NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Memorandum 33-301

Volume II

Tracking and Data System Support for Surveyor Missions III and IV

N. A. Renzetti

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

September 1, 1969

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Memorandum 33-301

Volume II

Tracking and Data System Support for Surveyor Missions III and IV

N. A. Renzetti

VOL. 1 - N69-34960
VOL. 3 - N70-15105
VOL. 4 - N70-15106
VOL. 5 - N70-13207

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

September 1, 1969

PRECEDING PAGE BLANK NOT FILMED.

Preface

The work described in this report was performed by the tracking and data acquisition organizations of the Jet Propulsion Laboratory, Air Force Eastern Test Range, Manned Space Flight Network, and the NASA Communications Network of Goddard Space Flight Center.

This volume is the second in a series of five to record the technical activities of the Tracking and Data System in support of the flights of *Surveyors I–VII*. Volume I covered *Surveyor* Missions *I* and *II*. This Volume II covers the support of *Surveyors III* and *IV*; and Volumes III, IV, and V will record the tracking and data acquisition activities for *Surveyors V*, *VI*, and *VII*, respectively.

Acknowledgment

The author expresses gratitude to the planning engineers and operational staff members of the participating groups and agencies who made valued contributions of skill, knowledge, and dedication to the Tracking and Data System support that was provided the *Surveyor* Project.

This report has been prepared largely from Jet Propulsion Laboratory internal documents and from certain publications from the Air Force Eastern Test Range and Goddard Space Flight Center. Special recognition is given the following contributors:

A. Berman	R. M. Grace	R. K. Mallis
J. W. Capps	J. A. Holladay	H. D. Moss
R. L. Chafin	C. A. Holritz	D. J. Mudgway
I. L. Emig	S. V. Kozak	P. J. Rygh
H. T. England		R. Stevens

Further, the author acknowledges the contribution of Edward Allen, who assisted with the organization of the extensive material and its preparation for this final report.

Finally, the author recognizes the significant contributions of A. C. Belcher and M. E. Binkley in obtaining support for this work. Both men are in the Office of Tracking and Data Acquisition at NASA Headquarters.

Contents

Contents (contd)

Contents (contd)

Contents (contd)

Tables

Contents (contd)

Tables (contd)

Contents (contd)

Tables (contd)

Contents (contd)

Tables (contd)

Figures

Contents (contd)

Figures (contd)

Contents (contd)

Figures (contd)

Contents (contd)

Figures (contd)

Contents (contd)

Figures (contd)

Contents (contd)

Figures (contd)

Contents (contd)

Figures (contd)

Abstract

This report covers the Tracking and Data System (TDS) activities for *Surveyors III* and *IV*, from the time the requirements on the system were established by the Project objectives and the spacecraft design, through the preparation of the network-support plans, the implementation of the necessary facility configurations, the performance of the requisite tests to establish operational readiness, the support of the actual flights to the end of each mission—with a comprehensive account of the tracking operations, and an evaluation of that support. To better define the requirements on the TDS, the *Surveyor* mission objectives are reviewed and descriptions of the *Atlas/Centaur* launch vehicle and of the spacecraft are included, as are synopses of the *Surveyor III* and *IV* flights. Associated equipment and activities of the three elements of the Deep Space Network—i.e., the Deep Space Instrumentation Facility, the Ground Communications Facility, and the Space Flight Operations Facility—in meeting the metric, telemetry, command, and tracking demands of the missions are documented. Tracking and telemetry summaries of the initial phases of the flights cover operations of the Goddard Space Flight Center, the Air Force Eastern Test Range, the Spacecraft Monitoring Facility at Cape Kennedy (DSS 71), and the Ascension Island Spacecraft Command and Guidance Station (DSS 72). Technical and statistical data concerning launch, trajectory, operating modes, tracking time, received-signal levels, command lockups, data transmission and reduction are presented.

Tracking and Data System Support for *Surveyor* Missions III and IV

I. Introduction

A. General

The purpose of this document is to provide a history of the technical activities of the Air Force Eastern Test Range (AFETR), the Goddard Space Flight Center (GSFC), and the NASA/JPL Deep Space Network (DSN) in support of *Surveyor* missions A through G (*Surveyor I* through *VII* missions). Included in this document are the Tracking and Data Acquisition (TDA) requirements, mission preparations of all participating agencies, a comprehensive account of the tracking operations, and a Tracking and Data System (TDS) performance evaluation summary. A brief description of the TDS, *Surveyor* series, as well as launch vehicles, spacecraft, and flight objectives, is also provided to convey an understanding of TDS activities.

The *Surveyor* Project is managed by the Jet Propulsion Laboratory (JPL) for the NASA Office of Space Science and Applications. The Project is supported by four major management and functional elements or systems: (1) Launch Vehicle System, (2) Spacecraft System, (3) Tracking and Data System, and (4) Mission Operations System (MOS). In addition to overall project management, JPL has been assigned the management responsibility for the spacecraft, tracking and data acquisition, and mission operations systems. NASA/Lewis Research Center (LeRC) has been assigned responsibility for the *Atlas/Centaur* launch vehicle system.

B. Tracking and Data System

The TDS provides the tracking and communications link between the space vehicle and committed earth-based stations. For *Surveyor* missions, the TDS uses the facilities of: (1) the AFETR for tracking and telemetry of the spacecraft and vehicle during the launch and near earth phases, (2) the DSN, for precision tracking commands, telemetry, communications, data transmission, processing, and computing, and (3) the Manned Space Flight Network (MSFN) and the National Aeronautics and Space Administration Communications System (NASCOM), both of which are operated by the GSFC.

The AFETR extends from the eastern United States mainland through the south Atlantic Ocean area eastward into the Indian Ocean. It includes all stations, sites, ocean areas, and air space necessary to conduct missile and space vehicle test and development. Administrative and management activities are largely concentrated at Patrick AFB, while actual missile launches and flight tests are conducted at Cape Kennedy Air Force Station (CKAFS) and over the downrange areas.

The AFETR uses major instrumentation systems to support those projects, programs, and organizations that use the AFETR launch facilities.

As a part of the TDS, the AFETR performs TDA functions for *Surveyor* missions during the countdown and launch phases of each flight. To meet the tracking and telemetry commitments for *Surveyor* missions, the AFETR has at its disposal: (1) Landbased Instrumentation Sites, (2) Range Instrumentation Ships (RIS), and (3) Range Telemetry Aircraft.

The DSN, established by the NASA Office of TDA, is under the system management and technical direction of JPL. The DSN is responsible for two-way communications with unmanned spacecraft traveling from approximately 10,000 mi from earth to interplanetary distances. Tracking and data-handling equipment to support these missions is provided. Present facilities permit simultaneous control of a newly launched spacecraft and a second one already in flight. In preparation for the increased number of United States activities in space, a capability is being developed for simultaneous control of either two newly launched spacecraft plus two in flight, or four spacecraft in flight. Advanced communications techniques are being implemented to obtain data from, and to track spacecraft to, planets as far out in space as Jupiter.

The DSN is distinct from other NASA networks such as the Space Tracking and Data Acquisition Network (STADAN), which tracks earth-orbiting scientific and communication satellites, and the Manned Space Flight Network (MSFN), which tracks the manned spacecraft of the *Gemini* and *Apollo* programs.

The DSN supports, or has supported, the following NASA space exploration projects: (1) the *Ranger, Surveyor,* and *Mariner* Projects of JPL; (2) the *Lunar Orbiter* Project of the Langley Research Center; (3) the *Pioneer* Project of the Ames Research Center; (4) the *Apollo* Project of the Manned Spacecraft Center (as backup to certain stations of the Manned Space Flight Network); and (5) the NASA *Voyager* Project. The main elements of the network are: The Deep Space Instrumentation Facility (DSIF), with communications and tracking stations located around the world; the Ground Communications Facility (GCF), which provides communications between all elements of the DSN; and the JPL Space Flight Operations Facility (SFOF), the command and control center for DSN supported projects.

The Deep Space tracking stations are situated such that three prime stations may be selected approximately 120 deg apart in longitude in order that a spacecraft in or near the ecliptic plane is always within the field of view of at least one of the selected ground antennas. The Deep Space stations and their respective locations are shown in Table 1.

The Deep Space acquisition of a spacecraft signal may involve six different functions: (1) pointing the antenna at the spacecraft; (2) tuning to, and locking receivers to the spacecraft transmitted frequency; (3) tuning and locking the ground transmitter to the spacecraft receiver frequency; (4) establishing range lock, where applicable;

Table 1. DSS station designations and locations

Location	Station ID number	Geodetic latitude, deg	Geodetic longitude, deg	Height above mean sea level, m	Geocentric latitude, deg	Geocentric longitude, deg	Geocentric radius, km
Goldstone, Calif. (Pioneer)	11	35.38950N	243.15175E	1037.5	35.20805N	243.15080E	6372.0341
Goldstone, Calif. (Echo)	12	35.29986N	243.19539E	989.5	35.11861N	243.19445E	6372.0176
Goldstone, Calif. (Venus)	13	35.24772N	243.20599E	1213.5	35.06662N	243.20507E	6372.2599
Goldstone, Calif. (Mars)	14	35.42528N	243.12222E	1160	35.24376N	243.12127E	6372.1341
Woomera, Australia	41	31.38314S	136.88614E	144.8	31.21236S	136.88614E	6372.5317
Canberra, Australia	42	35.40111S	148.98027E	654	35.21962S	148.98027E	6371.6686
Johannesburg, S. Africa	51	25.88921S	27.68570E	1398.1	25.73876S	27.68558E	6375.5415
Madrid, Spain, (Robledo)	61	40.429 N	355.751 E	800	40.238 N	355.751 E	6370.0868
Cape Kennedy, Fla.	71	28.48713N	279.42315E	4.0	28.32648N	279.42315E	6373.2913
Ascension Island	72	7.95474S	345.67242E	526.7	7.89991S	345.67362E	6378.23[illegible]

(5) synchronizing the telemetry system; and (6) in some cases, providing for immediate command transmission to the spacecraft. Selected DSIF stations are equipped with acquisition aid antennas mounted on the 85-ft antennas, to assist in the acquisition process. The acquisition aids have beamwidths of approximately 16 deg and are accurately boresighted with the 85-ft antennas. They have angle-error outputs which are connected to a separate angle channel receiver. By observing the angle errors generated simultaneously by both wide- and narrow-beamwidth antennas, a smooth change from tracking with the acquisition aid to tracking with the 85-ft antenna can be effected. Thus, tracking, telemetry, and control of the spacecraft are properly attained.

The MSFN is under the direction of the GSFC, located at Greenbelt, Maryland. The MSFN is part of a world wide network designed for supporting the Manned Space Flight effort. The GSFC MSFN has certain responsibilities, of tracking and data acquisition, communications, and computer support, placed upon it by the *Surveyor* Project.

From the MSFN facilities, launch, first tracking, and launch mark-event activities are monitored. By use of the Switching Communications and Monitoring Arrangements (SCAMA), voice operations and control are linked to all MSFN tracking stations committed to support the *Surveyor* missions.

All MSFN stations are tied together around the world through common timing, geodetic, control systems, and communications coordination by GSFC. This world-wide communications network, designated NASCOM, mentioned above, provides teletype, voice and data links in supporting the *Surveyor* missions.

C. *Surveyor* Series

The *Surveyor* Project comprises seven flights, identified prior to launch as missions A through G, which are being conducted under the auspices of NASA, with the following objectives: (1) accomplishing successful soft landings on the moon as demonstrated by operation of the spacecraft subsequent to landing, (2) providing basic data in support of *Apollo*, and (3) performing operations on the lunar surface which will contribute new scientific knowledge and understanding of lunar characteristics and provide further information for support of *Apollo*.

Of the seven missions planned three have been launched as of April 17, 1967. The first mission, *Surveyor I*, was carried out with complete success beginning with launch on the *Atlas/Centaur* booster on May 30, 1966. *Surveyor I* survived its first night on the moon and returned additional television pictures during its second lunar day. The second *Surveyor* spacecraft, *Surveyor II*, was launched on September 20, 1966, and failed during the midcourse maneuver due to a probable vernier propulsion system malfunction. *Surveyor III* was launched on April 17, 1967, and successfully touched down on April 19, 1967. The spacecraft landed in a crater 1.6 mi from the planned target area. *Surveyor III* was responsive to commands throughout the lunar day, which ended on May 3, 1967. A total of 6315 TV pictures were taken, including the earth, star maps, and photos of a lunar eclipse. The surface sampler operation was excellent throughout the mission. The mechanism dug four trenches, the deepest of which was 7½ in.

The *Surveyor* spacecraft have been designated as the A-21/A through A/21-G. *Surveyor* spacecraft carry engineering payloads to demonstrate successful transit and soft lunar landing and to gather basic engineering data relative to the performance of the spacecraft in the environments encountered in transit. The collection and transmission of scientific data concerning the lunar surface is also a major objective for *Surveyor*.

The *Surveyor* spacecraft has an injected weight of about 2200 lbs and is boosted to injection by an *Atlas/Centaur* launch vehicle. The *Centaur* vehicle uses a single burn direct ascent trajectory for the *Surveyor I, II,* and *IV* missions. *Surveyor III, V, VI* and *VII* missions will utilize a parking orbit trajectory. Lunar touchdown times are adjusted in such a manner that the target area is observable from the Goldstone Deep Space Station.

D. *Atlas/Centaur* Launch Vehicle

The two-stage launch vehicle, shown in Fig. 1, consists of an *Atlas* first stage and a *Centaur* second stage. Both stages are of a constant 10-ft diam and use a stainless-steel shell construction that maintains its shape through pressurization without any internal stiffening. All main engines plus the *Atlas* verniers are gimbaled for directional control. The gross weight of the 105-ft vehicle is approximately 300,000 lbs at liftoff.

The first stage of the *Atlas/Centaur* vehicle is a modified version of the *Atlas D* used on many previous NASA and Air Force missions such as *Ranger*, *Mariner* and *OGO*. The *Atlas* propulsion system consists of two booster thrust chambers rated at 165,000 lbs thrust each, a single

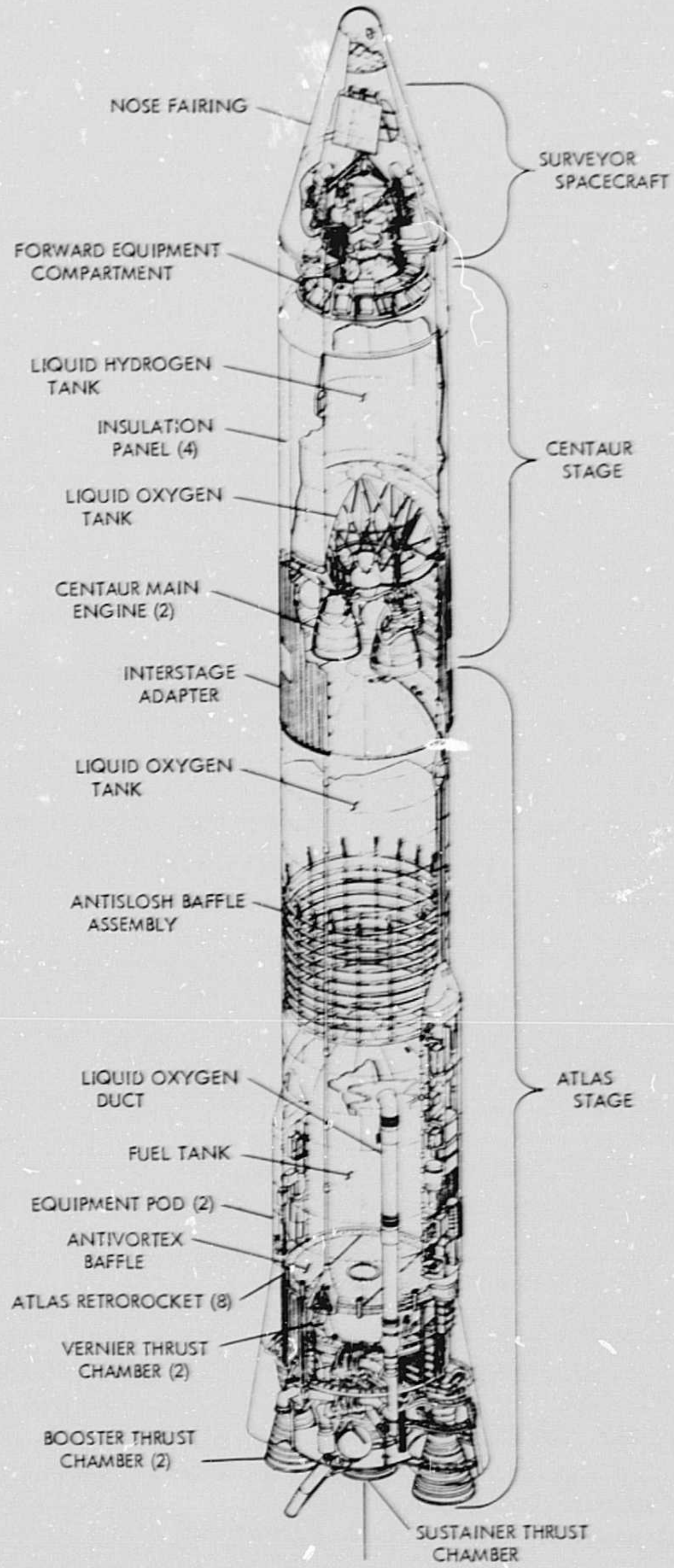


Fig. 1. *Atlas/Centaur/Surveyor* space vehicle configuration

sustainer rated at 57,000 lbs thrust, and two vernier thrust chambers rated at approximately 1000 lbs thrust each. All engines burn a propellant combination of liquid oxygen and RP-1 kerosene, producing a total liftoff thrust of approximately 388,000 lbs. The *Atlas* can be considered a 1½-stage vehicle because the "booster section," weighing 6000 lbs and consisting of the two booster engines together with the booster turbo pumps and other equipment located in the aft section, is jettisoned after about 2.5 min of flight. The sustainer and vernier engines continue to burn until propellant depletion. A mercury manometer propellant utilization system is used to control mixture ratio for the purpose of minimizing propellant residuals at *Atlas* burnout.

Flight control of the first stage is accomplished by the *Atlas* autopilot, which contains displacement gyros for attitude reference, rate gyros for response damping, and a programmer to control flight sequencing until *Atlas/Centaur* (A/C) separation. After booster jettison, the *Atlas* autopilot is also fed steering commands from the all-inertial guidance set located in the *Centaur* stage. Vehicle attitude and steering control are achieved by the coordinated gimballing of the five thrust chambers in response to autopilot signals.

The *Atlas* contains a single VHF telemetry system which transmits data on 118 first-stage measurements until *Atlas* separation. The system operates on a frequency of 229.9 Mc over two antennas mounted on opposite sides of the vehicle at the forward ends of the equipment pods. Redundant range-safety command receivers and a single destructor unit are employed on the *Atlas* to provide the Range Safety Officer with means of terminating the flight by initiating engine cutoff and destroying the vehicle. The system is inactive after normal *Atlas* staging occurs. The AZUSA tracking system has been deleted from the *Atlas* for *Surveyor* missions, leaving only the C-band tracking system on the *Centaur* stage. The *Atlas* launch vehicle is shown in Fig. 1.

E. *Centaur* Second Stage

The *Centaur* second stage is the first vehicle to utilize liquid hydrogen/liquid oxygen, high-specific-impulse propellants. The cryogenic propellants require special insulation to be used for the forward, aft, and intermediate bulkheads as well as the cylindrical walls of the tanks. The cylindrical tank section is thermally insulated by four jettisonable insulation panels having built-in fairings to accommodate antennas, conduits, and other tank protrusions. The insulation panel hinges were redesigned for A/C-10 to overcome a deployment control problem which had been suspected on vehicle development flights of A/C-6 and A/C-8. Most of the *Centaur* electronic equipment packages are mounted on the forward tank bulkhead in a compartment which is air-conditioned prior to liftoff.

The *Centaur* is powered by two constant-thrust engines rated at 15,000 lbs thrust each in vacuum. Each engine can be gimballed to provide control in pitch, yaw, and roll. Propellant is fed from each of the tanks to the engines by boost pumps driven with hydrogen peroxide turbines. In addition, each engine contains integral "bootstrap" pumps driven by hydrogen propellant, which is also used for regenerative cooling of the thrust chambers. A propellant utilization system is used on the *Centaur* stage to achieve minimum residual of one propellant at depletion of the other. The system controls the mixture ratio valves as a continuous function of propellant in the tanks by means of tank probes and an error ratio detector. The nominal oxygen/hydrogen mixture ratio is 5:1 by weight.

The second-stage all-inertial guidance system contains an on-board computer which provides vehicle steering commands after jettison of the *Atlas* booster section. The *Centaur* guidance signals are fed to the *Atlas* autopilot until *Atlas* sustainer engine cutoff and to the *Centaur* autopilot after *Centaur* main-engine ignition. *Surveyor I* was the first *Centaur* flight to employ an inertial platform containing new gyros having reduced gimbal stop angles, improved flex leads, better balanced spin motor, and reduced synchronous torque sensitivity. It was also the first flight during which the gyros were not torqued to correct for gyro drift characteristics. Gyro drifts were compensated for by the guidance system computer, which was programmed to set the torquing signals to zero during flight. The *Centaur* autopilot system provides the primary control functions required for vehicle stabilization during powered flight, execution of guidance system steering commands, and attitude orientation following the powered phase of flight. In addition, the autopilot system employs an electromechanical timer to control the sequence of programmed events during the *Centaur* phase of flight, including a series of commands required to be sent to the spacecraft prior to spacecraft separation.

The *Centaur* reaction control system provides thrust to control the vehicle after powered flight. For small corrections in yaw, pitch, and roll attitude control, the system utilizes six individually controlled, fixed-axes, constant-thrust, hydrogen peroxide reaction engines. These engines are mounted in clusters of three, 120 deg apart on the periphery of the main propellant tanks at the interstage adapter separation plane. Each cluster contains one 6-lb thrust engine for pitch control and two 3.5-lb thrust engines for yaw and roll control. In addition, four 50-lb thrust hydrogen peroxide engines are installed on the aft bulkhead, with thrust axes parallel with the vehicle axis. These engines are for use during retromaneuver and for executing larger attitude corrections if necessary. The cluster engines were slightly modified from the design used on the previous flight (A/C-8), in that the large aluminum B-nut on the thrust chambers was replaced with a steel flange joint to effect a more positive seal.

The *Centaur* stage utilizes a VHF telemetry system with a single antenna transmitting through the nose fairing cylindrical section on a frequency of 225.7 MHz. The telemetry system provides data on 140 measurements from transducers located throughout the second stage and spacecraft interface area as well as a spacecraft composite signal from the spacecraft central signal processor.

Redundant range safety command receivers are employed on the *Centaur*, together with shaped charge destruct units for the second stage and spacecraft. This provides the Range Safety Officer with means to terminate the flight by initiating *Centaur* main engine cutoff and destroying the vehicle and spacecraft retrorocket. The system can be safed by ground command, which is normally transmitted by the Range Safety Officer when the vehicle has reached injection energy.

Prior to final encapsulation and mating of *Surveyor*, a system is provided for the automatic destruction of the *Centaur* and spacecraft in the event of premature spacecraft separation.

A C-band tracking system is contained on the *Centaur* which includes a lightweight transponder, circulator, power divider, and two antennas located under the insulation panels. The C-band radar transponder provides real-time position and velocity data for the Range Safety Instantaneous Impact Predictor as well as data for use in guidance and trajectory analysis.

F. *Surveyor* Spacecraft

The general arrangement of the spacecraft and identification of its various elements are shown in Fig. 2. The spacecraft is composed of electronic and mechanical assemblies mounted on a basic spaceframe constructed of thin-walled aluminum alloy tubular members. Landing

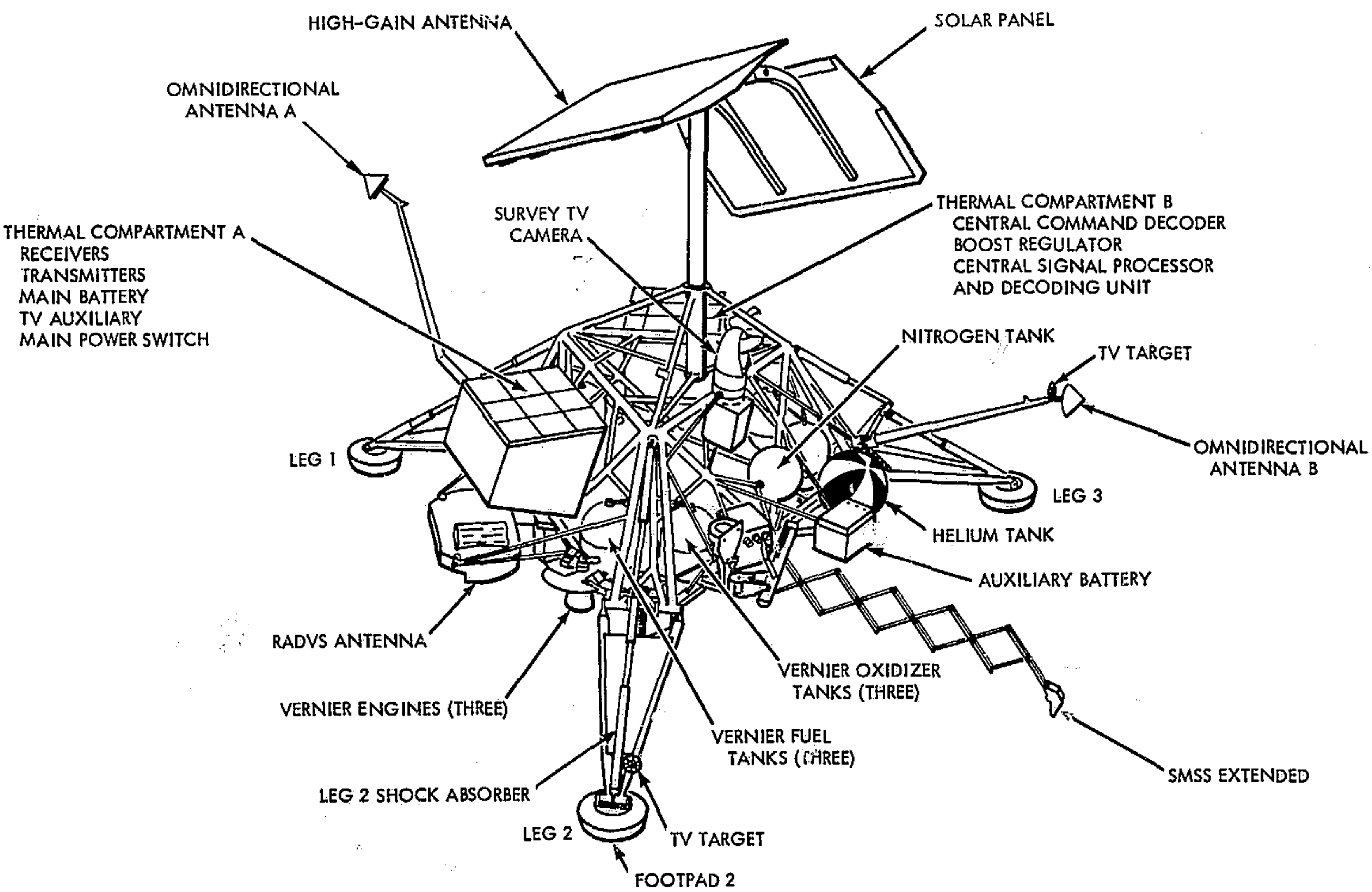


Fig. 2. *Surveyor* spacecraft configuration

shock is absorbed by a crushable structure and by the tripod landing gear, which also maintains correct attitude after landing.

The equipment to be carried on these first four missions includes flight control, propulsion, telecommunications, TV, and power sub-systems. The flight control subsystem provides attitude stabilization and control during all phases of the flight. The primary sun sensor and the Canopus sensor provide attitude reference during coast phases of the flight. Other elements of the flight control subsystem include gas jets, and inertial reference unit, and associated electronics. The altitude marking radar initiates the terminal descent phase by firing the vernier engines and main retro-rocket engine. The Radar Altimeter and Doppler Velocity Sensor (RADVS) provides signals to control the rate of descent and attitude during the descent phase.

The basic units of the telecommunications subsystem are two transmitters, two receiver/transponders, two omnidirectional antennas, and one high-gain planar array antenna. Additional units provide control and signal processing. The basic functions of the telecommunications subsystem include command reception, transit lunar surface telemetry transmission, and two-way doppler transponder operation.

In addition to these subsystems, the first four *Surveyor* spacecraft will carry an engineering payload. This payload consists of an auxiliary battery, the TV subsystem, accelerometers for measuring vernier engine thrust, strain gages for measuring main retro-rocket engine case pressure and touchdown shock, and temperature sensors to measure the thermal status of a variety of components of the system including the structure. The auxiliary engineering signal processor processes the sensor data for transmission.

The TV subsystem consists of an approach TV camera, a survey TV camera, and additional units to control the cameras. The approach TV camera provides pictures of the lunar landing site from a range of 1000 mi to approximately 80 mi above the lunar surface. The survey TV camera provides pictures of selected portions of the lunar surface, free space, and of the spacecraft after landing.

As has already been mentioned, the *Surveyor* spacecrafts have a nominal separated weight of approximately 2200 lbs and contain three extendable legs used for stability during touchdown on the lunar surface. The guidance system of each spacecraft maintains full attitude stabilization and directs the spacecraft through maneuvers in attitude and trajectory in response to commands from the ground. Cold gas jets are used to position and maintain the spacecraft in the required attitude. In this stabilized mode, the spacecraft uses the sun and Canopus as reference objects.

The spacecraft contains two propulsion systems: a solid-propellant, main retro engine that provides the primary braking during terminal descent, and a variable, low-thrust, liquid-propellant, vernier system capable of executing a midcourse trajectory correction and of providing braking and attitude control during terminal descent. During the terminal sequence, the propulsion system is controlled automatically by a radar system that measures attitude and velocity components with respect to the lunar surface.

The spacecraft derives its electrical power from a solar panel and from batteries for peak power requirements during transit, and after landing during the lunar night. It has a two-way communications S-band system that provides a method of telemetering information to the earth, provides command capability to the spacecraft, and provides angle tracking and one- or two-way doppler for orbit determination.

G. *Surveyor* Mission Objectives

The specific objectives of each *Surveyor* mission are denoted as "flight objectives." Flight objectives are specified in three categories: primary, secondary, and tertiary, as follows:

(1) Primary flight objectives are to:

(a) Demonstrate the capability of the *Surveyor* spacecraft to perform successful midcourse and terminal maneuvers and soft-landing on the moon.

(b) Demonstrate the capability of the *Atlas/Centaur* vehicle to successfully inject the *Surveyor* spacecraft on a lunar intercept trajectory.

(c) Demonstrate the capability of the *Surveyor* communications system and the DSN to maintain communications with the spacecraft during its flight and after the soft landing.

(2) Secondary flight objectives are to:

(a) Obtain in-flight engineering data on all spacecraft subsystems used in cruise flight.

(b) Obtain in-flight engineering data on all spacecraft subsystems used during the midcourse maneuver, terminal maneuver, and main retro phase.

(c) Obtain in-flight engineering data on the performance of the closed-loop terminal descent guidance and control system, consisting of the velocity and altitude radars, on-board analog computer, auto-pilot and vernier engines.

(d) Obtain engineering data on the performance of spacecraft subsystems used on the lunar surface.

(3) Tertiary flight objectives are to:

(a) Obtain post-landing TV pictures of a spacecraft footpad and the immediately surrounding lunar surface material.

(b) Obtain post-landing TV pictures of the lunar topography.

(c) Obtain data on the radar reflectivity of the lunar surface.

(d) Obtain data on the bearing strength of the lunar surface.

(e) Obtain spacecraft temperature data on the lunar surface for use in the analysis of lunar surface temperatures.

Prior to Mission A launch, a launch-hold criterion was established in that the capability must exist for all project systems to meet all objectives (primary, secondary, and tertiary) before the launch would be permitted.

(4) Definition of primary, secondary, and tertiary objectives are:

(a) Primary: Achievement of the primary objective is required for the mission to be considered successful. When developmental or operational conditions exist which jeopardize or prevent achievement of the primary objective, the launch will be delayed, or rescheduled. Further, nonstandard procedures, if required, will be executed during flight operations in such a manner as to accomplish the primary objective at the expense of the lesser objectives.

(b) Secondary: Achievement of the secondary objective is highly desirable; however, the failure to achieve the secondary objective, while a serious matter, is not regarded as mission failure. The scheduled launch would probably be delayed, or rescheduled if conditions exist which seriously jeopardize or prevent achievement of the secondary objective, but a decision would be made at that time based on the circumstances.

(c) Tertiary: Achievement of the tertiary objective is considered a bonus. If developmental or launch, transit, and lunar (e.g., lighting) readiness conditions which affect the accomplishment of the tertiary objectives are not satisfactory, the scheduled launch will proceed as planned without major delays.

(5) Additional mission objectives are to:

(a) Develop the requisite technology and accomplish a series of soft landings on selected areas of the lunar surface.

(b) Transport and soft land selected scientific instruments and perform experiments on the lunar surface for local area investigation.

(c) Obtain engineering data regarding performance of the spacecraft system which will aid in future space exploration.

(d) Telemeter the scientific and engineering data back to earth for retrieval, reduction, and dissemination.

(6) *Surveyor* project objectives are to:

(a) Accomplish successful soft landing on the moon as demonstrated by operations of the spacecraft subsequent to landing.

(b) Provide basic data in support of *Apollo*.

(c) Perform operations on the lunar surface which will contribute new scientific knowledge about the moon and provide further information in support of *Apollo*.

(7) *Surveyor III* mission objectives are:

(a) Primary objectives to:

(1) Perform a soft landing on the moon within the *Apollo* zone and east of the *Surveyor I* landing site.

(2) Obtain post-landing TV pictures, touchdown dynamics, radar reflectivity and thermal data on the lunar surface.

(3) Demonstrate the capability of the *Surveyor III* spacecraft to softland on the moon with an oblique approach angle not greater than approximately 35 deg.

(b) Secondary objectives to:

(1) Obtain information on lunar surface bearing strength, radar reflectivity and thermal properties.

(2) Use the surface sampler to manipulate the lunar surface.

(3) Observe effects with the TV camera.

(4) Demonstrate the capability of DSS 61 to support future *Surveyor* missions.

Figure 3 shows the lunar lighting and declination for April, May, June 1967 and presents the time remaining until sunset at 45 deg west selenographic longitude as a function of calendar date for 1967–68. However, if it is dark at 45 deg west, the time past sunset is shown. Since one deg of longitude is approximately equivalent to 2-h lighting (h/0.508 deg $\cong$ 2 h/deg), the lighting at any other longitude can be easily determined from these figures. For example, the time to sunset at 20 deg west longitude is 50 h less than that at 45 deg west [(45 deg $-$ 20 deg) $\times$ 2 h/deg $=$ 50 h] since 20 deg west is 50 h closer to the sunset terminator. The lighting curves are based on 45 deg west longitude because it is the western boundary of the *Apollo* landing zone and also the approximate, mean-vertical, impact longitude for 66-h parking-orbit trajectories.

Present lunar lighting constraints for *Surveyor* parking-orbit missions require that landing occur before sunset -150 h and after sunrise $+30$ h. Based upon the landing sites which have been selected for *Surveyor* and the maximum off-vertical incidence capability of the spacecraft, it can be expected that *Surveyor* landings will occur between 0 and 45 deg west longitude.

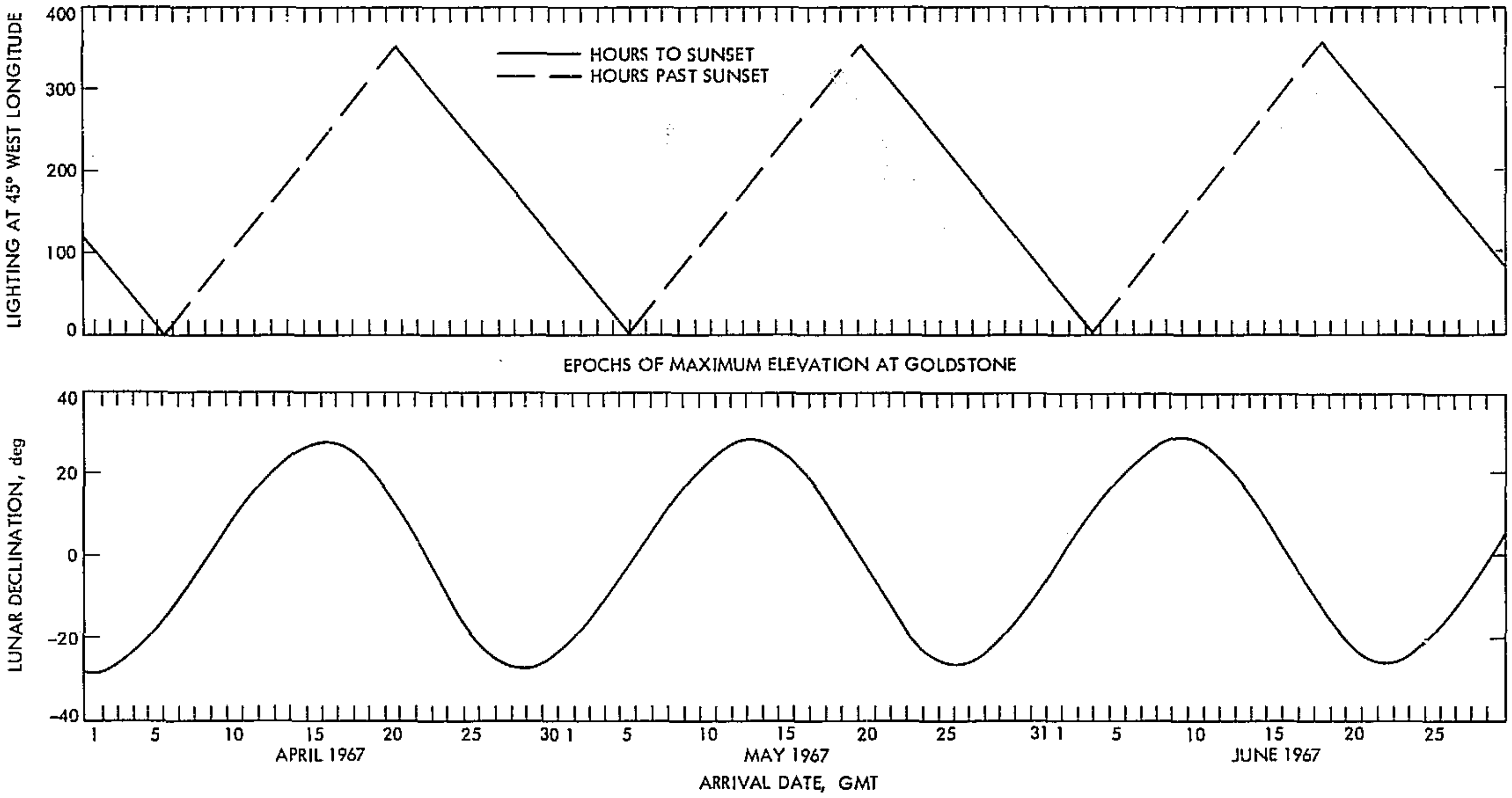


Fig. 3. Lunar lighting and declination, April 1967

In order to determine a launch period, one must first determine the corresponding arrival period. The arrival period is defined by the earliest and latest arrival dates of a consecutive set which satisfy the lighting constraints. Using the above criteria, the earliest arrival date is the first date on which landing can occur at 0 deg longitude at least 30 h after sunrise. The latest arrival date is the last date on which landing can occur at 45 deg west longitude at least 150 h before sunset. Note that if it is 30 h *after* sunrise at 0 deg longitude, it must be 5 h *before* sunrise (which is equivalent to 296 h after the previous sunset) at 45 deg west as illustrated in Fig. 4.

H. *Surveyor* Flight Description

The *Surveyor* spacecrafts are injected into the required lunar transfer trajectory by the *Atlas/Centaur* launch vehicle from Launch Complex 36 of the AFETR. The ascent mode used for *Surveyor* is either direct ascent trajectory or by parking-orbit. Direct-ascent trajectories are characterized by nearly continuous thrusting from liftoff to injection. The direct ascent mode was used by *Surveyor I* and *II* missions. *Surveyor III* mission is the first *Atlas/Centaur/Surveyor* launch to use a parking-orbit trajectory.

A lunar trajectory is usually dependent upon four impact parameters: (1) speed, (2) selenographic latitude, (3) selenographic longitude, and (4) the time of lunar impact. Other sets of four parameters can be used, but this set is the most useful for the *Surveyor* missions. Corresponding to the four impact parameters there are four launch parameters by which the trajectory can also

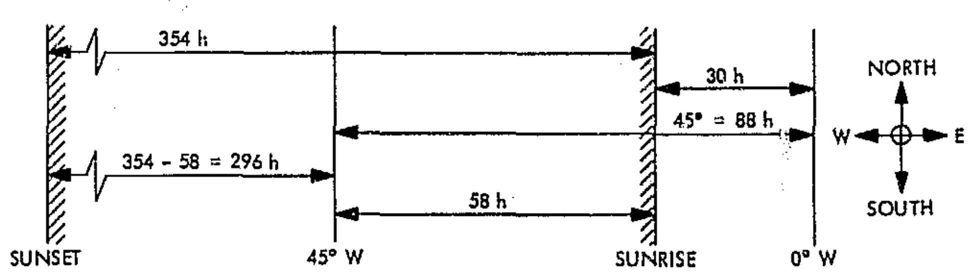


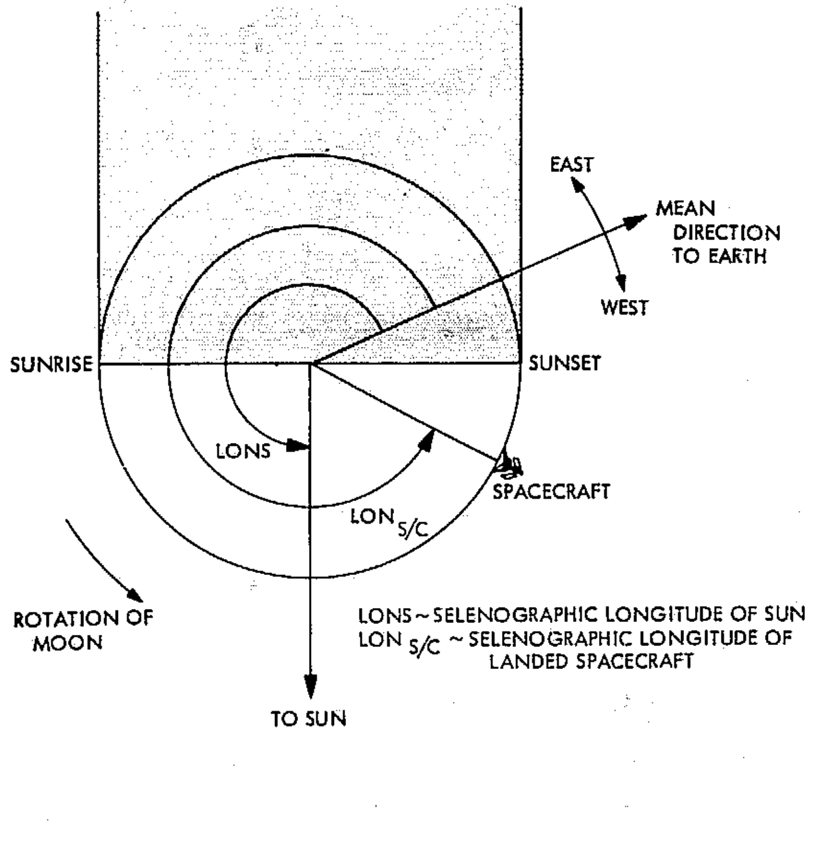
Fig. 4. Motion of terminators

be specified. They are: (1) the launch time, (2) launch azimuth, (3) inject flight path angle, and (4) energy. In the trajectory design, the impact parameters are used as search variables while the launch parameters are the control variables.

The launch periods for the *Surveyor* parking-orbit missions are determined primarily by the lunar lighting conditions during and following landing. The moon rotates at a nearly constant rate of 0.508 deg/h from west to east relative to the moon-sun line, as illustrated in Fig. 5. Consequently, the sub-solar point, which remains within two deg of the lunar equator, moves across the lunar surface from east to west at this rate. Sunrise occurs 90 deg west of the sub-solar point, and sunset occurs 90 deg east of it. The duration of the lunar day and night are both equal to 354 h (180 deg/0.508 deg/h = 354 h).

Therefore, the arrival period consists of those consecutive dates on which it is at least 296 h after the previous sunset and at least 150 h before the next sunset at 45 deg west at the time of landing.

Landing is further constrained to occur during visibility from the Goldstone DSS. The time at which the moon is at its maximum elevation over Goldstone is indicated by the arrival date shown in Fig. 2. The visibility constraints are such that landing must always occur within 5 h of the time of maximum elevation. Therefore,



the lighting criteria must be satisfied within 5 h of the timing marks on the graphs.

Having thus established the arrival dates, one merely subtracts 66 h (i.e., the approximate flight time) to determine the corresponding launch dates which compose the launch period.

The launch windows for *Centaur/Surveyor* parking-orbit ascent trajectories are primarily a function of the following parameters: lunar declination at arrival, launch azimuth sector, and minimum and maximum *Centaur* parking-orbit coast time. It is known that there are two corners (discontinuities) in each launch window curve so that each curve consists of three continuous segments. The left segment would correspond to windows that open at the northern launch azimuth constraint and close at the minimum coasting time constraint. The middle segment would correspond to windows that open at the northern azimuth constraint and close at the southern constraint. The right segment would correspond to windows that open at the maximum coasting time constraint and close at the southern launch azimuth constraint. Therefore, the corner points would indicate the range of declination over which each constraint is applicable.

Returning to Fig. 3, it is seen that the lunar declination is also presented as a function of calendar date. Consequently, having selected an arrival date, the corresponding declination can be obtained from these figures. Other calculations may then be used to determine the launch window and usable launch azimuth sector, respectively, for the arrival date. Recall that the launch date is obtained by subtracting 66 h from the arrival date. These figures present the launch windows and usable portion of the launch azimuth sectors based on both the 93–111 deg and the 78–115 deg sectors for the calendar years 1967 and 1968. The launch dates were selected on the basis of the previously discussed lunar-lighting criteria. It is seen that the 93–111 deg sector precludes launching on several days and reduces the launch windows on the remaining days by a factor of two on the average.

Figure 6 presents the earth track of the sub-spacecraft point for arrival at the lunar declination of +28 deg which was used by *Surveyor III*. The earth track is presented for the opening and closing launch azimuths which are based on the given declination, the requested 78–115 deg azimuth sector, and the *Centaur* coast time constraints. Tracking station coverage and the location of

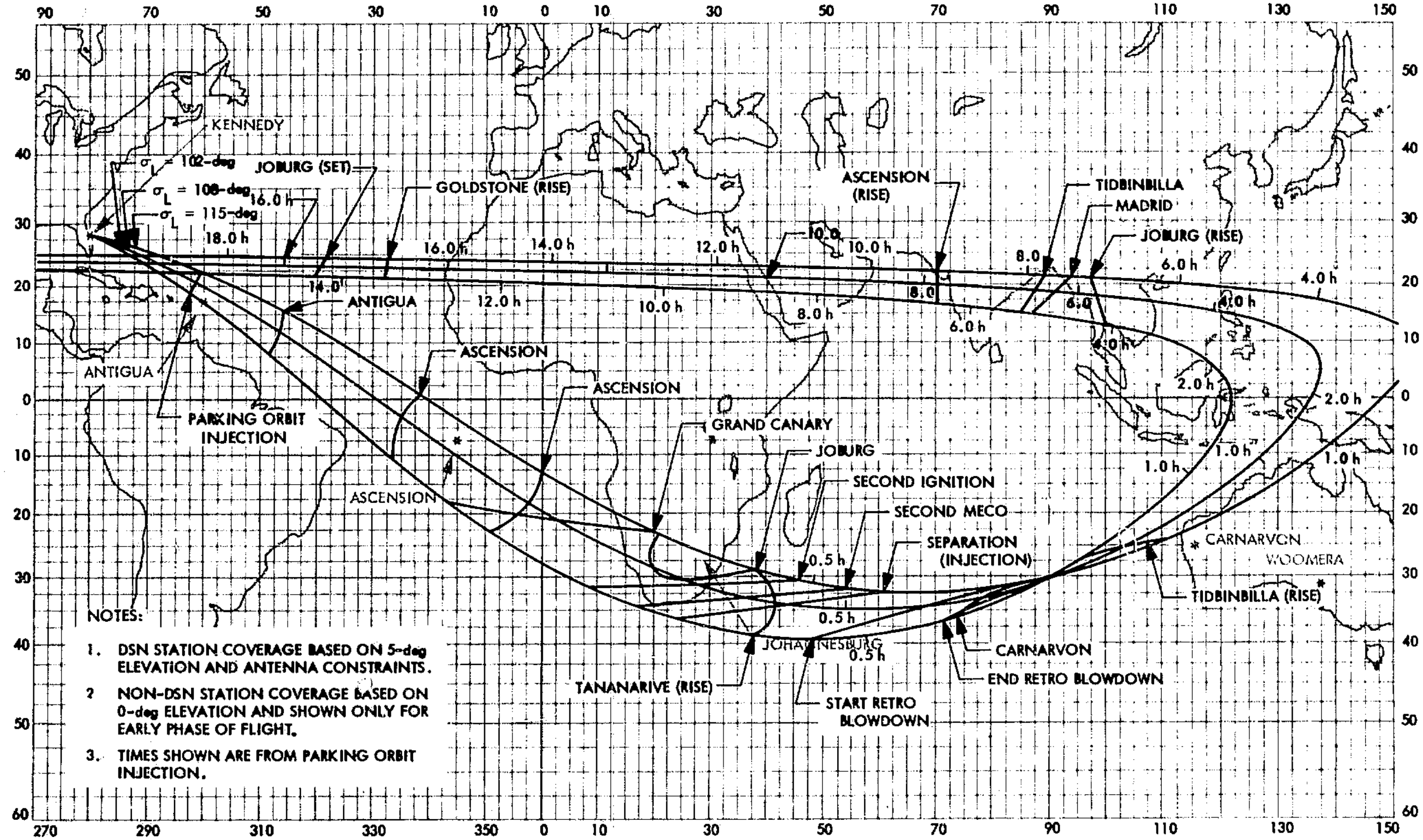


Fig. 6. *Surveyor* parking-orbit ascent-earth tracks and tracking coverage for arrival, lunar declination of +28 deg

key vehicle events is indicated on the figure. After having determined the declination for the arrival date corresponding to the launch date of interest, interpolation between the earth track figures may be performed. However, in this case it will be adequate to simply refer to the figure for the declination closest to the one of interest.

The nominal *Surveyor* trajectories are selected on the basis of the launch and impact parameters described above and the constraints imposed on them. The functional relationships involved in the selection of these parameters in trajectory design are presented in Fig. 7. This diagram shows the dependence of the parameters on the geometry of the lunar orbit and the mission design constraints. The dependence of the output of the design (i.e., the launch windows and periods, impact speeds, and landing locations) on these parameters is shown.

When all the *Surveyor* launch constraints are fully satisfied, the *Atlas/Centaur* launch vehicle is ready for firing. Two seconds after liftoff, the *Atlas* autopilot rolls the vehicle to the required heading and the pitch program is initiated after 15 s of vertical flight. When the axial thrust acceleration reaches 5.8 *g* (approximately 142 s after liftoff), the *Atlas* booster engines are shut down and jettisoned. At *Atlas* propellant depletion, approximately 238 s after liftoff, the sustainer engine is shut down and the *Centaur* main engine start sequence begins. After the *Atlas* is jettisoned, the *Centaur* main engine ignites.

For missions using a direct ascent trajectory, such as the *Surveyor IV* mission, injection into the required lunar transfer trajectory occurs at *Centaur* main engine cutoff, approximately 680 s after liftoff. When a parking orbit trajectory is used, the *Centaur* main engines burn until a circular parking orbit is attained at an altitude of approximately 90 nautical miles (nmi). The *Centaur* guidance system then commands the main engines to shut down; this is approximately 580 s after launch. After coasting in the parking orbit, the engines are restarted and operate until the proper lunar transfer trajectory conditions are achieved and injection is accomplished.

Shortly after injection, a *Centaur* programmer command deploys the spacecraft landing gears and omnidirectional antennas, and switches the spacecraft transmitter to high power. The spacecraft is then separated from the *Centaur.* At this time the *Centaur* executes a retro maneuver to remove itself from the vicinity of the spacecraft and to prevent interference with the spacecraft Canopus sensor later in the flight.

The lunar transfer trajectory can be approximated by a highly eccentric ellipse having one focus at the earth's center. Typical values for the eccentricity and semimajor axis are 0.98 and 384,000 km, respectively. The perigee altitude is 90 nmi. Lunar encounter occurs approximately one-half the distance from perigee to apogee.

After separation from the *Centaur*, spacecraft cold gas jets null the rotational rates imparted during separation. The solar panels are automatically erected and the sun acquisition is also accomplished automatically. This is the standard condition of the spacecraft at the initial Johannesburg, DSS 51, acquisition. In a nonstandard condition, DSS 51 will send the commands to erect the solar panels, and accomplish sun acquisition.

A midcourse correction maneuver, executed approximately 15 h after injection, provides the spacecraft with a trajectory that will terminate at the desired point on the lunar surface; this is called the terminal descent maneuver. This maneuver will be computed at the SFOF, Pasadena, from tracking information supplied by the DSIF.

The terminal maneuver is initiated by pointing the vehicle thrust axis in a direction that is precalculated at the SFOF, to be aligned with the predicted velocity vector at main retro ignition for vertical approaches. For off-vertical angles, a small bias angle is sometimes introduced. Then, when distance to the moon reaches a preset value (about 60 statute miles), a pulse-type radar altimeter generates a marking signal. After a suitable time delay, precomputed on earth and preset into the spacecraft flight control subsystem by command, the vernier engines and the main retro engine are ignited.

As the first step in the terminal maneuver, the spacecraft roll axis becomes aligned along the velocity vector. All radars are turned on approximately 5 min before predicted impact. Following a "command enabling" signal to the trigger radar, the landing sequence is automatic.

The retro engine separates from the spacecraft after burnout at a nominal lunar altitude of 30,000 feet. Vernier engines then operate under control of the doppler radar and the precision radar altimeter to slow the spacecraft velocity to about 5 ft/s at an approximate altitude of 13 ft, at which time the vernier engines shut off. The solar panel and planar array are unlocked and properly oriented after landing. Post-landing TV sequences are then selected in real time.

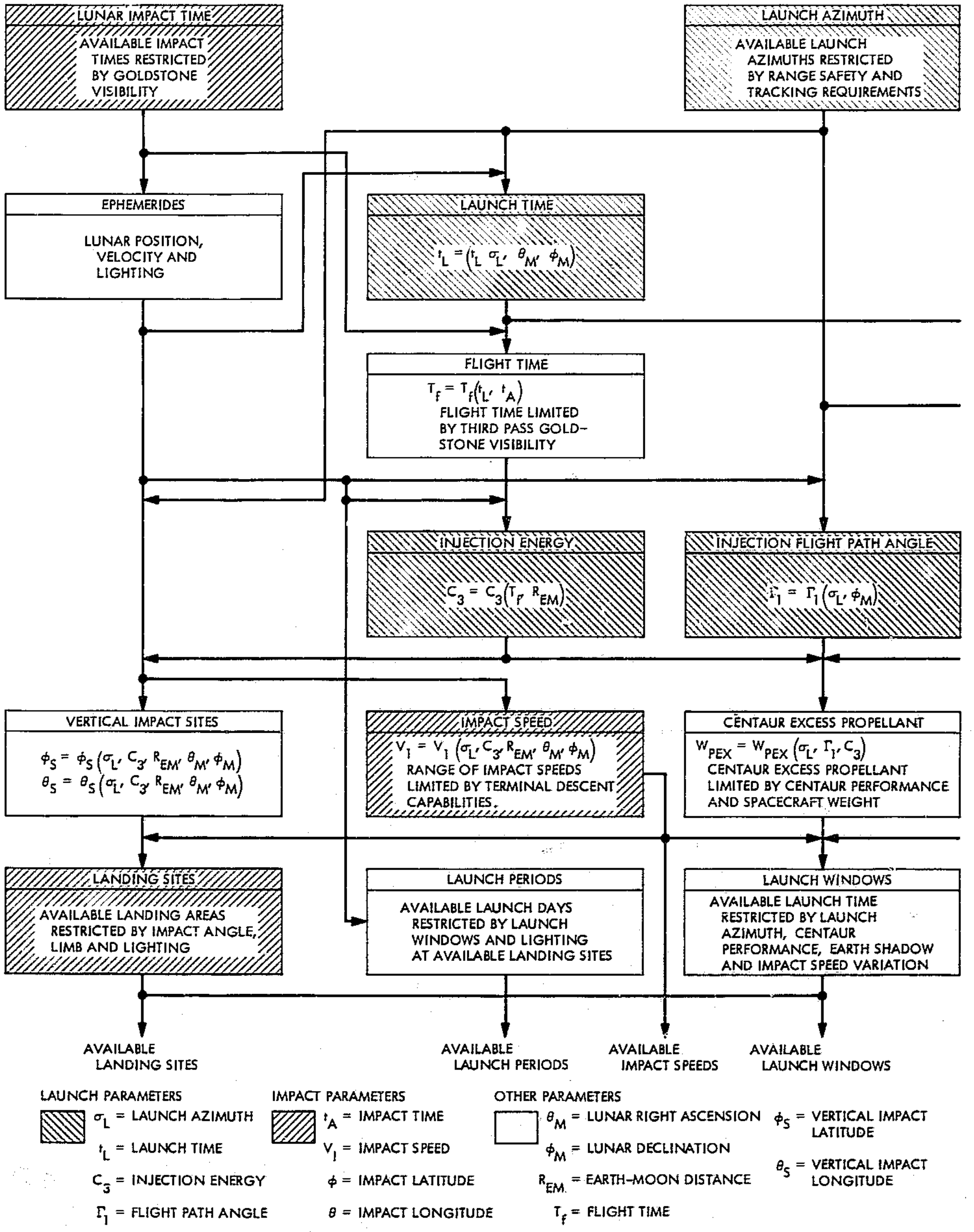


Fig 7. Functional relationships between launch parameters, impact parameters, mission design constraints and *Surveyor* trajectory design

II. *Surveyor III* Mission Synopsis

The transit phase of the *Surveyor III* mission was conducted from launch on April 17, 1967* (Day 107) through touchdown on April 20, 1967 (Day 110) with the spacecraft responding properly to some 345 commands. Lunar operations were conducted from touchdown through May 4, 1967 (Day 124), when the spacecraft was shut down for lunar night, and involved 57,503 commands.

Final countdown of the *Atlas/Centaur/Surveyor* space vehicle (AC-12/SC-3) on pad 36B proceeded smoothly down to the 10-min built-in hold at $T - 5$ min (05:58). The hold was extended an additional 51 min to resolve an apparent anomaly in the spacecraft roll actuator position signal. A special test performed on the SC-5 spacecraft indicated that the roll-actuator-locked position on SC-3 was normal and that observed telemetry variations were a spacecraft signature.

The countdown was resumed at 07:00:01 ($L - 5$ min), and liftoff occurred at 07:05:01.059, April 17, with a launch azimuth of 100.809 deg. Performance of the *Atlas/Centaur* launch vehicle was excellent throughout its flight period; all mark events occurred very close to predicted times. Spacecraft injection occurred at 07:38:49.7 on a trajectory that would have provided, with no midcourse correction, a total miss of 290 mi from the targeted lunar site of −3.33-deg latitude and 336.83-deg longitude. All programmed spacecraft flight events (extend landing legs, extend omnidirectional antennas A and B, turn on transmitter high power) were accomplished and verified in near-real time. *Surveyor* physical separation from the *Centaur* occurred at 07:39:54.4. After an estimated roll of −181 deg and yaw of +38 deg, sun sensor primary cell lock-on was indicated at approximately 07:48, and the automatic sun acquisition sequence was completed at 07:50 when the roll axis locked in transit position.

Initial DSN acquisition in one-way lock was obtained by the Canberra, Australia Station (DSS 42) at approximately 07:55 with two-way lock established at 08:01:50. Initial spacecraft operations were initiated at 08:09:48 with turnoff of high power and completed at 08:23:25 with the spacecraft configured in low power, coast phase commutator on, and transmitting at 1100 bits/s. The flight control "Cruise Mode On" command was not sent at this time due to a high intensity signal in the Canopus intensity channel. However, cruise mode was transmitted later at 10:52:48 and receipt by the spacecraft was verified.

*Greenwich Mean Time (GMT) is used throughout this report for all dates, days, and times.

As a result of the DSS 42 report that the sideband energy of the spacecraft signal was lower than anticipated, a nonstandard telecommunication evaluation was initiated at 13:07:03 during the Johannesburg, South Africa Station (DSS 51) pass. This involved use of various bit rates to determine if a modulation problem existed and a check of sideband energy in the unmodulated subcarrier. The test was completed at 14:12:23 after it was confirmed that the spacecraft telecommunication system was normal. The suspected anomalous condition was due to the technique used for measuring sideband power. It was decided to remain at the last rate selected during the test (550 bits/s) until the star verification/acquisition sequence.

At 16:02:24, transmitter B was commanded to high power. A nonstandard bit rate of 4400 bits/s was then selected to obtain a greater sampling rate of Canopus sensor signals than was possible at 1100 bits/s. Automatic Canopus acquisition was successfully accomplished at 16:27:51 after +565 deg of roll. During the star verification sequence (which started at 16:09:12), four stars (Procyon, Adhara, Canopus, Altair), the planet Jupiter, and the earth and moon were positively identified. In addition to these celestial bodies, two unidentified objects observed during the first roll were not observed during the second roll portion of the star mapping sequence. At the completion of the star acquisition sequence, the spacecraft was returned to the coast phase condition with a bit rate of 1100 bits/s.

During coast phase I, there were six standard engineering assessments of the spacecraft plus one gyro speed check and three gyro drift checks. The spacecraft continuously gave normal indications during this period except that the soil mechanics and surface sampler (SM/SS) auxiliary electronics temperature was running colder than predicted, and the roll and yaw gyro drift rates were indicating out of specification (i.e., greater than 1 deg/h). These indications were carefully monitored and evaluated relative to any possible constraint on the midcourse maneuvers.

Midcourse preparation was started at 04:12:54 on April 18 (Day 108) with an engineering interrogation. The spacecraft was then configured to the 4400-bits/s high-power mode at 04:21:31. A pre-midcourse attitude maneuver of +56.7 deg roll was executed at 04:46:49, followed by a −39.1 deg pitch at 04:50:08. Vernier engine pressurization and unlock of vernier engine 1 was commanded at 04:55:21. Thrust phase power was commanded at 04:57:03 and the roll actuator null condition verified at 04:57:22. Midcourse velocity correction was executed at 05:00:02 (the scheduled nominal time) for 4.277 s for a velocity change of 4.19 m/s. Following midcourse thrust, the reverse maneuvers were commanded. Sun and star reacquisition were obtained at 05:04:37 and 05:08:11, respectively. The midcourse maneuver corrected the miss distance to within 1.8 mi of the aiming point selected during flight.

Following the post-midcourse maneuvers, the spacecraft was configured for coast phase II and left at 1100 bits/s in low power. Post-midcourse data analysis indicated that there was a possible imbalance in the thrust levels of the vernier engines even though all indications were that the spacecraft was stable during the thrust period. It was concluded that this erroneous indication was probably due to a telemetry offset or calibration problem. Coast phase II was normal, with the exception that the SM/SS auxiliary electronics temperature remained lower than anticipated. Eight normal engineering interrogations were performed to assess the spacecraft thermal and operational status, and three power mode cycling sequences were conducted. The bit rate of the spacecraft was reduced to 550 bits/s at 08:50:08 on April 18 and to 137.5 bits/s at 09:57:36 on April 19 (Day 109). The 137.5-bits/s rate was maintained until start of preparations for terminal descent.

During coast phase II, ten gyro drift checks were performed to validate and refine the out-of-specification drift rates obtained for the roll and yaw gyros during the first gyro drift check. The final gyro drift rates utilized during terminal descent were: (1) roll +1.1 deg/h, (2) pitch +0.6 deg/h, and (3) yaw −0.8 deg/h.

Terminal descent was initiated during the Goldstone, California Station (DSS 11) pass at 23:07:40 on April 19; touchdown strain gages were turned on at 23:17:46. The spacecraft was commanded and successfully performed three terminal maneuvers with the following magnitudes: (1) yaw − 157.9 deg, (2) pitch − 76.7 deg, and (3) roll − 63.9 deg, initiated at 23:23:29.7, 23:30:17.2, and 23:34:35.2, respectively. Power was commanded *on* and verified at 23:56:32, followed by thrust phase power *on* at 23:57:32. Terminal descent appeared normal until time for the 14-ft mark, which did not occur; consequently, the vernier engines continued to thrust through touchdown. Touchdown occurred at 00:04:16.85 on April 20. The *Surveyor III* spacecraft executed a remarkable soft landing on the lunar surface; however, shortly thereafter, the telemetry data became anomalous and it was impossible to ascertain accurately the condition of the spacecraft. Figure 8 shows the *Surveyor III* touchdown. The normal post-landing shutdown procedure was executed, and it was later determined via touchdown strain gage data that there had been three landings since the engines were still thrusting until commanded *off* just before the third touchdown, which occurred at approximately 00:04:53. Table 2 gives a complete profile for the entire *Surveyor III* flight.

Immediately after the completion of the post-landing shutdown sequence, an assessment of the telecommunication signal processing system was initiated. It was determined that all analog data were affected at all bit rates then selected and that all on-off or discrete signals were normal. After more investigation, it was determined that analog data at the 17.2-bit rate were reasonably accurate and usable for assessment of the spacecraft. During this period of analysis, the spacecraft was configured for TV and good 200-line pictures and normal TV ID signals were received. The planar array was positioned toward the earth at 08:15:30 with a duty cycle of 33%; the spacecraft was configured for 600-line TV operation; and excellent pictures were obtained. Alternate engineering interrogations and TV operations were continued in accordance with the Lunar Operations Plan through the end of DSS 11 visibility at 10:10 on April 20. During this period, a total of 377 TV frames was obtained, 54 at 200-line and 323 at 600-line scan.

The final landing location of the spacecraft based on tracking data was −3.00-deg latitude and 336.57-deg longitude. However, from studies of *Lunar Orbiter* photographs of the site, the coordinates were determined to be −2.94-deg latitude and 336.66-deg longitude, a miss distance of 1.65 mi from the final aim point. The spacecraft came to rest on the east wall of a crater, with an inclination of 12 to 15 deg from the vertical.

Throughout the remainder of the lunar day, various scientific and engineering experiments were conducted. These activities included various wide-angle, narrow-angle, and color TV surveys of the spacecraft and the lunar terrain; extensive SM/SS operations; TV star and earth surveys including the solar eclipse; extensive thermal measurements; telecommunications tests; and a voice relay experiment. Figure 9 shows the *Surveyor III* soil sampling configuration. The spacecraft was finally shut down at 00:04 on May 4, 1967 (Day 124), approximately 6.5 h into the lunar night when compartment temperatures reached the established minimums.

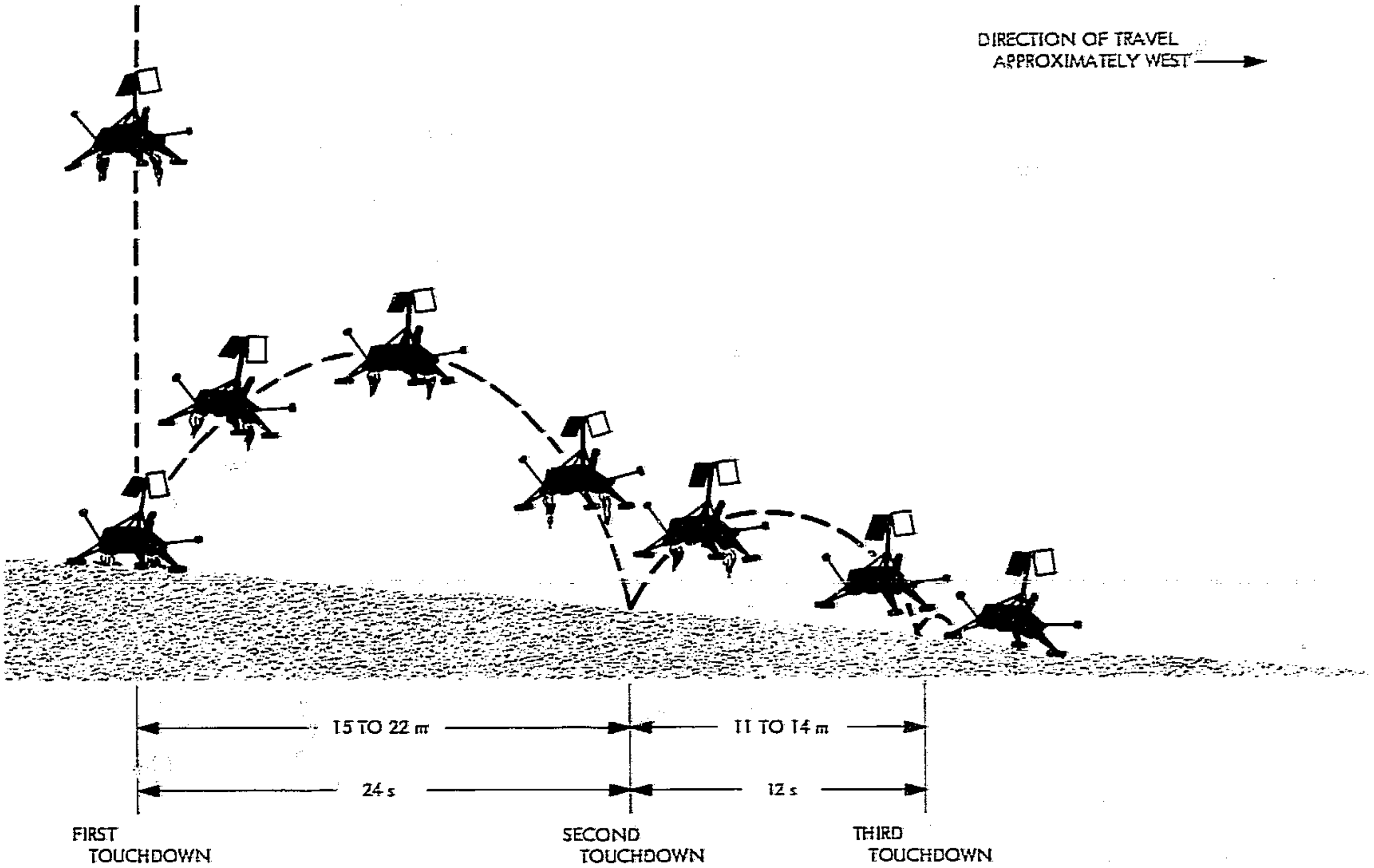


Fig. 8. *Surveyor III* touchdown

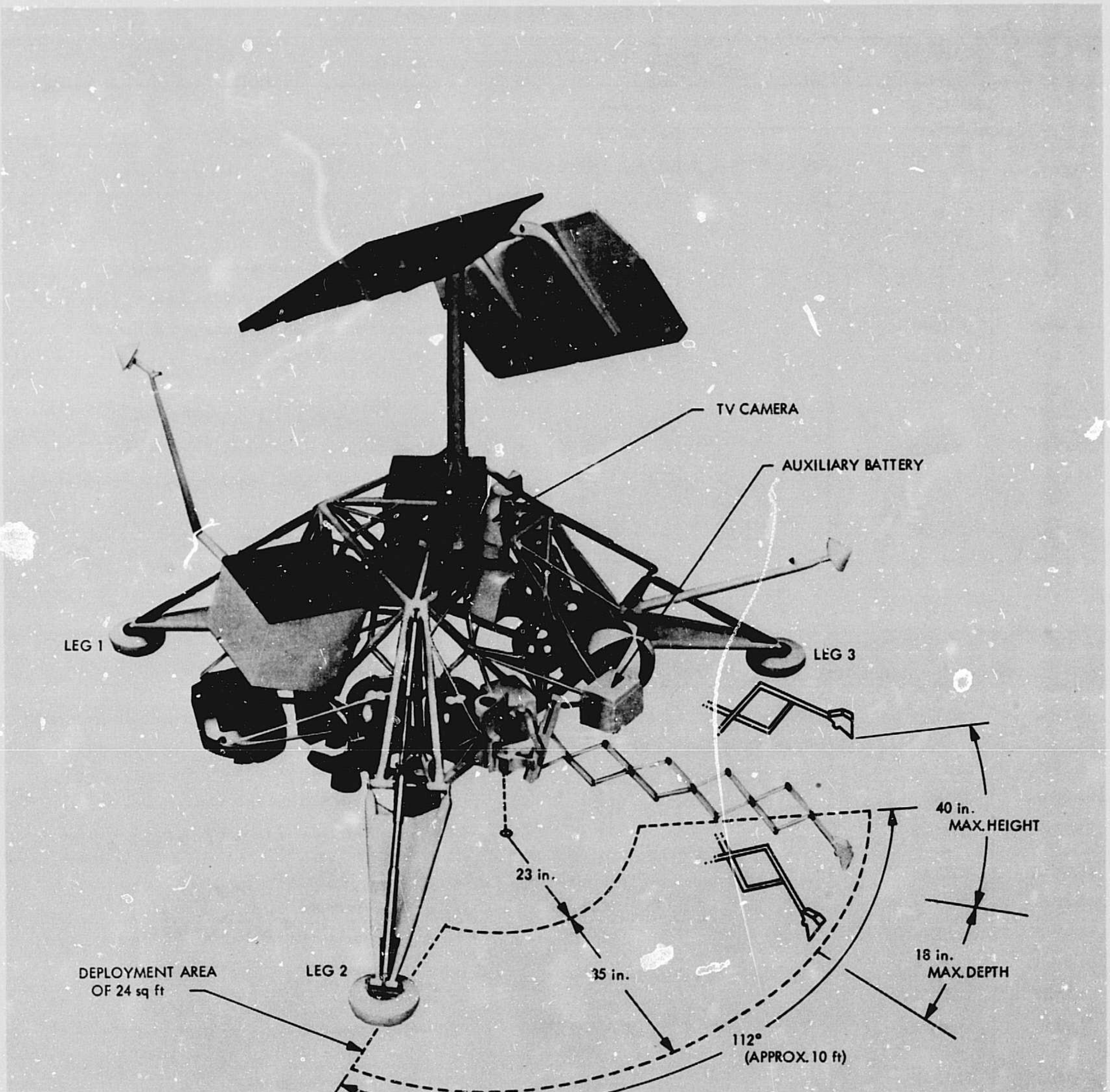


Fig. 9. *Surveyor III* soil sampling configuration

Table 2. *Surveyor III* mission profile

Time: Mission (time after launch)	Time: GMT	Command sequence: Major	Command sequence: Minor	Event
A. Mission phase: launch to separation				
00:00:00	07:05:01 (4/17/67)			Launch
				"Extend landing gears"; commanded by *Centaur*
				"Extend omni-antennas"; commanded by *Centaur*
00:34:42	07:39:43			"Transmitter high voltage on"; commanded by *Centaur*
00:34:53	07:39:54			Spacecraft/*Centaur* electrical disconnect
00:34:58	07:39:59			Separation
				Sun acquisition cell illuminated (after 181-deg roll)
00:41:21	07:46:22			Solar panel locked in transit position
00:42:59	07:48:00			Sun lock-on achieved (primary sun sensor cell illuminated after 38-deg yaw)
00:45:59	07:51:00			Roll axis locked in transit position
00:54:59	08:00:00			Initial DSIF acquisition completed (2-way lock)
B. Mission phase: DSIF acquisition through star acquisition				
		0400		Initial SC operations
01:04:47	08:09:48		0552	(1) Turn off transmitter high power
01:06:04	08:11:05		0050	(2) Turn off basic bus accelerometer amplifiers and solar panel deployment logic
01:07:12	08:12:13		0454	(3) "Rock" solar panel back and forth to seat locking pin
01:08:07	08:13:08		0455	(4) "Rock" roll axis back and forth to seat locking pin
01:11:07 to 01:18:24	08:16:08 to 08:23:25		0051, 0052, 0055, 0251, 1356, 1354	(5) Perform interrogation of mode 1, 4, 2, 5, 6 at 1100 bits/s
03:47:48	10:52:49		0054	Cruise mode commanded
06:02:03	13:07:04		0253	Nonstandard sequence for switching to 4400 bits/s
06:04:45	13:09:46			Sequence to return to bit rate of 1100 bits/s
06:26:55	13:31:56		0151	Bit rate reduced from 1100 to 550 bits/s
07:02:17	14:07:18		Command 0203	A/D converter turned off to measure change in carrier signal
07:07:22	14:12:23		Command 0201	A/D converter turned on again
				Star verification/acquisition
08:37:49	15:42:50	0046	0250, 0251, 0252, 0550	(1) 1100 bits/s engineering interrogation of modes 4, 2, 1, and 5
08:55:40	16:00:41	0247	0652, 0653	(2) Transmitter high power turn-on prior to star verification (high voltage on at 16:02:25 GMT)
08:58:29	16:03:30		0253	(3) Increased bit rate to 4400 bits/s for star verification
09:00:51	16:05:52		1050	(4) Transponder commanded off
09:01:53	16:06:54	0041	0654, 1251	(5) Execution of positive roll (roll begun at 16:09:12 GMT)

Table 2 (contd)

B. Mission phase: DSIF acquisition through star acquisition (contd)				
Time		Command sequence		Event
Mission (time after launch)	GMT	Major	Minor	
09:22:34	16:27:35		0655	(6) Star acquisition mode commanded after passing star Adhora the second time
09:25:27	16:30:28		0054	(7) Start cruise mode of flight control
09:26:25	16:31:26		1053	(8) Transponder B turned on and phase locked
09:31:26	16:36:27			(9) Bit rate of 1100 bits/s selected
09:34:27	16:39:28		0552	(10) Return to low-power operation
C. Mission phase: coast phase I				
10:24:17 to 12:11:31	17:29:18 to 19:16:32	0342	0354, 0054	Gyro drift check
12:18:34	19:23:35		0354	Start gyro drift check
14:14:47 to 14:21:10	21:19:48 to 21:26:11	0447	0250, 0251, 0550	Low power engineering interrogation of modes 4 and 2
14:36:53	21:41:54		0054	Terminate gyro drift check
16:11:20	23:11:21			Initiate gyro drift check in roll axis only
16:48:25 to 16:55:42	23:53:26 to 00:00:43	0247	0250, 0251, 0252	Engineering interrogation at 1100 bits/s—made with low-power
19:06:20	02:11:21		0054	Terminate gyro drift check
19:49:34 to 19:54:48	02:54:35 to 02:59:49		0250, 0251, 0252, 0550	Low power engineering interrogation of modes 1, 2, 4, and 5
19:56:49 to 19:59:48	03:01:50 to 03:04:49	0341	0350, 0351, 0353	Gyro speed check and return to 1100 bits/s telemetry data
D. Mission phase: midcourse correction				
				Midcourse correction sequence
21:07:53 to 21:12:55	04:12:54 to 04:17:56	0247	0250, 0251, 0252	(1) Engineering interrogation of modes 4, 2, and 1 at 1100 bits/s conducted with transmitter low power
21:14:09	04:19:10	0247	0652, 0653	(2) Turn-on of high power transmitter (high voltage on at 04:20:48 GMT)
21:16:29	04:21:30	0440	0253	(3) Increase telemetry rate from 1100 bits/s to 4400 bits/s
21:24:59	04:30:00	1140	1150	(4) Command desired roll maneuver magnitude and direction (roll +56.7 deg)
21:41:49	04:46:50	1140	1251	(5) Execute roll
21:44:26	04:49:27	1141	1152	(6) Command desired pitch maneuver magnitude and direction (minus pitch −39.12 deg)

Table 2 (contd)

D. Mission phase: midcourse correction (contd)				
Time		Command sequence		Event
Mission (time after launch)	GMT	Major	Minor	
21:45:07	04:50:08	1141	1255	(7) Execute pitch
21:47:35	04:52:36		0251, 0252	(8) Interrogate modes 2 and 1
21:49:28	04:54:29	0741	0751	(9) Propulsion strain gage powered, inertial mode and reset group IV outputs command
21:50:17	04:55:18		0750	(10) Turn off cyclic loads SM/SS, AMR, vernier line heaters
21:50:20	04:55:21	0740	0750	(11) Pressurize vernier system (helium), unlock vernier engine No. 1
21:52:02	04:57:03	0741	0752	(12) Thrust phase power on
21:52:23	04:57:24	0741	0753	(13) Command desired thrust duration (4.275 s)
21:55:01	05:00:02	0742	0754	(14) Execute midcourse thrust
21:55:08	05:00:09			(15) Command terminate thrust
21:55:29	05:00:30			(16) Turn off thrust phase power
21:55:49	05:00:50			(17) Turn off propulsion strain gage power
21:56:09	05:01:10	Sequence to obtain coast phase commutator data bits/s during reverse maneuvers		(18) Operations to obtain coast mode data
21:56:51	05:01:52		0755	(19) Cyclic loads turned on; vernier line, AMR, SM/SS heaters
21:57:32	05:02:33	1240	1254	(20) Command reverse pitch maneuver magnitude and direction (plus 39.1 deg)
21:58:18	05:03:19	1240	1255	(21) Execute pitch (sun reacquired at 05:05:12 GMT)
22:00:45	05:05:46	1244	1250	(22) Command reverse roll maneuver magnitude and direction (minus 56.7 deg)
22:01:17	05:06:18	1244	1251	(23) Execute roll (Canopus "reacquired" at approximately 05:09:04 GMT)
22:05:45 to 22:10:08	05:10:46 to 05:15:09	1245	0157, 0055, 0550	(24) Post midcourse engineering interrogation of modes 2, 4, and 5
22:10:28	05:15:29			(25) Bit rate reduced to 1100 bits/s
22:11:08	05:16:09	0547	0552	(26) Return to transmitter low-power operation
E. Mission phase: coast phase II				
23:58:03	07:03:04	0447	0250, 0251, 0550	Low power interrogation of modes 4 and 2 to obtain thermal data
24:30:57	07:35:58	0342	0354	Initiate gyro drift check
25:44:37	08:49:38		0151	Bit rate reduction 1100 to 550 bits/s
26:38:45	09:43:46		0054	Terminate gyro drift check
32:03:21 to 32:16:11	15:08:22 to 15:21:12	0447	0250, 0251, 0550	Low power interrogation of modes 2, 4, 5, and 6 to obtain thermal data

Table 2 (contd)

E. Mission phase: coast phase II (contd)				
Time		Command sequence		Event
Mission (time after launch)	GMT	Major	Minor	
34:26:25	17:31:26		0354	Initiate gyro drift check
36:26:49	19:31:50		Command 0702	Terminate gyro drift in pitch and yaw, continue roll
36:32:26	19:37:27		0354	Initiate gyro drift in pitch and yaw, continue drift in roll
36:57:48 to 37:11:13	20:02:49 to 20:12:14	0447	0250, 0251, 0550	Low power interrogation of modes 4 and 2 to obtain thermal data
37:17:34	20:22:35		0054	Terminate gyro drift check and null out accumulated error produced by drift
37:22:19 to 39:45:04	20:27:20 to 22:50:05		0354, 0054	Gyro drift check
39:48:59	22:54:00		Command 0702	Initiate gyro drift in roll only
41:47:24 to 42:02:19	00:52:25 to 01:07:20	0447	0250, 0251, 0550	Low power interrogation
42:10:43	01:15:44		0054	Terminate gyro drift check
42:18:35 to 44:31:31	01:23:36 to 03:36:32	0342	0354, 0054	Gyro drift check
44:52:25	03:57:26	0342	Command 0702	Initiate gyro drift check (roll gyro drift)
46:19:53 to 46:34:20	05:24:54 to 05:39:21	0447	0250, 0251, 0550	Low-power interrogation of modes 4 and 2
46:56:18	06:01:19	1741	2053	Start power mode cycling remaining in auxiliary battery mode to check rate of temperature rise of auxiliary battery
47:08:42	06:13:43	1741	2053	High current mode on—restore main battery mode. Both batteries directly on line
47:40:13	06:45:14		0054	Terminate gyro drift
47:43:52	06:48:53		0354	Initiate gyro drift
49:58:54	07:03:55	1341	1350	Vernier tank No. 2 thermal control on
50:04:20	09:09:21	Unscheduled sequence	0054	Terminate gyro drift check
50:52:12	09:57:13		Commands 0504, 0220, 0500	Bit rate reduction to 137.5 bits/s
50:57:47 to 51:14:43	10:02:48 to 10:19:44	0447	0250 Commands 0231, 0232, 0506	Low-power interrogation of mode 4, 2, 6 and 5
51:16:22	10:21:23		Command 0702	Initiate gyro drift check roll only

Table 2 (contd)

E. Mission phase: coast phase II (contd)				
Time		Command sequence		Event
Mission (time after launch)	GMT	Major	Minor	
51:54:59 to 52:08:33	11:00:00 to 11:13:34	1742	2054	Power mode cycling, with return to auxiliary battery (to ensure proper auxiliary battery temperature rise)
53:36:23	12:41:24		Command 0704	Terminate gyro drift
53:42:56 to 53:48:25	12:47:57 to 12:53:26	0447	0250, 0251 0550	Low-power interrogation of modes 4, 2 and 5
55:23:06	14:28:07		Command 0700	Initiate gyro drift check
56:44:51	15:49:52		1050, 1053	Perform VCXO check
57:50:52	16:55:53		Command 0704	Terminate gyro drift check
58:00:59	17:06:00		Command 0702	Initiate gyro drift roll only
58:12:03 to 58:19:20	17:17:04 to 17:24:21	0447	0250, 0251 0550	Low-power interrogation of modes 4, 2 and 5
59:09:20 to 59:21:24	18:14:21 to 18:26:25	1742	2054	Power mode cycling, with return to auxiliary battery mode (to ensure proper auxiliary battery temperature rise)
59:46:46	18:51:47	1740	1750	Turn on survey TV electronic thermal control power
60:38:08 to 60:49:35	19:43:09 to 19:54:36	0446	1355, 0250, 0251, 0550	Low-power interrogation of mode 6, 4, 2 and 5
61:45:50	20:50:51		0354 Sent inadvertently	Terminate gyro drift
61:51:12	20:56:13		0054	
62:19:39	21:24:40	0446	0250, 0251, 0252, 0550	Low-power interrogation of mode 4, 2, 1, 5 and a gyro speed check
62:31:50	21:36:51		Commands 0502 and 0221; 0351 Commands 0223, 0500	
62:35:23	21:40:24	0344	1050, 1053	VCXO check
63:56:55	23:01:56	0247	1355, 0250	Engineering interrogation of modes 6, 4 (accomplished with low power at 137.5 bits/s)
	23:07:41		1757	Vidicon temperature control on survey camera

Table 2 (contd)

F. Mission phase: terminal descent				
Time		Command sequence		Event
Mission (time after launch)	GMT	Major	Minor	
				Terminal descent
64:02:58 to 64:08:16	23:07:59 to 23:13:17		0652, 0653, 0255, 2057, 0251, 0550	(1) Interrogation of modes 4, 2, and 5 and turn on of high power transmitter (at 23:09:41 GMT) and adjustment of telemetry rate to 1100 bits/s (at 23:10:40); summing amplifiers off (to turn off pre-summing amplifier) and turn on of phase summing amplifier
64:12:00	23:17:01		1755	(2) Propulsion strain gage power turned on
64:12:44	23:17:45		1756	(3) Touchdown strain gage power and SCO's turned on
64:14:20	23:19:21	0044	1050	(4) Transponder power turned off and one-way lock achieved
64:16:26	23:21:27		0054	(5) Cruise mode commanded
64:16:26	23:21:27			(6) Yaw maneuver magnitude and direction commanded (minus 157.9 deg)
64:18:29	23:23:30			(7) Execute yaw
64:24:15	23:29:16			(8) Pitch magnitude and direction commanded (minus 76.7 deg)
64:25:16	23:30:17			(9) Execute pitch (retro thrust direction aligned properly at approximately 05:43:47 GMT)
64:28:22	23:33:23	1147	1157	(10) Roll maneuver magnitude and direction commanded (minus 63.9 deg)
64:29:34	23:34:35	1147	1257	(11) Roll executed
64:33:34	23:38:35	0044	1751, 1656	(12) Vernier thrust level (200 lbs) for retro phase and delay between AMR mark and vernier ignition (5.075 s) commanded
64:41:25	23:46:26	0044	1355	(13) Command on mode 6 data
64:47:20	23:52:21		1652	(14) Command reset group IV outputs
64:50:12	23:55:13	0044	1657	(15) Retro sequence mode on commanded
64:50:43	23:55:44	0044	1752	(16) Vernier lines and tanks—SM/SS, TV, and AMR thermal control commanded off
64:51:32	23:56:33	0044	1753	(17) AMR on
64:52:32	23:57:33	0044	1754	(18) Thrust phase power on
64:54:32	23:59:33	0044	2051	(19) AMR enabled
64:56:11	00:01:12	0044	2052	(20) Back-up AMR mark commanded
64:56:13.38	00:01:12.93*			(21) AMR mark
64:56:18.53	00:01:18.03*			(22) Vernier ignition
64:56:19.64	00:01:19.13*			(23) Retro ignition
64:56:20.23	00:01:19.79			(24) RADVS on
64:56:51.79	00:01:50.69			(25) RADVS
	00:02:01.39			(26) RORA
64:57:2.01	00:02:2.01			(27) Retro burnout
64:57:14.02	00:02:14.02			(28) Retro eject
				(29) Retro separation

Table 2 (contd)

F. Mission phase: terminal descent (contd)				
Time		Command sequence		Event
Mission (time after launch)	GMT	Major	Minor	
64:57:16	00:02:16			(30) Enable doppler control
64:57:32	00:02:33	0044	2152	(31) Pre-summing amplifier on commanded (to get touchdown strain gage data)
64:58:54	00:03:55*			(32) 1000-ft mark
64:59:09	00:04:10*			(33) 10-ft/s mark
	00:04:13.4*			(34) Beam 3 loses lock; RADVS and RORA lost
	None			(35) 14-ft mark
64:59:17	06:04:18.060**			(36) Initial touchdown indicated by strain gages

Times listed are from TM data received in Performance Analysis Area at SFOF (i.e., includes transit time from spacecraft to ground, SFOF processing delay, and commutation delay) except for those values which are asterisked.
*Based on reduced data obtained directly from the 96-kc microwave link data (1.21 s must be subtracted to account for RF propagation time).
**Based on the time mark generator code on the touchdown strain gage recordings (1.21 s must be subtracted to account for RF propagation).
Subtract 8 h from GMT values to obtain Pacific Standard Time.
Command sequence numbers are from EPD-180 except where noted.

