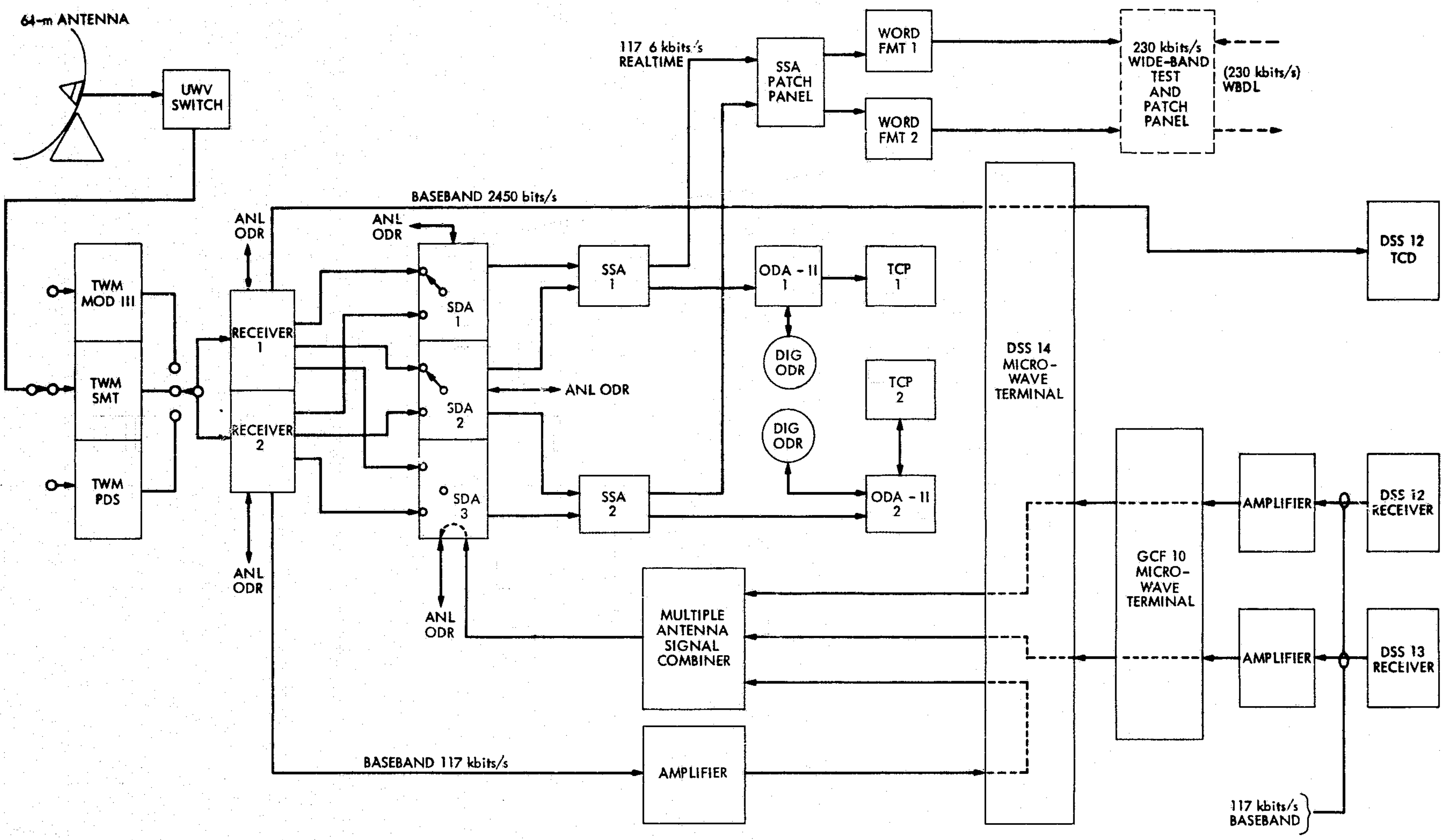


Figure 197. DSN antenna array configuration

recording of 117-kbps data. Since DSS 14 had only two telemetry strings and since both were tied up with 117-kbps data processing, the output of DSS 14's receiver no. 1 was also microwaved to DSS 12 wherein the low-rate subcarrier was detected and demodulated and the 2450-bps low-rate telemetry data was processed and transmitted in real-time to JPL.

On encounter day, performance monitor data from DSS 14 indicated that the alpha telemetry string was apparently performing about 0.5 dB better than the beta string. However, the arraying experiment had been hardwired into the beta string and it was not possible to switch to the apparently better performing alpha string. Even so, the arraying experiment gave approximately a 0.4 dB better performance than would have been realized without arraying. However, had the arraying experiment been on the alpha string, the test demonstrated that 0.7 dB gain would have been realized or exceeded. As shown in Fig. 198, the actual bit error rate at 117 kbps during the prime encounter TV sequences ranged from 3.1 to 3.6 per 100. This represented a significant improvement over the 4.5 to 5.0 per 100 expected without the arraying capability. The signal combiner device worked well, with no apparent difficulties.

Prior to encounter, tests were planned and conducted which evaluated the arraying performance, using actual spacecraft data during the far-encounter TV sequences. These tests provided the basis for deciding between the standard configuration and the arrayed configuration. Since the arrayed capability represented a significant increase in TV science data return, priority attention was given to the experiment's implementation and checkout.

The subsequent failure of the spacecraft tape recorder in August 1974 added a significant third difference to Mercury second encounter. There could be no preservation of high-quality TV frames on-board the spacecraft for later playback; only what was recovered on the ground in real-time would be available to the experimenters. The optional record-playback mode was no longer available, and that also added more importance to the arraying implementation. DSS 43 support was also employed as a part of the second encounter TV data acquisition plan. To provide for reasonable data quality, the low noise ultracone was maintained at DSS 43 through the second encounter.

To provide tracking coverage flexibility in the Spain longitude, DSS 61 was, for the first time, fully configured and checked out for Mariner 10 support. This also gave access to DSS 61's 20-kW transmitter for commanding during spacecraft loss of Canopus emergencies. The 230-kbps supergroup communications service between DSS 14 and JPL was reinstalled and checked out for encounter support. The service had been removed in the belief that real-time 117-kbps data would not be possible during the second encounter. The 28.5-kbps wideband communications service to the overseas 64-m stations was reactivated after being down during the cruise for cost avoidance reasons. Also, the DSS 14 to JPL standard 28.5-kbps circuit was converted to 50 kbps in preparation for Viking test support. Improvements were also made in DSS 14's backup antenna cone and maser performance by relocation of the maser nearer the feed horn in the cone. This provided an acceptable backup to DSS 14's standard cone-maser in the event of failure.

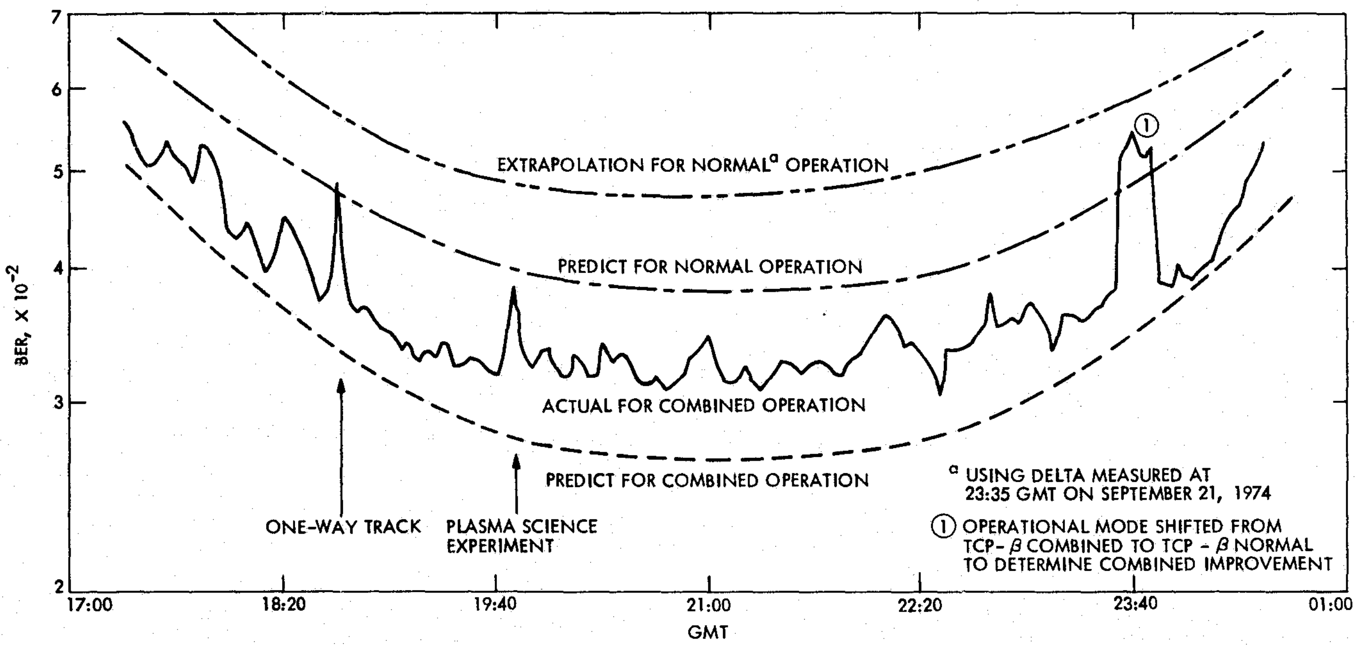


Figure 198. 117 kbps/s BER, Mercury II

DSN tracking support for the September 1974 period is summarized in Table 54. Of the 92 passes provided, 52 were from the 64-m subnet and 40 passes were from the 26-m subnet. The 64-m subnet provided 465 tracking hours out of the total 756 hours for the period; the 26-m subnet contributed 291 tracking hours. During this 30-day period, some 840 hours would have been required to provide full, overlapping coverage. Since 756 hours were provided, one sees that Mariner 10 realized some 90% of full coverage. This increased coverage and use of the 64-m subnet reflects the tracking and data acquisition requirements for Mariner 10's second Mercury encounter. No command aborts occurred during this period, which saw 2346 commands transmitted to the spacecraft.

9. Cruise to Third Encounter: October 1, 1974 - March 1, 1975

The primary objectives during this portion of the extended mission were to assure survival of the spacecraft for a third Mercury encounter through conservation of attitude control gas and to conduct trajectory correction maneuvers as necessary to target the spacecraft for a solar occultation zone pass. Special support activities included correction maneuvers Nos. 6 and 7 conducted on October 30, 1974, and on February 12-13, 1975, respectively. This period also saw the DSN interface organization involved in (1) the allocation of sufficient coverage to assure accurate orbit determination solutions, (2) monitoring of DSN implementation for Viking to assure maintenance of compatible interfaces and capabilities required for Mariner 10, and (3) the development of encounter coverage sequences and readiness test plans.

During October 1974, the DSN participated with the Project in planning and preparing for trajectory correction maneuver No. 6. A major effort went into obtaining sufficient tracking coverage for Mariner 10 in the face of high priority tasks: Pioneer 10 and 11, Helios A prelaunch tests, Viking implementation, and deep space station upgrades. This period saw DSS 44 down for conversion from the STDN to DSN configuration, DSS 14 down for Viking implementation, and DSS 63 down for gear box repairs. Limited but adequate coverage was provided for Mariner 10. Correction maneuver No. 6 was accurately performed on October 30, 1974, and there were no DSN support problems.

Owing to spacecraft attitude control problems and high usage of attitude control gas in October, the Project placed the spacecraft in a roll-drift mode with the high-gain antenna and solar panels positioned to produce torque in the pitch, yaw, and roll axes that would minimize gas consumption. This required communications to be conducted over the spacecraft low-gain antenna and lowering of the data rate to 8-1/3 bps. Furthermore, the spacecraft roll mode seriously impacted the navigation accuracy achievable with the previously negotiated DSN tracking times. The Project requested additional radio metric data, particularly three-way doppler data to understand the roll signatures in the doppler data and additional range points to refine the orbit determination solutions. Figure 199 gives a comparison of the following: (1) the Project's telecommunications performance prediction program output with Canopus acquired, (2) the theoretical low-gain antenna pattern

Table 54. DSN tracking support: September 1 - October 1, 1974

Item	California		Australia		Spain			Network totals
	DSS 12	DSS 14	DSS 42	DSS 43	DSS 61	DSS 62	DSS 63	
1. Tracking passes this period	17	18	9	19	9	5	15	92
2. Cumulative passes	169	209	155	106	9	218	139	1005
3. Tracking hours this period	102	140	80	191	70	39	134	756
4. Cumulative tracking hours	1337	1600	1319	1022	70	1726	1367	8441
5. Commands this period	574	1368	25	223	19	0	137	2346
6. Cumulative commands	5971	7427	1409	2326	19	1635	1680	20,467
7. Command aborts this period	0	0	0	0	0	0	0	0
8. Cumulative aborts	2	5	0	2	0	0	0	9

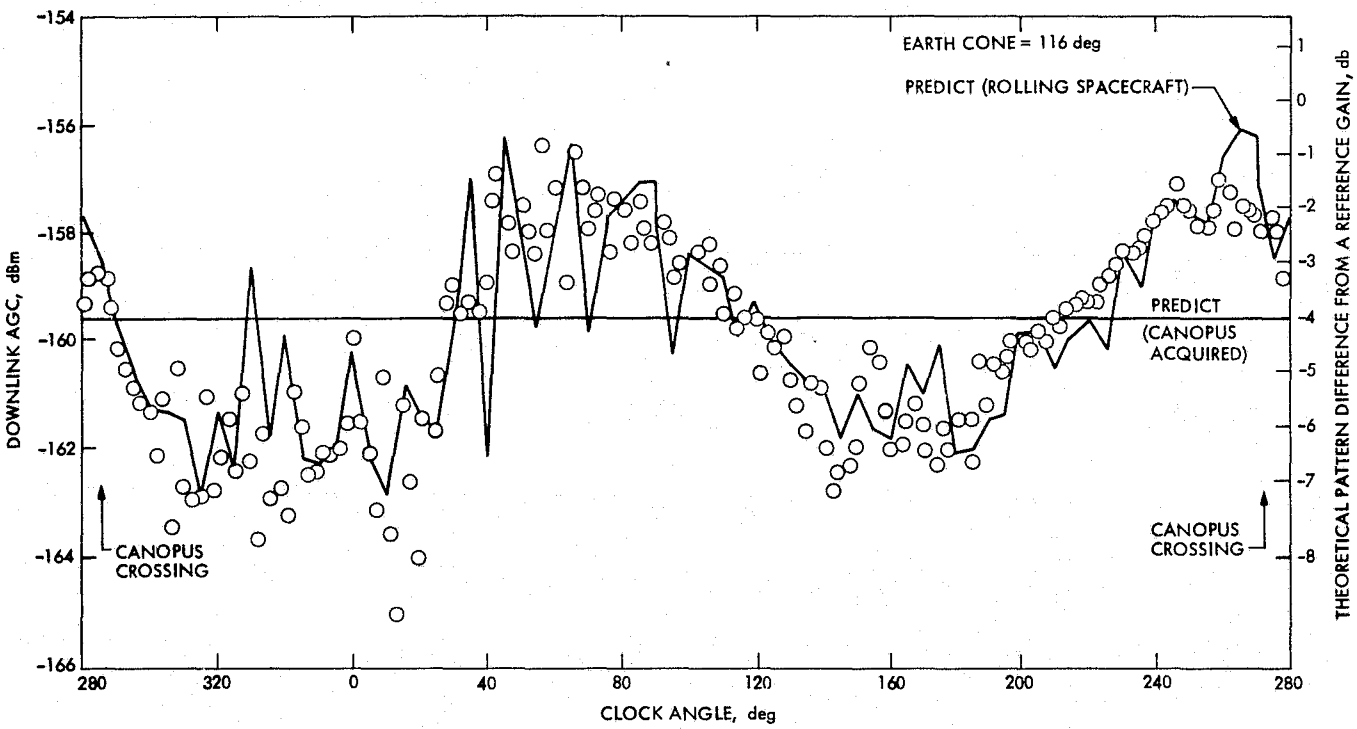


Figure 199. LGA performance comparison

through 360 deg of roll, and (3) the actual spacecraft downlink AGC recorded over DSS 43 on October 15, 1974. As can be seen, the telecommunications performance predict is totally unusable, while the theoretical pattern is usable only in a general sense as a trend indication. The theoretical pattern has a resolution of 5 deg in clock which, for a slow roll, was inadequate. Figures 200 and 201 yield a comparison of spacecraft downlink AGC data under similar conditions but with different roll rates. The primary difference is in the data scatter. When the spacecraft is rolling at a more rapid rate, much of the fine grain structure is smoothed over by the roll rate and the AGC sampling time. Downlink AGC is sampled once per minute. This sample is an average of 12.5-sec data samples from the tracking station. If the roll rate is high, then as much as 2 or more deg would be represented by one sample. Also, if the roll rate is low, then a higher resolution antenna pattern is obtained. The shortcomings of the low-gain antenna patterns are borne out in the later discussion on the Canopus acquisition sequence prior to Mercury third encounter.

Planning for trajectory correction maneuver 7 continued through November and early December 1974. In order to allow for a single maneuver strategy and to avoid coverage conflicts during the Helios A launch and Pioneer 11 encounter periods, correction maneuver 7 was rescheduled from early January 1975 to February 12, 1975. This permitted allocation of adequate coverage for Mariner 10 pre- and post-maneuver orbit determination activities. During this time, the spacecraft continued its flight in the solar torque, roll-control mode. Following resolution of these December 1974 to February 1975 tracking coverage allocations, full attention was given to the development of a compromise plan for the March 1975 period.

On December 16, 1974, DSN and Project people met to develop an understanding of essential encounter requirements, as well as the requirements of other flight projects during the March 1975 period. The "Ides of March" appeared to be an appropriate title for this near-impossible conflict situation. However, negotiations resulted in a significant reduction of Mariner 10's initial requirement for 8 days of continuous 64-m subnet coverage at encounter. This reduction was a key factor in permitting the DSN to draft a recommended solution to the problem. In summary the problem was as follows: (1) Helios and Mariner 10 view periods were almost entirely overlapping during March 1975; (2) Helios A perihelion, an event of prime interest, would occur on March 15, 1975, requiring 64-m subnet coverage during the period from March 5 to 25, 1975; (3) Mariner 10's Mercury encounter would occur on March 16, 1975, requiring 64-m subnet coverage during the period from March 12 to 20, 1975; (4) Pioneer 10 and 11 solar conjunction would occur on March 24, 1975, and April 4, 1975, respectively, requiring 64-m subnet coverage during the period March 19, to April 4, 1975. The problem was significantly reduced by the following reductions in requirements:

(1) Helios A would not use DSS 63 since coverage in this longitude was provided by the German tracking station.

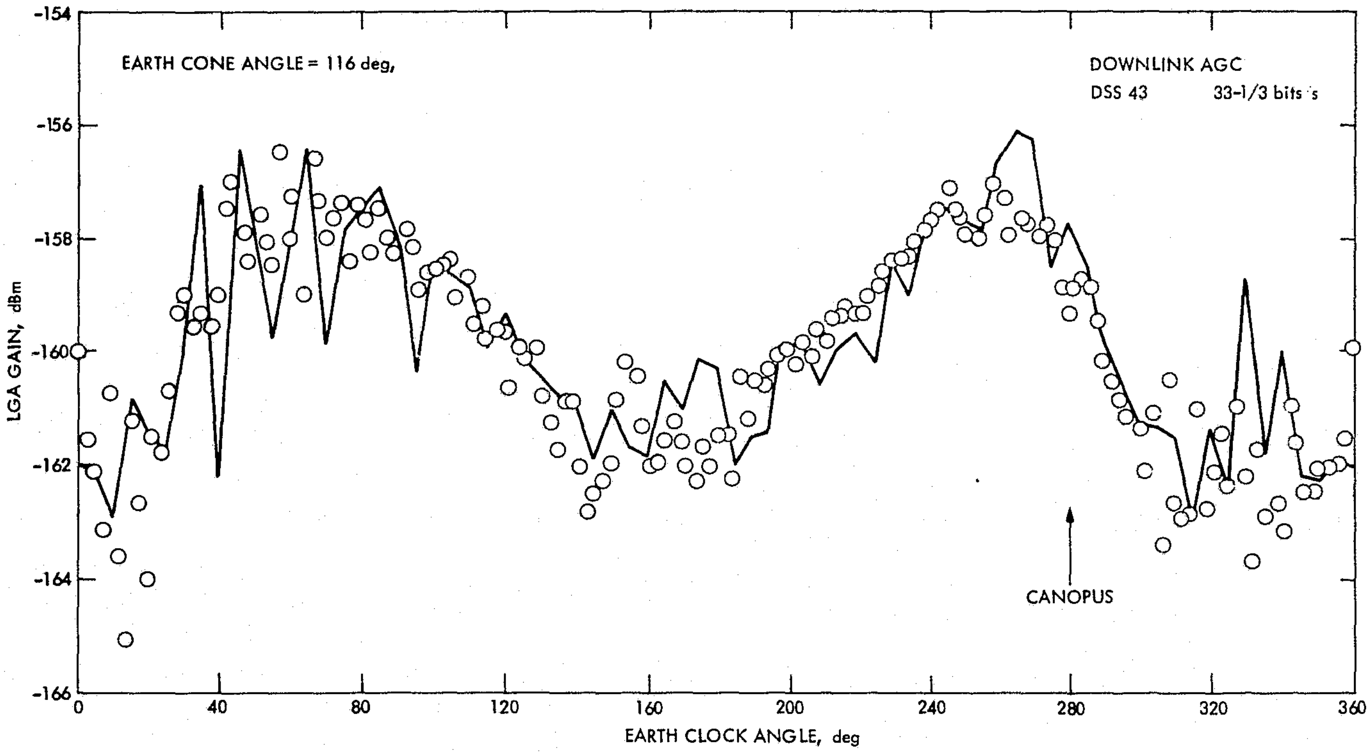


Figure 200. LGA performance, October 15, 1974

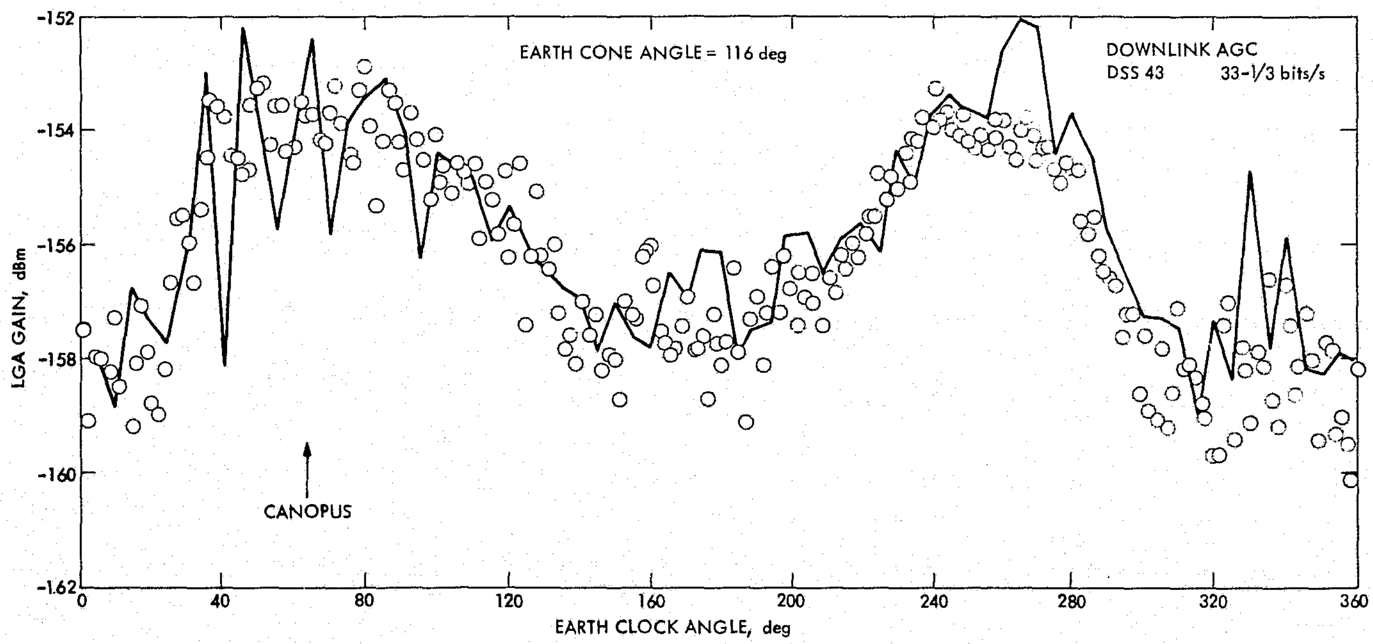


Figure 201. LGA performance, January 8, 1975

(2) Mariner 10 agreed to schedule pre-encounter critical events to occur over DSS 63. These included: (a) central computer and sequence load for encounter on March 11, 1975, (b) Canopus reacquisition on March 13, 1975, and (c) far-encounter TV calibrations and tests on March 14 and 15, 1975, thus leaving DSS 14 and 43 free to support other projects.

(3) Mariner 10 reduced the encounter 64-m subnet coverage requirements to the minimum essential needed to recover near-encounter imaging and nonimaging data, three consecutive passes on March 16-17 (GMT).

Meetings and negotiations continued between the flight projects throughout January 1975, to reach agreements on detailed tracking schedules based on these proposed compromises.

By early February 1975, plans for trajectory correction maneuver 7 were completed, and the required deep space station coverage was allocated. Since the spacecraft continued in the roll-drift mode, timing of the roll by monitoring Canopus and other star crossings was critical to proper execution of the maneuver. Coverage from 64-m stations was required to acquire these data at 33-1/3 bps since link conditions were inadequate for communications via the 26-m stations. However, shortly before start of the maneuver sequence on February 12, 1975, a change in time of the Canopus crossing was noted and the correction maneuver was postponed until February 13. The maneuver was conducted on February 13, 1975, and excellent support was provided by DSS 63. Recovery of data was continuous throughout the maneuver, even though a dropout had been expected due to the planned adverse pitch angle. DSS 63 accomplished two post-TCM replays of telemetry data acquired during the burn to fill gaps caused by difficulties at the JPL Data Processing Facility. Unfortunately, as evidenced by greater-than-planned changes in the doppler data, TCM 7 did not achieve the required correction accuracy. Early indications reflected a 20% error as a result of either engine overburn, roll error, pitch error, or a combination of all of these error sources. Consequently, it was necessary for the Project and the DSN to negotiated for additional deep space station tracking time to obtain sufficient doppler and range data to rapidly redefine the orbit.

DSN support plans for Mercury third encounter were also finalized during this period. A minimum, but adequate, test plan had been developed to revalidate the DSS 64-m subnet data systems and to reverify readiness to support special data rates and sequences at encounter. In many respects, third encounter planning was similar to the first encounter. The primary objective was to obtain nonimaging science data at 2450 bps, particularly from the solar occultation zone. As a secondary objective, imaging data was to be recovered during the near-encounter sequence, except when passing the dark portion of the planet in the solar occultation zone. Unlike the first encounter, however, the spacecraft would not pass through the Earth occultation zone during this third pass by the planet.

This targeting provided an opportunity to acquire data for support of celestial mechanics experiments which was not available on the previous encounters: the first encounter had a tracking gap due to the Earth occultation, giving a break in continuous two-way doppler near the planet; the second encounter was targeted to optimize television on the bright side pass and was too far from the planet to provide precise results. The low noise ultracone was maintained at DSS 43 for third encounter support and to do so required negotiation of the DSS 43 RF cone reconfiguration work scheduled in preparation for Viking 75. However, maintaining the low noise S-band megawatt transmit cone in place at DSS 14 could not be accommodated through a delay of cone reconfiguration work. During January 1975, the SMT cone was replaced with the S-band polarization diversity cone. The DSN did, however, install the SMT maser in the SPD cone to improve the system performance. Furthermore, the Mariner 10 Project was required to transfer operations to the DSN redesigned command system in mid-January 1975. After resolution of initial minor difficulties on January 15, 1975, the changeover took place smoothly and commanding continued in the redesign mode without difficulty. With Project agreement, the DSN also found it necessary to terminate the Block III planetary ranging capability at DSS 14 in order to meet the Viking schedule for completing the Block IV configuration. The 230-kbps supergroup communications service between DSS 14 and JPL was reactivated; the circuit had been deactivated during the cruise to avoid lease costs.

DSN tracking support for the October 1974-March 1975 period is summarized in Table 55. This period saw the DSN's support rather evenly split between the 26- and 64-m subnets. The 145 passes from the 64-m stations represented 50% of the period's tracking hours, while the 129 passes from 26-m stations contributed 50% of the coverage. During this 151-day period, some 4228 tracking hours would have been required to provide full, overlapping coverage. Since only 1908 hours were provided, one sees that Mariner 10 was hard pressed to obtain support in the face of higher priority demands of other flight projects; only some 45% of full coverage was realized. Two command aborts occurred during the period out of 1080 commands transmitted. Both were due to PN sync quality alarms.

10. <u>DSN Radio Metric Data</u>

This is a good point to pause and reflect on the use of DSN-generated radio metric data for Mariner 10 navigation and orbit determination. Definitive evaluation of DSN doppler, range and other radio metric data comes through its use by the Project for orbit determination purposes; consequently, much of the following information is taken from the Mariner 10 Navigation Team's final report. Encounter targeting results show that the Mariner 10 navigation system met or exceeded all of the planetary delivery requirements. Also, the nominal velocity changes required to achieve first Mercury encounter preserved sufficient propulsion capabilities for the additional second and third encounters. This was accomplished in the face of several spacecraft problems which made accurate navigation more difficult and which precluded the execution of standard trajectory correction maneuvers.

Table 55. DSN tracking support: October 1, 1974 - March 1, 1975

Item	California		Australia		Spain			Network totals
	DSS 12	DSS 14	DSS 42	DSS 43	DSS 61	DSS 62	DSS 63	
1. Tracking passes this period	44	32	18	67	65	2	46	274
2. Cumulative passes	213	241	173	173	74	220	185	1279
3. Tracking hours this period	268	204	149	467	521	19	280	1908
4. Cumulative tracking hours	1623	1804	1468	1489	591	1745	1647	10,367
5. Commands this period	125	428	74	287	43	64	59	1080
6. Cumulative commands	6096	7855	1483	2613	62	1699	1739	21,547
7. Command aborts this period	1	0	0	1	0	0	0	2
8. Cumulative aborts	3	5	0	3	0	0	0	11

Following the first Mercury encounter the uncorrected trajectory would have taken the spacecraft to a closest approach approximately 800,000 km below Mercury on the second encounter. The navigation activities required to achieve the desired closest approach distance of 50,000 km included two trajectory correction maneuvers and three periods of orbit redetermination. Trajectory correction maneuver 4 was designed to correct the major portion of the error during the period when the velocity change requirements were low, and correction maneuver 5 was accomplished to correct any residual errors and achieve an accurate flyby. Orbit determination activities involved reconverging the orbit prior to each of these maneuvers, plus a final reconversion after correction maneuver 5 to support the encounter sequence planning.

Navigation between the second and third Mercury encounters became much more challenging than on the previous leg. On one hand, the science return improved as the closest approach distance decreased, provided the spacecraft did not impact the planet. Thus, the need for highly accurate navigation. On the other hand, reduced supply of attitude control gas forced the Project to adopt the solar sailing mode, which in turn severely degraded both the doppler and range data. This data degradation had a potentially catastrophic effect upon the orbit determination accuracy and a major portion of the navigation effort on this leg was applied to correcting and working around this problem. Even with the problem of the inaccuracy in correction maneuver 7 and the requirement for an eighth correction maneuver, the spacecraft was delivered to a closest approach point of only 327 km above the surface. This distance was less than half the closest approach distance on the first Mercury encounter.

During the prime mission, both the priority of the MVM'73 Project and the DSN work load allowed sufficient tracking coverage to be scheduled, particularly from the 64-m subnet. However, during the extended mission the reversal of both these factors required that tracking requirements be carefully generated and coordinated with the DSN and other flight projects. As has been shown in various portions of the extended mission, the tracking coverage became critical to the success of the mission and special effort was required to schedule sufficient coverage to achieve the navigation objectives. The reduced coverage along with the comparative degradation of much of the extended mission radio metric data due to solar plasma corruption around superior conjunction and the rolling spacecraft data signature during the period of solar sailing made orbit determination significantly more complicated during the extended mission.

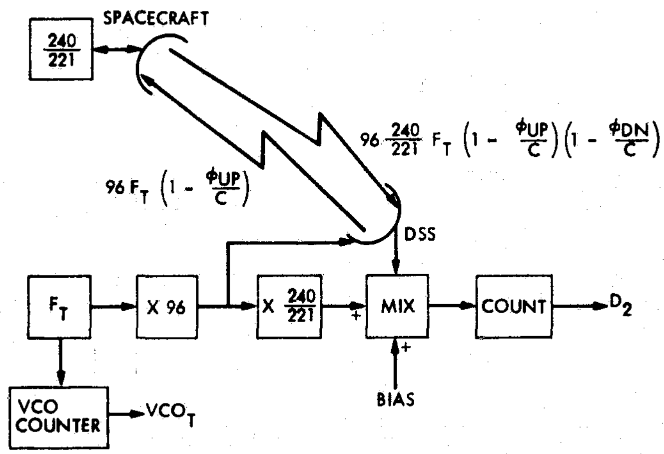
In order to generate doppler data for measuring range rate, the deep space stations provide a synthesizer frequency of approximately 22 MHz multiplied by a factor of 96 to produce a carrier tone of about 2200 MHz. This carrier was transmitted to the Mariner 10 spacecraft, wherein the received signal was then retransmitted at an S-band frequency 240/221 times higher and returned to Earth. An X-band transponder on the spacecraft also returned the carrier at a frequency adjusted by 880/221. However, one should note that this frequency could only be received by the Block IV receiver located at DSS 14. When the receiving deep space station is the same as the transmitting deep space station, the data is considered to be two-way doppler (F2), but if the receiving deep space station is different, the data is labeled three-way doppler (F3). When the spacecraft does not receive a signal from Earth, it transmits a constant beacon tone of about 2300 MHz. When the signal is received by a deep space station, it is considered to be one-way doppler (F1). The cycles of received signal are counted by a doppler counter at the deep space station. The cycle counter is then interrogated at a specific sample interval, and the count is transmitted along the high-speed data lines to the Project. The radial spacecraft velocity is a function of the measured doppler shift in the received signal. Figure 202 illustrates the configuration for the generation of two-way doppler data.

Measurements of spacecraft range are obtained by the deep space station transmitting a series of coded pulses via sidebands of the main carrier frequency to the spacecraft which are then retransmitted by the spacecraft back to Earth. Then the code received at the deep space station is matched against the transmitted code. The spacecraft range is a function of the phase shift between the two signals. In practice, the range measurements are influenced by daily variations in the spacecraft and deep space station hardware and timing devices, as well as local weather conditions at the station. Calibrations of local ranging delays must be taken at each station during its ranging track, and then combined with the current spacecraft delay to produce ranging adjustment values for calibration of the data in order to arrive at the proper range measurement. Although the DSN's Mark IA lunar ranging capability was used to acquire ranging data in the early part of the mission, the primary device for providing ranging during the remainder of the mission was the planetary ranging assembly, newly implemented at the 64-m stations. For a discrete planetary ranging point of N components, the final range value is ambiguous by multiples of 2^{10+N} range units (1 range unit is equivalent to 1/7 meter). Thus, to properly interpret a range point of 10 components, the spacecraft orbit positional uncertainty must be no greater than about 150 km.

The ranging system effectively divides the solar system into concentric shells, each shell being 2048 ranging units thick. The spacecraft position is determined with respect to this measuring system. The T_0 time is the second when the range code first returns to the ranging deep space station from the spacecraft. Then follows an interval of (T_1 + 1) second during which the spacecraft location is defined within one of the ranging shells. Following the T1 interval are (N - 1) T2 intervals, each (T2 + 1) seconds in duration, which successively define the particular shells containing the spacecraft. After the last T2 interval, a series of T3 intervals (each T3 seconds long) define Differenced Range Versus Integrated Doppler (DRVID) data. The range parameters were calculated as follows:

Clock acquisition time parameters

$$T_1 = 12.5 \left(\frac{15}{\sigma}\right)^2 \frac{N_0}{P_R} \text{ sec}$$



TWO-WAY DOPPLER: $F2 = BIAS + 96\ \frac{240}{221}\ VCO_T \left(\frac{UP + DN}{C}\right)$

ϕ_{UP} = SPACECRAFT RADIAL VELOCITY (km/sec) RELATIVE TO TRANSMITTING STATION

ϕ_{DN} = SPACECRAFT RADIAL VELOCITY (km/sec) RELATIVE TO RECEIVING STATION

C = SPEED OF LIGHT (km/sec)

F_T = SYNTHESIZER FREQUENCY OF TRANSMITTING STATION (NOMINALLY 22 mHz FOR BLOCK III RECEIVER AND 44 mHz FOR BLOCK IV RECEIVER)

VCO_T = COUNTED VCO FREQUENCY OF TRANSMITTING STATION, NOMINALLY 22 mHz

BIAS = 10^6 Hz FOR BLOCK III AND 5 TIMES 10^6 FOR BLOCK IV RECEIVER

Figure 202. DSS generation of two-way doppler (F2)

where

$$\frac{N_0}{P_R}\ (W/W) = 10^{-\rho/10}$$

σ is the desired range accuracy in meters

N_0 is the system noise spectral density

P_R is the power in the ranging channel

$\rho = \frac{P_R}{N_0}$(dB), signal-to-noise ratio, available from dumps of Project tracking tapes or telecommunications predictions.