An attempt to revive the spacecraft for second lunar day activity was initiated by the Robledo, Spain Station (DSS 61) rise which occurred at 20:52 GMT on May 23, 1967. Engineering and scientific experiments that were to be conducted included telemetry, video, and antenna mapping. Spacecraft revival was attempted during three passes of DSS 61 and 42, and four passes of DSS 11. A spacecraft receiver search was performed over the entire RF tuning range but no carrier signals were received. All attempts to revive the spacecraft for the second lunar day activity were unsuccessful. The final attempt was made at DSS 11 on May 28 after which the *Surveyor III* mission was terminated. Table 3 gives a detailed understanding of *Surveyor III* reactivation attempts to May 25, 1967.

III. *Surveyor III* TDS Mission Requirements

A. General

Delineated in this section are the detailed requirements and support capabilities for tracking and telemetry coverage of the *Atlas/Centaur/Surveyor III* space vehicle.

Table 3. *Surveyor III* reactivation attempts up to May 25, 1967

Day	Start			Stop		Station DSS
	Point	GMT	Transmitting system commanded	Point	GMT	
143	1	00:21:09	A and B	12	00:23:56	61
144	1	00:01:01	A and B	12	00:03:37	61
144	1	00:05:05	A and B	9	00:10:40	11
144	10	00:12:38	B	12	00:14:17	42
144	42	00:14:24	A	56	00:19:08	42
144	2	00:19:07	B	12	00:22:10	42 and 61
145	46	00:22:19	A	57	00:00:11	61

Requirements for tracking and data acquisition are placed in accordance with their importance to the successful accomplishment of the mission and are grouped into three classes. These classes are defined as follows:

(1) The class I requirements (see Fig. 10) reflect minimum essential needs to ensure accomplishment of the primary flight objectives. These are mandatory requirements which if not met may result in the decision not to launch.

(2) The class II requirements define the needs to accomplish all stated flight objectives.

(3) The class III requirements define the ultimate desired support. Such support should enable the Project to achieve the flight objectives early in the program.

The AFETR, MSFN and DSN elements of the TDS were required to support tracking and telemetry requirements during the near-earth phase (launch to $L + 4$ h).

The *Surveyor* Project placed the near-earth tracking and data acquisition support requirements on those elements of the TDS in order to obtain a timely and continuing evaluation of the status of the mission during this phase. This early evaluation was used to aid in maximizing the probability of acquisition by the Deep-Space Stations and to provide information for the conduct of subsequent space-flight operations.

The following requirements were placed on the TDS for the *Surveyor III* mission.

*1. **Launch.*** The requirements were as follows:

(1) The *Atlas/Centaur* boost vehicle will be utilized in a parking orbit mode of operation for Mission C (*Surveyor III*).

(2) Launch shall take place from Complex 36B of the Cape Kennedy facilities of the AFETR.

(3) Launch azimuth sectors are restricted to lie between 93 and 115 deg east of true north.

(4) The launch countdown shall have two built-in holds, one of at least 60 min duration at $T - 90$ min. The duration of the hold at $T - 5$ min is to be established.

*2. **Injection.*** The requirements were as follows:

(1) The nominal parking orbit altitude shall be 90 nmi.

(2) The nose fairing shall be ejected prior to injection, but not until the value of the product of the atmospheric density and the earth-fixed velocity (ρV^3) is less than 1.9×10^4 lb/s^3.

(3) During the period beginning 1 min after shroud ejection and ending at the time of *Centaur* second main-engine ignition (MEIG 2), the instantaneous 3σ value of the aerodynamic heating parameter, ρV^3, shall not exceed 2050 lb/s^3.

(4) Throughout the period from MEIG 2 until the end of significant aerodynamic heating effects, the 3σ integrated value of ρV^3 shall not exceed 10,300 lb-min/s^3, and the instantaneous 3σ value shall not exceed 4250 lb/s^3.

(5) Parking orbit coast time is restricted to vary between the limits of 116 s and 25 min. Minimum parking orbit coast time for the *Surveyor III* mission is 4 min.

(6) The *Centaur* retro maneuver shall be such that the *Surveyor/Centaur* separation distance at 5 h after injection will be at least 336 km.

*3. **Telecommunications.*** The requirements were as follows:

(1) No trajectory shall have an hour angle or declination rate in excess of 0.85 deg/s and acceleration in either hour angle or declination in excess of 5.0 deg/s^2 when station tracking is required.

(2) For the downlink initial acquisition phase following injection, there shall be 20 min of visibility which is not in violation of item (1) and for which the spacecraft slant range ensures at least 95% confidence of having the antenna gain required for zero minimum margin.

(3) For the uplink acquisition phase following injection, there shall be 20 min of visibility which is not in violation of item (1) and for which the spacecraft slant range ensures at least 99% confidence of having the antenna gain required for zero minimum margin.

(4) The spacecraft-centered angle between the sun and any DSIF station shall not exceed 175 deg in order to prevent the degradation of DSIF receiver sensitivity by solar noise. This constraint guarantees that signal-to-noise ratios will not be degraded by more than 1 dB.

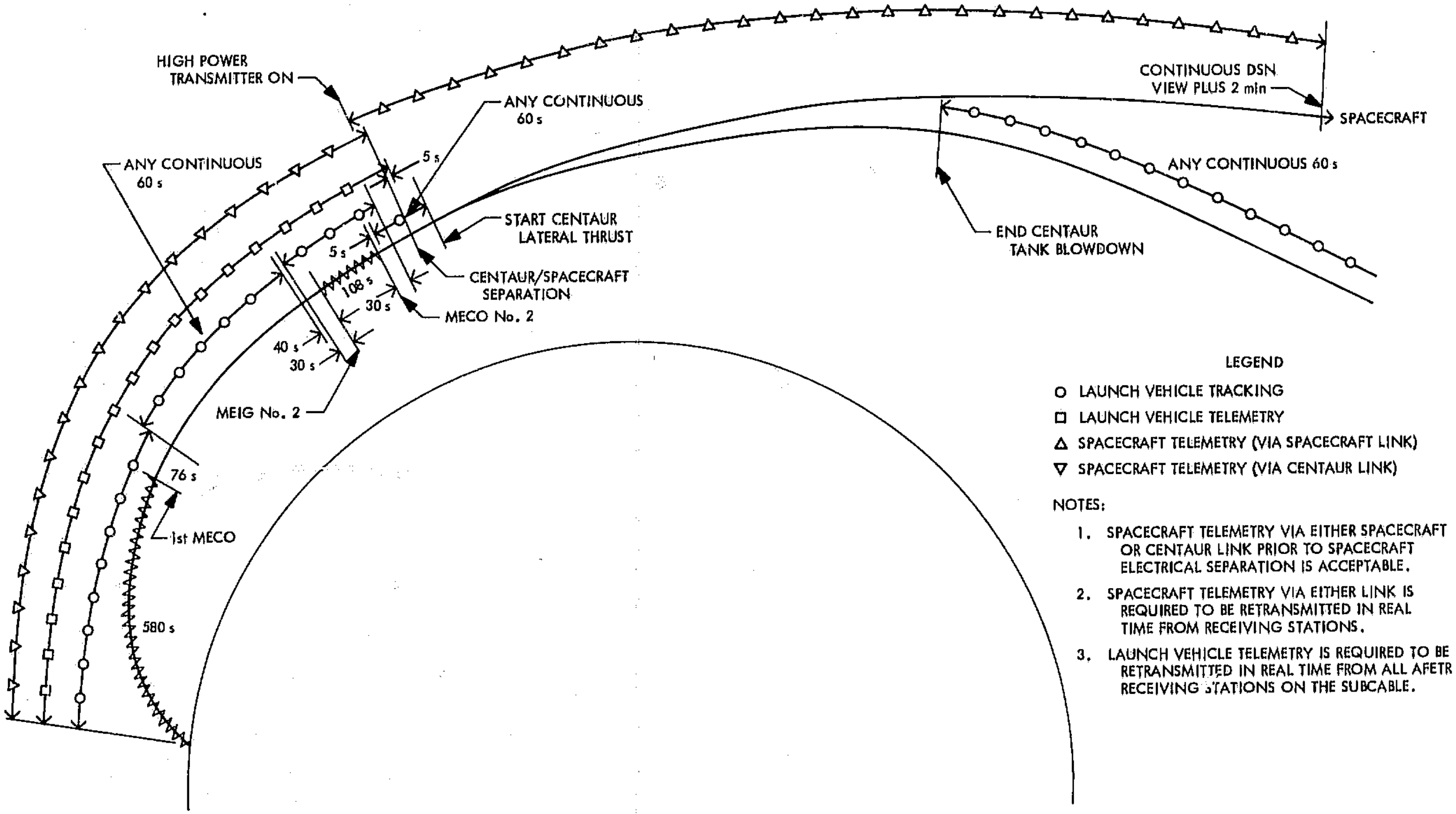


Fig. 10. ***Surveyor*** **near earth class I tracking and data acquisition requirements for the** ***Surveyor III*** **mission**

4. *Thermal control.* The requirements were as follows:

(1) The spacecraft is limited to a maximum duration of 42 min in the earth's shadow immediately after launch.

(2) The spacecraft is limited to a maximum duration of 30 min in the earth's shadow during any phase after initial sun acquisition.

(3) The spacecraft is limited to a maximum duration of 30 min at a random attitude to the sun during any phase between initial sun acquisition and lunar touchdown.

(4) The spacecraft is limited to a maximum duration of 30 min in the lunar penumbra shadow during any phase prior to touchdown.

(5) Initial spacecraft acquisition and the establishment of a command link must take place no later than 1 h after the "high power on" command in order to permit switching the transmitter from high to low power to satisfy thermal constraints.

5. *Midcourse maneuver.* The requirements were as follows:

(1) The spacecraft shall be capable of performing midcourse maneuvers of up to 46 m/s in magnitude for an unbraked impact angle of 35 deg and of up to 42 m/s for an unbraked impact angle of 45 deg. Nominal midcourse maneuver time is approximately 23 h after launch.

(2) Landing accuracy goal shall be less than or equal to 30 km.

6. *Lunar arrival.* The requirements were as follows:

(1) Flight times from injection to lunar impact shall be in the 66-h class.

(2) Transit trajectories are to be designed so that lunar arrival takes place not earlier than 2 h after DSS 11 (Goldstone, Pioneer Station) moon rise and not later than 3 h before DSS 11 moon set. Furthermore, DSS 11 post-landing visibility shall be maximized.

(3) It is desirable that landing occur before the sun elevation angle has exceeded 25 deg at the landing site.

7. *Terminal descent.* The requirements were as follows:

(1) The incidence angle at unbraked impact shall be between 18 and 45 deg from the vertical.

(2) The recommended roll parameter, ρ, will be constrained to values near 67 deg for unbraked impact angles near 25 deg and to values near 64 deg for unbraked impact angles near 40 deg. (The actual value of ρ will be based on the evaluation of final RADVS measurements at AFETR.)

(3) The range of allowable nominal unbraked impact speed is from 2658 m/s to 2670 m/s.

Figure 11 gives the earth tracks and TDS station coverage for April 17, 1967.

B. AFETR

The AFETR coverage capabilities and requirements presented herein are based on the configuration of various land and ship stations. The capabilities of these ships are listed in Table 4 below. Table 5 lists the planned positions of the ships prior to launch. These ship positions were selected by the AFETR. Any changes in these ship positions, or any changes in the availability of the four ships shown would necessarily indicate changes in coverage and, hence, possible changes in launch window designs.

The AFETR prepared to provide adequate coverage to meet all class I telemetry data receive-and-record requirements over all of the maximum launch windows. With the exception of a gap during the parking orbit, the AFETR was to meet all spacecraft telemetry data real-time retransmission requirements over all of the maximum launch windows. The gap in real-time retransmission data was expected and allowed. Consequently, the

Table 4. AFETR ship capabilities

Ship	Tracking capability (radar type)	Telemetry capability
Timber Hitch (10-knot cruising speed)	—	VHF
Sword Knot (10-knot cruising speed)	—	VHF; S-band
Coastal Crusader (10-knot cruising speed)	—	VHF; S-band
Twin Falls (15-knot cruising speed)	C-band (FPS-16)	VHF; S-band

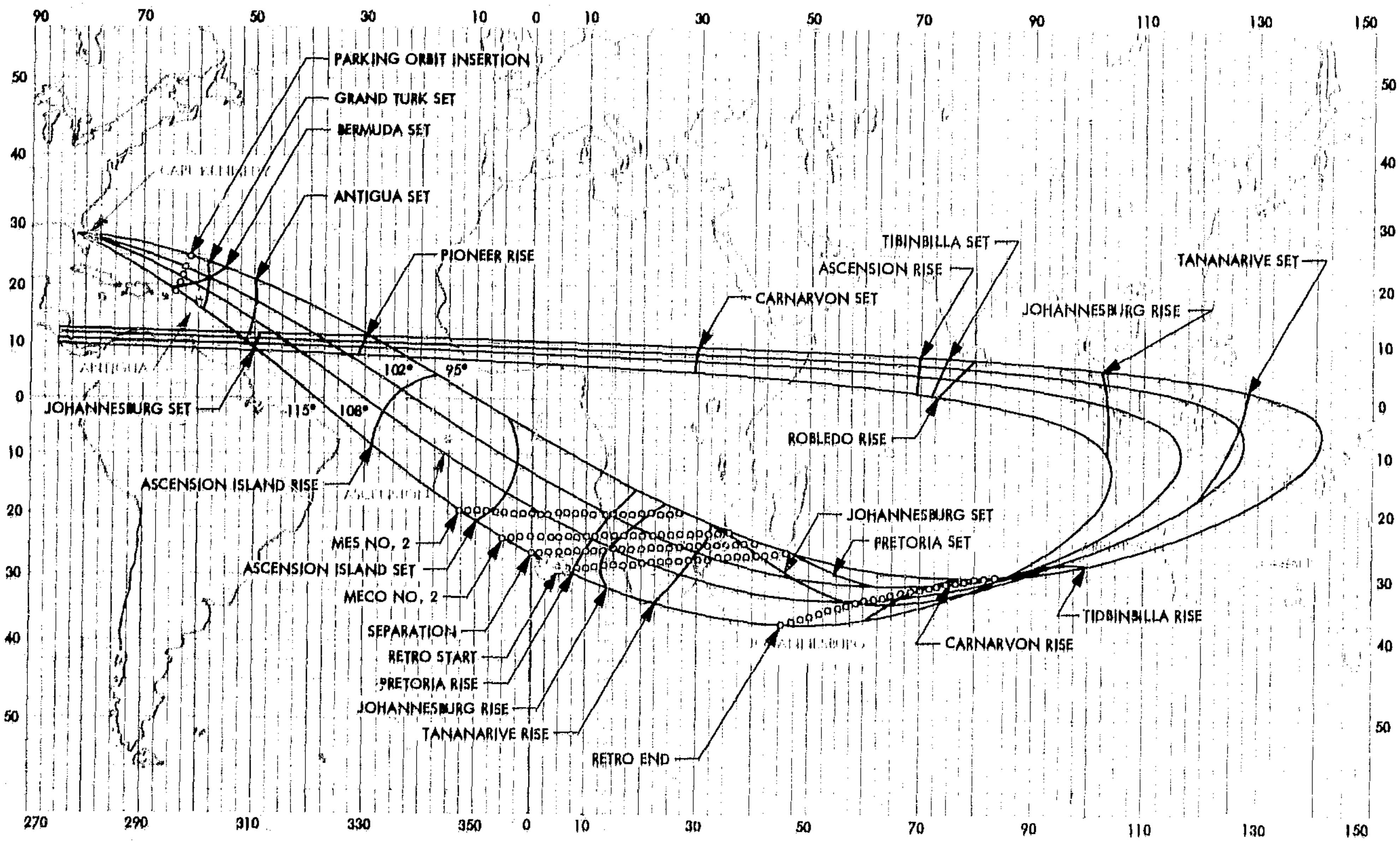


Fig. 11. Earth tracks and TDS station coverage for April 17, 1967

Table 5. Ship positions planned for *Surveyor III* mission

Day	Ship	Geocentric	
		Latitude, deg	Longitude, deg
April 15	*Timber Hitch*	12.5 N	41.0 W
	Coastal Crusader	4.0 N	28.0 W
	Twin Falls	21.0 S	10.0 E
	Sword Knot	29.5 S	42.0 E
April 16	*Timber Hitch*	12.5 N	41.0 W
	Coastal Crusader	4.0 N	28.0 W
	Twin Falls	20.0 S	7.0 E
	Sword Knot	26.75S	43.5 E
April 17	*Timber Hitch*	12.5 N	41.0 W
	Coastal Crusader	4.0 N	28.0 W
	Twin Falls	18.0 S	4.0 E
	Sword Knot	23.5 S	43.0 E
April 18	*Timber Hitch*	12.5 N	41.0 W
	Coastal Crusader	4.0 N	28.0 W
	Twin Falls	16.0 S	6.0 E
	Sword Knot	22.0 S	40.0 E
April 19	*Timber Hitch*	12.5 N	41.0 W
	Coastal Crusador	4.0 N	28.0 W
	Twin Falls	14.0 S	8.0 E
	Sword Knot	20.5 S	37.0 E
April 20	*Timber Hitch*	12.5 N	41.0 W
	Coastal Crusader	4.0 N	28.0 W
	Twin Falls	12.0 S	6.0 E
	Sword Knot	18.0 S	39.0 E
April 21	*Timber Hitch*	12.5 N	41.0 W
	Coastal Crusader	4.0 N	28.0 W
	Twin Falls	12.0 S	6.0 E
	Sword Knot	16.0 S	41.5 E

AFETR telemetry support capability was not expected to constrain the launch windows.

The AFETR prepared to meet all but one of the class I tracking data requirements. The one exception was the requirement for tracking data during the *Centaur* second burn. This requirement could not fully be met on the launch dates from April 18 to 21. However, it was not expected that this support deficiency would be a launch constraint. Figure 12 shows the *Surveyor III* mission planned near-earth coverage.

The tracking and telemetry coverage requirements placed on the AFETR are specified in the following paragraphs. These requirements originated from the following areas: (1) *Surveyor* mission requirements, (2) launch-vehicle requirements, and (3) range requirements.

1. Tracking requirements. The AFETR was required to track the C-band beacon on the *Centaur* stage. Continuous tracking of this beacon was required from launch to injection into the parking orbit and/or injection into the translunar trajectory (see Table 6). In the case of the *Surveyor III* parking orbit mission, it was required that the C-band beacon be tracked during the second burn of the *Centaur*. In order to establish the free-fall trajectories of the vehicles, it was required that the *Centaur* C-band be tracked continuously for at least 60 s after injection into the parking orbit and continuously for at least 60 s between injection in the translunar orbit and the start of the *Centaur* retro maneuver. There was also a requirement that the C-band beacon be tracked continuously for at least 60 s after the end of the *Centaur* retro maneuver in order to establish the final trajectory of the *Centaur*. The AFETR Real-Time Computer System (RTCS) was to utilize these tracking data in computing the orbits of the spacecraft and the *Centaur*, and for orbit mapping to lunar encounter, so that an early evaluation of the trajectories could be obtained. It was also required that the RTCS process these orbits in order to obtain in-flight acquisition data for the Deep Space Stations.

Table 6. AFETR tracking data accuracy requirements for *Surveyor* orbit determination

Class	Data type	Effective data noise[a] at 1 sample/6 s[b]		
		$T_I < 6$ s	$6\text{ s} \leq T_I < 10^m$	$T_I \geq 10^m$
I	Range, m	25.0	50.0	200.0
	Angles (Az-El), deg	0.05	0.12	0.15
II	Range, m	5.0	10.0	100.0
	Angles (Az-El), deg	0.01	0.04	0.045
III	Range, m	1.0	1.0	10.0
	Angles (Az-El), deg	0.005	0.005	0.007

[a]This table is based on a 10-min pass

[b]Effective data noise $= \left[\sum_i S_i^2 g_i^2 \max\left(1, T_{I_i}/T_B\right) \right]^{1/2}$

where

i error mode index

S_i standard deviation of error Mode i at same reference condition (i.e., where $g_i = 1$)

g_i "shape factor" of error Mode i. Equal to one at the reference condition. As an example, the azimuth angle jitter error source may have $g_{AZ\,AJ} = 1/\cos(EL)$ and the range (ρ) error due to oscillator drift rate may have the form $g_{OSC\,DR} = \rho/\rho_{ref}$

T_{I_i} correlation width of the i^{th} error source

T_B time between successive data points

$\max\left(1, T_{I_i}/T_B\right)$ means use either 1 or $\left(T_{I_i}/T_B\right)$, whichever is larger

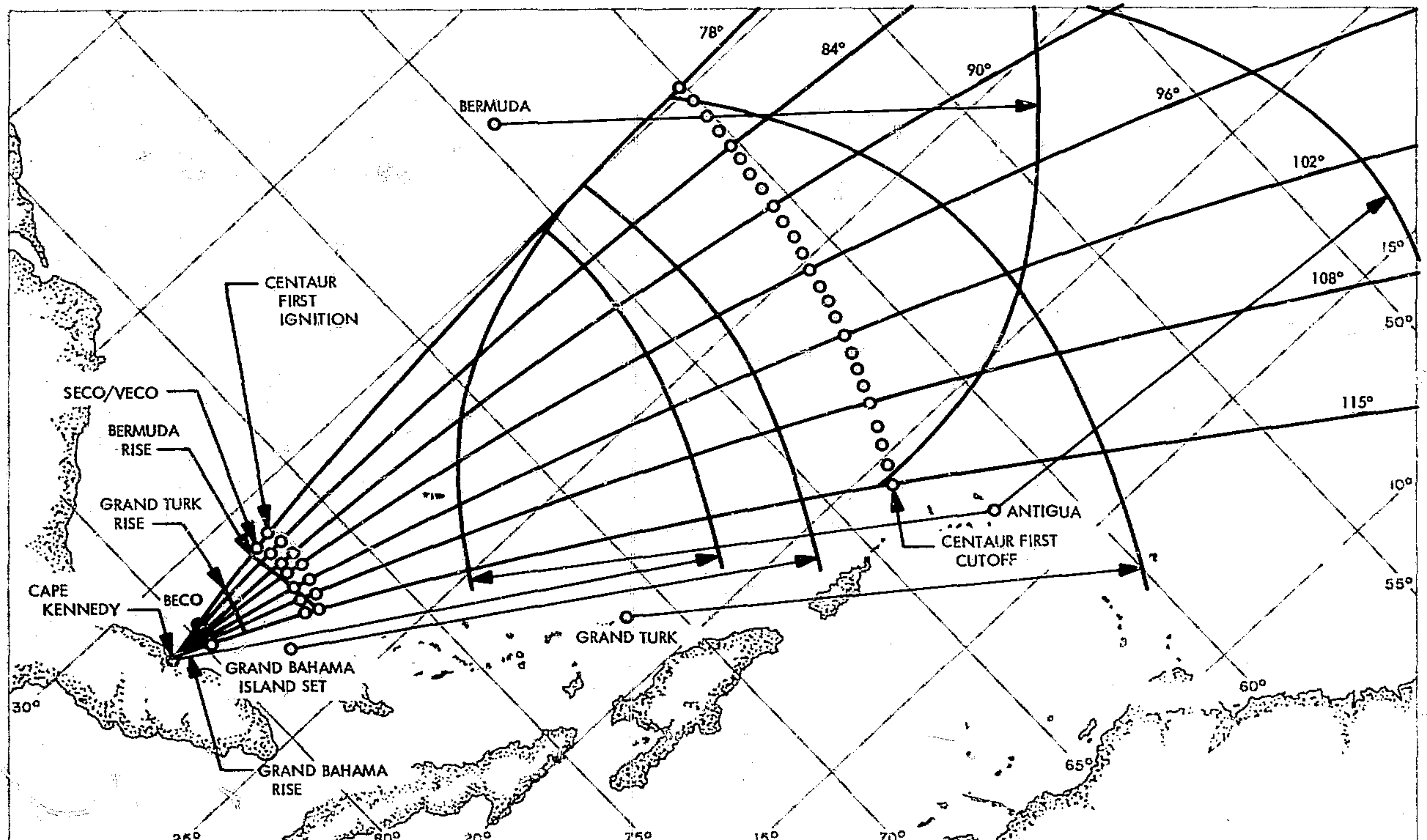


Fig. 12. *Surveyor III* mission planned near-earth coverage

The AFETR was committed to provide class I tracking data from launch to insertion into the parking orbit. C-band radars at Grand Bahama Island, Bermuda, Grand Turk, and Antigua were to provide data from *Atlas/Centaur* separation to *Centaur* MECO. C-band radars at Antigua, Ascension Island, Pretoria, and on metric ships were to provide data, from injection through *Centaur* retro-maneuver, for the generation of orbital elements, injection conditions, and DSIF acquisition data.

The AFETR was also required to generate accurate in-flight predicts to produce satisfactory look-angles for DSIF stations. In general, these accuracy requirements were met if class I data accuracy was met during the class I intervals specified. The DSIF look-angles had to be received at the site prior to the station view period. Thus, the AFETR operations were designed to provide these look-angles within a few minutes after receiving the raw tracking data.

Raw tracking data were required from AFETR for spacecraft orbit determination reliability and accuracy. The reliability was closely correlated with the number of tracking stations contributing data. For example, an independent third data source can prove invaluable in resolving apparent discrepancies between two other data sources, both of which appear to be operating properly. Thus, RIS (range instrumentation ship) data would be invaluable under a variety of circumstances, and it was important to know the ships' locations as accurately as possible.

The AFETR tracks the C-band beacon of the *Centaur* stage to provide metric data which included the following:

(1) Metric data requirements.

   (a) Class I metric data requirements included tabulation of acceptable C-band beacon performance parameters and readouts and S-band tracking.

   (b) Metric orbital and space data requirements included mapping to lunar encounter (based on final post-retro orbit) in-flight TAER (time-azimuth-elevation rate) and related data.

   (c) Transmission of in-flight trajectory data, by AFETR stations and appropriate RIS, was required from liftoff to Loss of Signal (LOS), as well as other raw data which were provided the DSN by 100-wpm teletype. Processing raw DSN tracking data was also necessary in real or near-real time (NRT). Table 7 shows the tracking data required by AFETR.

(2) Additional metric data requirements.

   (a) Any continuous 60-s span, between injection into transfer orbit and start of *Centaur* retro-maneuver, was included.

   (b) Any continuous 60-s span, after completion of *Centaur* retro maneuver, was included.

   (c) Delivery of data was requested in decimal format via teletype to building AO in near-real time.

   (d) AFETR pre-flight and in-flight requirements included metric and telemetry data acquisition, recording, and real time retransmission during particular intervals. In general, this data-support included launch-through-injection into the transfer trajectory and during the transition period until the spacecraft was acquired by the DSN which provided the spacecraft tracking and commands required to support the missions objectives.

The AFETR was committed to provide class I tracking data from launch to insertion into the parking orbit. C-band radars at Grand Bahama Island, Bermuda, Grand Turk, and Antigua were to provide data from *Atlas/Centaur* separation to *Centaur* MECO. C-band radars at Antigua, Ascension Island, Pretoria, and on metric ships were to provide data, from injection through *Centaur* retro-maneuver, for the generation of orbital elements, injection conditions, and DSIF acquisition data.

2. *VHF telemetry requirements.* The AFETR was to provide continuous launch vehicle telemetry coverage from launch to the end of the *Centaur* retro maneuver, real-time telemetry data retransmission from launch to $L + 10$ min, and near-real-time retransmission of selected portions of telemetry data. In addition to land stations, four RIS were provided to support VHF telemetry data acquisition.

The following information gives the coverage requirements and frequency band allocation used by the AFETR in support of the *Surveyor IV* mission.

(1) 229.9 MHz (*Atlas* link) $T - 300$ s to $T + 300$ s – recordings and real time analog stripouts.

Table 7. Tracking data required

Item No.	Data required		Interval	Amount of data required (data points/s)	Required data accuracy: Class I	Class II	Class III	Remarks
1	Orbital elements injection conditions and DSIF acquisition data	Position	Between injection and *Centaur* retro-start	Single data point	3000 m	300 m	60 m	
		Velocity			60 m/s	6 m/s	0.6 m/s	
2	Orbital elements and injection conditions	Position	Between completion of *Centaur* retro-start and launch + 1 h	Single data point	3000 m	300 m	60 m	
		Velocity			60 m/s	6 m/s	0.6 m/s	
3	Multiple station orbit	Position	Between injection and *Centaur* retro-start	As required	200 m	20 m	3 m	Refinement of Item 1. Required within 4 h of launch.
		Velocity			2 m/s	0.2 m/s	0.02 m/s	
4	Multiple station orbit	Position	Between completion of *Centaur* retro-start and launch + 1 h	Single data point	200 m	20 m	3 m	Refinement of Item 2. Required within 4 h of launch.
		Velocity			2 m/s	0.2 m/s	0.02 m/s	
5	Range		Class I Any continuous 60 s from injection to *Centaur* retro-start	1/6				
	Azimuth–elevation							
6	Range		Class II and III Continuous from injection to *Centaur* retro-start	1/6				
	Azimuth–elevation							

(2) 225.7 MHz (*Centaur* link) $T - 300$ s to $T + 756$ s (*Surveyor* separation + 5 s) – recordings; analog stripouts and real time transmission of data from Antigua to building AO and to KSC; as well as transmission of data from Antigua after LOS.

(3) 225.7 MHz, *Centaur/Surveyor* separation +5 s to end of *Centaur* retromaneuver – recording wherever coverage was available.

3. S-band telemetry requirements. The AFETR was required to receive, record and retransmit *Surveyor* S-band (2295 MHz) telemetry in real-time starting when the spacecraft transmitter high power is turned on until 15 min after DSS rise. For *Surveyor III*, Carnarvon was configured to transmit S-band telemetry to DSS 42; therefore, the AFETR was required to provide S-band information until Carnarvon rise plus 15 min.

(1) All S-band systems were used only on a limited basis as they were still under engineering control. Table 8 presents a detailed summary of the AFETR telemetry coverage requirements for the spacecraft data transmitted by the *Centaur* telemetry system and for the data transmitted by the spacecraft S-band telemetry system. Pre-launch requirements as well as data recording requirements are also shown in this table.

(2) During the class I interval after spacecraft separation, the spacecraft was not attitude stabilized. Therefore, the ground telemetry station was to be viewing the spacecraft with no knowledge of the actual spacecraft omni-antenna gain at any particular point in time. It was required that AFETR base their coverage commitments of the 2295 MHz telemetry link for the class I interval on the assumption that the omni-antenna nulls were not deeper than -13 dB during 90% of the time.

(3) Requirements for coverage of the spacecraft telemetry through the spacecraft S-band or *Centaur*

Table 8. Spacecraft system telemetry coverage requirements

Item	Telemetry link	Class I	Class II	Class III
1a	*Centaur*	$T - 280$ min to $T - 260$ min	Same as class I	Same as class I
b	*Centaur*	$T - 5$ min to station 1 loss of signal	$T - 5$ min to *Surveyor/Centaur* electrical disconnect	Same as class II
c	*Centaur*	MECO — 5 min to *Surveyor* high power on	—	—
2[a]	*Centaur*	$T - 0$ through *Surveyor/Centaur* electrical disconnect	—	—
3	Spacecraft S-band	From *Surveyor* high power on to DSIF nominal acquisition at injection +17 min	$T - 5$ min to DSIF late acquisition at approximately injection +27 min	$T - 5$ min to loss of signal

[a]Requirement is only for recording the data.

links were placed on the AFETR. A similar coverage requirement was to transmit S-band telemetry data in real time to building AO from $T + 745$ s to $T + 1583$ s. Requirements also existed for coverage of the launch-vehicle telemetry for vehicle evaluation. These latter requirements are placed only on the AFETR. The frequency use and location of telemetry equipment are listed below.

4. Computer requirements. The RTCS was to provide computed data for pre- and post-retromaneuver transfer orbits. The software was certified and the RTCS participated in joint operational readiness tests with the SFOF.

(1) The computer data requirements for the pre-retromaneuver transfer orbit are summarized below:

(a) Single-station solution orbital elements and injection conditions. Delivery requested via teletype to building AO in near real time after receipt of data at the RTCS facility.

(b) Multiple-station solution orbital elements, injection conditions. Delivery requested via teletype to building AO within 2 h after delivery of item (a).

(c) Orbital elements and injection conditions from telemetered *Centaur* guidance data. Delivery requested via teletype to building AO within 30 min of receipt of data at RTCS facility.

(d) Quick mapping (B-plane) to lunar encounter. Delivery requested via teletype to building AO immediately following item (a).

(e) Refined mapping to lunar encounter. Delivery requested via teletype to building AO immediately following delivery of item (b).

(f) AFETR inter-range vector (IRV). Concurrent delivery to building AO and DSS 72 via teletype requested in near-real time after receipt of data at RTCS facility.

(g) DSN acquisition data to station horizon break plus 14 h for any three of five stations. Delivery requested via teletype to building AO in near-real time after receipt of data at RTCS facility with concurrent transmission to DSS 72 when DSS 72 is one of the three selected stations.

(2) The computer data requirements for post-retromaneuver transfer orbit are summarized below:

(a) Single-station solution orbital elements and injection conditions. Delivery requested via teletype to building AO within 30 min of receipt of data at RTCS facility.

(b) Multiple-station solution orbital elements and injection conditions. Delivery requested via teletype to building AO within 2 h after delivery of item (a).

(c) Orbital elements and injection conditions from telemetered *Centaur* guidance data. Delivery requested via teletype to building AO within 30 min of data receipt at RTCS facility.

(d) Quick mapping (B-plane) to lunar encounter. Delivery requested via teletype to building AO immediately following delivery of item (a).

(e) Refined mapping to lunar encounter. Delivery requested via teletype to building AO immediately following delivery of item (b).

(f) AFETR inter-range vector (IRV). Concurrent delivery to building AO and DSS 72 via teletype requested within 30 min of receipt of data at RTCS facility.

5. Communications requirements. The requirements were as follows:

(1) The AFETR was required to have communication lines with the range tracking stations. This was especially needed by *Surveyor* with its requirement of real-time transmission of spacecraft telemetry data. However, with the AFETR functioning as designed, the communications system would be adequate to support *Surveyor III*. A possible exception is a state of RF "blackout" between a station and the Cape. Such an occurrence (only occasionally predictable) may cause a hold.

(2) Another requirement placed on the AFETR was that the *Centaur* VHF signal or the spacecraft S-band signal carrying the spacecraft information be transmitted from each AFETR station to the allocated *Surveyor* facilities at Cape Kennedy in real-time. These data were then to be relayed to the SFOF for spacecraft evaluation. The launch vehicle and spacecraft discrete event information obtained at the AFETR stations was to be transmitted by voice lines to the *Surveyor* Operations Center at AFETR in real-time for relay to the SFOF. The spacecraft information recorded at the AFETR stations was to be forwarded to the *Surveyor* facilities at AFETR in non-real time.

(3) *Surveyor* real time data requirements are listed below:

(a) Requirements are:

(1) $T - 300$ s to Station 1 LOS

(2) $T + 300$ s to $T + 1583$ s

(b) Data sources are:

(1) VHF or S-band telemetry until S-band high power on

(2) S-band telemetry after S-band high power on

(c) Data deliveries were:

(1) 550-bits/s spacecraft data from up to three AFETR stations or ships will be transmitted to building AO.

(2) One of the three 550-bits/s PCM signals being provided to building AO will be decommutated by AFETR with six channels converted to analog and transmitted to building AO for display.

(3) Each station receiving or transmitting 550-bits/s spacecraft data was to decommutate the data train and convert specified channels to analog for monitoring or voice reporting of events as the status changed.

(4) Certain real time voice communications requirements were also imposed upon the AFETR for the *Surveyor III* mission. These were:

(a) To report by voice in near real time the initial AOS and the final LOS of each station of the telemetry link containing spacecraft data. Reports were to be time-tagged to the nearest minute. (Links to be reported would normally be the 225.7-MHz link prior to Spacecraft High Power ON, and the 2295-MHz link after Spacecraft High Power ON. Should there be a failure to acquire the 225.7-MHz link, reporting of the 2295-MHz link was to be substituted.) Report also by voice in near real time any anomaly or unexpected occurrence during the station's view period. (Examples included, but were not limited to, loss of modulation or unexpectedly low received signal level.)

(b) To report by voice spacecraft events and conditions as observed at each station retransmitting spacecraft telemetry in real time.

(c) To provide the SFOF with a backup to the real time transmission of the spacecraft 550-bits/s PCM telemetry signal from the AFETR stations. Consequently, the requirement for voice reporting applied to each downrange station that received the spacecraft signal and transmitted it uprange in real time, specifically, Antigua, RIS, Ascension Island, and other stations assigned this function. These reports were highly desired at all times. They were of even greater importance if the quality of data being retransmitted in real time was degraded for any reason.

The *Surveyor III* mission requirements for tracking coverage resulted from the need to calculate orbital elements and DSIF look angles as acquisition aids and the need for raw data to contribute to the accuracy and reliability of the spacecraft orbit determination processes. Until separation, the orbits of the spacecraft and the *Centaur* were the same. At separation, a relative velocity of about 1 ft/s was imparted by a spring system. Since this separation velocity was small, the AFETR tracking of the *Centaur* stage, both prior to and subsequent to separation, was valuable in determining the spacecraft orbit and in checking other tracking systems. Even after the retro-maneuver of the *Centaur* stage (several minutes after separation), tracking information was helpful during flight.

It is clear that the processing of AFETR raw data after injection is involved with, and conditional upon, the telemetry identification of certain events. The relative weighting of the different AFETR data types (e.g., range and angles with respect to DSIF data) was a task requiring more information than was available to AFETR. Hence, it was important that raw data be supplied to the DSN. Therefore, these requirements, stating that the *Centaur* orbit would be determined by AFETR and that raw tracking data would be furnished to the DSN during launch, were greatly needed. Raw data can be defined as raw azimuth, elevation, and range points which have not been altered by smoothing, weighting, etc. One exception to this definition was exhibited by the desirability to correct the RIS raw data for the ships' motion. However, ships' range data are usually valuable even if the ships' motion has not been removed.

Thus, the AFETR data were to significantly improve the accuracy of the pre-midcourse orbit determination process. However, the data had to be more accurate for this process than for improving reliability. Table 7 shows the AFETR tracking data accuracy requirements for *Surveyor* orbit determination.

C. Goddard Space Flight Center

Tracking and telemetry coverage requirements placed on the MSFN, managed by the GSFC, were as follows:

(1) Provide C-band radar beacon tracking of the *Centaur* beacon for approximately 3.5 h.

(2) Provide telemetry receiving and recording of the *Centaur* links from Bermuda (BDA) acquisition of signal (AOS) until LOS at Carnarvon (CRO). Table 9 indicates the MSFN instrumentation support capability.

(3) Provide real-time confirmation of certain *mark* events.

(4) Provide real-time reformatting of CRO radar data at GSFC from CRO hexadecimal system to the 38-character radar data format, and to retransmit this data to the AFETR computers at Cape Kennedy.

(5) Provide receiving and recording of telemetry data and transfer same via modern NASCOM facilities to DSS 42.

(6) Provide NASCOM support to all NASA elements for simulations and launch, and to provide this communications support as necessary to interface with the combined worldwide Network.

Table 9. MSFN instrumentation support capabilities

System	Station					
	BDA	CYI	KNO	CRO	GSFC	MCC-K
Acquisition aid	X	X	X	X		
C-band radar	X			X		
Unified S-band						
Telemetry:						
PAM/FM						
PCM/FM	X	X	X	X		
FM/FM						
Magnetic Tape	X	X	X	X		
Real-time readouts	X	X	X			
Displays	X	X	X			
Command:						
Digital						
Tone	X[a]					
Voice (SCAMA)	X	X	X	X	X	X
Teletype	X	X	X	X	X	X
High-speed data	X			X	X	X
Doppler tracking						
Range safety	X					
Displays (Bldg. 14)					X	
Computer support					X	

[a]Range Safety.

(7) Provide the computing support required by the supporting MSFN stations.

Only the DSN facilities of the TDS support the mission during the translunar and post-landing phases of the mission, i.e., subsequent to the near-earth phase. The Project required continuous tracking of the spacecraft from injection to the end of the mission in order to satisfy the data needs for the flight path analyses that were essential to the achievements of the selected landing sites. Furthermore, these data were necessary for determining the actual post-landing position.

With the two-burn parking orbit such as used on the *Surveyor III* mission ascent mode, longer daily launch windows are usually more available than in direct ascent missions. Firing windows may range up to a maximum of about 4 h in length. The monthly launch period typically ranges from five to nine daily firing windows. The launch azimuth may vary from 78 to 115 deg during the firing windows, and the exact launch time depends upon the lunar lighting at arrival. A continuous launch capability, with respect to launch azimuth/launch time shift, is desired for launch windows up to 4 h in length. The *Centaur/Surveyor* vehicle will first be injected into a 90-n mi circular orbit, and the time spent in circular orbit will vary, depending on launch time and date. At the end of the coast phase, the *Centaur* main engines will be restarted and the *Surveyor* spacecraft will be injected into a translunar trajectory.

The *Atlas* booster engines cut off and will be jettisoned shortly after launch. Sometime before the sustainer and vernier engines burn out, commands from the *Centaur* programmer will initiate ejection of the *Centaur* insulation panels and the spacecraft nose fairing. After sustainer and vernier engine burn out, the *Centaur* will separate from the *Atlas*. Then, after a short coast, *Centaur* ignition will take place and the spacecraft will be boosted on a direct-ascent trajectory to the prescribed point of injection.

For the *Surveyor III* parking orbit mission, the *Centaur* stage will first inject into a parking orbit (90-nmi altitude). Starting at the end of first burn (Main Engine Cutoff), two 50-lb-thrust H_2O_2 rockets will be operated to stabilize propellant usage during the shutdown transient.

The ability of the TDS to satisfy the Project's tracking and telemetry coverage requirements is strongly dependent upon the characteristics of the trajectories, the availability of the TDS resources, and the capability of these resources. The *Surveyor* Project Class I requirements for TDS support during the near-earth phase are depicted in Fig. 10. Details of these requirements are stated elsewhere in the related applicable documents. The Project also has requirements for TDS support during the translunar and post-landing phases. These latter requirements are placed on the DSN portion of the TDS. In summary, the DSN is required to provide continuous telemetry coverage during the transit phase and during the post-landing phase from touchdown through the first lunar day and continuing through the first 10 h of the first lunar night.

Tracking and telemetry coverage requirements placed on the MSFN, managed by GSFC, are specified below:

1. Tracking. During the powered-flight phase of the mission, the Bermuda (BDA) FPQ-6 radar was to beacon-track the *Centaur* vehicle in conjunction with the AFETR radars. The BDA FPQ-16 radar was to passively angle-track the *Centaur* vehicle with the range slaved to the FPQ-6 radar. The radar data were to be transmitted in real-time at both high- and low-speed to GSFC and the RTCS at AFETR. The CRO FPQ-6 was to beacon-track the *Centaur* vehicle and transmit real-time and low-speed radar data to GSFC for reformatting and retransmission to the RTCS at AFETR.

The acquisition aids at BDA, Tananarive (TAN), and CRO were to track the A/C-12 vehicle and were to provide RF inputs to the telemetry receivers and steering inputs to the radar, where applicable. Performance recorders were used to record Automatic Gain Control (AGC) and angle error voltages for postmission analysis. Acquisition aid coverage was necessary from BDA AOS to CRO LOS.

Acquisition aid tracking of the *Atlas* (229.9 MHz) and the *Centaur* (225.7 MHz) links were to be in the 300-kHz bandwidth cross-correlation mode. BDA was required to track the *Atlas* and *Centaur* links; TAN and CRO were required to track the *Centaur* link.

2. VHF telemetry requirements. During the launch phase, BDA and TAN were to receive and record the *Centaur* TLM link from BDA AOS to LOS and from TAN AOS to LOS. Bermuda was also to receive and record the *Atlas* telemetry link. CRO was to receive and record the *Centaur* telemetry link on a "best obtainable" basis. All stations were to confirm certain flight events. Carnarvon was to also receive and record the spacecraft USB 550-bit, bilevel, telemetry data and transfer them via data-modem NASCOM facilities to DSN 42, Tidbinbilla. In addition, all MSFN stations were required to confirm various flight events. Table 10 indicates the flight events and the individual station confirmation requirement. Carnarvon coverage was to be on a "best obtainable" basis, due to excessive range. Predicted telemetry coverage for April 17, 1967 is illustrated by Table 11 and Fig. 13.

Table 10. Mark events for the *Surveyor III* mission

Station	Mark No.	Events	*T* + time s (min/s)	Link/channel (kHz)/pulse	Description
		2-in. motion-liftoff	0		2-in. motion from range
1[a]		*Atlas* BECO	143 (02:23)	229.9/0.96/contd	B-1 pump speed measurement goes out of band on low frequency side
2[a]		*Atlas* booster engine jettison	146 (02:26)	229.9/40/comm	All booster section measurements to open
3[a]		*Centaur* insulation panel jettison	177 (02:57)	229.9/70/5, 6	Segment levels change from 11% to 74%
4[a]		*Centaur* nose fairing jettison	204 (03:24)	229.9/5.4/contd 225.7/3.9/7	Segment levels change from 50% to 67% at jettison
5[a]		*Atlas* SECO/VECO	236 (03:56)	229.9/0.73/contd	Sustainer pump speed measurement goes out of band on low frequency side
BDA	6	*Atlas/Centaur* separation	238 (03:58)	225.7/30/1	Segment should increase from 0% to 100% at separation
BDA	7	*Centaur* MEIG No. 1	241 (04:01)	225.7/0.96/contd	C-2 chamber pressure goes from 0% to 75% of band
BDA	8	*Centaur* MECO No. 1	574 (09:34)	225.7/0.96/contd	C-2 chamber pressure goes from 75% to 100% of band
BDA	9	100-lb thrusters ON	574 (09:34)	225.7/7.35/6, 25	Segments go slowly from 0% to 50% of band
BDA	10	100-lb thrusters OFF	650 (10:50)	225.7/7.35/6, 25	Segments go slowly from 50% to 0% of band
BDA	11	6-lb thrusters ON	650 (10:50)	225.7/7.35/7, 28	Segments go slowly from 0% to 50% of band
TAN	12	100-lb thrusters ON	2037 (33:57)	225.7/7.35/6, 25	Segments go slowly from 0% to 50% of band
TAN	13	*Centaur* MEIG No. 2	2077 (34:37)	225.7/0.96/contd	Same as mark 7
TAN	14	*Centaur* MEIG No. 2	2077 (34:37)	225.7/0.73/contd	C-1 chamber pressure goes from 0% to 75%
TAN	15	*Centaur* MECO No. 2	2185 (36:25)	225.7/0.96/contd	Same as mark 8
TAN	16	*Surveyor* landing gear extend command sent	2211 (36:51)	225.7/3/7	Segment goes from 0% to 100% for one seg; signal is integrated
TAN	17	*Surveyor* omni-antenna extend command sent	2221 (37:01)	225.7/3/11	Command goes to approx 100%

[a]Vehicle is not in view of any MSFN station at this time.

NOTE:

1. The times listed for TAN and CRO are for a 25-min coast (variable 2–25 min).
2. Each segment represents two panel sections.

Table 10 (contd)

Station	Mark No.	Events	T + time s (min/s)	Link/channel (kHz)/pulse	Description
TAN	18	*Surveyor* high power ON	2242 (37:22)	2295.0 Mc	Receiver AGC shows increased signal
TAN	19	C/S electrical disc	2247 (37:27)	225.7/3/22	Measurement goes to 98%
TAN	20	C/S separation	2253 (37:33)	225.7/14.5/22/52.5/ contd	At release of payload signal goes to 100%
TAN	21	Begin *Centaur* turnaround	2258 (37:38)	225.7/70/5, 6	Both gradually increase from 60% to 80%
TAN	22	Start *Centaur* lateral thrust	2298 (38:18)	225.7/7.35/6, 25	Prior to *mark* 22, trace decays to high freq band. At *mark* 22, trace turns and goes to low freq band

Table 11. Predicted telemetry coverage for April 17, 1967

Launch AZ	Station	AOS		TLM lock[b]		TLM unlock[b]		LOS	
		GET	AZ	GET	AZ	GET	AZ	GET	AZ
96	BDA	0:03:50	252	0:04:20	249	0:10:40	137	0:10:50	135
	TAN	0:35:40	260	0:36:00	255	0:43:00	116	0:47:40	110
	CRO[a]	0:43:50	254					1:05:40	60
99	BDA	0:03:50	251	0:04:30	248	0:10:20	146	0:10:50	140
	TAN	0:35:10	251	0:35:30	248	0:42:40	118	0:52:20	107
	CRO[a]	0:43:10	253					1:04:50	45
102	BDA	0:04:00	251	0:04:30	246	0:10:10	152	0:10:40	146
	TAN	0:34:50	245	0:35:00	243	0:42:20	122	0:52:20	107
	CRO[a]	0:42:40	252					1:03:40	12
105	BDA	0:04:00	250	0:04:40	245	0:09:50	160	0:10:30	152
	TAN	0:34:10	242	0:34:30	238	0:41:50	127	0:52:20	108
	CRO[a]	0:42:10	250					1:02:20	313
108	BDA	0:04:00	249	0:04:40	244	0:09:40	167	0:10:10	159
	TAN	0:33:30	239	0:33:50	236	0:41:20	133	0:52:10	108
	CRO[a]	0:41:50	248					1:00:30	283
111	BDA	0:04:00	248	0:04:50	242	0:09:20	174	0:10:00	165
	TAN	0:33:10	232	0:33:20	234	0:40:40	142	0:52:00	110
	CRO[a]	0:41:30	247					0:58:30	269
114	BDA	0:04:00	247	0:05:00	240	0:09:00	182	0:09:40	172
	TAN	0:32:40	234	0:32:50	231	0:39:50	151	0:51:50	112
	CRO[a]	0:41:10	245					0:56:30	262
115	BDA								
	TAN	0:32:30	232	0:32:50	230	0:39:30	157	0:51:50	113
	CRO[a]	0:41:10	244					0:55:50	259

[a]Range in excess of 3600: no TLM coverage

[b]TLM coverage is based on the following: TLM range 3600 kyds; Acq. aid AOS/LOS Range 9000 kyds; 2-deg EL rise and set; −100 dBmW received signal.

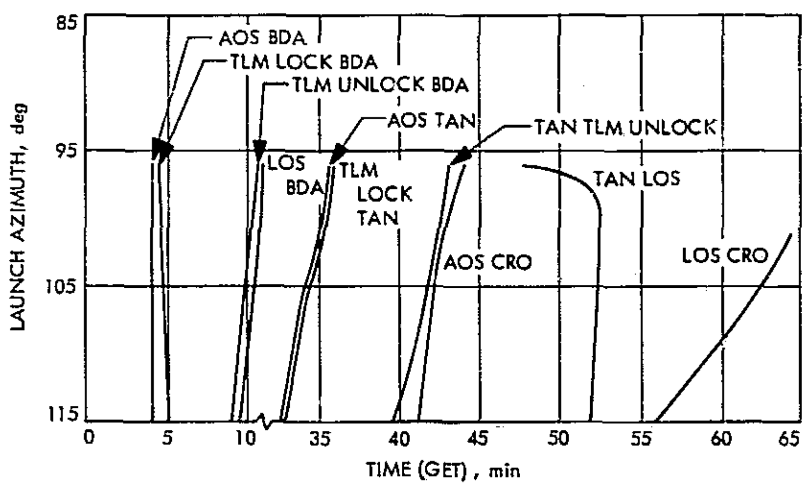


Fig. 13. Predicted telemetry coverage for April 17, 1967

The MSFN telemetry transmitter and antenna characteristics are listed below.

(1) Transmitter characteristics are:

Parameters	*Atlas*	*Centaur*
Frequency	229.9 MHz	225.7 MHz
Modulation	PAM/FM/FM	PAM/FM/FM
Bandwidth	300 kHz	300 kHz
Deviation	±150 kHz	±150 kHz
Average power	5 W	5.5 W

(2) Antenna characteristics are:

Parameters	*Atlas*	*Centaur*
Type	Cavity	Stub
Frequency range	228–248 MHz; fixed tuned	225–260 MHz; fixed tuned
Predominant polarization	Linear	Vertical (on launch pad)
Maximum gain (with respect to isotropic)	Essentially isotropic	Less than 3 dB
Effective radiated power	3 W	5 W

3. *Computer requirements.* The MSFN required support from GSFC computers for acquisition aid predicts. The GSFC Data Operations Branch was to provide computer support during prelaunch, launch, and orbital phases of the *Surveyor III* mission. Nominal pointing data were required to include view times for the participating stations. Post-launch data were to be supplied to the LeRC for launch-vehicle analysis. Nominal pointing data for Bermuda were to be provided by AFETR.

During the powered flight phase, GSFC computers were required to receive launch trajectory data for the vehicle from Bermuda and AFETR via the Launch Monitor Subsystem. The trajectory was to be computed and the resulting parameters made available to drive the Operations Control Center displays at GSFC.

The GSFC computers were committed to update and refine the orbit of the vehicle based upon the low-speed TTY data received from the participating radars. The resulting refined orbital parameters were to be available to drive the displays at GSFC as required.

Acquisition messages were to be generated and transmitted to the participating stations at 25 *min* prior to station acquisition and at 5 min prior to station acquisition.

The low-speed TTY data from CRO were to be reformatted to the standard 38-character radar data format by the GSFC computers and retransmitted via Mission Control Center, Cape Kennedy (MCC-K) to the RTCS. Reformatting and retransmission of data was to continue for approximately 15 min after *Centaur/Surveyor* separation.

At the end of *Centaur* first powered-flight (MECO No. 1, *mark* event 8), GSFC computers were to pass orbital injection parameters to the MSFN Network. The Network was then to pass these parameters by voice to building AE and by TTY to building AE and LeRC.

At the end of the retromaneuver thrust (*mark* event 24), GSFC was to pass orbital injection parameters to the MSFN Network. The Network was again to pass these parameters by voice to building AE and by TTY to building AE and LeRC. Additional appropriate orbit information was to be passed to the Network as it became available during the mission. The Network then was to TTY this information to building AE and LeRC.

D. Deep Space Network

The Deep Space Network was required to support the *Surveyor III* mission with the DSIF, the GCF, and the DSN facilities in the SFOF.

The DSN requirements included S-band tracking and two- and three-way doppler coverage. DSN responsibilities were to obtain continuous spacecraft telemetry coverage from the first acquisition by the Tidbinbilla, Australia Station (DSS 42) to the end of the mission. Three DSIF stations described below were required for this coverage. The full Goldstone Duplicate Standard (GSDS) S-band system in conjunction with the *Surveyor* telemetry system was used at these stations.

The quality and type of tracking data required is defined by Tables 12 and 13. With the requirements outlined by the foregoing tables, it was possible to specify the tracking coverage required to meet the orbit determination accuracy requirements. Before presenting the tracking coverage requirements, however, it would be appropriate to delineate the ground rules upon which the tracking coverage analysis was based.

The most basic and paramount ground rule was that the primary objective of this effort was to maximize the probability of mission success. Since the class I orbit determination accuracy requirement had to be satisfied to ensure that the primary mission objectives were met, it was necessary that these class I requirements be honored at all times. In addition, it was necessary that some class II orbit determination accuracy requirements be met to ensure achieving a mission success. Finally, the class III accuracy requirements would not have to be satisfied to ensure achieving a mission success. Therefore, the greatest effort was directed toward the goal of determining the optimum scheme for meeting the class I orbit determination accuracy requirements.

Specification of the class I tracking coverage requirements in support of the class I orbit determination accuracy was based upon the assumption that each DSN station supplying necessary data would, in fact, supply data of good quality. In order to ensure that there would be a supply of good-quality data, it was very desirable to assign additional DSN stations to a tracking pattern, arranged so as to provide redundancy.

The requirements for allowable errors due to the orbit determination are specified below:

Class I: The semimajor axis (SMAA) of the 1-σ error ellipse at the moon shall not be greater than 50 km on the final premidcourse maneuver orbit using tracking data available up to 1 h after the first Goldstone acquisition.

Table 12. DSN tracking data accuracy requirements

Data accuracy	Correlation width T_l, min	Effective noise at 1 sample/min: 2-way doppler (1-σ), Hz	Angles (1-σ), Hz	3-way doppler (1-σ), Hz	Time sync, s	Absolute frequency stability over 1-min intervals
A, guaranteed	$T_l < 1$	0.01	0.05	0.05	0.005	5.0×10^{-11}
	$1 \leq T_l < 10$	0.01	0.05	0.05		
	$T_l \geq 10$	0.1	0.2	20.0		
B, desired, not guaranteed	$T_l < 1$	0.005	0.01	0.005	0.001	3.0×10^{-12}
	$1 \leq T_l < 10$	0.005	0.01	0.005		
	$T_l \geq 10$	0.005	0.06	0.005		
C, ultimate *Surveyor* Block I	$T_l < 1$	0.001	0.005	0.001	0.00001	3.0×10^{-13}
	$1 \leq T_l < 10$	0.001	0.005	0.001		
	$T_l \geq 10$	0.001	0.014	0.001		

Table 13. DSN tracking data requirements

Coverage and sampling rate	Data required
1. Track spacecraft from separation to first midcourse at 1-min sample rate; (from initial DSIF acquisition to $L + 1$ h, the sample rate is 1 sample per 10 s)[a]	Doppler (two-way and three-way) and antenna pointing angles
2. Track spacecraft from first midcourse to touchdown at 1-min sample rate	Doppler (two-way and three-way)
3. Track spacecraft from touchdown to end of mission at 1-min sample rate during 1 h following 10-deg elevation rise, during 1 h centered around maximum elevation, and during 1 h prior to 10-deg elevation set for DSS 11, 42, and 62	Doppler (two-way and three-way) and antenna pointing angles
4. Track spacecraft during midcourse maneuver and terminal maneuver executions at 1-s sample rate, and transient data at 10-s sample rate.	Doppler (two-way and three-way or one-way)

[a]This coverage requirement may be partially satisfied by either AFETR or MSFN stations.

Class II: There are two class II requirements. They are listed below in order of their priority:

(1) The SMAA of the 1-σ ellipse must be ≤ 50 km using all tracking data available up to Johannesburg set -6 h (approximately $L + 4$ h). A maneuver could then be executed during the Johannesburg pass, if desired, and still meet the required premidcourse orbit determination accuracy.

(2) The SMAA of the 1-σ ellipse must be ≤ 25 km using all tracking data available 1 h after acquisition on the first Goldstone pass. The orbit determination uncertainties would then be comparable to the expected execution errors over the whole ensemble of corrections as determined by the statistical description of the injection vehicle inaccuracies. This figure is to be contrasted with the figure given for the class I requirement which assumed that a 45 m/s maneuver was performed.

Class III: The SMAA of the 1-σ ellipse must be ≤ 3 km, 6 h before the end of the Goldstone pass. The orbit determination uncertainties would then be negligible (0.1) in comparison with the midcourse execution errors.

A DSN/AFETR interface was required for proper spacecraft initial acquisition and inflight predictions.

This interface was supplied by the DSN to provide real-time transmission of down-range spacecraft telemetry data from building AO to the SFOF. The DSN was also responsible for the AFETR meeting the requirements for S-band telemetry coverage.

The DSN provided an interface for down-range telemetry from both VHF and S-band sources. The nominal switchover time was after S-band high-power-on was commanded and the spacecrafts response.

This interface requirement was to provide early spacecraft orbit information to allow calculation of look-angles for subsequent tracking. Thus, the DSIF could effect proper initial acquisition with the aid of preflight prediction data and inflight prediction messages based on actual SC orbit determinations from the AFETR. Subsequent acquisitions were to be made with prediction messages based on orbits calculated to satisfy the need for a final premidcourse maneuver orbit.

Additional interface requirements included: (1) down-range telemetry data from building AO to the SFOF, (2) providing down-range SC telemetry from both S-band and VHF, (3) a nominal switchover after S-band high-power-on is the input to the Command and Data-Handling Console (CDC), and then to the GCF.

1. Deep space instrumentation facility. The DSIF was required to provide coverage for the *Surveyor I* mission, by at least three prime stations on a 24-h per day basis from launch to lunar landing, and for the first lunar day and night. For succeeding lunar days and nights, the requirement was for 24-h per earth day coverage during the first three and last two earth days, and for 10 h per earth day in between.

The following Deep Space Stations, all having 85-ft antennas, were committed as prime and/or secondary stations for supporting the *Surveyor III* mission:

Prime:	Pioneer, Goldstone, Calif.	(DSS 11)
Prime:	Tidbinbilla, Canberra, Australia	(DSS 42)
Prime:	Robledo, Madrid, Spain	(DSS 61)
Secondary:	Johannesburg, S. Africa (Cislunar phase support only on a best effort basis)	(DSS 51)

Secondary: Cape Kennedy, Florida (DSS 71)
(Compatibility, pre-launch and launch support)

Secondary: Ascension Island (DSS 72)
(Launch and pass number one support)

Coverage for the *Surveyor III* mission by the DSIF stations mentioned above is provided in Table 14.

Requirements for data handling by the prime DSIF stations were as follows:

(1) Tracking data, consisting of antenna pointing angles and doppler (radial velocity) data, were required in near-real-time via teletype to the SFOF and post-flight in the form of punched paper tape. Two-way and three-way doppler data were required full-time during the lunar flight, and also during lunar operations at the *Surveyor* Project Office request. The two-way doppler function implied a transmit capability at the prime stations.

(2) Spacecraft telemetry data were to be received and recorded on magnetic tape. Baseband telemetry data were supplied to the CDC for decommutation and real-time readout. The DSIF also performed precommunication processing of the decommutated data, using an on-site data processing (OSDP) computer. The data were then to be transmitted to the SFOF in near-real time, using high-speed data modems.

(3) Command transmission was another function required by the DSIF. Approximately 280 commands to the spacecraft were to be made during the nominal sequence from launch to touchdown. Confirmation of the commands sent was to be processed by the OSDP computer and transmitted by teletype to the SFOF.

Table 14. DSIF-provided coverage

Phase	DSIF coverage
Transit	24-h/earth day
If landing is achieved	
(1) First lunar day and night	24-h/earth day
(2) Second lunar day[a]	(a) 24-h/earth day for first 3 earth days
	(b) 24-h/earth day for last 2 earth days
	(c) One 10-h pass/earth day between (a) and (b) above
(3) Succeeding lunar days and nights[a]	(a) 24-h/earth day for first 3 earth days
	(b) 24-h/earth day for last 2 earth days
	(c) One 10-h pass/earth day between (a) and (b) above
If no landing is achieved	(a) 24-h/earth day for not more than 3 earth days after encounter
	(b) 8-h/earth day for additional 10 earth days

[a]24-h/earth day coverage required whenever valuable data can be provided by spacecraft instruments.

The definition of the various categories of received data are listed below. Hard copy *Surveyor* data required for authorized users are divided into three categories as follows:

(1) Category I: Those data which were to be collected at a central location (SFOF Document Control, TV-1, each DSS, AFETR, and Central Tape Library), catalogued, reproduced, stored and/or issued to authorized users. These data are used primarily for post-flight analysis and are listed in Table 15.

(2) Category II: Those data which are produced as output of DPS program runs and which are used within the Space Flight Operations System for controlling the mission. These data consist of NCR Print, F-80 copy from SC-4020, and SC-4020 Microfilm Plots. These data are listed in Table 16 and defined in accompanying notes. In the past, these data have been defined in the "Bulk Data Distribution Plan."

(3) Category III: Those data which were produced in Operations Areas (FPAC, SPAC, SSAC and T&FA) and were used for operational functions within the area where the data are output. Included in this category of data are 100 wpm and 60 wpm TTY page print, 3070 printouts, 30- × 30-in. plots, Strip Chart recordings, Administrative Printer output, etc. The actual data formats vary in real time according to needs of the Area Director. There was no requirement or commitment from the DSN to collect, or distribute data in this category. Each Area Director was responsible for collecting, handling, and distributing this category of data. If requested, the DSN did microfilm and store data in this category but would not guarantee data content. Users who had a requirement for data of this type had to make pre-mission arrangements for

their collection and use with the cognizant Area Director.

a. Tracking. The DSIF tracking requirements were:

(1) Supply three deep space tracking stations for prime tracking support.

(2) Supply tracking data (S-band).

(3) Supply antenna pointing angles.

(4) Supply doppler (radial velocity) two- and 3-way data.

(5) Supply (24 h/day to touchdown first lunar day and night, first three and last two lunar days, and 10 h/earth day in between) tracking coverage.

(6) Meet or exceed the class I tracking coverage requirements so class I orbit determination accuracy could be met.

(7) Supply tracking data in near real time (NRT) via TTY to the SFOF.

(8) Supply tracking data in the form of punched paper tape at postflight.

Table 15. Category I data

Item no.	Data type	Source of collection	Format at central storage	Central storage location	Authorized user agencies	Additional remarks
1	Tracking data	Each DSS	TTY punched paper tape (primary TDH)	SFOF/DC	MA & E SDA	Copies upon request
2	Tracking data	Each DSS	TTY punched paper tape (secondary TDA)	SFOF/DC	MA & E SDA	Copies upon request
3	Tracking data	Each DSS	Microfilm of TTY page print (primary TDH)	SFOF/DC	MA & E SDA	One copy of original page print to SDA upon arrival from DSS
4	OSDP comm buffer output (CVR only)	Each DSS	5 level paper tape	SFOF/DC	SFOD	
5	Page print of OSDP CCN output	Each DSS	Microfilmed copy	SFOF/DC	SFOD	
6	Telemetry data	Each DSS and AFETR	FR-1400 original mag tape	SFOF/DC	SFOD MA & E	Redundantly recorded on site, backup retained for 90 days
7	Command data	Each DSS	CDC command printer tape	SFOF/DC	PS SCSM	Microfilm copies available upon request
8	Command data	Each DSS	CDC command messages (5-level punched TTY tape)	Each DSS	SFOD MA & E	Retained on site for 30 days after end of mission then destroyed unless otherwise instructed
9	Command data	Each DSS	CDC command messages (7-level punched mylar tape)	Each DSS	SFOD	Retained on site for 30 days after end of mission then destroyed unless otherwise instructed
10	Video recordings	Each DSS	FR-1400 mag tapes	SFOF/DC	PS GDHS	Available from overseas stations in 10 days. From DSS 11, for first 7 days after touchdown, available within 12 h, thereafter within 24 h except weekends.

Table 15 (contd)

Item no.	Data type	Source of collection	Format at central storage	Central storage location	Authorized user agencies	Additional remarks
11	Video recordings	Each DSS	FR-800 mag tapes	SFOF/DC	GDHS	Available from overseas stations in 10 days. From DSS 11, for first 7 days after touchdown, available within 12 h, thereafter within 24 h except weekends.
12	CDC film	Each DSS	35mm film exposed undeveloped	TV-1	GDHS	DSN provides transportation only same availability as items no. 10 and 11
13	70mm film	TV-11	70mm film exposed undeveloped	TV-1	GDHS	Available from overseas stations in 10 days. From DSS-11, for first 7 days after touchdown, available within 12 h, thereafter within 24 h except weekends.
14	Ground instrumentation parameters	Each DSS	Microfilmed CEC 36-channel oscillograph recordings	SFOF/DC	SFOD SCSM	Copies upon request Original to SCSM after microfilming
15	Station logs	Each DSS	Microfilmed copies (1 per pass)	SFOF/DC	MA & E PS	Selected portions available upon special request to track chief
16	Subsystem logs	Each DSS	Microfilmed copy	SFOF/DC	MA & E	Selected portions available upon special request to track chief
17	CDC log	Each DSS	CDC data tape log (microfilmed)	SFOF/DC	MA & E SCSM	Copies upon request
18	CDC and TCP I/O typewriter output	Each DSS	OSDP page print (microfilmed)	SFOF/DC	SFOD	Copies upon request
19	Analog mag tape	TPS	FR-1400 original analog mag tape	SFOF/DC	SFOD	Copies upon request—user must supply blank tape for dubbing.
20	Digital mag tape	TPS	PDP-7 digital mag tape	CTL	SFOD SCSM DPPE	Copies upon request—user must supply blank tape for dubbing.
21	7094 program output	DPES	TABS	SFOF/DC	MA & E SFOD	Copies upon request
22	Same	ODGX	TABS	SFOF/DC	SFOD MA & E	Copies upon request
23	Same	TDPX	TABS	SFOF/DC	SFOD MA & E	Copies upon request

Table 15 (contd)

Item no.	Data type	Source of collection	Format at central storage	Central storage location	Authorized user agencies	Additional remarks
24	Same	ODPS	TABS 4020 microfilm	SFOF/DC	SFOD MA & E	Copies upon request
25	Same	TRJX	TABS 4020 microfilm	SFOF/DC	SFOD MA & E PS	Copies upon request
26	Same	HPPS	TABS	SFOF/DC	SFOD MA & E	Copies upon request
27	Same	MTGS	TABS 4020 microfilm	SFOF/DC	SFOD MA & E	Copies upon request
28	Same	PRDX	TABS	SFOF/DC	SFOD MA & E SDA	Copies upon request
29	Same	SCP	TABS	SFOF/DC	SFOD	Copies upon request
30	Same	CVTS	TABS	SFOF/DC	SFOD	Copies upon request
31	Same	PLAS	TABS	SFOF/DC	SFOD SCSM	Copies upon request
32	Same	CPPM	TABS 4020 microfilm	SFOF/DC	SCSM MA & E	Copies upon request
33	Same	AGCM	TABS 4020 microfilm	SFOF/DC	SFOD	Copies upon request
34	Same	EDPL	TABS 4020 microfilm	SFOF/DC	SFOD SCSM	Copies upon request
35	Same	TVCS	TABS	SFOF/DC	SFOD	Copies upon request
36	Same	TRJX	Trajectory save tape	CTL	DPPE MA & E	Copies upon request
37	Same	ODGX	Orbit data file	CTL	DPPE MA & E	Copies upon request
38	Same	TDPX	TDP master data file	CTL	SDA DPPE MA & E	Copies upon request

Table 16. Category II data

Distribution	FPAC					SPAC					T & FA					SSAC					SFOD					DPPE					Repro		SFOF DC	Total					
Type	A	B	C	F	D	A	B	C	F	D	A	B	C	F	D	A	B	C	F	D	A	B	C	F	D	A	B	C	F	D	B*	F	M	A	B	C	F	D	M
Program:																																							
DPES		4	3																												1				4	3			
ODGX	1	4																													1			1	4				
TDPX	1	4																													1			1	4				
ODPX	1	4		1	3												1														1	1	1	1	5		1	3	1
TRJX		4	3					2					1																		1				4	6			
HPPS		4	3					2																							1				4	5			
MTGS	1	4	3	1	4		1	5					2																		1	1	1	1	5	10	1	4	1
RETM		3	3																												1				3	3			
PRDX		3	3																												1				3	3			
PLAS							3					1					1														1				5				
AGCM							3		1			1		1																	1		1		4		2		1
CPPM							3		1			1		1																	1		1		4		2		1
EDPL										5		5		2						1											1	1	1		5		3	6	1
SCPS							3						2				2														1				5	2			
CVTS							3										1														1				4				
TVCS																	1														1				1				
7044 DUMP†																											1				1				1				
7094 DUMP†																											1				1				1				

Type code:
- A — NCR print, rush processing, not separated, messenger delivered
- B — NCR print, separated, normal processing and delivery
- B* — NCR original, separated, normal processing and delivery, for library or copying
- C — Reduced copy of NCR print, covered, normal delivery
- F — SC-4020 plots, F80 copy, rush delivery
- D — SC-4020 plots, duplicates of F80, normal delivery
- M — SC-4020 microfilm plots, develop every eight hours, save in document control
- † — When requested by DACON

DSIF raw tracking data requirements are given in Table 17.

b. S-band telemetry. The DSIF was required to obtain S-band telemetry from the *Surveyor III* spacecraft and provide the SFOF with such data.

Spacecraft telemetry data were to be received and recorded on magnetic tape. Baseband telemetry data were required by the CDC (mission-dependent equipment) for decommutation and real-time readout. The DSIF was also to perform precommunication processing of the decommutated data, using an onsite data-processing (OSDP) computer. The data were then to be transmitted to the SFOF in near real time, using high-speed data modems.

The telecommunications system is designed to provide a two-way communication link between the DSIF and the *Surveyor* spacecraft. The DSIF-to-spacecraft up link will be a PCM/FM/PM system. The spacecraft-to-DSIF down link may be operated PCM/FM/PM (transponder mode), PCM/FM/FM, PCM/FM/PM, or direct FM throughout all phases of the mission. Transponder mode is employed during the transit phase to permit two-way doppler shift measurements.

Four spacecraft modes of operation were available during the *Surveyor III* flight, for selection by SFOF/DSIF command, with the total information bandwidth of the down link dependent on the mode selected. The modes and their usable information bandwidths while operating at lunar distance are:

(1) SC Mode A – High-gain antenna with transmitter in high-power mode; nominal information bandwidth is 220 kHz.

(2) SC Mode B – High-gain antenna with transmitter in low-power mode; nominal information bandwidth is 2 kHz.

(3) SC Mode C – Omnidirectional antenna with transmitter in high-power mode; nominal information bandwidth should be 1 kHz.

(4) SC Mode D – Omnidirectional antenna with transmitter in low-power mode; nominal information bandwidth is 10 Hz.

c. Commands. Command transmission was another function provided by the DSIF. The transmission of approximately 250 commands to the spacecraft was required during the nominal sequence from launch to touchdown. This command requirement placed a second critical requirement for two-way communication with the spacecraft. Confirmation of the commands sent was processed by the OSDP computer and transmitted by TTY to the SFOF. The OSDP computer was capable of being used to verify command tapes punched on-site from TTY instructions received from the SFOF, but this function was not to be used for the *Surveyor I* mission.

d. Video data. It was required that video data be received and recorded on magnetic tape. These data were to be sent to the CDC, and at DSS 11 only, to the TV Ground Data Handling System (GDHS) for photographic recording. In addition, video data from DSS 11 were to be sent in real time to the SFOF for magnetic and photographic recording by the TVGDHS.

Table 17. Raw tracking data required from DSIF stations

Time/distance coverage and sampling rate	Data required	Accuracy[a]			Data presentation 1: Inflight 2: Postflight
		Class I	Class II	Class III	
1. Track spacecraft from separation to first midcourse at 1-min sample rate (after first hour, 5-s sample rate to end of first hour).	Doppler (2- and 3-way) Angles	A A	B B	C C	1. TTY 2. Magnetic tape
2. Track spacecraft from midcourse to touchdown at 1-min sample rate.	Doppler (2- and 3-way)	A	B	C	1. TTY 2. Magnetic tape
3. Track spacecraft from touchdown to up to 90 days at 1-min sample rate.	Doppler (2- and 3-way)	A	B	C	1. TTY 2. Magnetic tape

[a]Accuracy codes A, B, or C refer to the way that the data accuracies are broken down.

e. Additional requirements. The requirements were as follows:

(1) DSS 42. The following minimum capabilities were required from DSS 42:

(a) Acquisition and tracking of the *Surveyor* spacecraft.

(b) Generation and transmission of tracking data to the communications terminal equipment at the site.

(c) Acquisition, recording, decommutation, display, and processing of *Surveyor* spacecraft telemetry data.

(d) Transmission of processed telemetry data both high speed and TTY to the appropriate communications terminal equipment at the site.

(e) Generation and transmission of *Surveyor* spacecraft commands.

(2) DSS 61. At the start of DSS 61 visibility, the following minimum capabilities were required from DSS 61:

(a) Acquisition and tracking of the *Surveyor* spacecraft.

(b) Generation and transmission of tracking data to the communications terminal equipment at the site.

(c) Acquisition, recording, decommutation, display, and processing of *Surveyor* spacecraft telemetry data.

(d) Transmission of processed telemetry data both high speed and TTY to the appropriate communications terminal equipment at the site.

(e) Generation and transmission of *Surveyor* spacecraft commands.

(3) DSS 51 or 72. The following minimum capabilities existed for DSS 51 or DSS 72 during the DSS 42/DSS 61 visibility gap which occurred about 3 to 6 h after launch on April 18, 19, 20, 21, 1967:

(a) Acquisition and tracking of the *Surveyor* spacecraft.

(b) Generation and transmission of tracking data to the communications terminal equipment at the site.

(c) Acquisition, recording, decommutation, display, and processing of *Surveyor* spacecraft telemetry data.

(d) Transmission of processed telemetry data both high speed and TTY to the appropriate communications terminal equipment at the site.

(e) Generation and transmission of *Surveyor* spacecraft commands.

(4) DSS 11. At the start of DSS 11 visibility, the following minimum capability existed:

(a) Acquisition and tracking of the *Surveyor* spacecraft.

(b) Generation and transmission of tracking data to the communications terminal equipment at the site.

(c) Acquisition, recording, decommutation, display, and processing of *Surveyor* spacecraft telemetry data.

(d) Transmission of processed telemetry data both high speed and TTY to the appropriate communications terminal equipment at the site.

(e) Generation and transmission of *Surveyor* spacecraft commands.

(f) Acquisition, recording, and processing of *Surveyor* spacecraft video data.

2. GCF/NASCOM. The DSN GCF is that portion of the NASCOM which supported the *Surveyor III* mission by providing communication paths between the various DSN tracking stations throughout the world and the SFOF. This Communication System comprised the landlines, undersea cables, and radio circuits which carried teletype, voice, and high-speed data in real-time support of the *Surveyor III* mission. Figure 14 illustrates the configuration of the GCF in support of *Surveyor III* and the type of data carried over these circuits.

Since NASCOM circuits are utilized to support many installations and activities, of which the DSN/GCF is but one part, circuit usage must be on a requested and scheduled basis from GSFC. Those circuits that do not pass through GSFC must also be scheduled to ensure their availability.

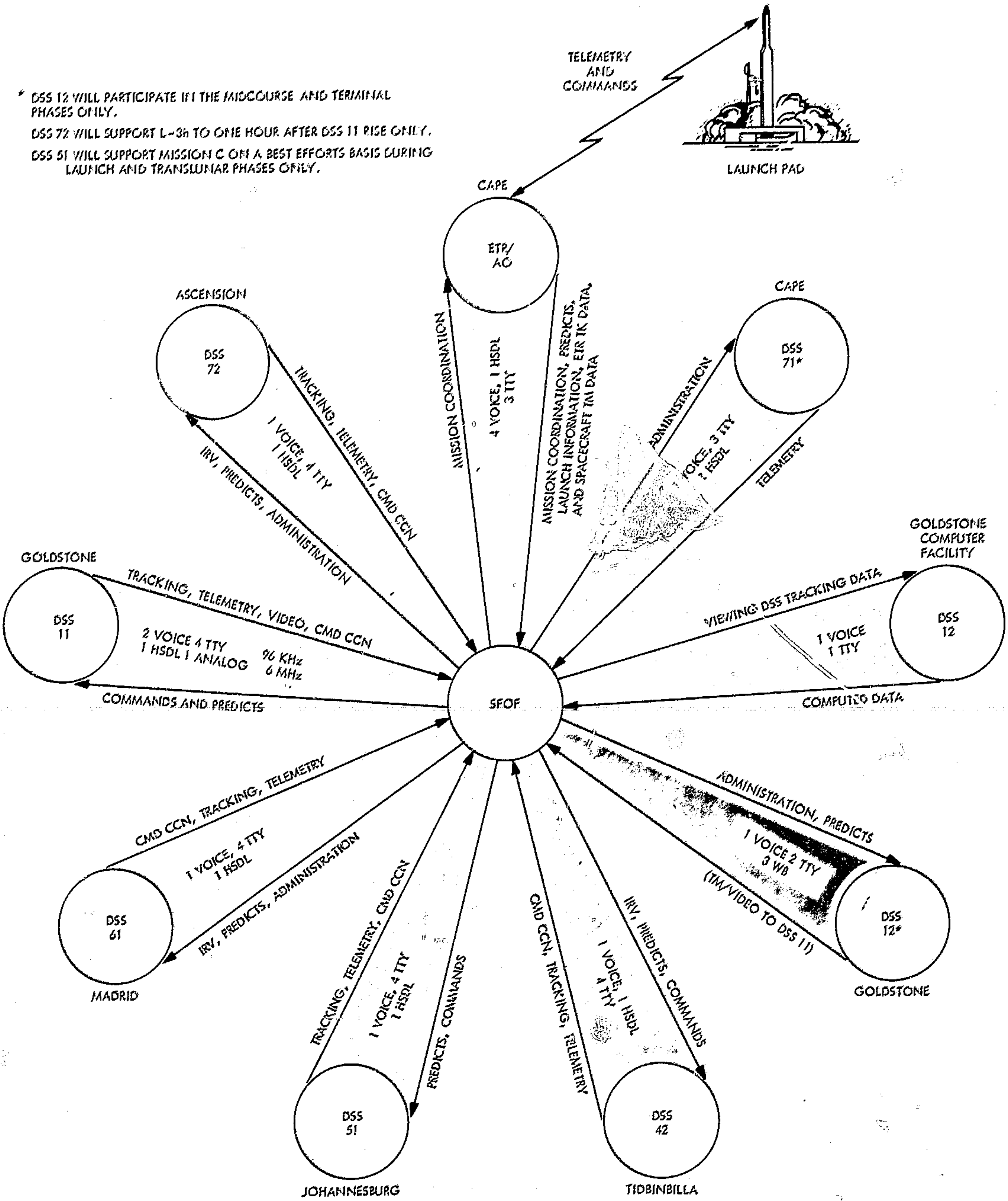


Fig. 14. NASCOM DSN/GCF circuit support for *Surveyor III* mission

a. Voice. The DSN/CCF provides a system of full-period, leased, four-wire, engineered, voice circuits to a majority of the sites in the network. Most of the voice circuits are routed via the GSFC Switching Center and comprise the SCAMA. Circuits are routed by hardwire and microwave wherever possible. These circuits extend to overseas points through transoceanic cables, or by high-frequency radio links in those cases where cables are not available.

b. Teletype. The DSN/CCF provides a system of full-period, full-duplex, leased links composed of leased and commercial facilities obtained from national, international, and foreign common carrier agencies. For purposes of reliability, overseas circuits employ undersea cables wherever possible, but are necessarily routed via radio facilities to reach certain locations.

c. DSS 42 communications. The *Surveyor* project requested that the outbound high-speed data lines from the SFOF to DSS 42 and DSS 61 be interfaced with project-supplied 202 data sets in order to permit transmission of simulated telemetry data from SDCC to the DSIF stations. This was done and the system was used to provide simulated data for *Surveyor III* testing. However, since the data sets were not standard equipment in the NASCOM system, some problems arose during test operations. Another significant development was the use of the *Intelsat* communications satellite to provide communications circuits to DSS 72, Ascension Island. Use of this satellite was committed by NASCOM for the *Surveyor III* mission. Due to the use of DSS 61, 71, and 72 in addition to the stations committed for the *Surveyor II* mission, additional lines between JPL and the Goddard Space Flight Center communications terminal are required. These circuits were ordered and provided for the C-5.0 test and the *Surveyor* launch. Also, an additional circuit requirement was necessitated by the transmission of real time telemetry data from the Carnarvon MSFN station to DSS 42. One voice and one high speed data line were to be supplied.

d. Additional requirements. The requirements were as follows:

(1) AFETR/SFOF. The minimum capabilities were:

(a) Two voice lines.

(b) One high-speed data line.

(c) One simplex TTY line from AFETR to SFOF.

(2) DSS 42/SFOF. The minimum capabilities were:

(a) One voice line.

(b) Two duplex TTY lines.

(3) DSS 61/SFOF. At the start of DSS 61 visibility, the following minimum communication capability existed:

(a) One voice line.

(b) Two duplex TTY lines.

(4) DSS 51 or DSS 72. During the DSS 42/DSS 61 visibility gap, the following capabilities existed:

(a) One voice line.

(b) Two duplex TTY lines.

(5) DSS 11/SFOF. At the start of DSS 11 visibility, the following minimum communication capabilities were operational:

(a) One voice line.

(b) One high-speed data line (1100 bits/s or 96 kHz).

(c) One duplex TTY line.

3. DSN/SFOF. The DSN/SFOF Communications System was to provide the capability for transferring all the necessary information required for space flight operations within the SFOF. Such system was required to include: (1) all voice communication capabilities within the SFOF, (2) all closed circuit TV, (3) all teletype distribution, (4) all high-speed data distribution and (5) all data received over microwave channels within the SFOF.

The SFOF was designed to provide a reliable, flexible, centralized, and relatively mission-independent capability to conduct and control simultaneous lunar or planetary missions. The SFOF, in meeting its requirements to the *Surveyor* Project, dedicated numerous of these mission-independent capabilities in support of the *Surveyor III* mission. These capabilities included such operating functions as communications, displays, and data processing.

a. Communications. The DSN Intracommunications System (DSN/ICS) for the *Surveyor III* mission consisted of those circuits, switching facilities, terminals, equipment, and personnel internal to the SFOF which were required in order to transmit, receive, and distribute various types of intelligence. The DSN/ICS was divided into nine subsystems as follows:

(1) Operational Voice Communications Subsystem (OVCS).

(2) Operational Status Recording Subsystem (OSRS).

(3) Operational Public Address Subsystem (OPAS).

(4) Operational Voice Recording Subsystem (OVRS).

(5) Operational Miscellaneous Audio Subsystem (OMAS).

(6) Operational Teletype Communications Subsystem (OTCS).

(7) Television Communications Subsystem (TVCS).

(8) High-Speed Data Subsystem (HSDS).

(9) Wide-Band Communications Subsystem (WBCS).

b. Displays. Specialized wall and projector displays were required to provide historical and current information for use in each of the following areas:

(1) Operations Area.

(2) Flight Path Analysis Area (FPAA).

(3) Mission Support Area No. 1A (SPAA).

(4) Mission Support Area No. 1B (SSAA).

c. Data processing. Various data processing functions were required, to effectively support the *Surveyor III* mission, within the SFOF. These requirements were:

(1) Computation of acquisition predictions for DSIF stations: antenna pointing angles and receiver and transmitter frequencies.

(2) Orbit determination.

(3) Midcourse maneuver computation and analysis.

(4) On-line telemetry processing.

(5) Command tape generation.

(6) Simulation data generation (telemetry and tracking data).

d. Facilities. Mission control facilities were also to be provided within the SFOF as follows:

(1) Space in the mission-dependent and mission-independent areas was provided. Mission Control Room No. 1 and Mission Support Area No. 1, which included the Spacecraft Performance Area and the Space Science Area, were devoted exclusively to the *Surveyor I* mission.

(2) Flight Path Analysis Area No. 1 was a shared area: however, the *Surveyor I* mission had its exclusive use during the flight. Common users areas required included DSIF Net Control, the Data Processing Area, and the Communications Center.

e. Additional requirements. The following minimum capabilities were required within the SFOF for *Surveyor III* support:

(1) One operational TPS 7288-7044 computer string in the Mode III configuration.

(2) Two operational 7094 computers in the Mode IV configuration.

(3) Diesel generators as the power source for all SFOF computers committed to *Surveyor.*

(4) The OVCS system committed to *Surveyor* less its intercom capability.

(5) CCTV displays of TTY data and line-status.

(6) Transmission of incoming telemetry data, both high speed and TTY, to the appropriate processing and display devices.

f. Ground communications. These included the following:

(1) AFETR/SFOF. The requirements were:

  (a) Two voice lines.

  (b) One high-speed data line.

  (c) One simplex TTY line from AFETR to SFOF.

(2) DSS 61/SFOF. The requirements were:

  (a) One voice line.

  (b) Two duplex TTY lines.

(3) DSS 11/SFOF. At the start of DSS 11 visibility, the following minimum communication capabilities were operational:

  (a) One voice line.

  (b) One high-speed data line (110 bits/s or 96 kHz).

  (c) One duplex TTY line.

(4) DSS 42/SFOF. At the start of DSS 42 visibility, the following minimum communication capability need existed: one duplex TTY line.

(5) The Project had requested that the outbound high-speed data lines from SFOF to DSS 42 and DSS 61 be interfaced with project-supplied 202 data sets in order to permit transmission of simulated telemetry data from SDCC to the Deep Space Stations. This was done and the system was used to provide simulated data for *Surveyor III* testing. However, since the data were not standard equipment in the NASCOM system, some problems arose during test operations. Another significant change was use of the *Intelsat* communications satellite to provide communications circuits to DSS 72, Ascension Island. Use of this satellite was committed by NASCOM for the *Surveyor III* mission. Due to the use of DSS 61, 71, and 72 in addition to the stations committed for the *Surveyor II* mission, additional lines between JPL and Goddard Space Flight Center communications terminal were required. These circuits were ordered and provided for the C-5.0 test and the *Surveyor* launch. Also, an additional circuit requirement is caused by the transmission of real-time telemetry data from the Carnarvon MSFN station to DSS 42. One voice and one high-speed data line were to be supplied.

IV. *Surveyor III* TDS Flight Preparation

The TDS had the responsibility to properly prepare for the *Surveyor III* Flight. Such flight preparation was accomplished by unique TDS configuration and testing which is treated in the following sections.

A. Configuration

The configuration of individual agencies that comprise the TDS, in preparation for the *Surveyor III* flight, is given below.

1. Air Force Eastern Test Range. The AFETR configuration that was prepared to meet the requirements placed on the TDS is presented here. The areas of preparation include (a) tracking, (b) VHF telemetry, (c) S-band telemetry, (d) RTCS, and (e) building, designated AO, located at Cape Kennedy.

Table 18. AFETR prelaunch configuration

Station	Radar	VHF telemetry	S-band telemetry
Merrit Island	X		
Cape Kennedy	X	X	X
Patrick AFB	X		
Grand Bahama Island	X	X	X
Grand Turk	X		
Timber Hitch		X	X
Coastal Crusader (RIS 1)		X	X
Ascension Island	X	X	X
Twin Falls	X	X	X
Pretoria	X	X	X
Sword Knot (RIS 2)		X	X

a. Tracking. The prelaunch configuration of the AFETR is shown in Table 18 complete with each station committed, radar, and telemetry capabilities.

A major element in the *Surveyor III* AFETR configuration was the positioning of the RIS. The RIS were located (according to launch day, time, azimuth criteria) for projected planned coverage of the *Surveyor III* launch. Figure 15 gives the RIS configuration for AFETR launch coverage, which was necessary to meet the aforementioned (see Section III, Table 8) class I requirements.

The Acquisition Aids at Bermuda, Grand Canary, and Kano were configured to tract the vehicle and provide RF inputs to the telemetry (TLM) receivers. Performance recorders were configured to record AGC and angle errors for postmission analysis. The acquisition aids would provide TLM RF inputs from Bermuda acquisition of signal through loss of signal at Kano. The C-band radars at Bermuda and Carnarvon were to provide radar beacon tracking, magnetic tape recording at a minimum of 10 points per second, and real time data transmission to GSFC and AFETR. Bermuda configuration would track the *Centaur* vehicle in conjunction with AFETR radars during the powered flight phase of the mission, and transmit real-time, high-speed data to GSFC and to the RTCS at AFETR. Also, Bermuda was to transmit real-time, low-speed radar data to GSFC.

The resources required primarily to satisfy the *Surveyor III* mission metric needs were:

(1) The FPQ-6 C-band radar at Antigua.

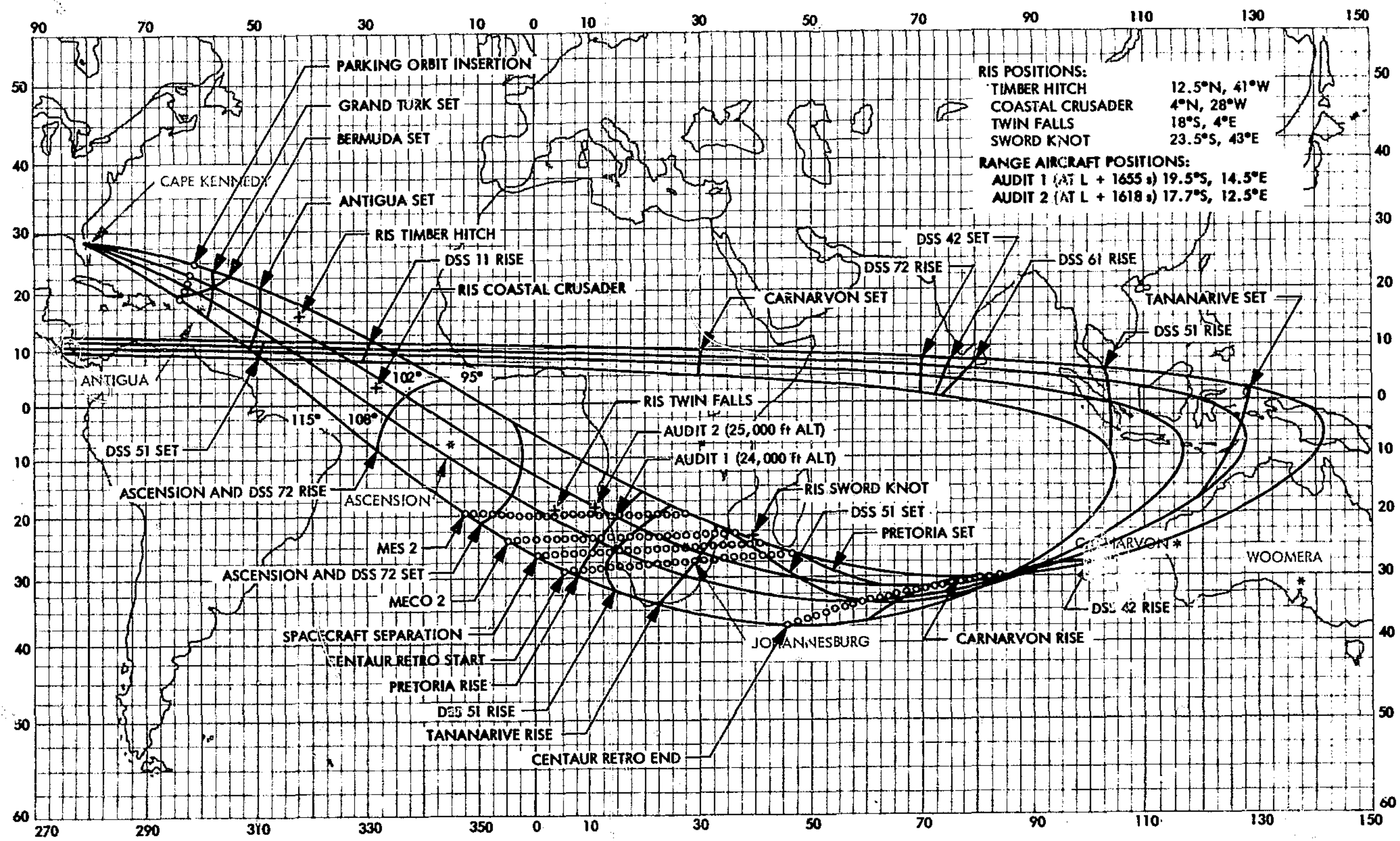


Fig. 15. *Surveyor III* near-earth phase, earth track

(2) The C-band radar aboard the RIS *Twin Falls.*

b. VHF telemetry. The AFETR resources committed to support the VHF telemetry requirements were: Tel 2, GBI, Antigua, *Timber Hitch, Twin Falls, Coastal Crusader, Sword Knot,* and Ascension Island. All class I requirements were expected to be met. The coverage plan in OD 3400 indicated some minor gaps in providing continuous coverage.

c. S-band telemetry. AFETR stations at Antigua, Ascension Island and the three RIS were configured to meet the *Surveyor III* S-band requirements.

A 3-ft S-band antenna with its associated downconverter, receiver, etc. was in place at Ascension Island. This system provided the S-band data from Ascension Island for the *Surveyor I* launch and was to be used to backup the TAA-3A antenna system. A similar backup system was later provided to Antigua. In addition, the RIS *Coastal Crusader* and *Timber Hitch* were to cover the early interval after the interval when the Antigua view was terminated.

The three RIS were to provide S-band coverage on a limited data commitment. Confidence ran fairly high in these systems because the RIS had successfully provided S-band coverage for former *Surveyor* missions and other space projects.

Prior to launch, the AFETR expressed confidence in the ability to meet all the Class I requirements.

d. Real-time computer system. The RTCS was configured to provide effective support for the *Surveyor III* mission.

RTCS configuration allowed for use of information from AFETR radars (pre- and post-retro data), and MSFN stations (post-retro data and post-injection data). The RTCS was to use the above information to compute orbital elements and injection conditions, which was to be transmitted to the SFOF. DSS acquisition information based on pre-retro orbital computations was also to be prepared by the RTCS.

In addition, the AFETR/RTCS was to transmit IRV messages and orbital predicts. A "mapping to lunar encounter" message was also required for both the pre- and post-retro orbits.

Following the single-station solutions, the RTCS was to compute and transmit to the SFOF pre- and post-retro recursive accumulative orbits. An I-matrix and a lunar mapping message based on each solution was to be included. Figure 16 gives the RTCS configuration for metric tracking and computed data flow.

e. Building AO. The configuration of major equipment components in building AO were the switch matrix for selecting the AFETR data, the CDC for processing the selected PCM spacecraft data, the bit synchronizer for data smoothing and signal conditioning, the asynchronous Bell 202-D data modem for data transmission, and the synchronous Hallicrafters modem which served as a backup. In addition, an analog display was available for the display of next-station or look-ahead data.

The various AFETR stations were interfaced with building AO to provide NRT and look-ahead data to the SFOF and committed stations. The stations were configured as follows.

Tel-2 was equipped to receive both S-band (low power) and VHF data before and after launch. From $L - 5$ until LOS, Tel-2 was to supply spacecraft data derived from the VHF link to building AO. The input to the discriminator bank was as shown in Fig. 17. Look-ahead data after launch was made available from GBI as shown in Fig. 17, also.

GBI was configured to receive the VHF data link only. These data were to be transmitted to Tel-2 on the sub-cable 14.5-kHz sub-carrier. Data could then be selected for transmission to the SFOF at any time after GBI acquisition, by selecting the TDM serial PCM data. At this point in time, there would be no look-ahead capability (due to sub-cable restrictions) until Antigua acquisition and verification that data from Antigua were of good quality. At this time, the switch was to be made at GBI to allow that Antigua was of good quality on the 14.5-kHz sub-carrier. The switch configuration at that time is as shown in Fig. 18. When this occurred, the look-ahead capability was retrieved to a limited extent. At Ship 1 acquisition, look-ahead data were to be obtained on the Ship 1/Cape HF link only.

Antigua was configured to serve as a relay for three down-range stations: Ship 1, Ship 2, and Ascension Island. Until spacecraft separation, Antigua was committed to receive and retransmit all data received on the

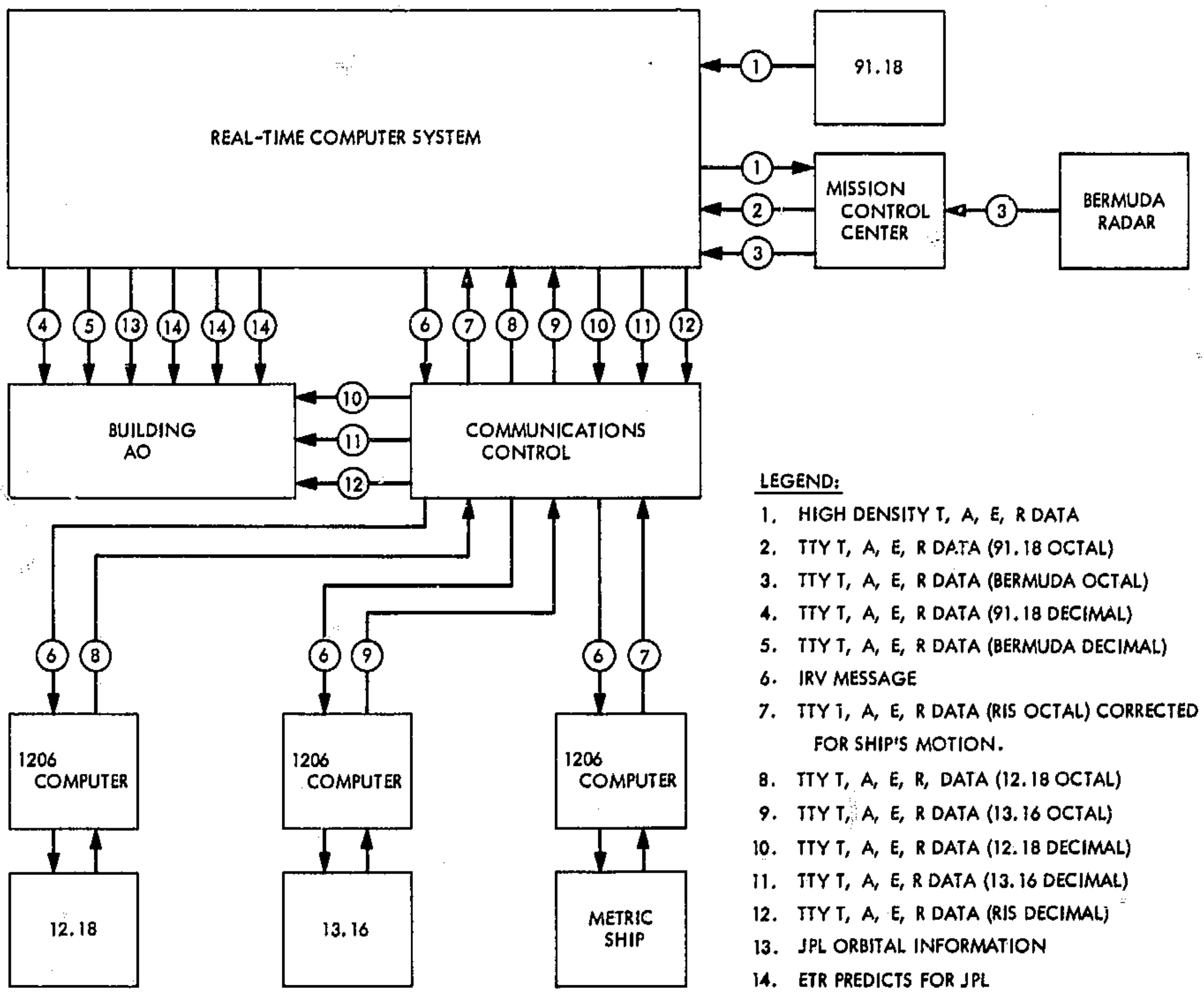


Fig. 16. Metric tracking and computed data flow

VHF link. At spacecraft separation, Antigua would repatch SCO inputs so that down-range data could be relayed on 14.5-kHz, 22-kHz, 30-kHz, and 40-kHz subcarriers, respectively.

The up-range RIS would be equipped to receive either S-band or VHF data links. If S-band signal strength was sufficient before *mark* event 15 to give good data quality, this link was to be used to obtain PCM data for retransmission.

The remaining RIS (2 and 3) and Ascension Island were configured to receive S-band data and retransmit, either directly by HF, or by HV relay, to Antigua. The configuration during tracking at Ascension Island is shown in Fig. 19.

2. ***Goddard Space Flight Center.*** The MSFN managed by GSFC, was configured to support the *Surveyor I* mission by providing tracking, VHF telemetry, and computer support.

Table 19 indicates the GSFC/MSFN Station and equipment configuration used for supporting *Surveyor III.*

a. Tracking. Acquisition Aid Tracking of the *Atlas* (229.9 MHz) and the *Centaur* (225.7 MHz) links was configured for the 300 kHz bandwidth cross-correlation mode.

Table 19. GSFC/MSFN *Surveyor III* station configuration

Station	Acq. aid	TLM	C-band radar	SCAMA	TTY	Radar HSD	Real-time read-outs	Radar LSD	USB
BDA	X	X	X	X	X	X	X	X	
TAN	X	X		X	X		X		
CRO	X	X[a]	X	X	X		X[a]	X	X
GSFC				X	X	X			

[a]If TLM signal is adequate.

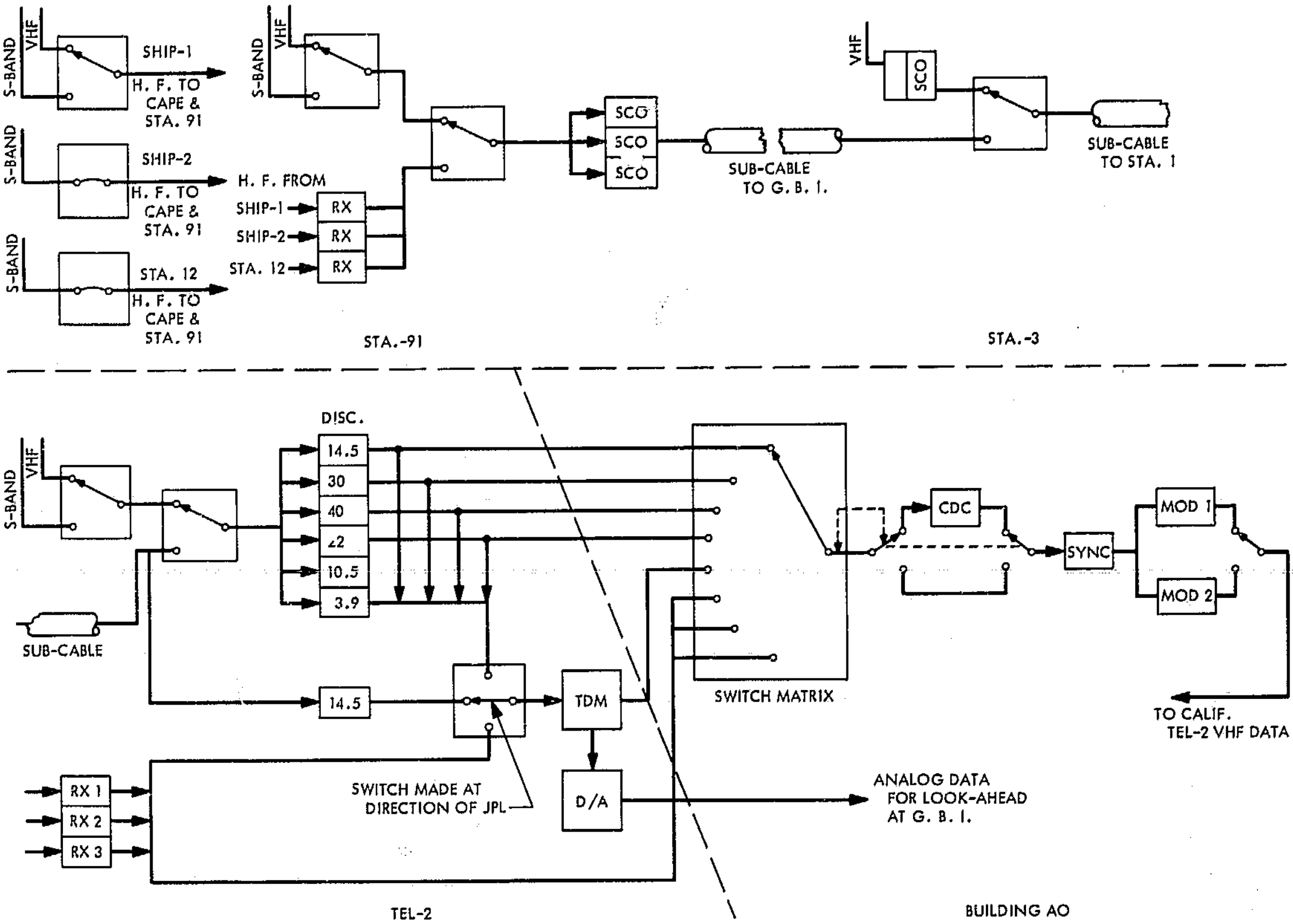


Fig. 17. Building AO from L–5 to Tel-2 set

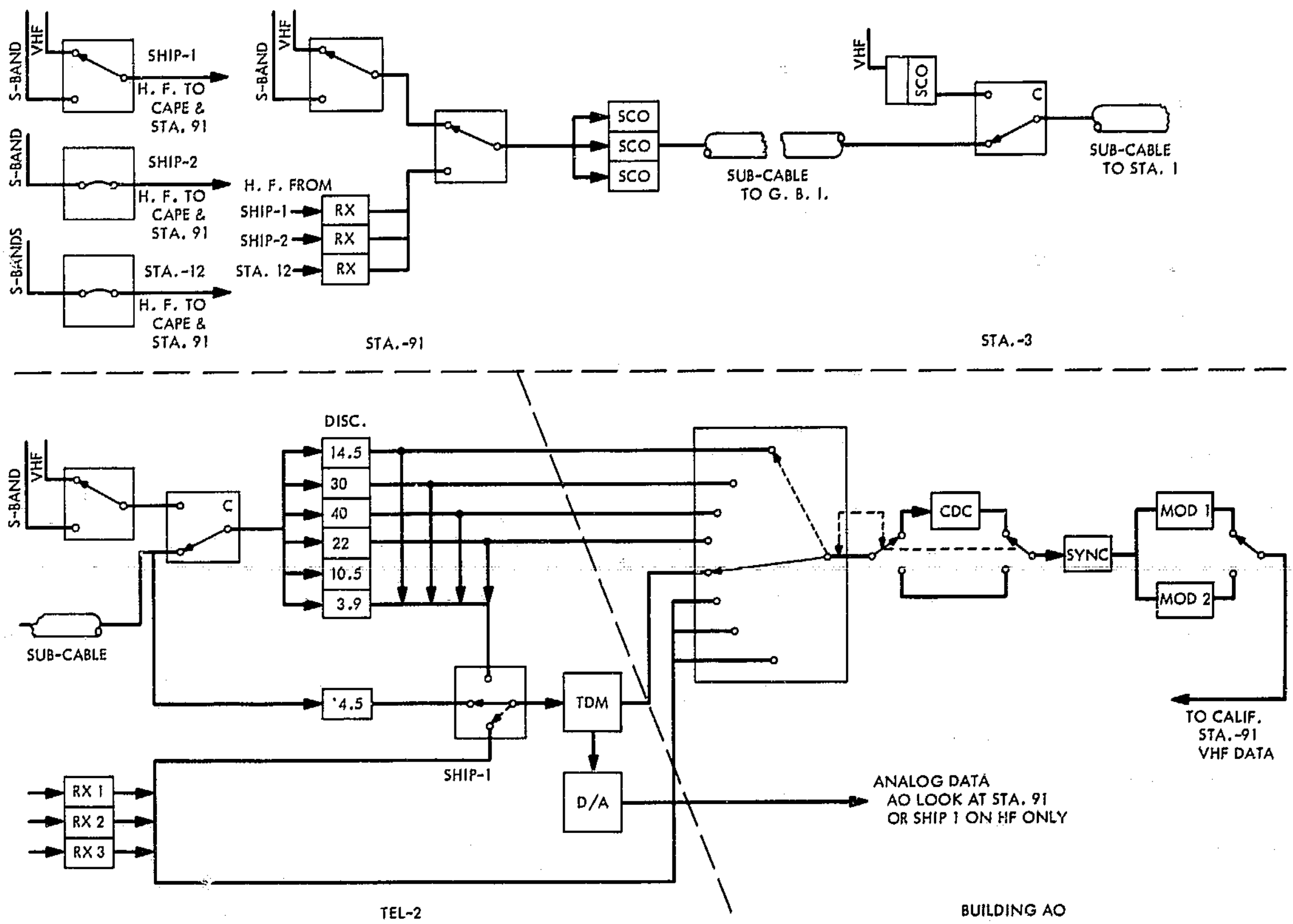


Fig. 18. Building AO from handover to station 9.1

The MSFN station at Bermuda was required to track both the *Atlas* and the *Centaur* links. The stations at Tananarive and Carnarvon had requirements, and were configured to track the *Centaur* link at 225.7 MHz.

b. VHF telemetry. The MSFN stations at Bermuda, Tananarive, and Carnarvon were to receive and record the *Centaur* telemetry link from Bermuda acquisition of signal to the Carnarvon loss of signal. The Bermuda station was also configured and required to receive and record the *Atlas* telemetry link. Additionally, all stations were to confirm various flight events. Carnarvon coverage was only on a "best obtainable" basis, due to range.

Concerning mark events, Bermuda, Tananarive, and Carnarvon were to confirm acquisition of signal, loss of signal and occurrence of mark events in the following manner:

(1) The event was to be verbally confirmed in real time.

(2) The GMT occurrence of each event was to be verbally confirmed as soon as possible after each occurrence.

(3) Confirmation of each event, occurrence, and time was to be reported via TTY in near real time.

(4) Tananarive was required to report readings at acquisition, after one minute of track, and at loss of signal.

(5) Carnarvon was required to report readings at acquisition, and then report changes recorded during the time the vehicle was in view.

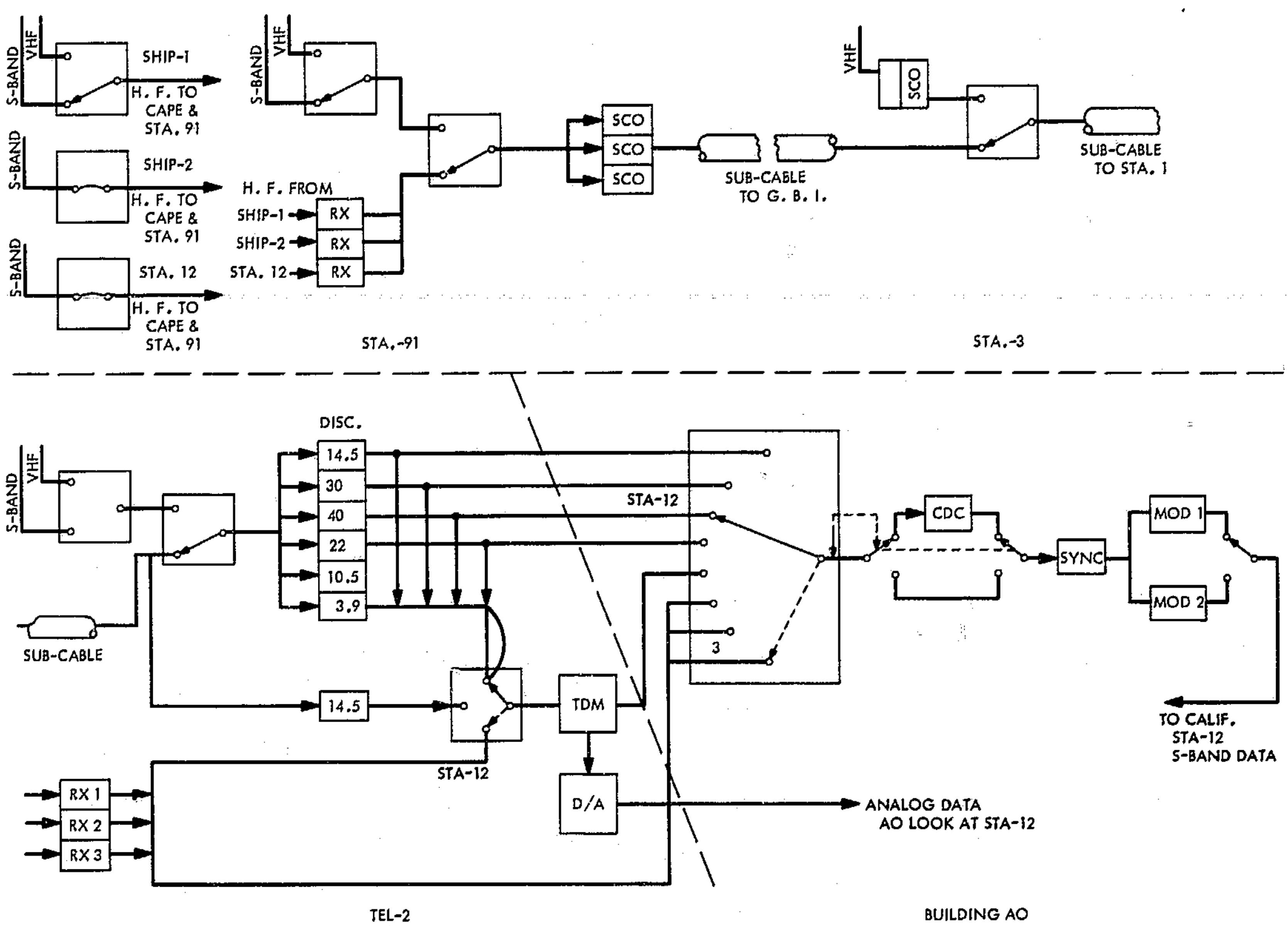


Fig. 19. Building AO from handover to Ascension Island

With the advent of the *Surveyor* parking orbit trajectory missions and the development of the unified S-band system, the resources of the AFETR are being strained in an attempt to provide full support. Therefore, Carnarvon participation would plan a significant role in solving this problem. Carnarvon was configured to receive 550-bit, bilevel, non-return-to-zero (NRZ) telemetry data via the S-band link and was required to transfer this data via the NASCOM facilities to the DSN Tidbinbilla station (DSS 42). Also, applicable engineering instructions were to be provided by the MSFN to alter the unified S-band (USB) configuration to meet this requirement. Figure 20 shows the *Surveyor* USB configuration.

The MSFN was also responsible to provide real-time telemetry data recordings at low speed.

c. Computer. GSFC computers were required to generate predict information for MSFN stations. In addition, the GSFC computers were to be configured to provide data in real time to the AFETR RTCS for orbit computation.

Prior to launch the GSFC Data Operations Branch (DOB) was to prepare nominal *Centaur* vehicle pointing data for the MSFN stations at Carnarvon and Tananarive. These data were required for transmission to the aforementioned stations by $L - 7$ days.

During the powered-flight phase, the GSFC computers were to receive launch trajectory data from Bermuda and AFETR via the launch monitor subsystem. The trajectory was to be computed and the resulting parameters

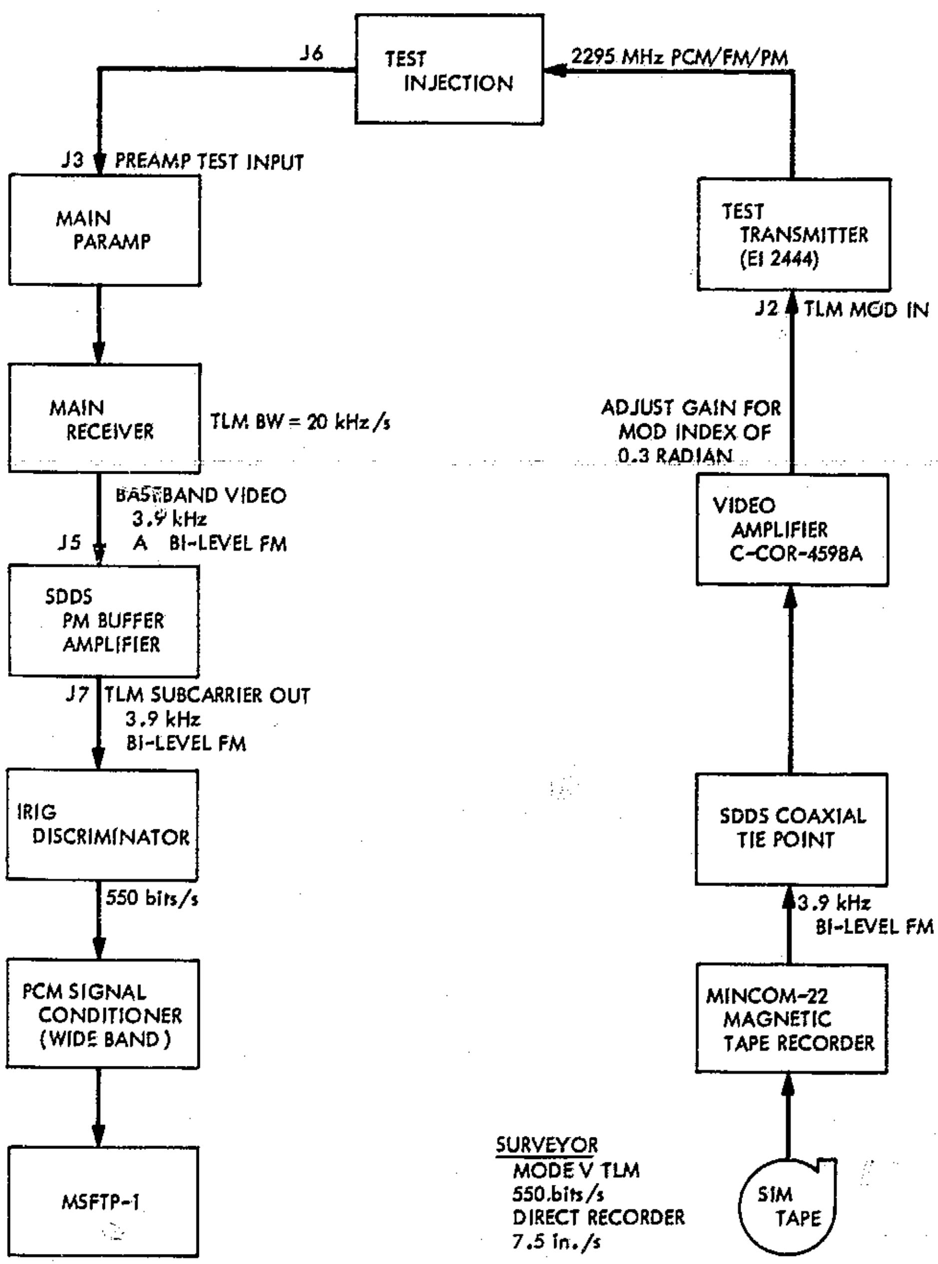


Fig. 20. Surveyor unified S-band configuration

used to drive displays at GSFC Operations Control Center (OPSCON). In Fig. 21, the *Surveyor III* ground communications configuration and computer support is shown.

At the end of the *Centaur* first powered flight (MECO No. 1, *mark* event 8), the DOB was to pass orbital injection parameters to the MSFN Network Controller. The Network Controller will pass these parameters by voice to building AE and by TTY to building AE and LeRC.

GSFC computers were configured to receive in-flight trajectory data from liftoff to LOS by AFETR stations and appropriate RIS. Data were to be transmitted via MCC-K to GSFC for computation of acquisition messages for MSFN stations.

Such acquisition messages were to be generated and transmitted to the participating MSFN stations at H −25 and H −5 min. The H −25 acquisition messages were based on actual first-burn and nominal second-burn data. The H −5 acquisition messages for Carnarvon would take into account post-injection tracking data from Pretoria (if available).

The low-speed TTY data from Carnarvon would be reformatted to the standard 38-character radar data format by the GSFC computers and retransmitted to the RTCS at AFETR.

At the end of the retromaneuver thrust (*mark* event 24), the DOB was to pass orbital injection parameters to the MSFN Network Controller. The Network Controller then passed these parameters by voice to building AE and by TTY to building AE and LeRC. Additional appropriate orbit information would be passed to the Network Controller as it became available during the mission.

As soon as it is possible after fulfillment of real-time mission support, the following data were to be reformatted on magnetic tape for delivery to LeRC for analysis:

(1) High-speed data received from AFETR in the tape format specified.

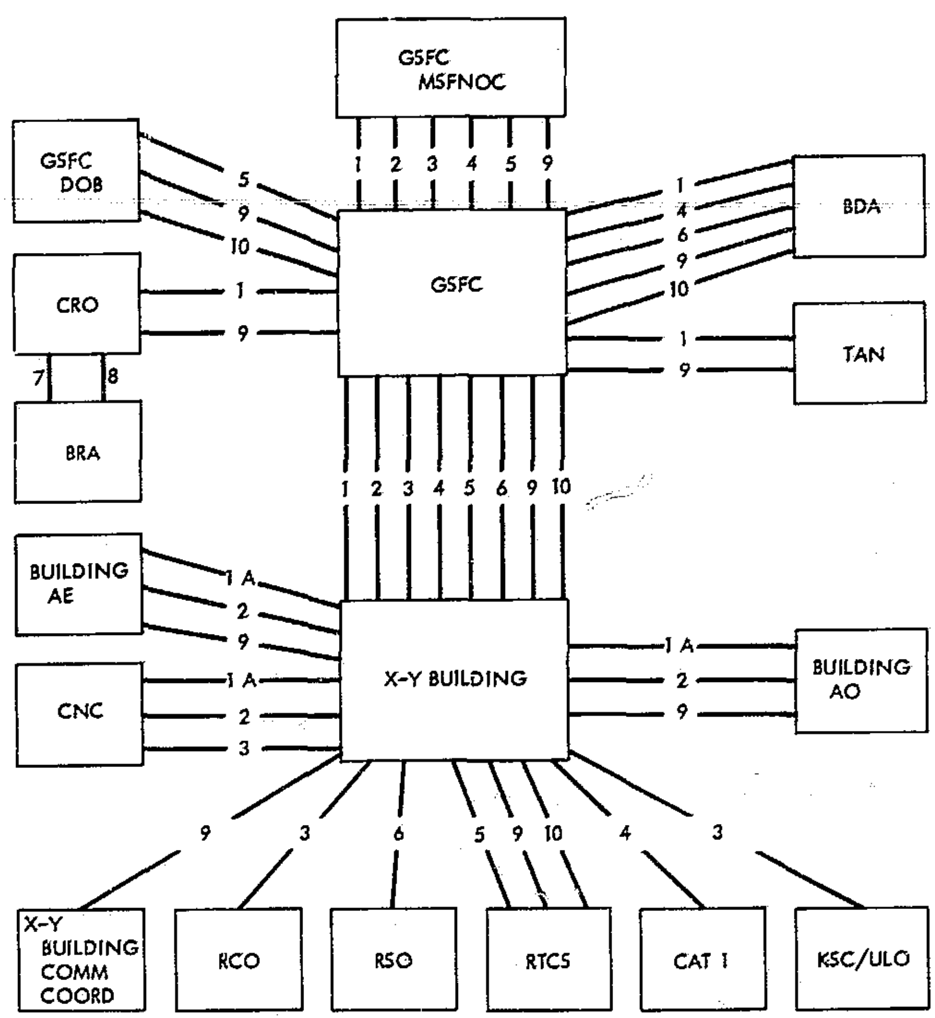


Fig. 21. *Surveyor III* near-earth phase ground communications configuration and computer support

(2) Low-speed TTY radar data reformatted on magnetic tape using the standard GSFC time-azimuth-elevation range format.

3. *Near-earth phase coverage summary.* A near-earth phase summary is given in the following paragraphs for all the agencies and their related stations supporting this portion of the *Surveyor III* flight.

Coverage intervals for the AFETR and MSFN tracking, radar, and telemetry stations are presented in graphical forms. Station coverage estimates, significant *Centaur* and spacecraft flight events and Class I instrumentation coverage requirements are also presented, so that coverage vs requirements may be evaluated.

Rise times for DSN stations are shown where they affect spacecraft coverage of S-band stations. The class I coverage requirements are shown as shaded areas on the various following figures. Figure 22 shows the estimated coverage of the 2295 MHz link for all days during the April 1967 launch opportunity. Figure 23 shows the estimated coverage of the 225.7 MHz link for all April launch days. Figure 24 gives the estimated coverage of S-band telemetry on the launch day of April 17, 1967. The projected coverage for C-band tracking radars is shown in Fig. 25. Finally, Fig. 26 indicates an estimation of the coverage that was expected for the *Centaur* VHF telemetry.

Table 20 gives the near-earth phase station abbreviations and radar identification as an aid to understanding the aforementioned Figs. 22 through 26.

All station and radar abbreviations used on the coverage charts (Figs. 22 through 26) are listed in Table 20.

a. C-band radar. The various rise and set times as noted in Figs. 22 through 26 are based on the following data:

(1) Start Time = ### 2 deg plus 10 s in most cases, except where influenced by ground clutter or the start of a range interval.

(2) End Time = ### 0.5 deg above the horizon for Mipir radars, or 2 deg above the horizon for FPS-16 or MPS-25 radars. These times may also be influenced by ground clutter. The FPS-16 and MPS-25 radars are carried out only to the end of the fourth range interval (approximately 4000 n. mi). It was expected that the beacon signal would be below a trackable level at these sites beyond the fourth range interval at 80 PRF.

Table 20. Near-earth-phase station abbreviations and radar identification

A. Station abbreviations	
Abbreviation	**Tracking station/location**
Tel-2	CKAFS
Tel-4	KSC
GBI	Grand Bahama Island (AFETR)
BDA	Bermuda (MSFN)
ANT	Antigua (AFETR)
LIM	RIS *Timber Hitch* (AFETR)
WHI	RIS *Coastal Crusader* (AFETR)
UNI	RIS *Twin Falls* (AFETR)
ASC	Ascension Island (AFETR)
PRE	Pretoria (AFETR)
YAN	RIS *Sword Knot* (AFETR)
CRO	Carnarvon (MSFN)
DSS 42	Tidbinbilla
B. Radar identification	
Radar	**Location**
BDA	Bermuda
7.18	Grand Turk
91.18	Antigua
T-11C	RIS *Twin Falls*
13.16	Pretoria
CRO	Carnarvon
12.18	Ascension Island

4. *Deep space network.* The major elements of the DSN, configured to support *Surveyor III*, were the DSIF, the GCF, and the SFOF.

a. Deep space instrumentation facility. The DSIF configuration for tracking and data acquisition stations (Deep Space Stations) are located around the earth, so the antennas of one of three selected stations situated 120 deg apart in longitude may continuously observe a spacecraft during its mission. The stations (see Table 21) were committed, as indicated, to support the TDS system for the *Surveyor III* mission.

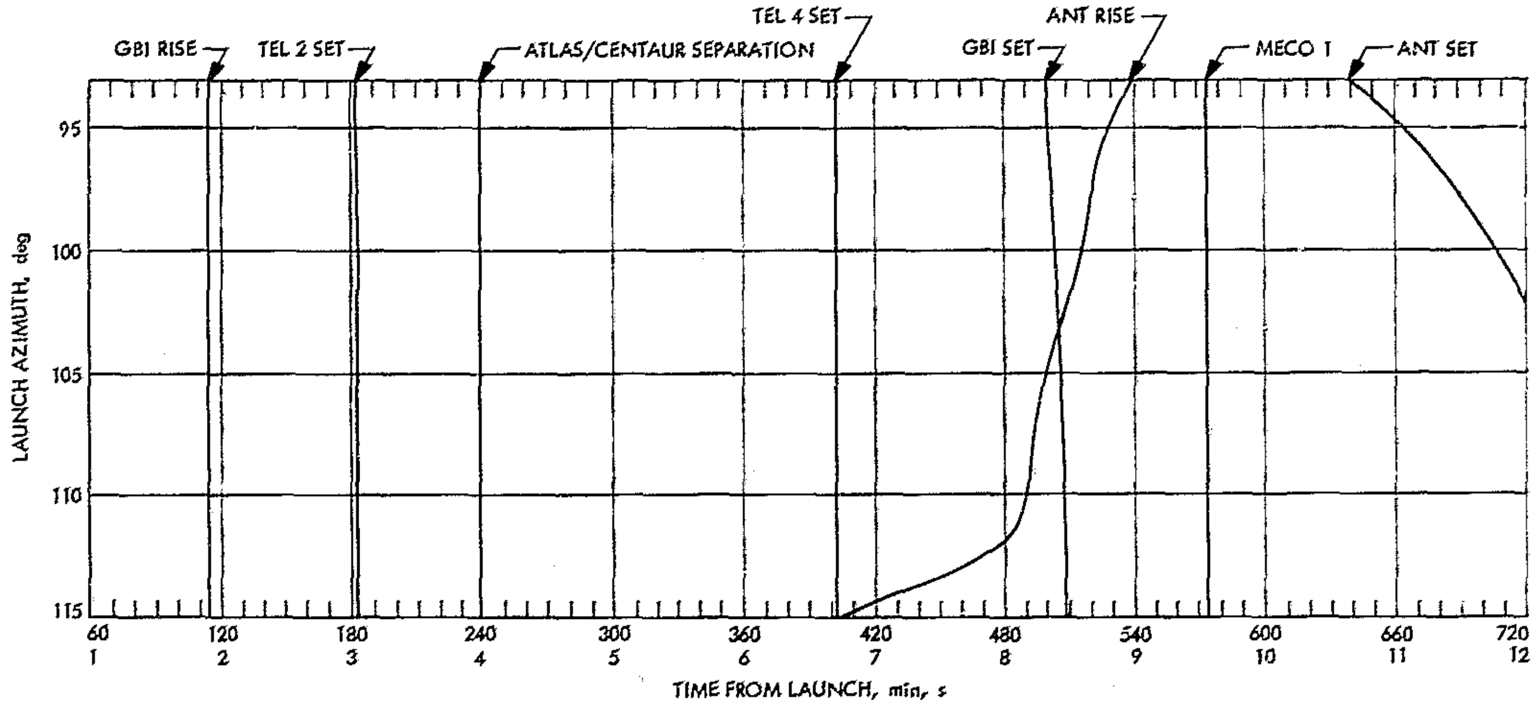


Fig. 22. Link 2295 MHz up-range coverage (all days)

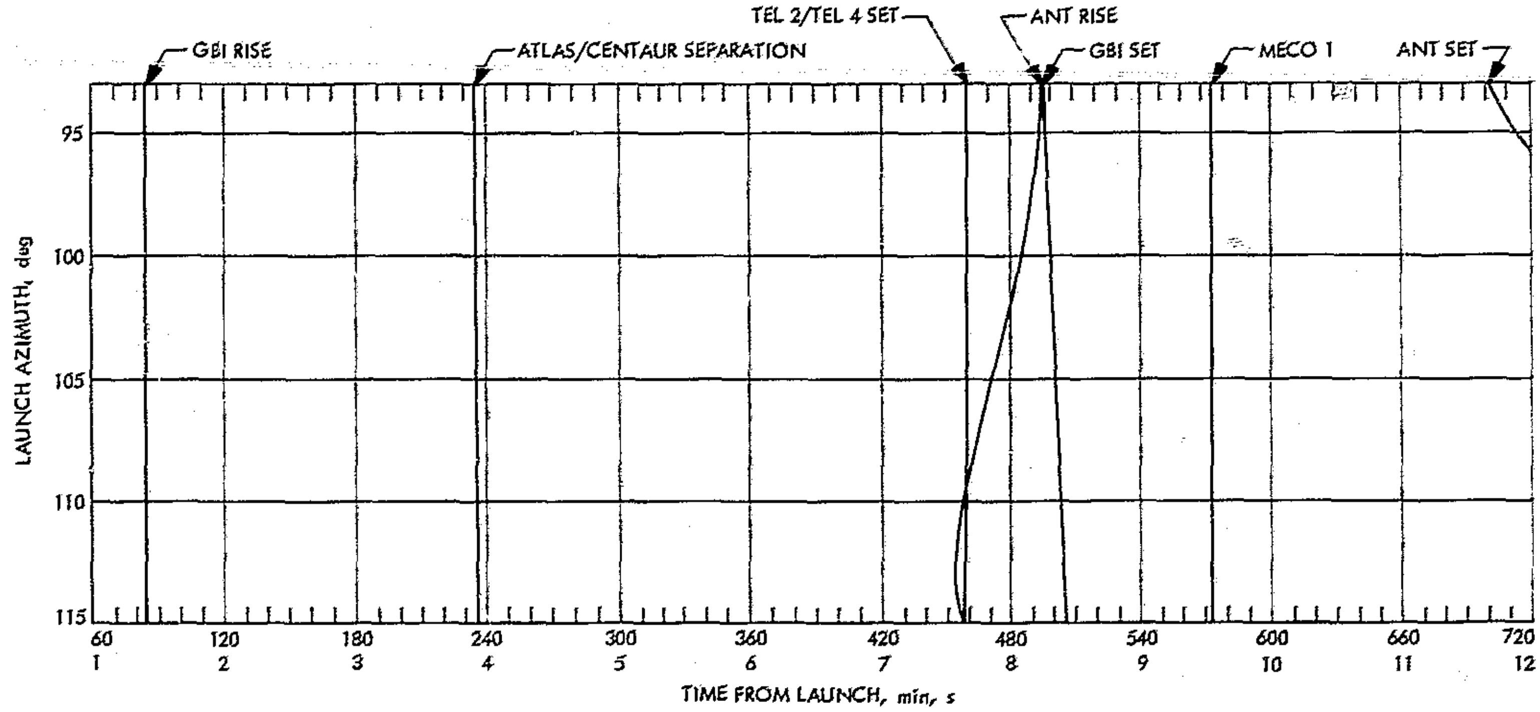


Fig. 23. Link 225.7 MHz up-range coverage (all days)

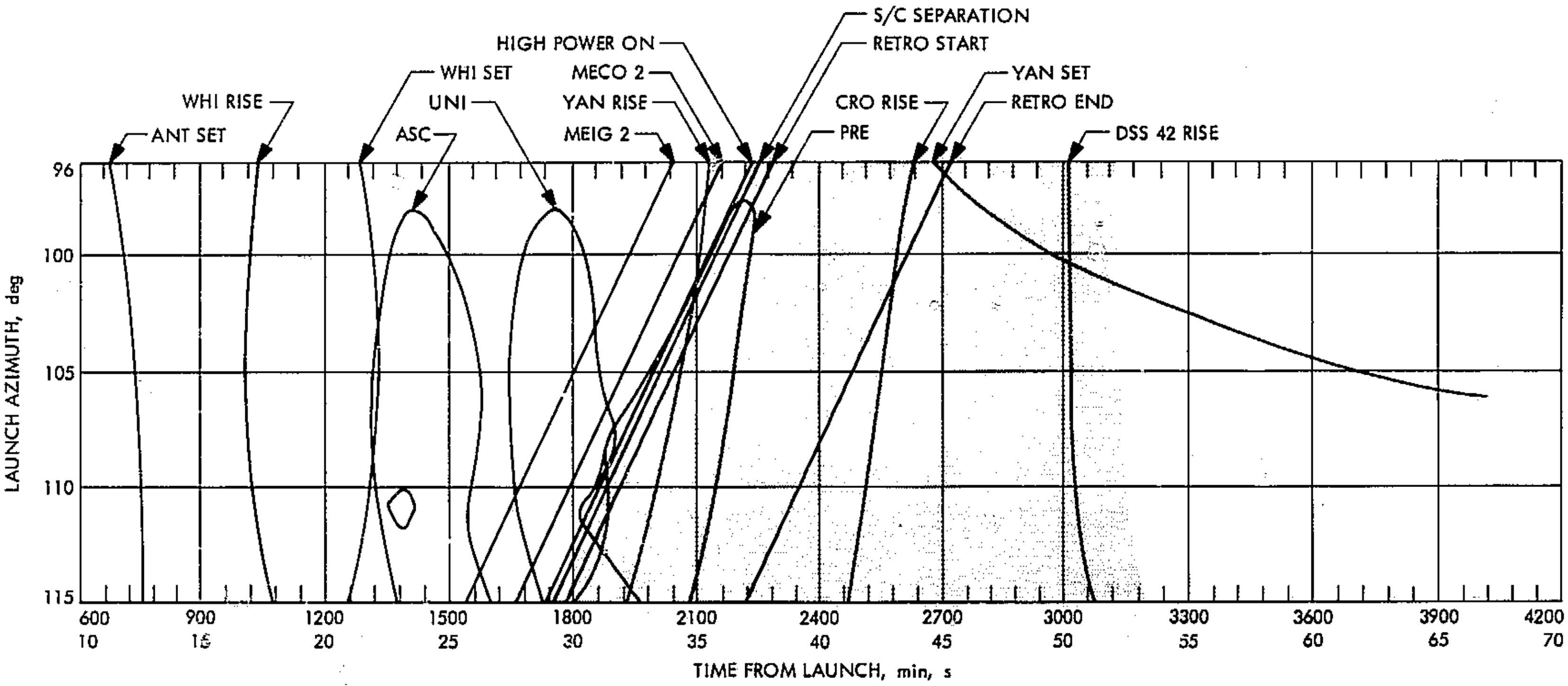


Fig. 24. Coverage for spacecraft telemetry S-band

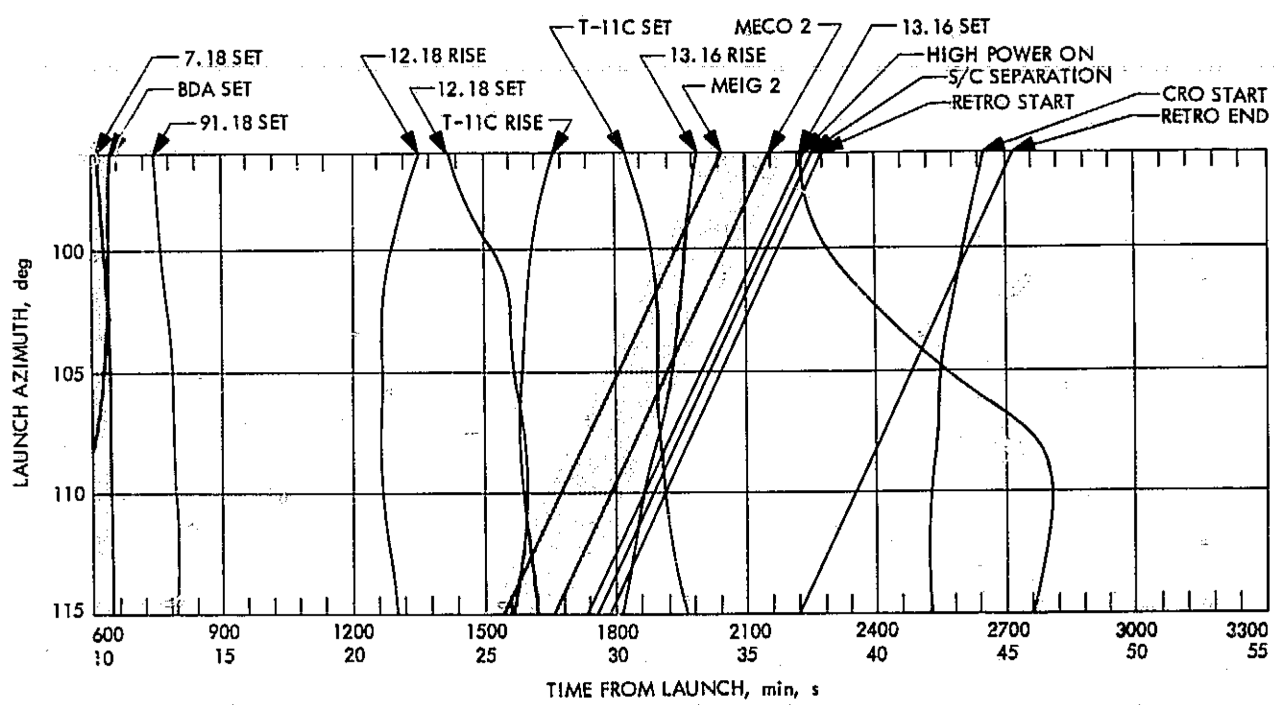


Fig. 25. Coverage for C-band tracking radars

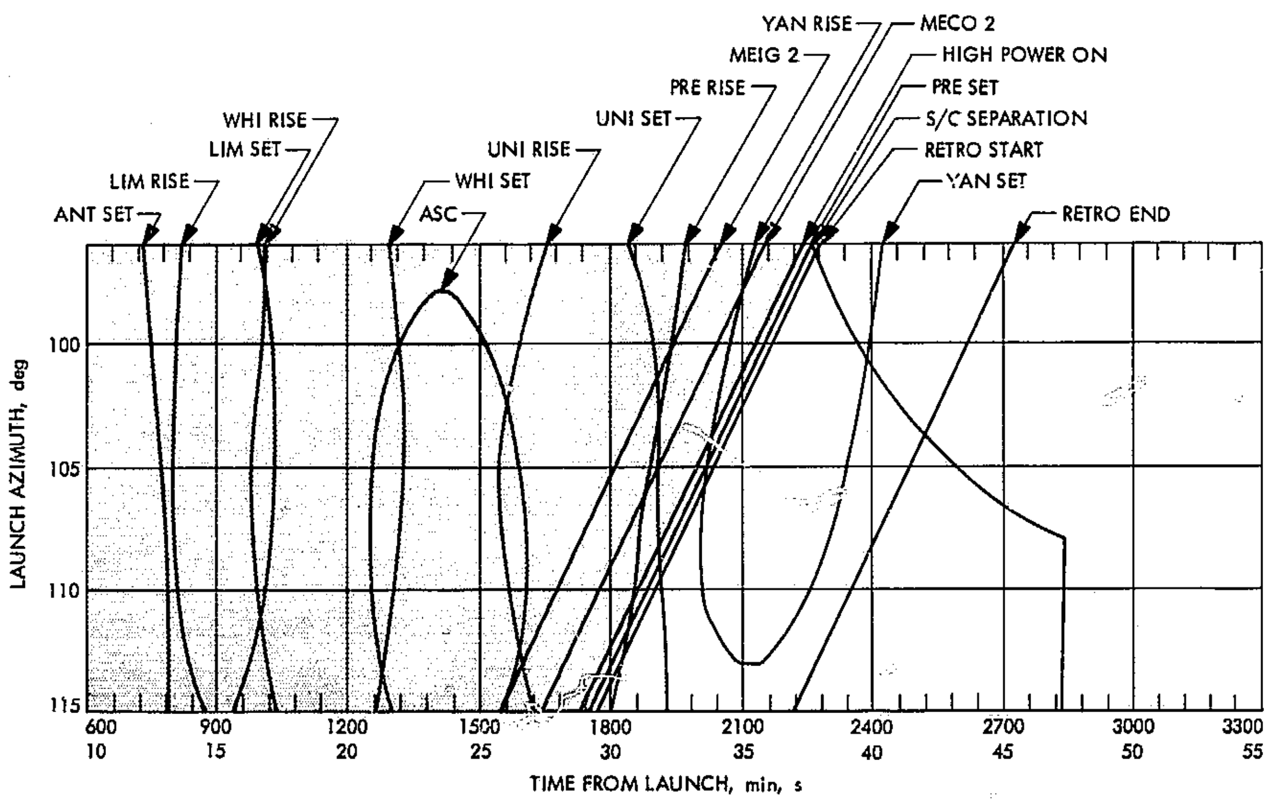


Fig. 26. Coverage of *Centaur* telemetry (VHF)

Table 21. DSIF stations committed to support of *Surveyor III*

Station	Designation	Location	Configuration
DSS 11	Prime	Goldstone, Calif. (Pioneer Site)	GSDS
DSS 42	Prime	Tidbinbilla, Australia	GSDS
DSS 51	Cislunar phase support only (best effort basis)	Johannesburg, South Africa	L/S
DSS 61	Prime	Robledo, Spain	GSDS
DSS 71	Compatibility, pre-launch and launch support	Cape Kennedy, Florida	
DSS 72	Launch and pass no. 1 support	Ascension Island	GSDS

Many distinct changes were made in the DSIF from the *Surveyor II* mission. These changes are described below.

(1) DSS 61 became a prime station for *Surveyor III*, essentially fulfilling the role that DSS 51 provided for *Surveyor II*.

(2) DSS 72 was to be used to fill the gap in telemetry coverage on certain days and on certain azimuths that may occur between DSS 42 set and DSS 61 rise.

(3) DSS 71 was to be used in a backup capacity for receiving, processing, and transmitting AFETR acquired down-range spacecraft telemetry data to the SFOF.

(4) Telemetry and command processors (TCP) were installed at all prime DSS stations. These were to provide 100% redundancy in on-site computing capabilities, over that which existed during *Surveyor I* and *II* missions.

(5) DSS 12 was to be used to provide backup transmit and receive capabilities during critical mission phases.

(6) A high speed data link was provided between the Carnarvon station and DSS 42 for the transmission of S-band telemetry data during Carnarvon's first pass tracking. This was to provide the capability to receive spacecraft telemetry data approximately 20 min to DSS 42 initial acquisition.

(7) The SPAA area in the SFOF was modified to accommodate the T&FA group. This was done by providing spacecraft telemetry data displays, recorders, and printers in parallel with those available to the SPAC performance analysis group.

(8) PCM telemetry data received in TPS was routed to the CDS 1219 computer at El Segundo, where it was to be processed and provided to the SFOF via six printers in the T&FA group area.

(9) The third computer string in the SFOF became operational just prior to the *Surveyor II* launch. A fourth computer string is also now operational, with limited capabilities. Whether or not this fourth computer string (V-string) is usable by the *Surveyor* Project during succeeding missions is yet to be determined. It does provide additional computing capability in the SFOF and allows greater flexibility in meeting the overall requirements placed upon the computing facility.

Due to the parking-orbit trajectory to be used for the *Surveyor III* mission, the initial two-way DSIF acquisition will be performed at DSS 42, Tidbinbilla. For this mission, the main changes in the DSIF are the MSFN modification, the addition of redundant computers to perform the telemetry and command processing function, and the use of FR-800 video recorders as committed equipment at all prime *Surveyor* stations. Inclusion of the Soil Mechanics/Surface Sampler (SM/SS) experiment on the spacecraft has required no changes to DSIF equipment. However, some minor changes to operational procedures at DSS 11 are required. In addition, DSS 42 will process real-time telemetry data received by the Carnarvon MSFN station, as described in Section III-D-1. The project has also placed a requirement for playback of a tape recording of SC-3 video calibration data at DSS 11 after each station pass during which video operations are conducted with the spacecraft. This support is presently being negotiated with the DSIF, and no problems are anticipated in meeting the requirement.

DSS 71 coverage: Cape Kennedy, DSS 71, is committed to support RF compatibility tests between SC-3, located on the launch pad, and DSS 71. These tests were successfully completed on March 5 and 6, 1967. At time of launch, DSS 71 receives and records telemetry data from L − 5 min to loss of signal. In addition, DSS 71 will use its CDC and TCP computer to process AFETR range telemetry data for transmission to JPL via NASCOM high-speed data line.

DSS 72 coverage: Ascension Island, DSS 72, is committed to support the *Surveyor III* mission from launch until DSS 11 acquisition + 1 h. The station will be capable of performing the tracking, telemetry, and command functions using its 30-ft dish, parametric amplifier, GSDS receivers, and 10 kW transmitter. It may be required to provide fill-in telemetry coverage during a potential gap in coverage between DSS 42 set and DSS 61 rise, for certain trajectories between April 18 and 21, 1967. Two-way doppler tracking data may also be requested from this station to provide increased confidence in pre-midcourse trajectory calculations.

DSS 51 coverage: Johannesburg, DSS 51, will participate in the *Surveyor III* mission on a best-efforts basis. It is expected that the equipment modifications and station reconfiguration now being done at that station will be completed in time for them to participate in the C-5.0 test. Configuration verification tests will be performed during the week of April 3, 1967. *Lunar Orbiter III* was successfully tracked on April 4, in both the one-way and two-way modes. DSS 51 may also be used to fill the gap in telemetry coverage between DSS 42 set and DSS 61 rise, as described above. With its 85-ft antenna and maser, it will permit higher data rates than DSS 72. Telemetry data will be provided on a best efforts basis.

Criteria for DSIF acquisition: The criteria for DSIF acquisition for a spacecraft are as follows:

(1) The DSIF will employ the acquisition aid antenna and either the parametric amplifier front end or the maser amplifier front end to the receiver.

(2) The tracking phase lock loop phase error due to the doppler rate will not exceed 30 deg.

(3) A signal to noise ratio of 9 dB in 2 B_{LO} is required in the receiver phase lock loop.

(4) The angular rate of the DSIF-Spacecraft vector must not exceed 0.1 deg/s during acquisition.

(5) The antenna angular rates must not exceed 0.85 deg/s during auto track.

(6) The acquisition procedure begins when the spacecraft appears above the local horizon. The initial effort is an RF search.

(7) Auto track on SCM cannot be obtained when the elevation angle is less than 10 deg above the local horizon.

(8) From the 10 deg elevation point, 20 min will be allowed for the DSIF to acquire the spacecraft and obtain auto track on SCM.

(9) Any RF two-way operation, before SCM auto track is obtained, will be on SAA aided track.

Most of the DSS 51 trajectories include the second burn of the parking orbit and the final injection. Therefore, the criteria for the 10-deg elevation, before SCM auto track, are not used; instead the 0.1 deg/s rate limitation is applied to the acquisition procedure.

The range is at 10-deg elevation + 20 min, and the range at the first SCM attempt is +20 min. This is the range which would be experienced if the station required the full 20 min to obtain auto track on SCM after the first attempt. The range limitation for DSS 42 with acquisition aid antenna and maser at 152 Hz tracking loop bandwidth is 25,100 km to meet the criteria of 9 dB SNR. This range can be extended to 44,700 km by using a tracking loop bandwidth of 48 Hz.

The range limitation for DSS 51 with acquisition aid antenna and parametric amplifier at 152 Hz tracking loop bandwidth is 11,650 km and can be extended to 20,750 km at 48 Hz. These limitations are based on worst-case conditions.

b. DSN communications system. The DSN Communications System is divided into two major categories: (1) the DSN Ground Communications Facility (DSN/GCF), and (2) the DSN Intracommunications System (DSN/ICS). The DSN/GCF, in general, consists of those circuits, equipment, facilities, and personnel external to the SFOF that provide the means whereby the SFOF may communicate with outside agencies. The DSN/ICS, in general, consists of those circuits, equipment, facilities, and personnel internal to the SFOF that provide not only a means whereby intelligence may be transmitted to and received from the DSN/GCF, but also a means of internal communications between the various areas within the SFOF.

The DSN Communications System is capable of providing four distinct methods of intelligence transmission. All four of these methods, (1) voice, (2) teletype, (3) high speed data, and (4) wide band (including video), are applicable to both the DSN/GCF and the DSN/ICS.

DSN/GCF: The DSN/GCF is a particular configuration of NASCOM that includes the services, facilities, and equipment required to provide an integrated network for the DSN in the support of space flight operations and systems tests. The DSN Communications Center at JPL is not only a major end terminal of NASCOM but is the major switching center of the DSN/GCF. The DSN/GCF thus interconnects the DSIF stations with the SFOF as well as the various non-DSIF agencies with the SFOF.

The Goddard Space Flight Center has responsibility for technical control of the NASCOM circuits used by the DSN, and technical control maintenance of the communications network, including restoration of service and selection of alternate routes when available.

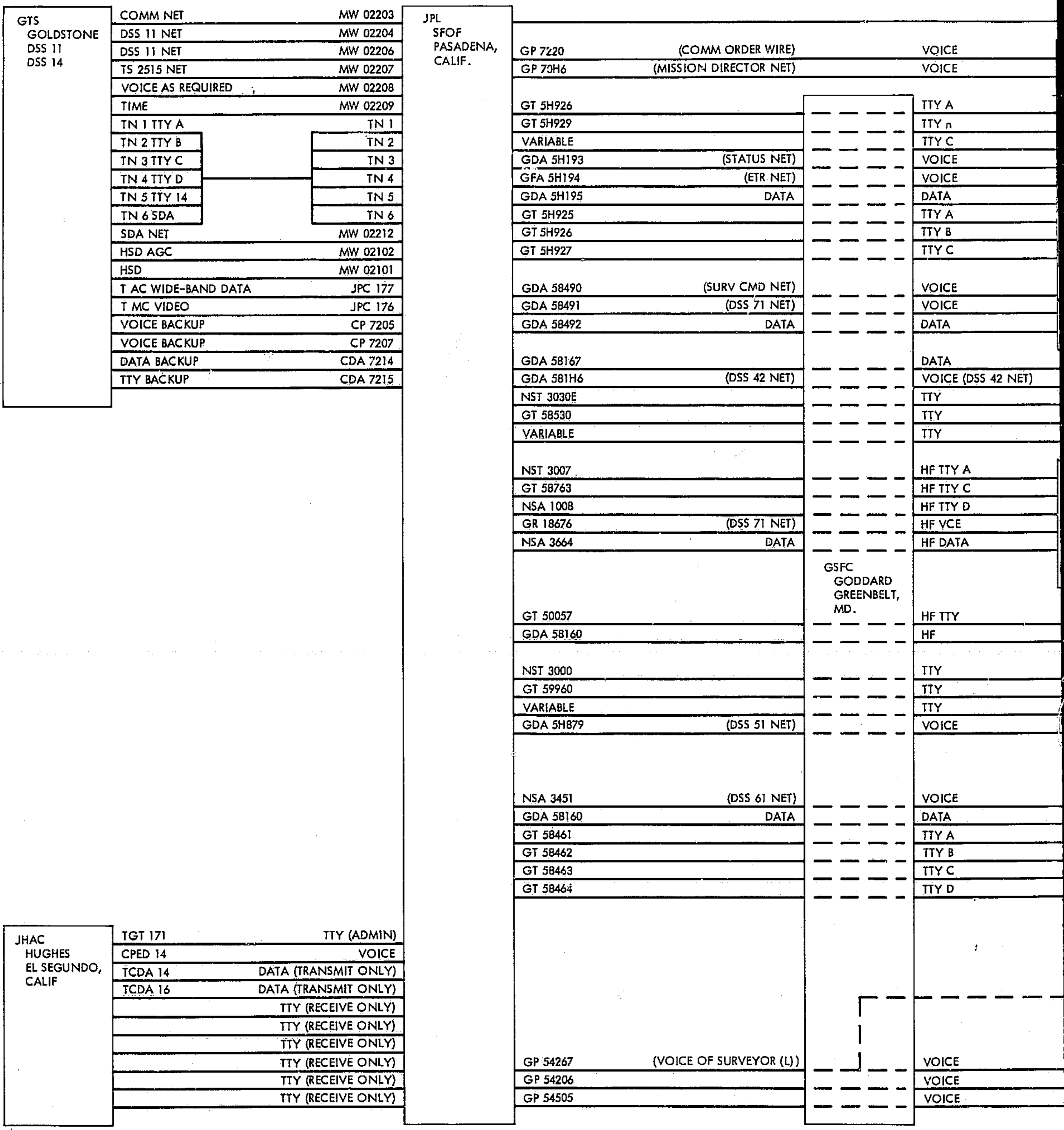
Mission control of the DSN/GCF is vested in the DSN Communications Center, which is physically located in the SFOF. The DSN Communications Center consists of the personnel, hardware, and procedures required to schedule, coordinate, and operationally control the DSN Ground Communications System during DSN operational periods.

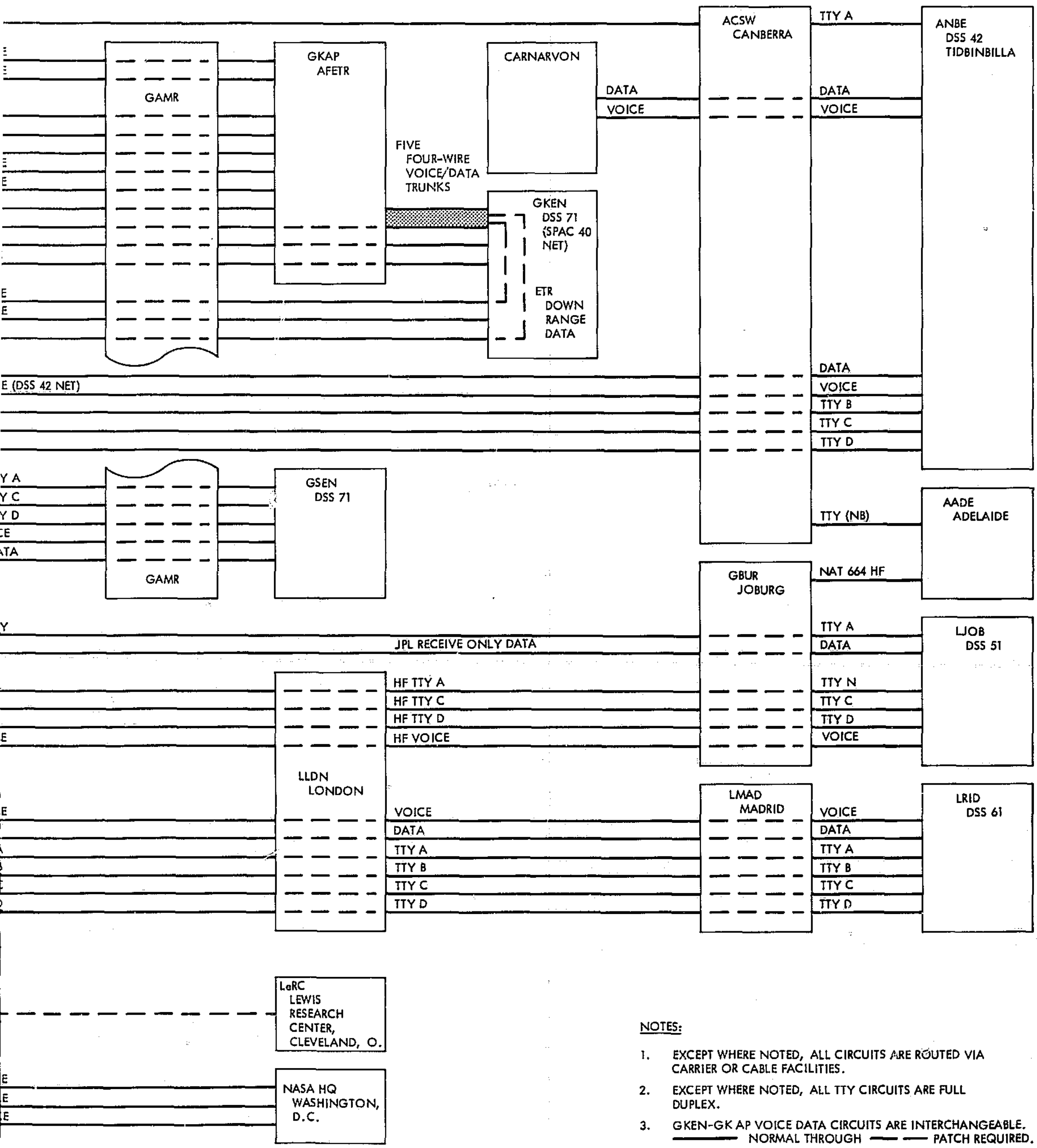
Figure 27 illustrates the *Surveyor III* support configuration and routing of the DSN/GCF circuits.