Constraint

$$T1 = J\ T_s - 1 \text{ sec}$$

where T_s is the tracking and data handler sample rate and J is an integer

Probability of false acquisition parameter

$$T2 = 10^{(9-\rho)/10} \text{sec}$$

provides for PE < 1/1000

Constraint

$$T2 = 20K - 1 \text{ sec (K an integer)}$$

DRVID post range acquisition integration time

$$T3 = \frac{1}{88}\ 12.5 \left(\frac{15}{\sigma}\right)^2 \frac{N_0}{P_R} \text{ sec}$$

Constraints

$$T3 = L(T2 + 1) \text{ sec (L an integer)}$$

$$T3 = MT_s \text{ sec (M an integer)}$$

Optimal values of N, T1, T2, T3 and the suggested interval between successive T0 times were periodically transmitted from the navigation team to the DSN Operations Chief, who would communicate the values to the individual deep space station. During the MVM'73 extended mission, the capability was developed to take ranging from the conjoint 26-m stations, DSS 42 and 61. The technique involved sharing the planetary ranging assembly of the conjoint 64-m deep space stations. Due to its smaller antenna size, the P_R/N_0 for a 26-m deep space station was almost 16 dB weaker than a corresponding P_R/N_0 at a 64-m deep space station. Consequently, longer range integration times were required.

In one instance, when the spacecraft was in the solar-sail mode and communicating to Earth via its low-gain antenna, more than 3-1/2 hr was required to integrate a single 7-component   = 15 m conjoint range point. However, when the spacecraft ranging signal-to-noise ratio was favorable, range point parameters were generally adjusted to provide $\leq$ 5 m and N $\geq$ 10.

The raw range reading provided by the planetary range assembly at a deep space station is not the final desired range measurement. As seen in Fig. 203, the raw PRA range value will contain an unwanted round trip through path ABC plus a station hardware delay (as electronic impulses pass through cabling and are processed by the ranging equipment). In order to calibrate the unwanted component (which may vary daily due to local meteorological conditions at the station), a signal is transmitted from a zero delay device (ZDD) through the station feed horn and electronics and then returned to the ZDD. The round trip through path DEF and the station equipment duplicates the travel of the actual spacecraft signal, so that when the ZDD calibration and the current spacecraft delay are subtracted from the raw PRA reading, the range measurement PQ (Fig. 203) results. Since the desired range measurement is PR (the distance from the spacecraft to the deep space station axis), the Z-height value (the distance between the ZDD and DSS axis) is then added to the intermediate result.

In practice, the ZDD measurement for each ranging pass was transmitted to the Network Analysis Team (NAT) in the form of a posttrack report, which then became available to the navigation team.

In the course of the mission it was observed that the consistency of valid range measurements at a particular deep space station was on the order of a few meters. This minor variation could in part be due to the limitation on the clock acquisition time parameter T1. However, there still remain serious biases on the order of 20 m between individual deep space station facilities, which apparently arise due to inconsistencies in the calibration procedures within the DSN, as well as survey errors in the deep space station locations (Fig. 204).

As expected, near superior conjunction the doppler data was seriously corrupted by interactions with solar plasma (Fig. 205). It was not, however, anticipated that serious charged-particle corruption would be apparent as soon as or for as long as it in fact was observed. Plasma interactions in the form of spurious wavy signatures were developing in early March 1974, when the Sun-Earth-probe angle was greater than 30 deg (Fig. 206). Consistently serious corruptions were observed from mid-April through late August 1974. Figure 207 shows an example of the characteristically poor data received during this period, which may be contrasted against the clean data received for most of the prime mission as in Fig. 208. Circulatory motion in the transmission point of the low-gain antenna introduced a sinusoid in the doppler tracking data (Fig. 209).