For the *Surveyor III* mission, the GCF transmitted tracking, telemetry, and command data from the DSIF to the SFOF and provided control and command functions from the SFOF to the DSIF by means of NASCOM facilities. It also transmits simulated tracking data to the DSIF, and video data and baseband telemetry from DSS 11, Goldstone DSCC, to the SFOF.

Voice circuits: The DSN/GCF configured a system of four-wire engineered voice circuits to a majority of the sites in the network. Most of the voice circuits were routed via the GSFC Switching Center and comprised the SCAMA. Circuits were routed by hardwire and microwave wherever possible. Voice circuits to overseas points used the transoceanic cables or high-frequency radio links when cables were not available. These circuits were to be used for operational and non-operational traffic. Both common user and private lines were provided.

Teletype circuits: The DSN/GCF configured a system of full-duplex links composed of leased and commercial facilities obtained from national, international, and foreign common carrier agencies. For reliability purposes, the overseas circuits were undersea cables wherever possible but were necessarily routed via radio facilities to reach certain locations. Error detection and correction systems were provided on the overseas circuits by the common carriers to reduce error rates to the minimum possible within the state of the art.


GTS
GOLDSTONE
DSS 11
DSS 14
COMM NET MW 02203
DSS 11 NET MW 02204
DSS 11 NET MW 02206
TS 2515 NET MW 02207
VOICE AS REQUIRED MW 02208
TIME MW 02209
TN 1 TTY A TN 1
TN 2 TTY B TN 2
TN 3 TTY C TN 3
TN 4 TTY D TN 4
TN 5 TTY 14 TN 5
TN 6 SDA TN 6
SDA NET MW 02212
HSD AGC MW 02102
HSD MW 02101
T AC WIDE-BAND DATA JPC 177
T MC VIDEO JPC 176
VOICE BACKUP CP 7205
VOICE BACKUP CP 7207
DATA BACKUP CDA 7214
TTY BACKUP CDA 7215
JPL
SFOF
PASADENA,
CALIF.
GP 7220 (COMM ORDER WIRE) VOICE
GP 70H6 (MISSION DIRECTOR NET) VOICE
GT 5H926 TTY A
GT 5H929 TTY n
VARIABLE TTY C
GDA 5H193 (STATUS NET) VOICE
GFA 5H194 (ETR NET) VOICE
GDA 5H195 DATA DATA
GT 5H925 TTY A
GT 5H926 TTY B
GT 5H927 TTY C
GDA 58490 (SURV CMD NET) VOICE
GDA 58491 (DSS 71 NET) VOICE
GDA 58492 DATA DATA
GDA 58167 DATA
GDA 581H6 (DSS 42 NET) VOICE (DSS 42 NET)
NST 3030E TTY
GT 58530 TTY
VARIABLE TTY
NST 3007 HF TTY A
GT 58763 HF TTY C
NSA 1008 HF TTY D
GR 18676 (DSS 71 NET) HF VCE
NSA 3664 DATA HF DATA
GSFC
GODDARD
GREENBELT,
MD.
GT 50057 HF TTY
GDA 58160 HF
NST 3000 TTY
GT 59960 TTY
VARIABLE TTY
GDA 5H879 (DSS 51 NET) VOICE
NSA 3451 (DSS 61 NET) VOICE
GDA 58160 DATA DATA
GT 58461 TTY A
GT 58462 TTY B
GT 58463 TTY C
GT 58464 TTY D
JHAC
HUGHES
EL SEGUNDO,
CALIF
TGT 171 TTY (ADMIN)
CPED 14 VOICE
TCDA 14 DATA (TRANSMIT ONLY)
TCDA 16 DATA (TRANSMIT ONLY)
TTY (RECEIVE ONLY)
TTY (RECEIVE ONLY)
TTY (RECEIVE ONLY)
TTY (RECEIVE ONLY)
TTY (RECEIVE ONLY)
TTY (RECEIVE ONLY)
GP 54267 (VOICE OF SURVEYOR (L)) VOICE
GP 54206 VOICE
GP 54505 VOICE



NOTES:

1. EXCEPT WHERE NOTED, ALL CIRCUITS ARE ROUTED VIA CARRIER OR CABLE FACILITIES.
2. EXCEPT WHERE NOTED, ALL TTY CIRCUITS ARE FULL DUPLEX.
3. GKEN-GKAP VOICE DATA CIRCUITS ARE INTERCHANGEABLE.
   NORMAL THROUGH — — PATCH REQUIRED.

Fig. 27. NASCOM DSN/GCF circuits supporting *Surveyor III* mission

FOLDOUT FRAME 2

PRECEDING PAGE BLANK NOT FILMED.

DSN/ICS: The DSN/ICS is the configuration of those internal circuits and equipment required to provide an integrated multipurpose communications network for the support of all *Surveyor* space flight missions and simulations conducted in the SFOF. Both special-purpose and conventional communications equipment is used. The DSN/ICS is configured to perform the following functions:

(1) To provide an end-terminal and switching capability for NASCOM and other special-purpose circuits external to the SFOF. In this respect, the DSN/ICS is capable of the reception of voice, teletype, high-speed, and wide-band data from the various data acquisition stations through the media of the DSN/GCF. In addition to these reception capabilities, the DSN/ICS is capable of transmission of voice and teletype data from the SFOF to various external terminals.

(2) To provide a facility whereby incoming data to the SFOF may be properly routed throughout the SFOF to user areas. In this respect, the DSN/ICS is capable of distributing such data by both audio and visual methods.

(3) To provide a facility whereby user areas of the SFOF are interconnected to each other. In this respect, the DSN/ICS is capable of providing both audio and video transmission and reception capabilities.

The subsystems that comprised the DSN/ICS configuration are listed below:

(1) Audio Subsystems. These included the Operational Public Address Subsystem (OPAS), Operational Voice Recording Subsystem (OVRS), Operational Voice Communications Subsystem (OVCS), Operational Status Recording Subsystem (OSRS), and Operational Miscellaneous Audio Subsystem (OMAS).

(2) Operational Teletype Communications Subsystem. The teletype subsystems were configured to serve two prime functions: (1) the transmission and receipt of non-operational traffic, and (2) operational support. (See Fig. 28 for the Operational Teletype Subsystem Block Diagram.)

(3) Television Communications Subsystem (TVCS). The TVCS was configured in three sections: (1) video inputs, (2) central controls, and (3) monitors. (Figure 29 gives a diagram of generalized capabilities of the DSN/ICS TVCS.) The TVCS was configured to perform the following functions: (1) area surveillance, (2) teletype presentation, (3) status and hard copy display, (4) commercial TV display, and (5) Goldstone deep-space station video display.

(4) High-Speed Data Subsystem. The DSN configured a system of high-speed data circuits for the purpose of transmitting spacecraft telemetry requiring a higher bit rate than that of teletype. These circuits were used solely for operational traffic.

The high-speed data subsystem provided a method of terminating the high-speed data circuits external to the SFOF and a method of interconnecting these circuits to various user areas.

The DSN Communications Center was equipped with six high-speed data modems, any one of which could be connected to any external high-speed data circuit. Full-duplex capability was provided. Internally, the output (or input) of these modems was patchable to various internal circuits of either the TPS or the SDCC.

(5) Wide-Band Data Circuits. The DSN configured several wide-band data circuits between the SFOF and the Goldstone DSS stations. These circuits were for operational traffic only.

The wide-band data subsystem provided a method of patching external wide-band data circuits to internal distribution circuits.

The DSN Communications Center was configured to interconnect the 96-kHz circuit to Goldstone (FDX) and to several areas of the SFOF including TPS/TVGDHS and SDCC. In addition, the capability existed to interconnect the 6-MHz circuit to Goldstone (Simplex) to the Ground Data Handling Area of the SFOF.

DSN interfaces: The following paragraphs describe the interfaces configured between the DSN Communications Center and the indicated agencies.

(1) Simulation Data Conversion Center (SDCC). The prime function of the SDCC was the simulation of space-flight data for use within the SFOF. These data were routed to various users throughout the SFOF and DSIF stations by means of the existing communications circuits and equipment. In this manner, operations personnel were exposed to conditions simulating the conditions that would exist during actual space-flight operations. All means

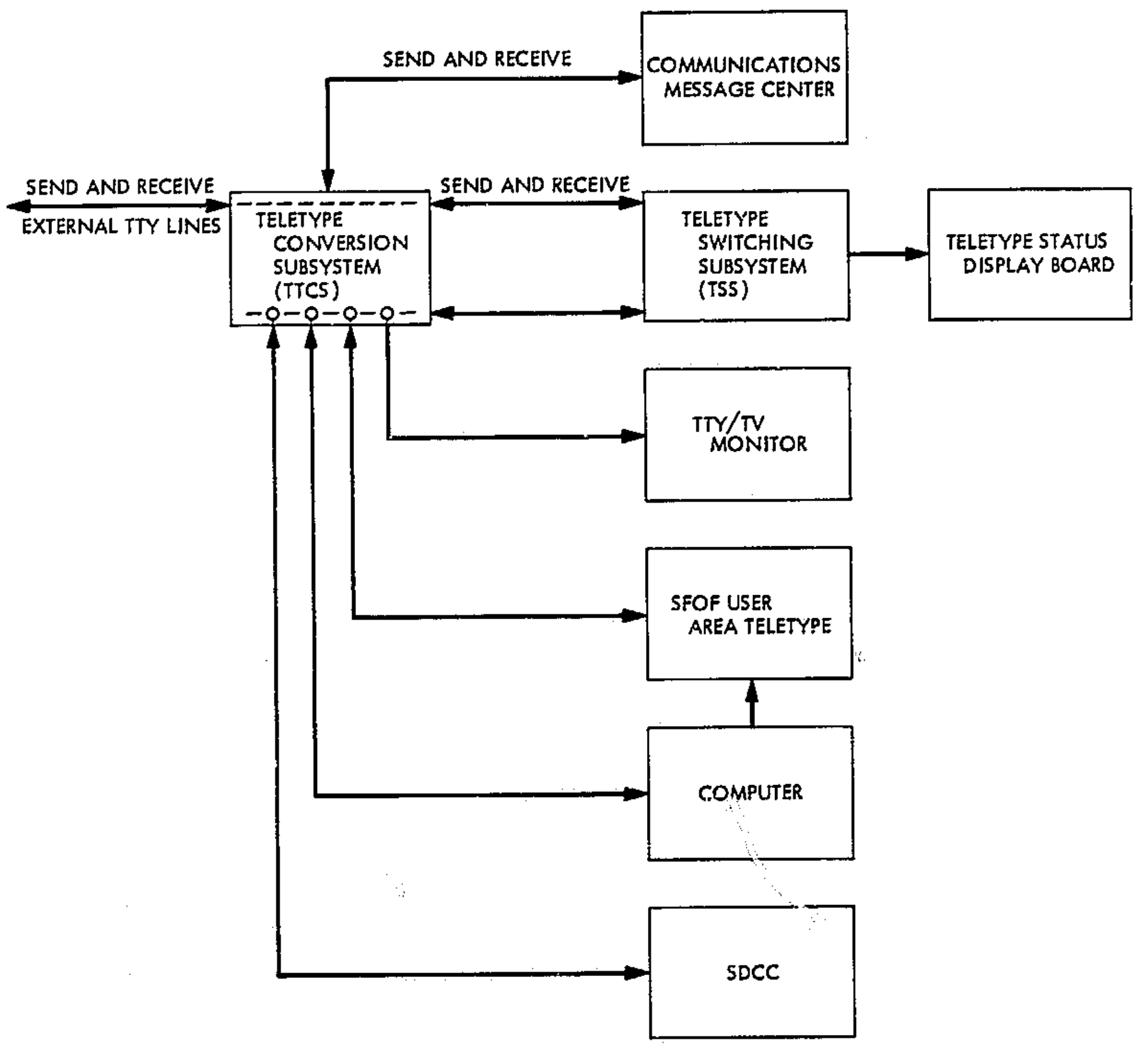


Fig. 28. Operational Teletype Communications Subsystem

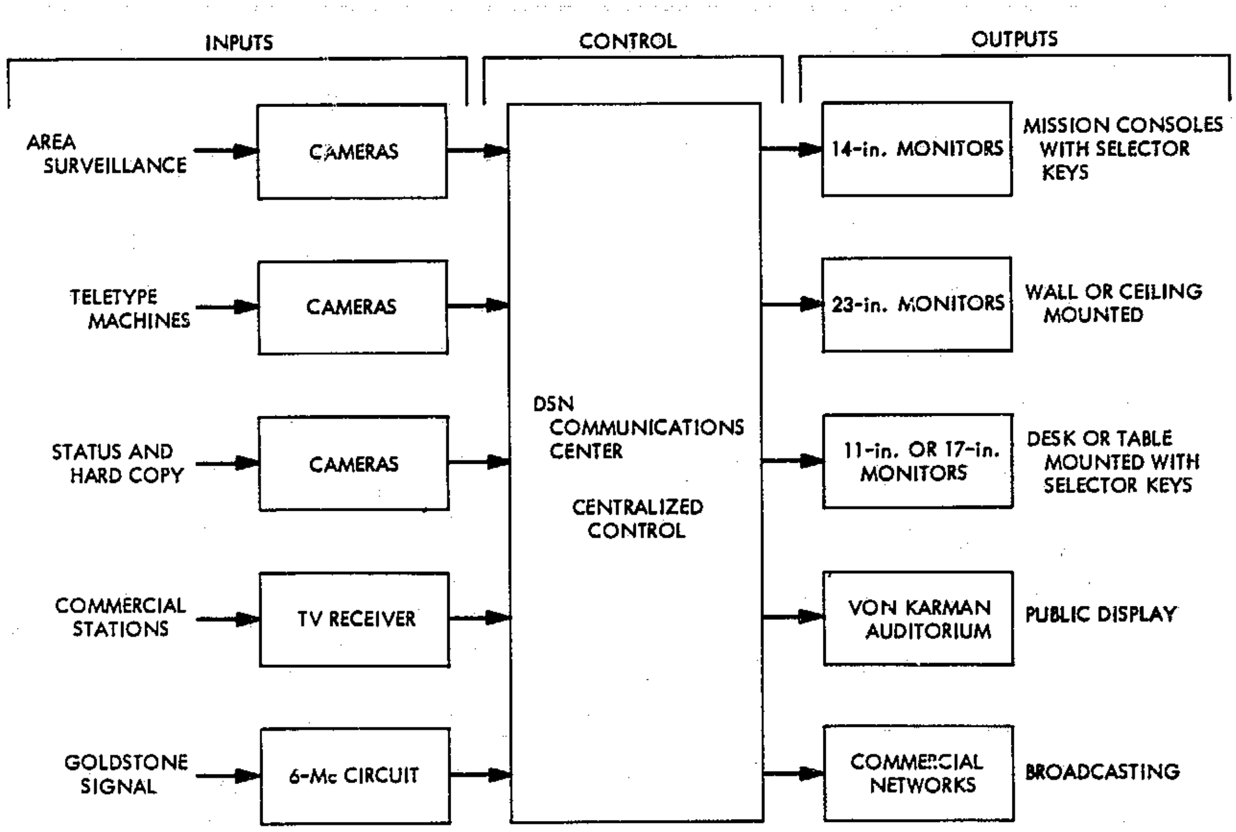


Fig. 29. Generalized capabilities of the DSN/ICS television communications subsystem

used to communicate with the DSIF (i.e., teletype, voice, high-speed data, and wide-band circuits) were available for use to conduct simulations from the SDCC.

(2) Telemetry Processing Station (TPS). The TPS processed and formatted incoming telemetry data and converted them into a format compatible with computer processing requirements. Its interface with external stations consisted of data lines from the communications area. Lines that require TPS processing were patched to one of the existing communications/TPS lines for subsequent processing by the computer.

(3) Television Ground Data Handling System (TVGDHS). The functions of the TVGDHS were to record television observations of the moon and planets, to support NASA experiments and JPL scientists, and to support spacecraft tests, operations, and TV operational tests. The interface between the DSN Communications Center and the TV Ground Data Handling System consisted of three wide-band data lines, two of which were normally connected to the 6-Mc microwave line from Goldstone.

(4) Data Processing System (DPS). The operational functions of the Data Processing System were to process, handle, and display information as required for space-flight operations. The operational functions of the DSN Communications System were to provide and operate communications as required for space-flight operations. Since most of the spacecraft data and operational information entering the Data Processing System was obtained by communications media, an important and intimate functional interface existed between the two systems.

(5) Public Information Office (PIO). As the name implies, the PIO was responsible for the dissemination of information to the public and to other interested parties. Space-flight operations information was obtained from various sources within the SFOF as well as from external agencies. Circuits, controlled by the DSN Communications Center, provided for those requirements to NASA Headquarters and the press.

(6) Teletype Status Display. This display indicated the status of all active teletype circuits and indicated how, in the SFOF, users could obtain page copy of teletype traffic or view this traffic on TV monitors.

(7) Audio Status Display. This display indicated the status of all active voice or HSD circuits, audio bridges, and interconnections of modems to DSSs.

(8) DSN/AFETR/MSFN Interface. This included the following:

   (a) Carnarvon to DSS 42 data link. A new system was implemented for transmission of *Surveyor* real-time telemetry data from the MSFN station at Carnarvon, Australia to the SFOF at JPL. The 30-ft antenna, parametric amplifier, and unified S-band receiver at Carnarvon were used to receive S-band telemetry signals from the *Surveyor* spacecraft. The Carnarvon station then interfaces the 550 bits/s serial bit stream from the spacecraft with a Bell 202 data set in order to transmit the data to DSS 42, Tidbinbilla. At DSS 42, the output of the 202 data set was fed to the CDC demodulator, where it entered the normal system for processing and transmission back to the SFOF. By this method, the PCM data from Carnarvon was processed in exactly the same manner as PCM data from the receiver at DSS 42. The system was to be used for transmission of the data from Carnarvon to DSS 42.

   The purpose of implementing this capability was to provide spacecraft data from the Australian continent prior to DSS 42 rise and to extend the total tracking and data system capability for telemetry coverage over the Indian Ocean. This, in turn, was to reduce the requirements for AFETR telemetry ship coverage in that area, and thereby make it possible to satisfy the Project requirement for continuous telemetry data from liftoff to touchdown, without restricting launch azimuth due to unavailability of telemetry coverage.

   The final version of the implementation plan for this data link was issued prior to launch. Implementation was completed and the link was successfully used in both C-3.0 tests. No problems were anticipated in providing the required telemetry coverage during the *Surveyor III* launch.

   (b) Processing of AFETR range telemetry data at DSS 71. For the *Surveyor III* mission, AFETR range telemetry received at Building AO was to be sent to DSS 71 for processing by the CDC and TCP computer and subsequent transmission to JPL via NASCOM high-speed data lines. This capability was implemented in order to provide a standard data transmission interface with the SFOF for AFETR real-time telemetry data, in a manner similar to the data transmission from prime DSIF tracking stations. This data transmission from DSS 71 was to be done in parallel with the previously used method of transmission from Building AO to the SFOF via Bell data sets, which is unchanged from the *Surveyor II* mission. The transmission route via DSS 71 was used as the prime source for range data for *Surveyor III*, with the data-set data available for backup if required. If the DSS 71 data were satisfactory, this information will be the sole data source for future *Surveyor* flights.

The data link from Building AO to DSS 71 to SFOF was exercised in engineering tests and in both C-3.0 tests. The only problem noted in the C-3.0 tests was an operational problem associated with the rapid spacecraft mode changes during the spacecraft countdown period. Cape Kennedy (DSS 71) must respond rapidly in identifying the data fed to the SFOF. To facilitate this, the *Surveyor* Telemetry Coordination Net between Building AO and the SFOF was extended to DSS 71 so that the station would be immediately aware of any changes in spacecraft data mode. No problems were anticipated with this data link for the *Surveyor III* flight.

c. Space flight operations facility. The SFOF, located at JPL, was the focal point of the DSN in supporting *Surveyor III*. From this building, the operation of the entire DSN in support of tests and missions was controlled. All command, data processing, data analysis, communications, and support functions were controlled therein. Capabilities existed to produce and/or control a number of tests/missions simultaneously. The functions necessary to support space activities were performed through the following systems:

(1) DSN Monitor System (DSN Monitor Area) in the SFOF: Monitored the operational status of all major hardware complexes in the SFOF Data Processing System (DPS); the status of the programs operating in the input/output (I/O) computer; and the flow of data among the processing components.

(2) Data Processing System: Provided the means in real time and near-real time for processing all data generated for and during tests and missions. Telemetry, tracking, command, and station performance data were processed to provide usable information for the projects.

The significant DPS differences for the *Surveyor III* mission as compared to prior missions are as follows:

(a) A new version of the *Surveyor* on-site computer program (SOCP) was used which had the following new capabilities:

  (1) Commands transmitted to the spacecraft were also transmitted to the SFOF via teletype and in English text. They were intelligible as received and required no computer processing.

  (2) Spacecraft command 1101, TV Null (Spacer), was interpreted as a 0.5-s delay character on the TTY.

  (3) An option was made to the SOCP to read the average/alarm modes, heretofore stored in memory, into the on-site computer via punched paper tapes. Therefore, the SOCP did not require a change when spacecraft telemetry assignments were made.

  (4) The SOCP was capable of generating NASCOM headers in order to transmit teletype over the NASA Communications Processors (CP), which were used occasionally during lunar operations.

(b) The IBM 7044s at the SFOF were reprogrammed to generate NASCOM headers for transmitting teletype (predicts and commands) to the tracking stations.

(c) A telemetry commutator frame dump capability was added to SPAC's IBM 7094 computer program.

(d) A new computer program for liftoff and translation was added to the FPAC repertoire of programs. This program was checked out on SFOF Mode 4, but was not used since the experiment for lunar liftoff and translation was not attempted.

(e) A checkpoint scheme was programmed into the IBM 7094 monitor. This scheme stored, on the disk, a "snapshot" of the computer's memory at frequent intervals, permitting clearing the computer's memory, reloading the disk, and continuing to run the program.

(f) Numerous hardware changes were successfully made to the computing system and interfaces to the peripheral devices, including one to the X string during the DSN freeze.

(3) DSN Communications System: Provided internal communication circuits, such as voice nets, intercom, closed-circuit television, and public address within the SFOF in addition to links connecting the SFOF with the DSSs, facilities, NASA, and manufacturing and research agencies, all of whom were concerned with tests and the missions.

(4) Support System: Provided project requirements for all peripheral services such as technical area assistance, documentation, scheduling, data distribution, reproduction and storage, access control, hardware supplies, and building services such as electrical, air-conditioning, and general plant maintenance.

(5) Simulation Data Conversion Center: Designed to provide a centralized facility within the SFOF for the conduct of DSN certification and training tests, for use in hardware and computer program validation and personnel training, as a means of generating prerecorded simulated data, and as a source of real-time simulated data for insertion into DSS systems via NASCOM.

It should be noted that the SFOF is a flexible facility in which areas and hardware can be configured to meet the needs of the following various projects:

(1) SFOF/Data Processing System (DPS). The DSN configured a Data Processing System (DPS) in the SFOF that performed the following functions for the *Surveyor III* mission:

(a) Computation of acquisition predictions for DSIF stations (antenna pointing angles and receiver and transmitter frequencies).

(b) Orbit determination.

(c) Midcourse maneuver computation and analysis.

(d) On-line telemetry processing.

General configuration of the SFOF DPS is shown in Fig. 30.

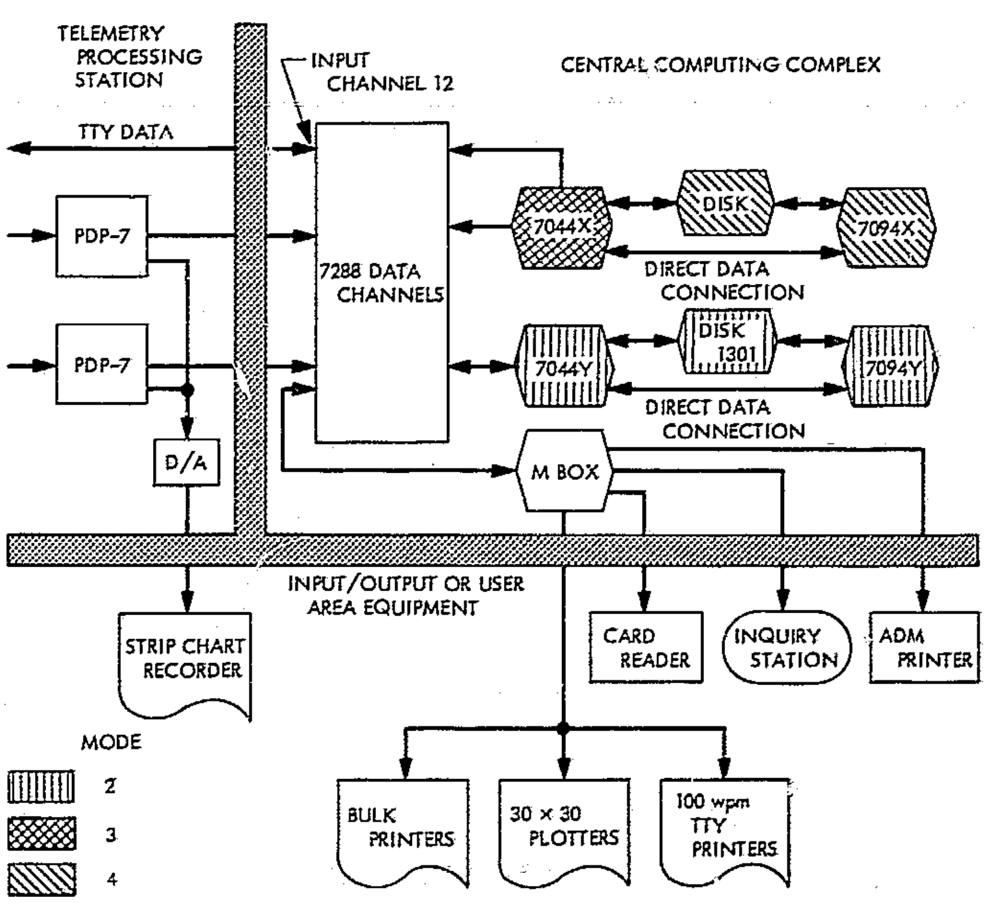


Fig. 30. General configuration of the SFOF data processing system

The SFOF DPS provided the data processing and data display equipment necessary to analyze the spacecraft engineering and scientific telemetry information and to execute the mission control operation. All programs operating in the DPS were the responsibility of the *Surveyor* Project. The DPS was divided into four subdivisions: (a) Telemetry Processing Station (TPS), (b) Analysis Computers, (c) the Input/Output (I/O) System, and (d) SFOF Operational Readiness, as follows:

(a) Telemetry Processing Station. The TPS was used to receive and convert all high-speed telemetry data into a 36-bit format whereupon it was transferred through the subchannels of the IBM 7288 to the Analysis Computers. The TPS configuration for *Surveyor III* consisted of two PDP-7 computers and related software. Both of these computers were thoroughly checked out prior to the mission.

(b) Analysis Computers. The Analysis Computers consisted of two strings of IBM 7044/7094 computer combinations. The 7044 computers accepted all real-time data from TPS and the Communications Center and also all requests or parameters entered via the I/O devices in the user areas. The 7094 computers served as the high-speed arithmetic capability and contained various analysis programs. Both 7044/7094 strings were totally operational.

(c) Input/Output System. The I/O System provided the means for entering data control parameters into the 7044/7094s and for obtaining computed data in the technical areas via the output or display devices. This system was configured for full operational support of the *Surveyor III* mission.

(d) SFOF Operational Readiness. With respect to SFOF operational readiness, SFOF personnel were given all *Surveyor* tests plus other Project tests as well as conducting special proficiency tests of their own. These mission-independent personnel (DPS and COMM) operated on a 24-h/day, 7-day/week basis regardless of which Project was utilizing the SFOF. The SFOF equipment was in the *Surveyor* configuration, except for last minute change requests. The last minute overall assessment was that the SFOF was ready to support the *Surveyor* launch as it was then scheduled.

(2) SFOF Facilities Support. Certain areas within the confines of the SFOF were configured for the purpose of providing effective support to the *Surveyor III* mission. The areas were used for Operations Flight Path Analysis and Mission Support, which are briefly described below:

(a) Operations Area. Mission Status Board No. 1 display equipment consisted of: Eidophor Projector, Teleprompter Projector, Mission Events Projector, Flight Path No. 1 DDU Display Board, special time displays (countdown/up clocks), and miscellaneous supporting display equipment.

(b) Flight Path Analysis Area. Displays in the FPAA included: the Maneuver Board, Orbital and Mission Parameters Board, Tracking Data Board, and a Trajectory Display Board. Wall space, not specifically devoted to particular displays, was utilized for chalkboards and/or information boards.

(c) Mission Support Area No. 1A. Displays in the SPAA included:

(1) SPAA Communications Status Display Board (preformatted chalkboard)

(2) Spacecraft Telemetry Measurement Display Board (preformatted chalkboard)

(3) Flight Sequence Display Board (formatted Digital Display Unit (DDU)/chalkboard)

(4) Mission Status Board No. 1 and 2 in the Operations Area (remotely actuated DDU board)

(5) Spacecraft Model Room which was incorporated in the SPAA to permit visualization of the attitude of the spacecraft in the celestial sphere through which it was traveling.

(6) Wall space not devoted to displays or glass participations was utilized for chalkboards and/or information boards for the use of the technical personnel.

(d) Mission Support Area No. 1B. Displays in the SSAA included: the Engineering Sensor Display (preformatted DDU/chalkboard) and the Television Identification (TV-ID) Display Board. Wall space, not specifically devoted to particular displays, was utilized for chalkboards and/or information boards for the use of technical personnel.

Mission-dependent equipment space and facility support was provided for the TVGDHS (located in the west wing of the second floor of the SFOF).

Support, including operation of display devices, data distribution in the facility, supervision of access control, and building housekeeping functions, were also provided.

B. Tests

The *Surveyor III* mission required much support in the area of testing, to ensure a successful mission. The various classes of tests and actual testing performed are listed below:

(1) "A" Tests — Facility Internal Tests. These tests were scheduled and conducted by each Station Manager and involve only the individual station. The "A" tests utilized the standard Sequence of Events and were employed by the station as a countdown exercise. The two test phases were as follows: Those that prepare the station for "B" tests and those that were designed to train for "C" tests. Both test phases developed the ability of personnel to use the proper procedures and hardware within a given time constraint. All prime stations completed sequences of "A" tests. The stations continually perform significant sequences in the "A" tests for practice, station countdown, and training of new people.

(2) "B" Tests — Functional Compatibility Tests. The "B" tests were designed to ensure that ground based facilities were capable of processing telemetry data and video data (DSS 11 only) as received from the spacecraft. Command capability was also verified in all configurations and modes of operation. The Sequence of Events was also incorporated into this series.

Because the "B" tests were not performed in real time, it was not necessary to adhere rigidly to the operational procedures.

During these tests, data were sent from the prime and support stations to the SFOF for processing, and full mission support in the SFOF was required.

The "B" tests were conducted in conjunction with DSS 61 only.

(3) "C" Tests — Operational Tests. The purpose of the "C" tests was to verify that all prime and support stations, communications, and the SFOF were fully prepared to meet *Surveyor III* mission responsibility. Selected portions of the Sequence of Events were followed rigidly, using both standard and nonstandard procedures.

All "C" tests were completed prior to launch. A summary of tests conducted in support of the *Surveyor III* mission is shown below in Table 22.

(4) Compatibility Tests. Compatibility tests were run between the test spacecraft (T-21), and the prime deep space stations, DSCC, CDC, and the SFOF, to establish mutual compatibility between all of these elements of the network. The tests include RF tests, command tests, and telemetry tests.

Table 22. Summary of tests conducted prior to *Surveyor III* launch

Tests	December 1966					January 1967				March 1967				April 1967		
	3	10	17	24	31	7	14	21	28	4	11	18	25	1	8	15
A-1.2 (2 tests)				▲						▲						
B-1.5 (1 test)							▲									
C-1.5 (1 test)									▲							
C-3.0 (2 tests)													▲	▲		
C-5.0 (1 test)																▲

(5) Training Tests. DSS back-up and stations under engineering cognizance conducted training tests for operator crews. T-21 was used for SSAC/SPAC lunar sequence training and as a data source for B- and C-tests with DSS 11 only.

(6) Surveyor On-Site Computer Program Integration Tests. These tests are designated to check out the *Surveyor* on-site computer program (SOCP) and to verify data that could be transmitted from a DSIF station of the SFOF and be processed there. Such tests were run on a regular basis with each prime station. These tests were concluded with a check-out of the final mission version of the SCOP Program.

*1. **AFETR.*** Testing of facilities used as regularly as those the AFETR used in support of *Surveyor III* is so routine as to require little comment. However, the situation in the S-band telemetry area was an exception. The following information is provided for general understanding of the AFETR pre-launch status for *Surveyor III* mission support.

a. Metric Data. Metric (C-band radar) data facilities received routine testing. However, three Operational Readiness Tests (ORTs) were necessary to complete the checkouts of range instrumentation and interface with the range user. On the first two ORTs, RF propagation problems prevented receiving sufficient information from the RIS *Sword Knot.* Also on the first ORT, poor RF propagation prevented adequate communication with the RIS *Coastal Crusader* and *Twin Falls.* Similar problems with communications to the *Twin Falls* were experienced on the second ORT. It was stated that due to the range initiative in making additional tests between ORTs to prove the adequacy of range readiness in areas affected by the poor RF propagation, the required number of ORTs was reduced. Specifically, telemetry and radar internal tests were conducted to ensure that the proper configurations would be available for the last ORT. The last ORT was very successful and all agencies were satisfied that this would be sufficient for the launch.

b. VHF telemetry. The VHF telemetry facilities were tested in a routine manner. However, such testing included reconfiguring telemetry equipment to band frequencies that were to be used during the actual *Surveyor III* flight.

c. S-band. The committed S-band facilities were tested in accordance with the operations directives. All primary S-band systems were reported in a state of readiness to support the *Surveyor III* mission.

d. Real time computer system. Surveyor real time data facilities were tested on a routine schedule. The real time computer system was in almost constant use and received routine testing daily.

After tests of the various systems were completed, several ORTs were conducted to demonstrate the readiness of the AFETR to support the mission.

e. Operational readiness testing. There were three ORTs run in preparation of the *Surveyor III* launch. One special telemetry test and one special metric test were run with only building AO participating with the range sites involved.

(1) ORT 1: This test was plagued with many minor anomalies and two significant problems. Because of docking scheduling, the Sword Knot could not participate. Communications were alternately fair to very poor because of radio propagation effects. The test was assessed as fair.

(2) ORT 2: The Sword Knot could not participate in the second ORT either. Difficulties developed in delivery of telemetry data from Pretoria to the Cape. The cause was later identified as an operational limitation at Ascension brought about in simulations only. The Twin Falls was not able to deliver metric data in the plus count; however, its role was simulated at the RTCF. Test evaluation was fair. A special metric test was subsequently run which established that the Twin Falls could perform properly. A special telemetry test was run at a different time of day to check again the telemetry configuration. The Sword Knot could not participate in it. The test was successful. It was agreed that if the Sword Knot did not deliver in the last ORT, a series of special tests would be set up to establish its readiness to support the launch.

(3) ORT 3: The last ORT was good. The system operated as it should. The Sword Knot participated and demonstrated its ability to support the launch.

*2. **GSFC.*** Successful simulation tests to support the *Surveyor III* mission flight were conducted the week prior to launch by GSFC. These tests were held in conjunction with the AFETR facilities involved.

Simulation tapes 405D and 107A were airmailed to Carnarvon on or about February 28, 1967. Unfortunately, these tapes arrived at the station on April 12; all simulations having been accomplished. The initial simulations were supported by recording PCM telemetry data transmitted by DSS 42 to the Carnarvon MSFN site via high-speed data.

Two additional tapes, 405F and 107C, were mailed to Carnarvon and arrived on site March 21. These tapes were employed for later simulations. In Table 23 is a tabulation of telemetry data flow tests involving data flow from Carnarvon to DSS 42.

Table 23. Carnarvon/DSS 42 simulation test results

Data	Description	Results
March 15, 1967	CRO/DSS 42 compatibility tests	Very good
March 17, 1967	CRO on-site tests	Very good
March 21, 1967	ORT I	Very good
March 31, 1967	ORT II	Very good
April 10, 1967	ORT III	Very good

3. *DSN.* The DSN supported the *Surveyor* project test plan which included various operational, compatibility, and integration tests. Figure 31 shows the development of DSIF equipment readiness. The actual testing conducted for *Surveyor III* support is defined below.

a. CDC/DSIF Compatibility. These tests prove the compatibility of the command data-handling console with the DSIF. They are required after initial CDC installation and after any significant modification of a DSIF station or CDC.

Periodic compatibility tests are performed for personnel training and checkout. Table 24 shows the disposition of DSIF compatibility testing the week prior to the *Surveyor III* launch.

b. SC-3/MOS Compatibility. The SC-3/Mission Operations System Compatibility Test was performed at the AFETR on March 5 through 7, 1967. The total test effort was divided into two parts: SC-3/Tel-2 Compatibility, and SC-3/DSS 71 Compatibility. The SC-3/Tel-2 test was essentially a functional compatibility test and was completed on a non-interference basis during the J-Fact test.

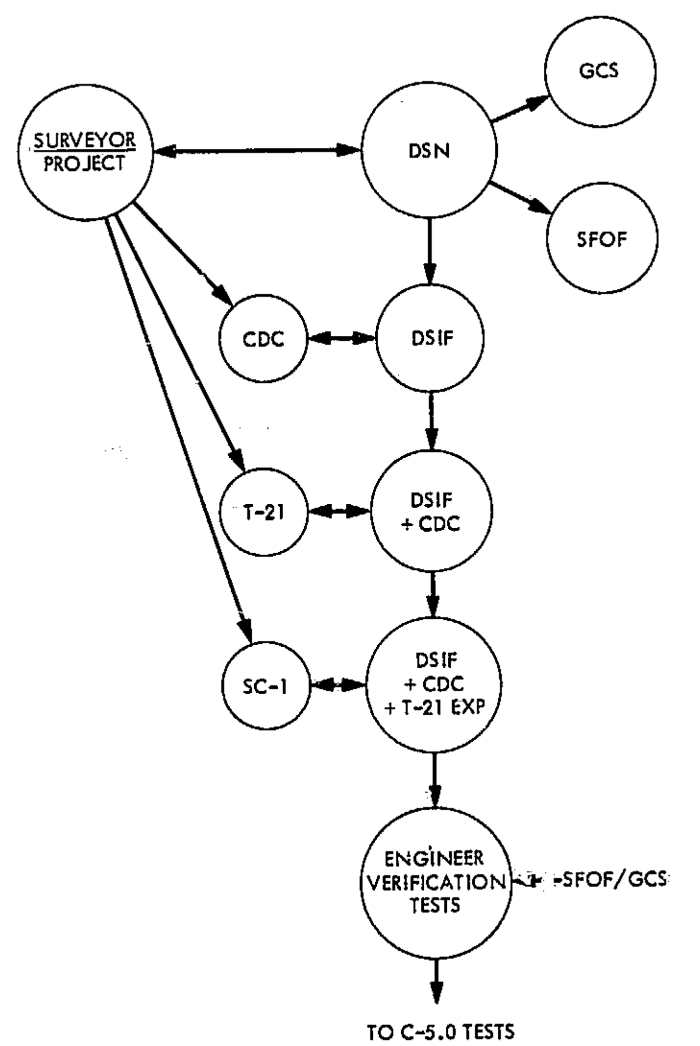


Fig. 31. Development of DSIF equipment readiness

Table 24. DSIF test disposition

Test	DSIF/CDC compatibility	DSIF/SC-3 compatibility	Configuration verification test
DSS 11	C	N/A	C
DSS 12	N/A	N/A	C
DSS 42	C	N/A	C
DSS 51	Required retesting; could not be accomplished before the *Surveyor III* mission	N/A	C
DSS 61	C	N/A	C
DSS 71	C	C	C
DSS 72	C	N/A	C

C = Completed
N/A = Not Applicable

The SC-3/DSS 71 compatibility test was begun on March 5, 1967 and was completed on March 6, 1967. This particular category of the test is discussed as follows:

(1) SC-3/Tel-2 Compatibility Test: The objective of this portion of the SC-3/MOS Compatibility Test was to demonstrate the ability of a typical range receiver facility, represented by Tel-2, to receive, detect, and transmit to Building AO the *Surveyor* SC-3 telemetry data received via the *Centaur* VHF and spacecraft S-band RF links.

The test objectives were met on a non-interference basis and required no special test configurations or procedures. The test was essentially a functional compatibility test for the purpose of demonstrating the ability of the STEA-CDC decommutator to acquire lock with the serial PCM obtained from either the *Centaur* or SC-3 RF links via the Tel-2 VHF or Tel-4 S-band receivers, respectively. The signal to the decommutator was switched between the Tel-2 receiver output (after discrimination of the PCM from the subcarrier) and the reconstructed TDM-1 decommutator PCM output. At Tel-2, a tape recording was made of the telemetry subcarrier in the format specified in JPL PRD 3400.

(a) VHF Link Telemetry (6.2). The STEA CDC decommutator successfully acquired lock with the 550-bits/s serial PCM telemetry received via the Tel-2 receiver output and the TDM-1 decommutator. The DSN bit synchronizer was capable of maintaining lock with either the Tel-2 bit stream or the bit stream from the CDC decommutator.

(b) S-Band Link Telemetry (6.3). The same comments that appear above for the VHF link telemetry (6.2) apply here except that the telemetry was received via the *Surveyor* spacecraft S-band RF link and the Tel-4 S-band receiver. The Tel-2 S-band system was not operational at the time of the tests, necessitating use of Tel-4.

(c) Conclusion. This portion of the SC-3/MOS Test was considered successfully concluded. All primary objectives were achieved and no significant problems were encountered.

The STEA-CDC demonstrated the ability to synchronize with the SC-3 spacecraft telemetry received from both the *Centaur* VHF link and the spacecraft S-band link.

(2) SC-3/DSS 71 Compatibility Test. The primary objective of this portion of the SC-3/MOS Compatibility Test was to demonstrate the ability of a typical DSIF station, represented by DSS 71, to acquire a command configuration with the SC-3 spacecraft. This involved measuring those spacecraft and ground RF systems' parameters that related to the command link. Such parameters include transmitter and receiver frequencies, receiver thresholds, and receiver acquisition and tracking ranges.

A secondary objective of this test was to obtain measurements of the SC-3 telemetry modulation parameters to verify the numbers, thereby gaining further confidence in the telemetry subsystem's performance predictions which are based on these numbers.

During this test on March 5 and 6, 1967, the SC-3 spacecraft was encapsulated in the shroud and mounted on the launch vehicle on pad 36, and the entire assemblage was then enclosed by the service tower. The directional RF link between the service tower and Building AO was operational. DSS 71, being within the beamwidth, thus communicated with the spacecraft through this link.

During the B-System tests, RF link fluctuations of ± 0.5 dB or less were observed, while A-System test fluctuations were up to ± 1.5 dB. The reason for link variations is unknown.

The DSS 71 configuration during this test was as shown in Fig. 32. The variable attenuators between the antenna and the transmitter and receiver were for performing threshold tests of the spacecraft and DSS 71 receivers. The printer was used to print out an apparent biased doppler frequency during the NBVCXO frequency drift test. The spectrum analyzer provided a means of observing the spectral content of the WBVCXO during the WBFM test. The wave analyzer and RMS voltmeter (part of the wave analyzer) were used during the search for spurious signals and the carrier suppression and subcarrier sideband power tests. The magnetic recorder recorded all test sequences. The use of the DIS to control the DSS 71 transmitter frequency was devised by the station personnel. This technique was especially useful during the phase-lock tuning range test and the

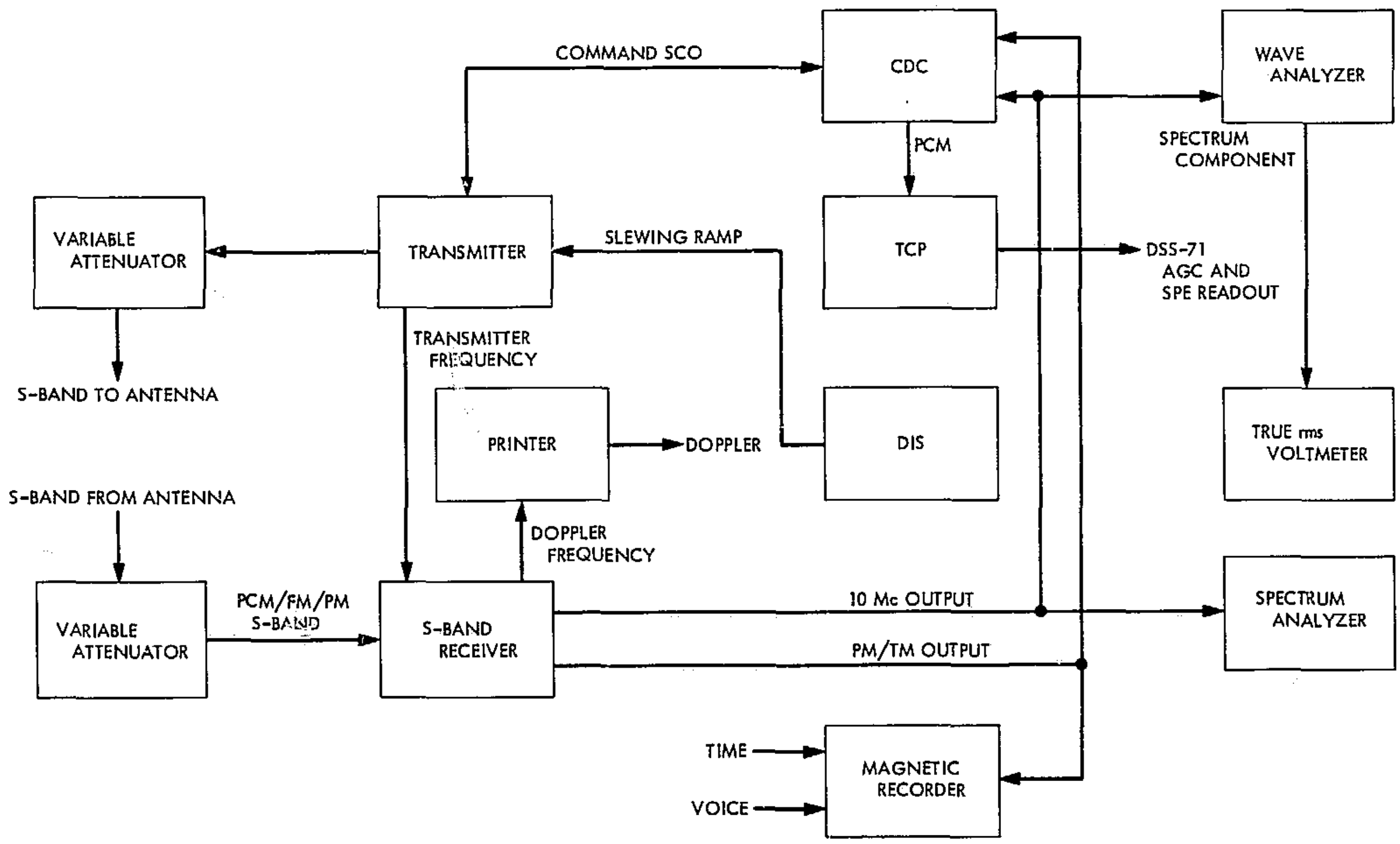


Fig. 32. DSIF 71 test configuration

automatic phase control (APC) and AFC acquisition frequencies tests. The computer was programmed to slew the transmitter frequency linearly in time at a prescribed rate. In the phase lock mode tests, the desired spacecraft reaction resulted in loss of down-link lock which automatically stopped the computer from further tuning the transmitter. In the AFC mode tests, the STEA telemetry engineer reported the occurrence of the desired spacecraft response and the computer was stopped manually.

The CDC at DSS 71 was used during all test periods, except during power turn on, to command the spacecraft. Command modulation was applied for all up-link tests, except APC and AFC acquisition frequencies tests.

(a) VHF Link Telemetry. The STEA-CDC decommutator successfully acquired lock with the spacecraft telemetry received via the *Centaur* VHF link, and data were transferred to the SFOF at the JPL.

(b) S-Band Link Telemetry. The STEA-CDC decommutator successfully acquired lock with the SC-3 telemetry received via the spacecraft S-band link, and data were transferred to the SFOF at JPL.

(c) Spurious Signals. Both transmitters were checked for spurious signals at signal levels down to 30 dB below the carrier level; no spurious signals were noted on their system.

(d) Carrier Suppression and Sideband Power. If allowance is made for the measurement uncertainty due to RF signal fluctuations, the SC-3 telemetry-modulations parameters fell within the limits specified.

There was no significant change in carrier suppression when the A/D converter was off (unmodulated subcarrier) as opposed to when it was on.

(e) DSS Receiver Threshold. There was no apparent degradation in DSS receiver performance as a function of the spacecraft telemetry mode for any of the modes tested.

(f) NBVCXO Frequency Drift. The maximum rate of change of the transmitter B system, NBVCXO, due to heating in the high power mode, was 3.8 Hz and 3.0 Hz for the A transmitter system.

(g) SCO Frequencies and Telemetry Error Rate. All parity error rates were normal. SCO offsets were noted but were within specifications.

(h) WBFM Telemetry. The frequency of transmitter B in WBVCXO mode was 2295.010687 MHz, and transmitter A was 2294.954624 MHz. No spurious signals were observed in the spectrum.

(i) Conclusion. This portion of the SC-3/MOS Test was also successfully accomplished. The SC-3 spacecraft proved compatible with the existing DSS 71 systems. The SC-3/DSS 71 systems test met or exceeded specifications or requirements for the mission in all areas tested.

c. Operational readiness testing. For a mission success to be realized, it was necessary for extensive tests to be conducted to determine the DSN readiness to support the *Surveyor III* mission. A summary of tests performed is provided below:

(1) Class A Tests:

(a) Facility Internal Tests: The objective of these tests was to ensure that the equipment, software, and personnel at the SFOF and DSS have the required capability and are prepared to support subsequent tests and the *Surveyor* mission. The conduct of the tests is discussed under each operational area.

(b) A-Test Series Summary. Two series of A-1.2 tests were conducted by the SPAC Director prior to the *Surveyor III* mission. These tests exercised the SPAC organization during the midcourse and terminal descent phases of the mission, with certain failures being simulated. These tests were conducted with participation from FPAC and DSS-11 (Goldstone), and resulted in refined operating procedures that would be used if the spacecraft should malfunction in any of the ways simulated. A general plan was evolved and recommended for executing Terminal Descent, up to and including failure of ignition. Timing techniques and thrust level determination procedures were refined for general case usage as standard operating procedures.

(2) Class B Tests:

(a) SFO/DSN Functional Compatibility Tests: The broad objective of these tests was to ensure that the ground-based facilities were compatible with, and were capable of processing, spacecraft command, telemetry, and video data. Class B tests were not performed in real time and did not require adherence to operational procedures.

(b) B-1.5 DSS 61/SFOF Test: This test was conducted in three sessions rather than the two as originally planned. The DSS 61/SFOF configuration was exercised by tracking, telemetry, and command data corresponding to those portions of the flight sequence appropriate to the DSIF station visibility periods. The first command test was unsuccessful due to a faulty command tape reader at DSS 61 (Madrid). However, the repeat of this test phase was successful. This test was used to verify the DSS 61/SFOF capability to:

(1) Handle selected combinations of engineering telemetry commutator modes and bit rates.

(2) Correctly display known spacecraft status bits and polarity-indicating words.

(3) Process tracking data.

(4) Transmit and receive, via TTY, command messages and transmit, via the DSS 61 transmitter, valid spacecraft commands.

(5) Correctly process Command Confirmation Network (CCN) information.

(3) Class C Tests:

(a) Operational Tests: The primary objective of these tests was to ensure that all elements of the SFO/DSN, including the technical and operational personnel, were capable of totally supporting the mission in accordance with the *Surveyor* Space Flight Operations Plan (SFOP). Class C tests were:

(1) Utilized the full complement of personnel required for *Surveyor* flight operations.

(2) Included standard operational procedures and heavily emphasized nonstandard operational procedures.

(3) Required handling, processing, and interpretation of the full range of mission data under conditions of normal and degraded communications.

(4) Generally established the operational readiness of the SFO/DSN for the *Surveyor* mission.

(b) C-Test Series Summary. This summary is as follows:

(1) C-1.5 DSS-61/SFOF Integration Test: The objective of this test was to exercise the SFOF and DSS 61 personnel in conducting the star verification portion of the mission (for which DSS 61 is prime), the midcourse correction (for which DSS 61 is the backup facility), and the coast phase I activities. The objectives were fully realized and it was decided by the Space Flight Operations Director (SFOD) that the DSS 61/SFOF interface was acceptable for future tests and the mission.

(2) C-3.0 Integration Tests. The objective of this test was to exercise the total Space Flight Operations System (SFOS) in a simulated mission, emphasizing the sequential/simultaneous interactions between the SFOF, all DSIF stations, and the AFETR. Two of these tests were conducted. According to planning, each test was to be conducted in two phases: the first phase would start with pre-launch activities and continue through the midcourse correction; and the second phase would start at retro firing minus 5 h 40 min (R − 5 h 40 min) and continue through lunar operations. Both tests were to contain spacecraft and SFOS anomalies that are inserted by the test coordinator.

Phase I of both tests were completed successfully even though certain deficiencies were spotlighted. The coordination between AFETR–AO and Bus 1 was poor since the AFETR–AO did not know event times on the simulated data. SPAC did not "catch" the analog-to-digital converter problem as quickly as was desired. When the problem was first reported, it was incorrectly assumed that the problem was in the ground system. In the first C-3.0 test, simulation accidentally caused a transmitter failure and SPAC responded properly and quickly, so that the midcourse was completed successfully.

Phase 2 of both tests had similar problems. The tests started at unrealistic R− times (retro firing), and the operators were given Mission-Director decisions for touchdown much too late. In both cases, however, SPAC was able to overcome the obstacle and successfully complete the touchdown phase. The lunar phase was a disappointment to SPAC, in both tests, in that the simulation had not realistically simulated the Bus, and SPAC was released from that part of the test. (Realistic simulation and testing of the lunar operations would have been of great value.)

(3) C-5.0 SFOF/DSN/AFETR Operational Readiness Test. The objective of this test was to provide a final preflight verification and demonstration of the adequacy of personal proficiency and ground equipment capability to meet the requirements of the mission. The planned test profile and participation requirements for this test were the same as for the previous C-3.0 tests.

d. Telemetry simulation. In support of the A, B, and C test series, simulated telemetry data packages were developed to provide time-correlated spacecraft data both in engineering units and telemetry signal voltages for a simulated *Surveyor* mission. The time-correlated data were entered on IBM cards for use in producing FR-600 telemetry magnetic tapes that utilized a PDP-1 computer and the telemetry processing system at JPL. The mission time covered by this simulation is from prelaunch −1 h 30 min to touchdown +8 h.

V. TDS Flight Support

A. General

The Tracking and Data Acquisition Support, provided by the AFETR, GSFC and the DSN, for *Surveyor III* are summarized herein. A brief flight review and actual flight coverage is presented, from countdown through the end of the mission, placing emphasis on the significant events.

B. Countdown

The countdown included a total of 70 min of planned, built-in holds; one of 60 min duration at $T - 90$ min and a second of 10 min duration at $T - 5$ min. The launch window for April 17 extended from 06:14 to 07:25 GMT, giving a duration of 71 min.

The countdown proceeded normally down to the built-in hold at $T - 5$ min. The count was not picked up as scheduled after the planned 10-min hold, however, because of an apparent anomaly in the spacecraft roll-actuator position signal. The hold was extended an additional 51 min, while a special trouble-shooting sequence was performed on SC-3 and on SC-5. Both of these tests and the SC-2 data review showed similar characteristics; it was determined that the spacecraft was performing properly and ready for launch. The countdown was resumed at 07:00 and proceeded normally to liftoff, which occurred at 07:05:01.059, with a flight azimuth of 100.809 deg.

All *Atlas*, *Centaur*, and spacecraft operations, with the above exception, were normal and on schedule (or ahead of schedule) throughout the supporting research and technology (SR&T) and launch countdown.

No significant problems or anomalies were reported by either the AFETR or the MSFN during the countdown.

During the countdown, the JPL/AFETR Field Station kept the SFOF and MSFN informed of status and progress through the count; it also forwarded telemetry data and radar static points from participating stations, as well as information on spacecraft frequencies and anticipated launch time and azimuth.

All systems of the launch vehicle, spacecraft, AFETR, MSFN, and DSN were *go* at launch. A countdown summary of prelaunch events for *Surveyor III* is shown in Table 25. A more comprehensive report of *Surveyor III* countdown operations is presented in Table 26.

Table 25. *Surveyor III* mission countdown summary

Event	Time, min	Time, GMT
Started spacecraft SR&T	T — 680	17:44
Started range countdown	T — 335	23:29
Completed spacecraft SR&T	T — 290	00:14
Started 60-min BIH	T — 90	03:34
Started spacecraft countdown	T — 90	04:19
End BIH; resumed count	T — 90	04:34
Started 10-min BIH	T — 5	05:59
Hold extended	T — 5	06:09
Resumed count	T — 5	07:00
Liftoff	T — 0	07:05

Table 26. *Surveyor III* AFETR countdown operations log (AFETR test 6950, Launch Countdown 1, April 16–17, 1967)

GMT	Time, min	Event
17:00	—	Mission operations center set up and operational
17:44	T — 680	SR&T started
19:20	T — 584	T — 500 (SR&T) spacecraft frequency report in
20:10	T — 534	T — 500 spacecraft frequency report TTY message out
21:30	T — 454	Nominal *mark* event times TTY message out
21:53	T — 431	T — 400 (SR&T) spacecraft frequency report in
22:05	T — 419	T — 400 spacecraft frequency report TTY message out
22:32	T — 392	Weather forecast for T — 0: ceiling: none; visibility: 15 mi; precipitation: none; low clouds: none; middle clouds: none; high clouds: none; surface winds: 8 knots from 290 deg; maximum wind at altitude: 50 knots at 45,000 ft; maximum shear: 6 knots per 1,000 ft; surface temperature: 66 deg F
22:40	T — 384	Above weather forecast sent verbally to SFOF
22:50	T — 374	C-band on
22:54	T — 370	C-band off. Range readout will not be ready until T — 335
23:06	T — 358	T — 360 RF propagation forecast for T — 0 (1 = best, 4 = worst): *Sword Knot*: 3; *Twin Falls*: 2; *Coastal Crusader*: 2; *Timber Hitch*: 2; Pretoria: 2; Ascension: 2
23:15	T — 349	Update on weather forecast: surface winds: 8 knots, varying from 10 to 90 deg; maximum wind at altitude: 50 knots at 45,000 ft from 310 deg; maximum shear: 6 knots per 1,000 ft at 45,000 ft; all other conditions same
23:25	T — 339	C-band beacon on
23:28	T — 336	Range interrogating C-band beacon
23:29	T — 335	Starting range countdown
23:52	T — 312	Addition to weather forecast: relative humidity: 80%
23:57	T — 307	Spacecraft frequency report in
00:03	T — 296	Spacecraft frequency report TTY message out
00:14	T — 290	Spacecraft SR&T complete
00:15	T — 289	Spacecraft power going off
01:05	T — 239	Receiving DSS 42 TDH data from SFOF
01:07	T — 237	SFOF reports problem with backup computer at DSS 42 (garbling average alarm)
01:30	T — 214	Grand Turk static points coming in; Antigua SPs following
01:37	T — 207	Communications failure between DSS 42 and Carnarvon; no estimate
01:44	T — 200	Communications between DSS 42 and Carnarvon back in
02:07	T — 177	RF silence lifted

Table 26 (contd)

GMT	Time, min	Event
02:08	T — 176	T — 190 RF propagation forecast for T — 0 received; no change from T — 360 forecast
02:30	T — 154	The only time DSS 42 has backup computer problem is on CVR program
02:39	T — 145	Problem experienced getting MSFN status net from AFETR
02:49	T — 135	Hold-fire checks received
03:03	T — 121	MSFN status net in
03:04	T — 120	Starting service tower removal
03:12	T — 112	Maser 1 at DSS 61 in red (warmed up); no explanation, no estimate
03:15	T — 109	TPS locked up on Pretoria data
03:24	T — 100	DSS 61 Maser; no hardware problem at this time; just waiting for it to cool down; should be on time with no problems
03:34	T — 90	Started built-in hold; estimated 60-min duration
03:55	T — 90	Spacecraft power on to run trouble-shooting sequence on roll actuator
04:27	T — 90	Receiving DSS 51 TDH data; sending to RTCS
04:32	T — 90	SFOF reports DSS 72 circuits to be lost for estimated 15 min because of reconfiguration of satellite circuits
04:34	T — 90	Resumed count (end of built-in hold)
04:37	T — 87	Spacecraft frequency report in
04:45	T — 79	Telemetry checkout complete for all downrange stations and ships except *Sword Knot*
04:53	T — 71	Spacecraft frequency report TTY message out
04:59	T — 65	SFOF reports DSS 51, 42, 11, 72, 61, net control, comm, TPS, SPAC, FPAC all go
05:02	T — 62	Starting *Atlas* LO_2 tanking
05:22	T — 42	Spacecraft frequency report in; sent out verbally
05:47	T — 17	Spacecraft frequency report in; sent out verbally
05:54	T — 10	Spacecraft frequency report TTY message out
05:57	T — 7	100 words/min circuit to *Twin Falls* down; will go 60 words/min (octal data)
05:59	T — 5	Started built in hold; estimated 10 min duration
06:06	T — 5	Hold extended a minimum of 15 min; possible anomaly with spacecraft roll-actuator signal
06:08	T — 5	AFETR and MSFN go
06:24	T — 5	Hold extended an additional 30 min
06:32	T — 5	Spacecraft looks good (SC-5 exhibited same electrical characteristics); should pick up soon
06:36	T — 5	Spacecraft frequency in; sent out verbally (2-way rather than 1-way)
06:52	T — 5	Hold extended an additional 5 min
06:55	T — 5	Estimated count will be resumed in approximately 5 min
06:56	T — 5	Anticipated liftoff at 07:05:00; flight azimuth of 100.809 deg
07:00	T — 5	Resumed count; azimuth 100.809
07:01	T — 4	*Centaur* to internal; spacecraft to internal
07:02	T — 2:35	*Atlas* LO_2 topping secured
07:03	T — 2:15	Starting flight pressurization
07:03	T — 2	*Surveyor* retro armed; *Atlas* to internal; range safety commands armed
07:04	T — 90s	Securing LH_2 tanking; spacecraft go; range clear to launch
07:04	T — 75s	Securing *Centaur* LO_2 topping
07:04	T — 60s	Flight azimuth verified as 100.809 deg; pressurization to internal. Programmers armed
07:05	T — 30s	Launch director go
07:05	T — 0	Liftoff at 07:05:01.059 (GMT); azimuth 100.809 deg

C. Liftoff to DSIF Acquisition

Liftoff of *Surveyor III* occurred at 07:05:01.059 GMT on day 107 (April 17, 1967) on a launch azimuth of 100.809 deg.

Performance of the *Atlas/Centaur* launch vehicle was excellent throughout its flight period, as all *mark* events occurred very close to the predicted times. A summary of the *Surveyor III*, *mark* event times is contained in Table 27. Injection of the spacecraft occurred at 07:38:49.8 GMT, Day 107, on a trajectory that would have provided, with no midcourse correction, a total miss of 290 mi from the targeted lunar site of −3.33-deg latitude, 336.83-deg longitude. All spacecraft programmed flight events (high power, extend landing legs, and extend omnidirectional antennas A and B) were accomplished and verified in near-real time, due to data outages from AFETR. *Surveyor* physical separation from *Centaur* occurred at 07:39:54.4 GMT. The sun was acquired, sun sensor primary cell lock-on indicated at approximately 07:48 GMT, and the automatic sun acquisition sequence completed at 07:51 GMT after an estimated minus roll of approximately 181 deg and positive yaw of 38 deg.

The AFETR experienced no significant difficulties in receiving spacecraft telemetry and transmitting the data in real time back to Cape Kennedy, although some data outage did occur. Good telemetry data were received from Tel-2 and Tel-4, GBI, Antigua, Ascension Island, Pretoria and the range instrumentation ships *Sword Knot*,

Table 27. *Surveyor III* mission in flight event times

Event	Time, GMT	Readout from
Liftoff	07:05:01.059	Cape Kennedy
Mark 1	07:07:23.5	Cape Kennedy
Mark 2	07:07:26.5	Cape Kennedy
Mark 3	07:07:57.5	Cape Kennedy
Mark 4	07:08:24.65	Cape Kennedy
Mark 5	07:08:58.3	Cape Kennedy
	07:08:58.3	Bermuda
Mark 6	07:09:01.0	Cape Kennedy
	07:09:01.2	Bermuda
Mark 7	07:09:11.7	Cape Kennedy
	07:09:11.6	Bermuda
Mark 8	07:14:50.85	Cape Kennedy
	07:14:50.8	Bermuda
	07:14:50.6[a]	Antigua
Mark 9	07:14:52.5	Cape Kennedy
	07:14:52.0	Bermuda
	07:14:50.6[a]	Antigua
Mark 10	07:15:19.55	Cape Kennedy
	07:16:06.5[a]	Antigua
Mark 11	07:17:20.3	Cape Kennedy
	07:16:06.5[a]	Antigua
Mark 12	Not reported	—
Mark 13	07:36:59.7	Pretoria
	07:36:59.68	Audit 1 (telemetry aircraft)
	07:36:59.68	Audit 2 (telemetry aircraft)
Mark 14	07:36:59.7	Pretoria
	07:36:59.72	Audit 1
	07:36:59.75	Audit 2
Mark 15	07:38:49.8	Pretoria
	07:38:49.8	Audit 2
Mark 16	07:39:15[a]	Pretoria
Mark 17	07:39:25[a]	Pretoria
Mark 18	07:39:43.5	Pretoria
Mark 19	07:39:49[a]	Pretoria
Mark 20	07:39:54.4	*Sword Knot*
	07:39:55.5[a]	Pretoria
	07:39:54.4[a]	Audit 1
Mark 21	07:39:56.7	Pretoria
Mark 22	07:40:52.8	Tananarive
Mark 23	Not reported	—
Mark 24	07:43:54.5	Pretoria
	07:43:54.5	Tananarive
Mark 25	07:48:04.8	Tananarive
Mark 26	07:49:44.6	*Sword Knot*
	07:49:44.5	Tananarive
	07:49:54.7	Carnarvon

[a]Times were taken from the AFETR Preliminary Test Report, which was received after the test; all other times were as reported during the plus count.

Coastal Crusader and *Twin Falls*. Inflight spacecraft telemetry were received from the AFETR stations and relayed to SFOF until approximately $T + 56$ min.

Station Tel-2 data were transmitted to SFOF from liftoff to approximately $T + 7$ min, when a switch to Antigua data was made. The Antigua data were left on-line to SFOF until LOS at approximately $T + 13.5$ min. Telemetry data were not available from this point until *Crusader* AOS at approximately $T + 17$ min. *Crusader* data were transmitted from $T + 17$ to $T + 21$ min, when the data source was switched to Ascension Island. Ascension Island data were left on line until $T + 25$ min when *Twin Falls* data were selected. The *Twin Falls* data started deteriorating in quality about one minute later and, at approximately $T + 27$ min, were considered unusable. Data were not available from this point until approximately $T + 34.5$ min when Pretoria and *Sword Knot* AOS occurred. *Sword Knot* data were selected for transmission to SFOF, and were left on-line until LOS at approximately $T + 56$ min.

The downrange spacecraft event readouts were deleted in real time because of the excellent telemetry data being received from the AFETR stations.

Telemetry coverage, from the AFETR preliminary test report, is shown in Table 27, which displays event readouts.

Both Bermuda radar sites, as well as Carnarvon, delivered excellent metric data in real time.

Grand Turk and Antigua delivered good raw data in real time during the parking orbit. Ascension Island data were delivered in real time and on the whole were considered good. However, data quality began to deteriorate prematurely toward the end of the pass. The last data points showed an elevation of about 7 deg. The *Twin Falls* did not acquire any radar data during its pass. Pretoria was late in delivering raw data; the first data points were at about 8-deg elevation. About 30% of the pass indicated intermittent offtrack. As is noted later, however, the RTCS was able to compute a fair transfer orbit from Pretoria data in a timely manner.

All data were received, reduced, and transmitted in a timely manner. Specifically, the parking orbit messages, as well as the predicts based upon them, were delivered on time. Transfer orbit computations and associated predicts were transmitted a little earlier than expected. Of special note was the time that the first orbit using DSN data was generated at the RTCS. It was transmitted at $T + 85$ min and the second orbit was delivered 20 min later. Both of these orbits, as well as the one generated from Pretoria data, compared favorably with the orbit which was subsequently generated by the SFOF and used as the basis for the midcourse maneuver.

With the exception of a 30-s gap at $L + 360$ s, AFETR land stations and ships obtained continuous S-band telemetry coverage from liftoff through Antigua LOS at $L + 725$ s. Although Ascension Island experienced a dropout between $L + 1492$ s and $L + 1522$ s, the interval was adequately covered by the RIS *Twin Falls*. The RIS *Sword Knot* experienced an expected dropout between $L + 2728$ s and $L + 2833$ s as a result of acquisition of the spacecraft transponder by DSS 42, which then provided the required coverage.

Estimated and actual S-band telemetry coverages are shown in Figs. 35, 40, and 41. All class I, II, and III requirements were met.

The *Sword Knot*, which was estimated to provide coverage from $L + 2037$ s to $L + 3222$ s, dropped track at about 3159 s because of a ship maneuver. This was expected because the ship positions itself for optimum acquisition and then during a prolonged tracking period the ship's superstructure comes between the antenna and spacecraft and the ship must maneuver to maintain the antenna pointing at the spacecraft.

The RIS *Twin Falls* S-band system lost track sooner than expected because on this flight azimuth the spacecraft passed over zenith. The RIS *Twin Falls* did not reacquire the spacecraft.

All requirements were met. The VHF telemetry data, including the spacecraft data, were transmitted in real time to the SFOF from liftoff to spacecraft high power *on*. At high power *on*, AFETR switched as planned to real-time transmission of spacecraft S-band telemetry data to building AO. Real time data flow was very good. In addition, all *mark* events except 12 and 23 were read out and reported.

Ascension Island (DSS 72) tracked the spacecraft one way for a few minutes during the parking orbit phase. Johannesburg (DSS 51) also tracked one way for a brief post-injection period. Two-way lock was acquired by DSS 42 at 08:00:22, and indicated that telemetry and communications were good. The spacecraft was transferred to DSS 51 at 12:15:00, followed by a transfer to DSS 61 at 14:30:00.

The transfer to DSS 51 at 17:00 was marked by an acquisition delay; a two-way lock was confirmed at 17:17:11.

Control of the spacecraft was regained at DSS 61 by transfer at 20:30:00. During this time, DSS 72 tracked the spacecraft in one- and three-way lock for approximately 8½ h. The DSS 61 to DSS 11 transfer was accomplished at 22:15.

D. DSIF Acquisition to Midcourse Maneuver

Initial DSIF acquisition, one-way lock, was obtained by DSS 42 at approximately 07:55 GMT with two-way lock established at 08:01:50 GMT. Initial spacecraft operations were initiated at 08:09:48 with the turnoff of high power and completed at 08:23:25 GMT with the spacecraft configured in low power; the coast phase commutator was *on* and transmitting at 1100 bits/s. The flight-control cruise mode on command was not utilized at this time due to a high-intensity signal in the Canopus intensity channel. Cruise mode was transmitted, however, and receipt by the spacecraft was verified at 10:52:47 GMT.

As a result of DSS 42 reporting that the sideband energy of the spacecraft signal was lower than anticipated, a nonstandard telecommunication evaluation procedure was initiated by SPAC (during the DSS 51 pass) at 13:07:03 GMT and completed at 14:12:23 GMT. The result of this SPAC telecommunication evaluation was that the spacecraft telecommunication system was normal and the suspected anomalous condition was due to the technique utilized for measuring sideband power. During this test, the bit rate was dropped to 550 bits/s at 13:31:55 GMT and remained at this bit rate until the star mapping sequence.

Automatic Canopus acquisition was successfully accomplished at 16:27:51 after some 565 deg of roll. During the star mapping sequence (which started at 16:09:12 GMT), four stars (Procyon, Adhara, Canopus, and Altair), one planet (Jupiter), as well as the earth and moon, were positively identified. In addition to the aforementioned celestial bodies, two unidentified objects seen during the first roll were not seen during the second roll portion of the star mapping sequence. At the completion of the star map sequence, the spacecraft was returned to the coast phase condition with a bit rate of 1100 bits/s.

During coast phase I, there were six standard engineering assessments of the spacecraft, one gyro speed check, and three gyro drift checks. The spacecraft continuously gave normal indications during this period except that: (a) the SM SS auxiliary electronics temperature was colder than predicted, and (b) the roll and yaw gyro drift rates indicated out of specification: i.e., greater than 1 deg/hr. The above indications were carefully watched and evaluated against any constraint during the upcoming midcourse maneuvers.

Midcourse preparation was started at 04:12:54 GMT, day 108, with an engineering interrogation. The spacecraft was then configured to the high-power mode at 4400 bits/s at 04:21:31 GMT. A pre-midcourse correction maneuver of a plus roll of 56.7 deg was executed at 04:46:49 GMT followed by a negative pitch of 39.1 deg at 04:50:08 GMT. The vernier engines pressurization, and the unlock of vernier engine 1, were commanded at 04:55:21 GMT. Thrust phase power was commanded at 04:57:03 GMT and the roll actuator null condition verified at 04:57:22 GMT. Midcourse velocity correction was executed at 05:00:02 GMT (the scheduled nominal time) for 4.277 s for a delta velocity change of 4.19 m/s (see Table 2.) It was found that SPAC TLM verification and doppler shift indicated the velocity correction was as commanded. Following midcourse thrust, the reverse maneuvers were commanded. Sun and star reacquisition were obtained on day 108, at 05:04:11 GMT and 05:08:04 GMT, respectively. The midcourse maneuver corrected the miss distance of the aiming point, selected during flight, to a miss of only 1.8 mi.

E. Midcourse Maneuver to Terminal Descent

Early analysis of the *Surveyor III* trajectory indicated that a midcourse maneuver during the first pass over DSS 11 would be advantageous; therefore, the midcourse maneuver was executed during this pass. Engine ignition was programmed for April 18, at 05:00:00 GMT, with a total burn time of 4.275 s. Results of the maneuver as seen in the two-way doppler data over DSS 11 are presented in Fig. 14.

Following the post-midcourse maneuvers, the spacecraft was configured for coast phase II and the spacecraft left at 1100 bits/s in low power. Postmidcourse analysis by SPAC flight control and propulsion specialists indicated that there was a possible unbalance in the thrust levels of the vernier engines even though all indications were that the spacecraft was stable during the thrust period. Considerable real-time analysis was performed by SPAC and it was concluded that this erroneous indication was probably due to a telemetry offset or calibration problem on engine 2 as these indications could not possibly be to a center of gravity shift. The TFR 18258 was written against this anomalous indication. Coast phase II was normal, with the exception that the SM SS auxiliary electronic temperature remained lower than anticipated and Trouble Failure Report 18257 was written against this failure. Eight normal engineering assessments were performed to assess the spacecraft thermal and operational status. Three power-mode cycling sequences were performed. The bit rate of the spacecraft was reduced at 08:50:08 GMT on day 108 to 550 bits/s, and at 09:57:36 GMT on day 109 to 137.5 bits/s. The 137.5 bits/s rate was maintained until start of preparations for terminal descent.

During transit phase, 10 gyro drift checks were performed to validate and refine the out-of-specification drift rates obtained for the roll and yaw gyros during the first gyro drift check. The final gyro drift rates supplied to FPAC and utilized during terminal descent were: (1) roll +1.1 deg/h, (2) pitch +0.6 deg/h and (3) yaw −0.8 deg/h.

From the time of two-way acquisition by DSS 42 until the midcourse maneuver, the DSN tracked *Surveyor III* in the two-way mode with only minor exceptions and returned high-quality two-way doppler data with the exception of the initial two-way track at DSS 61. At 14:32:02 GMT, on April 17, DSS 61 began taking two-way doppler, and approximately one-half hour later the results of the tracking data monitor program indicated that the two-way doppler from DSS 61 was excessively noisy. This program was subsequently traced to a faulty bit in the last digit of the doppler counter. A transfer to DSS 51 was scheduled at 17:00:00 but was not effected until approximately 17:20:00 because of a minor procedural error at DSS 51. The problem at DSS 61 was corrected and DSS 61 was able to reassume the transmitter assignment at approximately 20:30:00; from this time on, the transmitter returned high-quality doppler data. The midcourse maneuver was executed according to schedule, and from this time until the landing phase, the DSN tracked the *Surveyor III* spacecraft continuously in the two-way mode and returned high quality two-way doppler data throughout this period.

F. Terminal Descent to Touchdown

Terminal descent was initiated during the DSS 11 pass at 23:07:40 GMT on day 109. The spacecraft was commanded and successfully performed three terminal maneuvers. The terminal maneuvers magnitudes were:

(1) a minus yaw of 157.9 deg, (2) a minus pitch of 76.7 deg, and (3) a minus roll of 63.9 deg, initiated at 23:23:29.7, 23:30:17.2, and 23:34:35 GMT on day 109, respectively. Touchdown strain gages were turned on at 23:17:46 GMT. The AMR power was commanded on and verified at 23:56:32 GMT followed by thrust phase power *on* at 23:57:32 GMT. The AMR was enabled at 23:59:32 and the emergency AMR signal was automatically transmitted at 00:01:11.9 GMT on day 110.

Canberra (DSS 42) acquired *Surveyor III* on pass 2 by transfer at 08:40. On this pass, transfers were accomplished to DSS 61 at 14:40, to DSS 51 at 16:40, to DSS 61 at 18:10, back to DSS 51 at 21:10, to DSS 11 at 22:20, to DSS 61 at 00:20, on April 19, 1967, and then back to DSS 11 at 02:20.

At 06:40, DSS 42 acquired the spacecraft in a two-way lock for pass 3. From 06:44 to 08:22, during the mutual review period with DSS 42, DSS 11 conducted antenna switching from right-hand circular polarization to left-hand circular polarization for an axial ratio experiment. A nominal signal change of 7 dB was apparent. A transfer back to DSS 11 occurred at 08:40, followed by transfers to DSS 42 at 09:45, to DSS 61 at 14:20, to DSS 51 at 18:00, to DSS 61 at 18:45, and then DSS 11 at 22:15.

Frequent spacecraft transfers between Deep Space Stations were employed to facilitate the determination of doppler biases at the stations and to update orbit determinations. The terminal descent appeared normal until the 14-ft mark was not received, and the vernier engines continued to thrust through touchdown. Touchdown occurred at 00:04:18 on day 110. Shortly after touchdown, the received data at the SFOF went bad and it was impossible to ascertain accurately the condition of the spacecraft. The normal postlanding shut-down procedure was executed, and it was later determined via touchdown strain-gauge data, that there had been three landings as the engines were still thrusting until commanded *off* in the post landing shut down sequence.

G. Touchdown to End of Mission

The Goldstone Pioneer Tracking Site (DSS 11) acquired the spacecraft in three-way lock at 22:10:54, on pass 3, the touchdown pass, and went two-way at 22:15. At 22:57 the transmitter VCO offset frequency of 490 binary-coded decimal (BCD) was set in. This provided the capability for rapid reacquisition of the uplink, should it be lost during retro-engine ignition or touchdown.

The pre-touchdown maneuvers started at 23:21:30 and were completed at 23:36:46. Following this event, the receiver VCO frequency was offset +14.3 kHz to compensate for doppler frequency shift. Retro-engine ignition occurred at 00:01:24 on April 20 and touchdown occurred at 00:04:18 without loss of receiver lock.

Spacecraft engineering interrogations were accomplished, followed by 200-line video configuration. This sequence was repeated twice.

The remainder of the pass included the repositioning of the solar panels and additional 200-line and 600-line video sequences.

The Goldstone Echo Site (DSS 12) and Mars Site (DSS 14) provided backup transmitter power and backup telemetry recording, respectively, for DSS 11 during the touchdown pass.

Canberra (DSS 42) acquired the spacecraft at 06:20:06 and recorded 380 TV pictures commanded by DSS 11. Two-way transfer to DSS 42 occurred at 10:10.

Final calculations indicated retro-engine ignition would be initiated on April 20, 1967 at 00:01:17.7 GMT and touchdown at 00:04:20.1 GMT. Fig. 33 presents the *Surveyor III* landing profile, with the three separate touchdowns clearly indicated.

The first two impacts with the lunar surface also affected various spacecraft subsystems. On the initial contact, the RADVS high voltage was turned off (which would normally indicate that a voltage transient on the order of 4 to 6 V with a duration of 5 to 30 μs had occurred). This high voltage was reapplied after 18 s, during the first spacecraft hop, as it normally should. On the second touchdown, the RADVS high voltage was again turned off, and the decoders were indexed (from B to A), the high current mode was turned off and the power system reverted to the auxiliary battery mode shortly thereafter, within three frames of data, and all analog signals became erroneous (TFR 18256).

The conclusions reached as a result of these sequences were: (1) all analog data were affected on all bit rates but the effect at the lower bit rates was less for some signals, particularly the electrical currents and mechanism signals, and (2) all discrete signals were normal.

The engineering investigation was interrupted for an interval to permit the SSAC group to take emergency

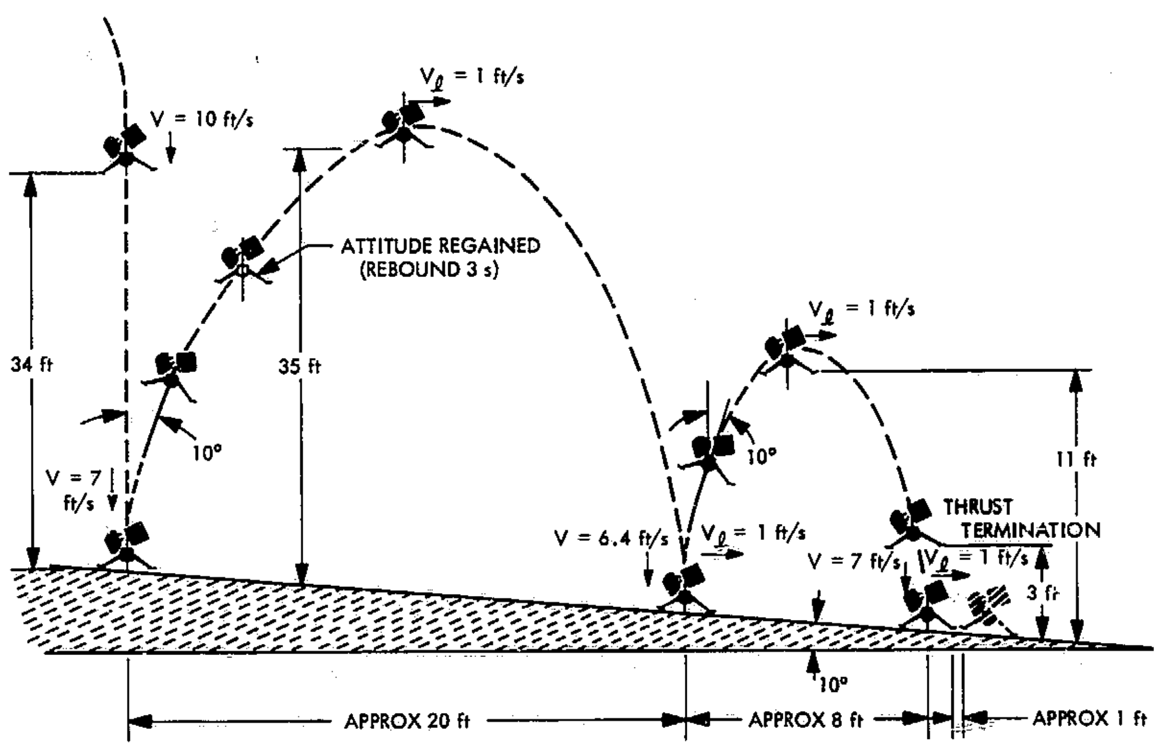


Fig. 33. *Surveyor III* landing profile

mode TV pictures. The first of these was taken at 58 min 14 s after touchdown. It was of interest to note that the TV-frame ID data were all normal.