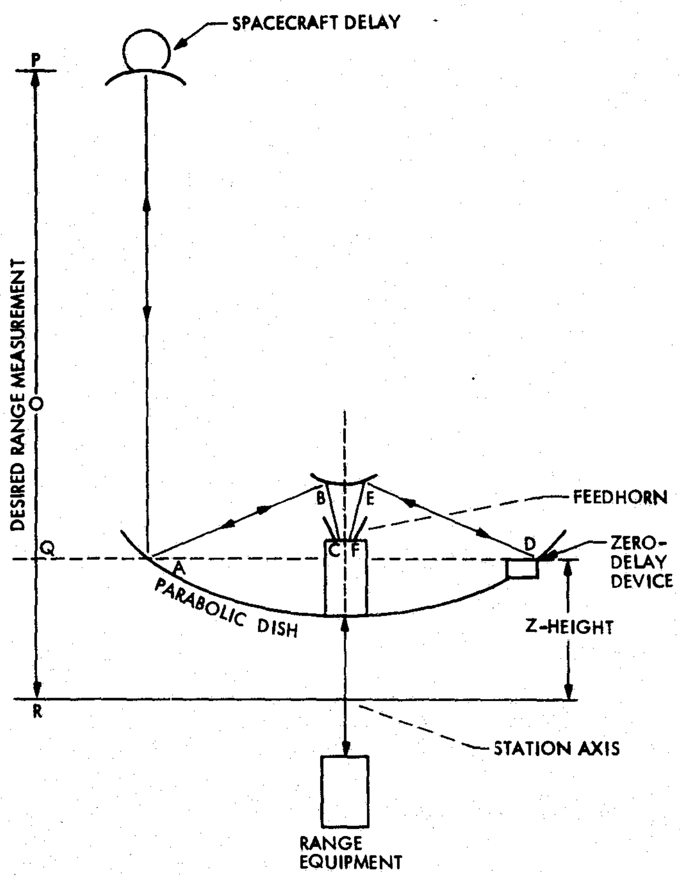


Figure 203. Range calibration at a deep space station

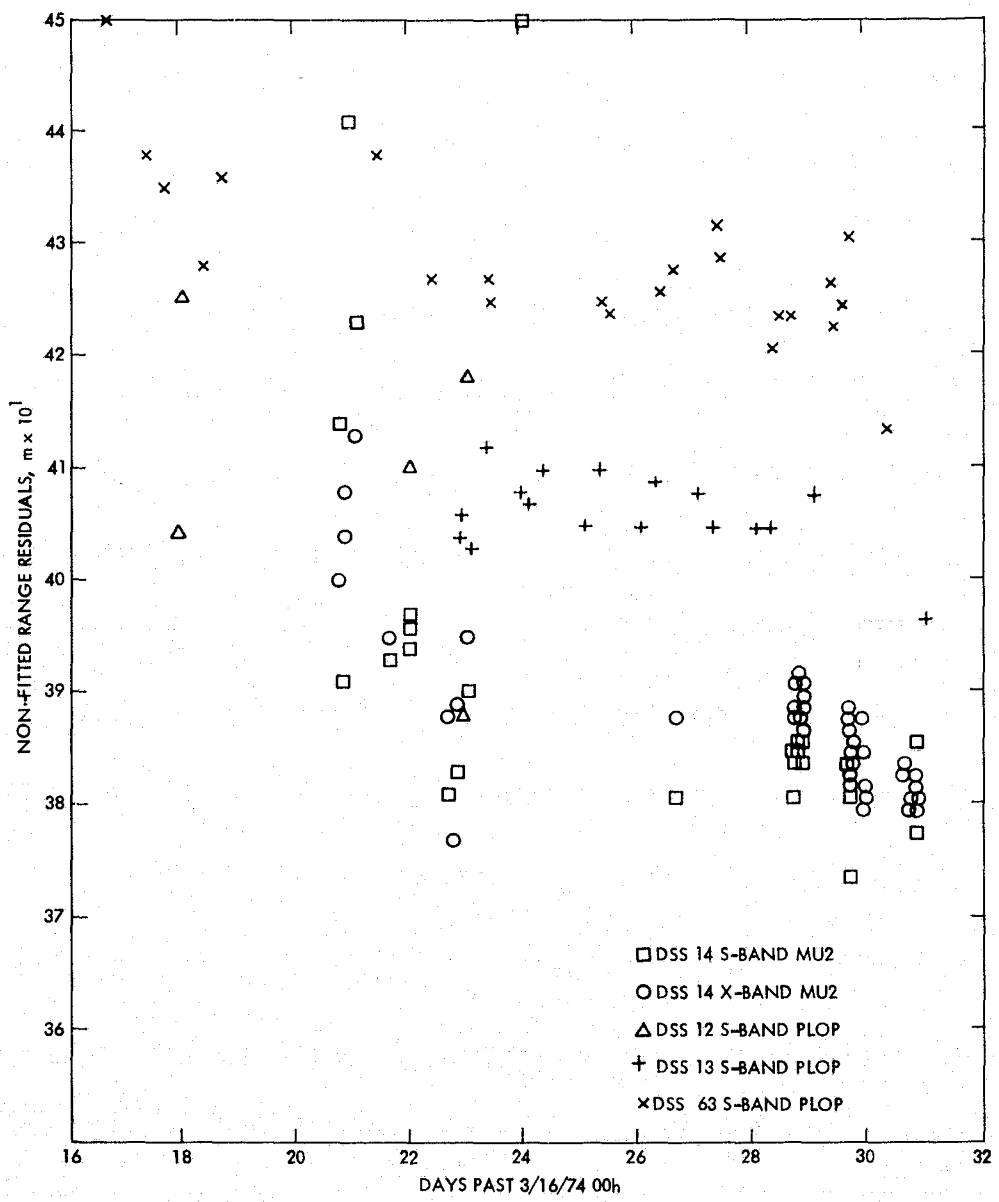


Figure 204. DSS range residuals

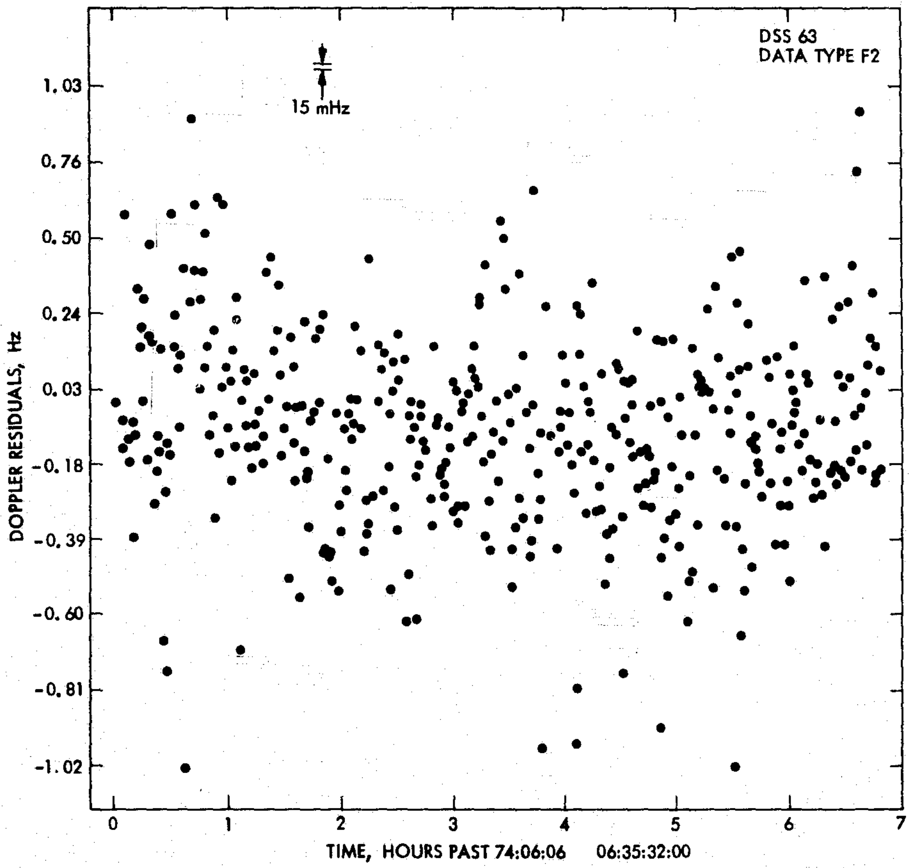


Figure 205. F2 data on day of superior conjunction

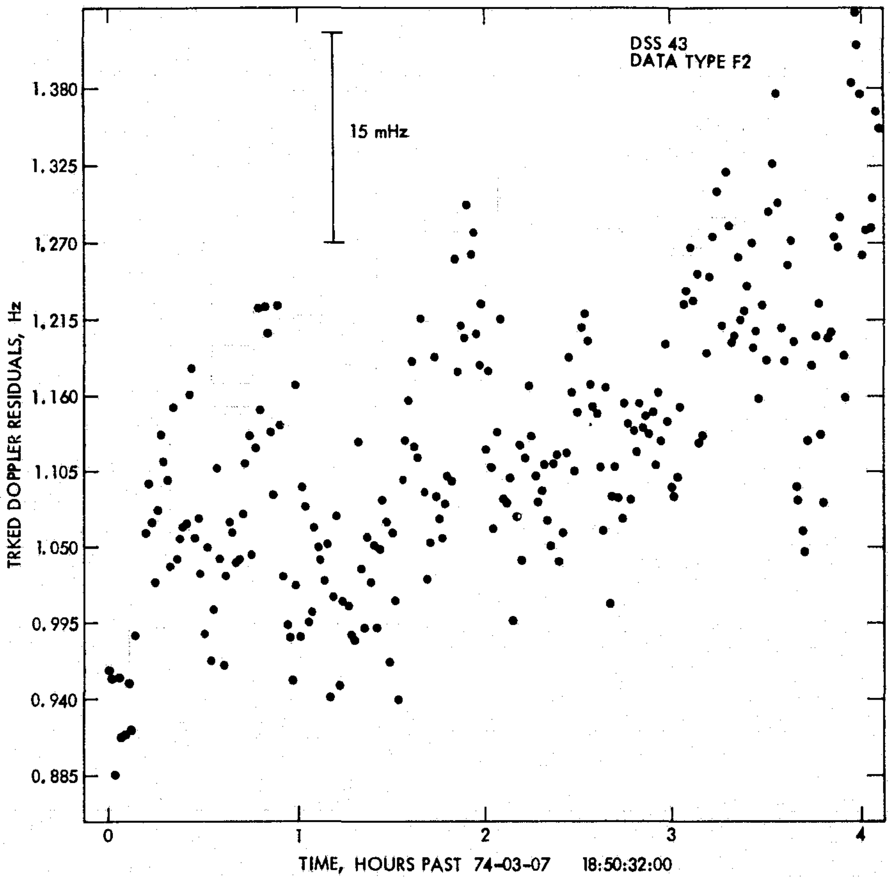


Figure 206. Assumed plasma-corrupted F2 residuals

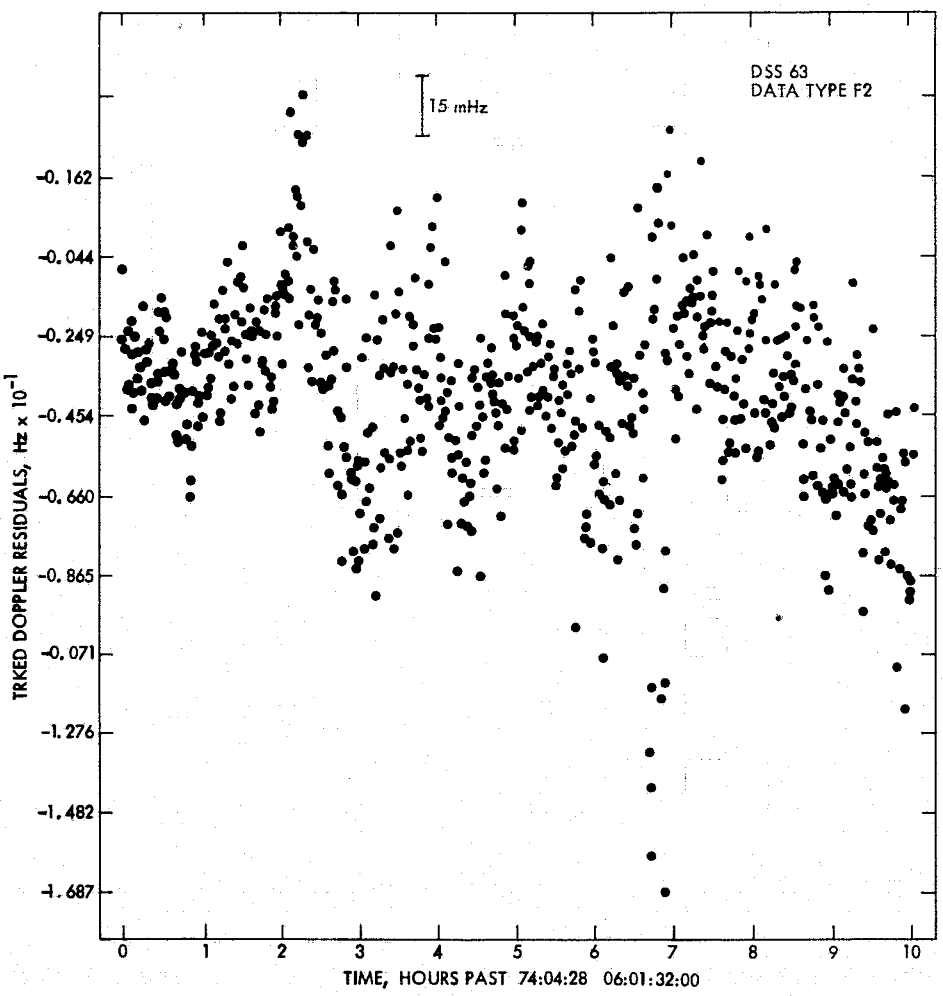


Figure 207. Plasma-corrupted F2 residuals

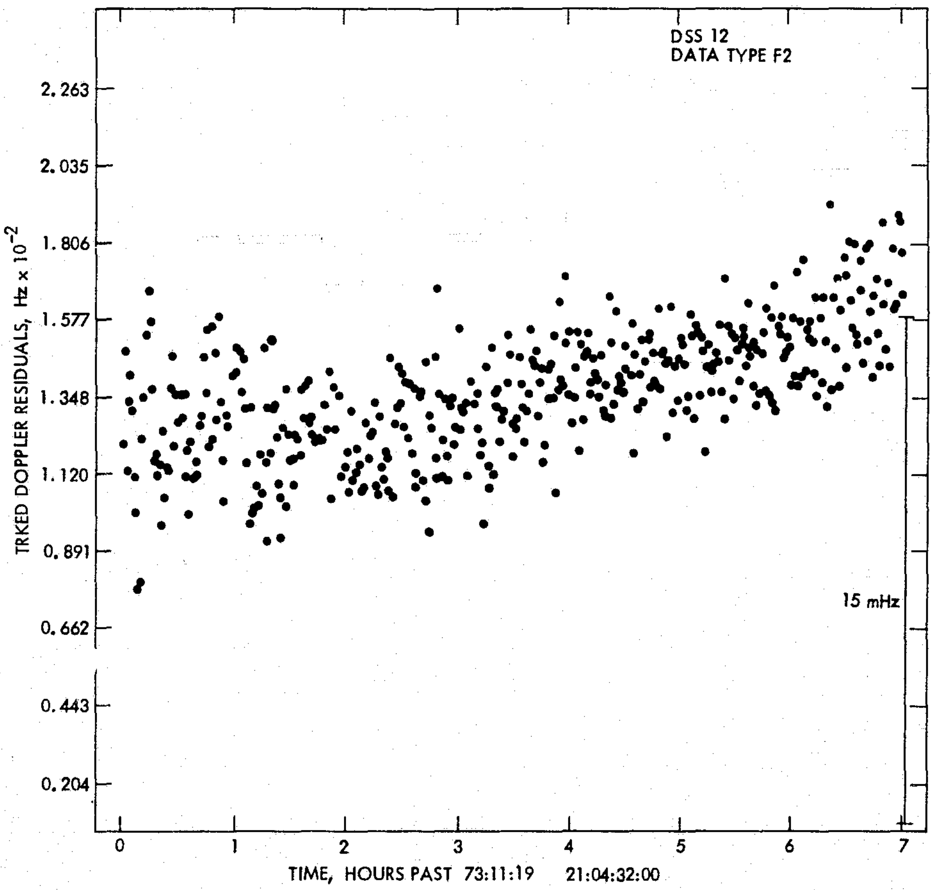


Figure 208. Clean F2 residuals data

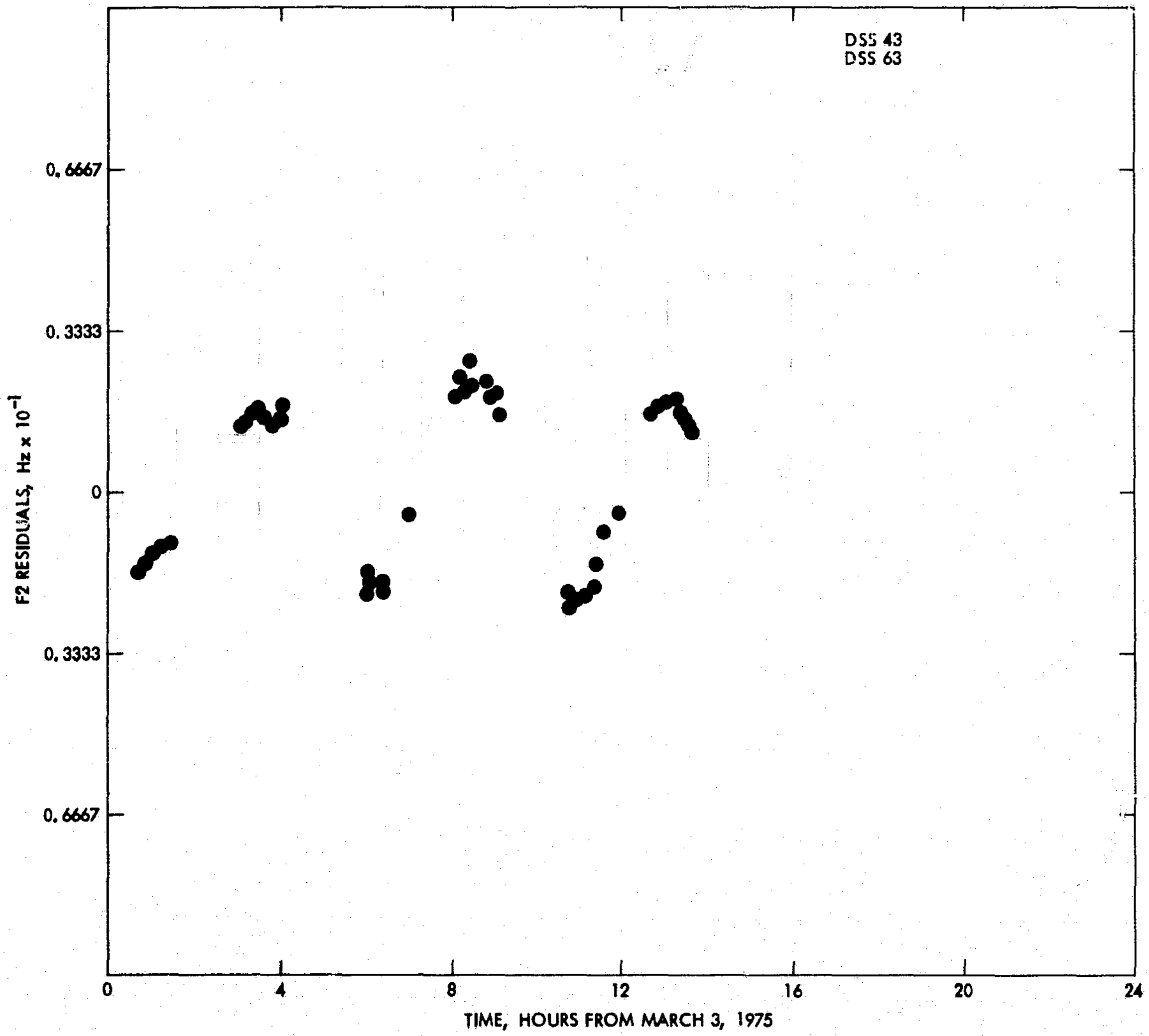


Figure 209. Uncorrected F2 residuals

Superior conjunction degraded the orbit determination capability by causing high data noise and spurious data signatures. Figure 210 plots the observed 1- data noise (for 1-min doppler samples) as a function of time during the superior conjunction phase. Also plotted is the Sun-Earth-probe angle, and the predicted data noise based upon the results of the Mariner 9 superior conjunction. The agreement with the observed noise was good at the limbs of the curve, but not at its peak.

There were demonstrations of four different techniques during the flight: (1) dual-frequency S/X data used to calibrate the effect of charged particles on the radiometric data, (2) simultaneous doppler used to reduce the effect of unmodeled solar corona effects and unmodeled spacecraft acceleration, (3) near-simultaneous range used to enhance the measurement of declination when the spacecraft has low declination, and (4) the ramp ranging experiment where the range was deduced directly from doppler data. The results of each of these are described.

Charged particles in the space plasma and ionosphere are one of the primary error sources in radiometric navigation. The ionosphere alone can produce errors of a few hundred kilometers in the target plane of Jupiter. Generally, the effects of the space plasma are not as severe. However, if the radio signal passes close (15 deg) to the Sun or is corrupted by a large space plasma event, the navigation can be severely degraded (100 - 1000 km).

Attempts at calibrating charged particles began during Mariners 6 and 7. Techniques employing ionosonde, Faraday or DRVID data have shown varying degrees of success but seldom anything startling. By far the most encouraging charged particle calibration results were obtained from the S/X dual-frequency data obtained from Mariner 10. The spacecraft had the capability of receiving S-band doppler and range and returning to DSS 14 S-band and X-band doppler and range. Since the effect of the charged particles on the radiometric data is dispersive, the dual-frequency data provides an ideal means of calibrating the charged particles.

The first portion of the Mariner 10 S/X demonstration consisted of determining the data quality of S/X calibrations by comparing them with Faraday rotation calibrations of the ionosphere. As illustrated in Fig. 211, Faraday rotation calibrations are obtained by monitoring a polarized signal transmitted from a stationary earth satellite and then mapping the result to the spacecraft line-of-sight. Figure 212 contains a comparison of S/X doppler and Faraday rotation calibrations for three tracking passes. The agreement during the first pass is very good, always within 10 cm. The agreement during the second pass is not nearly as good at low elevations. This difference is thought to be produced by deficiencies in the technique used to map the Faraday rotation data to the spacecraft line-of-sight. The dramatically different results displayed in the third pass were caused by a large space plasma event which was detected by several different techniques. In general, the comparison of the S/X and Faraday techniques showed the S/X calibrations to be accurate to approximately 30 cm, the estimated limit of the Faraday mapping. The high-frequency noise of the S/X data suggests that the calibrations may be good to a few centimeters.

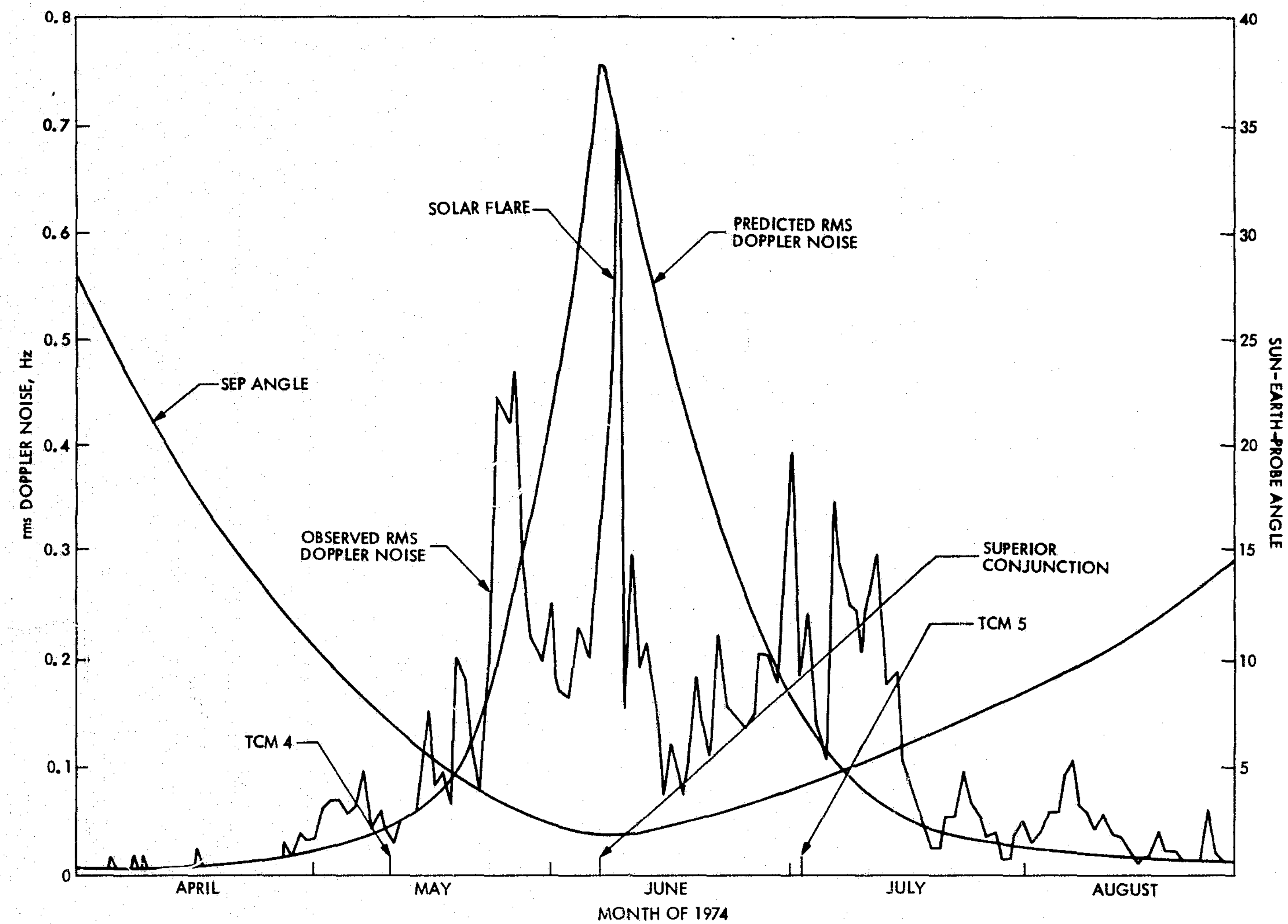


Figure 210. Doppler noise vs Sun-Earth-probe angle

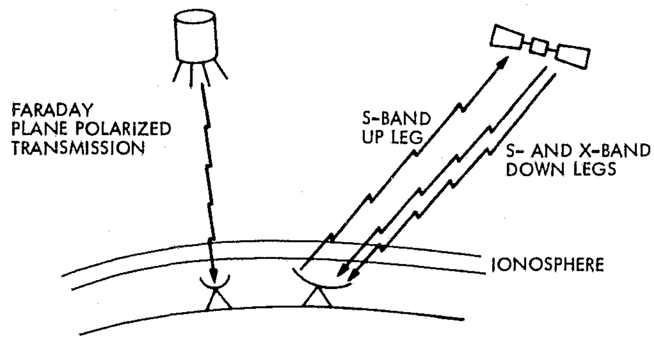


Figure 211. Faraday rotation and S/X data configurations

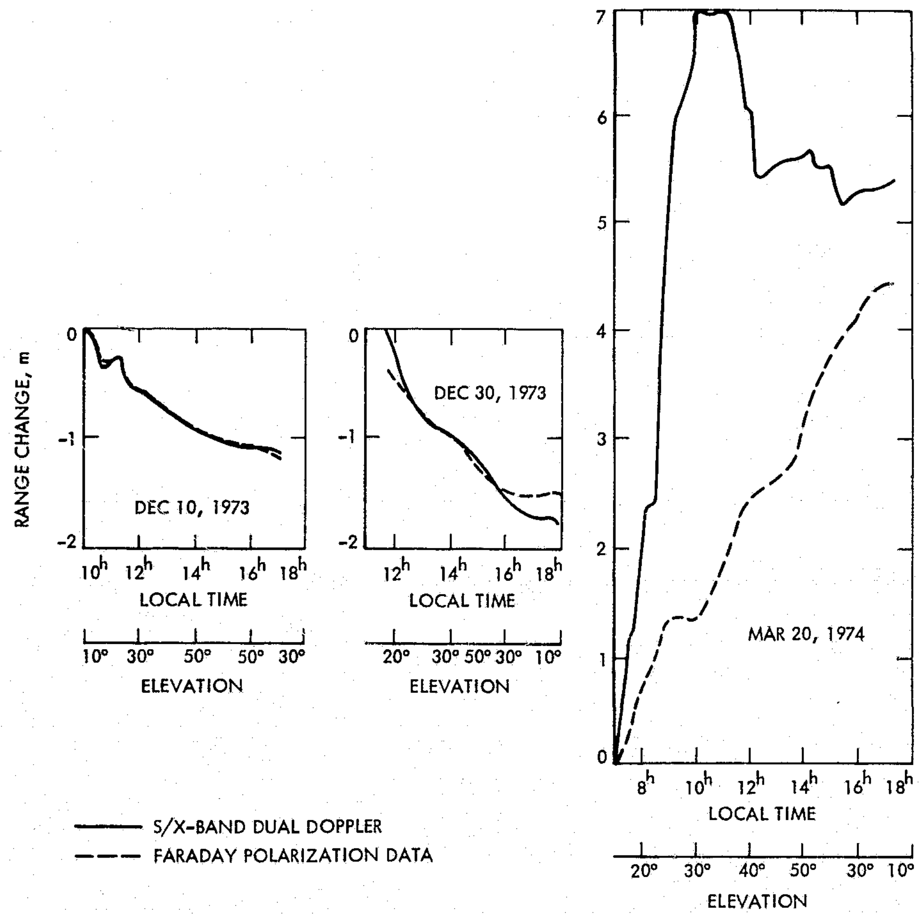


Figure 212. Comparison of Faraday rotation and S/X charged particle calibrations

The best way to demonstrate the effectiveness of a new data type is to include it in the orbit determination procedure and see how much it improves navigation capabilities. Unfortunately, because of budget cutbacks, hardware problems, station conflicts with Pioneer 10 and other problems, not nearly as much S/X data was obtained as was expected. However, because of the extraordinary efforts of some JPL telecommunication engineers and members of the Radio Science Team, enough S/X doppler data was obtained between the pre-Mercury maneuver and Mercury encounter to yield a calibrated orbit determination solution. Figure 213 shows uncalibrated and S/X calibrated B-plane solutions using six passes of data from DSS 14, taken between Mercury-13 days and Mercury-14 days. Also included in Fig. 213 is the current best estimate (CBE) of the actual trajectory based upon both pre- and post-encounter data. Comparison of the solutions included in Fig. 213 shows that for the same set of data the S/X doppler calibrations reduce the error in the orbit determination solution from 600 to 100 km. The solution using Faraday rotation calibrations is approximately the same as the uncalibrated solution.

These pre-Mercury S/X results are very encouraging but by no means definitive. One of the limitations of the primary Mariner 10 mission to demonstrate new data types is that there was a maneuver a couple of weeks before both Venus and Mercury. Thus, the demonstrations were limited to short arcs shortly before encounters so that possible velocity errors which would produce large aim plane errors over a longer mapping time may not be particularly visible.

The information contained in radiometric data comes from two sources, namely the spin of the earth and the geocentric acceleration of the spacecraft. The geocentric acceleration can be a very powerful information source. Generally, however, the stronger the acceleration information the more the orbit determination solution may be degraded by unmodelled accelerations. This sensitivity to unmodelled accelerations can be almost entirely removed by differencing the data taken simultaneously from widely separated stations. The differencing removes the accelerations information (along with the sensitivity of unmodelled accelerations) but preserves information provided by the spin of the Earth.

The easiest method of obtaining simultaneous doppler is to use two-way and three-way data. The difficulty with this technique is that since the transmitted and received signals of three-way data employ different frequency standards, the three-way data will contain a bias which may vary. This bias must be solved for in the OD fit. This in turn degrades the solution somewhat.

Another method of obtaining simultaneous doppler from a spacecraft having a ranging transponder that doesn't have the bias in the three-way data is the simultaneous interference tracking technique (SITT). In principle this technique should allow simultaneous doppler data to be taken from both stations which has the same quality as conventional two-way data. Doppler residuals obtained from Mariner 10 with Stations 12 and 14 during the SITT demonstration show that this technique is capable of providing simultaneous doppler data which is not subject to the typical frequency system errors.

Many orbit determination solutions using differenced doppler data were made during Mariner 10 operations. The effectiveness of differenced data to reduce the effect of moderate unmodelled accelerations is illustrated in Fig. 214. This figure shows the B-plane solutions using conventional and differenced data from Venus -13 days to Venus -3 days, when the solar pressure model has been turned off. Turning off the solar pressure model introduces an unmodelled acceleration of approximately 10^{-10} km/s^2, which is 30 times larger than Mariner 10 specifications. This unmodelled acceleration produces a 300-km aim plane error in the solution using conventional data. The solution using the differenced data is only 30 km away from the current best estimate of where the spacecraft actually went. Thus, the differenced data was an order of magnitude less sensitive than conventional data to moderate unmodelled accelerations as predicted by the accuracy analysis studies.

For the differenced data to be effective in eliminating the effects of small unmodelled accelerations usually experienced by Mariner-class spacecraft (10^{-12} km/s^2), it will probably be necessary to have full S/X calibrations and either frequency systems based on hydrogen masers or SITT data.

Although the differenced data techniques were developed primarily to remove problems caused by unmodelled accelerations, experience gained during Mariner 10 also showed that it can be a very powerful method of reducing errors caused by the space plasma near superior conjunction. Figure 215 shows two-way, three-way and differenced doppler data taken 4 weeks (12 deg) before superior conjunction. Usually the conventional doppler residuals would be around 5 MHz. However, the solar corona has already started to severely degrade the data. As shown in Fig. 215, the corruption of the two- and three-way data is nearly common and is substantially removed in the differencing process. Figure 216 shows the daily standard deviation of the two-way and differenced doppler residuals. This figure shows that generally the differencing procedure reduces the noise introduced to the data by the solar corona by a factor of 5.

Unfortunately, the Australian stations were generally unavailable for tracking between the maneuvers one month before and one month after superior conjunction. The differenced data during this period consisted of 1 to 3 hours of Spain-Goldstone tracking passes. Even with this limited amount of data, the long-arc Mercury II solutions starting one month before superior conjunction and continuing for five to eight weeks using the differenced data solutions agreed with the conventional solutions to within a few hundred km. Because of the large noise contained in the data around superior conjunction the short-arc conventional data solutions (10 to 20 days) were generally quite unstable, having a scatter of approximately 2000 km. However, the few short-arc differenced data solutions were much better, having a scatter of about 400 km. The analysis of the superior conjunction data is continuing, but as has just been discussed, the preliminary results are very encouraging.