1. First lunar day. DSS 11 was the prime command station for lunar phase television and commanded the majority of television pictures. Television pictures, however, were both commanded and received by DSS 42 on passes 11, 12, 13, 15, and 16, and DSS 61 on passes 15 and 16.

Operations consisted of engineering interrogations, television pictures, and photographs of the eclipse on April 24 as well as Soil Mechanics/Surface Sampler experiments, which included surface bearing and trenching experiments.

The spacecraft was turned off for the first lunar night by DSS 42 at 00:03:58 on May 4, 1967.

2. Second lunar day. On May 23, 1967 at 20:52:17, DSS 61 attempted to revive the spacecraft by using points of *Nonstandard Procedure 32, Spacecraft Revival.*

Deep Space Stations 61, 42, and 11 attempted to revive the spacecraft on their first three passes with no success. Thereafter, only DSS 11 was active in spacecraft revival attempts on passes 4 through 9.

When DSS 11 locked up on a signal on pass 9, DSS 14 was brought up to provide the additional gain of the larger antenna. It was decided that a spurious *Lunar Orbiter D* spacecraft signal was being received.

The SFOD authorized the termination of the attempted spacecraft revival at 18:56:09 on June 1, 1967.

H. Summary of DSIF Station Operations

1. General. The following comprises a summary of DSIF station operations for *Surveyor III* mission. A description of the tabular columns of Table 28 follows.

a. Station number. This number refers to the designation of the DSIF station participating in this mission. The stations participating were:

DSS 11	(Pioneer), Goldstone, California
DSS 12	(Echo), Goldstone, California
DSS 14	(Mars), Goldstone, California
DSS 42	Tidbinbilla, Australia
DSS 51	Johannesburg, South Africa
DSS 61	Robledo, Spain
DSS 71	Cape Kennedy, Florida
DSS 72	Ascension Island

Table 28. Summary of DSIF station operations

Station No.	Acquisition/end of track, GMT: Day of year	Time, h, min, s	Tracking: Ground mode[a]	Length of time, h, min, s	Ground-received signal level, −dBm, max, min	Total commands sent	TV pictures received: By command	Non-command	Significant events, equipment failures, and anomalies
					Launch				
71	107	07:05:01 07:08:30	1 Total	00:03:29 00:03:29		0	0	0	*Surveyor III* launch occurred at 107/07:05:01.059. Azimuth was 100.809 deg
					Launch pass				
72	107	07:29:38 07:32:19	1 Total	00:02:41 00:02:41	100 117	0	0	0	TDH doppler counter failed, dropping MSD of doppler readout
51	107	07:39:46 07:43:50	1 Total	00:04:04 00:04:04	99 99	0	0	0	Receiver 1, 50 MHz IF, indicated strong sidebands on spectrum analyzer. Problem was traced to VCO power supply
					Pass 1				
42	107	07:55:00 14:21:00	1 2 3 Total	00:04:39 04:14:59 02:05:39 06:25:17	90 136	50	0	0	At 107/10:41 TCP computers were changed to solve average alarm anomaly At 107/10:29 sideband energy at 1100 bits/s rate was down 11 dB from carrier instead of nominal 2.5 dB separation. Later check showed 550 bits/s rate was correct Transfer of spacecraft to DSS 51 occurred at 107/12:15:00
51	107	12:04:19 23:05:00	1 2 3 Total	00:16:41 05:27:53 05:16:07 11:00:41	133.3 135.7	15	0	0	TDH preamble generator caused garbling due to low current at the generator. This caused distortion of communications output to line Due to Exciter operator error, Transmitter was prematurely turned on from 107/16:59:00 to 107/16:59:30, just prior to standard transfer from DSS 61 to DSS 51. Transmitter turn on was 1 s late at transfer turn on at 107/17:00:1 Receivers locked onto sidebands and there was an erroneous indication of phaselock caused by loss of decommutator lock. Receivers were returned to carrier and decommutator lock was re-established; no phase-lock was confirmed. Uplink search was necessary. Phaselock was obtained and confirmed at 107/17:17:11 The spacecraft was transferred to DSS 61 at 107/14:30:00 and 107/20:30:00
61	107 108	13:45:16 02:07:22	2 3 Total	04:15:41 08:06:12 12:21:53	116.3 145.7	32	0	0	VCO counter counted in error; sensitivity was adjusted. Transformer failed in CEC recorder TDH unable to print digit 8 or 9 in 8th position of doppler counter. Doppler printout poor in 6th and least significant digits AIS galvanometer failed in CEC recorder Average alarm skipped certain locations. Post-calibration test on PCM simulator showed the only time error occurred was when a parameter was zero and some other number during the 3-number summation. Suspected error was in program since most parameters are never zero Spacecraft transferred to DSS 51 at 107/17:00 and to DSS 11 at 107/22:15

Table 28 (contd)

Station No.	Acquisition/end of track, GMT: Day of year	Acquisition/end of track, GMT: Time h, min, s	Tracking: Ground mode[a]	Tracking: Length of time, h, min, s	Ground-received signal level, −dBm, max, min	Total commands sent	TV pictures received: By command	TV pictures received: Non-command	Significant events, equipment failures, and anomalies
					Pass 1 (contd)				
72	107	14:26:40 23:00:00	1 3 Total	00:00:18 08:30:52 08:31:10	127.3 149.5	0	0	0	TTY preamble generator dropped parity bit
					Midcourse pass				
11	107/108	21:47:44 09:35:48	1 3 Total	10:23:37 02:24:27 12:48:04	117.5 141.8	96	0		TDH data garbled at JPL. Momentary 10-dB drop in signal level on Receiver 1 only, as monitored on CEC oscillograph. IMP will not display AGC Pre-track TV-11 GDHS did not output good data Spacecraft was transferred to DSS 42 at 108/08:40
12	107/108	23:00:00 05:24:00	3 Total	06:24:00 06:24:00	117.0 138.6	0	0	0	Provided TXR backup to DSS 11
					Pass 2				
42	108	05:33:40 14:58:30	2 3 Total	06:00:02 03:24:48 09:24:50	138.0 141.8	5	0	0	Reperforated tape of AVA unusable between 11:30 and 12:04 due to a stuck punch IMP does not process D3 doppler correctly Filters inserted in CEC recorder angle channel to reduce noise Spacecraft transferred to DSS 61 at 108/14:40
51	108	13:06:58 23:19:00	2 3 Total	02:40:02 07:32:00 10:12:02	140.6 143.6	1	0	0	Patch missing from TCD to tracks 2 and 6; no TLM recorded from 13:07 to 13:20. Patch removed when checking FR 1400 tape from Pass 1 on FR 1200. Patch replaced at 13:20 LF oscillograph channel 2 not working Spacecraft transferred to DSS 61 at 108/18:10 and to DSS 11 at 108/22:20
61	108/109	13:56:25 02:41:17	2 3 Total	07:00:06 05:04:48 12:04:54	140.9 165.0	22	0	0	At 19:18 and at 01:35, CEC paper jammed, with no loss of data Spacecraft transferred to DSS 51 at 108/16:40 and 108/21:10 and to DSS 11 at 109/02:20
11	108/109	22:06:12 09:50:20	2 3 Total	07:26:00 04:18:08 11:44:08	142.7 152.5	13	0	0	Isolation amplifier replaced on receiver 2 At 06:55 IMP would not switch from D2 to D3 predicts From 06:44 to 08:22 antenna switching from RCP/LCP for axial experiment; nominal signal change of 7 dB Spacecraft transferred to DSS 61 at 109/00:20 and to DSS 42 at 109/06:40 and 109/09:45
					Pass 3				
42	109	06:01:30 15:07:00	2 3 Total	06:35:00 02:30:30 09:05:30	142.7 147.5	23	0	0	Spacecraft transferred to DSS 11 at 109/08:40 and to DSS 61 at 109/14:20
51	109	13:19:46 23:23:15	2 3 Total	00:45:02 09:18:27 10:03:29	145.5 153.0	4	0	0	Bad threshold due to rain collecting on cone Spacecraft transferred to DSS 61 at 109/18:45
61	109/110	14:04:15 02:56:17	2 3 Total	07:09:59 05:42:03 12:52:02	122.5 165.0	34	0	11	Spacecraft transferred to DSS 51 at 109/18:00 and DSS 11 at 109/22:15

Table 28 (contd)

Station No.	Acquisition/end of track, GMT		Tracking		Ground-received signal level, −dBm, max, min	Total commands sent	TV pictures received		Significant events, equipment failures, and anomalies
	Day of year	Time, h, min, s	Ground mode[a]	Length of time, h, min, s			By command	Non-command	
	Pass 3 (contd)								
11	109/110	22:10:54 10:13:25	0 2 3 4 Total	02:24:00 01:03:56 00:04:06 08:14:52 11:46:54	102.6 151.3	6,680	377[a]	0	Spacecraft touchdown at 00:04:18 on April 20 TCP-A failure necessitated switching to TCP-B. TV-11 film recorder failed; undetermined number of frames actually recorded Spacecraft transferred to DSS 42 at 110/10:10 [a]Includes fifty-four 200-line pictures
12	109/110	22:09:22 06:31:00	3 Total	08:21:38 08:21:38	120.5 148.2	0	0	0	Backup TXR power for DSS 11
14	109/110	22:39:00 03:40:00	3 Total	05:01:00 05:01:00	115.0 140.8	0	0	0	TLM backup recording for DSS 11
	Pass 4								
42	110	06:20:06 15:49:00	1 2 3 Total	04:14:54 04:45:02 00:28:58 09:28:54	94.0 145.0	99		380	IMP doppler printouts outside limits because of incorrect DNS (computer equation) entry due to operator error. Rectified error at 14:51 Spacecraft transferred to DSS 61 at 110/15:20
51	110/111	13:52:00 00:37:15	3 Total	10:45:15 10:45:15	98.0 120.0	0	0	70	LF oscillograph timing stylus heater opened
61	110/111	14:33:48 03:24:30	2 3 Total	08:00:02 04:50:40 12:50:42	112.5 118.6	17	0	311	Spacecraft transferred to DSS 11 at 110/23:20
11	110/111	23:00:42 11:05:30	2 3 4 Total	00:37:58 00:29:53 10:56:57 12:04:48	93.6 120.5	5,801	1,089	0	The command generator was left in *auto* mode with inhibit switch off after a command search. Three commands were sent in error Backup VCO counter bad CDC-TCP Bravo interface intermittent. Spacecraft transferred to DSS 42 at 111/10:55
	Pass 5								
42	111	06:39:59 17:03:50	1 2 3 4 Total	04:15:01 05:13:18 00:33:48 00:21:44 10:23:51	99.5 120.0	553	0	279	Program hung up on TCP Alpha. Program was reloaded but anomaly still existed. TCP changed to Beta Prime. Later checkout on Alpha could not confirm anomaly with Alpha. Computer now good Spacecraft transferred to DSS 61 at 111/16:30
61	111/112	15:42:45 03:53:06	2 3 Total	07:55:02 04:15:19 12:10:21	118.7 167.0	46	0	131	TCP Beta computer down Spacecraft transferred to DSS 11 at 112/00:25
11	112	00:11:13 11:57:12	1 2 3 4 Total	00:12:10 01:53:09 00:13:47 09:25:53 11:44:59	100.6 131.4	1,669	187	0	Replaced a blown fuse on the Beta computer; cause unknown Spacecraft transferred to DSS 42 at 112/11:45

Table 28 (contd)

Station No.	Acquisition/end of track, GMT		Tracking		Ground-received signal level, —dBm, max, min	Total commands sent	TV pictures received		Significant events, equipment failures, and anomalies
	Day of year	Time h, min, s	Ground mode[a]	Length of time, h, min, s			By command	Non-command	
				Pass 6					
42	112	07:10:00 18:10:30	1 2 3 Total	05:39:53 02:01:07 00:40:30 08:21:30	115.5 156.0	15	0	42	Conducted uplink test from 14:33 to 17:22 Spacecraft transferred to DSS 61 at 112/17:20
61	112 113	17:07:08 04:23:16	2 3 Total	08:00:00 03:16:08 11:16:08	96.1 146.2	361	0	7	Spacecraft transferred to DSS 11 at 113/01:30
11	113	01:17:22 11:00:00	1 2 3 4 Total	00:28:47 00:12:30 00:43:19 08:13:05 09:37:41	103.2 142.0	578	30	0	Bad connector on maser 1 was replaced Maser 1 had intermittent low frequency modulation—source unknown Spacecraft transferred to DSS 42 at 113/10:30
				Pass 7					
42	113	07:38:00 19:20:50	1 2 3 Total	03:34:00 07:33:00 00:35:50 11:42:50	101.8 124.0	1,769	0	12	Spacecraft transferred to DSS 61 at 113/18:45
61	113 114	18:17:50 04:45:00	1 2 3 Total	00:00:54 09:22:56 01:02:04 10:25:54	102.6 121.0	25	0	0	Spacecraft transferred to DSS 11 at 114/04:10
11	114	04:00:00 12:59:00	0 2 3 4 Total	02:20:11 00:11:56 00:18:58 05:57:40 08:48:45	102.7 124.3	1,307	118	0	Intermittent command verification problem on TCP Beta Spacecraft transferred to DSS 42 at 114/12:50
				Pass 8					
42	114	08:08:00 20:37:00	2 3 Total	07:25:02 05:03:58 12:29:00	97.8 134.5	808	0	50	Backup photo recorder camera drive faulty Spacecraft transferred to DSS 61 at 114/20:15
61	114 115	19:48:35 05:24:00	2 3 Total	07:44:08 01:49:13 09:33:21	120.6 128.4	28	0	0	Spacecraft transferred to DSS 12 at 115/04:00
11	115	03:38:00 13:15:00	3 Total	09:37:00 09:37:00	122.8 157.0	0	0	0	Three-way with DSS 12 for antenna pattern experiment
12	115	03:30:00 13:21:00	1 2 3 Total	00:25:30 08:48:50 00:36:10 09:50:30	99.2 156.2	159	0	0	Spacecraft transferred to DSS 42 at 115/13:15

Table 28 (contd)

Station No.	Acquisition/end of track, GMT: Day of year	Acquisition/end of track, GMT: Time, h, min, s	Tracking: Ground mode[a]	Tracking: Length of time, h, min, s	Ground-received signal level, —dBm, max, min	Total commands sent	TV pictures received: By command	TV pictures received: Non-command	Significant events, equipment failures, and anomalies
				Pass 9					
42	115	08:45:00 21:55:30	2 3 4 Total	07:55:10 04:50:28 00:24:52 13:10:30	99.0 157.0	31	0	0	Tape reader in CDC area incompatible with TCP At 13:39, maser 1 failed due to helium storage tank under pressure conditions. Rectification was made and maser 1 was used later in the pass While on acquisition aid antenna, servo operator erroneously switched antenna to slave mode, causing antenna to run away and drop lock on spacecraft Spacecraft transferred to DSS 61 at 115/21:35
61	115 116	21:10:00 05:55:00	1 2 3 Total	00:03:54 07:30:40 01:07:06 08:41:40	122.1 122.9	789	0	5	Spacecraft transferred to DSS 11 at 116/05:10
11	116	04:57:00 13:30:00	0 2 3 4 Total	01:24:27 01:49:51 00:13:00 03:28:45 06:56:03	103.7 150.8	3,403	276	0	TV-11 film recorder problem Spacecraft transferred to DSS 42 at 116/13:15
				Pass 10					
42	116	09:33:36 23:05:27	1 2 3 4 Total	00:19:28 08:56:02 02:01:27 00:19:00 11:35:57	102.0 150.0	1,800	0	28	Loss of dummy frames after data transferred due to program hangup in B computer A 1-MHz ripple appeared on all receiver ISO amp outputs, fed to AIS. Cause was crosstalk in AIS from 1 MHz mixed with 36-bit time code on recorder track 4. Crosstalk interferes with IMP During pass countdown, two unexplained 5-min periods of instability occurred in maser 1 crosshead. Mechanical operation found to be unsatisfactory. Maser 2 was prime FR 800 was operational for pass as it was temporarily repaired Spacecraft transfer to DSS 51 occurred at 116/22:30
51	116 117	22:02:47 06:22:40	2 3 Total	05:58:22 02:19:51 08:18:13	98.0 155.0	1,878	0	0	Due to a mismatch in the AIS, no PCM data to track 5 of the recorders CDC and printer column 4 not printing; needed proper adjustment Spacecraft transfer to DSS 61 occurred at 117/04:30
61	117	00:52:30 06:37:37	2 3 Total	01:59:18 03:43:50 05:43:08	121.6 122.3	5	0	0	Spacecraft transfer to DSS 11 occurred at 117/06:30
11	117	06:18:07 14:42:00	0 1 2 3 4 Total	06:00:41 00:24:06 00:20:25 00:11:53 01:26:37 08:23:42	122.5 123.8	1,169	190	630	TV 11 film recorder was inoperative for a long portion of the pass due to power supply failure Spacecraft transferred to DSS 42 at 117/12:05

Table 28 (contd)

Station No.	Acquisition/end of track, GMT: Day of year	Acquisition/end of track, GMT: Time h, min, s	Tracking: Ground mode[a]	Tracking: Length of time, h, min, s	Ground-received signal level, −dBm, max, min	Total commands sent	TV pictures received: By command	TV pictures received: Non-command	Significant events, equipment failures, and anomalies
				Pass 11					
42	117 118	10:22:00 00:16:00	1 3 4 Total	01:43:00 00:26:00 11:45:00 13:54:00	115.7 137.3	3,822	611	81	Tape reader 1 fails media test with TCP, but is satisfactory with command generator. Any other combination of reader and punch are all right Probable RF interference at 117/10:56 thought to be morse code Decommutator 1 failed at 18:44 Spacecraft transfer to DSS 51 occurred at 117/23:50
51	117 118	23:00:36 07:44:00	2 3 Total	03:10:04 05:33:20 08:43:24	121.1 123.6	5	0	0	Spacecraft transferred to DSS 61 at 118/02:40 and to DSS 11 at 118/07:40
61	118	01:08:40 07:34:08	2 3 Total	04:40:00 01:45:28 06:25:28	120.9 121.6	14	0	0	Spacecraft transferred to DSS 51 at 118/07:20
11	118	07:29:10 15:39:00	0 2 3 4 Total	06:21:55 00:35:06 00:10:50 00:38:49 07:46:40	103.1 124.8	2,280	218	541	Spacecraft transfer to DSS 42 occurred at 118/13:45
				Pass 12					
42	118 119	11:16:00 01:06:00	1 2 3 4 Total	02:29:00 08:14:00 00:21:00 02:46:00 13:50:00	120.0 121.0	2,233	534	41	Rubidium standard on loan from DSS 41 was returned. DSS 42 has only one rubidium standard at this time Alpha computer down due to probable program loading error. Time was not available for rechecking Decommutator 1 has intermittent VCO card. Bit-error rate portion inoperative. Holding as backup otherwise Spacecraft transfer to DSS 51 occurred at 119/00:45
51	119	00:19:00 08:45:42	2 3 Total	03:52:04 04:34:38 08:26:42	120.5 122.6	0	0	0	Spacecraft transferred to DSS 61 at 119/02:00 and to DSS 11 at 119/08:37
61	119	01:11:28 08:31:00	2 3 Total	04:00:00 03:19:32 07:19:32	121.9 122.7	48	0	0	Spacecraft transferred to DSS 51 at 119/06:00
11	119	08:27:34 16:31:00	1 2 3 4 Total	02:51:00 00:07:47 00:10:27 04:54:12 08:03:26	104.6 154.7	2,471	458	546	Maser 2 had a defective crosshead Unable to saturate the klystron on the transmitter, but able to maintain a constant 10 kW. Did not anticipate any problems Noise spikes appeared in 50 MHz IF when station TXR was on. This was a recurring problem but cause is unknown at this time Spacecraft transfer to DSS 42 occurred at 119/13:40

Table 28 (contd)

Station No.	Acquisition/end of track, GMT: Day of year	Acquisition/end of track, GMT: Time, h, min, s	Tracking: Ground mode[a]	Tracking: Length of time, h, min, s	Ground-received signal level, −dBm, max, min	Total commands sent	TV pictures received: By command	TV pictures received: Noncommand	Significant events, equipment failures, and anomalies
				Pass 13					
42	119 120	12:11:00 02:03:00	1 2 3 4 Total	01:29:00 08:35:00 00:33:00 03:15:00 13:52:00	121.5 134.3	3,128	538	391	Spacecraft transfer to DSS 51 occurred at 120/01:30
51	120	00:49:54 08:02:30	2 3 Total	06:05:02 01:07:34 07:12:36	122.5 123.1	7	0	0	Spacecraft transfer to DSS 61 occurred at 120/07:35
61	120	03:48:03 09:30:47	2 3 Total	01:49:31 03:51:50 05:41:21	122.2 122.8	13	0	0	Due to poor communication with DSS 51, DSS 61 was requested to acquire spacecraft as soon as possible on a best efforts basis Spacecraft transfer to DSS 11 occurred at 120/09:25
11	120	09:14:49 17:57:36	2 3 4 Total	00:05:50 00:21:42 08:15:16 08:42:48	135.0 138.1	4,874	861	0	Spacecraft transfer to DSS 42 occurred at 120/17:35
				Pass 14					
42	120 121	15:28:00 02:50:00	1 2 3 4 Total	02:07:00 09:00:00 00:10:00 00:10:00 11:27:00	120.8 121.9	54	0	74	Acquisition delay of 9 min due to exciter unserviceability. During countdown, exciter suffered loss of output, and acquisition volts became erratic. Replaced exciter acquisition potentiometer and distributor amplifier A 60-Hz ripple at exciter output. Investigation revealed a test equipment installation problem Spacecraft transfer to DSS 61 occurred at 121/02:45
61	121	02:22:00 10:44:00	2 3 Total	07:34:02 00:46:33 08:20:35	121.3 123.1	342	0	3	Spacecraft transfer to DSS 11 occurred at 121/10:20
11	121	09:50:45 19:05:00	2 3 4 Total	00:07:35 00:29:45 08:36:55 09:14:15	125.1 161.5	2,215	289	0	Spacecraft transfer to DSS 42 occurred at 121/18:50
				Pass 15					
42	121 122	18:00:00 03:34:02	1 2 3 4 Total	00:50:27 07:59:02 00:19:02 00:20:33 09:29:04	121.0 122.0	1,104	11	0	IMP and APS apparently glitched about 19:48 when APS pulled in 3 samples and drove antenna off predictions. Uplink and downlink were dropped. IMP readouts stopped from 19:45 until 20:05 when program was reloaded. Spacecraft on high power planar array for SAA/SCM (S-band acquisition aid/S-band cassegrain monopulse) collimation test from 02:00 to 02:50 Spacecraft transfer to DSS 61 occurred at 122/03:15
61	122	02:55:15 11:49:19	2 3 Total	07:20:02 01:33:39 08:53:41	121.4 123.1	1,488	5	36	Spacecraft transferred to DSS 11 at 122/10:35
11	122	10:24:41 20:09:00	2 3 4 Total	01:17:13 00:18:34 08:08:08 09:43:55	122.2 123.4	1,909	252	2	Took 8 shadow progression pictures Spacecraft transfer to DSS 42 occurred at 122/19:45

Table 28 (contd)

Station No.	Acquisition/end of track, GMT: Day of year	Acquisition/end of track, GMT: Time h, min, s	Tracking: Ground mode[a]	Tracking: Length of time, h, min, s	Ground-received signal level, —dBm, max, min	Total commands sent	TV pictures received: By command	TV pictures received: Non-command	Significant events, equipment failures, and anomalies
	Pass 16								
42	122 123	19:00:00 03:52:00	1 2 3 4 Total	00:08:10 07:35:00 00:43:50 00:25:00 08:52:00	99.0 120.0	470	32	2	Decommutator 1 did not hold lock on 17.2 bits/s. Replaced a sheared wheel in the local oscillator potentiometer Took TV shadow progression pictures Spacecraft transfer to DSS 61 occurred at 123/03:45
61	123	03:16:48 12:51:14	2 3 Total	06:59:50 02:32:30 09:32:20	100.5 135.2	419	28	0	New rubidium standard R-20 had 16-V potential between the rubidium chassis and system ground. This created an intermittent short on the power supply source through the power supply monitor. The power supply source furnishes power for the datex clock (PC-141) and Knight oscillator. Removed rubidium R-20 from chassis for further analysis. Reset datex clock to astrodata and WWV Spacecraft transfer to DSS 11 occurred at 123/10:55
11	123	10:45:17 21:16:00	1 2 3 4 Total	00:28:57 01:36:04 00:08:02 08:15:33 10:28:36	120.7 150.5	869	222	0	Maser 1 high-pressure valve was low by 15 psi. Conducted voice test between SFOF/DSS 11/spacecraft/and DSS 11 which was noisy, but legible TV shadow progression pictures Spacecraft transfer to DSS 42 occurred at 123/21:00
	Pass 17								
42	123 124	20:00:00 00:06:15	0 1 4 Total	01:54:17 01:05:00 01:06:58 04:06:15	118.9 119.8	57	0	32	Transmitter water leak problem corrected Spacecraft turned off for lunar night
	First lunar day, totals					57,107	6,326	3,705	
	TV pictures, total						10,031		
	Second lunar day, Pass 1								
61	143 144	20:52:17 03:45:00				604	0	0	Maser 1 unusable as a backup. Warming up TDH tape feed failure punch 2. Punch changed Revival attempt unsuccessful. Used some points of NSP 32
11	144	04:56:00 12:08:55				236	0	0	At 01:17, FR 800 playback to TV 11 noisy At 01:30, receiver/TV 11 unable to interface At 04:56, servo off point due to Day 143 predicts instead of Day 144 predicts. Servo on point with new predicts at 05:47 Attempted spacecraft revival with negative results. Station performed receiver search over entire frequency capability with no spacecraft carrier signal received. Performed NSP 32
42	144	11:36:00 21:47:00				524	0	0	TDH preamble generator 13 thought to be causing preambles because TDH was not being seen by track. When TPG was changed track could see TDH. Later, however, there were similar outages. The original fault may have been something in the CP operation Revival attempt unsuccessful. Used points of NSP 32

Table 28 (contd)

Station No.	Acquisition/end of track, GMT: Day of year	Acquisition/end of track, GMT: Time, h, min, s	Tracking: Ground mode[a]	Tracking: Length of time, h, min, s	Ground-received signal level, —dBm, max, min	Total commands sent	TV pictures received: By command	TV pictures received: Noncommand	Significant events, equipment failures, and anomalies
					Pass 2				
61	144 145	21:26:00 05:18:00				744	0	0	Maser 1 still unusable as backup Spacecraft revival attempt failed
11	145	05:20:00 13:08:00				104	0	0	FR 800 and FR 1400 playbacks noisy Lost receivers 1 and 2 dynamic phase error and AGC for 8 min. Problem caused by a loose connector. Performed receiver search over entire frequency range with no spacecraft carrier received. Performed NSP 32
42	145	13:05:00 22:54:00				541	0	0	At 13:32 the transmitter tripped due to collector flow interlock NSP 32 performed but no spacecraft revival accomplished
					Pass 3				
61	145 146	22:40:00 06:12:00				580			Maser 1 still down; a carry-over from previous passes Revival attempt unsuccessful. NSP 32 utilized
11	146	06:19:00 11:48:00				176	0	0	Unsuccessful attempt to revive spacecraft. NSP 32 utilized
42	146	12:55:00 23:18:00				464	0	0	Revival attempt unsuccessful. Utilized NSP 32
					Pass 4				
11	147	07:11:00				312	0	0	FR 800 marginal. Processed video had random blocks of noise The FR 1400 was unusable. The TV GDHS synchronization will not go out of lock at TXR off times Spacecraft revival attempt unsuccessful. Performed NSP 32, Rev. D, from point 1 to point 12
					Pass 5				
11	148	07:55:00 16:31:00				312	0	0	FR 1400 B still noisy Attempted spacecraft revival with negative results per NSP 32, Rev. D, from point 1 to point 12
					Pass 6				
11	149	08:32:00 17:50:00				528	0	0	FR 1400 B still noisy Attempted spacecraft revival per NSP 32, Rev. D, with negative results, from point 1 to point 10
					Pass 7				
11	150								Revival attempt cancelled.
					Pass 8				
11	151					304	0	0	Maser 2 out of service; crosshead problems. Estimate 15 h before service returns TDH/TD NR 1 caused open TTY line; switched to punch 2 Attempted revival of spacecraft per NSP 32, Rev. D, with negative results from point 1 to point 10

Table 28 (contd)

Station No.	Acquisition/end of track, GMT: Day of year	Acquisition/end of track, GMT: Time, h, min, s	Tracking: Ground mode[a]	Tracking: Length of time, h, min, s	Ground-received signal level, −dBm, max, min	Total commands sent	TV pictures received: By command	TV pictures received: Noncommand	Significant events, equipment failures, and anomalies
	Pass 9								
11	152	10:15:44 18:56:09				400	0	0	TDH punch 1 is unreliable and maser 2 out of service. Both items are carried over from previous pass From 117/11:47:09 to 12:31:30 and from 14:04:00 to 14:23:47, receivers appeared to be in lock on a spurious signal from *Lunar Orbiter D* Attempted spacecraft revival per NSP 32, Rev. D, with negative results SFOD authorized the termination of spacecraft revival attempts
14	152	14:00:00 18:50:00				0	0	0	After first DSS 11 lock on *Lunar Orbiter D*, spurious signal, station called to provide backup
		Second lunar day, totals				5,929			
		First and second day, totals				63,036			
		TV pictures, totals					6,326	3,705	
							10,031		

[a]See Table 29.

b. Acquisition/end of track (GMT), day of year, time (h, min, s). Each station entry in these columns consists of two sets of numbers. The first set is the day and time, in hours, minutes, and seconds, in GMT, of spacecraft acquisition. The second set of numbers indicates the day and time that tracking terminated.

c. Tracking, GM, length of time (hms). These columns list the duration (in hours, minutes, and seconds) of each tracking ground mode. The ground mode indications, numerals 0 through 5, are defined in Table 29. At the end of each station entry is the total tracking time in all modes.

d. Ground-received signal level, −dBmW (max, min). The ground-received signal level column contains two figures for each station's entry. These figures are the maximum and minimum signal levels received at the indicated station. The values are given in minus decibels relative to 1 mW (−dBmW).

Table 29. Ground modes

Indicator	Ground mode
0	Transmit only
1	One-way (receive only)
2	Two-way coherent
3	Three-way coherent
4	Two-way noncoherent
5	Three-way noncoherent

e. Total commands sent. The figures in this column indicate the number of commands sent by each station.

f. TV pictures received by command and noncommand. Unless otherwise indicated, these figures represent 600-line television pictures received by a station while the spacecraft was under its command. Noncommand pictures were pictures received by a station while the spacecraft was commanded by another station.

g. Significant events, equipment failures and anomalies. As indicated, this column notes important events, equipment failures, and problems. All times given in this column are in GMT in hours and minutes (four-digit numbers) or hours, minutes, and seconds (six-digit numbers). When the day is given with the time, the day and time are separated by a diagonal.

h. Tracking summary.

DSS 11 (Goldstone). During the mission, Goldstone provided support for 16 passes, including the midcourse maneuver and the terminal descent phase. These maneuver portions of the mission were executed using command tapes transmitted from the SFOF. The midcourse maneuver portion was executed without any problems, and the spacecraft remained stable and completely controllable. The terminal descent was a standard sequence with all commands transmitted at the predetermined time. After touchdown, the analog telemetry signals indicated incorrect readings, and commanding was performed to obtain information as to the nature of the spacecraft malfunction. About 1 h after touchdown, the decision was made to turn on the TV camera; 54 pictures were taken in the 200-line mode. During the remainder of the lunar day, the activity at Goldstone included 600-line TV operations, SM/SS operations, and engineering interrogations. The TV operations were conducted mainly with prepunched command tapes, although extensive keyboard commanding was done as the TV mirror became balky when stepping in azimuth and elevation. All SM/SS operations were conducted by Goldstone. The computer was used in the tape search mode to locate the proper minor sequence on the SM/SS command glossary tape.

DSS 42 (Canberra). Canberra provided support for 17 passes, including initial acquisition. Spacecraft telemetry was first acquired at $L + 43$ min via a dataphone link from the Carnarvon station located on the western coast of Australia. About 10 min later, the spacecraft, traveling from west to east relative to the earth, came into view of DSS 42 and the switch to its receiver was made. The station was able to begin commanding approximately 1 h after launch.

DSS 51 (Johannesburg). Johannesburg provided support for nine passes, including a period immediately after *Surveyor/Centaur* separation when the CDC decommutator was in lock for nearly 3 min. At this time, $L + 35$ min, the spacecraft was traveling very fast and some unusual techniques were required to obtain data. One of the data analysts was present at the Pretoria tracking station (AFETR 13) to observe the accelerometer data and some telemetry signals being recorded there. The station had a limited commitment for this mission but performed a more active part than anticipated.

Table 30 gives a complete tracking data summary of the individual participating stations from the near-earth flight phase through lunar touchdown.

Table 30. Tracking data summary

Tracking Station	Day	Pass	Data received		Sample rate	Total samples	Total good samples	Bad/questionable samples			Percentage good samples	Remarks
			from	to				Bad DCC	Garbled	Total		
AFETR 73	107	1	07:06:30	07:11:30	6 s	51	30	18	3	21	58.82	
AFETR 74	107	1	07:11:12	07:18:24	6 s	73	63	8	2	10	86.30	
AFETR 82	107	1	07:07:06	07:15:00	6 s	80	35	37	8	45	43.75	
AFETR 75	107	1	07:27:12	07:31:42	6 s	47	16	31	0	31	34.04	
AFETR 75	107	1	07:38:18	07:46:12	6 s	80	37	43	0	43	46.25	
AFETR 83	107	1	07:50:06	08:47:42	6 s	577	545	8	24	32	94.45	
DSS 51	107	1	07:35:10	07:44:10	10 s	55	23	32	0	32	41.82	One-way data. Good doppler, not auto tracking
DSS 42[a]	107	1	07:51:12	08:01:42	10 s	64	23	41	0	41		One-way data. Good data when doppler is good
			08:01:52	08:51:52	10 s	301	301	0	0	0		Two-way data
			08:52:02	12:15:02	1 min	196	186	3	7	10		Two-way data
			12:16:02	14:20:02	1 min	125	113	4	8	12		Three-way data
					Total	686	623	48	15	63	92.45	
DSS 51	107	1	12:03:02	12:21:02	1 min	19	10	9	0	9		Three-way data
			12:22:02	14:30:02	1 min	129	117	1	11	12		Two-way data
			14:31:02	17:03:02	1 min	153	137	9	7	16		Three-way data
			17:04:02	20:30:02	1 min	207	183	13	11	24		Two-way data
			20:31:02	22:02:02	1 min	92	84	2	6	8		Three-way data
					Total	600	531	34	35	69	88.50	
DSS 61[a]	107/108	1	14:37:02	16:08:02	1 min	92	79	0	13	13		Two-way data
			16:09:02	16:31:02	1 min	23	15	0	8	8		One-way data

[a]Sample rate converted to 1 sample/s for computation of percentage.

Table 30 (contd)

Tracking Station	Day	Pass	Data received		Sample rate	Total samples	Total good samples	Bad/questionable samples			Percentage good samples	Remarks
			from	to				Bad DCC	Garbled	Total		
DSS 61[a] (Contd)			16:32:02	16:54:02	1 min	23	19	4	0	4		Two-way data
			16:55:02	17:33:02	1 min	39	10	29	0	29		Three-way data; station transfer
												No DSS 61 data from 17:34 to 18:41 due to station doppler problem
			18:41:02	18:52:02	1 min	12	12	0	0	0		Three-way data
			18:52:52	20:24:52	10 s	553	536	0	17	17		Three-way data
			20:25:02	20:49:02	10 s	144	80	62	2	64		Two-way data
			20:50:02	22:10:02	1 min	121	114	1	6	7		Two-way data
			22:11:02	02:08:02	1 min	238	213	9	16	25		Three-way data
					Total	1245	1078	105	62	167	85.02	
DSS 11[a]	107/108	1	21:45:02	22:10:02	1 min	26	14	12	0	12		Three-way data
			22:11:02	04:39:02	1 min	389	366	7	16	23		Two-way data
			04:39:27	05:12:17	10 s	198	197	0	1	1		Two-way data, not auto tracking
			05:13:02	08:40:02	1 min	208	206	2	0	2		Two-way data, seven samples not auto tracking
			08:41:02	09:36:02	1 min	56	55	1	0	1		Three-way data
					Total	877	838	22	17	39	94.64	
DSS 51	108	2	13:06:02	16:41:02	1 min	216	191	10	15	25		Three-way data
			16:42:02	18:10:02	1 min	89	82	1	6	7		Two-way data
			18:11:02	21:10:02	1 min	180	166	5	9	14		Three-way data
			21:11:02	22:20:02	1 min	70	67	1	2	3		Two-way data
			22:21:02	23:19:02	1 min	59	55	3	1	4		Three-way data
					Total	614	561	20	33	53	91.37	
DSS 42	108	2	05:34:02	05:36:02	1 min	3	2	1	0	1		One-way data
			05:37:02	08:40:02	1 min	184	180	1	3	4		Three-way data
			08:41:02	14:40:02	1 min	360	358	1	1	2		Two-way data
			14:41:02	14:59:02	1 min	19	17	2	0	2		Three-way data
					Total	566	557	5	4	9	98.41	
DSS 61	108/109	2	13:55:02	14:34:02	1 min	40	35	4	1	5		Three-way data
			14:35:02	16:35:02	1 min	121	106	9	6	15		Two-way data
			16:36:02	18:04:02	1 min	89	79	8	2	10		Three-way data
			18:05:02	21:05:02	1 min	181	169	9	3	12		Two-way data
			21:06:02	00:19:02	1 min	194	171	21	2	23		Three-way data
			00:20:02	02:16:02	1 min	117	106	5	6	11		Two-way data
			02:17:02	02:41:02	1 min	25	20	5	0	5		Three-way data
					Total	767	686	61	20	81	89.44	

[a]Sample rate converted to 1 sample/s for computation of percentage.

Table 30 (contd)

Tracking Station	Day	Pass	Data received from	Data received to	Sample rate	Total samples	Total good samples	Bad/questionable samples: Bad DCC	Garbled	Total	Percentage good samples	Remarks
DSS 11	108/109	2	22:03:02	22:19:02	1 min	16	13	3	0	3		Three-way data
			22:20:02	00:20:02	1 min	121	112	9	0	9		Two-way data
			00:21:02	02:19:02	1 min	119	116	3	0	3		Three-way data
			02:20:02	06:41:02	1 min	262	253	8	1	9		Two-way data
			06:42:02	08:35:02	1 min	114	107	7	0	7		Three-way data
			08:36:02	09:39:02	1 min	64	56	7	1	8		Two-way data
			09:40:02	09:50:02	1 min	11	4	7	0	7		Three-way data
					Total	707	661	44	2	46	93.49	
DSS 42	109	3	05:58:02	06:35:02	1 min	38	27	11	0	11		Three-way data
			06:36:02	08:36:02	1 min	121	113	8	0	8		Two-way data
			08:37:02	09:40:02	1 min	64	58	6	0	6		Three-way data
			09:41:02	14:20:02	1 min	280	274	6	0	6		Two-way data
			14:21:02	15:08:02	1 min	48	40	8	0	8		Three-way data
					Total	551	512	39	0	39	92.92	
DSS 51	109	3	16:18:02	18:00:02	1 min	103	84	5	14	19		Three-way data
			18:01:02	18:45:02	1 min	45	44	1	0	1		Two-way data
			18:46:02	23:19:02	1 min	274	215	14	45	59		Three-way data
					Total	422	343	20	59	79	81.28	
DSS 61[a]	109	3	14:15:02	17:55:02	1 min	221	190	18	13	31		Two-way data. Data lost 14:16:02 through 14:26:02
			17:56:02	18:39:02	1 min	44	35	8	1	9		Three-way data
			18:40:02	22:13:02	1 min	214	189	20	5	25		Two-way data
			22:14:02	23:19:02	1 min	66	61	4	1	5		Three-way data
			23:20:02	23:49:02	1 min	30	29	1	0	1		One-way data
			23:50:10	00:09:20	10 s	116	116	0	0	0		One-way data
			00:10:02	00:15:02	1 min	6	6	0	0	0		One-way data. Terminate monitor ground support
					Total	697	626	51	20	71	88.17	
DSS 11[a]	109	3	22:10:02	23:18:02	1 min	69	56	13	0	13		Two-way data
			23:19:02	23:49:02	1 min	31	29	2	0	2		One-way data
			23:50:18	00:17:08	10 s	162	162	0	0	0		One-way data. Terminate monitor support
					Total	262	247	15	0	15	88.19	

[a]Sample rate converted to 1 sample/s for computation of percentage.

I. Space Flight Operations Facility

1. Communications systems. The communications system consisted of the DSN/ICS support, internal nets, and the video.

a. DSN/ICS support. The DSN/ICS provided the capability of receiving, switching, and distributing, to designated areas of users within the SFOF, all types of information required for space flight operations. The system included all voice communication capabilities within the SFOF, television communications subsystem (TVCS) teletype, high speed data, and data received over the microwave channels. This system (DSN/ICS) performed in an exceptional manner with only minor problems noted.

b. Internal nets. There were some minor patching problems on the Mission Commentary Net (Voice of *Surveyor*) during launch due to the number of patches required. During this touchdown phase it was patched to Edwards Air Force Base and the Boeing Company, Seattle, in addition to the NASA and DSS requirements.

The *Surveyor* command net was patched at all times to the active DSS voice net. At one time there was a delay in getting it patched to the DSS 11 voice net, which caused a few minutes delay; this was rectified in real time.

From the *Surveyor II* mission, the communications status display had been divided into two parts, one showing TTY status and the second the voice and HSDL status. This worked very well.

c. Video. Extensive tests were conducted prior to the mission and no problems were experienced on the COMM/TV GDHS 6-MHz video line interface.

Only minor equipment problems were experienced on the TV communications subsystem and they were all repaired in real time. There was a shortage of TTY/TV monitors during launch phase as there were only 12 monitors and 23 active circuits. All monitors were assigned to *Surveyor* project. The output of the scan converter was normalized to PIO at all times and no problems were encountered.

Many areas in the SFOF do not have the scan converter or external buttons on the television area selectors. This caused a myriad of requests for the scan converter to be patched to individual area monitors during the lunar operations phase.

2. Data processing system.

a. Communications error problems. The most significant problem experienced during the *Surveyor* flight was the *command error 1* problems on the 7044-7094 computer strings. Exhaustive diagnostic testing in May isolated this discrepancy to a software problem, and this long-standing problem may now be closed out.

b. COMM/TPS patching. There was a great deal of confusion prior to the *Surveyor III* flight as to the patching of HSD between the communications center and TPS and the parties authorized to change this patching. This area has also been thoroughly investigated, and the results indicate that revised SOPs identifying the standard configuration and procedures for operating this configuration are mandatory; once these are initiated and complied with, patching will no longer create adverse conditions to the *Surveyor* project or DSN.

c. SFOF timing. A new timing system was implemented in the SFOF and was used for the *Surveyor III* mission. This system was synchronized with the Lab Standard each day and demonstrated a deviation of 50–70 ms/day. On May 3, 1967, the oscillator was adjusted and the current deviation dropped to the microsecond level.

VI. TDS Performance Evaluation

A. Near-earth Flight Phase

During the flight, the space-vehicle *mark* events were reported in near real time, followed with a report of the times at which they occurred. Table 31 lists the *mark*-events times as reported by the various tracking stations during the operations. For purposes of comparison, Table 31 also lists the nominal times of the events for the actual launch, as well as the actual times determined by postflight analyses from the recorded telemetry data.

The only notable deviations in the events from the nominals were the durations of the first and second burns of the *Centaur*. The first burn was 13.4 s longer than expected and the second burn was 4.7 s longer than expected. All concern over the long first burn duration was removed when the first RTCS parking orbit computation indicated nominal parking orbit insertion conditions. This first parking orbit, based on Antigua radar data, was computed about 4 min after the end of the first propellant settling phase of the *Centaur* at MECO 1 plus 76 s. The second-burn duration was within the 3-sigma dispersions of the trajectory.

Table 31. *Mark* events, Surveyor *III* mission

Mark event	*Mark* times		
	Nominal, s	Actual, s	GMT actual
Liftoff	$L + 0$	0	07:05:01.059
1	$L + 142.9$	142.546	07:07:23.605
2	$L + 146.0$	145.441	07:07:26.500
3	$L + 176.9$	176.441	07:07:57.500
4	$L + 203.9$	203.591	07:08:24.650
5	$L + 236.4$	237.241	07:08:58.300
6	$L + 238.4$	239.941	07:09:01.0
7	$L + 247.9$	250.641	07:09:11.7
8	$L + 574.9$	589.79	07:14:50.85
9	$L + 574.9$	590.941	07:14:52.0
10	$L + 650.9$	618.491	07:15:19.55
11	$L + 650.9$	739.241	07:17:20.3
12	$S - 216.0$		
13	$S - 176.0$	174.7	07:36:59.7
14	$S - 176.0$	174.7	07:36:59.7
15	$S - 67.9$	64.6	07:38:49.8
16	$S - 42.0$		
17	$S - 31.5$		
18	$S - 11.0$	10.9	07:39:43.5
19	$S - 5.5$		
20	$S + 0.0$	0	07:39:54.4
21	$S + 5.0$	2.3	07:39:56.7
22	$S + 45.0$	58.4	07:40:52.8
23	$S + 65.0$		
24	$S + 240.0$	240.1	07:43:54.5
25	$S + 490.0$	490.1	07:48:04.3
26	$S + 590.0$	590.1	07:49:44.5
Midcourse		05:00:00	April 18, 1967
Retro-engine ignition		00:01:16.891	April 20, 1967
Touchdown		00:04:19.299	April 20, 1967

The normality of the flight from launch to parking orbit insertion was further confirmed by several information sources. One of the most important of these information sources was the real-time commentary of the "quick-look" analyses of the real-time space vehicle telemetry data. The commentary lasted from launch to the end of the Antigua station view period, about 2 min after parking orbit insertion. The reports of the uprange tracking stations view periods and the commentaries of the range safety trajectory analyses also indicated a nominal flight.

For the remainder of the near-earth flight phase, the evaluation of the status of the flight was dependent upon the RTCS trajectory calculations, reports of spacecraft performance, *mark* event reports, and reports of tracking-stations performance and view periods. A post-view replay of some of the recorded channels of the *Centaur* telemetry data from the Pretoria station also provided some analysis of the second burn about ½ h after it had occurred. Prior to initial DSN acquisition at DSS 42, four tracking stations, two tracking ships, and two tracking aircraft reported acquisition of the space vehicle at near nominal times. The only exception to these reports was the failure of the RIS *Twin Falls* to acquire the *Centaur* C-band radar beacon, although it did acquire the space vehicle telemetry signals.

As stated earlier, *mark* event reporting by the near-earth stations is summarized in near-real time. The three spacecraft events (landing gear extended, unlock omni-antennas, and turn on transmitter high-power mode) were commanded by the *Centaur* programmer as planned. Spacecraft telemetry data confirmed these events.

The RTCS computed nine orbits: three parking orbits, one theoretical transfer orbit based upon the actual parking orbit and an assumed nominal second burn, four actual transfer orbits, and one postretro *Centaur* orbit. Three of the actual transfer orbits and the postretro *Centaur* orbit were mapped to lunar encounter by the RTCS.

The first transfer orbit, Number 5, was computed at MECO 2 plus 19 min, and was based on the Pretoria stations radar data. Although the fit of this orbit was considered fair (the data contained many off-track points), it did indicate that the spacecraft was on a lunar intercept trajectory, well within the midcourse correction capability. In fact, rough calculations based on this orbit indicated a midcourse maneuver of only 6–7 m/s (the actual midcourse maneuver was 4.19 m/s). It should be noted that DSS 42 acquired the spacecraft at about MECO 2 plus 17 min (45 s later than the preflight nominal predicts for DSS 42 rise), or about 2 min before the first actual transfer orbit by the RTCS. This further points out that the greatest value of the RTCS is that it provides a quick and early evaluation of the trajectory which is of sufficient accuracy for this purpose. On the other hand, the value of the RTCS for providing DSN acquisition information can only be realized if the DSN has acquisition problems, a situation of relatively small likelihood.

The RTCS computed three orbits based on DSS 42 tracking data. The second DSS 42 data orbit was computed in order to obtain a better fit, while the third was requested by the SFOF and entailed a mapping of the second orbit back to an epoch selected by the latter.

Thus, the third DSS 42 data orbit by the RTCS provided the best basis for comparison with the SFOF orbit. The ninth orbit indicated that it was possible to ascertain early that the *Centaur* retro maneuver was good and would result in a lunar miss of about 32,000 km about 3 days after the retro maneuver.

The MSFN also performed well in support of *Surveyor III* mission. Generally, all requirements were met or exceeded. *Mark* events were read out where required. The GSFC computers also performed their required function well.

Figure 15 shows the *Surveyor III* near-earth phase at earth track.

The following detailed support evaluation will provide further understanding of the AFETR and GSFC activity.

1. AFETR. The AFETR provided coverage for tracking (metric) data, *Atlas/Centaur* telemetry (VHF), and *Surveyor* telemetry (VHF and S-band), using land stations, range instrumentation ships, and aircraft. The AFETR stations from Cape Kennedy to Antigua provided continuous tracking coverage to $L + 00{:}12$; Ascension Island and Pretoria tracking followed. Continuous and substantially redundant VHF telemetry data were received from launch countdown through *Sword Knot* loss of signal at $L + 00{:}47$; in fact, *Atlas/Centaur* telemetry coverage was greater than predicted. Two telemetry aircraft were provided to help cover the gap between Ascension Island and Pretoria in order to obtain data during the critical *Centaur* second-burn prestart sequence. Pretoria observed *Surveyor/Centaur* separation. (The data analyst from DSS 51 was at Pretoria for this event and performed evaluation of the accelerometer data.) The AFETR stations, ships, and aircraft also reported on all but two (*mark* event 12 and *mark* event 23) of the *mark* events requested.

AFETR land stations obtained nearly continuous S-band telemetry coverage from liftoff through Antigua loss of signal at $L + 00{:}12$. Although Ascension Island experienced a short dropout, the interval was adequately covered by the *Twin Falls*. Since the MSFN station at Carnarvon was configured to transmit S-band telemetry to DSS 42, AFETR was required to provide S-band information until after Carnarvon rise. After this requirement was met, the *Sword Knot* continued S-band coverage until after DSS 42 acquisition. The ship experienced an expected dropout for 1 min and 5 s when DSS 42 acquired the spacecraft transponder, then finally lost receiver lock at about $L + 00{:}52{:}39$ while maneuvering from its original position. (During a prolonged viewing period, the ship's superstructure may come between the antenna and spacecraft. Maneuvers are then required to regain an unobstructed view of the spacecraft.)

Grand Bahama Island experienced a weak C-band signal which was apparently caused by balance-point shift. Toward the end of its pass, Ascension Island radar noted premature deterioration of signal strength and early loss of signal, apparently resulting from launch vehicle roll which changed the aspect angle. Pretoria radar also experienced the low-gain portion of the antenna pattern.

The *Twin Falls* failed to acquire the *Centaur's* C-band beacon, although signal strength records, thorough radar system precalibration, and the ship's position indicated that it should have received a good signal. Acquisition attempts included slaving the radar to the ship's S-band system, which was receiving telemetry; however, the results were unsuccessful. Tests performed immediately after the pass verified that all radar systems were functioning properly. The S-band system received telemetry successfully but lost track sooner than expected since the spacecraft passed through the zenith; the *Twin Falls* did not reacquire the spacecraft.

All AFETR requirements for tracking and telemetry data were met. Real-time spacecraft data, via VHF, were transmitted to the SFOF from liftoff to turn on of spacecraft high power, at which time AFETR switched to real time transmission of spacecraft S-band telemetry to building AO at Cape Kennedy.

The RTCS computed parking and transfer orbits as well as predicts, and RTCS support was considered excellent. The first lunar transfer orbit computation using DSN data was transmitted at $L + 00{:}85$; the second orbit was delivered 20 min later. Both orbits, as well as one generated from Pretoria data, compared favorably with the orbit generated in the SFOF. The near-earth flight of A/C-12/SC-3 was considered quite nominal with all events occurring as expected, although the first burn of the *Centaur* was 13 s longer than nominal. The RTCS calculations of the parking and transfer orbits and the associated B-plane mappings showed that injection was extremely accurate.

a. Tracking. The estimated C-band tracking coverage support for *Surveyor III* mission, near-earth phase, was 775 s as opposed to the requirement of 665 s of continual

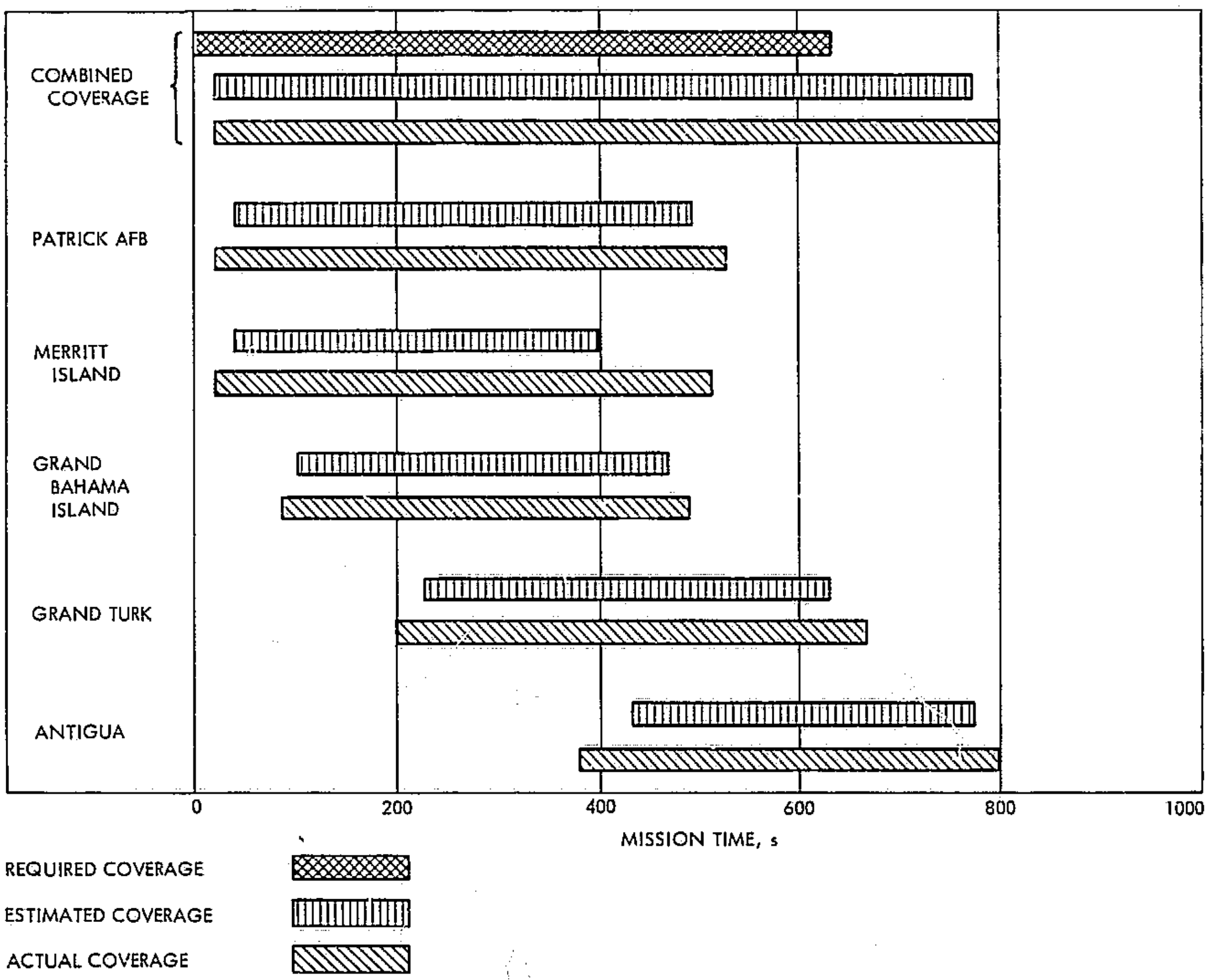


Fig. 34. AFETR C-band radar coverage, liftoff through Antigua

coverage. Figure 34 shows the AFETR C-band radar, required estimated and actual coverage from liftoff through Antigua set.

As indicated the actual data coverage compared very favorably to that which had been predicted.

Figure 35 shows the AFETR radar coverage from Ascension Island through Pretoria. Again, there was more coverage provided than required. However, certain problem areas did arise, and these are treated below.

Problem areas. The FPS-16 radar at Ascension Island experienced a decay in signal strength which was not abrupt, but a gradual decay. It decreased from solid lock to just noise. Since the radar has a computer which could map ahead, the antenna was driven along the trajectory; however, it did not receive any additional signals. The *Twin Falls* saw nothing and the range does not consider this a problem. Since a thorough precalibration was made on the radar before the track, immediately after the track a sphere of known reflectivity and cross section was released and the radar tracked it on skin track, verifying that the servo system and other systems of the radar were functioning. The second test performed was that the radar was locked on a beacon aboard the ship which was attenuated. This tested for sensitivity and the beacon track mode. Third, the power output of the transmitter was tested. All of the measurements of the pre- and post-calibrations compared with those of the prelaunch and the nominal radar with very small tolerances. The conclusion is that the radar aboard the *Twin Falls* was operative. The *Twin Falls* did have a preflight interrange vector (IRV) and did not receive the inflight IRV; however, the radar went to S-band slave mode in which the C-band antenna was slaved to the S-band system which was receiving telemetry.

As a further indication, there were no changes made to the radar. The system provided good data for the *Lunar Orbiter* project. General Dynamics/Convair and Lewis Research Center said that due to antenna patterns the decay of the signal strength at Ascension Island could be explained by the early loss of signal. Furthermore, the late acquisition of C-band signal from the Pretoria MPS-25 could also be explained. However, from their

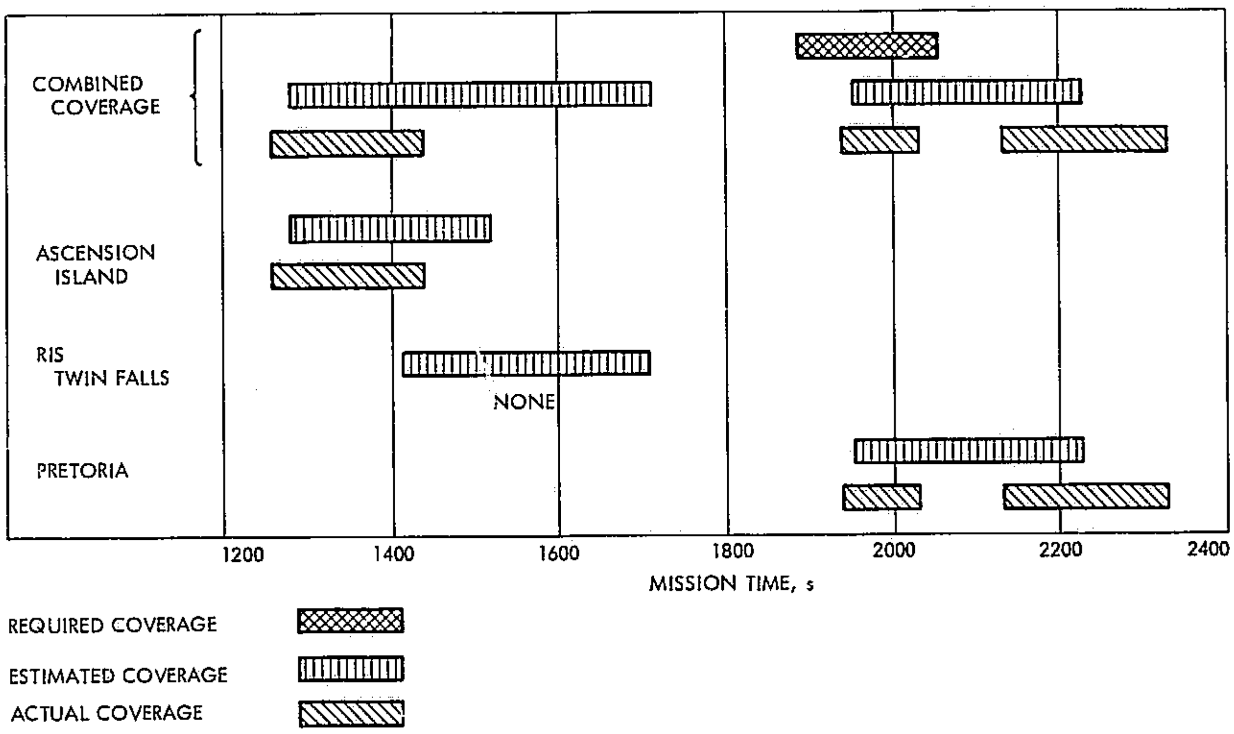


Fig. 35. AFETR radar coverage, Ascension Island through Pretoria

signal strength record, it could not be explained why the *Twin Falls* did not acquire C-band track. This item will continue to be investigated by Lewis Research Center, General Dynamics/Convair, and AFETR.

The MPS-25 radar at Pretoria, South Africa acquired the signal about at the estimated time, rather than early; however, the signal strength was low. They lost lock at 2040 s due to signal-strength problems. During this loss of track, the hydraulic system on the radar failed. They went to a battle-short condition; i.e., they bypassed the safety switches and reacquired track shortly thereafter, and tracked for the predicted amount of time. General Dynamics/Convair did not expect decay; however, the roll in aspect angle showed that it is not unreasonable, and their data are in the jumbled part of the antenna interference pattern during the early part of the track at Pretoria and the late part of Ascension. However, at the *Twin Falls* position it looked as if they should have seen a good signal. The radar problem will be further reported on at the next tracking panel.

Evaluation. AFETR met all C-band tracking coverage requirements with the exception of the period between $L + 2040$ s and $L + 2127$ s due to the lack of track from the *Twin Falls*. Table 32 indicates all actual AFETR C-band (metric) radar coverage by each station individually.

b. VHF telemetry. The AFETR was to provide continuous launch vehicle telemetry coverage from launch to the end of the *Centaur* retro maneuver; real-time telemetry data retransmission from launch to $L + 10$ min; and near-real-time retransmission of selected portions of telemetry data. In addition to land stations, four RIS

Table 32. AFETR C-band (metric) radar coverage

Station and radar	Coverage intervals, s	Comments
Cape Kennedy		
1.16	0–360	
19.18	18–510	
0.18	19–520	
Grand Bahama Island		
3.16	93–230	Intermittent track 3.18 at 353 and 480–487 due to weak beacon; apparently a balance point shift.
3.18	94–353, 360–479, 480–487	
Grand Turk		
7.18	195–661	HD/LD data loss. No plotting boards. The XY pen of P/B 7.2 malfunctioned. Loss of data item 7.4–58U. Malfunction occurred in data handling. Under investigation.
Antigua		
91.18	397–803	
Ascension Island		
12.16	1273–1440	
Twin Falls		
T11-C	Negative track	T11-C problem under investigation. Did not receive good IRV.
Pretoria		
13.16	1941–2040, 2127–2355	

were provided to support VHF telemetry data acquisition. The estimated VHF telemetry coverage was from 0–755 s; from 755–804 s was considered untrackable, and from 804–1713 s good coverage was estimated. However, from 17:13–19:39 s was estimated for a best obtainable coverage, then from 19:39–24:47 s good telemetry was again estimated obtainable.

The actual VHF telemetry coverage provided was more than either that requirement or the estimated coverage. Continuous VHF telemetry data were received from liftoff through RIS *Sword Knot* LOS at 2833 s. Figure 36 shows the VHF coverage provided from liftoff through Ascension Island. Figure 37 shows the coverage from Ascension Island through *Sword Knot* set.

c. S-Band telemetry. The AFETR was required to receive, record, and retransmit *Surveyor* S-band (2295 MHz) telemetry in real time starting when the spacecraft transmitter high power is turned *on* until 15 min after DSS rise. For *Surveyor III,* Carnarvon was configured to transmit S-band telemetry to DSS 42; therefore, the AFETR was required to provide S-band information until Carnarvon rise plus 15 min. Thus *Surveyor III* S-band telemetry coverage was required from 2084 s to 3150 s. Estimated S-band coverage was of intervals from 0 to 717 s, 1015 to 1322 s, 1338 to 1713 s, and 2075 to 3222 s.

Actual S-band telemetry coverage provided was continuous except for a 30 s gap at $L + 360$ s. Figure 38 shows the AFETR S-band telemetry stations and ships coverage from liftoff through RIS *Coastal Crusader.* Figure 39 gives the coverage from RIS *Coastal Crusader* through RIS *Sword Knot* set. Table 33 gives the total AFETR telemetry coverage for the *Surveyor III* mission.

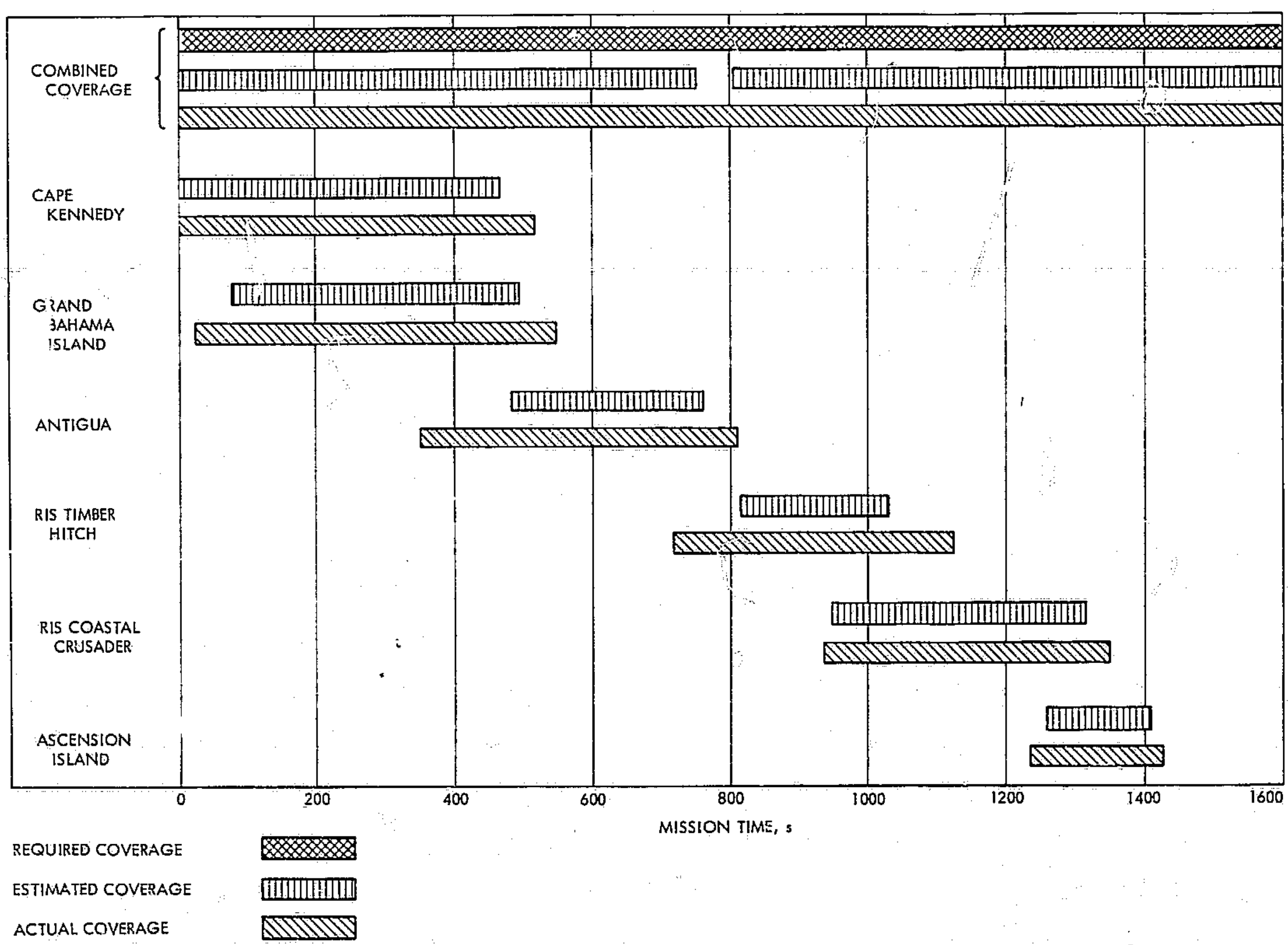


Fig. 36. AFETR VHF telemetry coverage, liftoff through Ascension Island

Fig. 37. AFETR VHF telemetry coverage, Ascension Island through RIS *Sword Knot* set

Problem areas. Ascension Island experienced a dropout between $L + 1492$ and $L + 1522$ s; however, the RIS *Twin Falls* provided coverage during this interval. The RIS *Sword Knot* experienced an expected dropout between $L + 2728$ and $L + 2833$ s as a result of acquisition of the spacecraft transponder by DSS 42, which then provided the required coverage. To keep the antenna pointing at the spacecraft, the RIS *Sword Knot* maneuvered, placing the ship's superstructure between the antenna and the spacecraft. This maneuver caused a loss of track at $L + 3159$ s, instead of the expected LOS of $L + 3222$ s. The *Twin Falls* S-band system lost track sooner than expected because on this flight azimuth the spacecraft passed over zenith. The *Twin Falls* did not reacquire the spacecraft.

Evaluation. The AFETR met all class I, II, and III requirements with the exception of coverage from $L + 2728$ to $L + 2833$ s due to the expected acquisition of the spacecraft transponder by DSS 42, which then provided S-band coverage.

d. RTCS. In general, support by the RTCS was considered excellent. There were no anomalies associated with the facility during the support of this launch. In the areas where metric support (raw and computed) was critical, the AFETR and MSFN performance was considered excellent. Any anomalies noted were in noncritical areas.

For the launch and near-earth phase of the mission, the RTCS provided trajectory computations based on tracking data and vehicle guidance data. The RTCS output included:

(1) The IRV, the standard orbital parameter message (SOPM), and orbital elements.

(2) Predicts, look angles, and frequencies for acquisition use by downrange stations.

(3) I-matrix and moon map for mapping injection conditions and estimating trajectory accuracy. Provides for early orbit evaluation prior to orbital data generated by FPAC.

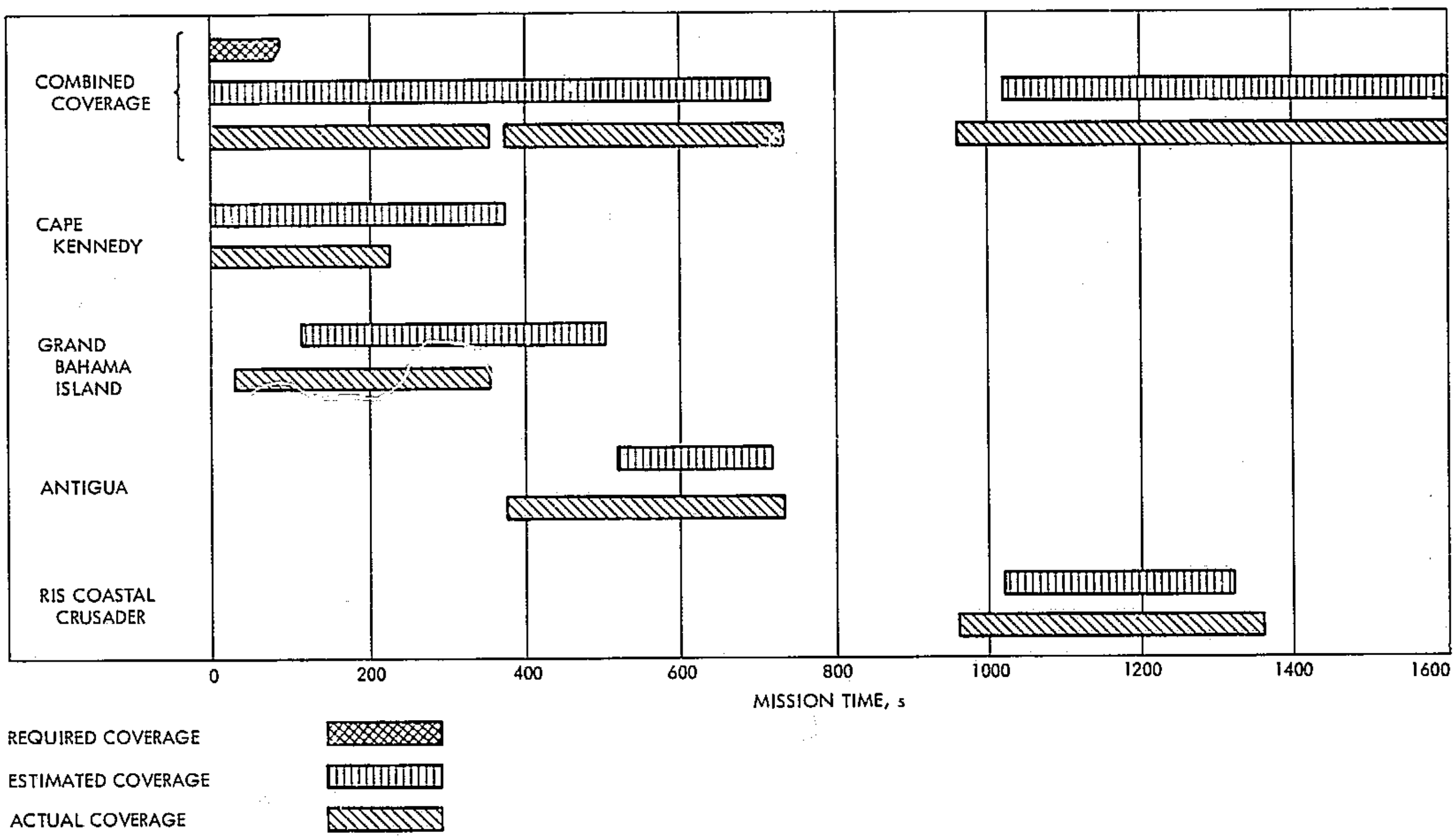


Fig. 38. AFETR S-band telemetry coverage, liftoff through *Coastal Crusader*

The RTCS computed parking and transfer orbit messages as well as predicts. The first orbit computation generated at the RTCS using DSN data was transmitted at $L + 85$ min; the second orbit was delivered 20 min later. Both orbits, as well as one generated from Pretoria data, compared favorably with the orbit which was subsequently generated by the SFOF. Support by the RTCS was considered excellent.

2. ***Real-time data.*** The AFETR retransmits *Surveyor* data (VHF or S-band) to Building AO, Cape Kennedy, for display and for retransmission to the SFOF. In addition, downrange stations monitor specific channels and report events via voice communication.

For the *Surveyor III* mission, existing hardware and software facilities were utilized to meet the real-time data requirements.

All requirements were met. VHF telemetry data, including the spacecraft data, were transmitted in real time to the SFOF from liftoff to spacecraft high power *on*. At high power *on*, AFETR switched as planned to real-time transmission of spacecraft S-band telemetry data to building AO. Real-time data flow was very good. In addition, all *mark* events except 12 and 23 were read out and reported.

3. ***GSFC.*** A major change in MSFN support was implemented on the *Surveyor III* mission. The Carnarvon station was required to receive, record, and retransmit to DSS 42 real-time spacecraft S-band telemetry data. This capability, in turn, reduced the requirement for AFETR ship coverage over the Indian Ocean and made it possible to satisfy the project's requirement for continuous telemetry data from liftoff to touchdown, without unnecessarily restricting launch azimuths due to unavailability of telemetry coverage. Carnarvon successfully received and recorded 550-bits/s unified S-band telemetry data for about 11 min, transmitting it in real time by dataphone to DSS 42 where it was routed through the CDC to the on site data processor, converted to 1200 bits/s, and transmitted over the high-speed data line to the SFOF.

MSFN support was good, and there were no equipment failures or discrepancies. The successful operation of the USB system, which is different from regular Carnarvon coverage, has a bearing on future parking orbit missions. The station could bridge a gap between near-earth AFETR coverage and DSIF acquisition if such a gap should arise.

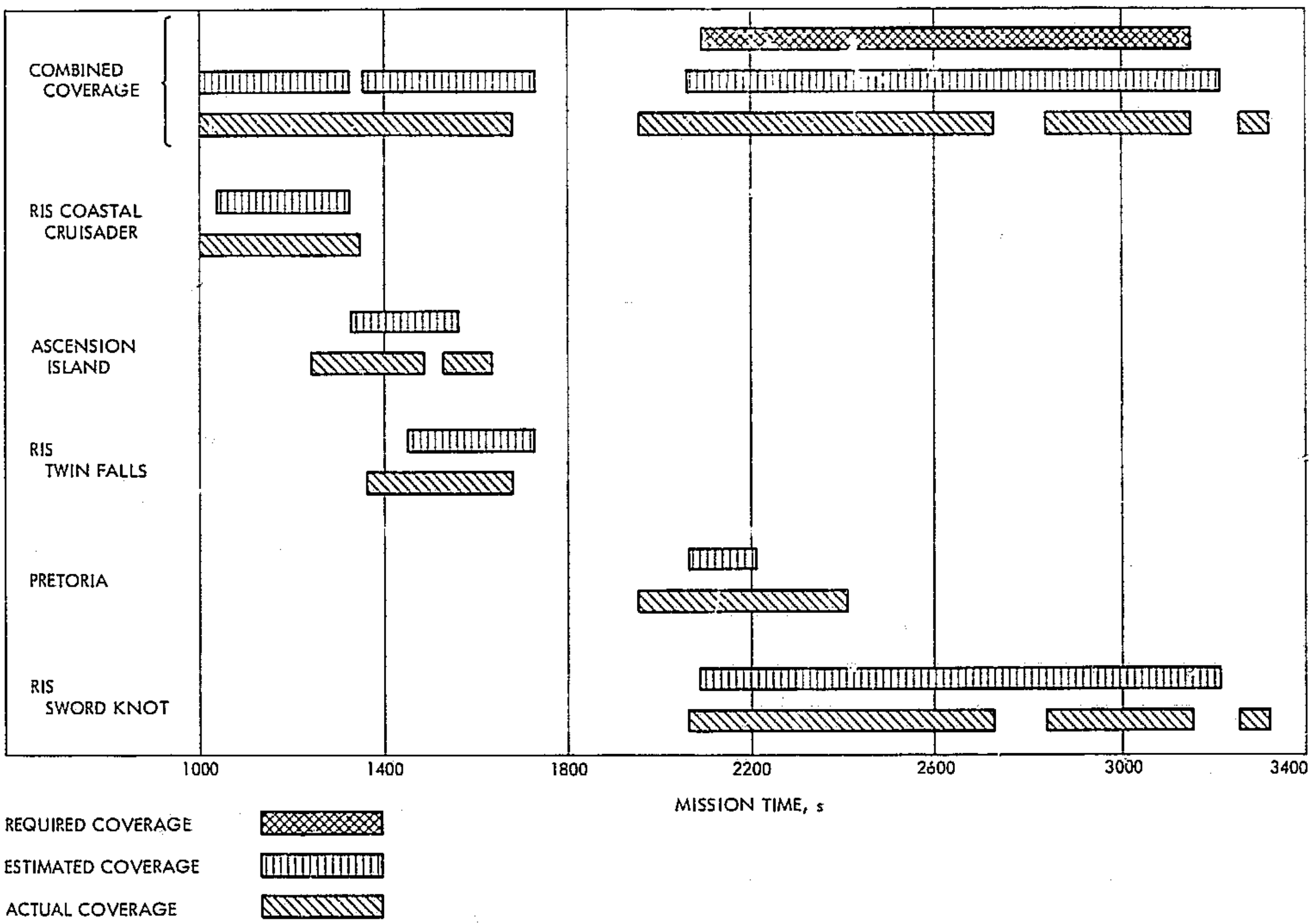


Fig. 39. AFETR S-band telemetry coverage, *Coastal Crusader* through *Sword Knot* set

The MSFN stations at Bermuda, Tananarive, Carnarvon, GSFC computers, and portions of the NASA communications network contributed support for the *Surveyor III* mission. The attached tables and figures depict the actual coverage provided, versus predicted coverage.

a. Tracking. The MSFN had requirements to track the C-band beacon on the *Centaur* stage of the launch vehicle and provide real-time magnetic tape recording from AOS through LOS.

At the MSFN station located on Bermuda the FPQ-6 radar achieved 432 s of auto-track with good beacon return, reporting signal strengths up to 36 dB S/N ratio at PCA. The FPS-16 radar achieved 246 s of automatic tracking, also reporting strong beacon replies. The reduced amount of FPS-16 radar coverage was due to the obscuring of the FPS-16 by the FPQ-6 antenna as described in detail in the network operations plan (NOP) for the AC-12 mission. The estimated coverage for the Burmuda FPS-16 for the actual launch azimuth was approximately 232 s.

There were no system failures.

At Carnarvon the FPQ-6 radar achieved approximately 4100 s of autotrack and reported beacon returns with up to 22 dB SNR at PCA.

Figure 40 shows the estimated and actual MSFN radar coverage for *Surveyor III* mission.

b. VHF telemetry. To meet the VHF-telemetry coverage requirements, the MSFN was to receive, decommutate, and record the *Centaur* 225.7-MHz link from AOS through LOS and receive and record the *Atlas* 229.9-MHz link for AFETR safety purposes. Figure 41 shows the MSFN VHF telemetry coverage.

At the Bermuda station the AFETR safety requirements on both the *Atlas* and *Centaur* links were met without difficulty, although they reported the data polarity as being normal vice inverted, as specified in the NOP. *Mark* events 5 through 9 on the 225.7-MHz *Centaur* link were

Table 33. AFETR station and link telemetry coverage

Station and link	Coverage intervals	Comments
Tel-2		
225.7	$T-80$ to $+531$	
229.9	$T-80$ to $+499$	
2295	$T-80$ to $+146$, 160 — 184, 190 — 207	
Tel-4		
225.7	$T-80$ to $+528$	Early LOS on 2295 due to flame attenuation
229.9	$T-80$ to $+496$	
2295	$T-80$ to $+226$	
Grand Bahama		
225.7	28–555	S-Band signal fade before end of station commitment. S-Band signal strength, −80 dBmW, good until fade
229.9	28–555	
2295	28–360	
Antigua		
225.7	350–802	S-Band signal strength average, −80 dBmW, quality good
2295	390–725	
Timber Hitch		
225.7	713–1128	
Coastal Crusader		
225.7	950–1362	Average S-Band signal strength, −105 dBmW with slow, smooth ripple. Tape reader on 1218 computer failed at +20 s, resulting in inability to load IRV
2295	955–1362	
Ascension		
225.7	1230–1641	S-Band signal strength, −100 dBmW, quality good
2295	1242–1492, 1522–1625	
Twin Falls		
225.7	1359–1761	Average S-Band signal strength, −80 dBmW. Max S-Band signal strength, −90 dBmW
2295	1361–1683	
Audit 2		
(Telemetry aircraft at 25,000 ft.)		
225.7	1618–2099	
Audit 1		
(Telemetry Aircraft at 24,000 ft)		
225.7	1655–2157	
Pretoria		
225.7	1900–2520	S-Band signal strength, −100 dBmW, quality good
2295	1943–2500	
Sword Knot		
225.7	2048–2833, 2950–2975	No. 1 pen recorder failed; transport stopped 2638–2683 s
2295	2061–2728, 2833–3159, 3258–3317	

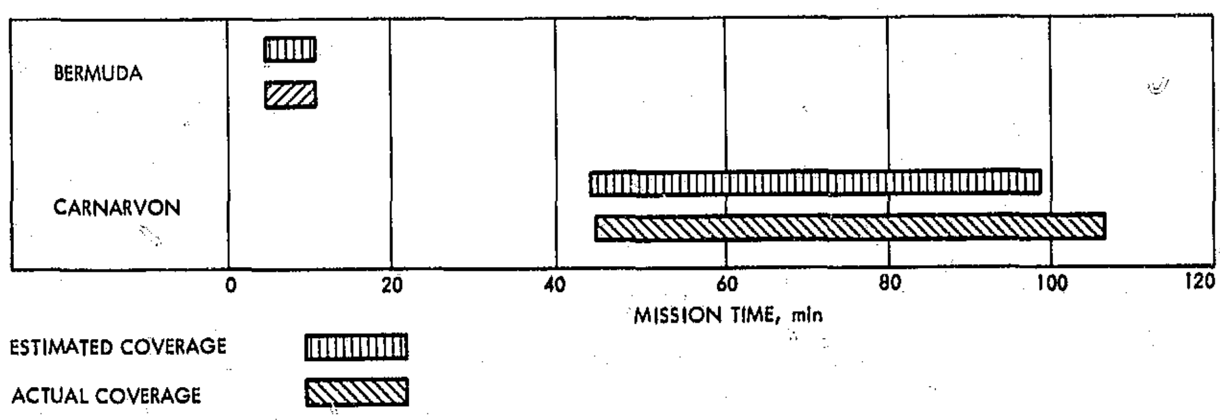


Fig. 40. MSFN radar coverage

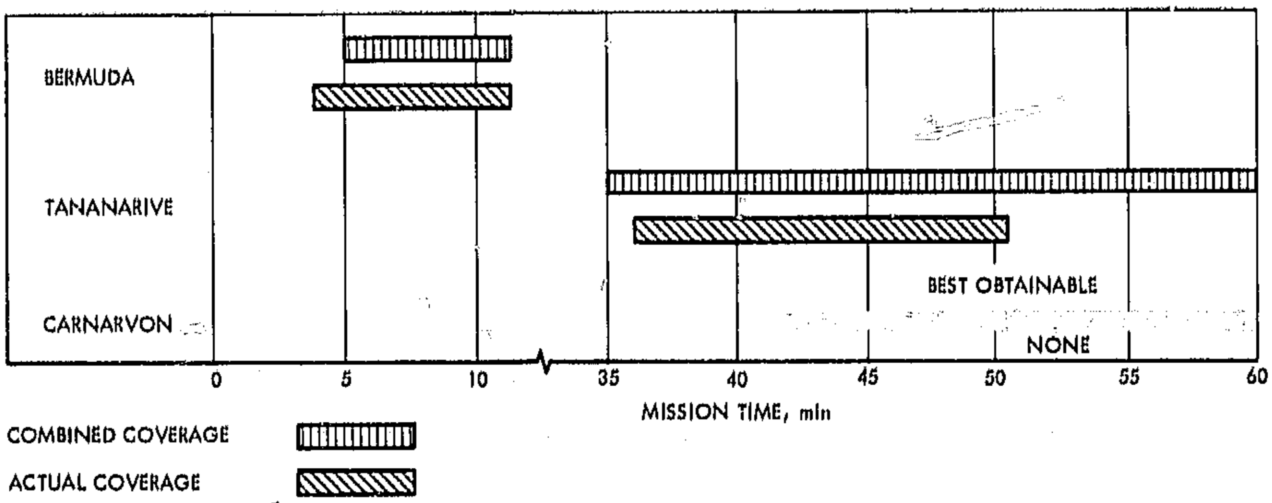


Fig. 41. MSFN VHF telemetry coverage

decommutated, displayed, and confirmed. (See Table 34 for *mark* event times.)

TAN received a strong signal on the 225.7-MHz *Centaur* link and achieved good decommutator lock. Three sets of continuous channel readouts for LH_2, LO_2, pitch, yaw, and roll rate measurements were given in real time. *Mark* events 22, 24, 25, and 26 were decommutated, displayed and confirmed. Due to differences between the NOP description and actual signals received, *mark* event 23 was not confirmed. There were no system failures during the mission.

At Carnarvon there was heavy interference on the telemetry channels, and problems were experienced in the decom. As a result, no readout was obtained for *mark* event 25, and only a postpass readout for *mark* event 26 was affected. The poor signal quality can be attributed to two factors: (a) the extreme range of the vehicle (greater than 3600 kyd), and (b) local interference from airport distance measuring equipment radio signals.

Table 34. MSFN predicted and actual *mark* event times

Mark	Predicted, GMT	Actual, GMT
5	07:08:57	07:08:58.3
6	07:08:59	07:09:01.2
7	07:09:02	07:09:11.6
8	07:14:35	07:14:50.8
9	07:14:35	07:14:52.2
22	07:43:19	07:40:52.8
24	07:46:34	07:43:54.5
25	07:50:44	07:48:04.8
26	07:52:24	07:49:44.5

Tananarive received a strong signal on the 225.7-MHz *Centaur* link and achieved good decommutate lock. Three sets of continuous channel readouts for LH_2, LO_2, pitch, yaw, and roll rate measurements were given in real time. *Mark* events 22, 24, 25, and 26 were decommutated, displayed and confirmed. Due to differences between the NOP description and actual signals received, *mark* event 23 was not confirmed. There were no system failures during the mission.

Problem areas, Bermuda. All data and range safety requirements were met. Bermuda reported that their PAM decommutators were set up to receive inverted polarity data as specified in the NOP; however, at AOS the data polarity was noted to be in a normal mode. Through conversations with LeRC and an analysis of the mission tapes, it was determined that the data on each subcarrier oscillator channel should have been in normal polarity. The *Data Supplement Centaur-12, AC-12,* dated November 25, 1966, was used as the basis for that part of the NOP. This document indicated inverted polarity on all *Centaur* channels and one normal polarity channel on the *Atlas* link; all others were to be inverted. Bermuda also reported that segment 15, IRIG 11, of the 225.7-MHz *Centaur* link was received at 0 vice 100% calibration. This did not result in loss of data but did require Bermuda to use the sync pulse to lock the decommutator.

Problem areas, Tananarive. Tananarive reported they were unable to confirm *mark* event 23 because the signal did not vary according to the final NOP description. However, an analysis of the Tananarive magnetic tape confirmed that there was no discernible change of the waveform characteristics in either direction at the time *mark* event 23 was to have occurred.

Problem areas, Carnarvon. The following information was received from Carnarvon relative to the DME problem:

"The DME at the local airport operated on a frequency of 224 Hz. The signal caused very bad pulse interference with the TLM signal of 225.7 Hz. DME interference from the airport has not been a problem in the past, since we rarely operate at frequencies below 230 Hz and most mission passes occur at night when the DME is off." Attempts will be made in the future to provide a workable arrangement with the airport to have the DME switched off during a pass.

c. S-Band telemetry. The S-band telemetry requirements placed on the MSFN was for Carnarvon to receive and record 550-bit, bilevel, NRZ telemetry data, and to transfer it via data modems of NASCOM facilities to DSS 42. Figure 42 gives the estimated and actual MSFN S-band telemetry coverage.

Carnarvon unified S-band system support was required to bridge the gap from near-earth AFETR coverage to DSN acquisition. This was accomplished. The expeditious station reconfiguration and readiness achieved with respect to a relatively brief time to mission status was of significance.

Carnarvon acquired one-way at 07:47:57 GMT, April 17, 1 min and 3 s prior to predicted time on the horizon. PCM lockup (AOS) was reported as 07:48:01 GMT. There were no problems with PCM data flow to DSS 42. All data received by DSS 42 were satisfactory. Continuity of USB receiver lock was disrupted, apparently upon acquisition of the spacecraft transponder by DSS 42. CRO attributed loss of lock to the 50-Hz-bandwidth receiver loop filter being employed at that time. During possible future missions, it is suggested CRO (1) be supplied with frequency predict information, (2) switch to 200-Hz receiver loop bandwidth, and (3) be provided with near-real-time frequency information or any of the aforementioned to preclude a reoccurrence.

As expected, signal strength decreased inversely with the range of the *Surveyor III* spacecraft. CRO reported PCM loss of signal as 08:14:01 GMT. A total of two PCM dropouts occurred with a maximum duration of 32 s. Total PCM track time amounted to 1648 s. CRO dropped track at 08:46:45 GMT due to good PCM data at DSS 42. During track, a total of 3534 s was accrued. The RF dropout attributed to DSS 42 uplink occurred at 08:00:14 GMT; reacquisition recorded as 08:00:26 GMT.

d. Computer support. The GSFC data operations branch provided timely support for *Surveyor III* launch and near-earth phase flight.

During the launch phase, GSFC computers accepted high-speed data from BDA and the RTCS at AFETR via the launch monitor subsystem. The resulting parameters were used to drive displays in the GSFC OPSCON and computer operations area.

GSFC DOB generated and transmitted H-25 and H-5 acquisition messages to TAN and CRO based on low-speed data from ETR radars. RTCS transmitted look angles to TAN and CRO based on actual first-burn data and theoretical second burn.

GSFC DOB generated (off-line) and transmitted USB 29-point acquisition messages (at $T + 20$ min) to CRO based on the actual launch azimuth. Upon the arrival of the state vector from JPL, USB 29-point acquisition messages were generated and transmitted to BDA, ASC, GWM, CNB, HAW, TEX, and MAD. These stations received the acquisition messages as an aid in participation of one-way tracking of the spacecraft (on a non-interference basis).

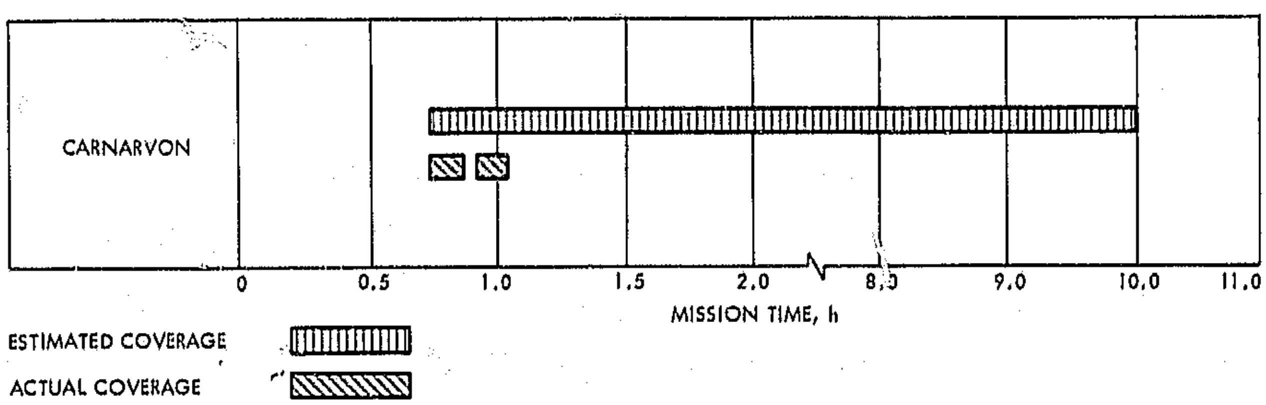


Fig. 42. MSFN S-band telemetry coverage

CRO hexidecimal low-speed data was reformatted at GSFC to the standard 38-character octal-radar data format and retransmitted to RTCS. GSFC DOB provided the network controller with printouts of the *Centaur* vehicle orbital parameters shortly after MECO 1, *mark* event 8, and end of blowdown, *mark* event 25.

The following data were reformatted on magnetic tape for delivery to LeRC for analysis:

(1) High-speed data for AFETR in tape format XYZ and $\dot{X}\dot{Y}\dot{Z}$.

(2) Low-speed TTY data using the standard GSFC time, azimuth elevation, and range format.

Bermuda high-speed raw-radar data was reformatted to the IBM 729 format for delivery to Patrick AFB, Fla.

B. Deep Space Network Phase

With some rather minor exceptions, *Surveyor III* was a nominal mission and the DSN provided support at a high level of performance. Support was provided for all operational tests and continuous tracking, and data processing coverage was provided from DSS 42 acquisition at $L + 50$ min until the end of first lunar day activities. In general, the DSN did meet its commitments.

Figure 43 shows the *Surveyor III* mission deep-space phase earth track, complete with major spacecraft events and DSS rise and set times.

From the time of two-way acquisition by DSS 42 until the midcourse maneuver, the DSN tracked *Surveyor III* in the two-way mode with only minor exceptions, and returned high quality two-way doppler data with the exception of the initial two-way track at DSS 61. At 14:32:02 GMT, on 17 April, DSS 61 began taking two-way doppler, and approximately ½ h later the results of the tracking data monitor program indicated that the two-way doppler from DSS 61 was excessively noisy. This problem was subsequently traced to a faulty bit in the last digit of the doppler counter. A transfer to DSS 51 was scheduled at 17:00:00, but was not effected until approximately 17:20:00 because of a minor procedural error at DSS 51. The problem at DSS 61 was corrected and DSS 61 was able to reassume the transmitter assignment at approximately 20:30:00, and from this time on returned high-quality doppler data. The midcourse maneuver was executed according to schedule, and from this time until the landing phase, the DSN tracked in *Surveyor III* spacecraft continuously in the two-way mode and returned high-quality two-way doppler data throughout this period.

1. DSIF. The following DSIF stations performed tracking and telemetry functions in support of the *Surveyor III* mission: The prime stations were DSS 11, DSS 42, DSS 51 (on a best-effort basis during cislunar phase and touchdown plus one pass), DSS 61, DSS 71 (prelaunch support and track to loss of signal), and DSS 72 (tracking provided during first pass only). The recording and transmitter backup station, DSS 12, provided recording backup during midcourse and retro/touchdown, and provided transmitter capability to back up DSS 11 transmitter.

DSS 14 was not committed for any support because of mechanical work being done on the antenna bearings. However, DSS 14 recorded the retro maneuver and touchdown. The recordings were included in the DSS 11 data package.

The above DSIF stations supported *Surveyor III* with a high level of performance, based on the quality of telemetry data obtained and the spacecraft commanding operations. Continuous tracking and telemetry coverage was provided from $L + 0049$ to the end of the first lunar day. From the initial two-way acquisition until the landing phase, *Surveyor III* was tracked in the two-way mode with only minor exceptions. During two-way track, high-quality two-way doppler data were received, with the exception of initial two-way track at DSS 61. High-quality angular tracking data were also received throughout the mission.

All measured station parameters were within nominal performance specifications. The signal levels received corresponded very closely to the normal limit of SPE. Several best-lock frequency measurements were made and the predicts were biased accordingly.

SPAC AGC recorder calibration delays during the mission resulted in slow and complicated DSS 11/SFOF integration.

On April 20 (Day 110), TV-11 did not film-record a few 200-line pictures due to high spacecraft-frequency drift rate. Furthermore, the 70-mm film-transport journal lost approximately 25 frames as the result of an incorrectly adjusted film-tensioning spring. During countdown, the film recorder-monitor photomultiplier gain adjust had been found inoperative; it was remedied during this pass by replacing the potentiometer. There was no effect on the mission. Two other TV-11 anomalies occurred. Three-fourths of the April 27 (day 117) data was lost and the

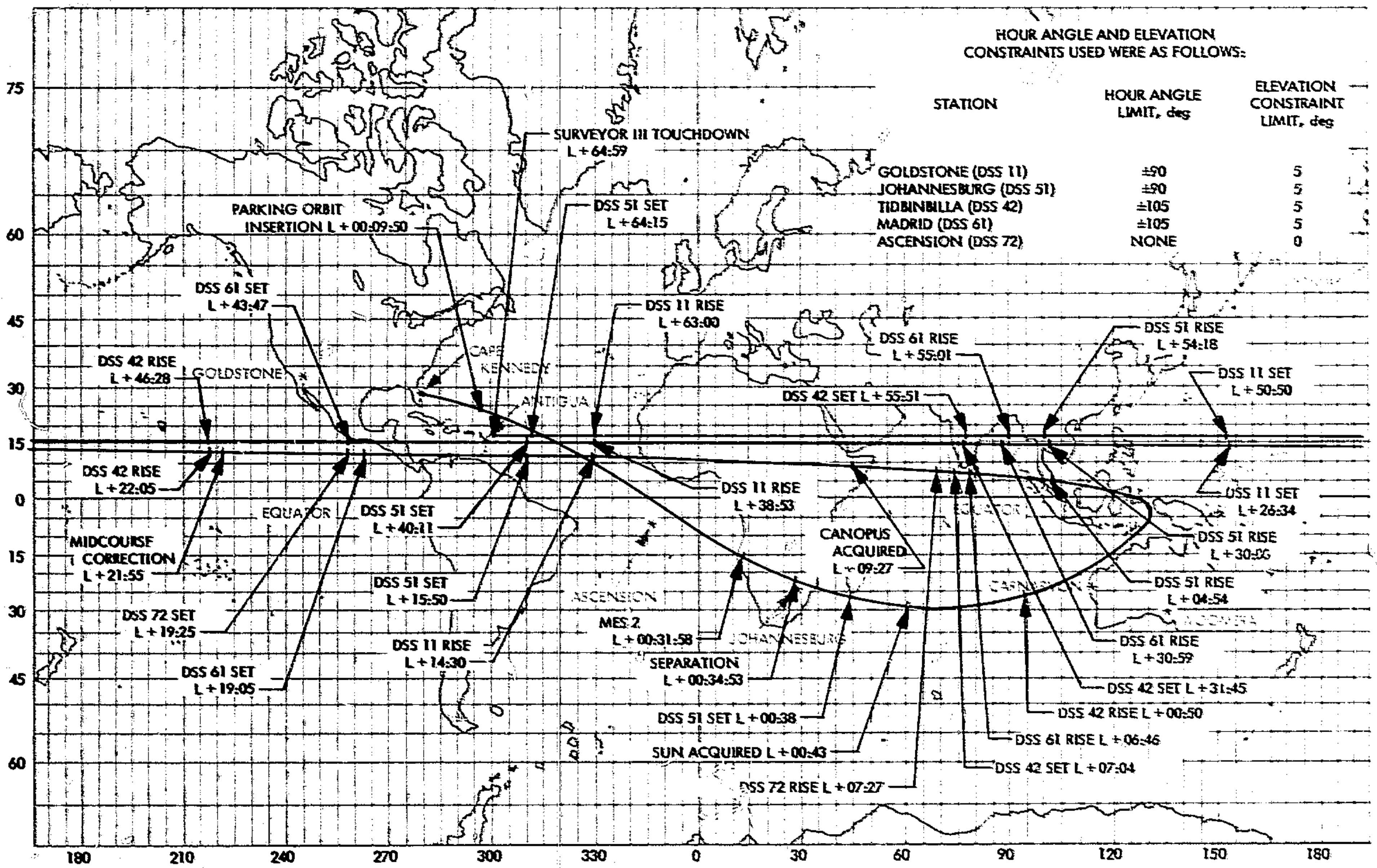


Fig. 43. *Surveyor III* deep space phase, earth track

rest was uncalibrated due to loss of vertical and horizontal deflection in the film recorder. To correct the problem, the amplifier, two power supplies, and two transistors were replaced; later the amplifiers and power supplies were repaired. On May 3 (day 123), the last day of TV operations, two frames were lost due to the difference in sync tip frequency between the end of the previous pass and the beginning of this one. The sync tip filter was reset, and some corrective action was taken.

a. Station coverage and performance. Individual DSIF station coverage and performance are provided below.

DSS 12, Goldstone (Echo), California. The Echo tracking site at Goldstone provided recording and command backup to DSS 11 during midcourse maneuver, terminal descent, and first pass after touchdown. During Goldstone's [illegible] pass, a microwave link was established between the two stations, and on April 25 (day 115), DSS 12 transmitted 159 commands. (The spacecraft was used on that date to calibrate the 85-ft antenna at DSS 11.) The station also received the telemetry signal. Both command and telemetry data were sent to DSS 11 via microwave and processed in the normal manner. Except for the problem described under DSS 11 above, no problems or anomalies occurred.

DSS 14, Goldstone (Mars), California. Prior to the mission, DSS 14 had been designated the backup station to DSS 11. However, due to mechanical work being done on the antenna hydrostatic bearing, DSS 14 was not committed and the backup function was transferred to DSS 12. DSS 14 did record during retro and touchdown, and the recordings were included in the DSS 11 data package. No problems occurred.

DSS 42, Tidbinbilla, Australia. Tidbinbilla was committed as a prime station. Participation during transit included initial two-way acquisition, periodic commanding, and telemetry processing during each view period. During lunar operations, the station monitored TV and SM/SS operations commanded by DSS 11 and performed signal processing troubleshooting, sun and earth searches, frequency checks, A/SPP positioning, thermal experiments, and 600-line TV commanding. DSS 42 shut down the spacecraft for lunar night on May 4 (day 124) at 00:04 (GMT).

DSS 51, Johannesburg, South Africa. Johannesburg was committed on a best-effort basis during transit since, shortly before launch, the station RF equipment was changed from the L/S configuration to full S-band configuration, and full testing was not completed. However, the station performed a much more active role. The CDC was operating with less than a full complement of spares and test equipment since some items had been sent to DSS 61 for *Surveyor III.* DSS 51 monitored the spacecraft during launch pass, then tracked in parallel with DSS 61 through transit and for one day after touchdown, when it was relieved of further commitments to *Surveyor.* Three days later, the station was required to track during four more passes as prime station to relieve DSS 61 for other commitments. DSS 51 performed planar array and solar panel positioning on April 26 (day 116).

Hardware problems were negligible and involved the low-frequency oscillator and command printer. During first transfer from DSS 61, DSS 51 lost the uplink, with subsequent loss of command capability and two-way doppler for 17 min.

DSS 61, Robledo, Spain. Robledo was committed as a prime station. The station was able to achieve two-way lock in less than 50 s and to promptly reconfigure for either TV or PCM. During lunar operations, DSS 61 performed RF communications tests, telecommunications signal processing tests, dumping of spacecraft helium, A/SPP positioning, an axial ratio test, and both commanded and monitored TV sequences. Almost every capability of the CDC was exercised, and no difficulties were encountered.

The station reported that information received from the SFOF concerning progress of the spacecraft and scientific experiments was excellent, that excellent exchange of information was experienced with SPAC, and that all inquiries were readily answered in a manner indicative of the demonstrated teamwork.

An average/alarm problem in the SOCP computer occurred. Later in the mission no average/alarm data were printed out when TV PCM was being received; this was caused by an incorrect patching specification.

About ½ h after DSS 61 began taking two-way doppler, a dropped 8-bit in the least significant digit of the DSS 61 doppler counter caused excessive noise in the data. DSS 61 twice stopped three-way tracking for repair operations, which were complicated by having to give up the voice line for commanding periods. A transfer to DSS 51 could not be scheduled until approximately 2 h later due to Canopus acquisition. Approximately 2 h of two-way doppler data were thus lost, but the effect on the mission was negligible. After repairing a bad plug in the TDH, the station returned to high-quality data.

DSS 71, Cape Kennedy, Florida. Cape Kennedy was designated as an alternate capability for processing AFETR downrange telemetry data (received via Tel-2), using the CDC and TCP computer, and transmitting the data to the SFOF via high-speed data line. This was the first mission in which the data were sent from DSS 71 in the same format as that used by the other DSIF stations. The CDC decommutator remained locked, using the various downrange data sources, until $L + 00{:}45$. The data were good except for outages during gaps between AFETR stations. No problems were encountered by DSS 71.

DSS 72, Ascension Island. Ascension was activated primarily to provide coverage during the latter part of the launch period. The station promptly acquired the spacecraft during the launch pass and remained in lock for 6 min. The spacecraft was in the pre-injection, low-power, antenna-stowed configuration, which is not the usual configuration for DSIF initial acquisition; however, the decommutator locked up immediately after the receiver obtained lock. DSS 72 two-way doppler obtained during the first postlaunch pass provided data for premidcourse trajectory calculations.

The only problem encountered at the station involved the VCO counter, which functioned incorrectly in the two most significant digit printout positions.

DSS 11, Goldstone (Pioneer), California. Goldstone was committed as a prime station. Midcourse and terminal descent sequences were executed on schedule and without problems, using command tapes generated from command data transmitted from the SFOF. Lunar operations included commanding all SM/SS sequences and all but a few TV sequences. During SM/SS operations, since rapid changeover from TV to telemetry was desired, TV-11 was used to process television pictures on one receiver while the CDC remained in the engineering TM mode on the other receiver.

During several passes, personnel problems between DSS 11 and DSS 12 communications resulted in loss of data on the 96-kHz line. Switching of TCP computers from primary to backup on April 20 (day 110) delayed commanding and caused loss of data for 12 min. The excessive delay was due to equipment configuration and location.

The SOCP program gave some problems. When a telemetry value varied between 0 BCD and any other number, the average/alarm printout of that signal was meaningless. The command confirmation (CCN) garbled several commands intermittently throughout the mission.

Several erroneous commands were transmitted due to operator error. As mentioned, only one of these incidents had an adverse effect on the mission. Several hardware failures occurred but did not adversely affect the mission (Ref. 4). Invalid telemetry made spacecraft temperatures unreliable after touchdown and prevented DSS 11 from predicting best-lock frequencies of the spacecraft.

b. Tracking. All assigned tracking stations counted down for launch with only several minor discrepancies, all of which were removed prior to launch. Launch occurred at 07:05:01.059Z on April 17, ~~1967,~~ on the assigned launch azimuth of 100.806 deg.

The DSIF provided the *Surveyor* Project with continuous support from launch to end of the first lunar day. The support was adequate and the anomalies discussed in Table 35 did not significantly affect the mission.

The attached received signal level plot for the cislunar phase, Fig. 44, showed that the received signal levels corresponded very closely with the predicted levels. The predicted levels prior to star acquisition track were not given because the spacecraft was not roll stabilized during this period. Therefore, the received signal level could vary over a wide range due to the variations in the spacecraft antenna pattern. The groups of data points labeled star acquisition, midcourse, and touchdown indicated high-power operation and were 20 dB above the low-power signal level. The data bit-rate changes occurred within 2 dB of the predicted thresholds (not shown). The gyro drift test was conducted during the track as shown at the top of the plot. The random drift and subsequent antenna pattern variations produced a spread in the received signal levels of approximately ± 3 dB. These variations can be observed in the plot.

Ascension Island was approximately 10 dB below the other DSN stations consistent with its 30-ft antenna compared with the 85-ft antennas. Goldstone DSS 11 was consistently 1 to 2 dB below other stations tracking at the same time. This difference is apparently due to differences in calibration and is consistent with performance of *Surveyors I* and *II*. Table 35 gives a summary of tracking data received from pass 1 through pass 3.

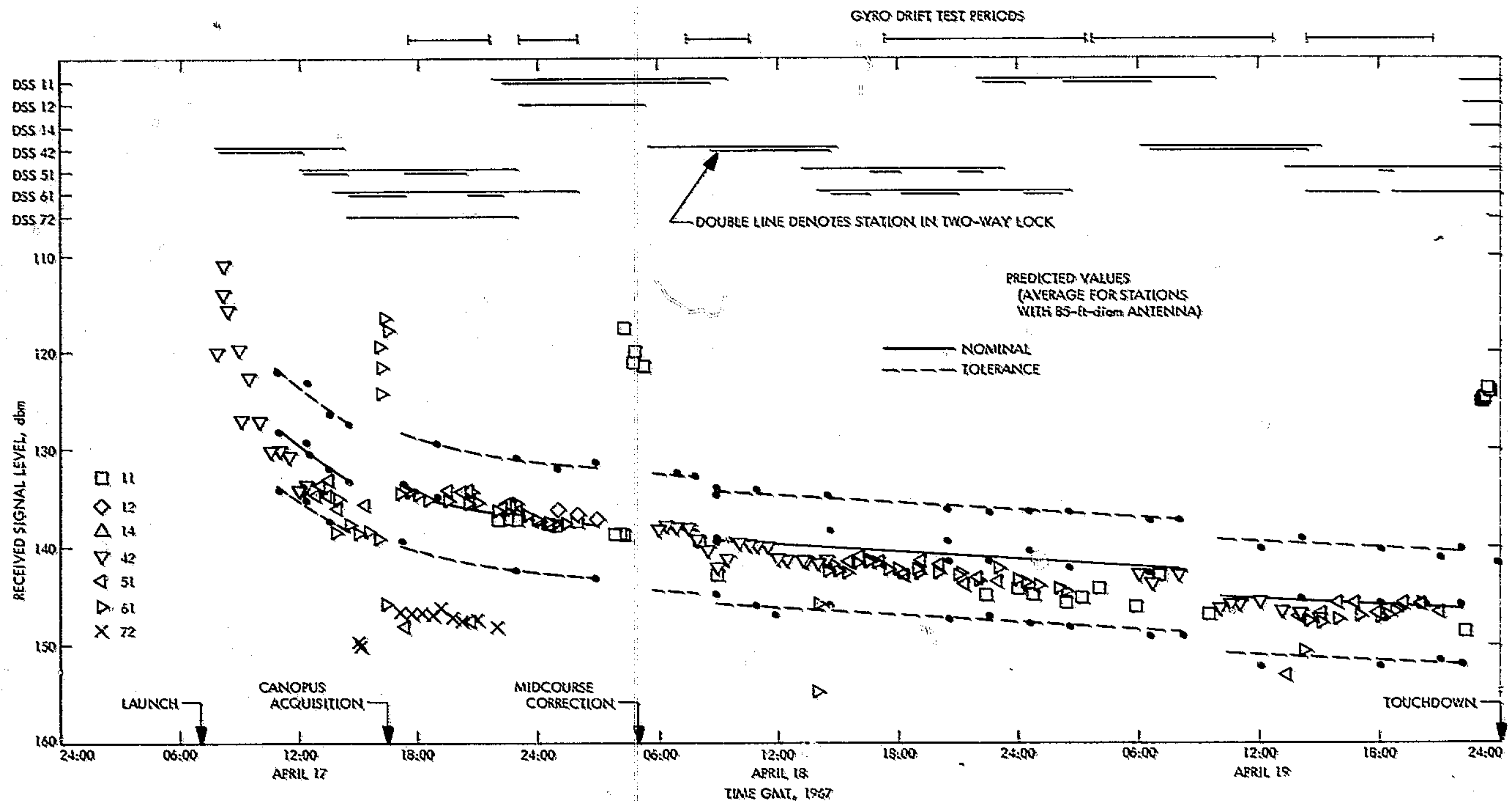


Fig. 44. Surveyor III DSIF received signal levels

Item	Station	Pass	Time, GMT	Anomaly	Immediate reaction
1	51	Launch	17/00:25	Receiver 1, 50 MHz if indicating strong sidebands on spectrum analyzer	Problem isolated to transmitter power supply
2	42	Launch	17/04:40	Station reported offset in HA channels on SAA antenna	
3	61	Launch	17/04:50	Maser 1 partial warmup	Maser 2 used as prime
4	72	Launch	17/05:58	Dropping two most significant digits in VCO counter for THD printout	
5	51	1	17/13:24	Preamble generator causing distortion at commutator output to line SA	Preambles entered manually
6	61	1	17/14:33	CEC recorder inoperative	Switched to spare CEC
7	61	1	17/15:24	[illegible]H doppler printout bad; no 8s or 9s in least significant digit, and the 6th position of count was incorrect	
8	72	1	17/15[illegible]	[illegible] preamble generator dropping parity bit	Unit replaced by spare
9	61	1	17/18[illegible]	[illegible] galvanometer failed on CEC recorder	Replaced defective galvanometer
10	11	1	17/20:30	TV-11 VDS PCM intermittent. CDC has problems trying to lock up	
11	51	2	18/13:07	Patch missing from TCD K-17 to tracks 2 and 6	Patch replaced at 13:20
12	11		18/20:50	TCH TD 2 inoperative	Switch to spare
13	11	3	19/09:00	TV-11 film processing problem	
14	11	3	19/18:38	Receiver 2 noise temperature 20 deg high	
15	42	5	21/07:01	Alpha TCP program hung up	Program reloaded; no improven Changed to Beta computer
16	11	5	21/22:55	Blown fuse in Beta computer	Changed fuse
17	61	5	22/00:30	TCP Beta computer down	
18	11	6	23/00:05	Maser 1, intermittent low-frequency modulation	
19	42		24/17:07	Backup photo recorder camera drive fault	Blown fuse replaced
20	42	9	25/08:36	Tape reader in CDC area incompatible with TCP. Can use with command generator but unable to pass TCP test	
21	42	9	25/13:33	Alarm on maser 1	Switched to maser 2
22	42	9	25/16:20	Servo operator switched antenna to slave mode in error, while on SAA; lost spacecraft lock	Swept uplink; receivers in 2-way at 16:28:35

FOLDOUT FRAME

Table 35. Surveyor III DSIF anomalies

...te reaction	Effect on the mission	Current action	Comments
to transmitter VCO		Under investigation	Problem temporarily cleared by a capacitive shunt on the supply output, but anomaly did not reappear when capacitor was removed
	Acquisition jeopardized; however, slow trajectory rates and intermittent nature of problem minimized this anomaly	Under investigation	Reason is unknown at present and investigation is difficult since fault is intermittent and short-lived
ime			Problem cleared before spacecraft rise 4/17 by adjustment of JT pressures flow
			Defective parallel digital outputs from the TDH VCO counter. Awaiting replacements for final repair
manually			Using 60-mA equipment into 40-mA PO circuits; problem resolved when relay was installed
CEC			Transformer F 802 failed. Station placed requisition for replacement part
	No doppler data from 17/15:24 to 18/02:07		TDH printout normal after defective connector replaced at 08:30, April 18
pare		Defective unit being repaired	
galvanometer	No CEC recording during repair period		
	No effect on mission	Under investigation	Oscillations in PCM; reason unknown at this time
13:20	No telemetry recorded from 13:07 to 13:20		Patch was removed when checking FR-1400 tape from pass 01 on FR 1200
		TD 2 in repair depot	
		Film sent to laboratory for analysis	Problem was in 5-1 emulsion, either film or processing. Shipped all 5-1 to laboratory; using emulsion 7-1 with good results
	No spare for period of repair		Replaced S-band band mixer, and system noise temperature returned to normal
; no improvement. computer			This was caused by reports entry. Possibly due to a long frame output on the W buffer I/O TTY occurring the same time as reports entry
			Bad connection on fuse post repaired
	No backup computer 00:30 to 14:40		Card failure cleared at 14:40, April 22
			After replacing defective connector, maser was normal
d			No explanation; possible mechanical overload
		Under investigation	
2 ivers in 2-way lock			Alarm sounded due to low storage tank pressure

FOLDOUT FRAME 2

Table 35 (contd)

Item	Station	Pass	Time, GMT	Anomaly	Immediate reaction	Effect on the
23	42	10	26/08:08	1 MHz on all receiver ISO amps fed to AIS		
24	42	10	26/08:08	Motor drive amplifier failed on FR-800	Installed temporary replacement transistor until replacement arrived	
25	11	10	26/05:12	Power supply failure in 70-mm on-site film recorder		Lost data during 2/3 TV-1 acquisition d
26	51	10	26/21:55	No data on track 5 of the recorders due to mispatch in the AIS		No PCM data recor from DSS 51
27	51	10	26/23:00 to 07:40	CDC command printer 4 not printing properly. Needs adjustment throughout the pass		
28	42	11	27/21:22	Decommutator 1 will not lock up	Decommutator 2 prime at 08:44	No spare decommuta
	42	12	28/11:00	Intermittent VCO card on decommutator 1.		
	42	16	02/17:45	Decommutator 1 will not hold back lock on 17.2 bits/s		
29	11	12	29/04:20	Maser 2 defective		No backup maser
30	11	12	29/05:30	Transmitter; unable to saturate klystron	Level checked; transmitter maintained a constant 10-kW output	No effect
31	42	14	30/12:00	During countdown, lost exciter output, acquisition voltage became erratic	Exciter acquisition potentiometer distribution amplifier replaced	DSS 42 acquisition
32	42	14	30/12:00	60-Hz ripple at exciter output		
33	61	16	03/08:21	Clock had 2 min outage	Patch replaced at 08:22	
34	51			920 computer problem; incorrect TTY/TLM output		

FOLDOUT FRAME

t on the mission	Current action	Comments
		Crosstalk in AIS wiring and patches, getting back to receiver ISO amplifiers, e.g., receiver agc and affecting IMP
		Correct replacement installed week of April 28
ing 2/3 of DSS 11 pass. ition data missed at 11		This involved the 32- and 100-v power supplies. Inadequate spares at TV-11 caused the delay
a recorded for 37 min 1		
ommutator		Sheared gear wheel in local oscillator potentiometer, made calibrated values for bit rate changes invalid
aser		Replaced defective crosshead
		Caused by metering problem
isition delayed 68 min		
		Fault located as excessive 60 Hz between null meter low-input and ground. This is a test equipment installation problem
		Operator error
		Repaired an intermittent ground wire solder joint on the arming interrupt chassis. In-house tests and OSDP/SFOF linkup on May 11 were conducted with no problems

FOLDOUT FRAME 2

c. Telemetry. After the mission, an assessment of the quality of DSIF telemetry indicated that excellent support was rendered the *Surveyor III* mission.

Figure 45 shows the DSIF tracking data received versus time from DSIF acquisition to touchdown.

d. Commands. Table 36 lists the times each DSS tracked the spacecraft, from the initial two-way acquisition by DSS 42 to the end of the first lunar day. Also shown are the total commands per station per pass. The initiation and quality of commands sent were excellent, even in the face of bad spacecraft data, particularly at touchdown.

Figure 46 shows individual station track view periods and commands from launch through touchdown. Figure 47 shows the station view periods and commands transmitted from touchdown to lunar sunset.

e. Video data. Table 37 lists the total TV pictures received by each station. These totals are divided into: (1) pictures made by command, and (2) those received and not commanded by that station.

Video data received were of excellent quality. The selenographic information provided was evaluated to be of great worth in support of *Apollo.*

Table 36. Tracking times and commands sent

DSS	Day, GMT, 1967	Times, GMT	Commands sent	DSS	Day, GMT, 1967	Times, GMT	Commands sent
71	April 17	07:05:01 07:08:30	0	14	April 19 and 20	22:39:00 03:40:00	0
72	April 17	07:29:38 07:32:19	0	42	April 20	06:20:06 15:49:00	99
51	April 17	07:39:46 07:43:50	0	51	April 20 and 21	13:52:00 00:37:15	0
42	April 17	07:55:00 14:21:00	50	61	April 20 and 21	14:33:48 03:24:30	17
51	April 17	12:04:19 23:05:00	15	11	April 20 and 21	23:00:42 11:05:30	5801
61	April 17 and 18	13:45:16 02:07:22	32	42	April 21	06:39:59 17:13:00	553
72	April 17	14:26:40 23:00:00	0	61	April 21 and 22	15:42:45 03:53:06	46
11	April 17 and 18	21:47:44 09:35:48	96	11	April 22	00:11:13 11:57:12	1689
12	April 17 and 18	23:00:00 05:24:00	0	42	April 22	07:10:00 18:10:00	15
42	April 18	05:33:40 14:58:30	5	61	April 22 and 23	17:07:08 04:23:16	36
51	April 18	13:06:58 23:19:00	1	11	April 23	01:17:22 11:00:00	578
61	April 18 and 19	13:56:25 02:41:17	22	42	April 23	07:38:00 19:20:50	1769
11	April 18 and 19	22:06:12 09:50:20	13	61	April 23 and 24	18:17:50 04:45:00	25
42	April 19	06:01:30 15:07:00	23	11	April 24	04:00:00 12:59:00	1307
51	April 19	13:19:46 23:23:15	4	42	April 24	08:08:00 20:37:00	808
61	April 19 and 20	14:04:15 02:56:17	34	61	April 24 and 25	19:48:35 05:24:00	28
11	April 19 and 20	22:10:54 10:13:25	6680	11	April 25	03:38:00 13:15:00	0
12	April 19 and 20	22:00:22 06:31:00	0	12	April 25	03:30:00 13:21:00	159

Table 36 (contd)

DSS	Day, GMT, 1967	Times, GMT	Commands sent	DSS	Day, GMT, 1967	Times, GMT	Commands sent
42	April 25	08:45:00 21:55:30	31	42	April 29 and 30	12:11:00 02:03:00	3128
61	April 25 and 26	21:10:00 05:55:00	789	51	April 30	00:49:54 08:02:30	7
11	April 26	04:57:00 13:30:00	3403	61	April 30	03:48:03 09:30:47	13
42	April 26	09:33:36 23:05:27	1800	11	April 30	09:14:49 17:57:36	4874
51	April 26 and 27	22:02:47 06:22:40	1878	42	April 30, and May 1	15:28:00 02:50:00	54
61	April 27	00:52:30 06:37:37	5	61	May 1	02:22:00 10:44:00	342
11	April 27	06:18:07 14:42:00	1169	11	May 1	09:50:45 19:05:00	2215
42	April 27 and 28	10:22:00 00:16:00	3822	42	May 1 and 2	18:00:00 03:34:02	1104
51	April 27 and 28	23:00:36 07:44:00	5	61	May 2	02:55:15 11:49:19	1488
61	April 28	01:08:40 07:34:08	14	11	May 2	10:24:41 20:09:00	1909
11	April 28	07:29:10 15:39:00	2280	42	May 2 and 3	19:00:00 03:52:00	470
42	April 28 and 29	11:16:00 01:06:00	2233	61	May 3	03:16:48 12:51:14	419
51	April 29	00:19:00 08:45:42	0	11	May 3	10:45:17 21:16:00	869
61	April 29	01:11:28 08:31:00	48	42	May 3 and 4	20:00:00 00:08:00	57
11	April 29	08:27:34 16:31:00	2471			TOTAL	57,107

Table 37. TV pictures received

DSS	Commanded	Noncommanded
71	0	0
72	0	0
42	1726	1412
51	0	70
61	33	504
11	4567	1719
12	0	0
	Total 6326	Total 3705

f. Spacecraft center frequencies. In order that spacecraft predictions may be generated and supplied to the DSN tracking stations for purposes of spacecraft acquisition, aided track, and station-to-station transfers of the spacecraft, it is essential that the spacecraft transmitter (one-way) center frequency and spacecraft transponder (two-way) center frequency be accurately known. The nominal values for these frequencies are 2295.000000-MHz/s (at carrier level) for the transmitter center frequency and 22.013670-MHz (at station VCO level) for the transponder center frequency. Normally, these frequencies are measured months before the mission for use in the preflight prediction document, and then they are measured several times in the last 10 h of the countdown for use in real time predictions. The frequencies which were used in the preflight prediction document were:

2294.996667 (one-way, transmitter A)

2294.995700 (one-way, transmitter B)

22.013666 (two-way, transponder A)

22.013703 (two-way, transponder B)

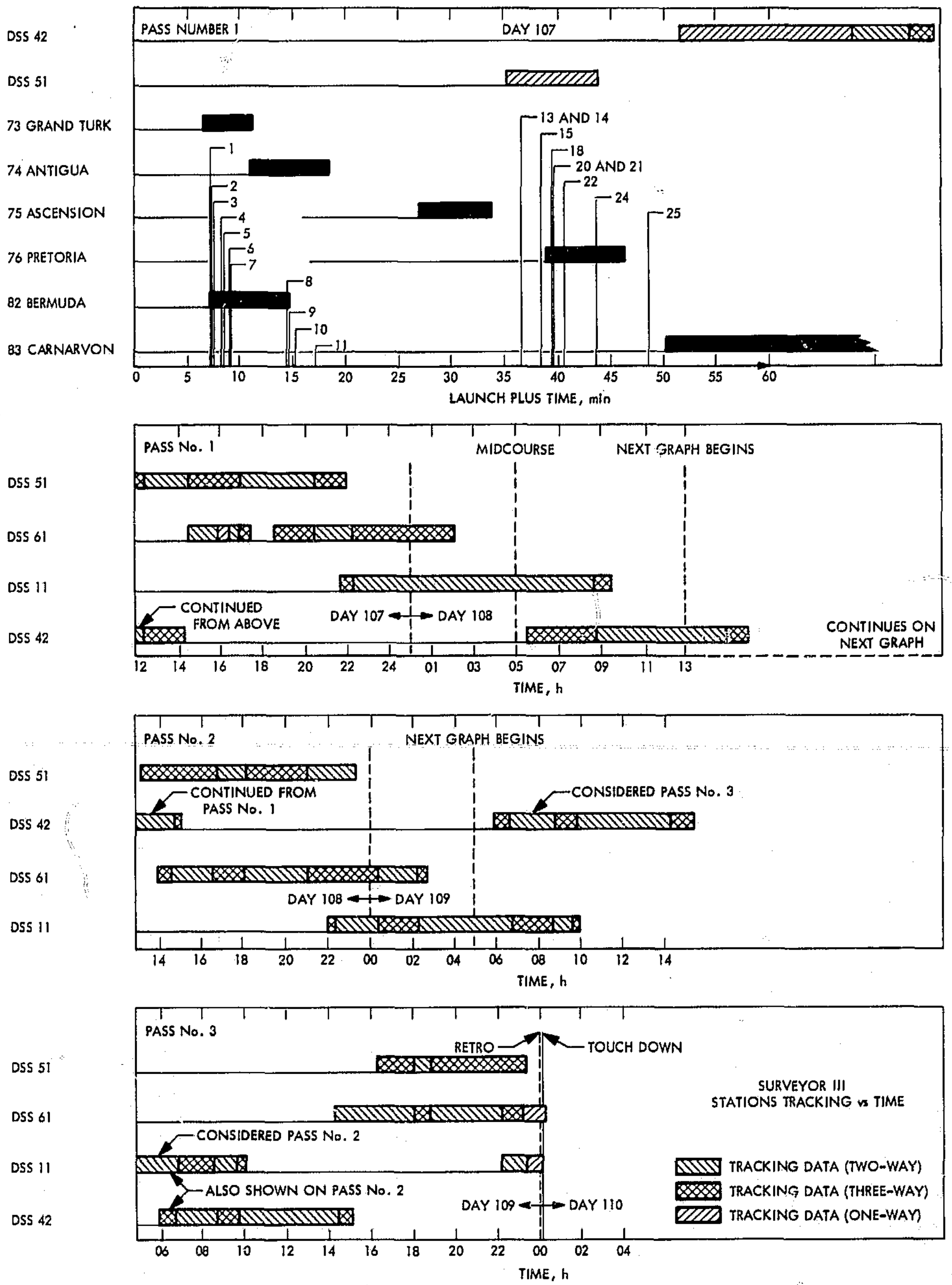


Fig. 45. DSIF tracking data time

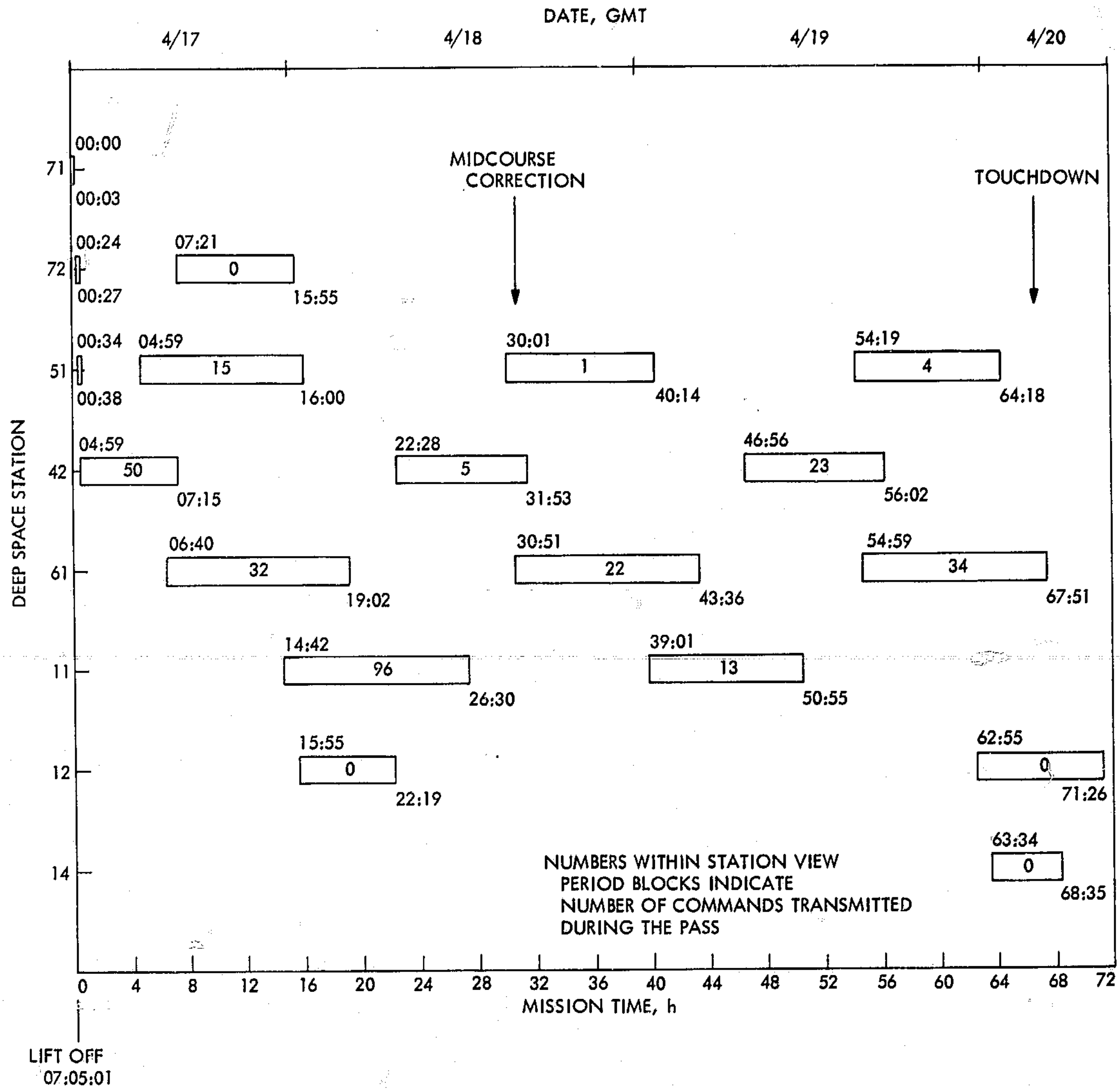


Fig. 46. *Surveyor III* DSIF view periods, launch through touchdown

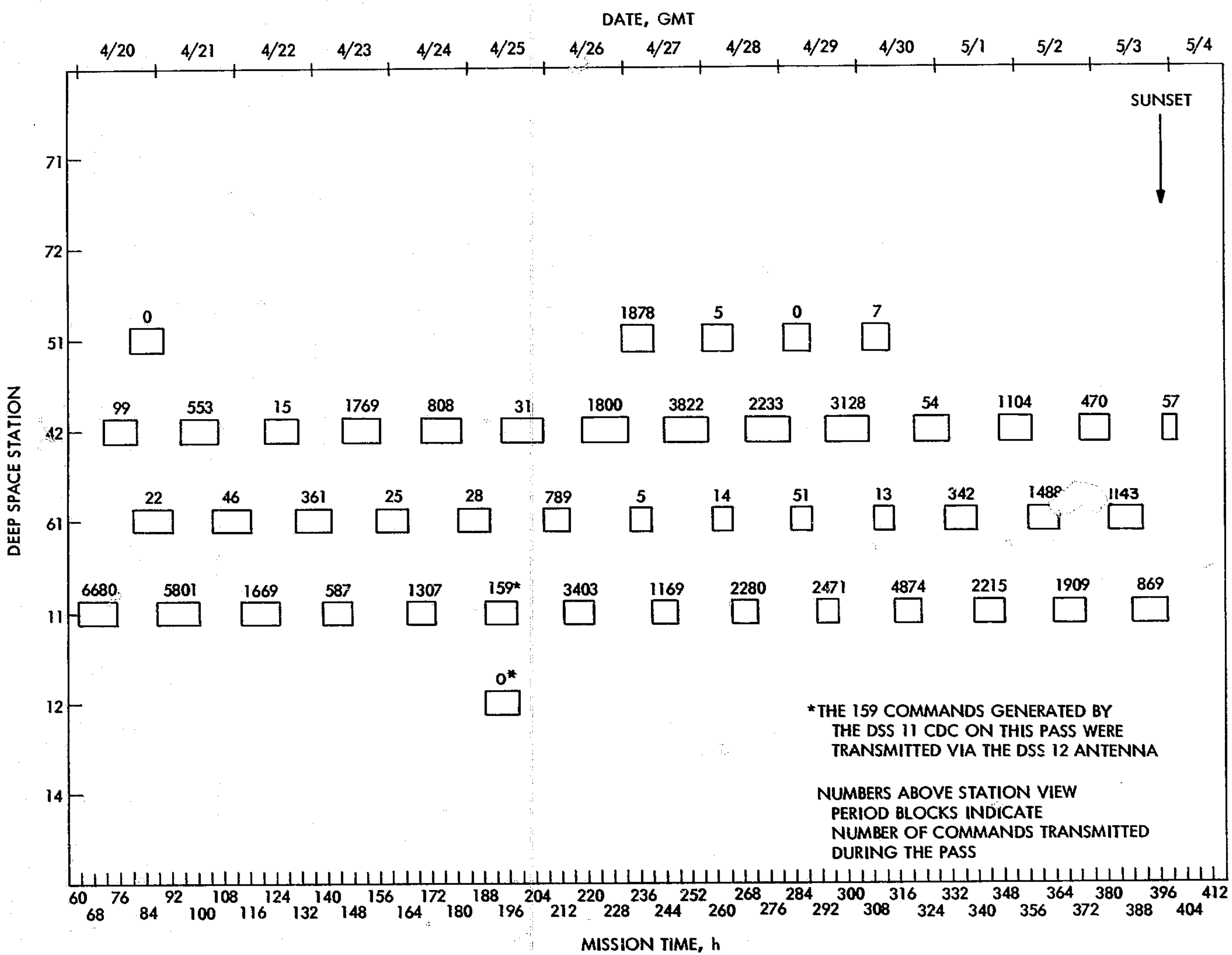


Fig. 47. Surveyor *III* DSIF commands and view periods from touchdown through lunar sunset

These frequencies were abstracted from preflight data supplied by HAC for an estimated launch temperature of 90°F. During the countdown, frequency measurements were made and sent to the SFOF at $T-500$ min, $T-400$ min, $T-274$ min, $T-90$ min, $T-40$ min, $T-20$ min, and $T-5$ min as called for in the sequence of events. These measurements were used to adjust the preflight frequency versus temperature curves by a constant bias in frequency (see Figs. 48–51). Finally, using the temperature predictions for *Surveyor III* generated by the SFOF, tables of the appropriate frequencies to be used throughout the mission were constructed and incorporated in the various inflight prediction sets (see Table 38). The one deviation from this sequence was the

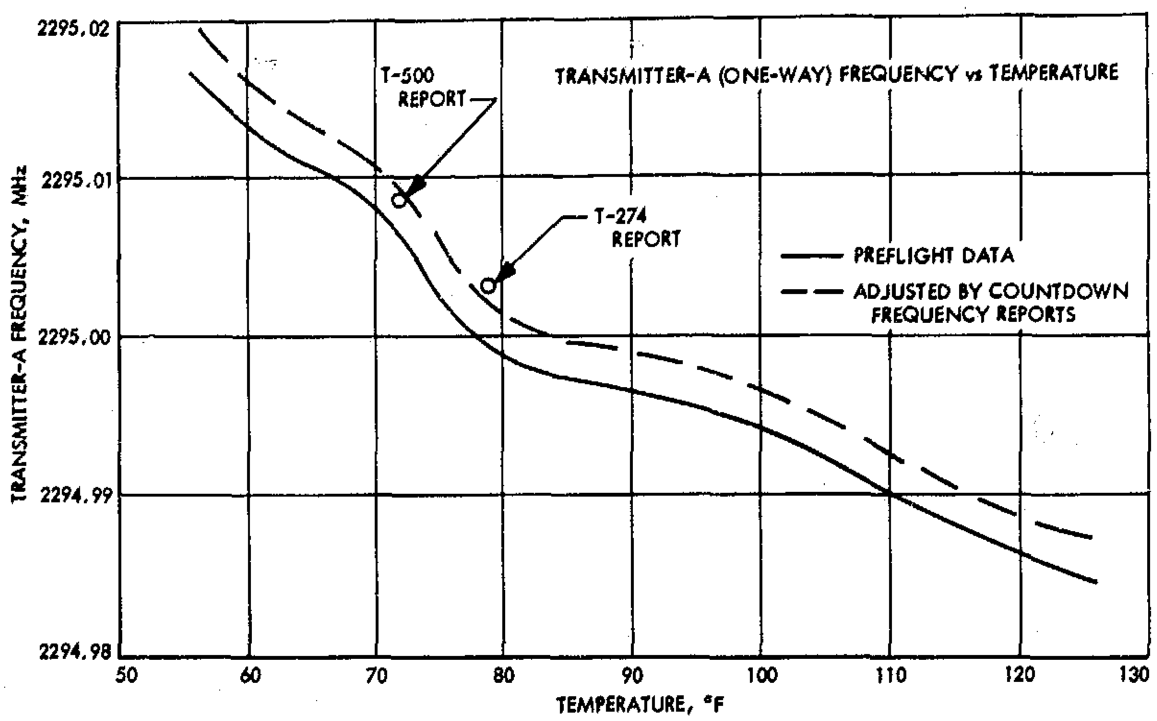


Fig. 48. Transmitter A temperature, °F frequency ranging

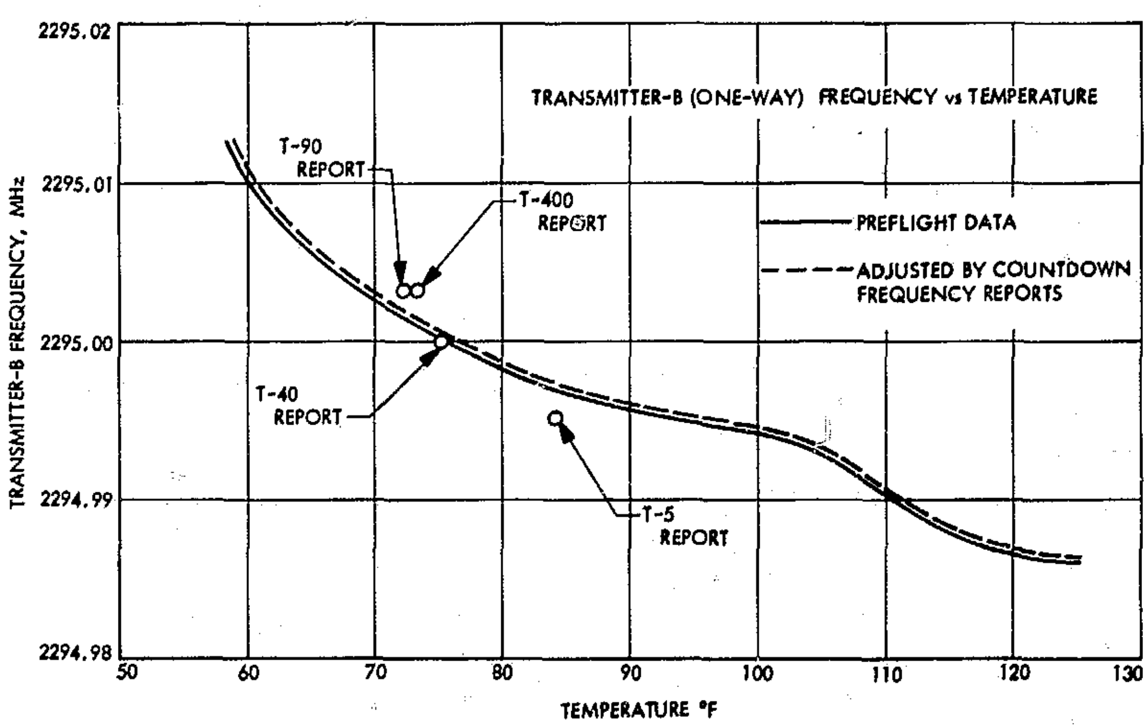


Fig. 49. Transmitter B temperature, °F frequency ranging

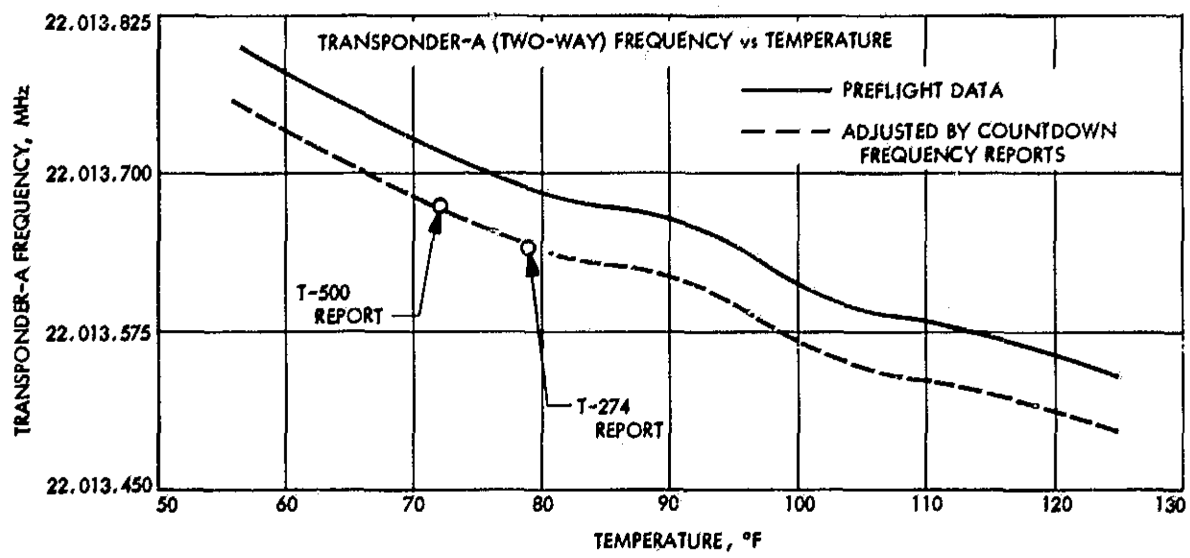


Fig. 50. Transponder A temperature, °F frequency ranging

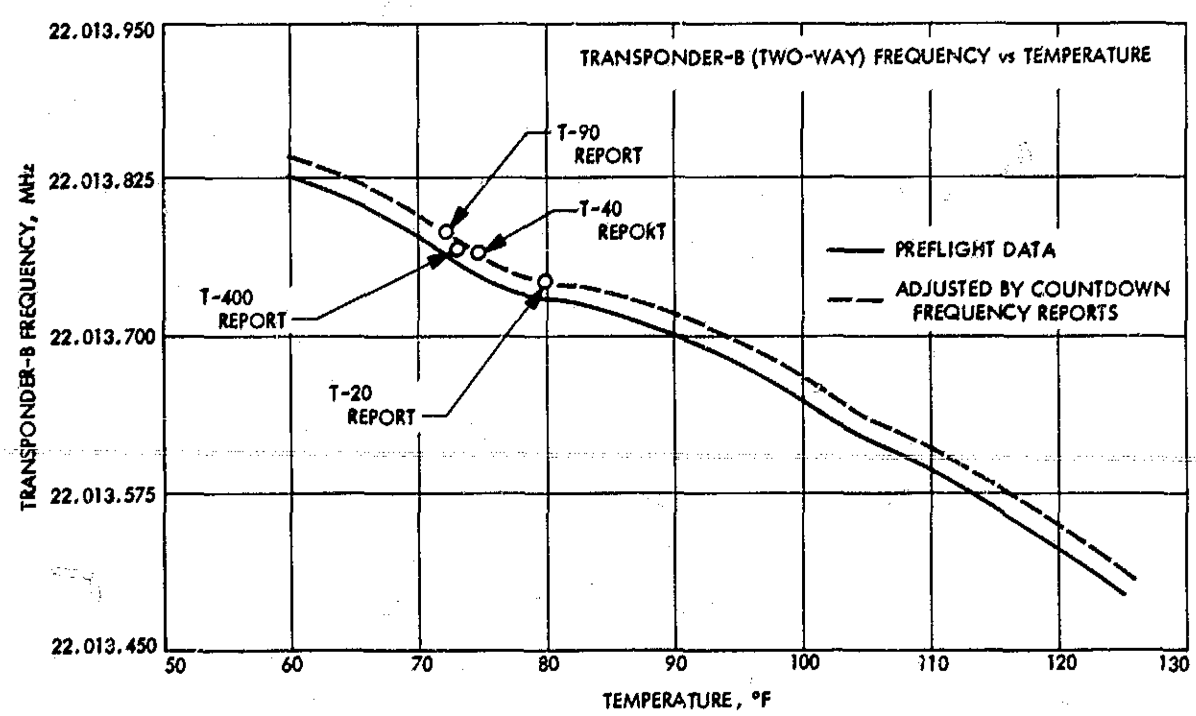


Fig. 51. Transponder B temperature, °F frequency ranging

predict set for initial acquisition at DSS 42, which utilized special acquisition frequencies as predicted by the SFOF (2294.995900 and 22.013704, for transponder B).

g. Spacecraft predictions. Spacecraft predictions, which are composed of time-tagged station observables such as pointing angles, one-way doppler, two-way doppler, best-lock ground transmitter frequency, etc., are more or less routinely provided to the DSN tracking stations to ensure the success of spacecraft acquisitions, aided track, and station transfers of the spacecraft. However, during the launch phase, the provision of accurate predictions to DSS 42 and other tracking stations becomes a critical matter because of the crucial need for early acquisition and commanding of the spacecraft. For first two-way acquisition at DSS 42 there are three distinct sets of predictions available:

(1) Preflight prediction document

(2) $L - 5$-min predictions based on actual launch azimuth

(3) AFETR predictions based on actual postinjection tracking data

Table 38. *Surveyor III* inflight frequency predictions[a]

Time	Temperature, °F	Frequency, MHz
	Transmitter A	
Launch to $L + 30$ h	75	2295.005500
$L + 30$ h to $L + 65$ h	65	2295.014600
$L + 65$ h to $L + 68$ h	72.5	2295.008200
	Transmitter B	
Launch to $L + 3$ h	110	2294.991500
$L + 3$ h to $L + 30$ h	97.5	2294.995500
$L + 30$ h to $L + 65$ h	85	2294.998000
$L + 65$ h to $L + 68$ h	105	2294.993350
	Transponder A	
Launch to $L + 4$ h	92.5	22.013614
$L + 4$ h to $L + 30$ h	85	22.013626
$L + 30$ h to $L + 65$ h	80	22.013638
$L + 65$ h to $L + 68$ h	87.5	22.013623
	Transponder B	
Launch to $L + 4$ h	92.5	22.013704
$L + 4$ h to $L + 30$ h	85	22.013738
$L + 30$ h to $L + 65$ h	80	22.013752
$L + 65$ h to $L + 68$ h	87.5	22.013732

[a]Transmitter B and Transponder B were used during the entire in-flight portion of the *Surveyor III* mission.

Although both the preflight predictions and $L - 5$-min predictions are generated before launch, the $L - 5$-min predictions have two important advantages over the preflight predictions in that they are based on updated frequency information, and they are generated for the exact actual launch azimuth. Because of these two factors, the $L - 5$-min predictions were generated and sent to DSS 42, DSS 51, and DSS 72 with the advisement that they be used instead of the preflight prediction document. DSS 72 acknowledged receipt of the $L - 5$-min predicts approximately 2 min before rise and were able to successfully acquire and view the *Surveyor III* parking orbit pass over DSS 72 using these predicts. At about $L + 20$ min, predictions from AFETR based on actual post-parking-orbit injection tracking data were received at JPL, which very closely matched the $L - 5$ min predictions, thereby verifying that DSS 51 had accurate acquisition predicts. These predicts were used by DSS 51 to acquire the *Surveyor III* in one-way during their launch pass, which included viewing part of the *Centaur* second burn and the subsequent injection into lunar transfer orbit. At approximately $L + 55$ min, AFETR predicts based on actual postinjection tracking data were received at JPL, which again closely matched the $L - 5$ min-predicts, indicating that DSS 42 had accurate acquisition predicts. Accordingly, DSS 42 used the $L - 5$ min-predicts for its initial acquisition; no difficulties were encountered.

During the cruise phase, predictions were routinely supplied to the participating Deep Space Stations, and after touchdown exact "on the moon" predictions were generated with the use of a newly added capability to the prediction generation (PRDX) program and were subsequently supplied to the DSS.

h. Initial two-way acquisition at DSS 42. Predictions indicated a *Surveyor III* rise at DSS 42 at 07:54:57 (GMT), 17 April. DSS 42 reported good one-way doppler data at 07:55:42 (rise + 00:45), automatic tracking on the SAA (acquisition-aide antenna) at 07:57:50 (rise + 02:53), automatic tracking on the SCM (antenna main beam) at 08:00:44 (rise + 05:47) and good two-way doppler data at 08:01:52 (rise + 06:55). The current acquisition procedure does not allow transfer to the SCM and uplink (two-way) acquisition search to begin until the spacecraft is 10 deg above the local horizon, which in this case occurred at 07:58:10 (rise + 03:13). In light of this, the initial acquisition at DSS 42 can be considered smooth and close to optimum. Analysis of the one-way doppler data from DSS 42 indicates a spacecraft transmitter B center frequency (no doppler) of 2294.993500 MHz at 07:57:47, as compared to the predicted value of 2294.995900. Acquisition of the uplink by DSS 42 at 08:00:07 at a ground transmitter frequency of 22.013946 MHz would indicate a corresponding value of 22.013739 MHz for the spacecraft transponder B center frequency, as compared to the SPAC prediction of 22.013704 MHz for transponder B.

i. Near real-time tracking-data monitor. All two-way tracking data taken during the in-flight portion of the *Surveyor III* mission was computer monitored in near-real time; this resulted in the timely discovery of a hardware malfunction in the doppler counter at DSS 61 during their first pass.

j. Tracking performance. The DSN provided continuous angular and doppler tracking of the *Surveyor III* from initial one-way acquisition by DSS 42 at 07:55:42 on April 17, 1967 until lunar touchdown of *Surveyor III* at 00:04:18.1 on April 20. The DSN then continued to track the spacecraft on the lunar surface through the first lunar day, with tracking being terminated at 00:03:58, on May 4, or approximately 2 h and 23 min after lunar sunset. In general, the overall quality of the tracking data taken during the *Surveyor III* mission can be described as very good. Data types used before touchdown in the orbit determination program (ODP) were angular data taken during the first pass over DSS 42, DSS 61, and DSS 51 and two-way doppler taken during all passes over DSS 42, DSS 51, DSS 61, and DSS 11. A summary of the data used in the ODP, together with data statistics, is given in Table 39. The relative quality of the tracking data taken at each station can be obtained by comparing the standard deviations, the root-mean-squares, and the first moments of the data as listed in the table. Changes in the quality of the same data as reflected in different orbits are largely attributable to the particular selection criteria of each orbit as determined by the Orbit Determination Group. Orbit identifications are as follows:

Predict orbit	= PROR
Injection condition evaluation orbit	= ICEV
Preliminary pre-midcourse orbit	= PREL
Data consistency orbit	= DACO
Nominal midcourse orbit	= NOMA
Last pre-midcourse orbit	= LAPM
Pre-midcourse cleanup orbit	= PRCL
Post flight analysis orbit	= POST
Nth post-midcourse orbit	= N POM
Computer string X	= X
Computer string Y	= Y

Table 39. DSIF premaneuver tracking data used in computing *Surveyor III* orbit

Orbit identification	DSIF sta	Data type	Beginning of data (month/day, GMT)	End of data, month/day, time (GMT)	Number of points	Standard deviation	Root mean square	Mean error	Sample rate, s
PROR YA	42	CC3	4/17-08:01:57	4/17-08:17:49	93	0.0189	0.0189	0.000478	10
		HA	4/17-07:57:42	4/17-08:17:52	104	0.0210	0.0210	−0.000318	10
		Dec	4/17-07:57:42	4/17-08:17:52	104	0.0438	0.0438	−0.00103	10
PROR XA	42	CC3	4/17-08:04:37	4/17-08:22:07	99	0.0271	0.0902	−0.0861	10
		HA	4/17-07:57:42	4/17-08:22:12	107	0.0106	0.0106	−0.000196	10
		Dec	4/17-07:57:42	4/17-08:22:12	106	0.00500	0.00501	−0.000335	10
ICEV YA	42	CC3	4/17-08:01:57	4/17-09:20:32	319	0.0382	0.0389	0.00735	10, 60
		HA	4/17-07:58:02	4/17-09:21:02	331	0.00672	0.00825	−0.00479	10, 60
		Dec	4/17-07:58:02	4/17-09:21:02	331	0.0200	0.0216	−0.00818	10, 60
ICEV XA	42	CC3	4/17-08:04:37	4/17-09:55:32	318	0.0375	0.0382	0.00720	10, 60
		HA	4/17-07:58:02	4/17-09:56:02	329	0.00791	0.00969	−0.00558	10, 60
		Dec	4/17-07:58:02	4/17-09:56:02	329	0.0187	0.0203	−0.00787	10, 60
PREL XA	42	CC3	4/17-08:04:37	4/17-10:24:32	342	0.0190	0.0190	0.000420	10, 60
PREL YA	42	CC3	4/17-08:01:57	4/17-10:24:32	364	0.0453	0.0462	0.00869	10, 60
		HA	4/17-07:58:02	4/17-10:25:02	383	0.0087	0.0107	−0.00629	10, 60
		Dec	4/17-07:58:02	4/17-10:25:02	383	0.0211	0.0243	−0.0121	10, 60
UPDATE XB	42	CC3	4/17-08:04:37	4/17-11:45:32	401	0.0176	0.0176	0.00018	10, 60
	51	CC3	4/17-12:23:32	4/17-13:41:32	67	0.00907	0.00907	−0.000364	60
UPDATE YA	42	CC3	4/17-08:01:57	4/17-11:45:32	427	0.0169	0.0169	−0.000056	10, 60
	51	CC3	4/17-12:23:32	4/17-13:47:32	63	0.00809	0.00810	−0.000349	60
	61	CC3	4/17-14:32:32	4/17-14:41:32	10	0.0456	0.0456	−0.00132	10
UPDATE YB	42	CC3	4/17-08:01:57	4/17-08:56:32	287	0.0201	0.0201	0.0000817	10
		CC3	4/17-08:57:32	4/17-11:45:32	139	0.00429	0.00429	−0.000302	60
	51	CC3	4/17-12:23:32	4/17-14:27:32	94	0.00879	0.00881	−0.000473	60
	61	CC3	4/17-14:32:32	4/17-15:44:32	39	0.0151	0.0151	−0.000313	60
DACO YA	42	CC3	4/17-08:01:57	4/17-08:56:32	287	0.0201	0.0201	0.000116	10
	42	CC3	4/17-11:45:32	4/17-11:45:32	139	0.00422	0.00423	−0.00033	60
	61	CC3	4/17-12:23:32	4/17-14:32:32	1	0.0000	0.000977	−0.000977	60
	61	CC3	4/17-14:33:32	4/17-16:49:32	55	0.0154	0.0154	0.0000888	60
DACO YB	51	CC3	4/17-08:01:57	4/17-14:27:32	93	0.00844	0.0084[illegible]	−0.00080	60
		CC3	4/17-17:04:32	4/17-18:16:32	45	0.00984	0.00989	−0.00106	60
	61	CC3	4/17-14:32:32	4/17-14:32:32	1	0.0000	0.000977	−0.000977	60
		CC3	4/17-14:33:32	4/17-16:49:32	55	0.0153	0.0154	−0.00103	60

Table 39 (contd)

Orbit identification	DSIF sta	Data type	Beginning of data (month/day, GMT)	End of data, month/day, time (GMT)	Number of points	Standard deviation	Root mean square	Mean error	Sample rate, s
DACO XA	61	CC3	4/17-14:32:32	4/17-14:32:32	1	0.0000	0.000488	0.000488	60
		HA	4/17-14:22:02	4/17-14:32:02	5	0.00402	0.0076	0.0064	60
		Dec	4/17-14:22:02	4/17-14:32:02	5	0.00402	0.0120	−0.011	60
		CC3	4/17-14:33:32	4/17-16:52:32	83	0.0470	0.0478	0.00923	60
		HA	4/17-14:33:02	4/17-16:53:02	112	0.0122	0.0123	0.00121	60
		Dec	4/17-14:33:02	4/17-16:53:02	112	0.0160	0.0276	0.0225	60
		HA	4/17-17:07:02	4/17-17:33:02	13	0.00577	0.0065	−0.00299	60
		Dec	4/17-17:07:02	4/17-17:33:02	13	0.00773	0.011	0.00781	60
DACO XA	51	CC3	4/17-12:23:32	4/17-14:27:32	49	0.0121	0.0131	0.00540	60
		HA	4/17-12:16:02	4/17-14:28:02	115	0.00533	0.0572	0.0570	60
		Dec	4/17-12:16:02	4/17-14:28:02	115	0.00505	0.0353	−0.0349	60
		CC3	4/17-17:04:32	4/17-17:58:32	36	0.0101	0.0118	−0.00613	60
		HA	4/17-14:34:32	4/17-18:02:02	166	0.0071	0.055	0.0545	60
		Dec	4/17-14:34:32	4/17-18:02:02	166	0.0102	0.0299	−0.0281	60
	42	CC3	4/17-08:04:37	4/17-08:52:47	276	0.038	0.038	0.00198	10
		HA	4/17-07:58:02	4/17-08:55:02	283	0.00586	0.00722	−0.00422	10
		Dec	4/17-07:58:02	4/17-08:55:02	283	0.00666	0.0472	−0.0467	10
		HA	4/17-08:57:02	4/17-08:57:02	1	0.000	0.00219	0.00219	60
		Dec	4/17-08:57:02	4/17-08:57:02	1	0.000	0.0516	−0.0516	60
		CC3	4/17-08:57:32	4/17-08:57:32	1	0.000	0.040	0.04	60
		CC3	4/17-08:58:32	4/17-11:45:32	124	0.0367	0.0385	−0.0117	60
		HA	4/17-08:58:02	4/17-11:51:02	137	0.00669	0.0158	−0.0143	60
		Dec	4/17-08:58:02	4/17-11:51:02	137	0.00445	0.0478	−0.0476	60
		HA	4/17-12:28:02	4/17-14:19:02	98	0.0102	0.0353	−0.0338	60
		Dec	4/17-12:28:02	4/17-14:19:02	97	0.0103	0.0373	−0.0359	60
DACO XB	61	HA	4/17-12:16:02	4/17-14:32:02	5	0.00403	0.00907	0.00812	60
		Dec	4/17-12:16:02	4/17-14:32:02	5	0.00404	0.0154	−0.0149	60
		HA	4/17-14:33:02	4/17-16:53:02	112	0.0122	0.0125	0.00284	60
		Dec	4/17-14:33:02	4/17-16:53:02	112	0.0159	0.0244	0.0185	60
		HA	4/17-17:07:02	4/17-18:44:02	16	0.00653	0.00720	−0.00304	60
		Dec	4/17-17:07:02	4/17-18:44:02	16	0.0165	0.0169	−0.00388	60
	51	CC3	4/17-12:23:32	4/17-14:27:32	99	0.00986	0.0109	0.00454	60
		CC3	4/17-17:21:32	4/17-17:21:32	1	0.000	0.0337	0.0337	60
		CC3	4/17-17:22:32	4/17-18:42:32	62	0.0118	0.0306	0.282	60
	42	CC3	4/17-08:04:37	4/17-08:52:47	276	0.0334	0.0346	0.00903	10
		HA	4/17-07:58:02	4/17-08:55:02	283	0.00594	0.00595	−0.00023	10
		Dec	4/17-07:58:02	4/17-08:55:02	283	0.00953	0.0406	−0.395	10
		HA	4/17-08:57:02	4/17-08:57:02	1	0.000	0.00548	0.00548	60
		Dec	4/17-08:57:02	4/17-08:57:02	1	0.000	0.0487	−0.0487	60
		CC3	4/17-08:57:32	4/17-08:57:32	1	0.000	0.0352	0.0352	60
		CC3	4/17-08:58:32	4/17-11:45:32	124	0.0401	0.0495	−0.0289	60
		HA	4/17-08:58:02	4/17-15:51:02	137	0.0069	0.0137	−0.0119	60
		Dec	4/17-08:58:02	4/17-11:51:02	137	0.00503	0.0484	−0.0481	60
		HA	4/17-12:28:02	4/17-14:19:02	98	0.0102	0.0337	−0.0321	60
		Dec	4/17-12:28:02	4/17-14:19:02	97	0.0101	0.0403	−0.039	60

Table 39 (contd)

Orbit identification	DSIF sta	Data type	Beginning of data (month/ day, GMT)	End of data, month/day, time (GMT)	Number of points	Standard deviation	Root mean square	Mean error	Sample rate, s
DACO YC	42	CC3	4/17-08:01:57	4/17-08:56:32	288	0.0204	0.0204	0.000268	10
		CC3	4/17-08:57:32	4/17-11:45:32	139	0.00432	0.00432	0.000102	60
	51	CC3	4/17-12:23:32	4/17-17:21:32	94	0.00836	0.00836	0.0000779	60
		CC3	4/17-17:22:32	4/17-18:41:32	61	0.00923	0.00923	0.00064	60
DACO XC	61	HA	4/17-14:22:02	4/17-14:32:02	5	0.00403	0.00465	0.00233	60
		Dec	4/17-14:22:02	4/17-14:32:02	5	0.00400	0.0114	−0.0107	60
		HA	4/17-14:33:02	4/17-16:53:02	112	0.0122	0.0125	−0.00283	60
		Dec	4/17-14:33:02	4/17-16:53:02	112	0.0162	0.0287	0.0237	60
		HA	4/17-17:07:02	4/17-19:21:12	176	0.00547	0.0166	−0.0156	60
		Dec	4/17-17:07:02	4/17-19:21:12	176	0.0122	0.0323	−0.0299	60
	51	CC3	4/17-12:23:32	4/17-14:27:32	99	0.00843	0.0137	0.0108	60
		HA	4/17-07:58:02	4/17-14:28:02	115	0.00532	0.0529	0.0526	60
		Dec	4/17-07:58:02	4/17-14:28:02	115	0.00493	0.0354	−0.0350	60
		HA	4/17-14:34:02	4/17-17:21:02	128	0.00678	0.0525	0.0520	60
		Dec	4/17-14:34:02	4/17-17:21:02	128	0.0102	0.0313	−0.0296	60
		CC3	4/17-17:21:32	4/17-17:21:32	1	0.000	0.0259	−0.0259	60
		CC3	4/17-17:22:32	4/17-19:20:32	103	0.0172	0.0306	−0.0254	60
		HA	4/17-17:22:02	4/17-19:21:02	117	0.00509	0.0447	0.0444	60
		Dec	4/17-17:22:02	4/17-19:21:02	117	0.00476	0.0135	−0.0126	60
	42	CC3	4/17-08:04:37	4/17-08:52:47	276	0.0227	0.0238	−0.00689	10
		CC3	4/17-08:57:32	4/17-08:57:32	1	0.0000	0.00195	−0.00195	60
		CC3	4/17-08:58:32	4/17-11:45:32	124	0.0141	0.0220	0.0169	60
DACO XD	61	CC3	4/17-14:32:32	4/17-14:32:32	1	0.000	0.0176	−0.0176	60
		CC3	4/17-14:33:32	4/17-16:52:32	83	0.0464	0.0497	−0.0178	60
	51	CC3	4/17-12:23:32	4/17-14:27:32	99	0.00847	0.0183	−0.0162	60
		CC3	4/17-17:21:32	4/17-17:21:32	1	0.000	0.0244	−0.0244	60
		CC3	4/17-17:22:32	4/17-19:44:32	121	0.0160	0.0273	−0.0221	60
	42	CC3	4/17-08:04:37	4/17-08:52:47	276	0.0211	0.0223	−0.00742	10
		CC3	4/17-08:57:32	4/17-08:57:32	1	0.000	0.00488	−0.00488	60
		CC3	4/17-08:58:32	4/17-11:45:32	124	0.00460	0.0130	−0.0122	60
DACO YE	61	CC3	4/17-14:32:32	4/17-14:32:32	1	0.000	0.00146	−0.00146	60
		CC3	4/17-14:33:32	4/17-16:49:32	55	0.0153	0.0153	−0.0000089	60
	51	CC3	4/17-12:23:32	4/17-17:21:32	94	0.00840	0.00846	−0.00103	60
		CC3	4/17-17:22:32	4/17-19:44:32	122	0.0161	0.0162	−0.00164	60
	42	CC3	4/17-08:01:57	4/17-08:56:32	287	0.0201	0.0201	−0.000362	10
		CC3	4/17-08:57:32	4/17-11:45:32	139	0.00423	0.00423	−0.0000703	60
NOMA XA	61	CC3	4/17-14:32:32	4/17-14:32:32	1	0.000	0.00684	−0.00684	60
		CC3	4/17-14:33:32	4/17-20:31:27	54	0.0155	0.0160	−0.00380	60
		CC3	4/17-20:31:37	4/17-22:02:32	84	0.0137	0.0160	0.00824	60
	51	CC3	4/17-12:23:32	4/17-17:21:32	100	0.00841	0.00841	0.0000293	60
		CC3	4/17-17:22:32	4/17-20:29:32	145	0.0106	0.0115	−0.00435	60
	42	CC3	4/17-08:04:37	4/17-08:57:32	274	0.0205	0.0205	0.000127	10
		CC3	4/17-08:58:32	4/17-11:45:32	124	0.00440	0.00445	0.000665	60