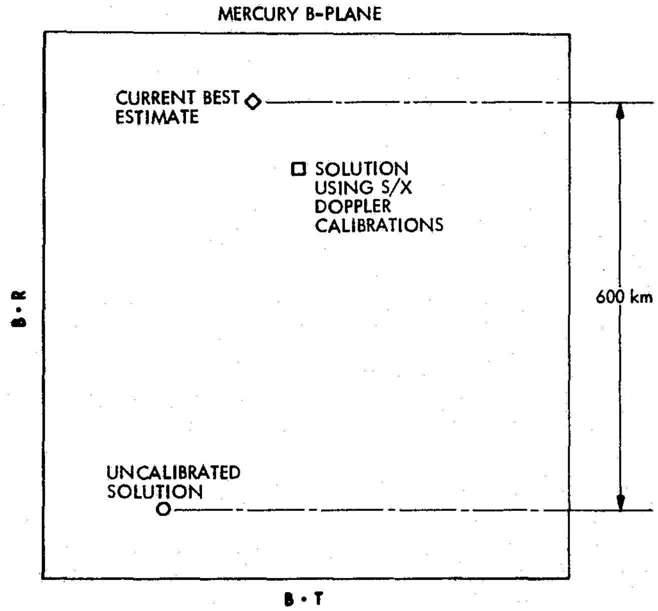


Figure 213. Calibrated and uncalibrated solutions using six passes between Mercury -13 and Mercury -4 days

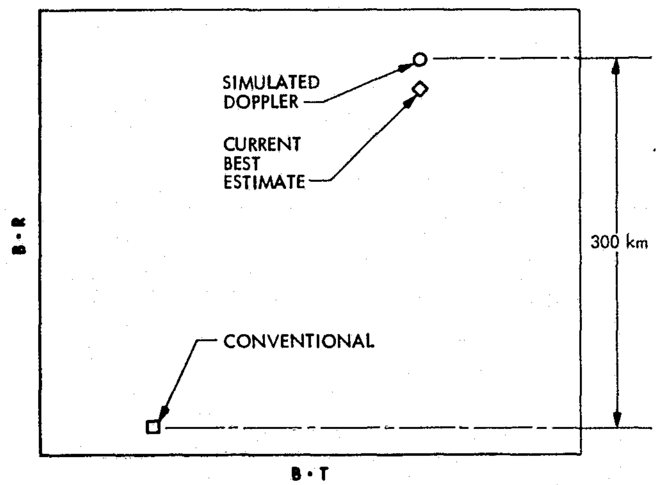


Figure 214. Conventional and differenced data solutions using data from Venus -13 days to Venus -3 days with no solar pressure model

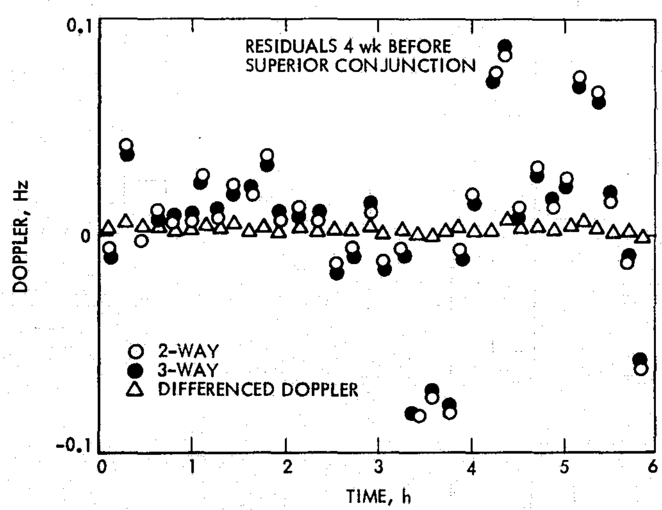


Figure 215. Two-way, three-way, and differenced doppler 4 weeks before superior conjunction

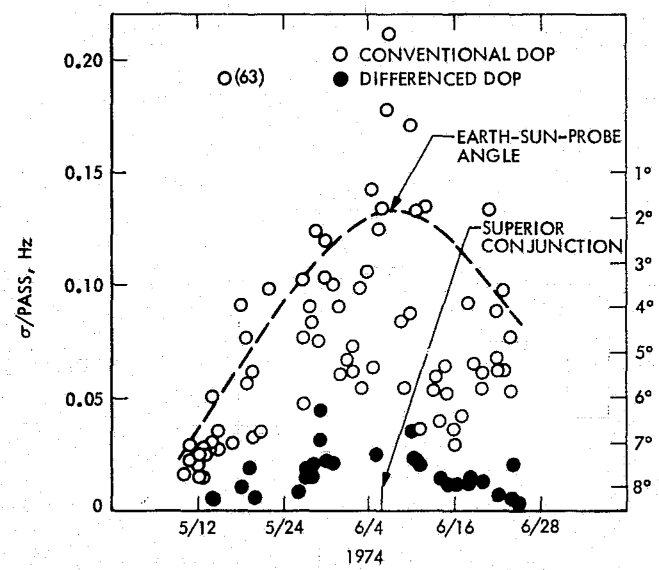


Figure 216. Standard deviation per pass of two-way and differenced doppler residuals

Low declination geometries present special problems for navigation based on conventional data. The problems arise because for short arcs the determination of the declination of the spacecraft is based upon a measure of the cosine of the declination. Several years ago it was proposed that simultaneous range measurements from northern and southern hemisphere stations would provide a measure of the sine of the declination of the spacecraft and remove all the low declination problems. Figure 217 shows the principle behind this technique using the simple example of two stations on the same longitude and equal but opposite latitudes viewing an infinitely distant spacecraft at meridian crossing. In practice the range measurements do not have to be taken simultaneously but may be separated by 30 to 45 min. For the simultaneous or near-simultaneous range technique to be effective, the measurements between stations have to be consistent to within a few meters.

Shortly before Venus encounter, experience with Goldstone and Australian range residuals, particularly those obtained from alternating range passes, indicated that the range measurements were consistent to within a few meters. Figure 218 shows Venus B-plane solutions, using doppler only, doppler and single station range, single station range only, and nearly simultaneous range data taken between Venus -8 days and Venus -5 days. The current best estimate of the actual trajectory using pre- and post-Venus data is also shown. The doppler-only solution using 300 data points is in error by 120 km. The single station range-only solution is much worse, having an error of over 500 km. Combining the doppler data with the single station range data reduces the error to only 30 km. An equally good solution is obtained by using 24 points of nearly simultaneous range data. This result was extremely encouraging and shows that nearly simultaneous range data is not only capable of eliminating the low declination problem but may provide highly accurate short-arc range-only solutions.

After Venus the range data quality from Station 43 seemed to degrade a bit and was not capable of supporting a nearly simultaneous range solution at Mercury.

By using the DSN digitally controlled oscillator (DCO) device, linear ramps can be imposed on the transmitted carrier frequency. The pattern on the carrier frequency received from the spacecraft is dependent on the round trip light time, enabling measurement to be made of the topocentric distance from the station to the spacecraft. The advantage of this technique is that range measurements can be made to a spacecraft without a ranging transponder, e.g., Pioneer 10 and 11.

On November 12, 1973, a ramp test was performed using DSS 14. The range obtained from this technique was compared directly to range measurements taken using the MARK1A system at DSS 42 and 62. The results showed that the ramped doppler was sensitive to one-way range errors of about 1.5 km.

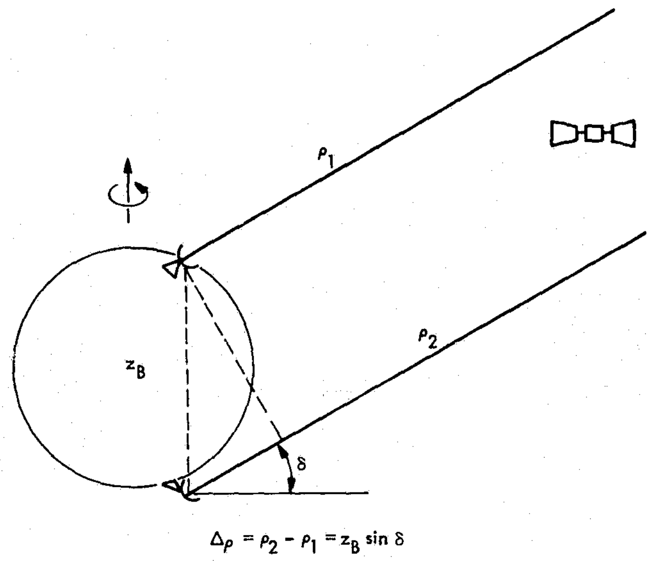


Figure 217. Simultaneous range measurements

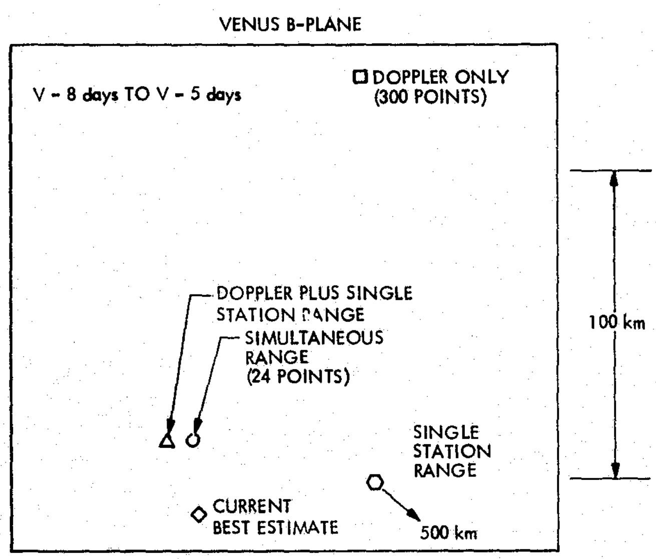


Figure 218. Doppler-only, doppler and single station range, and nearly simultaneous range solutions using data from Venus -8 days to Venus -5 days

11. Mercury Third Encounter, March 1975

The primary objective during March 1975 was, of course, a successful third encounter of the planet Mercury on March 16. Other special support activities included trajectory correction maneuver 8 conducted on March 7 and restabilization of the spacecraft via acquisition of the reference star Canopus. As reported in the discussions in the previous period, trajectory correction maneuver 7 was not of the required accuracy. By late February, orbit solutions indicated that about 50% of the 3-sigma target elipse was within the planetary impact/capture zone. An eighth trajectory correction maneuver was therefore required to give the spacecraft the required 90% probability of no impact. Trajectory correction maneuver 8 was conducted on March 7. The maneuver was of a sun line type with the spacecraft placed in the all-axis inertial mode during the engine burn. Following the burn, the spacecraft was, however, returned to the roll drift, solar sailing mode to assure preservation of attitude control gas for Mercury encounter operations. A slow 24-hr period roll rate was planned to help accommodate later acquisition of Canopus and to provide suitable telecommunications link conditions for loading the encounter sequence in the spacecraft computer. In keeping with coverage conflict resolution agreements, the eighth correction maneuver was timed to be supported by DSS 63. Deep Space Network support for the maneuver as well as special post-burn radio metric data generation activities were very satisfactory, leading to rapid verification that the required aimpoint had been achieved.

Canopus acquisition, the next critical event prior to encounter, proved to be a delicate and difficult operation. Uncertainty in the spacecraft roll rate and less than continuous 64-m subnet coverage contributed to the acquisition problem. Again, for coverage conflict resolution purposes, it was planned that Canopus acquisition would be conducted during the DSS 63 view period. Assuming accurate knowledge of the spacecraft roll rate, the planned procedure was to send a command sequence which would turn on the roll attitude control when Canopus entered the tracker's field of view. With the slow spacecraft roll rate, Canopus would then still be acquired following the 18-min RTLT. The spacecraft would then be placed in the roll axis inertial control mode to preclude the possibility of a bright particle incident causing loss of roll reference prior to or during encounter. Consequently, the acquisition would be accomplished without risking the possibility of attitude control gas depletion due to oscillations induced by roll search. Obviously, accurate knowledge of the spacecraft's roll position and roll rate were essential to achieving Canopus acquisition using the described procedure. The reader is reminded that communication with the spacecraft while in the roll drift mode was via the spacecraft's low-gain omnidirectional antenna. The resulting antenna pattern provided only a few peaks and deep nulls in a relatively flat signal level for determining spacecraft roll. However, by comparison of 64-m deep space station received signal levels with known antenna patterns, the Project expected to be able to clock the spacecraft's roll with sufficient precision to initiate the Canopus acquisition sequence.

DSS 63 passes on March 10, 11, and 12 were devoted to spacecraft roll timing, and the Project's calculations indicated that the best time for an acquisition attempt fell at a time when no 64-m deep space station coverage could be made available. Therefore, the Project took action to slow the spacecraft roll rate such that the Canopus crossing would be delayed to occur over DSS 43 where partial pass coverage could be scheduled. However, the ensuing acquisition attempt on March 12 was not successful. The next acquisition attempt on March 13 was also unsuccessful since the spacecraft roll rate was apparently higher than expected, resulting in the spacecraft being stopped about 7 deg beyond Canopus. Mission controllers then executed a series of spacecraft roll direction changes in an attempt to find Canopus, but without success. Concern grew and a spacecraft emergency was declared. The DSN negotiated with the JPL Helios project representative for release of DSS 14 and 43 from Helios A support to provide two Mariner 10 tracking passes. Although the Helios project agreed in this one case, there was strong opposition to any further reduction in 64-m subnet coverage; to do so would seriously impact Helios prime mission objectives at perihelion on March 15.

At one point, in the absence of 64-m DSS support, DSS 12 employed an experimental tracking loop of 3 Hz bandwidth in the block 3 receiver to improve signal detection capability. This effort was successful in providing Project critical signal level information which indicated that the spacecraft was in fact rolling toward a position of improved signal rather than toward a deep null. It rapidly became clear that the low-gain antenna mapping technique was not an adequate tool for Canopus acquisition. It was decided that the spacecraft high-gain antenna with its narrow beam and precisely calibrated pattern offered the best means of determining the spacecraft's position and, consequently, Canopus acquisition. This required stopping the spacecraft roll in pointing the high-gain antenna at earth. The plan was put into effect, and DSS 42 was employed to first get a precise calibration on the roll position. Then using received signal level and the pattern to confirm roll position, the spacecraft was allowed to roll-drift toward Canopus. This process took place in carefully controlled steps to assure success. The spacecraft was stopped about 40 deg short of Canopus and again at 7 deg short to confirm the roll position. At this point, signal level readouts from DSS 63 were provided every 5 sec as the spacecraft rolled the last 7 deg. The reported signal level tracked very precisely along the predicted plot. At the proper time, allowing for one-way communication, the roll-drift stop commands were sent, to be received at the spacecraft while Canopus was still acquired by the spacecraft tracker. The technique worked and Canopus was acquired. The spacecraft was stabilized to celestial reference, and the encounter sequence was initiated shortly thereafter.

The DSN encounter readiness test activities planned for early March were compromised by severe scheduling difficulties in that limited DSS time was available for tests because of the higher priority activities of other projects and Mariner 10's critical events described above. By March 6 the situation had become critical and special steps were taken to gain additional test time for a concentrated effort on March 7 and 8. The stations were instructed to give priority to completion of internal system performance tests. Negotiations with the Viking project resulted in cancellation of one Viking system integration test in order to provide DSS 14 test time for Mariner 10. All basic test objections were met by March 10, and the DSN held a brief encounter readiness review on March 13. Although the review verified that DSN preparations for encounter were adequate and complete, concern continued to be expressed regarding the limited number of test and training exercises and the newly implemented Block 4 receiver-exciter configuration at DSS 14. In addition, it was also planned that end-to-end data flow tests would be conducted with the spacecraft following Canopus acquisition on March 12. The availability of actual spacecraft data rather than simulated data would have provided a precise demonstration. Unfortunately, these tests were cancelled due to Canopus acquisition difficulties. Consequently, the DSN supported a third encounter with the benefit of only one successful test with each supporting 64-m station.

The encounter sequence was initiated on March 15, with turn-on of the TV cameras at about 1000 GMT over DSS 63. An incoming TV mosaic was performed as planned. However, the planned color mosaic was delayed 2 hr due to a spacecraft inertial reference update being required. This slipped the color mosaic activity into the DSS 14 view period, and ground commanding was required to accomplish the mosaic. Problems at the DSS 14 Block 4 exciter-transmitter interface caused command aborts during the second command of this sequence. Action was taken to reestablish DSS 14's command capabilities through the Block 3 exciter. Although this was subsequently accomplished, the colar mosaic sequence was too far behind the time line and had to be aborted.

Before further discussion of DSN support for the third Mercury encounter and another problem associated with that support, it is important to first understand the objectives and the situation. As previously stated, the primary objective of a third Mercury encounter was the investigation of Mercury's magnetic field and particles. The aimpoint was optimized to provide acquisition and return of these nonimaging data. Also, as previously discussed, third encounter offered excellent geometry for the celestial mechanics experiment through the continuous acquisition of two-way doppler data and ranging points. As a secondary objective, TV data was to be acquired at the full-resolution 117-kbps rate. The nonimaging 2450-bps science was a prime data type having priority over other data for accomplishment of objectives. Consequently, the DSN configuration was such to ensure the acquisition, recording, and real-time handling of 2450-bps data rather than video data as on previous encounters. This means that redundant DSN equipment and data paths were assigned to the nonimaging science rather than to video. Attention was, however, also given to the generation of radio metric data for celestial mechanics purposes and to the acquisition of TV data, but not at the expense of the prime data type. As with previous Mercury encounters, acquisition of full-resolution video data at 117 kbps depended upon proper operation of the experimental R&D supercool maser ultracone at DSS 43. This R&D ultracone was installed at DSS 43 prior to Mercury first encounter to provide for mission enhancement well beyond that which could be gained via the standard 22-kbps misson. Successful use of the ultracone on the first two Mercury encounters resulted in TV science returns well beyond expectations. R&D devices are only occasionally used in the DSN for operational support, with the understanding that they are for mission enhancement purposes, for experimental tests in parallel with operations, and are provided on a "best efforts" basis with spares, documentation, testing, and training much less than normally associated with operational commitments. The use of such equipment carries a higher risk of failure which must be weighed against potential increases in returns. On MVM'73, returns appeared to be well worth the gamble. The foregoing is offered to point out that failures in R&D equipment should not be unexpected and that such failures should not be considered as having a serious effect on primary objectives. Postencounter reports from other areas have offered comments to the contrary.

As the reader might suspect, the DSN had problems with the R&D ultracone supercooled maser at DSS 43 during third encounter. On March 14, word was received that the maser was not cooling down as expected. DSN maser cognizant design engineers were assigned to work with DSS 43 via the voice circuit in an all-out effort to effect repairs. The maser was removed, equipped with a new crosshead, and cleaned. JPL engineers continued coordination with DSS 43 throughout the period of March 14-16 and provided special instructions and recommendations regarding cooldown procedures. However, this effort was not successful, and the maser remained warm. The failure was, of course, reported to Project and frequent progress reports were provided in order that the Project could be ready to make a decision as encounter approached. Even with the standard cone and maser at DSS 43, two options were still apparently open: (1) acquire 117-kbps video containing a high bit error rate (6 to 10 bits in error per 100) while gaining area coverage, or (2) change the data rate to 22 kbps to acquire very high quality, but quarter frame pictures. The Project opted in favor of quality rather than quantity and flew the 22-kbps encounter profile.

The DSN provided continuous, high-quality acquisition and real-time handling of the 2450-kbps nonimaging data throughout the third encounter. Also, continuous two-way S-band doppler data was generated and periodic ranging points were acquired as required for celestial mechanics. DSS 43 performed in an excellent manner for acquisition and transmission of all 22-kbps video data in real-time to JPL. Following the encounter, the DSN supported a number of science calibration and spacecraft engineering tests through March 24, 1975. On March 24, data received reflected that the spacecraft had depleted its attitude gas supply. Shortly thereafter, at 1200 GMT, the command was sent to turn off the spacecraft transmitter. DSS 63 observed a loss of signal 1 RTLT later indicating that the mission indeed had ended.

Table 56 summarizes DSN tracking activities for the March 1975 period. One can readily see the conflict resolution strategy reflected in the tracking pass allocations, wherein DSS 63 support was made available but 64-m coverage was lacking in the California and Australia longitudes. Even though approaching encounter, Mariner 10 did not enjoy full coverage as evidenced by the total number of passes being less than the 48 required for full coverage through March 16. Also, one can see that the seven passes provided by DSS 12 were of very short duration. Table 56 is also of interest since it provides the final cumulative data for the entire mission.

Table 56. DSN tracking support: March 1975

Item	California		Australia		Spain			Network totals
	DSS 12	DSS 14	DSS 42	DSS 43	DSS 61	DSS 62	DSS 63	
1. Tracking passes this period	7	3	9	6	4	0	16	45
2. Cumulative passes	220	244	182	179	78	220	201	1324
3. Tracking hours this period	16	20	95	51	38	0	114	334
4. Cumulative tracking hours	1639	1824	1563	1540	629	1745	1761	10,701
5. Commands this period	46	29	585	210	82	0	1115	2067
6. Cumulative commands	6142	7884	2068	2823	144	1699	2854	23,614
7. Command aborts this period	0	1	0	0	0	0	0	1
8. Cumulative aborts	3	6	0	3	0	0	0	12

The mission period from November 3, 1973, to March 24, 1975, ran 506 days, or a total of 12,144 hr. This mission duration breaks down into 164 days (or 3936 hr) for the prime mission and 342 days (or 8208 hr) for the extended mission. The rather short prime mission required continuous coverage of its 3936 hr, and we see from Table 50 that 4609 DSN tracking hours were provided for an average of 28 tracking hours per day. Consequently, continuous coverage, including deep space station overlap time for signal handovers, was provided. The 10,701 tracking hours given in Table 56 for the entire mission, less the 4609 tracking hours for the prime mission, shows that extended mission received 6092 tracking hours. A portion of this time was, of course, DSS overlap hours. Therefore, to get a truer picture of the coverage provided, one should consider the 342 days requiring an average of 28 hr per day for continuous coverage, a total of 9576 hr. Given the 6092 tracking hours provided to the extended mission, the coverage provided then was about 64% of continuous. Ignoring the overlap periods of dual coverage and considering 24 hr per day for the 342-day period, 8208 hr would represent continuous coverage, and this would show that the DSN provided 74% coverage for the extended mission. However, since some of the extended mission tracks did not include overlaps and some did, the true coverage figure must lie somewhere between 64 and 74%. This is consistent with the 2/3 or 67% average coverage which was estimated to be available and planned at the start of the extended mission operations.

We can also look at the tracking hours in terms of the type of coverage provided, 26- or 64-m subnet. Of the total 10,701 tracking hours provided during the entire mission, 5125 hr (48%) came from the 64-m subnet and 5576 hr (52%) from the 26-m subnet. The equivalent figures for the prime mission were 1743 hr (38%) from the 64-m subnet and 2866 hr (62%) from the 26-m subnet. Spacecraft problems and increased radio metric data requirements are reflected by the higher 64-m subnet usage during extended mission, wherein 56% of the coverage was provided by the 64-m subnet and 44% by the 26-m subnet. Unquestionably, the 64-m support percentage would have been much higher had Mariner 10 not seen strong competition for the large antennas.

A total of 23,614 commands were handled by the DSN and transmitted to the spacecraft, 14,317 during the prime mission and 9297 during the extended mission.

V. OBSERVATIONS, EVALUATIONS, AND RECOMMENDATIONS

A. GENERAL

This section may be unique in reports of this nature in that it contains some rather candid observations and comments from many of the TDS elements involved as well as inputs from other sources. Since we tend to reflect more on our problems than on our successes, one should view this as a constructive effort rather than a criticism of the recognized outstanding tracking and data acquisition support provided to the MVM'73 mission. Furthermore, the lateness of this report does not mean that these comments have been ignored; many have been or are in the process of being incorporated into DSN planning.

B. COMMENTS

Appearance of comments herein does not mean that the author agrees with everything that is said; one will note some disagreement between different comments. However, they were made and they appeared noteworthy. The reader may judge for himself.

(1) Stations benefit more from internal testing than from DSN operational verification tests; the latter are of very little use to the station.

(2) DSN OVT's and MOS tests are of little value if equipment is not first thoroughly checked out and functioning properly.

(3) The large number of system performance tests (DSS internal) required by the DSN for MVM'73 were beneficial for system operational checkout and for personnel familiarization, more so than OVT's etc.

(4) DSN OVT's and PDT's were very beneficial in accomplishing operator proficiency during the final phase of testing and training.

(5) OVT's are of little value until DSS internal tests and training are satisfactorily completed.

(6) Phased delivery and late delivery of engineering changes seriously handicapped premission testing in a period of heavy concurrent operational support commitments. More care must be taken to assure that capabilities prerequisite to testing are available (for example, tape playback software and line printer were late for MVM'73).

(7) Equipment should not be delivered to the DSS for installation without first passing the "first station" installation-integration demonstration. Otherwise, stations waste many valuable hours trying to integrate faulty equipment (a flagrant example: the new DIS high-speed jet printer).

(8) Planners should better recognize the conjoint stations' inherent internal conflicts for use of common equipment for operational and test support.

(9) The DSN-provided video-tape training and information packages were invaluable, second only to a live instructor. Perhaps more use could be made of this medium to convey requirements and procedures as well.

(10) The concept of incorporating all DSN operations information for MVM'73 into a single document (Network Operations Plan), rather than the previous documentation through several documents, deserves special praise. However, improvement in timeliness is needed.

(11) Operational documentation was very good but late.

(12) Sequence of events were generally late and in most cases did not allow sufficient study time prior to their execution.

(13) Teletype changes and updates to instructions and procedures were confusing and at times contradictory; since these may be generated by various sources, they should be validated by one individual before transmission.

(14) Last minute arrival of test information or changes at the DSS adds confusion and anxiety to an otherwise straightforward test.

(15) If possible avoid teletype deviations from the operations plan; if necessary, they must be followed immediately by a special instruction message.

(16) Visibility for problem isolation when in the long-loop simulation mode is inadequate. One cannot determine whether troubles are in the Project data source, ground communications, simulation conversion, operators, etc. Consequently, erroneous or invalid discrepancy reports are written, which everyone dislikes.

(17) The requirement for shipment of MVM'73 telemetry original data record tapes to JPL necessitated standardized, accurate tape labels to insure proper identification during the Project's data record production process. Numerous manual errors observed suggest that this function be mechanized. Also, use of different magnetic tapes for MVM'73 further complicated the situation.

(18) The policy of selecting only one tape type as applied to MVM'73 should be the standard rule for all missions.

(19) Performance and reliability of current DSS digital recorders are not adequate for high-density recording activities.

(20) The Project's philosophy in getting all it could from the spacecraft and mission appeared to stimulate interest and incentive in all personnel. (Author's note: This is interesting and contrary to what one might intuitively believe.)

(21) Greater use of facsimile transmissions between JPL and the DSS is being made. If this mode is to continue, stations would benefit by an on-site terminal.

(22) Mission bulletins and other handouts were considered valuable, well-produced, and much appreciated.

(23) From an investigation point of view, the new type modular software programs are difficult to understand with respect to the module that has been loaded. Searches as to where a particular routine was loaded is time-consuming and subject to errors. The program-produced label map is inadequate.

(24) Long periods of silence on the DSN control net are worrisome, especially during critical or emergency tracks. People on both ends want to know what's going on. An effort should be made to improve voice information exchange between the NOCC and the DSS.

(25) Establishing a standard multiple mission (MVM'73 and Pioneer) analog tape recording channel configuration was a noteworthy improvement.

(26) The radio science experiment invited problems due to inadequate statement of requirements, changing and late requirements, hastily designed configuration, and poor operational procedures. Radio science should be handled like any other Project requirement, and a systematic approach should be employed in implementation.

(27) The DSN engineering change process was not adequate for monitoring and managing Network changes required for MVM'73.

(28) Rapid configurations aided in reducing coverage conflicts between MVM'73, Pioneer and Helios. However, this placed a heavy burden on station personnel. Additional work toward standard configurations and computer-aided countdowns and calibrations is required to further facilitate quick turnarounds.

(29) Current analog recorders were at the margin of acceptability at the MVM'73 higher data rates; improvement or replacement is suggested.

(30) We should strongly resist the use of R&D equipment in the Network for critical or mandatory operational support.

(31) Use of R&D equipment in the Network was a key factor in the "explosion" of scientific information which resulted from MVM'73.

(32) Real-time and non-real-time analysis of Network performance was not adequate during the MVM'73 mission. Analysis, reporting, and followup capabilities need to be improved, including the handling, analysis, and closure of discrepancy reports.

(33) Due to its inherent problems, long-loop simulation is of little value for DSN or mission operations test and training activities. Internal or short-loop simulation modes should be used.

(34) The scheduling interface between the Project, DSN, and MCCC did not work well.

(35) Experience has shown that a strong DSN interface support organization is required throughout the life of the Project in order to cope with problems, changing requirements, new configurations, extended mission, etc.

(36) Improved, systematic reporting procedures are needed to facilitate timely production of comprehensive and useful reports of this nature.

The foregoing list of comments was not meant to be exhaustive; it was developed to offer a wide range of observations which would relate to all TDS elements. For those who made the effort to communicate their observations, it should be rewarding to note that management attention and resources are being applied to essentially all problem areas mentioned or implied.

APPENDIX A

TDA MILESTONE SCHEDULES

JET PROPULSION LABORATORY

APPROVAL RESPONSIBILITY: W. E. Giberson

ACHIEVEMENT RESPONSIBILITY: E. K. Davis

MARINER VENUS/MERCURY 1973 TRACKING & DATA SYSTEM MILESTONE SCHEDULE

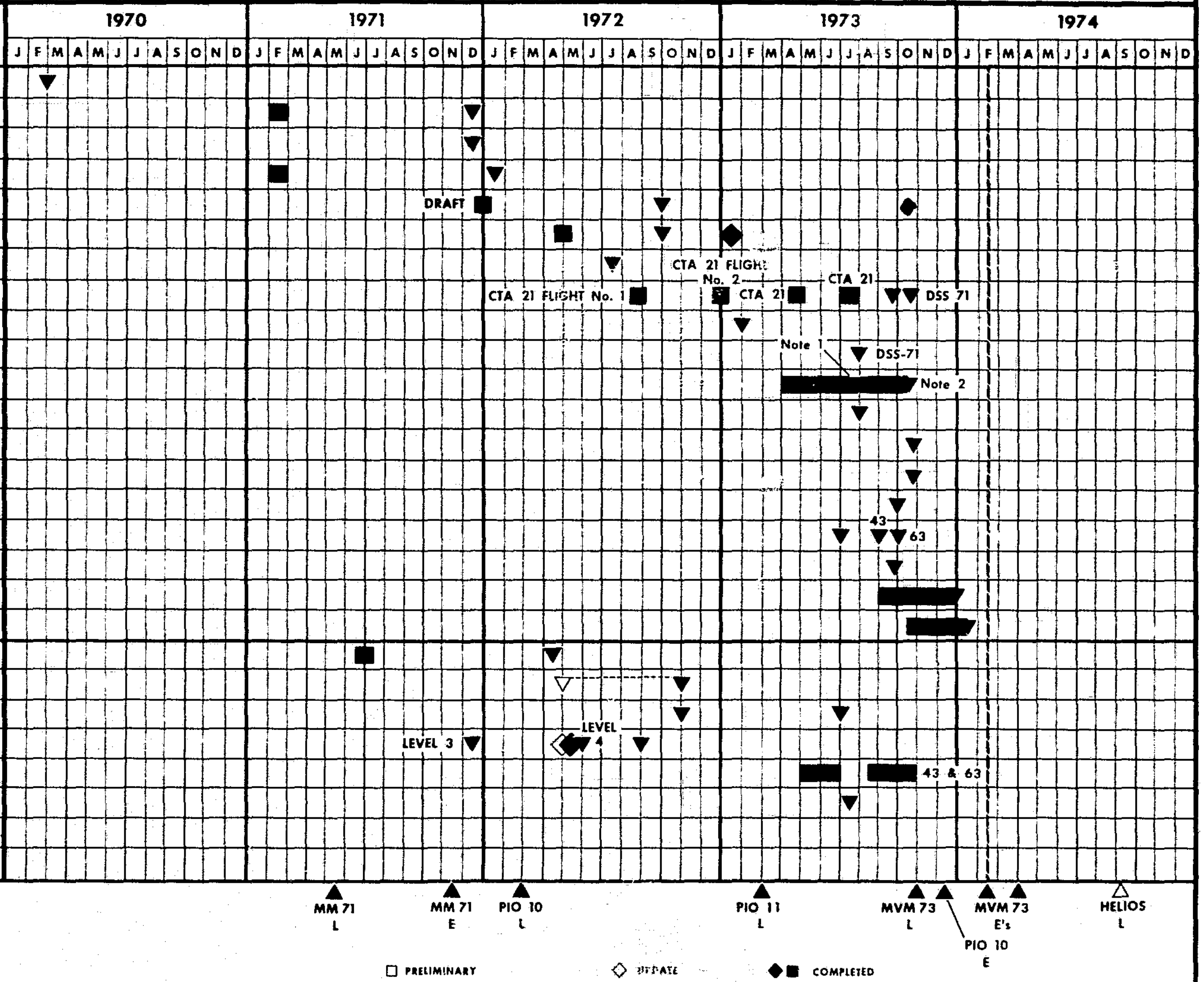
3 Level

ORIGINAL SCHEDULE APPROVAL: 15 December 1971 (Date)

LAST SCHEDULE CHANGE: 15 October 1972 (Date) (No.) (Initials)

STATUS AS OF: 15 February 1974 (Date) (Initials)

	MILESTONES
1	TDS PLANNING TEAM FORMED
2	TDS/PROJ. LEVEL 3 MILESTONE SCHED. ESTAB.
3	TDS FUNCTIONAL DESIGN REVIEW
4	DSN/PROJ. LEVEL 5 MILESTONE SCHED. ESTAB.
5	NSP PUBLISHED - JPL APPROVED
6	DSN SUPPORT PLAN PUBLISHED
7	TDS DETAILED DESIGN REVIEW
8	DSN/SPACECRAFT RF COMPATIBILITY DEMON.
9	DSN PROGRESS REVIEW
10	SPACECRAFT TEST SUPPORT FACILITIES OP'L
11	DSN SYSTEM TESTS
12	TDS AVAIL. FOR PROJ. OP'L TESTS & TRAINING
13	NEAR-EARTH OPERATIONAL READINESS
14	LAUNCH READINESS REVIEW
15	DSS 43 AND 63 OPERATIONAL
16	DSN TECH READINESS/26-meter & DSS 14
17	DSN OPERATIONS READINESS/REVIEW
18	S/X-BAND IMPLEMENTATION AT DSS 14
19	PLANETARY RANGING - DSS 43/63
20	SIRD PUBLISHED
21	PROGRAM REQ's DOCUMENT (PRD) PUBLISHED
22	DESIGN DATA FOR NEAR-EARTH PLANNING AVAIL.
23	MOS DESIGN BOOK PUBLISHED
24	GDS INTEGRATION
25	GDS DEMO
26	
27	



NOTES:

1) DSS 12, 42, 62, 14, 71

2) DSS 43 AND 63

□ PRELIMINARY ◇ UPDATE ◆■ COMPLETED

▽ SCHEDULED COMPLETION ▭▽ IN PROGRESS ▬▼ COMPLETED

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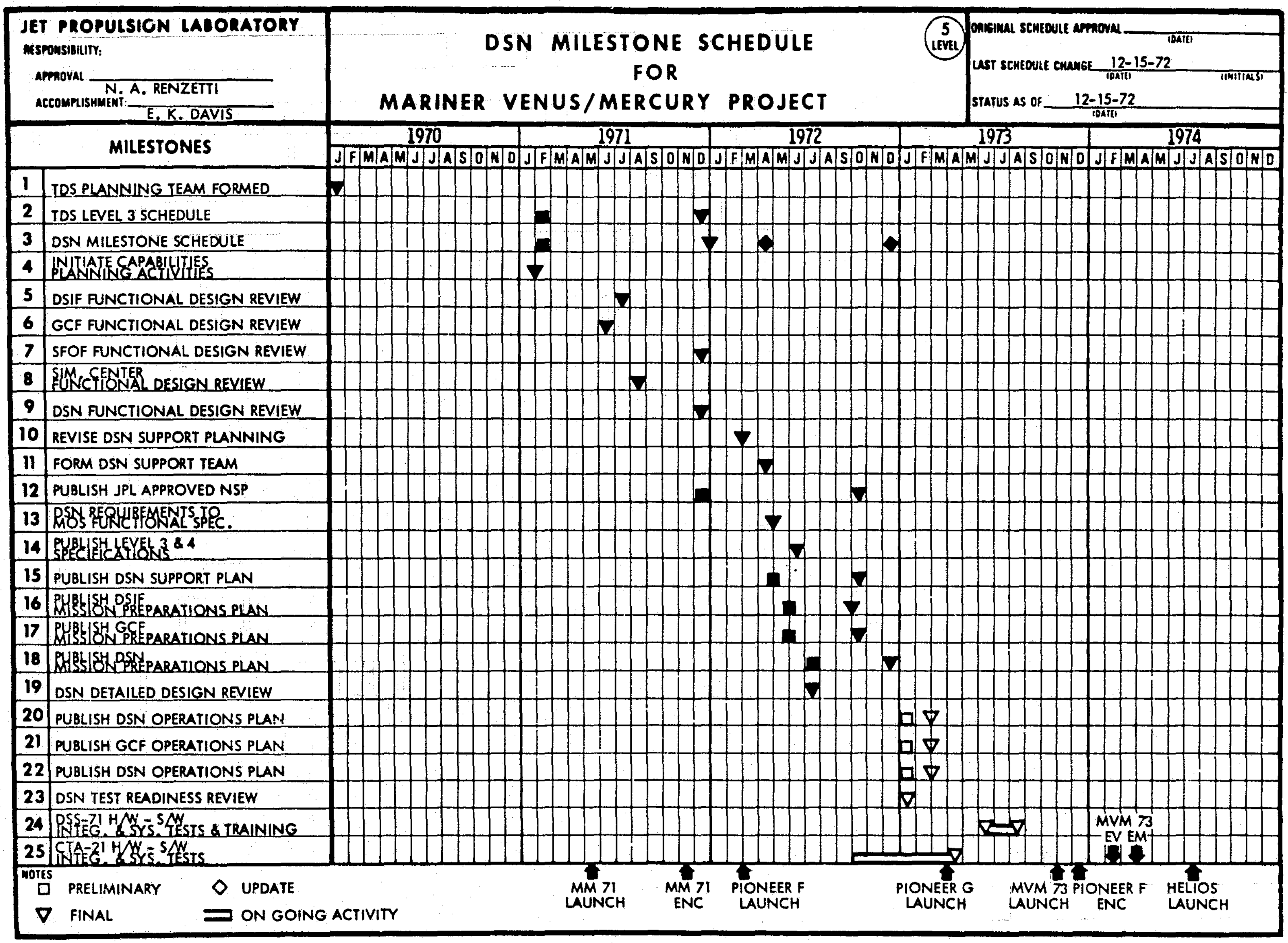
JET PROPULSION LABORATORY
RESPONSIBILITY:
APPROVAL N. A. RENZETTI
ACCOMPLISHMENT: E. K. DAVIS
DSN MILESTONE SCHEDULE
FOR
MARINER VENUS/MERCURY PROJECT
5 LEVEL
ORIGINAL SCHEDULE APPROVAL (DATE)
LAST SCHEDULE CHANGE 12-15-72 (DATE) (INITIALS)
STATUS AS OF 12-15-72 (DATE)
MILESTONES
1970
1971
1972
1973
1974
J F M A M J J A S O N D
1 TDS PLANNING TEAM FORMED
2 TDS LEVEL 3 SCHEDULE
3 DSN MILESTONE SCHEDULE
4 INITIATE CAPABILITIES PLANNING ACTIVITIES
5 DSIF FUNCTIONAL DESIGN REVIEW
6 GCF FUNCTIONAL DESIGN REVIEW
7 SFOF FUNCTIONAL DESIGN REVIEW
8 SIM. CENTER FUNCTIONAL DESIGN REVIEW
9 DSN FUNCTIONAL DESIGN REVIEW
10 REVISE DSN SUPPORT PLANNING
11 FORM DSN SUPPORT TEAM
12 PUBLISH JPL APPROVED NSP
13 DSN REQUIREMENTS TO MOS FUNCTIONAL SPEC.
14 PUBLISH LEVEL 3 & 4 SPECIFICATIONS
15 PUBLISH DSN SUPPORT PLAN
16 PUBLISH DSIF MISSION PREPARATIONS PLAN
17 PUBLISH GCF MISSION PREPARATIONS PLAN
18 PUBLISH DSN MISSION PREPARATIONS PLAN
19 DSN DETAILED DESIGN REVIEW
20 PUBLISH DSN OPERATIONS PLAN
21 PUBLISH GCF OPERATIONS PLAN
22 PUBLISH DSN OPERATIONS PLAN
23 DSN TEST READINESS REVIEW
24 DSS-71 H/W - S/W INTEG. & SYS. TESTS & TRAINING
25 CTA-21 H/W - S/W INTEG. & SYS. TESTS
MVM 73
EV EM
NOTES
PRELIMINARY
UPDATE
FINAL
ON GOING ACTIVITY
MM 71 LAUNCH
MM 71 ENC
PIONEER F LAUNCH
PIONEER G LAUNCH
MVM 73 LAUNCH
PIONEER F ENC
HELIOS LAUNCH