Table 39 (contd)

Orbit identification	DSIF sta	Data type	Beginning of data (month/day, GMT)	End of data, month/day, time (GMT)	Number of points	Standard deviation	Root mean square	Mean error	Sample rate, s
NOMA YA	61	CC3	4/17-14:32:32	4/17-14:32:32	1	0.000	0.00684	−0.00684	60
		CC3	4/17-14:33:23	4/17-20:31:27	55	0.0155	0.0161	−0.00435	60
		CC3	4/17-20:31:37	4/17-22:07:32	86	0.0146	0.0162	0.00696	60
	51	CC3	4/17-12:23:32	4/17-17:21:32	92	0.00772	0.00772	−0.000138	60
		CC3	4/17-17:22:32	4/17-20:29:32	133	0.00793	0.00903	−0.00431	60
	42	CC3	4/17-08:01:57	4/17-08:56:32	275	0.0186	0.0186	0.000087	10
		CC3	4/17-08:57:32	4/17-11:45:32	139	0.00439	0.00439	0.000239	60
NOMA YB	61	CC3	4/17-14:32:32	4/17-14:32:32	1	0.000	0.00586	−0.00586	60
		CC3	4/17-14:33:32	4/17-20:31:32	55	0.0155	0.0156	−0.00171	60
		CC3	4/17-20:31:57	4/17-22:07:32	84	0.0161	0.0185	0.00917	60
	51	CC3	4/17-12:23:32	4/17-17:21:32	90	0.00777	0.00851	−0.00347	60
		CC3	4/17-17:22:32	4/17-20:28:32	134	0.00807	0.00845	−0.00249	60
	42	CC3	4/17-08:01:57	4/17-08:56:32	272	0.0187	0.0187	0.000582	10
		CC3	4/17-08:57:32	4/17-11:45:32	139	0.00564	0.00565	0.000341	60
	11	CC3	4/17-22:18:32	4/17-23:00:32	10	0.00426	0.0170	0.0165	60
NOMA XB	61	CC3	4/17-14:32:32	4/17-20:31:32	52	0.0121	0.0122	−0.00199	60
		CC3	4/17-20:31:57	4/17-22:07:32	82	0.0119	0.0151	0.00923	60
	51	CC3	4/17-12:23:32	4/17-17:21:32	93	0.00756	0.00888	−0.00466	60
		CC3	4/17-17:22:32	4/17-20:28:32	132	0.00846	0.00888	−0.00270	60
	42	CC3	4/17-08:04:37	4/17-08:57:32	260	0.0189	0.0189	0.000193	10
		CC3	4/17-08:58:32	4/17-11:45:32	124	0.00636	0.00638	−0.000441	60
	11	CC3	4/17-22:18:32	4/17-23:16:32	21	0.00426	0.0101	0.00918	60
LAPM YA	61	CC3	4/17-14:32:32	4/17-20:31:32	56	0.0154	0.0156	−0.00245	60
		CC3	4/17-20:31:57	4/17-22:07:32	84	0.0160	0.0176	0.00733	60
	51	CC3	4/17-12:23:32	4/17-17:21:32	84	0.00718	0.0100	−0.00699	60
		CC3	4/17-17:22:32	4/17-20:28:32	132	0.00841	0.00911	−0.00350	60
	42	CC3	4/17-08:01:57	4/17-08:56:32	275	0.0193	0.0193	0.000151	10
		CC3	4/17-08:57:32	4/17-11:45:32	139	0.00697	0.00719	−0.00175	60
	11	CC3	4/17-22:18:32	4/17-00:28:32	119	0.00562	0.00594	0.00193	60
LAPM XA	61	CC3	4/17-14:32:32	4/17-20:31:32	52	0.0120	0.0122	−0.00221	60
		CC3	4/17-20:31:57	4/17-22:07:32	82	0.0120	0.0146	0.00841	60
	51	CC3	4/17-12:23:32	4/17-17:21:32	89	0.00733	0.00935	−0.00581	60
		CC3	4/17-17:22:32	4/17-20:28:32	130	0.00847	0.00911	−0.00336	60
	42	CC3	4/17-08:04:37	4/17-08:57:32	258	0.0188	0.0188	−0.0000927	10
		CC3	4/17-08:58:32	4/17-11:45:32	124	0.00697	0.00710	−0.00131	60
	11	CC3	4/17-22:18:32	4/17-00:20:32	92	0.00461	0.00522	0.00245	60
LAPM YB	61	CC3	4/17-14:32:32	4/17-20:31:32	56	0.0154	0.0154	−0.000872	60
		CC3	4/17-20:31:57	4/17-22:07:32	84	0.0160	0.0182	0.00862	60
	51	CC3	4/17-12:23:32	4/17-17:21:32	84	0.00724	0.00971	−0.00648	60
		CC3	4/17-17:22:32	4/17-20:28:32	134	0.00846	0.00896	−0.00296	60
	42	CC3	4/17-08:01:57	4/17-08:56:32	275	0.0193	0.0193	0.000914	10
		CC3	4/17-08:57:32	4/17-11:45:32	139	0.00706	0.00719	−0.00138	60
	11	CC3	4/17-22:18:32	4/17-00:57:32	145	0.00666	0.00767	0.00380	60

Table 39 (contd)

Orbit identification	DSIF sta	Data type	Beginning of data (month/day, GMT)	End of data, month/day, time (GMT)	Number of points	Standard deviation	Root mean square	Mean error	Sample rate, s
LAPM XB	61	CC3	4/17-14:32:32	4/17-20:31:32	52	0.0120	0.0210	−0.0000563	60
		CC3	4/17-20:31:57	4/17-22:07:32	82	0.0120	0.0156	0.0101	60
	51	CC3	4/17-12:23:32	4/17-17:21:32	89	0.00723	0.00952	−0.00619	60
		CC3	4/17-17:22:32	4/17-20:28:32	131	0.00841	0.00886	−0.00278	60
	42	CC3	4/17-08:04:37	4/17-08:57:32	277	0.0216	0.0216	0.00162	10
		CC3	4/17-08:58:32	4/17-11:45:32	124	0.00716	0.00730	−0.00144	60
	11	CC3	4/17-22:18:32	4/18-01:19:32	156	0.00731	0.00877	0.00484	60
LAPM YC	61	CC3	4/17-14:32:32	4/17-20:31:32	56	0.0154	0.0157	−0.00308	60
		CC3	4/17-20:31:57	4/17-22:07:32	83	0.0149	0.0162	0.00635	60
	51	CC3	4/17-12:23:32	4/17-17:21:32	77	0.00641	0.0102	−0.00796	60
		CC3	4/17-17:22:32	4/17-20:28:32	131	0.00830	0.00983	−0.00526	60
	42	CC3	4/17-08:01:57	4/17-08:56:32	274	0.0190	0.0190	0.000672	10
		CC3	4/17-08:57:32	4/17-11:45:32	139	0.00735	0.00801	−0.00318	60
	11	CC3	4/17-22:18:32	4/18-01:22:32	165	0.00719	0.00728	0.00117	60
PRCL YC	11	CC3	4/17-22:18:32	4/18-04:37:32	344	0.00969	0.0109	0.00490	60
		CC3	4/18-04:39:32	4/18-04:46:32	43	0.0214	0.0245	0.0119	60
	42	CC3	4/17-08:01:57	4/17-08:52:47	288	0.0221	0.0222	0.00254	10
		CC3	4/17-08:55:32	4/17-11:45:32	141	0.00950	0.0110	−0.00549	60
	51	CC3	4/17-12:23:32	4/17-18:48:32	155	0.00844	0.0115	−0.00779	60
		CC3	4/17-18:49:37	4/17-18:52:37	19	0.0358	0.0385	−0.0141	60
		CC3	4/17-18:54:32	4/17-20:24:32	68	0.00825	0.0179	−0.0159	60
1 POM YD	11	CC3	4/18-05:09:12	4/18-05:12:12	19	0.0346	0.0372	−0.0137	10
		CC3	4/18-05:14:32	4/18-08:33:32	180	0.0043	0.00431	0.000301	60
	42	CC3	4/18-08:43:32	4/18-13:44:32	288	0.00585	0.00585	0.0000543	60
2 POM YA	11	CC3	4/18-05:01:92	4/18-05:12:12	19	0.0345	0.0371	−0.0138	10
		CC3	4/18-05:14:32	4/18-08:33:32	18	0.00429	0.0043	0.000168	60
	42	CC3	4/18-08:43:32	4/18-14:39:32	338	0.00638	0.00638	−0.0000455	60
	51	CC3	4/18-16:42:32	4/18-17:07:32	26	0.00846	0.00853	−0.00106	60
	61	CC3	4/18-14:43:32	4/18-16:33:32	94	0.00528	0.00529	0.000183	60
2 POM YD	11	CC3	4/18-05:09:12	4/18-05:12:12	10	0.0148	0.0172	−0.00869	10
		CC3	4/18-05:14:32	4/18-08:33:32	180	0.00505	0.00505	−0.0000814	60
		CC3	4/18-22:23:32	4/18-23:21:32	56	0.00422	0.00842	0.00728	60
	42	CC3	4/18-08:43:32	4/18-14:39:32	338	0.00611	0.00627	0.00138	60
	51	CC3	4/18-16:42:32	4/18-21:11:32	75	0.00771	0.0139	−0.01[illegible]5	60
		CC3	4/18-21:12:32	4/18-22:19:32	62	0.00844	0.00952	−0.00429	60
	61	CC3	4/18-14:43:32	4/18-16:33:32	94	0.00550	0.00735	−0.00488	60
		CC3	4/18-18:13:32	4/18-21:03:32	153	0.00618	0.00760	0.00442	60
3 POM YA	11	CC3	4/18-05:09:12	4/18-05:12:12	10	0.0146	0.0163	−0.00725	10
		CC3	4/18-05:14:32	4/18-08:33:32	180	0.00475	0.00476	0.000281	60
		CC3	4/18-22:23:32	4/18-23:50:32	85	0.00480	0.00817	0.00667	60
	42	CC3	4/18-08:43:32	4/18-14:39:32	338	0.00616	0.00629	0.00125	60
	51	CC3	4/18-16:42:32	4/18-21:11:32	75	0.00781	0.0147	−0.0124	60
		CC3	4/18-21:12:32	4/18-22:19:32	62	0.00851	0.00939	−0.00397	60
	61	CC3	4/18-14:43:32	4/18-16:33:32	94	0.00539	0.00824	−0.00623	60
		CC3	4/18-18:13:32	4/18-21:03:32	153	0.00629	0.00749	0.00408	60

Table 39 (contd)

Orbit identification	DSIF sta	Data type	Beginning of data (month/day, GMT)	End of data, month/day, time (GMT)	Number of points	Standard deviation	Root mean square	Mean error	Sample rate, s
3 POM YA (contd)									
3 POM YE	11	CC3	4/18-05:09:12	4/18-05:12:12	11	0.0135	0.0144	−0.00510	10
		CC3	4/18-05:14:32	4/18-08:38:32	169	0.00566	0.00600	0.00201	60
		CC3	4/18-22:23:32	4/19-00:07:32	102	0.00530	0.00532	0.000511	60
		CC3	4/18-02:22:32	4/19-06:34:32	246	0.00522	0.00524	−0.000429	60
	42	CC3	4/18-08:43:32	4/18-14:33:32	290	0.00607	0.00625	−0.00149	60
		CC3	4/19-06:43:32	4/19-07:33:32	37	0.00593	0.0119	−0.0103	60
	61	CC3	4/18-16:42:32	4/18-16:33:32	93	0.00581	0.00637	−0.00260	60
		CC3	4/18-18:13:32	4/19-00:28:32	151	0.00629	0.00683	−0.00267	60
		CC3	4/19-00:29:32	4/19-02:11:32	94	0.00836	0.00906	0.00349	60
4 POM XF	11	CC3	4/18-05:09:12	4/18-05:12:12	12	0.0161	0.0163	−0.00222	10
		CC3	4/18-05:14:32	4/18-08:33:32	169	0.00553	0.00596	0.00223	60
		CC3	4/18-22:23:32	4/19-00:07:32	86	0.00508	0.00516	0.000887	60
		CC3	4/19-02:22:32	4/19-06:34:32	246	0.00512	0.00515	−0.000558	60
	42	CC3	4/18-08:43:32	4/18-14:33:32	275	0.00465	0.00471	−0.000785	60
		CC3	4/19-06:43:32	4/19-14:19:32	318	0.00586	0.00661	0.00305	60
	51	CC3	4/18-21:11:32	4/18-21:11:32	1	0.000	0.00684	−0.00684	60
		CC3	4/18-21:12:32	4/18-22:13:32	59	0.00711	0.0106	−0.00788	60
	61	CC3	4/18-14:43:32	4/18-16:33:32	71	0.00460	0.00554	−0.00310	60
		CC3	4/18-18:13:32	4/19-00:28:32	151	0.00624	0.00681	−0.00272	60
		CC3	4/19-00:29:32	4/19-02:11:32	71	0.00900	0.00989	0.00410	60
		CC3	4/19-14:23:32	4/19-16:18:32	50	0.00903	0.0104	−0.00517	60
4 POM YF	11	CC3	4/18-05:01:92	4/18-05:12:12	19	0.0346	0.0348	−0.00320	10
		CC3	4/18-05:14:32	4/18-08:33:32	180	0.00623	0.00624	0.000412	60
		CC3	4/18-22:23:32	4/19-00:13:32	92	0.00519	0.00528	0.000983	60
		CC3	4/19-02:22:32	4/19-06:34:32	242	0.00500	0.00573	−0.00281	60
	42	CC3	4/18-08:43:32	4/18-14:33:32	287	0.00442	0.00444	−0.000419	60
		CC3	4/18-06:43:32	4/19-14:19:32	329	0.00512	0.00549	0.00196	60
	61	CC3	4/18-21:11:32	4/18-16:33:32	72	0.00453	0.00488	0.00182	60
		CC3	4/18-18:13:32	4/19-00:28:32	155	0.00586	0.00586	0.000197	60
		CC3	4/19-00:29:32	4/19-02:13:32	67	0.00829	0.00833	−0.000813	60
		CC3	4/19-14:23:32	4/19-16:28:32	61	0.00981	0.00995	−0.00165	60
5 POM XD	61	CC3	4/19-18:49:32	4/19-20:32:32	87	0.00625	0.00625	0.0000884	60
FINAL YA	61	CC3	4/19-18:21:32	4/19-21:52:32	162	0.00766	0.00766	0.000190	60
FINAL XA	61	CC3	4/19-18:21:32	4/19-21:57:32	151	0.00779	0.00779	0.000125	60
FINAL YB	61	CC3	4/19-18:21:32	4/19-22:09:32	173	0.00779	0.00779	0.0000734	60
FINAL XB	11	CC3	4/19-22:18:32	4/19-22:25:32	8	0.00312	0.00990	0.00940	60
	61	CC3	4/19-18:49:32	4/19-22:11:32	157	0.00949	0.00949	−0.000304	60
FINAL YC	11	CC3	4/19-22:18:32	4/19-22:26:32	9	0.00384	0.00952	0.00871	60
	61	CC3	4/19-18:21:32	4/19-22:12:32	176	0.00896	0.00896	−0.000153	60
FINAL XC	11	CC3	4/19-22:18:32	4/19-22:40:32	23	0.0127	0.0128	0.00202	60
FINAL YD	11	CC3	4/19-22:18:32	4/19-22:45:32	28	0.0111	0.0111	0.00142	60
	61	CC3	4/19-18:21:32	4/19-22:12:32	176	0.00949	0.00949	−0.000221	60
FINAL YD	11	CC3	4/19-22:18:32	4/19-22:50:32	33	0.00797	0.00811	0.00154	60

Table 39 (contd)

Orbit identification	DSIF sta	Data type	Beginning of data (month/day, GMT)	End of data, month/day, time (GMT)	Number of points	Standard deviation	Root mean square	Mean error	Sample rate, s
FINAL YE	11	CC3	4/19-22:18:32	4/19-22:56:32	39	0.00349	0.00413	0.00221	60
	61	CC3	4/19-18:21:32	4/19-22:12:32	176	0.0111	0.0111	−0.000298	60
1 POM YA	42	CC3	4/18-08:43:32	4/18-09:59:32	76	0.00534	0.00534	0.000077	60
	11	CC3	4/18-05:09:12	4/18-05:12:12	19	0.0346	0.0362	−0.0105	10
		CC3	4/18-05:14:32	4/18-08:33:32	182	0.00428	0.00429	0.000278	60
5 POM YA	11	CC3	4/18-05:09:12	4/18-05:12:12	19	0.0346	0.0346	−0.00204	10
		CC3	4/18-05:14:32	4/18-08:33:32	180	0.00617	0.00649	0.00200	60
		CC3	4/18-22:23:32	4/19-00:13:32	92	0.00508	0.00508	0.00000398	60
		CC3	4/19-02:22:32	4/19-09:38:32	272	0.00512	0.00605	−0.00322	60
	42	CC3	4/18-08:43:32	4/18-14:33:32	287	0.00438	0.00461	−0.00144	60
		CC3	4/19-06:43:32	4/19-14:19:32	329	0.00525	0.00649	0.00381	60
	61	CC3	4/18-21:11:32	4/18-16:33:32	72	0.00455	0.00490	0.00181	60
		CC3	4/18-18:13:32	4/19-00:28:32	155	0.00582	0.00584	−0.000438	60
		CC3	4/19-00:29:32	4/19-02:13:32	67	0.00830	0.00957	−0.00477	60
		CC3	4/19-14:23:32	4/19-17:54:32	140	0.00990	0.00993	−0.000746	60
5 POM YD	11	CC3	4/18-05:09:12	4/18-05:12:12	19	0.0345	0.0346	0.00227	10
		CC3	4/18-05:14:32	4/18-08:33:32	180	0.00618	0.00882	0.00629	60
		CC3	4/18-22:23:32	4/19-00:13:32	92	0.00468	0.00729	−0.00559	60
		CC3	4/19-02:22:32	4/19-09:38:32	272	0.00565	0.00700	−0.00412	60
	42	CC3	4/18-08:43:32	4/18-14:33:32	287	0.00442	0.00544	−0.00317	60
		CC3	4/19-06:43:32	4/19-14:19:32	329	0.00647	0.00791	0.00454	60
	61	CC3	4/18-21:11:32	4/18-16:33:32	72	0.00456	0.00462	−0.000744	60
		CC3	4/18-18:13:32	4/19-00:28:32	155	0.00583	0.00604	−0.00156	60
		CC3	4/19-00:29:32	4/19-02:13:32	67	0.00838	0.0131	−0.0101	60
		CC3	4/19-14:23:32	4/19-20:34:32	236	0.0104	0.0109	0.00308	60
POST 1	11	CC3	4/18-05:09:12	4/18-05:12:12	19	0.0344	0.0355	0.0085	10
		CC3	4/18-05:14:32	4/18-08:38:32	169	0.0072	0.0117	0.0092	60
		CC3	4/18-22:23:32	4/18-00:07:32	86	0.0049	0.0049	0.0003	60
		CC3	4/19-02:22:32	4/19-08:43:32	247	0.0050	0.0075	−0.0056	60
	42	CC3	4/18-08:43:32	4/18-14:33:32	275	0.0051	0.0062	−0.0035	60
		CC3	4/19-06:43:32	4/19-14:19:32	318	0.0052	0.0061	0.0032	60
	51	CC3	4/19-21:11:32	4/18-21:11:32	1	0.0000	0.0010	0.0010	60
		CC3	4/18-21:12:32	4/19-18:44:32	100	0.0069	0.0069	0.0004	60
	61	CC3	4/18-14:43:32	4/18-16:33:32	71	0.0046	0.0116	−0.0106	60
		CC3	4/18-18:13:32	4/19-00:28:32	151	0.0068	0.0095	−0.0067	60
		CC3	4/19-00:29:32	4/19-02:11:32	71	0.0090	0.0090	−0.0008	60
		CC3	4/19-14:23:32	4/19-22:11:32	288	0.0141	0.0151	0.0055	60

In general, DSIF station operations during the *Surveyor III* mission were effectively implemented. This is best judged by the fact that the DSN was able to provide such high-quality data to the ODG that they were able to meet all orbital accuracy requirements for such events as the midcourse maneuver, retro motor ignition backup, etc. From the time of first acquisition of the spacecraft over DSS 42 until the time of lunar touchdown, the spacecraft was almost continuously in two-way lock; with one exception, station transfers were rapid and efficiently executed. The exception occurred on the first transfer from DSS 62 to DSS 51; the transfer was scheduled at 17:00:00 on April 17. Johannesburg DSS 51 lost lock at the time of transfer and was not able to reacquire the uplink until 17:17:00 because: (1) there was a delay in forwarding instructions from JPL to DSS 51, (2) the frequency search used by DSS 51 was too small, and (3) the frequency tuning rate used by DSS 51 was too slow. The only significant loss of prime two-way doppler data during the *Surveyor III* mission occurred during the first pass over DSS 61. At 14:32:02, on April 17, DSS 61 began taking two-way doppler data, and approximately 15 min later the results of the data monitor program indicated excessive noise in the DSS 61 data. The problem was traced to a dropped 8 bit in the least significant digit of the doppler counter. A transfer to DSS 51 could not be scheduled until 17:00:00 because of Canopus acquisition. At 17:33:02, DSS 61 stopped three-way tracking to repair the counter. Three-way tracking was resumed at 18:36:31. Investigation disclosed that bits were being dropped from the fifth significant digit in the doppler counter and DSS 61 stopped tracking from 19:24:32 to 19:51:22 to again effect repairs on the doppler counter. After 19:51:22, no further problems were encountered with the DSS 61 doppler counter. The effect on the mission of the loss of approximately 2 h of two-way doppler data was negligible.

The pre-midcourse phase is described in the following paragraphs.

Angular tracking. In general, doppler data yield far greater accuracy in the determination of a spacecraft orbit than do angular data and are, therefore, used almost exclusively in the orbit determination process during most of the mission. The one exception is the launch phase, when few doppler data are available and a quick determination of the orbit necessitates the use of both doppler and angle data. During the *Surveyor III* mission, angle data from DSS 42, DSS 61, and DSS 51 were used in the orbit determination program during the pre-midcourse phase of the mission. To improve the quality of the angular data to be used in the orbit determination program, they are first corrected for antenna optical pointing error (OPE). The OPE is determined by having the DSS optically track several stars at the expected, mission-dependent, spacecraft declinations. A polynomial curve fit is then made to the differences between the refraction-corrected ephemeris values of the star positions and the observed values as read from the antenna angle encoders. The correction coefficients used in the *Surveyor III* mission-inflight orbit computations can be seen in Table 40.

Experience gained in past missions has shown that the OPE correction coefficients do not remove all systematic pointing errors. This is reasonable since the RF and optical axes of the antenna are not necessarily the same;

Table 40. Antenna correction coefficients for DSS 42[a]

Coefficient	Correction	Coefficient	Correction
A_{00}	1.241637739E-02	B_{00}	7.580054461E-02
A_{01}	2.788428530E-04	B_{01}	7.158720897E-04
A_{02}	1.107933456E-06	B_{02}	1.265069671E-05
A_{03}	−6.075030236E-09	B_{03}	−4.082247376E-07
A_{10}	−3.906063323E-04	B_{10}	−3.114752889E-05
A_{11}	5.944488677E-06	B_{11}	−4.326730631E-06
A_{12}	−9.943308762E-08	B_{12}	−8.348400771E-07
A_{13}	7.454471863E-10	B_{13}	1.769479559E-08
A_{20}	2.211845590E-06	B_{20}	−7.768849965E-06
A_{21}	1.058964062E-07	B_{21}	−1.697554984E-07
A_{22}	−7.393294554E-10	B_{22}	−3.111461041E-09
A_{23}	−1.914168005E-10	B_{23}	3.246078218E-10
A_{30}	2.123897135E-08	B_{30}	−3.018066365E-08
A_{31}	2.436833188E-09	B_{31}	4.904492523E-10
A_{32}	7.920282695E-11	B_{32}	2.056612252E-10
A_{33}	1.055377395E-12	B_{33}	−3.812621648E-12
A_{00}	−2.823094562E-02	B_{00}	1.529098827E-02
A_{01}	5.353777033E-05	B_{01}	3.410829831E-04
A_{02}	−3.082597437E-05	B_{02}	−4.336071801E-06
A_{03}	−6.626461141E-07	B_{03}	6.109815447E-07
A_{10}	−3.171398689E-04	B_{10}	−1.559484352E-04
A_{11}	9.542137245E-06	B_{11}	−2.032267916E-06
A_{12}	−3.367726933E-07	B_{12}	5.779247847E-08
A_{13}	−8.201321554E-09	B_{13}	−2.831355530E-10
A_{20}	1.589100967E-06	B_{20}	−1.186130483E-05
A_{21}	1.835756063E-07	B_{21}	−5.239010283E-08
A_{22}	3.851291638E-09	B_{22}	−2.152496155E-10
A_{23}	−8.191144217E-11	B_{23}	−4.436567279E-11
A_{30}	4.599327736E-08	B_{30}	−2.298149026E-08
A_{31}	3.344301616E-09	B_{31}	8.193320409E-10
A_{32}	1.386713245E-10	B_{32}	−1.910069905E-11
A_{33}	1.816077278E-12	B_{33}	−7.276751867E-13

[a]The useful range of these functions is for elevations >15 deg; Dec between 30 deg N and 30 deg S inclusive.

i.e., the RF axis is a function of the position of the quadripod feed, whereas the optical axis is not. Thus, if there is a quadripod deflection (due to thermal effect or gravitational loading) at some given instant of time, the optical error and the RF error would not be the same. Furthermore, the optical refraction and the RF refraction are not the same due to the difference in respective wavelengths. In addition to these effects, the RF pointing error is also a function of feed alignment, received signal-to-noise ratio, and received polarization angle, since the antenna null pattern does not have the same slope at all polarization angles.

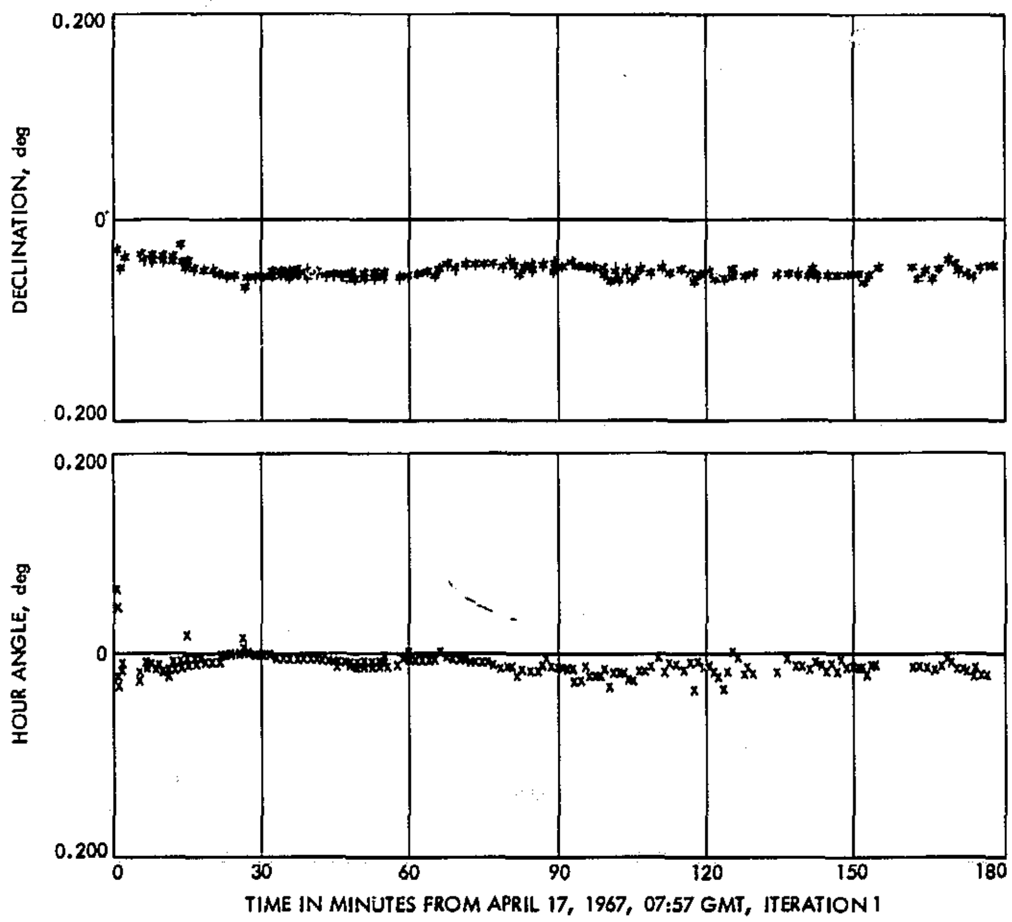


Fig. 52. DSS 42 angular residuals, pass 1, 07 h 57 min

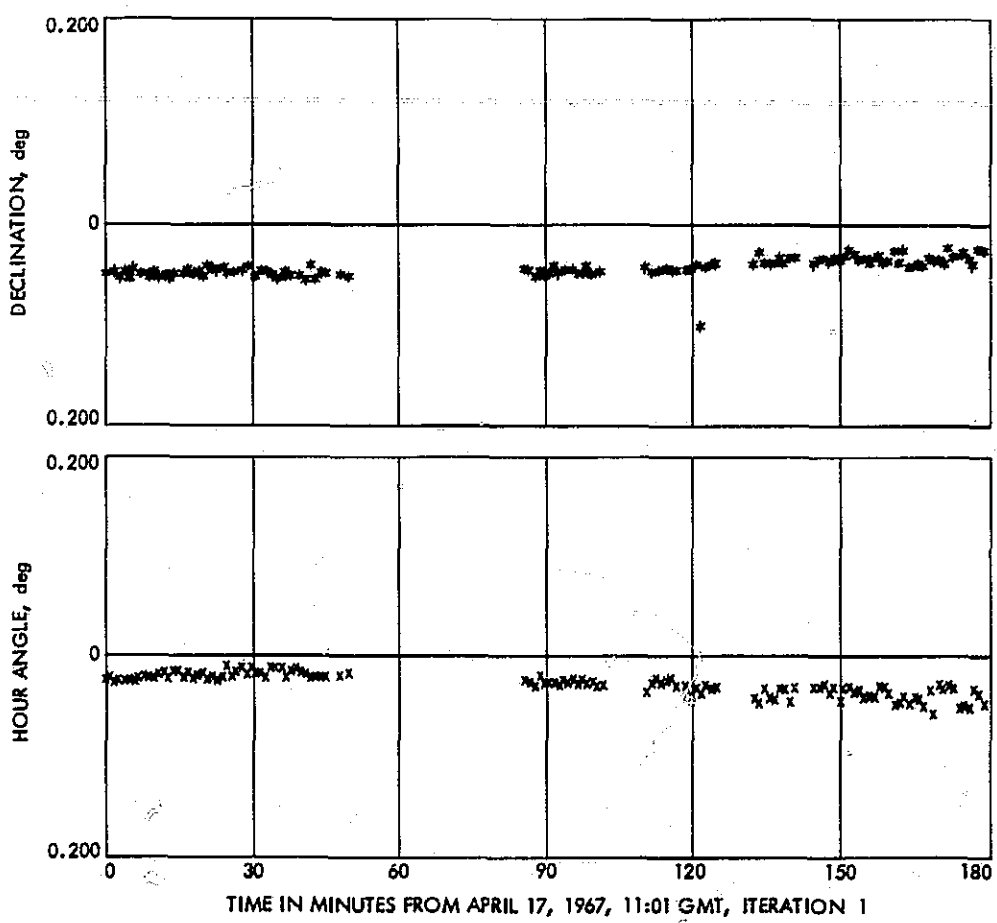


Fig. 53. DSS 42 angular residuals, pass 1, 11 h 01 min

Since DSS 42 was the initial acquisition station, the angular data taken by it were the most important angular data for use in the early orbits. These data, when fit through the final postflight orbit, show a bias of −0.015 deg in hour angle and a bias of −0.050 deg in declination. These biases are quite consistent with the results of a study of the present DSS 42 correction coefficients made by the ODG. The results indicated at the time that the DSS 42 correction coefficients worked reasonably well in hour angle but were less satisfactory in declination. DSS 42 angular residuals are seen in Figs. 52 and 53.

First-pass angular data from DSS 51, when fit through the final post flight orbit, show biases of +0.040 deg in hour angle and −0.025 deg in declination. These values are in reasonable agreement with the ODG study of DSS 51 correction coefficients and also correlate well with past experience on the *Surveyor* Project. For instance, the first pass over DSS 51 during the A/C-9 mission indicated a bias of +0.030 deg in hour angle and −0.030 deg in declination. The DSS 51 angular residuals are presented in Figs. 54–57.

Angular data from DSS 61, for which no correction coefficients exist, showed a bias of −0.020 deg in hour angle and −0.015 deg in declination; these data compare favorably with the data from the corrected stations (DSS 51 and 42). The DSS 61 angular data also show a marked improvement over similar data taken during *Surveyor I*, when the corresponding residuals were −0.030 deg in hour angle and −0.050 deg in declination, and the hour angle data exhibited excessively high, short-term noise. First-pass angular residuals for DSS 61 may be viewed in Figs. 58–61.

The DSS 72 tracked the *Surveyor III* spacecraft during its first pass, and postflight analysis indicates a bias of −0.070 deg in azimuth and −0.165 deg in elevation. DSS 72 angular data are also uncorrected, but these values, besides being poor, are significantly worse than those resulting from angular data taken during previous *Surveyor* missions at DSS 72 (for instance, the A/C-9 and *Surveyor II* average biases of +0.043 deg in azimuth and −0.057 deg in elevation). DSS 72 angular residuals are presented in Figs. 62–64. Finally, it should be noted that efforts are under way to use RF sources (*Surveyor*, posttouchdown) to generate new, and, hopefully, more accurate, correction coefficients.

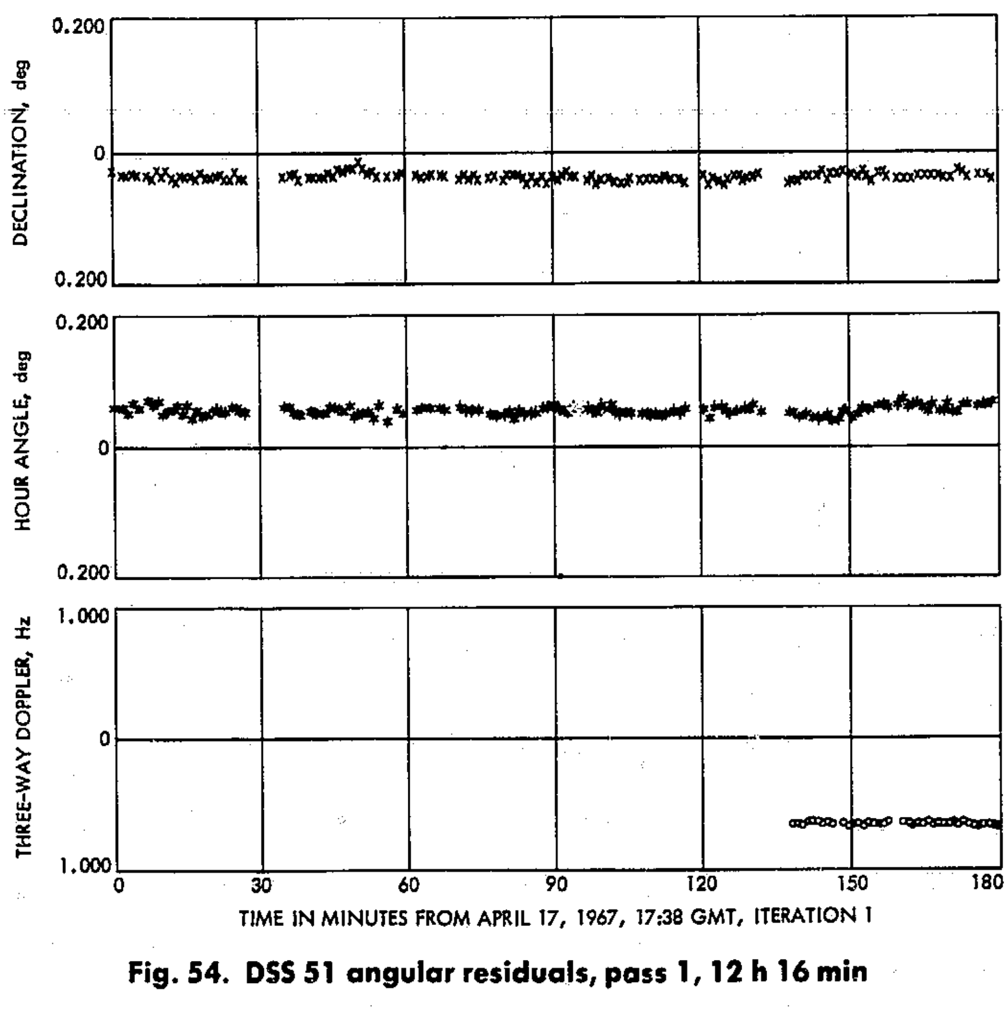


Fig. 54. DSS 51 angular residuals, pass 1, 12 h 16 min

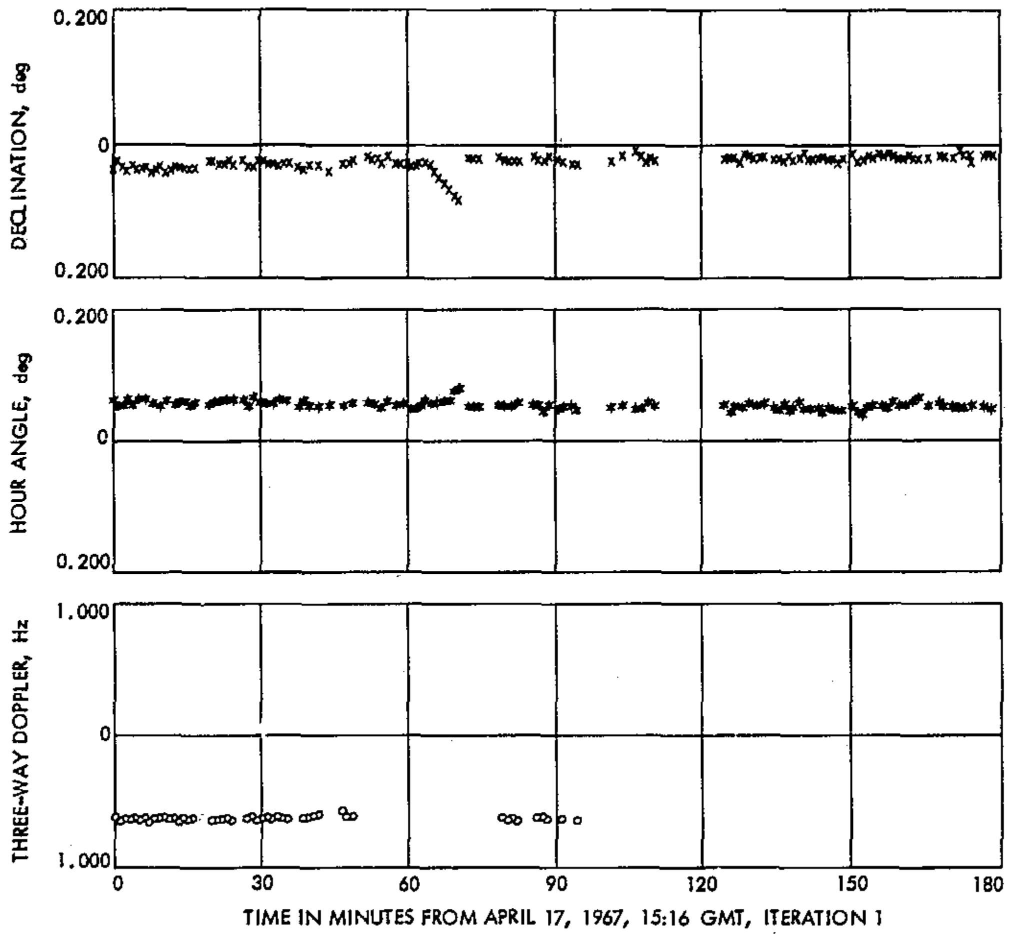


Fig. 55. DSS 51 angular residuals, pass 1, 15 h 16 min

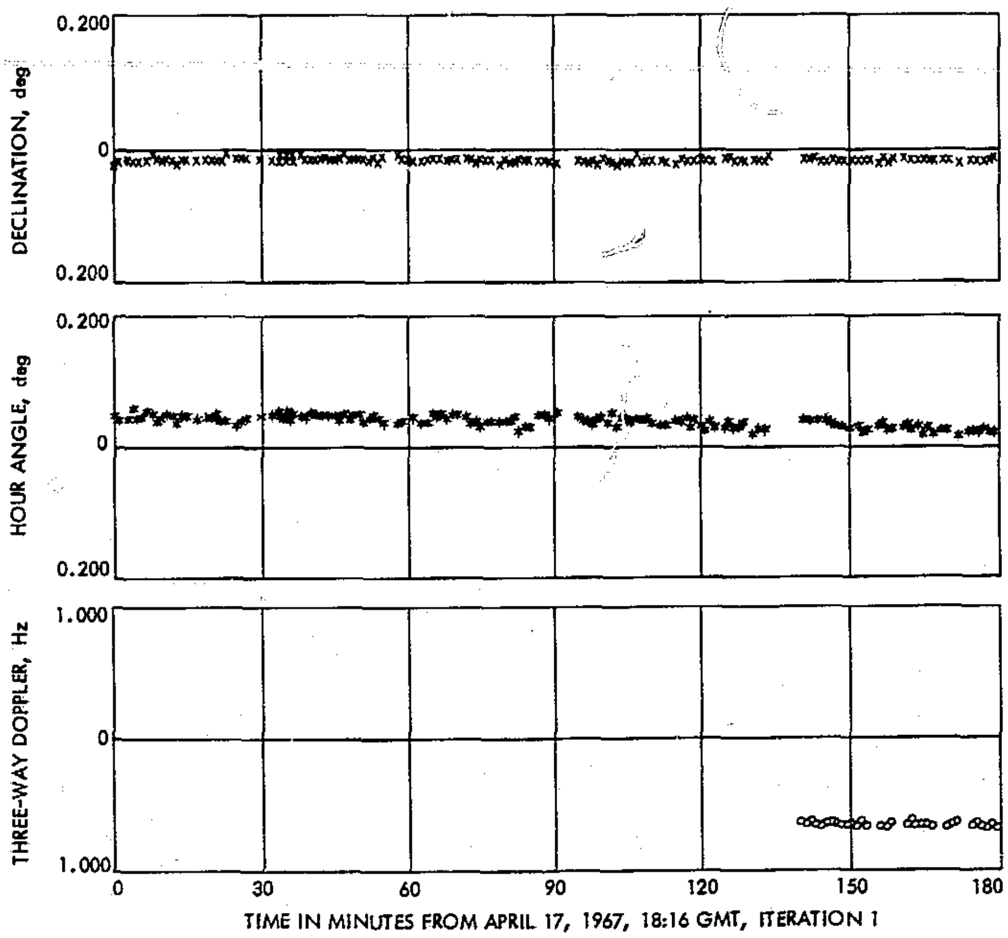


Fig. 56. DSS 51 angular residuals, pass 1, 18 h 16 min

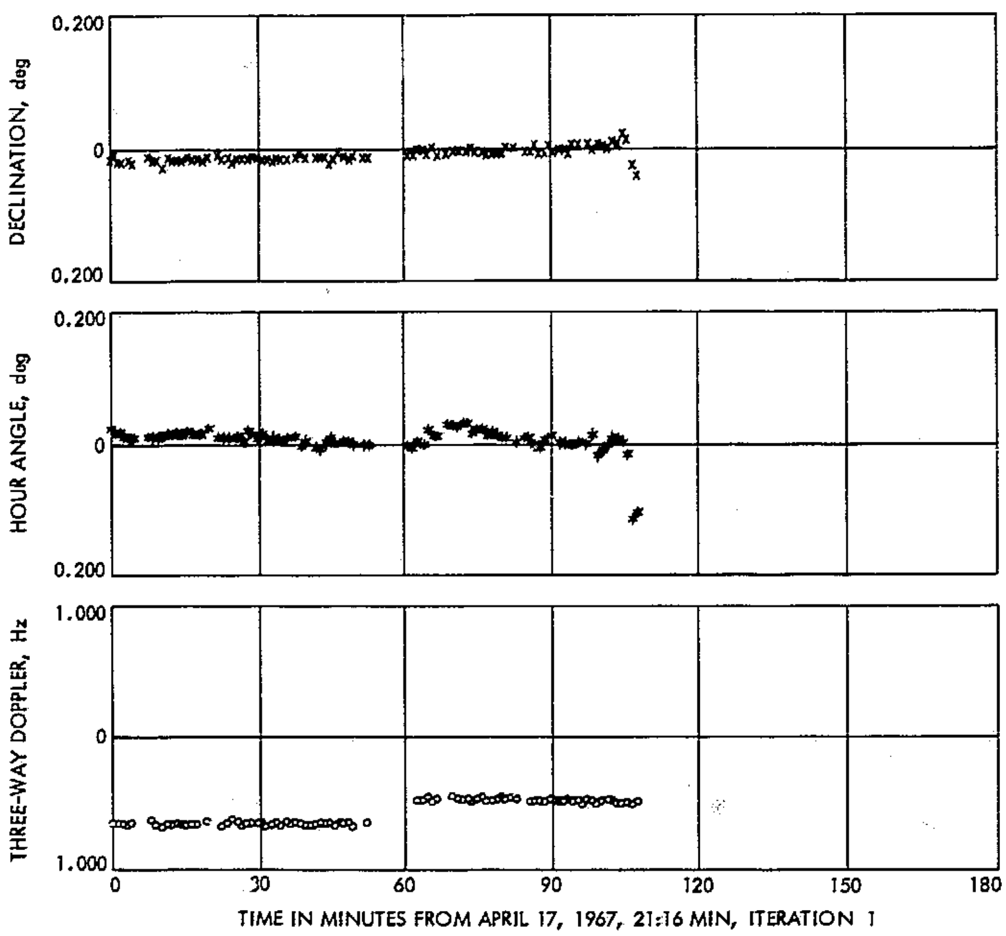


Fig. 57. DSS 51 angular residuals, pass 1, 21 h 16 min

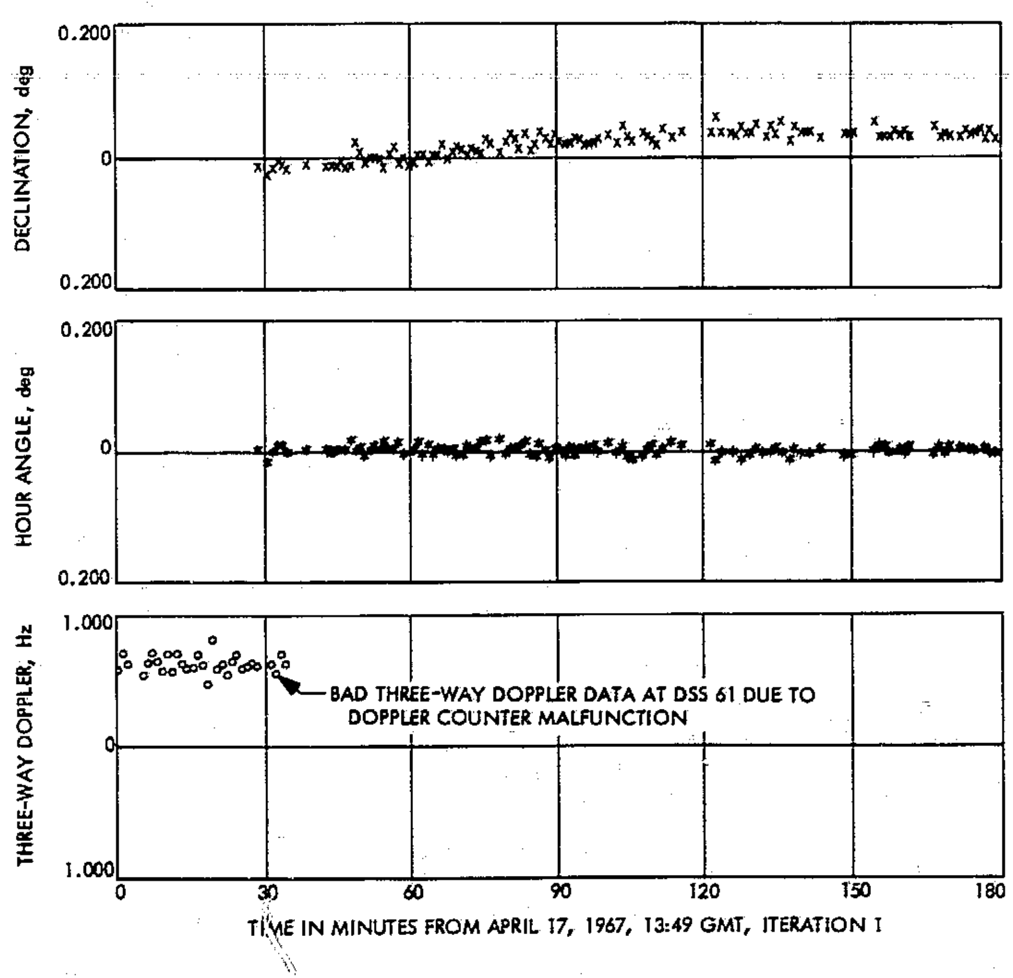


Fig. 58. DSS 61, pass 1, 13 h 49 min

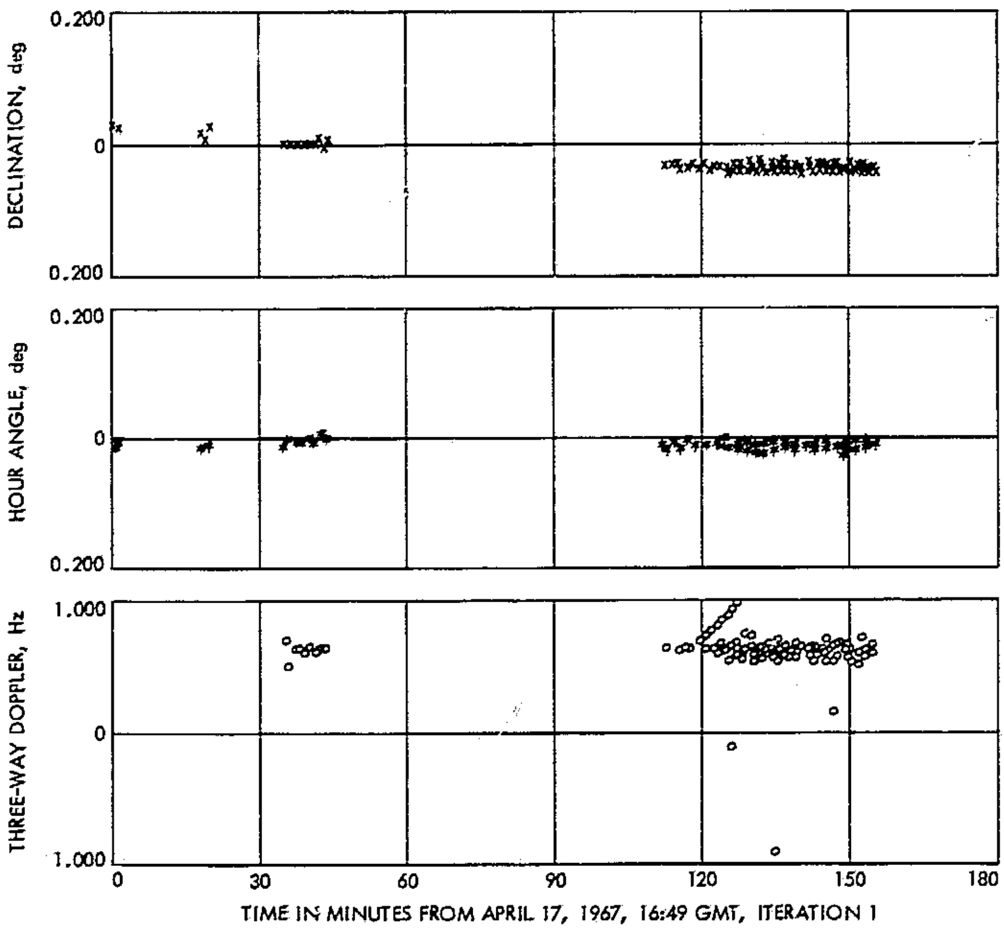


Fig. 59. DSS 61, pass 1, 16 h 49 min

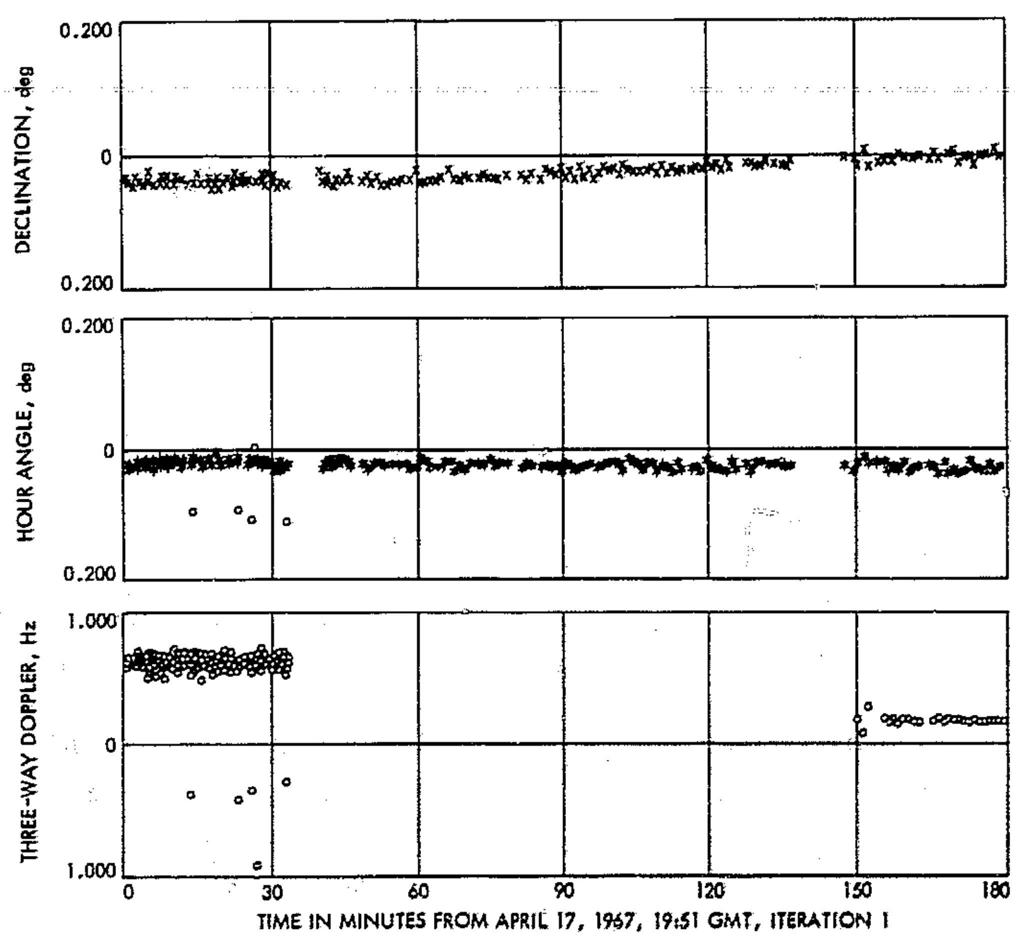


Fig. 60. DSS 61, pass 1, 19 h 51 min

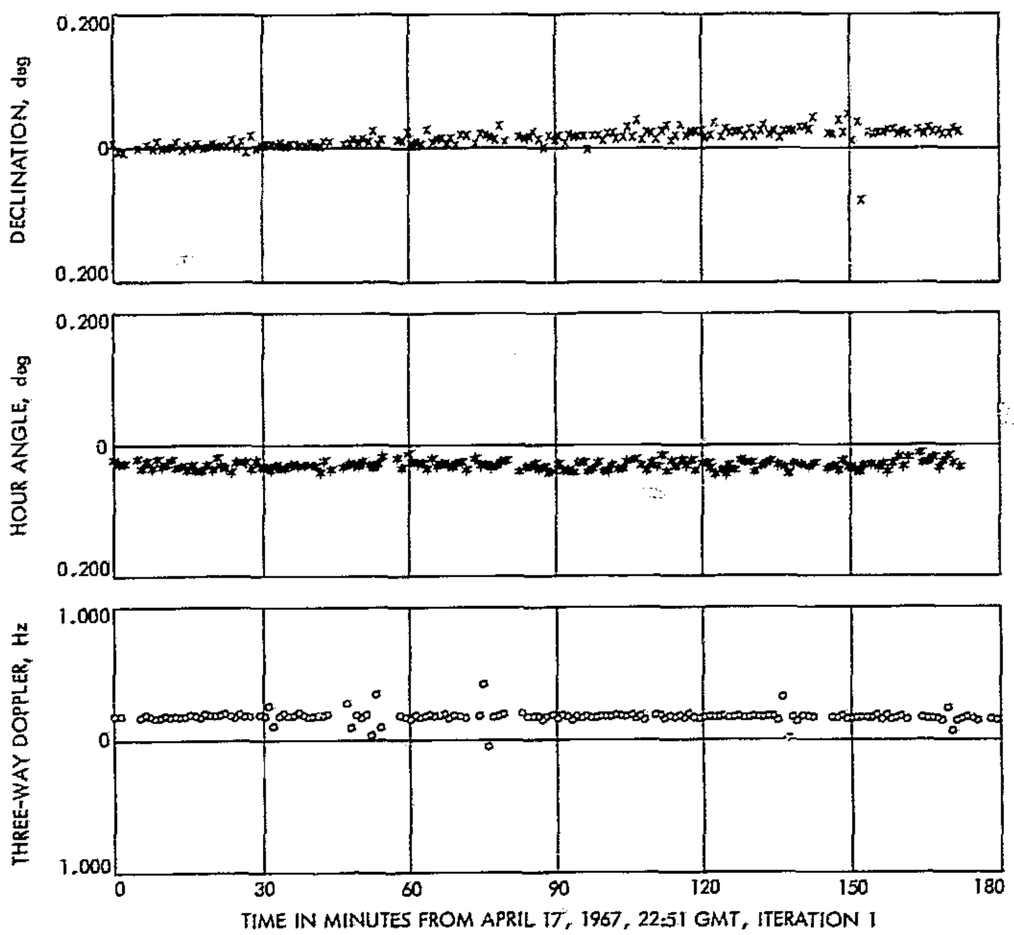


Fig. 61. DSS 61 angular residuals, pass 1, 22 h 51 min

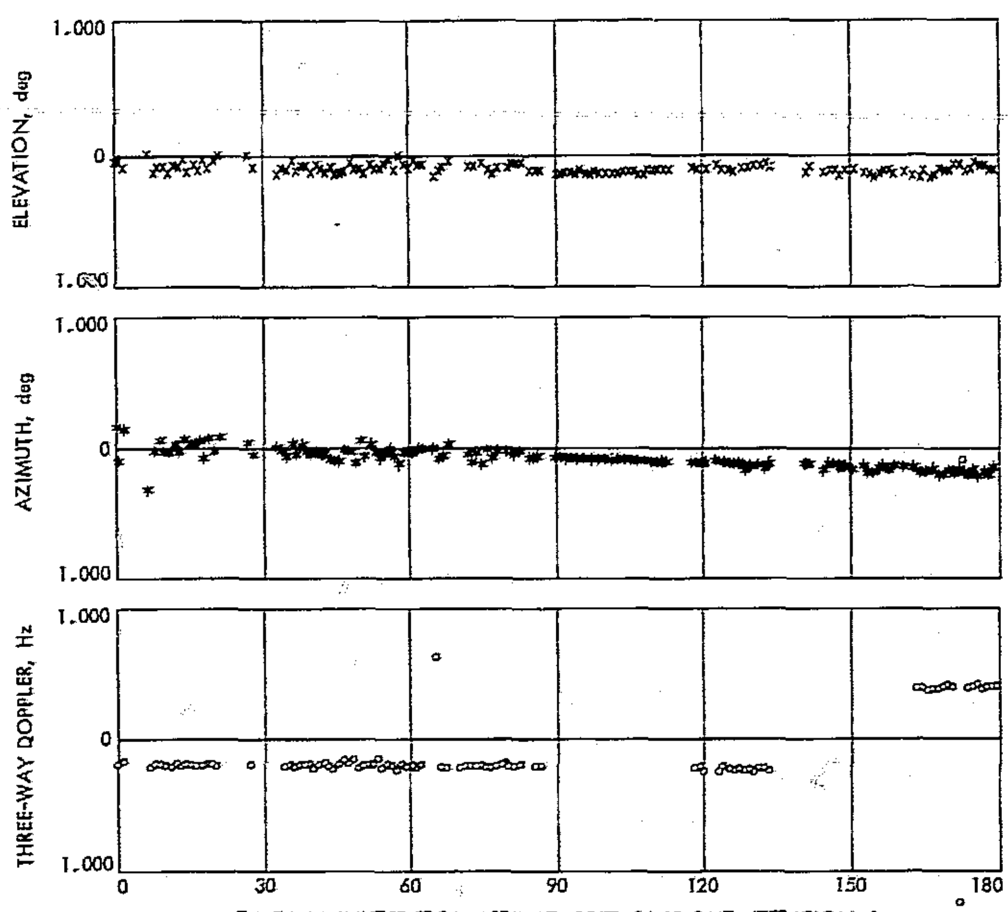


Fig. 62. DSS 72 angular residuals, pass 1, 14 h 38 min

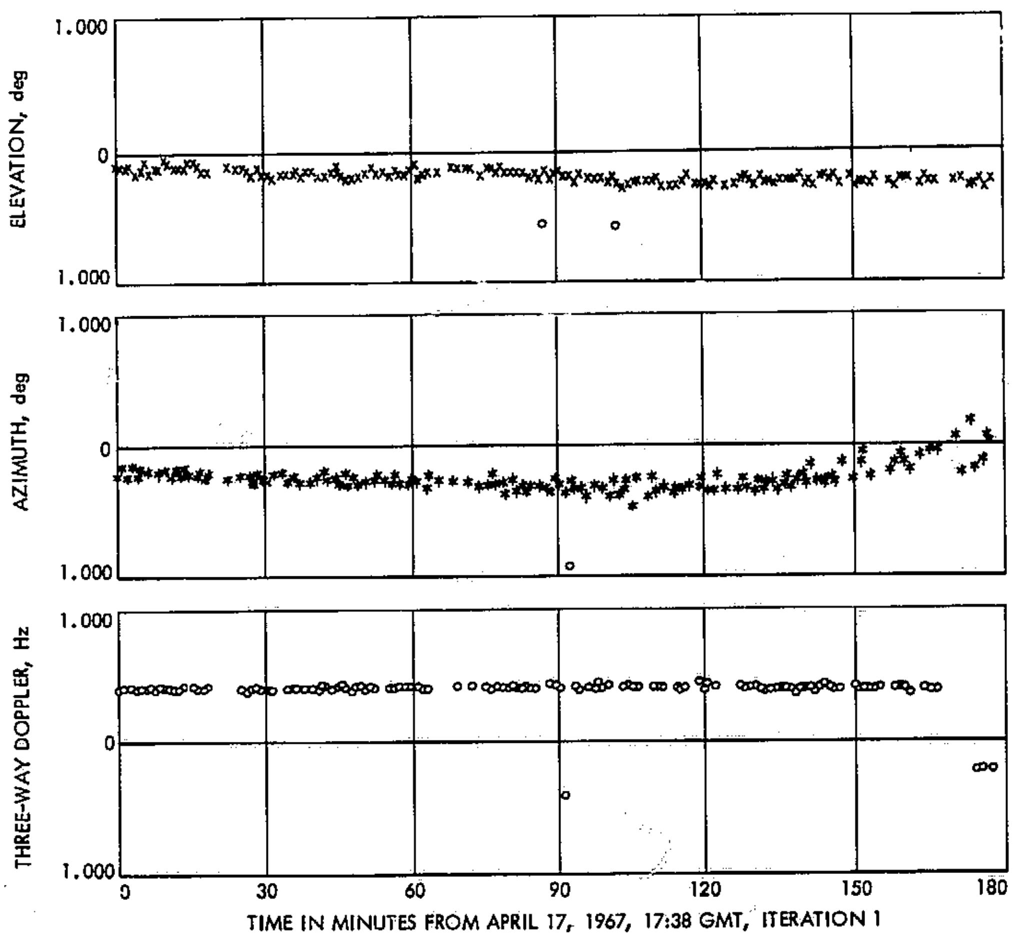


Fig. 63. DSS 72 angular residuals, pass 1, 17 h 38 min

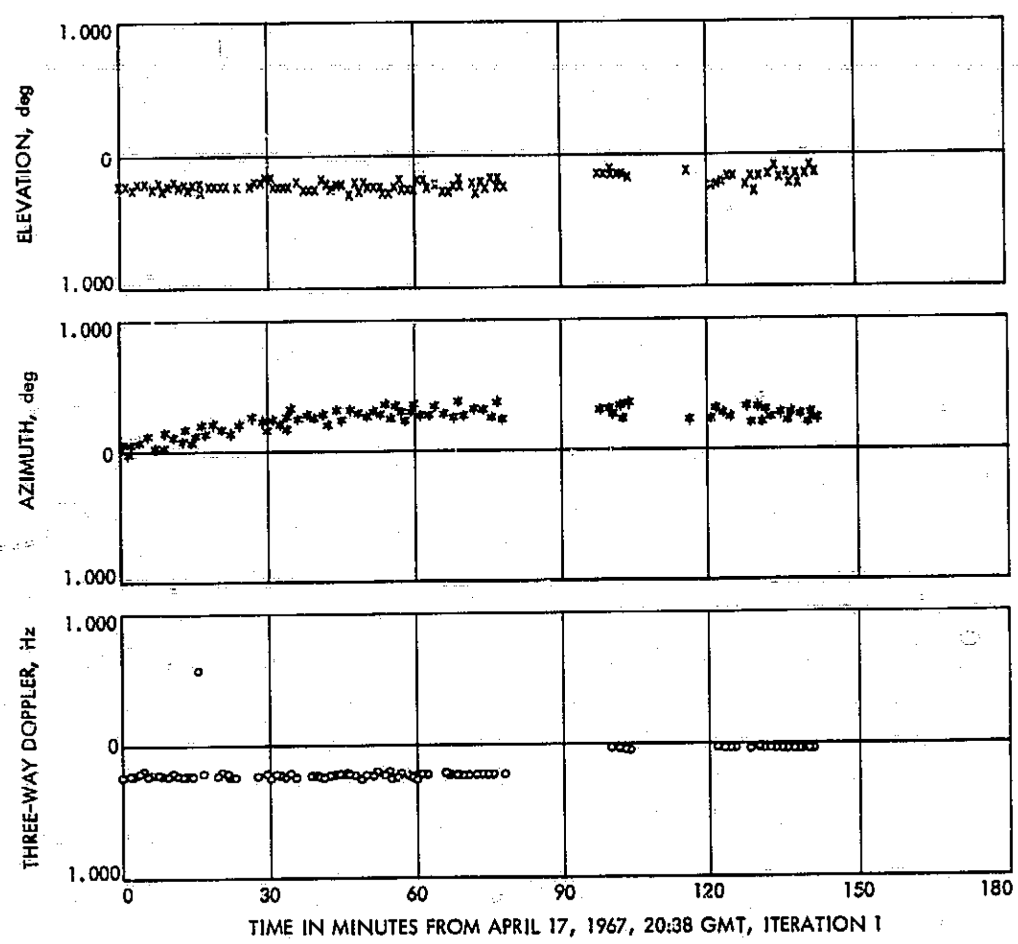


Fig. 64. DSS 72 angular residuals, pass 1, 20 h 38 min

Doppler tracking. DSS 42, the first prime station to see the spacecraft after injection, began taking good two-way, 10-s-count doppler data at 08:01:52 on April 17, 1967. The switch to 60-s-count doppler was made at 08:54:02, and DSS 42 stayed in this configuration until 12:15:02, when a transfer of the spacecraft was made to DSS 51. The early data from DSS 42 were nominal, showing a standard deviation of 0.020 Hz for the 10-s-count data and 0.010 Hz for the 60-s-count data; very few data were lost. The doppler residuals for this initial pass over DSS 42 may be seen in Figs. 65 and 66. DSS 51 was in good data, two-way mode at 12:22:02 and continued in this configuration until 14:30:02, when the transmitting assignment was transferred to DSS 61. The doppler data taken by DSS 51 during this period were, like previous DSS 42 data, nominal, showing a standard deviation of 0.009 Hz for 60-s-count data. The DSS 51 doppler data taken during this period, and later during its first pass, can be seen in Figs. 67–69. As was already discussed, a malfunction of the DSS 61 doppler counter caused the two-way doppler data from 14:30:02 to 17:00:00 to be bad. These data can be seen in Fig. 70. After the problem was substantially cleared, DSS 61 took two-way doppler from 20:25:02 to 22:10:02; these data are shown in Fig. 71. As can be seen, the higher-than-normal incidence of bad data during this period indicates that perhaps the problem was still not entirely eliminated. DSS 11 began taking good two-way doppler at 22:20:02 and continued to do so until the time of the midcourse maneuver at 05:00:00 on April 18. The data from DSS 11 was quite good, having a standard deviation of 0.009 Hz, and can be seen in Figs. 72–75.

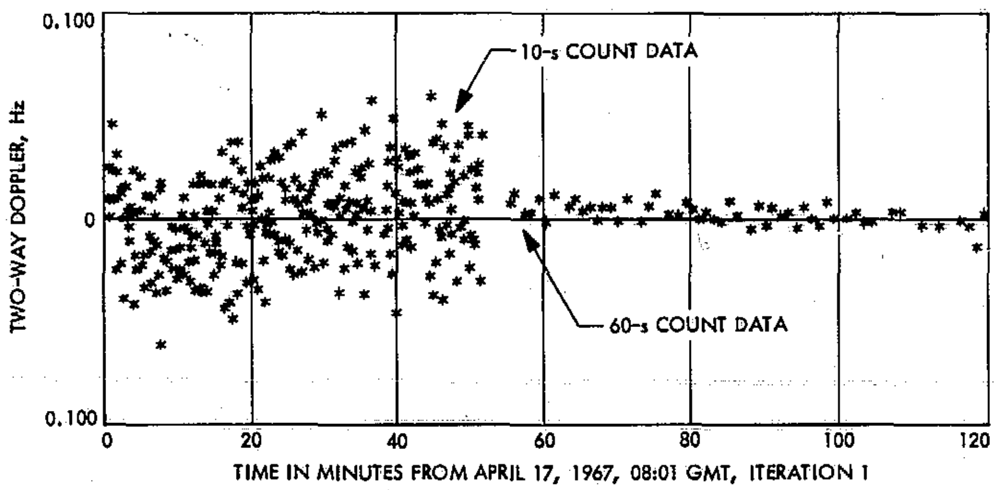


Fig. 65. DSS 42 doppler residuals, pass 1, 08 h 01 min

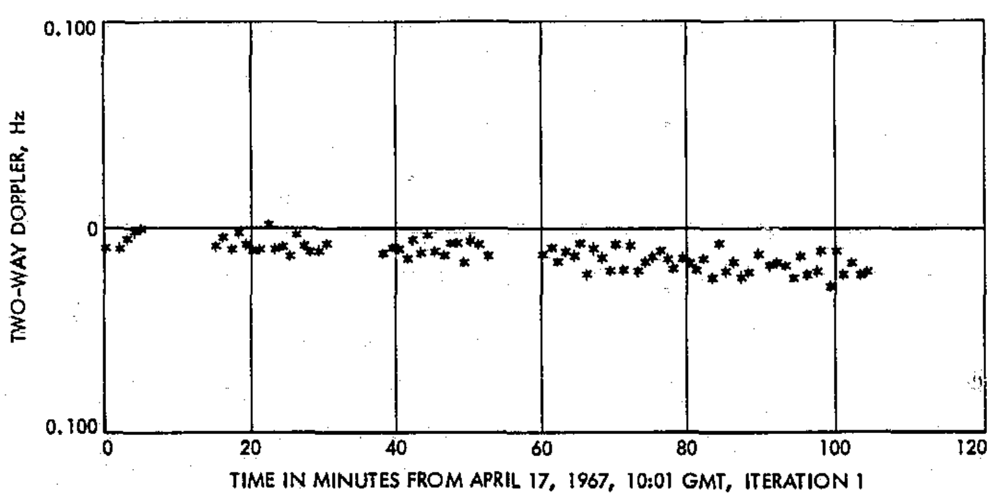


Fig. 66. DSS 42 doppler residuals, pass 1, 10 h 01 min

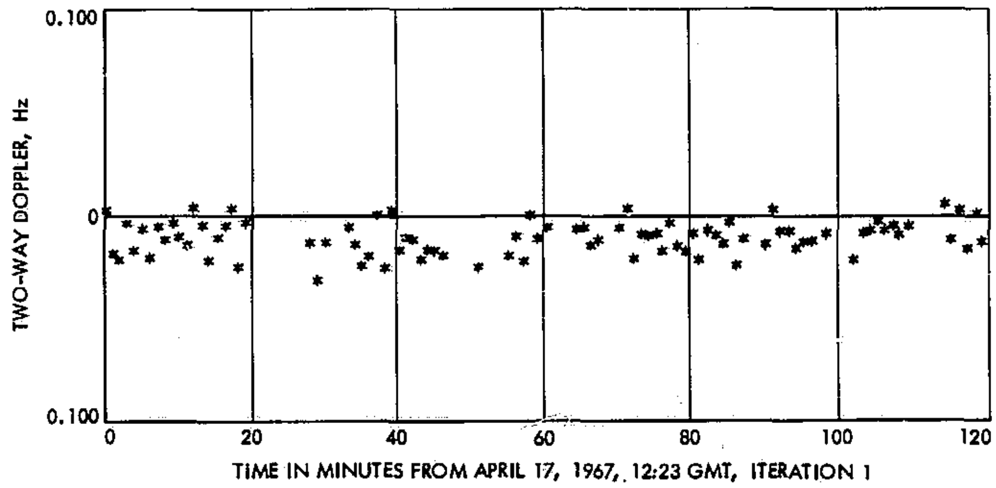


Fig. 67. DSS 51 doppler residuals, pass 1, 12 h 23 min

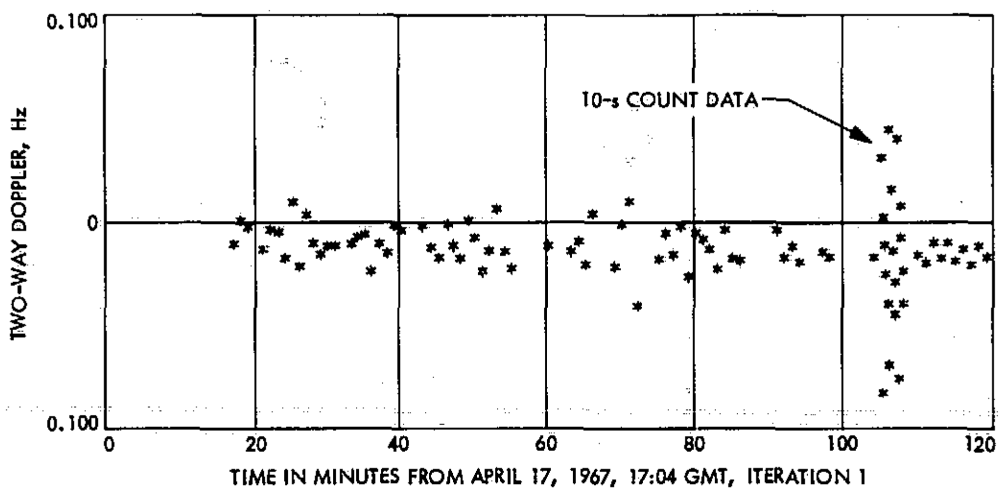


Fig. 68. DSS 51 doppler residuals, pass 1, 17 h 04 min

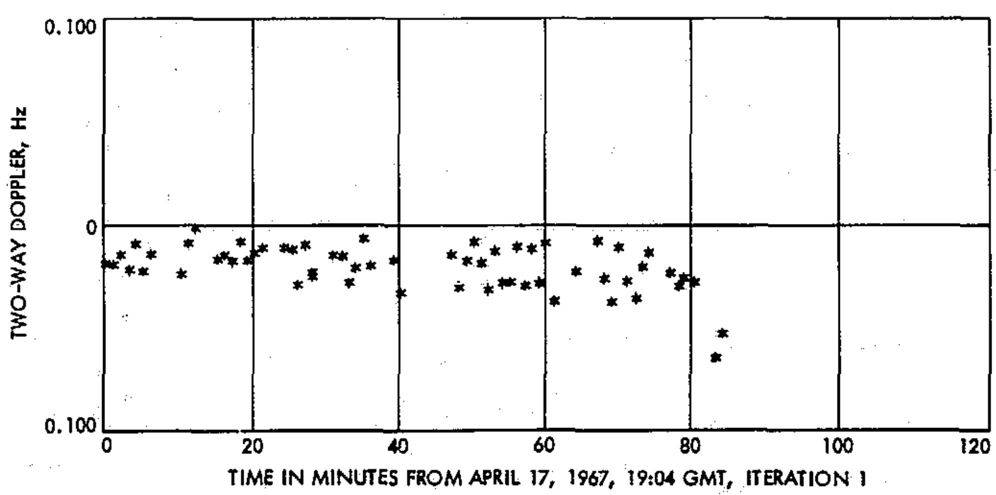


Fig. 69. DSS 51 doppler residuals, pass 1, 19 h 04 min

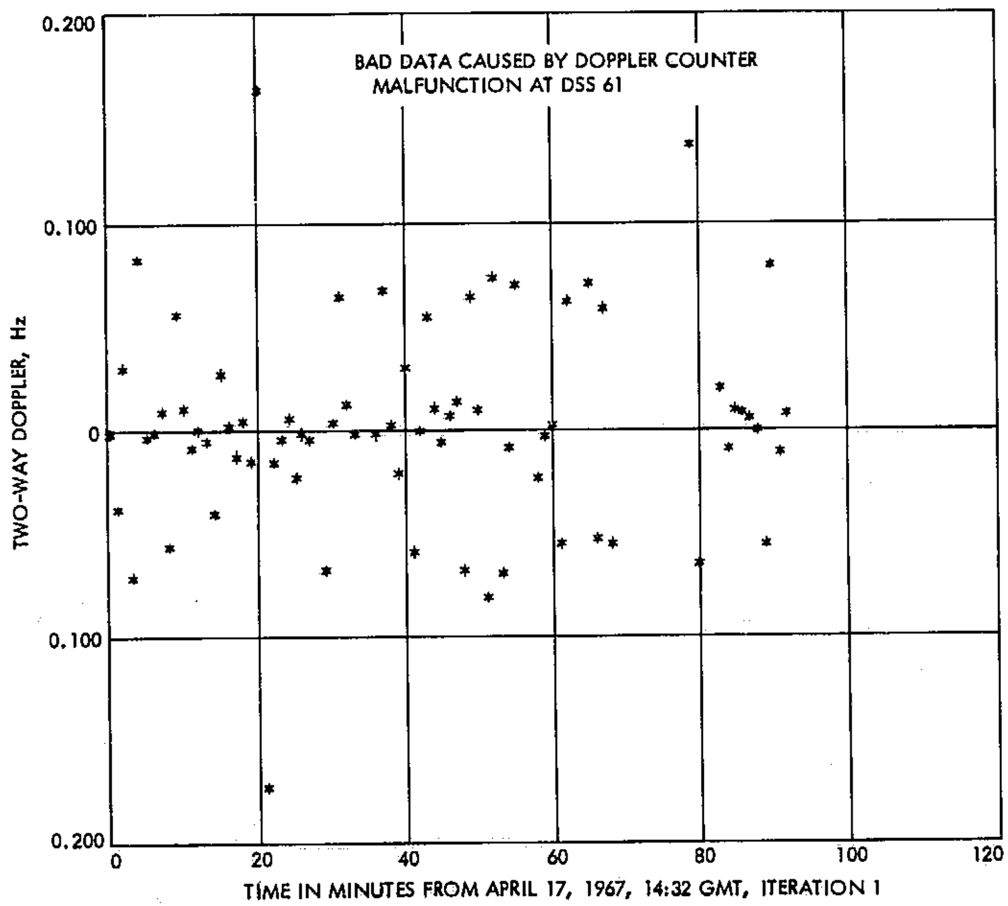


Fig. 70. DSS 61 doppler (malfunction) residuals, pass 1

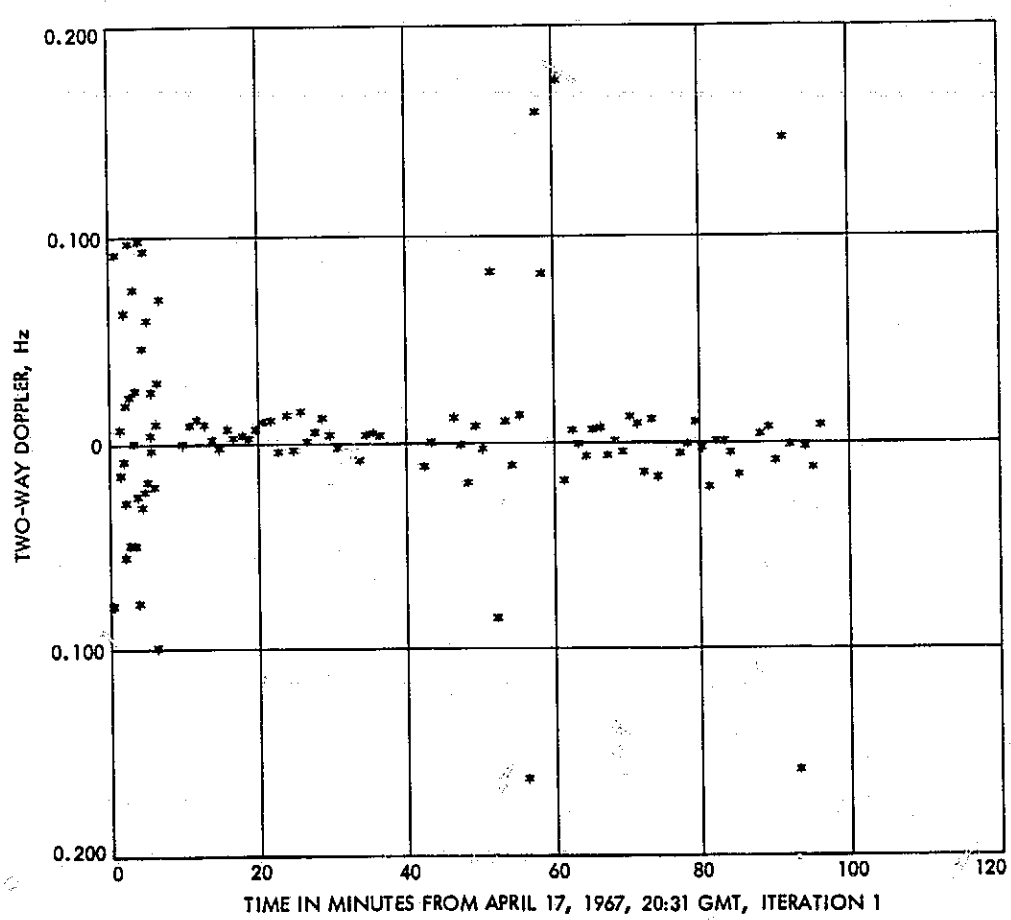


Fig. 71. DSS 61 doppler residuals, pass 1

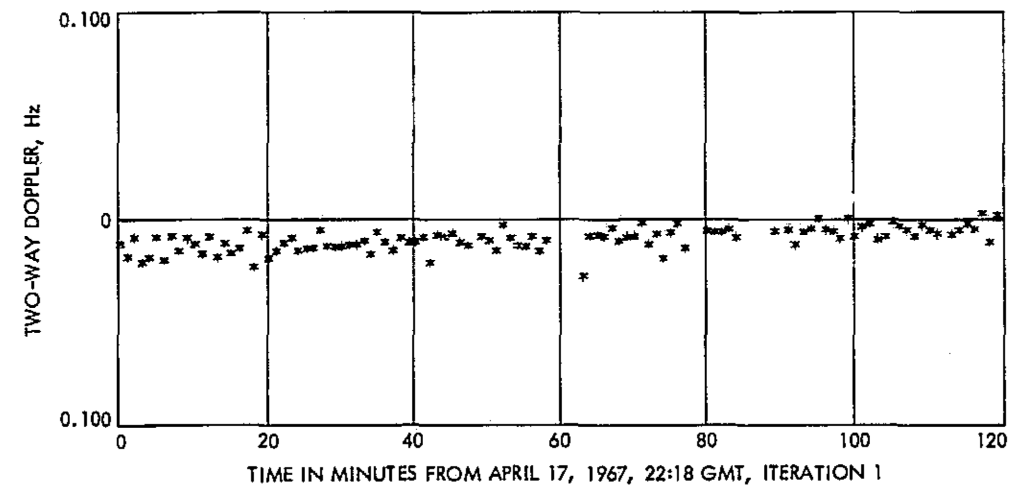


Fig. 72. DSS 11 doppler residuals, pass 1, 22 h 18 min

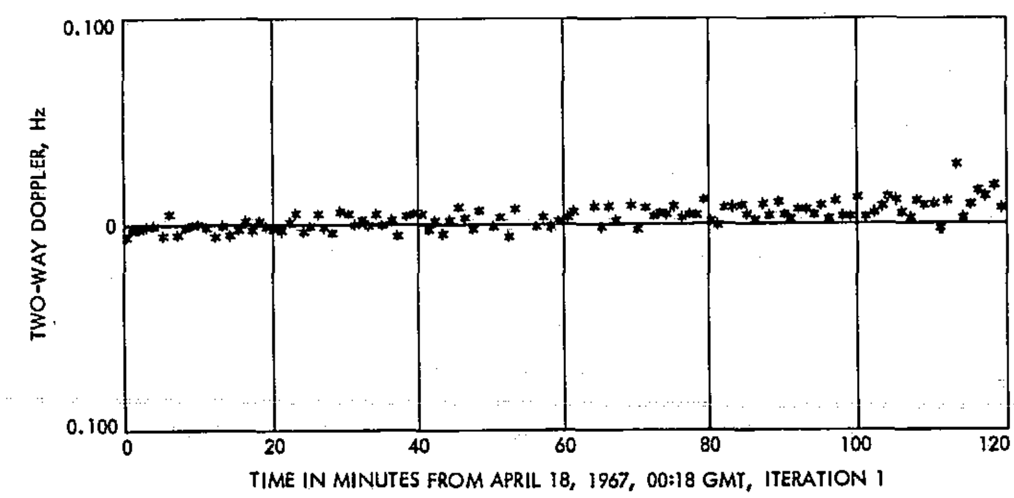


Fig. 73. DSS 11 doppler residuals, pass 1, 00 h 18 min

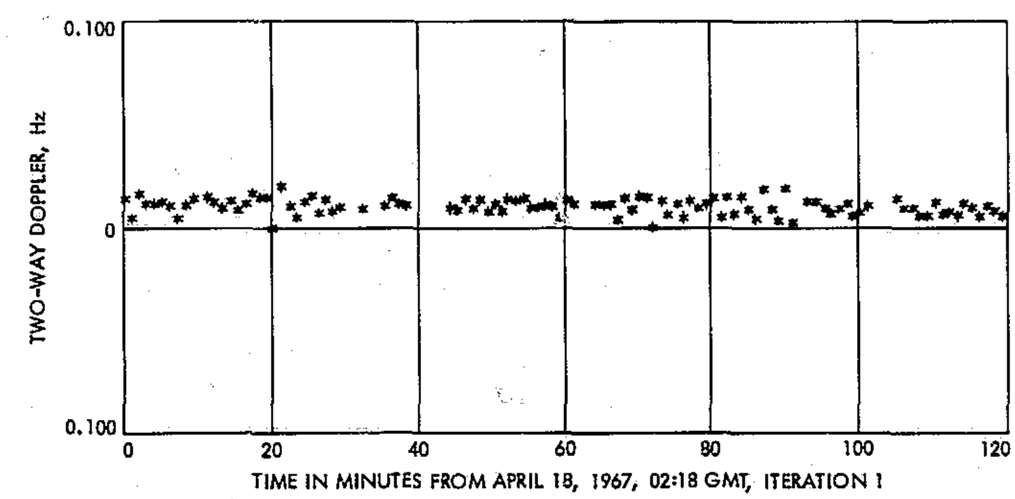


Fig. 74. DSS 11 doppler residuals, pass 1, 02 h 18 min

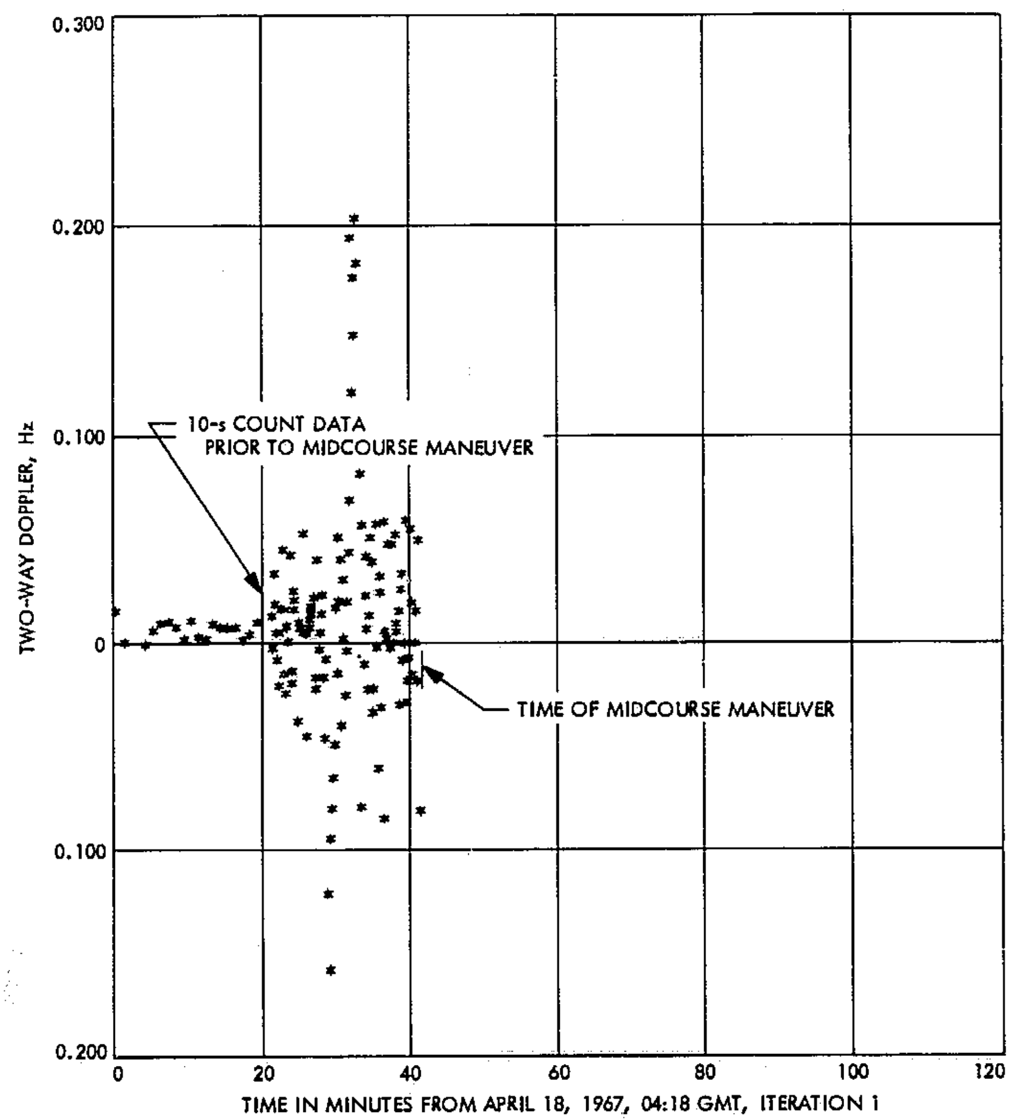


Fig. 75. DSS 11 doppler residuals, pass 1, 04 h 18 min

Midcourse maneuver. Early analysis of the *Surveyor III* trajectory indicated that a midcourse maneuver during the first pass over DSS 11 would be advantageous, and, therefore, the midcourse maneuver was executed during this pass. Engine ignition was programmed for April 18 at 05:00:00 GMT, with a total burn time of 4.275 s. Results of the maneuver as seen in the two-way doppler data over DSS 11 are presented in Fig. 76. As can be seen in the data, the midcourse maneuver resulted in a doppler shift over DSS 11 of approximately −48.0 Hz.