JET PROPULSION LABORATORY
RESPONSIBILITY:
APPROVAL N.A. RENZETTI
ACCOMPLISHMENT E. K. DAVIS

DSN MILESTONE SCHEDULE FOR MARINER VENUS/MERCURY PROJECT (Cont'd)

5 LEVEL

ORIGINAL SCHEDULE APPROVAL ______ (DATE)
LAST SCHEDULE CHANGE 12-15-72 (DATE) (INITIALS)
STATUS AS OF 12-15-72 (DATE)

	MILESTONES
26	DSS-12, 14, 42, 62 H/W-S/W INTEG AND SYSTEM TESTS AND TRANSFER
27	DSS-43, 63 H/W-S/W INTEG. AND SYSTEM TESTS AND TRANSFER
28	GCF INTEGRATION AND SYSTEM TESTS
29	CTA-21 OPERATIONAL PROCEDURE VERIFICATION
30	DSN OVT FOR DSS 12, 14, 42, 61, & 62
31	DSN OVT FOR DSS 43, 63
32	DSN OPERATIONS READINESS REVIEW (DSS 12, 14, 42, 61, 62 & 71)
33	DSN OPERATIONS READINESS REVIEW (DSS 43, 63)
34	ORT AND LAUNCH READINESS REVIEW
35	230KBPS OPNL
36	SUPPORT GDS INTEGRATION
37	CTA-21 RF COMPAT TESTS
38	DSS 71 RF COMPAT TESTS
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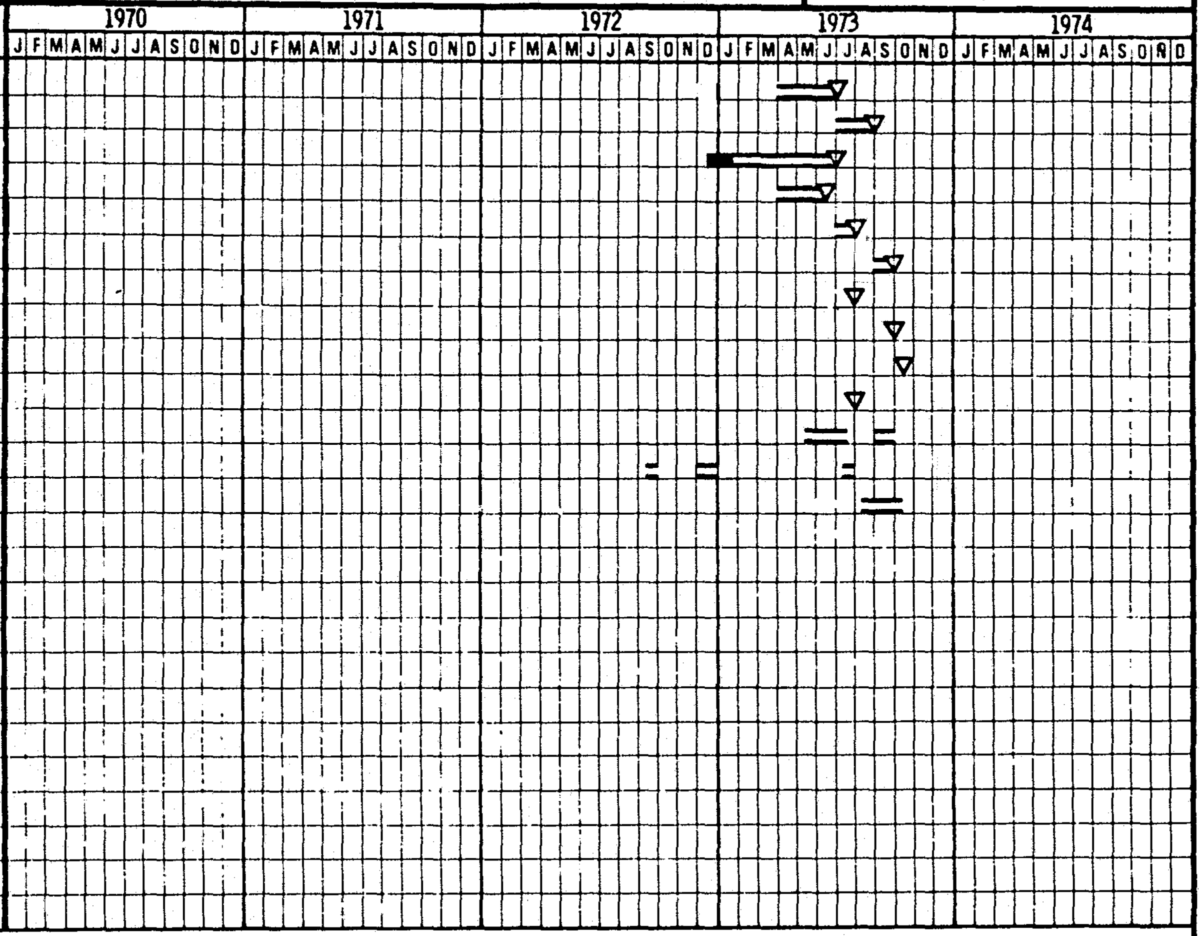

NOTES

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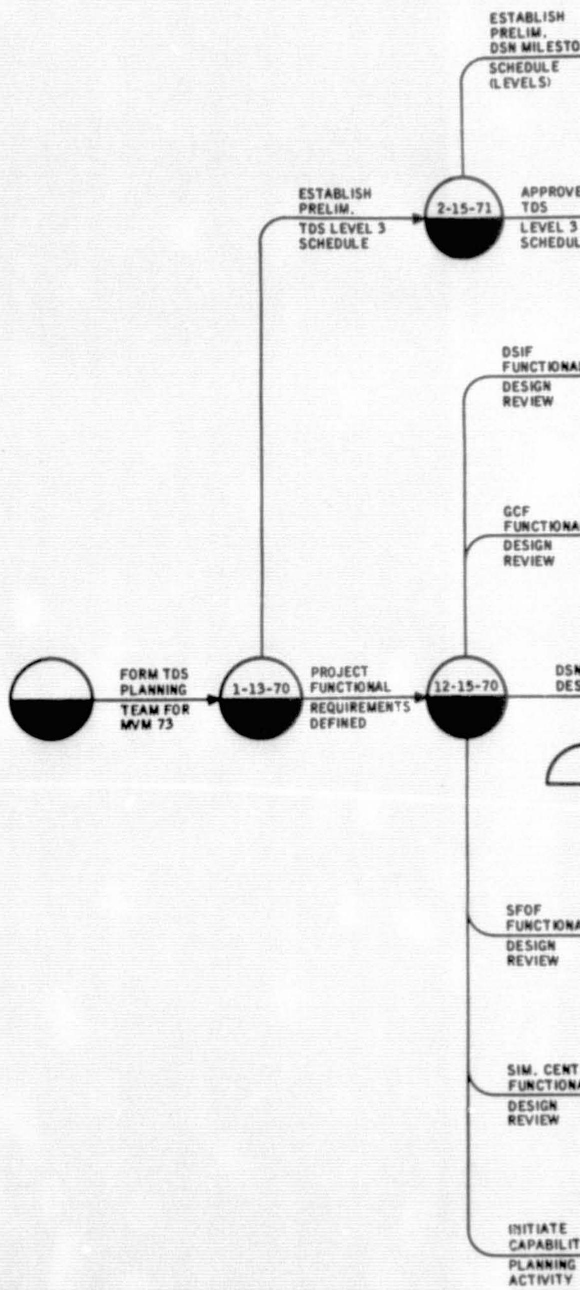
JET PROPULSION LABORATORY

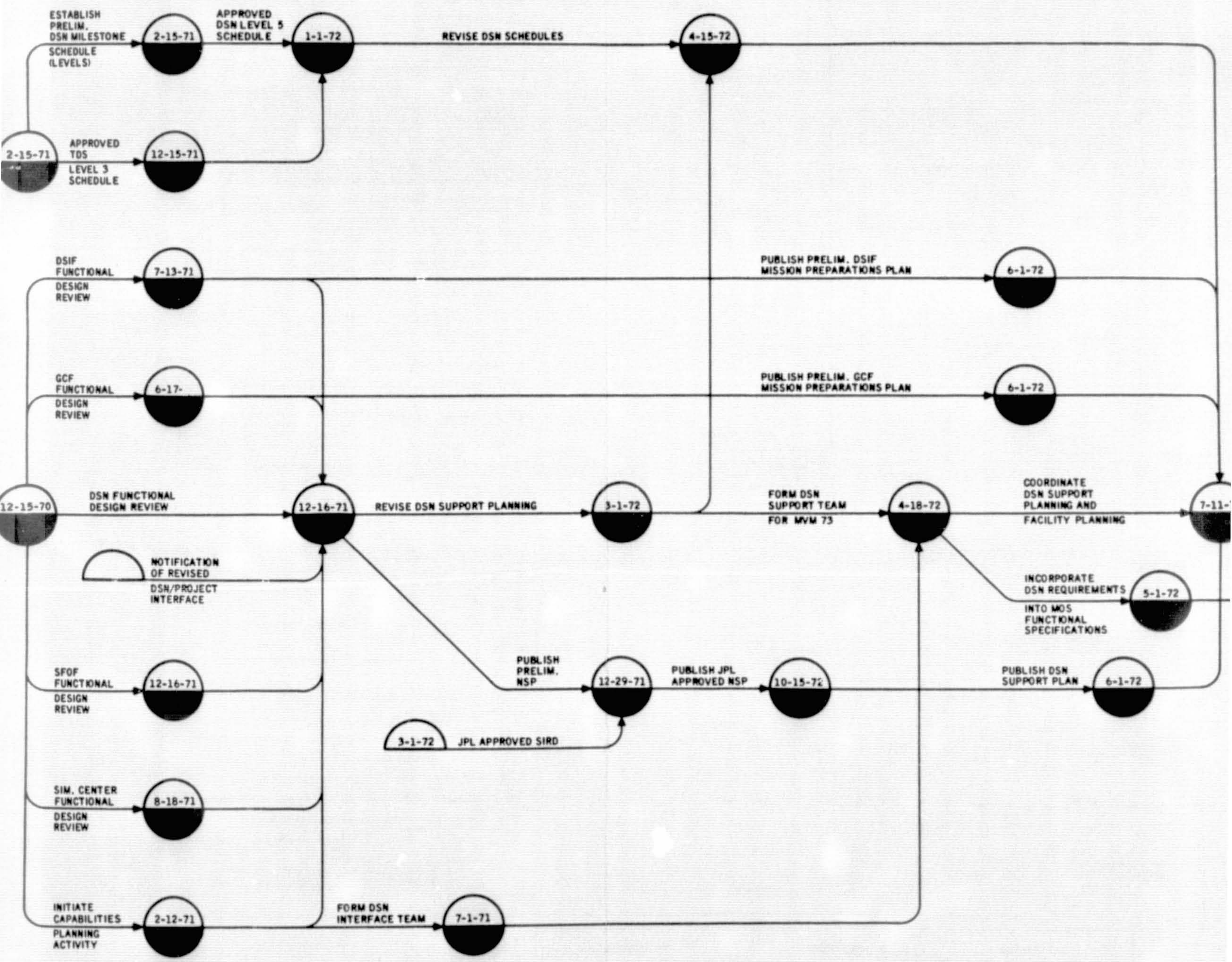
APPROVAL:

DSN: ______________________
N. A. RENZETTI

ACCOMPLISHMENT: *E.K. Davis*
E. K. DAVIS



DSN MILESTONE SCHEDULE FOR MVM 73



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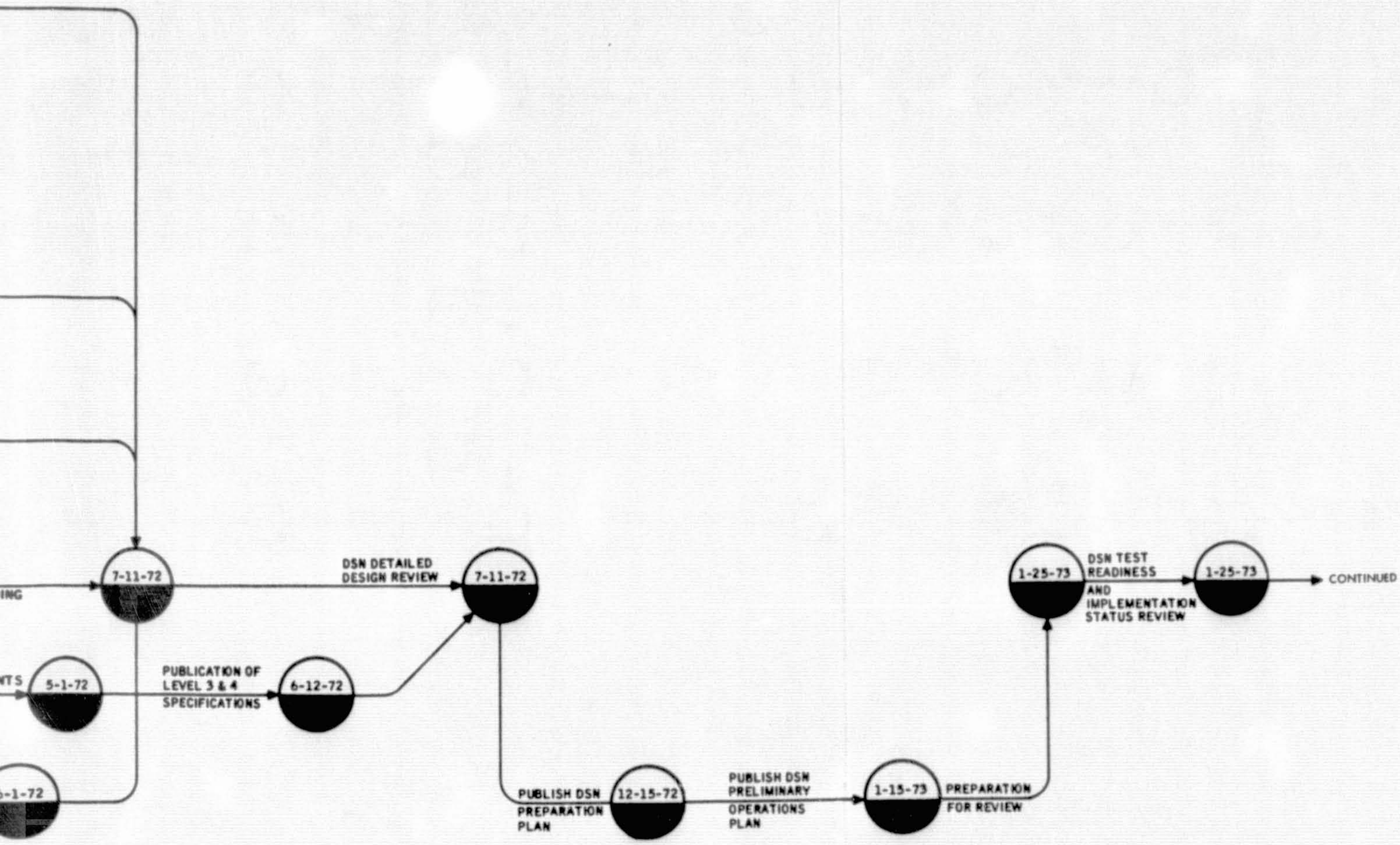
R MVM 73

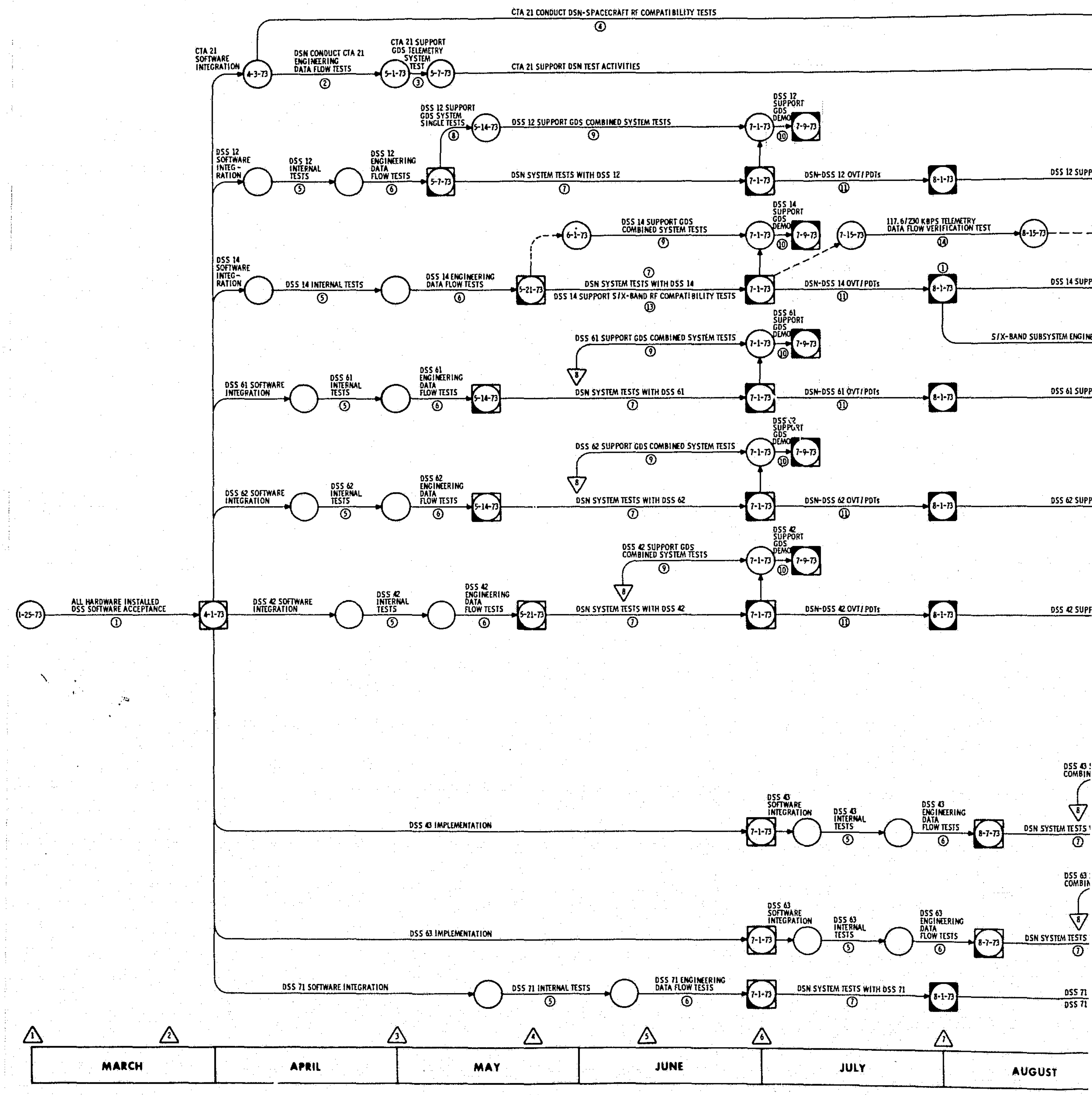
5 LEVEL

ORIGINAL SUMMARY APPROVAL: 1 JULY 1971

LAST SUMMARY CHANGE: 15 JAN 1973 (INITIALS)

STATUS AS OF: 15 JAN 1973 (DATE)





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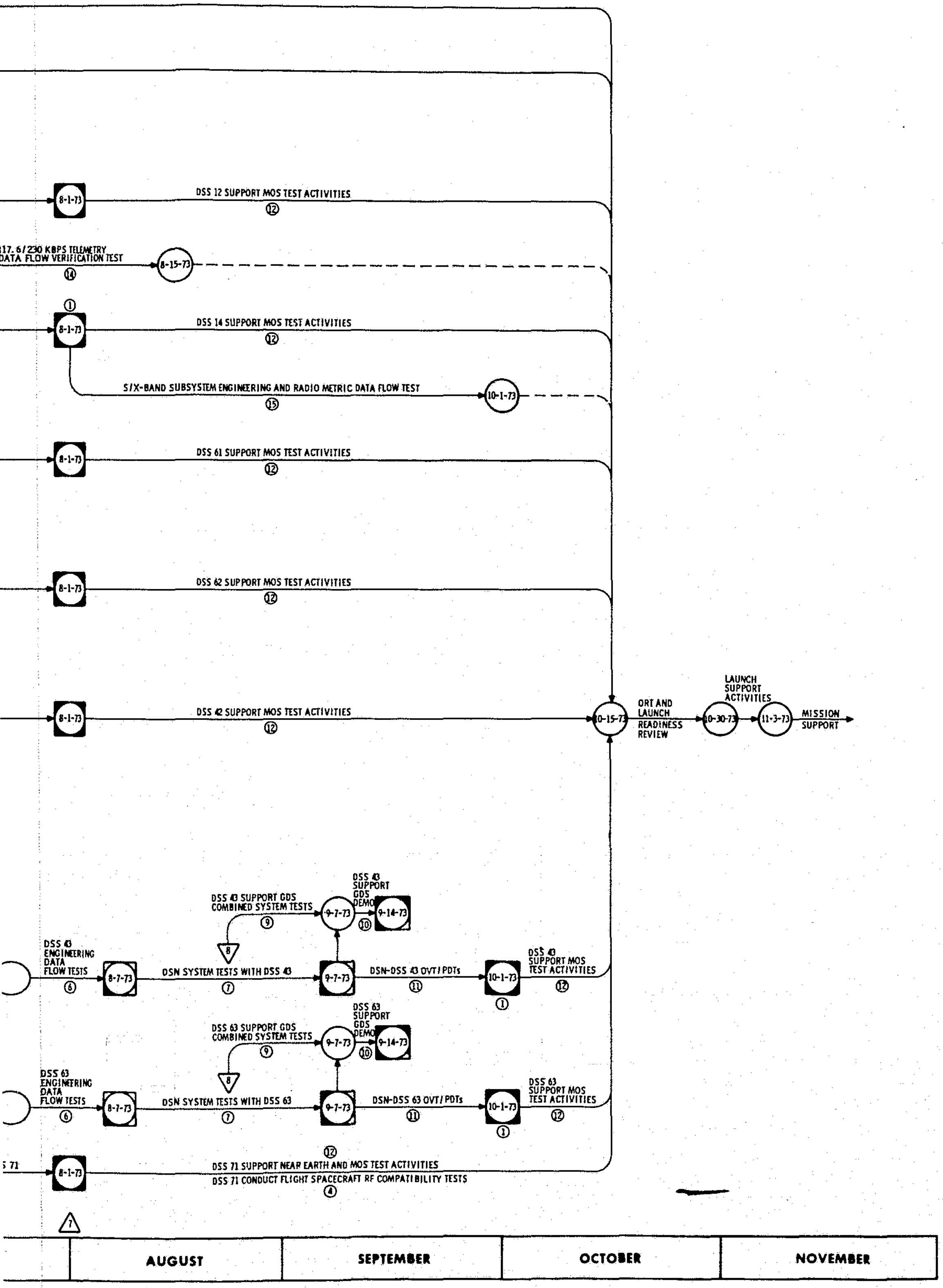

DSN TEST CRITERIA AND SCHEDULE GUIDELINES FOR MVM 73

NOTES:

1. EXCEPT DSS 14 S/X HARDWARE AND DSS 43/63 PLANETARY RANGING HARDWARE.
2. INITIAL ENGINEERING VERIFICATION OF DSN-MCCCS INTERFACES INCLUDING: SIMULATE TELEMETRY, TRACKING, COMMAND, AND MONITOR REAL-TIME DATA FORMATS ODR AND OPEN LOOP RECORDING NON-REAL-TIME DATA FORMATS. AS DEFINED IN 615-95.
3. ONE SUCCESSFUL 8-HOUR TEST: HIGH SPEED AND WIDEBAND DATA FLOW FROM CTA 21.
4. DEMONSTRATE RF COMPATIBILITY BETWEEN DSN AND FLIGHT S/C OR EQUIVALENT S/C USING INTEGRATED OPERATIONAL SOFTWARE. INCLUDE TRANSMISSION OF DATA TO MCCC APPROPRIATE ON NON-INTERFERENCE TO RF COMPATIBILITY DEMO.
5. VERIFY DSS SUBSYSTEM AND SYSTEM PERFORMANCE AS CONFIGURED TO MEET MVM 73 REQUIREMENTS USING DSS INTERNAL SIMULATION, TEST SOFTWARE AND COMM LOOP CAPABILITIES.
6. CONTINUE DSS SUBSYSTEM AND SYSTEM PERFORMANCE VERIFICATION IN LONG-LOOP. ALSO, ACCOMPLISH INITIAL ENGINEERING VERIFICATION OF DSS-MCCCS REAL-TIME AND NON-REAL-TIME DATA FORMAT INTERFACES. ACHIEVE READINESS TO SUPPORT NETWORK LEVEL SYSTEM TESTS. USE MCCCS 6050, 360/75, AND 1230 (MTC) CAPABILITIES AS REQUI TO PROVIDE DATA SOURCES AND VALIDATE INTERFACE COMPATIBILITY. SHIP TELEMETRY ODRS TO MTCF FOR COMPATIBILITY VERIFICATION.
7. THREE 12-HOUR TESTS PER DSS. COMBINED SYSTEMS MODE WITH DATA FLOW BETWEEN DS AND MCCCS EQUIVALENT TO FLIGHT SUPPORT CONDITIONS. INCLUDE DATA RECALL AND NEAR-REAL-TIME DATA RELAY VIA REDUCED RATE ODR REPLAY AS APPLICABLE TO MONITO EVALUATE AND VERIFY NETWORK LEVEL SYSTEM TECHNICAL PERFORMANCE INCLUDING VALIDATION OF ALL CONFIGURATIONS AND INTERFACES FOR MVM 73. INCLUDES SHIPPIN OF TELEMETRY ODRS FOR EVALUATION AT THE MTCF. TECHNICAL PERFORMANCE EVALUATIO SHALL INCLUDE: COMM H/W AND ELECTRICAL INTERFACES; DATA OUTPUT/INPUT INTERFAC FORMATS; DATA ACCURACY, QUANTITY, QUALITY IN REAL-TIME THRU PUT AND RECORD DSS AND GCF BER, LOCK, SYNC, MTF STATISTICS, PERCENTAGE GOOD DATA, AND DISTRIB OF ERRORS, TIMING; LOADING; CONFIRMS OPERATIONAL READINESS OF TECHNICAL ELEME
8. TWO 8-HOUR TESTS, AT LEAST 48 HOURS BETWEEN TESTS, CONDUCTED BY GDSE TO VERIFY END-TO-END DATA FLOW FROM DSS VIA GCF AND THRU MCCCS PROCESSORS. EARLY CHECK ON EACH GDS FUNCTIONAL SYSTEM TO VERIFY READINESS TO SUPPORT COMBINED SYSTEM TESTS. THESE SINGLE SYSTEM TESTS CONDUCTED ONLY WITH DSS 12.
9. ONE SUCCESSFUL 8-HOUR TEST, CONDUCTED BY GDSE. COMBINED SYSTEM MODE. TO VERI COMBINED SYSTEM DATA FLOW AND PERFORMANCE.
10. ONE 24-HOUR TEST, CONDUCTED BY GDSE. SIMULATED MISSION DAY USING MULTIPLE DS AND FULL MCCCS PROCESSING.
11. TWO TESTS (OVT) PER CREW FOR EACH DSS AND ONE TEST (PDT) PER DSS. DATA FLOW AND SEQUENCE OF EVENTS MODE. TO TRAIN CREWS, VALIDATE OPERATIONAL PROCEDURES AND CONFIRM OVERALL OPERATIONAL READINESS. REQUIRES MOS TEAMS' PARTICIPATION AN MCCCS SUPPORT.
12. SUPPORT MOS TEST AND TRAINING.
13. S/C S/X-BAND RADIO COMPONENTS TO BE MADE AVAILABLE FOR RF COMPATIBILITY TEST WITH DSS 14 S/X R&D HARDWARE.
14. TWO 8-HOUR TESTS, TO VERIFY REAL-TIME HANDLING OF 117.6 KBPS DATA, RECORDING A WORD FORMATTER INTERFACE, AND 230 KBPS WBDL PERFORMANCE. GDS MAY SUPPLY 117.6 KBPS DATA GENERATOR FOR RF INTERFACE WITH DSS 14, IF NOT, USE SCA PATTERN GENERATOR OR MTC DATA.
15. THREE 8-HOUR TESTS. TO VALIDATE INSTALLATION AND OPERATION OF R&D S/X-BAND EQUIPMENT AND RADIO METRIC DATA FLOW.

LEGEND:

- 4-1-73 — ALL ELEMENTS AVAILABLE FOR INTEGRATION/TEST: H/W, S/W, PLANS, PROCEDURE MANUALS, ETC.
- DSS INTERNAL SUBSYSTEM/SYSTEM TESTS AND INTERFACE ENGINEERING TESTS OR READY TO SUPPORT DSN SYSTEM TESTS.
- NETWORK LEVEL SYSTEM TESTS COMPLETE. DSN TECHNICAL SYSTEM PERFORMANCE DEMONSTRATED. TRANSFER TO OPERATIONS.
- GROUND DATA SYSTEM TECHNICAL PERFORMANCE DEMONSTRATED.
- 8-1-73 — ALL DSN TEST/TRAINING COMPLETED. DSN OPERATIONAL READINESS VERIFIED.
- Triangle 1 — MTCF INTERFACE, GCF FRAME SYNC, AND SDR WRITE AVAILABLE FOR SUPPORT. ALL SIMULATION AND COMMAND ELEMENTS READY FOR TEST SUPPORT.
- Triangle 2 — WIDEBAND (28.5 KBPS) CIRCUIT LONG LOOP CAPABILITY AVAILABLE AT CTA 21.
- Triangle 3 — MCCCS TRACKING AND MONITOR/CONTROL ELEMENTS READY FOR TEST SUPPORT.
- Triangle 4 — WIDEBAND (28.5 KBPS) CIRCUIT LONG-LOOP CAPABILITY AVAILABLE AT DSS 14.
- Triangle 5 — WIDEBAND (28.5 KBPS) CIRCUIT LONG-LOOP CAPABILITY AVAILABLE AT DSS 71.
- Triangle 6 — WIDEBAND (28.5 KBPS) CIRCUIT LONG-LOOP CAPABILITY OPERATIONAL AT DSS 43.
- Triangle 7 — WIDEBAND (230 KBPS) CIRCUIT LONG-LOOP OPERATIONAL AT DSS 14.
- Triangle 8 — DSS TO SUPPORT GDS COMBINED SYSTEM TESTS AS EARLY AS POSSIBLE IN THE MAY PERIOD, BUT NOT BEFORE SATISFACTORY COMPLETION OF AT LEAST ONE DSN SYSTEM AS DEFINED IN 7. THIS CONSTRAINT SHALL NOT APPLY TO DSS 12 AND 14. SEE DIAGRAM. SCHEDULING GUIDELINE: ALLOCATE TIME FOR EACH DSS FOR GDS TESTS DESCRIBED IN 9 NO EARLIER THAN THE START OF WEEK TWO OF TEST PERIOD 7.

DOCUMENTATION:

DETAILED RESPONSES TO THESE REQUIREMENTS WILL BE DOCUMENTED IN THE DSN OPERATIO PLAN FOR MVM 73

APPENDIX B

GLOSSARY OF ABBREVIATIONS

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ACN	Ascension Island, NASA STDN station
ACTS	Area Communications Terminal Subsystem
AGC	automatic gain control
ANT	Antenna Mechanical Subsystem
AOS	acquisition of signal
APS	Antenna Pointing Subsystem
ATS	Applications Technology Satellite
BCD	binary-coded decimal
BDA	Bermuda, NASA STDN station
BDA	Block Decoder Assembly
BER	bit error rate
BMXR	block multiplexer
BDXR	block dimultiplier
bps	bits per second
BUR	Johannesburg, NASA STDN station
CCTS	Central Communications Terminal Subsystem
CJMA	Communications Junction Module Assembly
CMA	Command Modulator Assembly
CMD	Coded Multiplexer/Demultiplexer
COMGEN	Command Generation Program
CRO	Carnarvon, Australia, NASA STDN station
dB	decibel
dBi	decibels antenna gain referred to isotope antenna
dBm	decibels referred to 1 milliwatt
DCES	DSS Communications Equipment Subsystem
DDA	Data Decoder Assembly
dec	declination

DIS	Digital Instrumention Subsystem
DLA	declination of outgoing asymptote
DMC	DSIF Monitor and Control Subsystem
DOY	day of year
DPTRAJ	Double Precision Trajectory Program
DRVID	Differenced Range Versus Integrated Doppler
DSIF	Deep Space Instrumentation Facility
DSN	Deep Space Network
DSS	Deep Space Station
DTV	Digital Television
EDR	Experiment Data Record
E_m	Encounter at Mercury
E_v	Encounter at Venus
FAZ	flight azimuth
FTS	Frequency and Timing Subsystem
GCF	Ground Communications Facility
GDS	Ground Data System
GMT	Greenwich Mean Time
GSFC	Goddard Space Flight Center
HA	hour angle
HSD	high-speed data
HSDL	high-speed data line
HSS	High Speed System
IF	intermediate frequency
ISTS	Intersite Transmissions Subsystem
JPL	Jet Propulsion Laboratory
kbps	kilobits per second

KPNO	Kitt Peak National Observatory
LASL	Los Alamos Scientific Laboratory
LCP	left (-hand) circular polarization
LOS	loss of signal
MCCC	Mission Control and Computing Center
MCCCS	Mission Control and Computing Center System
MDR	Master Data Record
MIL	Merritt Island, NASA STDN station
MOS	Mission Operations System
MSA	Mission Support Area
MTC	Mission and Test Computer
MVM'73	Mariner Venus/Mercury 1973
NAA	Network Analysis Area
NASA	National Aeronautics and Space Administration
NAT	Network Analysis Team
NIC	Network Information Control
NASCOM	NASA Communications Network
NBS	National Bureau of Standards
NOP	Network Operations Plan
NSP	NASA Support Plan
OC	Operations Chief
OCIS	Office of Computing and Information Systems
OCT	Operations Control Team
ODR	Original Data Record
OVT	Operational Verification Test
PCM	pulse-code modulation
PE	Project Engineer

PET	Probe Ephemeris Test
PM	phase modulation
PMR	Project Management Report
PN	pseudorandom noise
PSK	phase-shift keyed
R&D	research and development
RCP	right (-hand) circular polarization
RF	radio frequency
RIC	Remote Information Center
RTLT	round-trip light time
S/C	spacecraft
SCA	Simulation Conversion Assembly
SDA	Subcarrier Demodulator Assembly
SDR	System Data Record
SEDR	System Experiment Data Record
SEP	Sun-Earth probe
SFOF	Space Flight Operations Facility
SIRD	Support Instrumentation Requirements Document
SNR	signal-to-noise ratio
SOE	Sequence of Events
SSA	Symbol Synchronizer Assembly
STDN	Space Tracking and Data Acquisition Network
TAN	Tananarive, Malagasy Republic, NASA STDN station
TCD	Telemetry and Command Data Handling Subsystem
TCP	Telemetry and Command Processor Assembly
TDA	Tracking and Data Acquisition
TDH	Tracking Data Handling Subsystem

TDS	Tracking and Data System
TREL	relative launch times
TTS	Teletype System
TTY	teletypewriter
TWM	traveling-wave maser
TWT	traveling-wave tube
TXR	transmitter
UWV	Antenna Microwave Subsystem
VCO	voltage-controlled oscillator
VCS	Voice System
WBDL	wideband data line
WBS	Wideband System
WFA	Word Formatter Assembly