Post-midcourse phase. All post-midcourse orbit computations used only two-way doppler from the prime stations, DSS 11, DSS 42, DSS 51, and DSS 61. Good to very good two-way doppler data were obtained throughout the post-midcourse phase without exception. Doppler data returned by DSS 42 and DSS 11 were of uniformly high quality and generally indicated a standard deviation of approximately 0.006 Hz. DSS 11 residuals during the postmidcourse phase are shown in Figs. 77–83, and those for DSS 42 are seen in Figs. 84–89. The doppler data taken by DSS 51 during this period was not as good as that taken at DSS 11 and DSS 42; the doppler data showed an average standard deviation of approximately 0.010 Hz. Furthermore, one block of DSS 51 data from 16:40:00 to 18:10:00 on April 18 shows an unusually large bias of about −0.030 Hz, which is so far unexplainable (see Fig. 90). Two-way doppler residuals for DSS 51 are presented in Figs. 90–92. Doppler data taken during the post-midcourse phase of *Surveyor III* by DSS 61, although quite acceptable, were also not quite as good as the data taken by DSS 42 and DSS 11. In general, the DSS 61 data seemed to be a bit more noisy than the other stations; for instance, the second pass standard deviation of the two-way DSS 61 doppler data was 0.007 Hz and the third pass standard deviation was greater than 0.010 Hz. The DSS 61 residuals can be seen in Figs. 93–100.

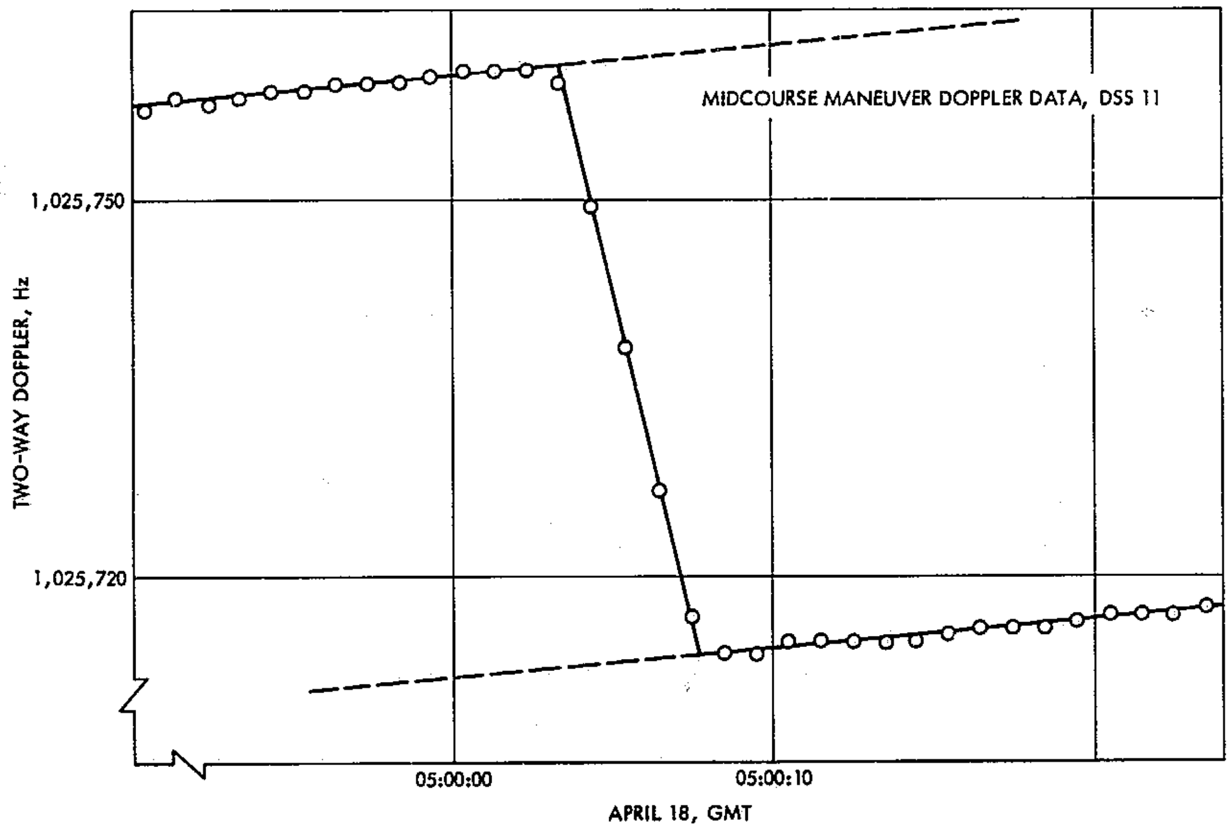


Fig. 76. Midcourse maneuver doppler data, DSS 11

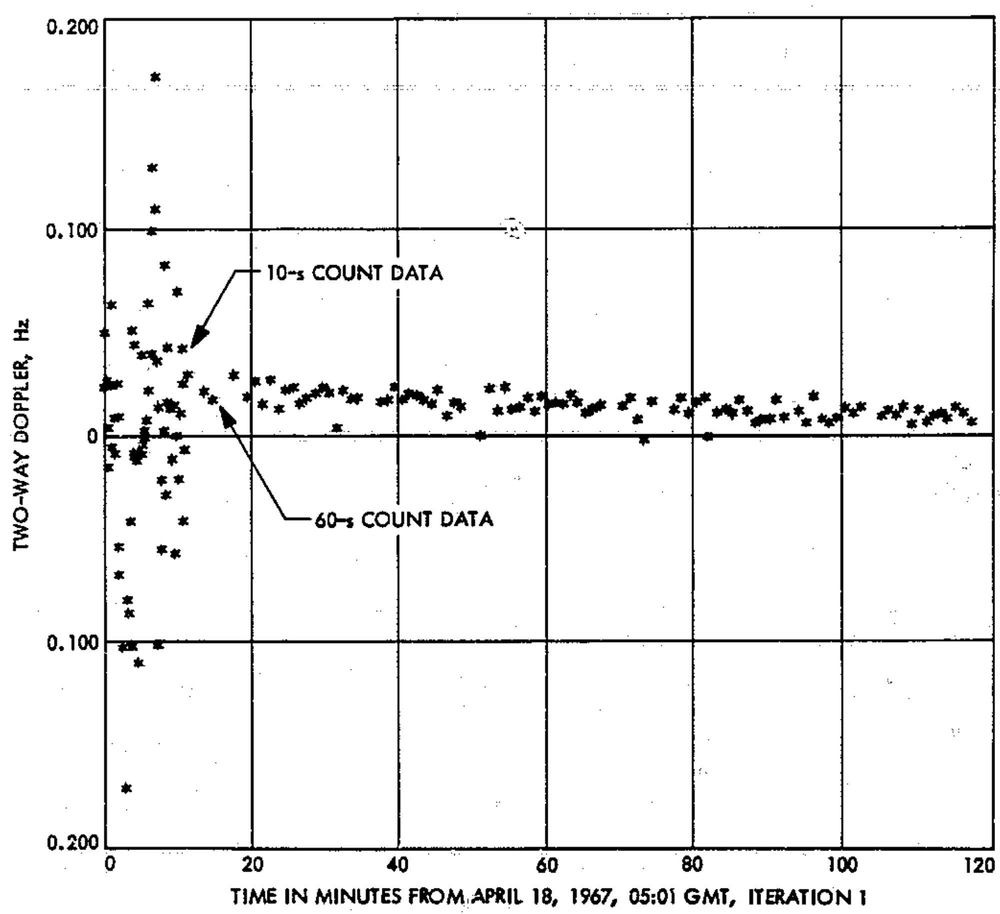


Fig. 77. DSS 11 post midcourse doppler data, pass 1, 05 h 01 min

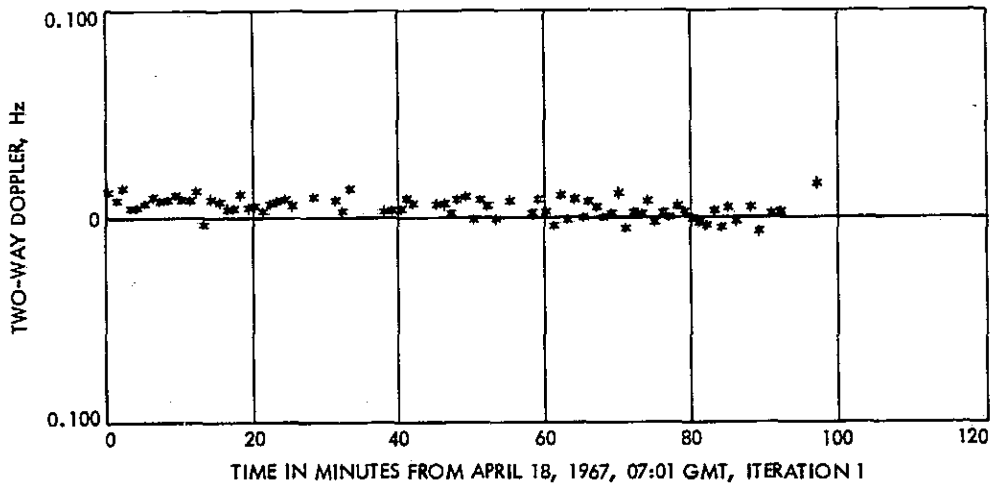


Fig. 78. DSS 11 post midcourse doppler data, pass 1, 07 h 01 min

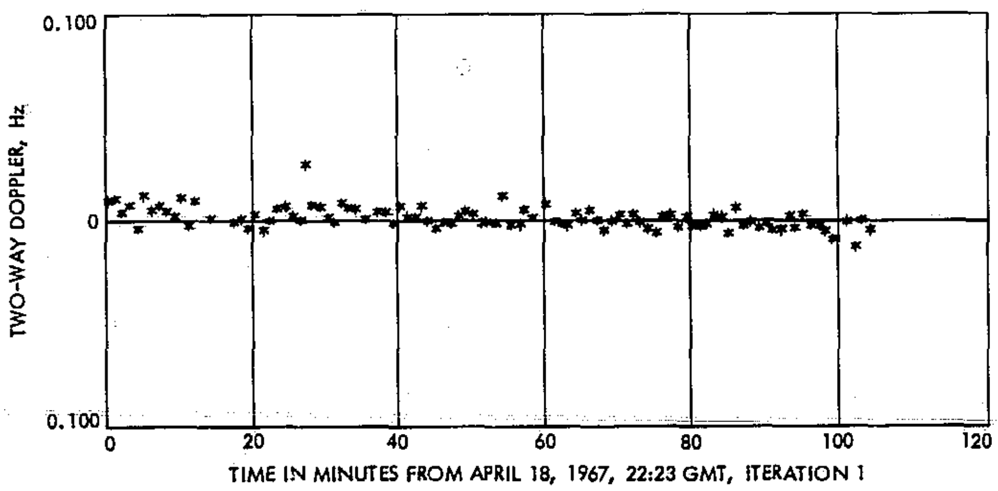


Fig. 79. DSS 11 post midcourse doppler data, pass 2, 22 h 23 min

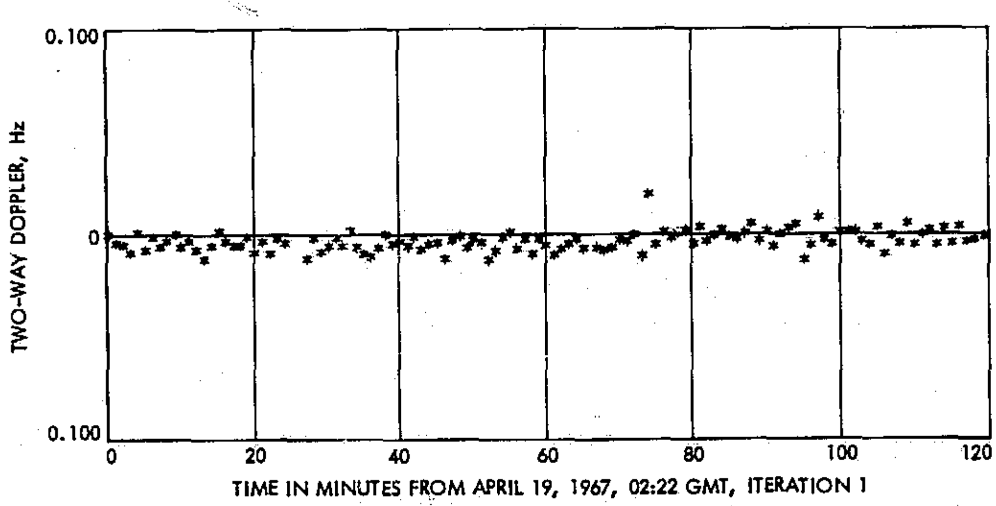


Fig. 80. DSS 11 post midcourse doppler data, pass 2, 02 h 22 min

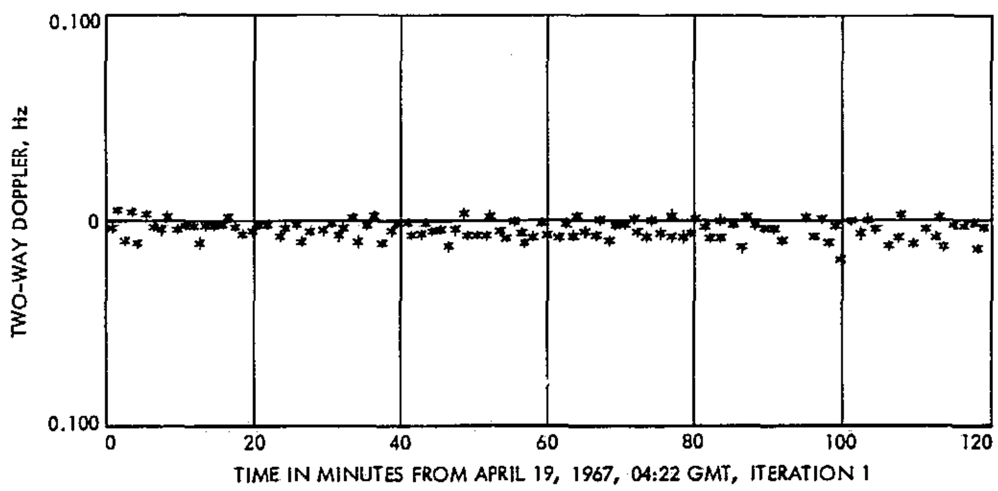


Fig. 81. DSS 11 post midcourse doppler data, pass 2, 04 h 22 min

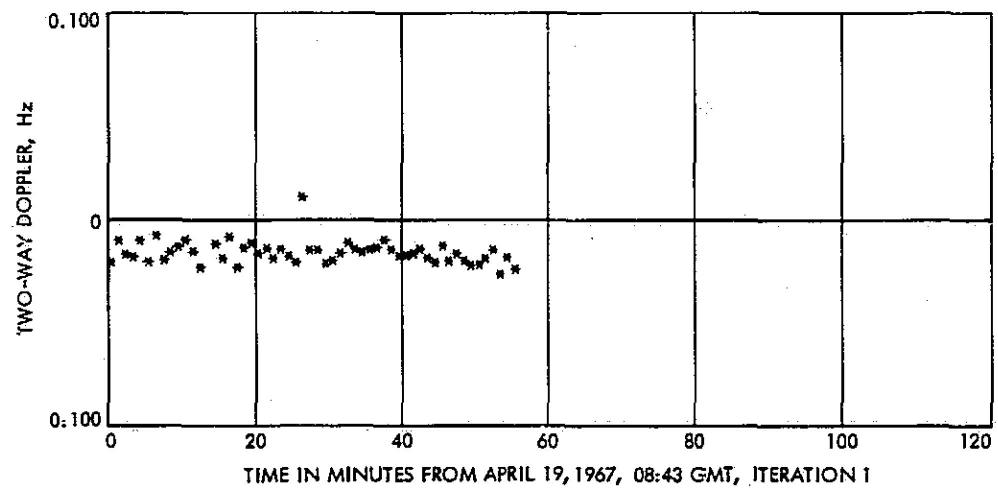


Fig. 82. DSS 11 post midcourse doppler data, pass 2, 08 h 43 min

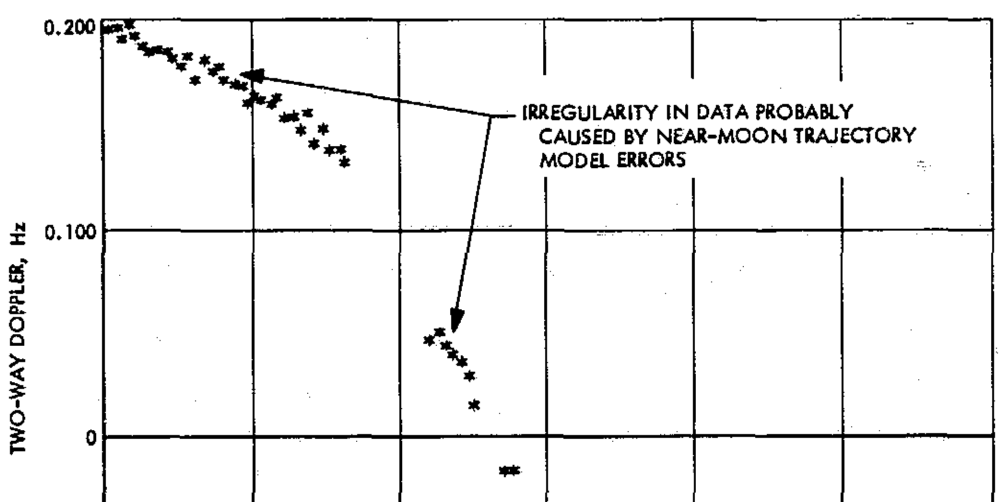


Fig. 83. DSS 11 post midcourse doppler data, pass 3, 22 h 18 min

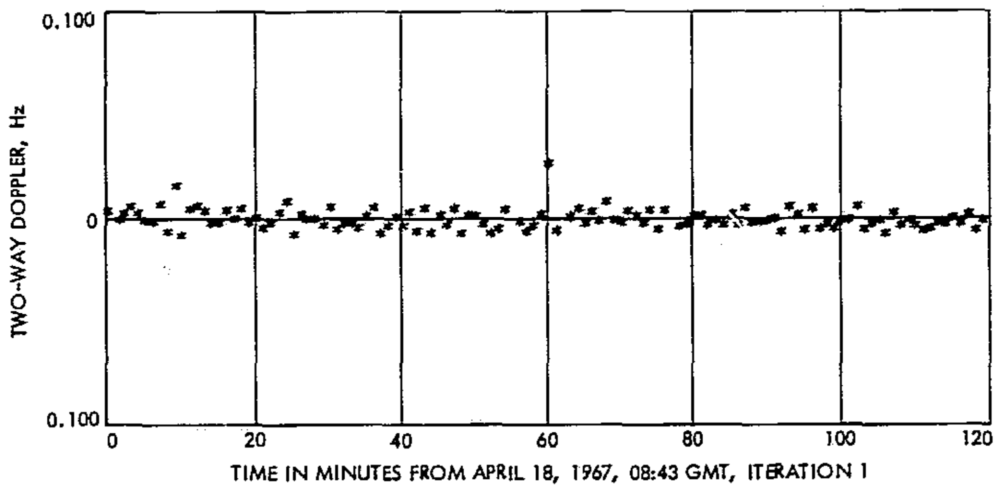


Fig. 84. DSS 42 post midcourse doppler data, pass 2, 08 h 43 min

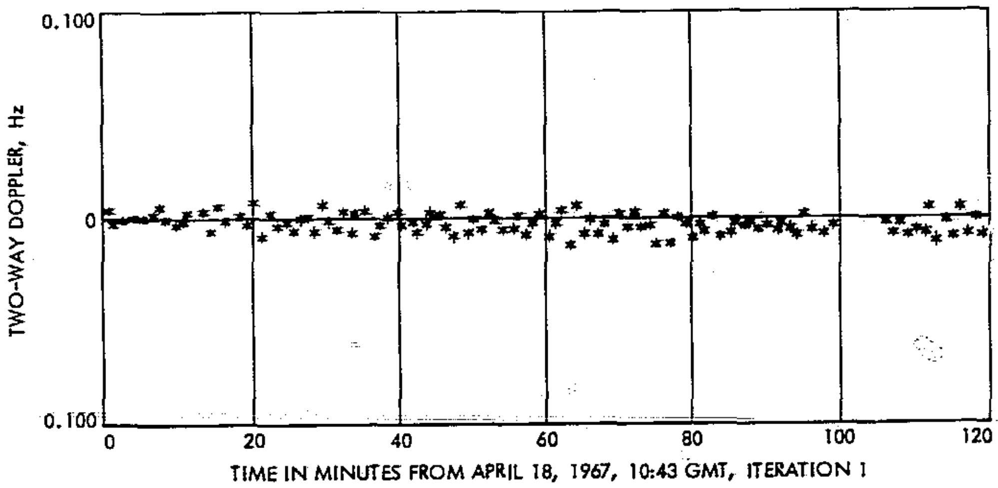


Fig. 85. DSS 42 post midcourse doppler data, pass 2, 10 h 43 min

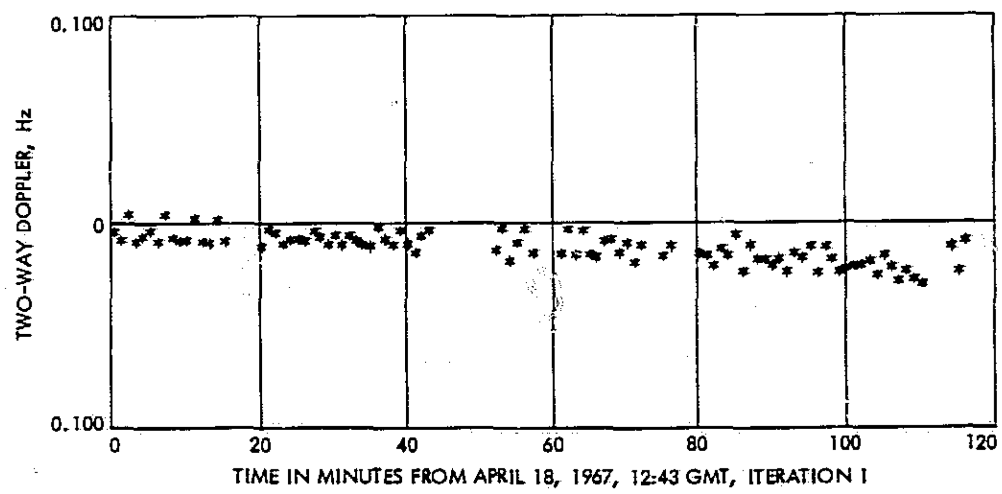


Fig. 86. DSS 42 post midcourse doppler data, pass 2, 12 h 43 min

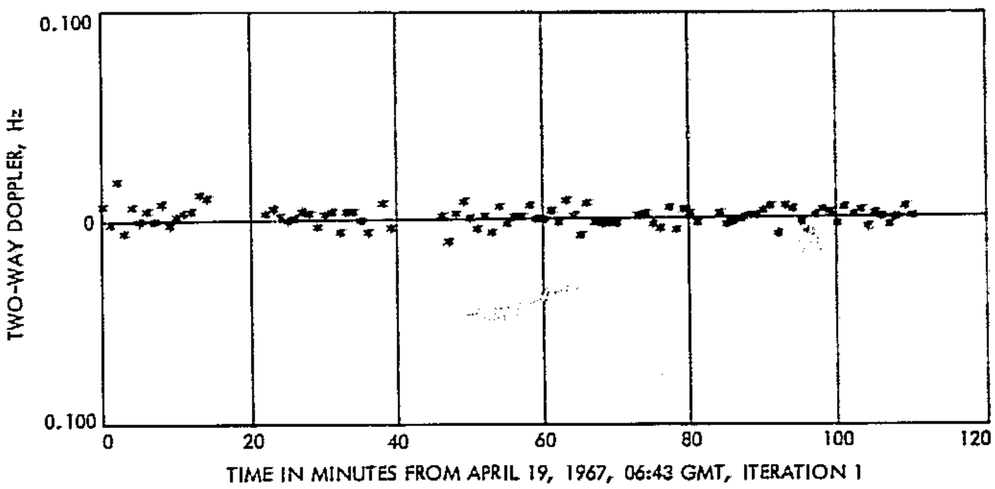


Fig. 87. DSS 42 post midcourse doppler data, pass 3, 06 h 43 min

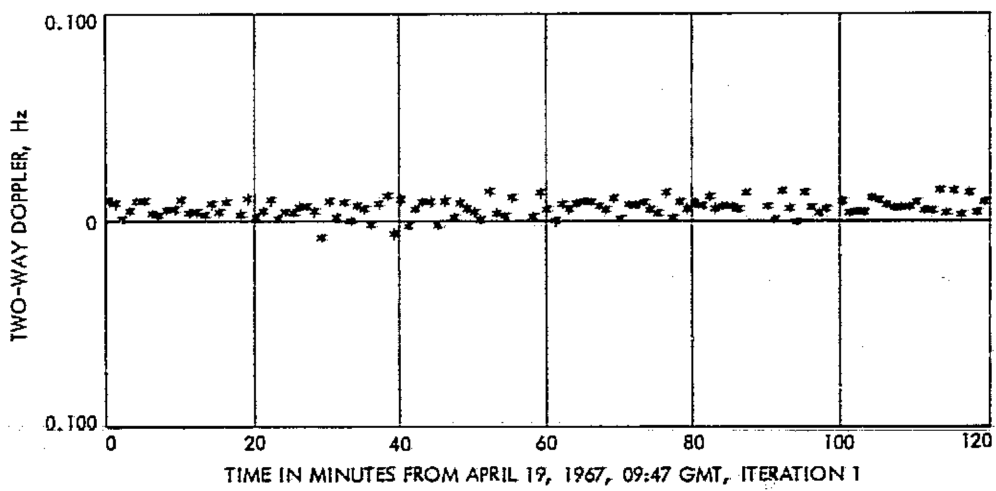


Fig. 88. DSS 42 post midcourse doppler data, pass 3, 09 h 47 min

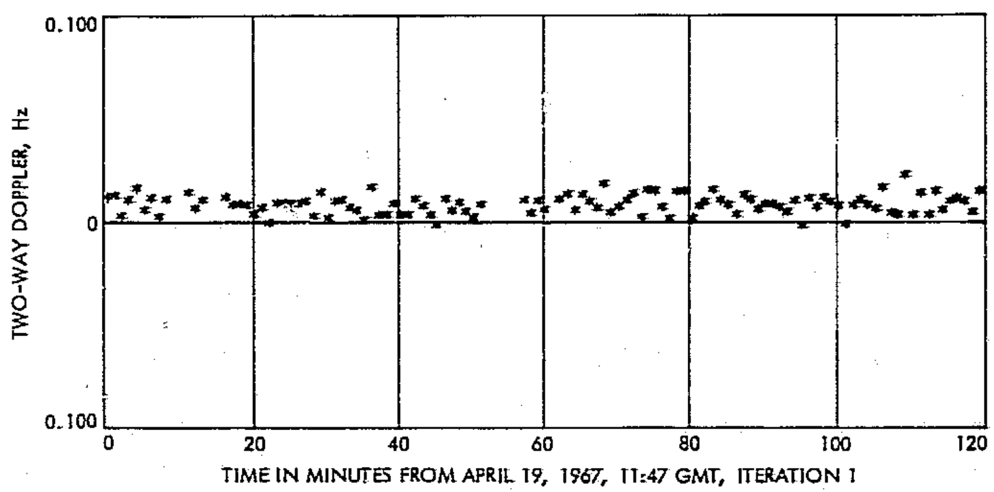


Fig. 89. DSS 42 post midcourse doppler data, pass 3, 11 h 47 min

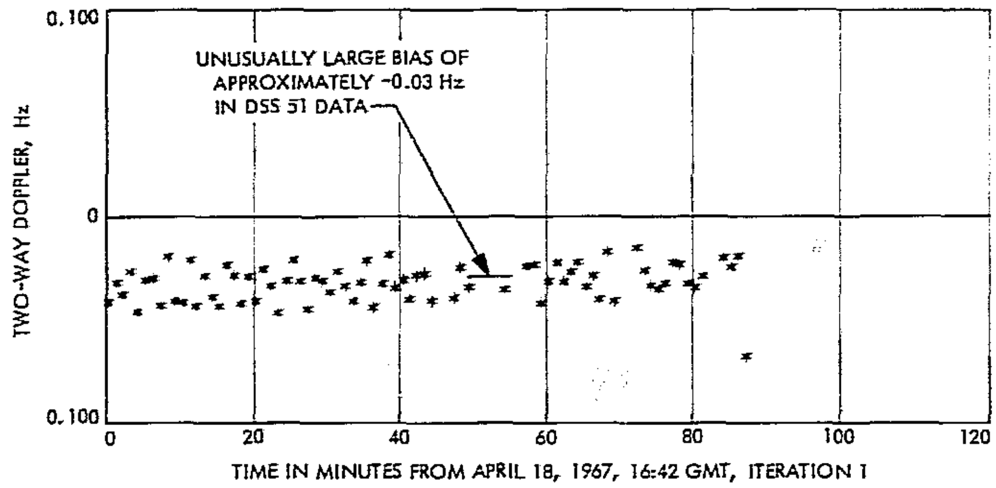


Fig. 90. **DSS 51 two-way doppler residuals, pass 2, 16 h 42 min**

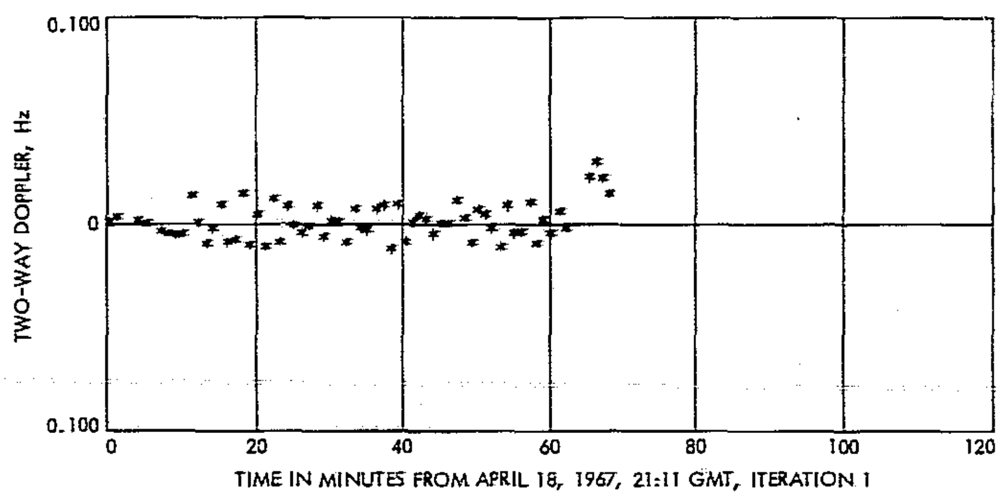


Fig. 91. **DSS 51 two-way doppler residuals, pass 2, 21 h 11 min**

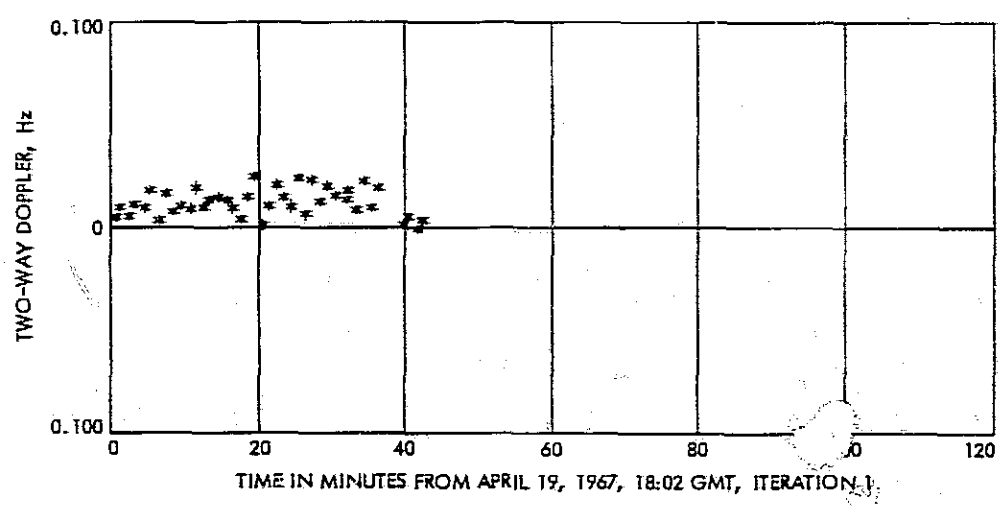


Fig. 92. **DSS 51 two-way doppler residuals, pass 3**

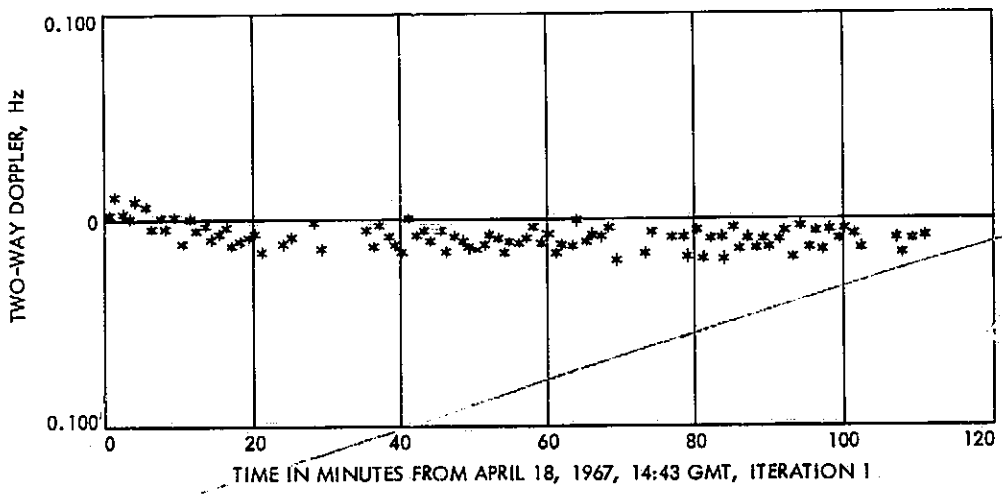


Fig. 93. DSS 61 post midcourse doppler data, pass 2, 14 h 43 min

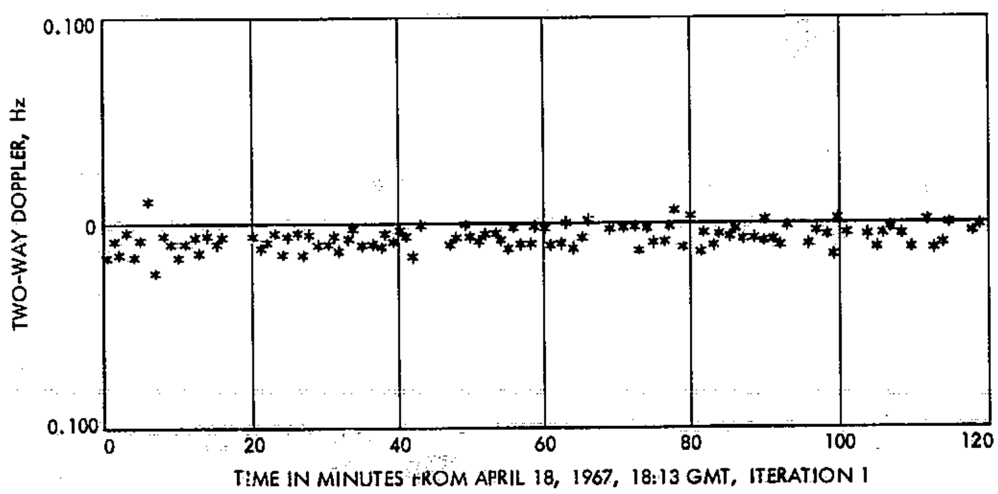


Fig. 94. DSS 61 post midcourse doppler data, pass 2, 18 h 13 min

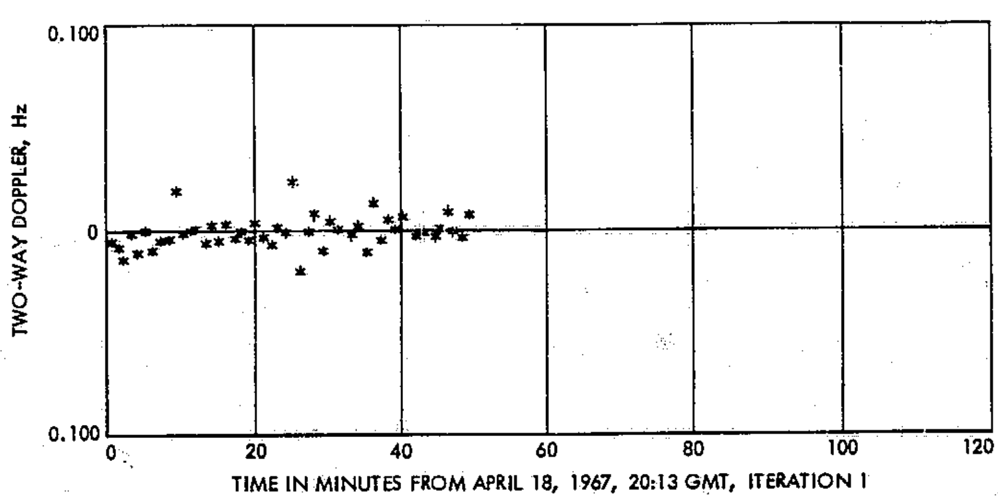


Fig. 95. DSS 61 post midcourse doppler data, pass 2, 20 h 13 min

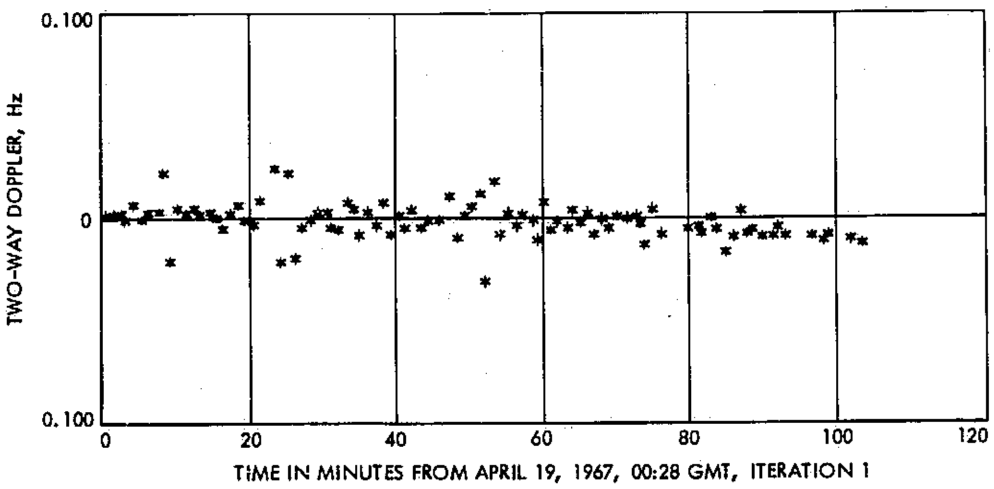


Fig. 96. DSS 61 post midcourse doppler data, pass 2, 00 h 28 min

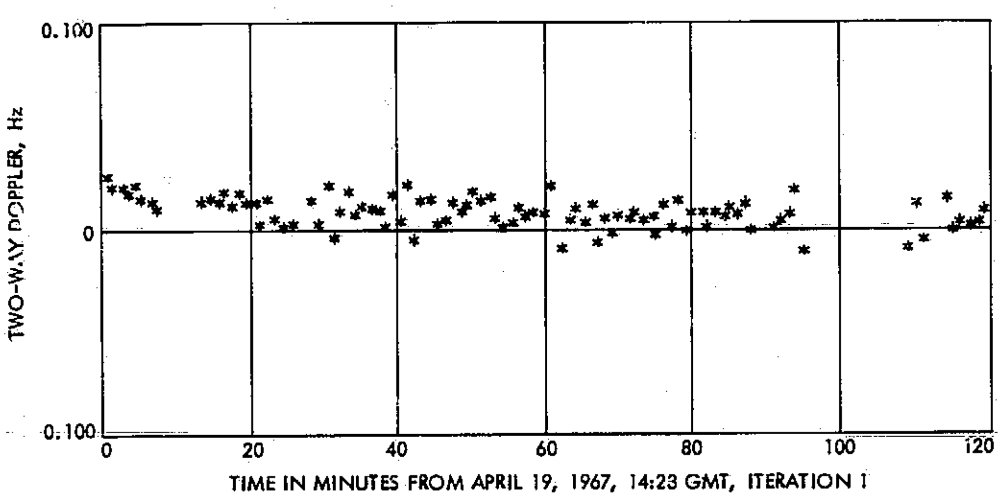


Fig. 97. DSS 61 post midcourse doppler data, pass 3, 14 h 23 min

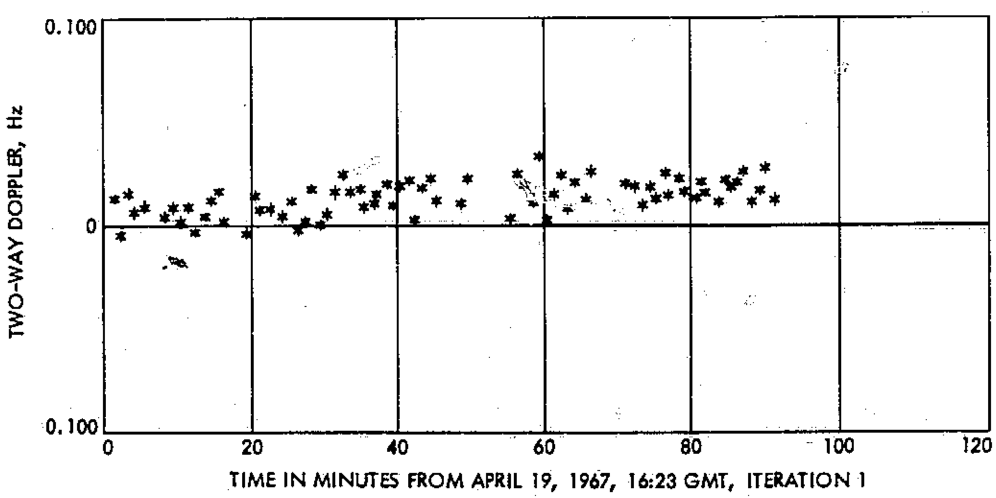


Fig. 98. DSS 61 post midcourse doppler data, pass 3, 16 h 23 min

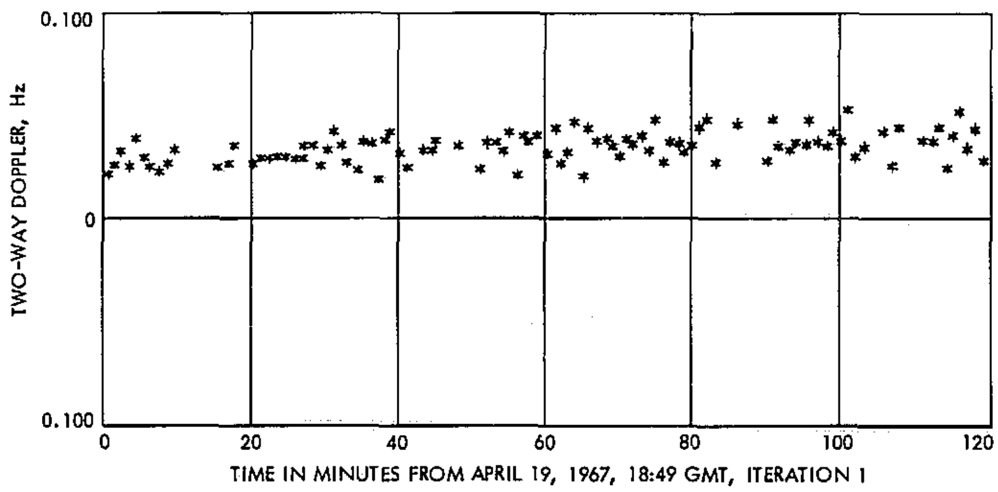


Fig. 99. DSS 61 post midcourse doppler data, pass 3, 18 h 49 min

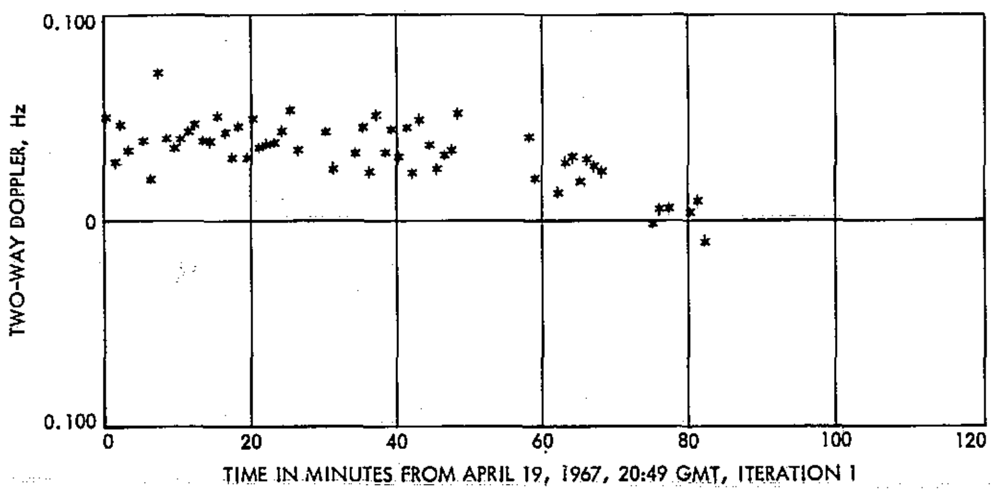


Fig. 100. DSS 61 post midcourse doppler data, pass 3, 20 h 49 min

Touchdown phase. Final inflight calculations by the ODG indicated that retroengine ignition occurred on April 20 at 00:01:17.7 GMT, and touchdown at 00:04:20.1 GMT. The results of the retroengine burn as seen in the one-way doppler data at DSS 11 are presented in Fig. 101; the vernier engine phase after retroengine cutoff is shown in Fig. 102; Fig. 103 presents the touchdown phase. To approximate the doppler of a stationary spacecraft on the lunar surface, a least-squares linear-curve fit was performed on the data immediately after touchdown; i.e., from 00:05:00 to 00:06:00. It was hoped this would remove the major effects of both one-way frequency drift and lunar surface/DSS 11 relative velocity. This data reduction indicated that during the touchdown period, the *Surveyor III*, doppler value, had the spacecraft been stationary on the lunar surface, could have been represented by

$$D1 = [1{,}010{,}522.87 + 2.18\,(\mathrm{GMT} - 00{:}05{:}00.5)]\ \mathrm{MHz}$$

This function is plotted against the actual data in Fig. 104. Table 41 lists the actual doppler, (D_1), the effective zero-velocity, lunar-surface referenced doppler, (D_2) and the difference between D_1 and D_2.

2. GCS/NASCOM. The Deep Space Network Ground Communications System (DSN/GCS) is that portion of NASCOM that provides communications between the various DSN tracking stations throughout the world and the SFOF at Pasadena, California. This communications system comprises the land lines, undersea cables, and high-frequency radio circuits that carried teletype, voice, and high-speed data in real-time support of the *Surveyor III* mission. The performance of the NASA communications network used to support the *Surveyor III* mission was considered excellent, again demonstrating its high degree of reliability. Goddard circuit restoration support was considered excellent. Figure 105 gives the GCS circuit

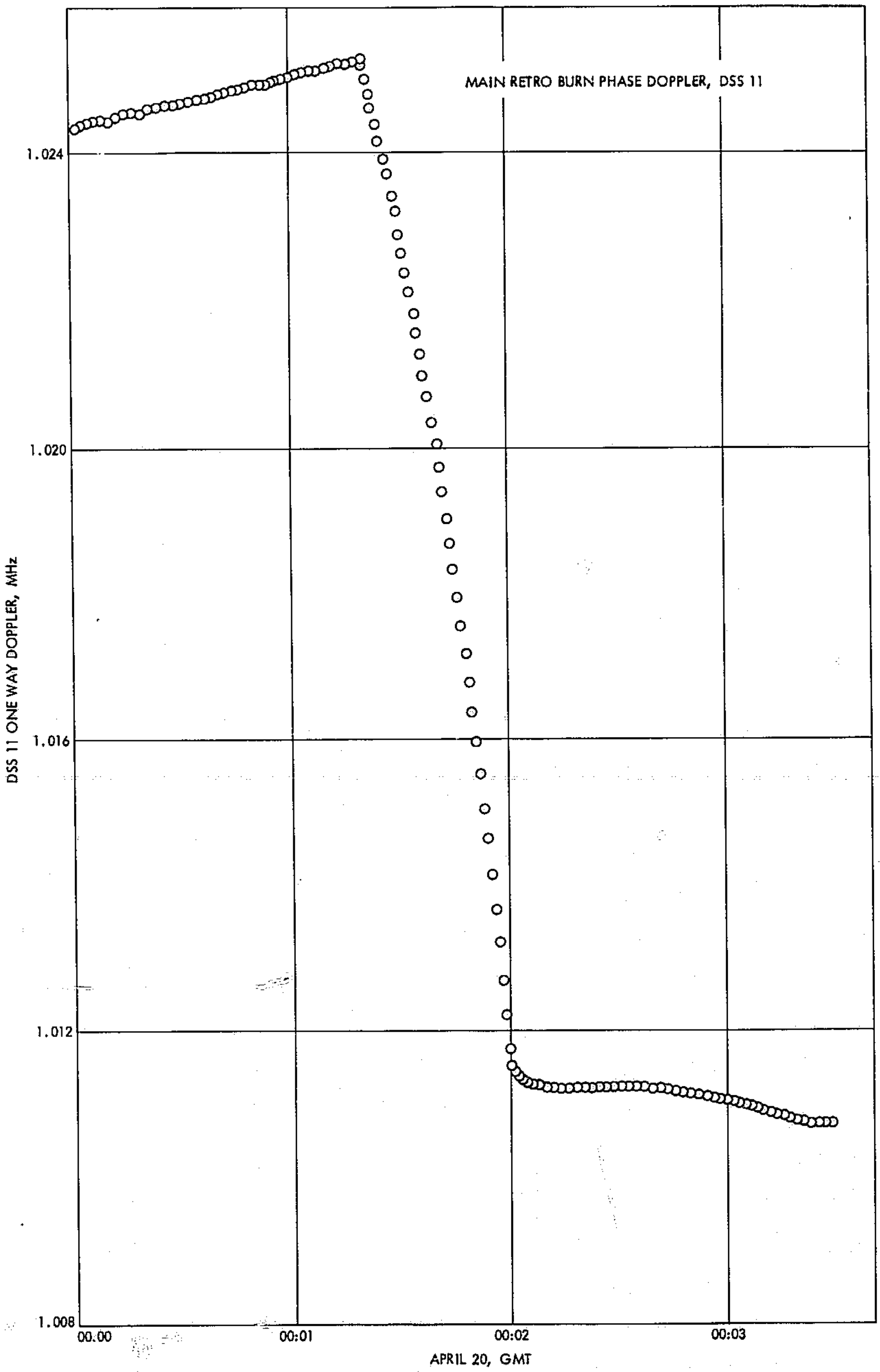


Fig. 101. DSS 11 one way doppler main retro burn phase

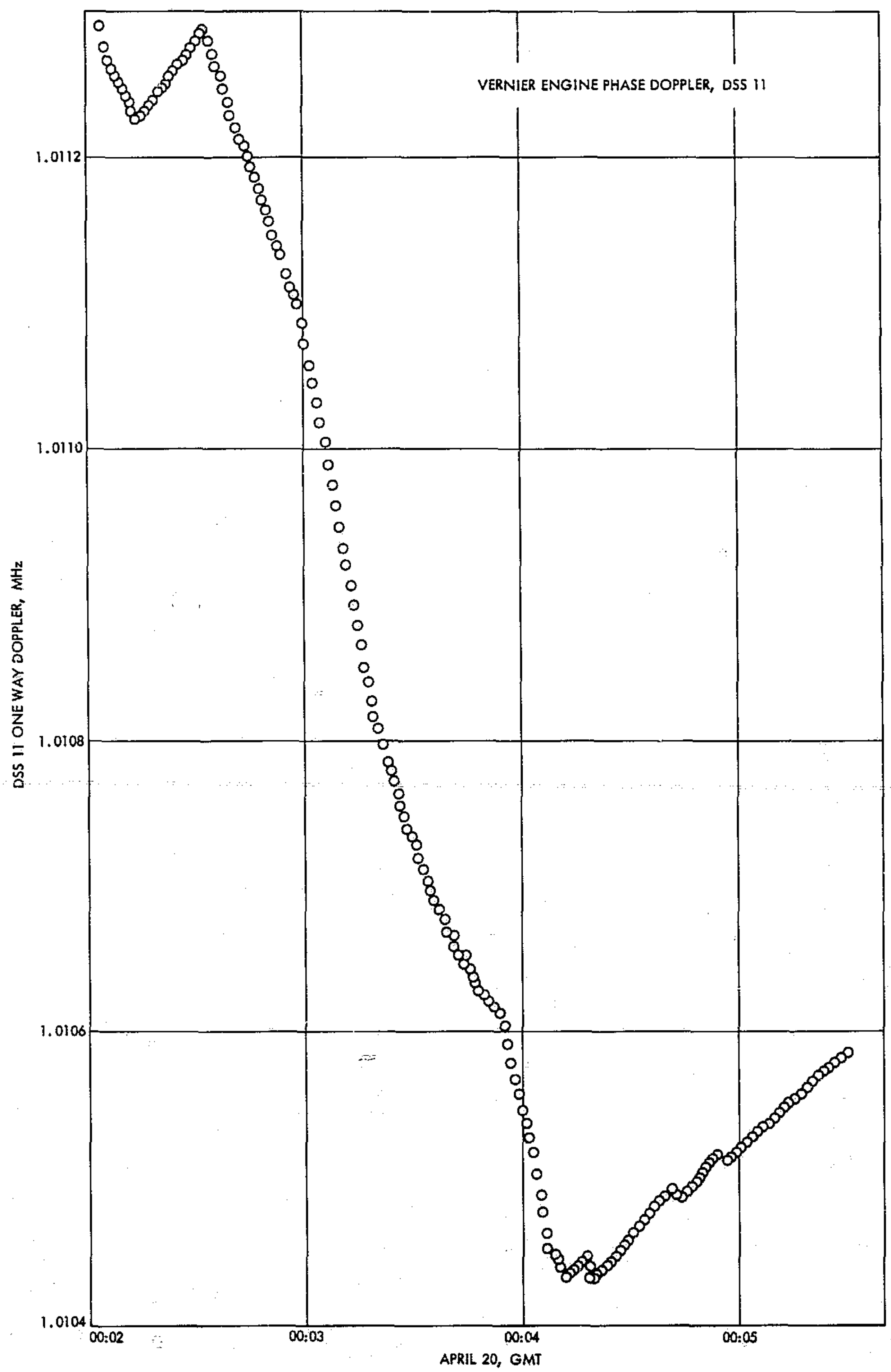


Fig. 102. DSS 11 one way doppler, vernier engine phase

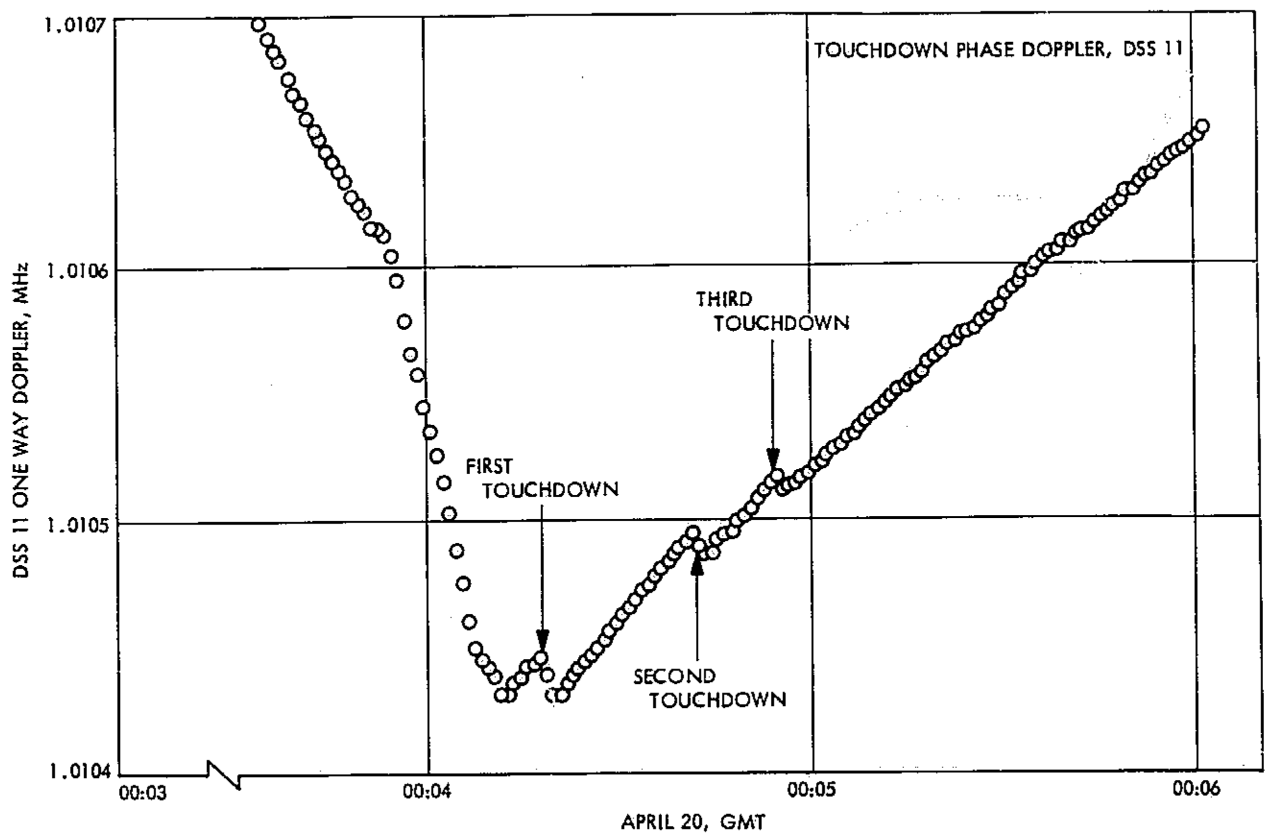


Fig. 103. DSS 11 one way doppler, touchdown phase

performance for the *Surveyor III* mission from launch through the first lunar day.

Except during periods of poor HF propagation at DSS 51 and 72, voice and teletype circuits were reliable with only minor problems. The high-speed data lines performed very well, and both the wideband microwave link and the 6-MHz video line between DSS 11 and the SFOF were 100% reliable. Commercial voice circuit performance was generally poor and unreliable.

The more outstanding communications problems and equipment failures are given below. None of these proved detrimental to the ultimate success of the mission.

(1) Prior to launch, the DSS 51 voice circuit failed due to HF radio propagation; the circuit was cleared before liftoff and completely restored at $L + 00{:}25$. During this time, the commercial overseas voice circuit was also out. The commercial call was maintained from $L - 01{:}00$ to $L + 01{:}00$ but was never usable when needed.

(2) Outages occurred on DSS 51 and DSS 72 teletype circuits due to propagation over HF radio paths. (No outages occurred on the DSS 72 satellite circuits.) A 3-h data loss occurred at DSS 51 during a period in which DSS 61 was not scheduled. DSS 61 was brought up in real time to handle the balance of the pass.

(3) Tracking data were lost at the beginning of midcourse pass due to an equipment and communications patch problem at DSS 11. Troubleshooting and restoration of circuits were delayed due to the split responsibility of DSS 12/DSS 11 communications and SFOF communications.

(4) Due to a patch problem in the SFOF (OVCS net), a bad patch between the Command Net and the DSS 11 voice net delayed commanding for 10 min at the beginning of midcourse pass.

(5) One of two 202 data lines from the SFOF TPS to the HAC 1219 computers in El Segundo was out for 6.5 h during midcourse. This was caused by a PT&T line failure. The PT&T maintenance personnel did not restore the circuit on a priority basis, and the outage restricted the 1219 computers to processing only one station's data at a time.

a. Voice lines. The NASCOM voice circuits provided for *Surveyor C* and tests performed well within expectations. Failures occurred on the DSS 51 voice circuit prior to launch due to propagation path. The circuit cleared prior to launch. During this time the commercial call was also out. The failure was longer on the commercial

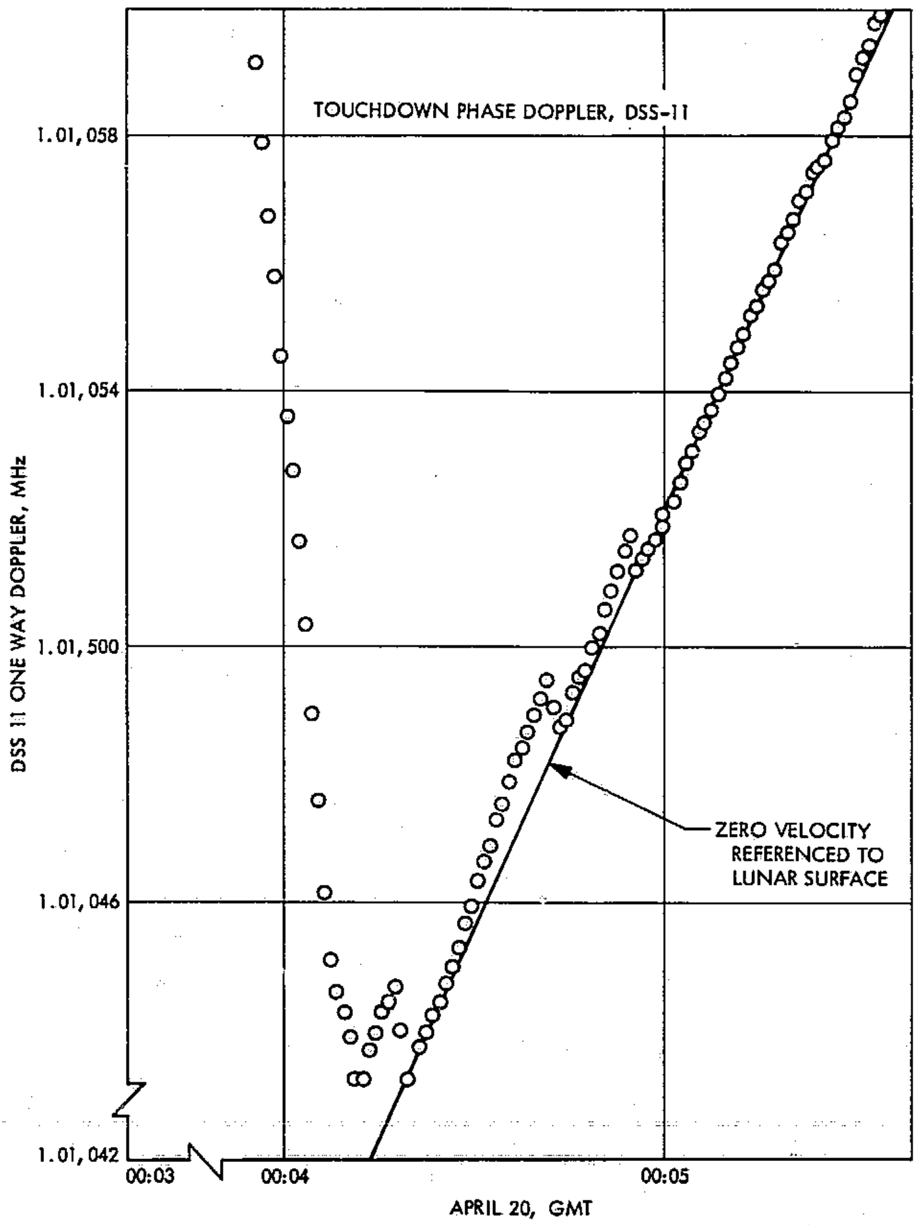


Fig. 104. Touchdown phase doppler, DSS 11

call than on the normal voice circuit. This call was maintained from $L - 1$ h until $L + 1$ h but was never usable when needed. The DSS 72 voice circuit was by satellite during the C-5.0 test and mission, and performed exceptionally well.

b. Teletype lines. The teletype circuit operation was highly reliable. There were outages due to propagation by high-frequency radio path on the DSS 51 circuits and the DSS 72 circuits.

During the C-5.0 test and the mission, the A and C circuits were via satellite and suffered no outage.

There was a 3-h delay getting one circuit from DSS 71 during the first C-3.0 test, due to rewiring at Cape Kennedy Space Center.

No make-good was available. During the C-5.0 test, all circuits with DSS 61 were lost due to a shorted cable in AT&T frame room at Garden City, Va.

c. High-speed data lines. This portion of the communications system performed exceptionally well during both the testing and mission phases. Both NASCOM and Hallicrafter data set were used.

d. Wide band data link. The Goldstone/SFOF Microwave System operated by the Western Union Company provided excellent communications service with 100% reliability.

3. DSN/SFOF. SFOF support during mission C was good. Personnel were provided as requested and also scheduled on a standby basis. Internal access control,

Table 41. Touchdown phase doppler data, DSS 11

Time, GMT	Doppler frequency, Hz		Difference, $D_1 - D_2$	
	D_1	D_2	Hz	ft/s
00:04:00.5	1,010,536.00	1,010,392.07	143.93	61.68
04:01.5	527.50	394.25	133.25	57.11
04:02.5	516.50	396.43	120.07	51.46
04:03.5	503.50	398.61	104.89	44.95
04:04.5	489.50	400.79	88.71	38.02
04:05.5	476.00	402.97	73.03	31.30
04:06.5	461.50	405.15	56.35	24.15
04:07.5	451.00	407.33	43.67	18.72
04:08.5	446.00	409.51	36.49	15.64
04:09.5	443.00	411.69	31.31	13.42
04:10.5	439.00	413.87	25.13	10.77
04:11.5	432.50	416.05	16.45	7.05
04:12.5	432.50	418.23	14.27	6.12
04:13.5	437.00	420.41	16.59	7.11
04:14.5	439.50	422.59	16.91	7.25
04:15.5	443.00	424.77	18.23	7.81
04:16.5	444.50	426.95	17.55	7.52
04:17.5	447.00	429.13	17.87	7.66
04:18.5	440.00	431.31	8.69	3.72
04:19.5	432.00	433.49	−1.49	−0.64
04:20.5	432.50	435.67	−3.17	−1.36
04:21.5	437.50	437.85	−0.35	−0.15
04:22.5	440.00	440.03	−0.03	−0.01
04:23.5	442.50	442.21	0.29	0.12
04:24.5	444.50	444.39	0.11	0.05
04:25.5	447.50	446.57	0.93	0.40
04:26.5	450.00	448.75	1.25	0.54
04:27.5	453.00	450.93	2.07	0.89
04:28.5	457.00	453.11	3.89	1.67
04:29.5	459.50	455.29	4.21	1.80
04:30.5	463.50	457.47	6.03	2.58
04:31.5	466.50	459.65	6.85	2.94
04:32.5	469.00	461.83	7.17	3.07
04:33.5	473.00	464.01	8.99	3.85
04:34.5	475.50	466.19	9.31	3.99
04:35.5	479.00	468.37	10.63	4.56
04:36.5	482.50	470.55	11.95	5.12
04:37.5	484.50	472.73	11.77	5.04
04:38.5	487.00	474.91	12.09	5.18
04:39.5	489.50	477.09	12.41	5.32
04:40.5	492.00	479.27	12.73	5.46
04:41.5	495.00	481.45	13.55	5.81
04:42.5	490.50	483.63	6.87	2.94
04:43.5	487.50	485.81	1.69	0.72
04:44.5	488.50	487.99	0.51	0.22
04:45.5	493.00	490.17	2.83	1.21
04:46.5	495.50	492.35	3.15	1.35
04:47.5	496.50	494.53	1.97	0.84
04:48.5	500.00	496.71	3.29	1.41
04:49.5	502.50	498.89	3.61	1.55
04:50.5	506.00	501.07	4.93	2.11
04:51.5	509.00	503.25	5.75	2.46
04:52.5	512.00	505.43	6.57	2.82
04:53.5	515.00	507.61	7.39	3.17
00:04:54.5	1,010,517.50	1,010,509.79	7.71	3.30
04:55.5	512.50	511.97	0.53	0.23
04:56.5	514.00	514.15	−0.15	−0.06
04:57.5	515.50	516.33	−0.83	−0.36
04:58.5	517.00	518.51	−1.51	−0.65
04:59.5	519.00	520.69	−1.69	−0.72
05:00.5	522.50	522.87	−0.37	−0.16
05:01.5	523.00	525.05	−2.05	−0.88
05:02.5	526.00	527.23	−1.23	−0.53
05:03.5	529.00	529.41	−0.41	−0.18
05:04.5	530.50	531.59	−1.09	−0.47
05:05.5	534.00	533.77	0.23	0.10
05:06.5	535.00	535.95	−0.95	−0.41
05:07.5	537.00	538.13	−1.13	−0.48
05:08.5	539.50	540.31	−0.81	−0.35
05:09.5	542.00	542.49	−0.49	−0.21
05:10.5	544.50	544.67	−0.17	−0.07
05:11.5	547.00	546.85	0.15	0.06
05:12.5	549.00	549.03	−0.03	0.01
05:13.5	552.00	551.21	0.79	0.34
05:14.5	553.50	553.39	0.11	0.05
05:15.5	556.00	555.57	0.43	0.18
05:16.5	557.50	557.75	−0.25	−0.11
05:17.5	559.00	559.93	−0.93	−0.40
05:18.5	563.50	562.11	1.39	0.60
05:19.5	565.00	564.29	0.71	0.30
05:20.5	567.00	566.47	0.53	0.23
05:21.5	570.00	568.65	1.35	0.58
05:22.5	571.50	570.83	0.67	0.29
05:23.5	574.50	573.01	1.49	0.64
05:24.5	575.50	575.19	0.31	0.13
05:25.5	576.50	577.37	−0.87	−0.37
05:26.5	579.50	579.55	−0.05	−0.02
05:27.5	581.50	581.73	−0.23	−0.10
05:28.5	583.00	583.91	−0.91	−0.39
05:29.5	585.50	586.09	−0.59	−0.25
05:30.5	590.00	588.27	1.73	0.74
05:31.5	592.50	590.45	2.05	0.88
05:32.5	594.50	592.63	1.87	0.80
05:33.5	598.00	594.81	3.19	1.37
05:34.5	599.50	596.99	2.51	1.08
05:35.5	602.00	599.17	2.83	1.21
05:36.5	604.50	601.35	3.15	1.35
05:37.5	606.00	603.53	2.47	1.06
05:38.5	607.50	605.71	1.79	0.77
05:39.5	610.50	607.89	2.61	1.12
05:40.5	611.50	610.07	1.43	0.61
05:41.5	613.00	612.25	0.75	0.32
05:42.5	615.00	614.43	0.57	0.24
05:43.5	616.50	616.61	−0.11	−0.05
05:44.5	618.00	618.79	−0.79	−0.34
05:45.5	620.00	620.97	−0.97	−0.42
05:46.5	622.50	623.15	−0.65	−0.28

[a] Effective doppler frequency of zero-velocity spacecraft, referenced to the lunar surface.

Table 41 (contd)

Time, GMT	Doppler frequency, Hz		Difference, $D_1 - D_2$		Time, GMT	Doppler frequency, Hz		Difference, $D_1 - D_2$	
	D_1	D_2	Hz	ft/s		D_1	D_2	Hz	ft/s
00:05:47.5	1,010,624.50	1,010,625.33	−0.83	−0.36	00:05:54.5	1,010,640.00	1,010,640.59	−0.59	−0.25
05:48.5	626.50	627.51	−1.01	−0.43	05:55.5	642.00	642.77	−0.77	−0.33
05:49.5	630.00	629.69	0.31	0.13	05:56.5	644.50	644.95	−0.45	−0.19
05:50.5	631.00	631.87	−0.87	−0.37	05:57.5	646.00	647.13	−1.13	−0.48
05:51.5	633.50	634.05	−0.55	−0.24	05:58.5	647.50	649.31	−1.81	−0.78
05:52.5	636.50	636.23	0.27	0.12	05:59.5	649.50	651.49	−1.99	−0.85
05:53.5	637.50	638.41	−0.91	−0.39	:06:00.5	652.00	653.67	−1.67	−0.72

special access control, and documentation services were provided as needed.

a. Communications. The DSN/ICS provides the capability of receiving, switching, and distributing to designated areas of users within the SFOF, all types of information required for space flight operations. The system includes all voice communication capabilities within the SFOF, television communications subsystem (TVCS), teletype, high-speed data, and data received over the microwave channels. This system (DSN/ICS) performed in an exceptional manner with only minor problems noted.

The major communications changes for *Surveyor III* were: (1) the provision of satellite circuits to DSS 72 for highly reliable voice, teletype, and HSDL communications during launch pass; and (2) the addition of a data circuit between Carnarvon and DSS 42. NASCOM also provided seven additional teletype and three additional voice circuits between JPL and Goddard to support the mission.

Voice audio patch panel. There were some minor patching problems on the mission commentary net (voice of *Surveyor*) during launch, due to the number of patches required. During touchdown phase it was patched to Edwards Air Force Base and Boeing Company, Seattle, in addition to the NASA and DSS requirements.

Special NASCOM support. Special circuit coverage was activated during the launch, midcourse, and touchdown phases. During touchdown, all JPL/Goldstone microwave relay points and terminals were manned by Western Union. No circuit failures occurred on microwave.

NASCOM provided seven additional teletype and three additional voice circuits between JPL and GSFC to support the mission and tests. There were not enough permanent circuits to support multimission requirements.

NASCOM data sets. The NASCOM data sets were used with all stations except DSS 51 and the reliability was very high. Sets 1, 2, and 3 were designated to *Surveyor* only. This gave some problem during launch when several stations were active and caused some problems in switching sets for each station to run data transfer tests. The DSS 51 used the Hallicrafter data sets, and the normal circuit problems due to propagation were experienced. Equipment problems did not occur.

Television communications subsystem. Only minor equipment problems were experienced on this system and they were all repaired in real time. There was a shortage of TTY/TV monitors during launch phase as there were only 12 monitors and 23 active circuits. All monitors were assigned to *Surveyor* Project. The output of the scan converter was normalized to PIO at all times and no problems were encountered.

Many areas in the SFOF do not have the scan converter or external buttons on the television area selectors. This caused a myriad of requests for the scan converter to be patched to individual area monitors during the lunar operations phase.

Evaluation of COMM support. In general, all communications support provided for this mission, including NASCOM, DSN/GCS, DSN/ICS, SFOF communications, and other contractor-furnished communications, was considered excellent-to-outstanding with communications imposing no constraints or major problems affecting the mission. New, highly reliable satellite circuits provided by NASCOM to DSS 72 (1-VCE, 1-HSDL, 2-TTY) during final test and launch phases are considered the spectacular change from the previous mission.

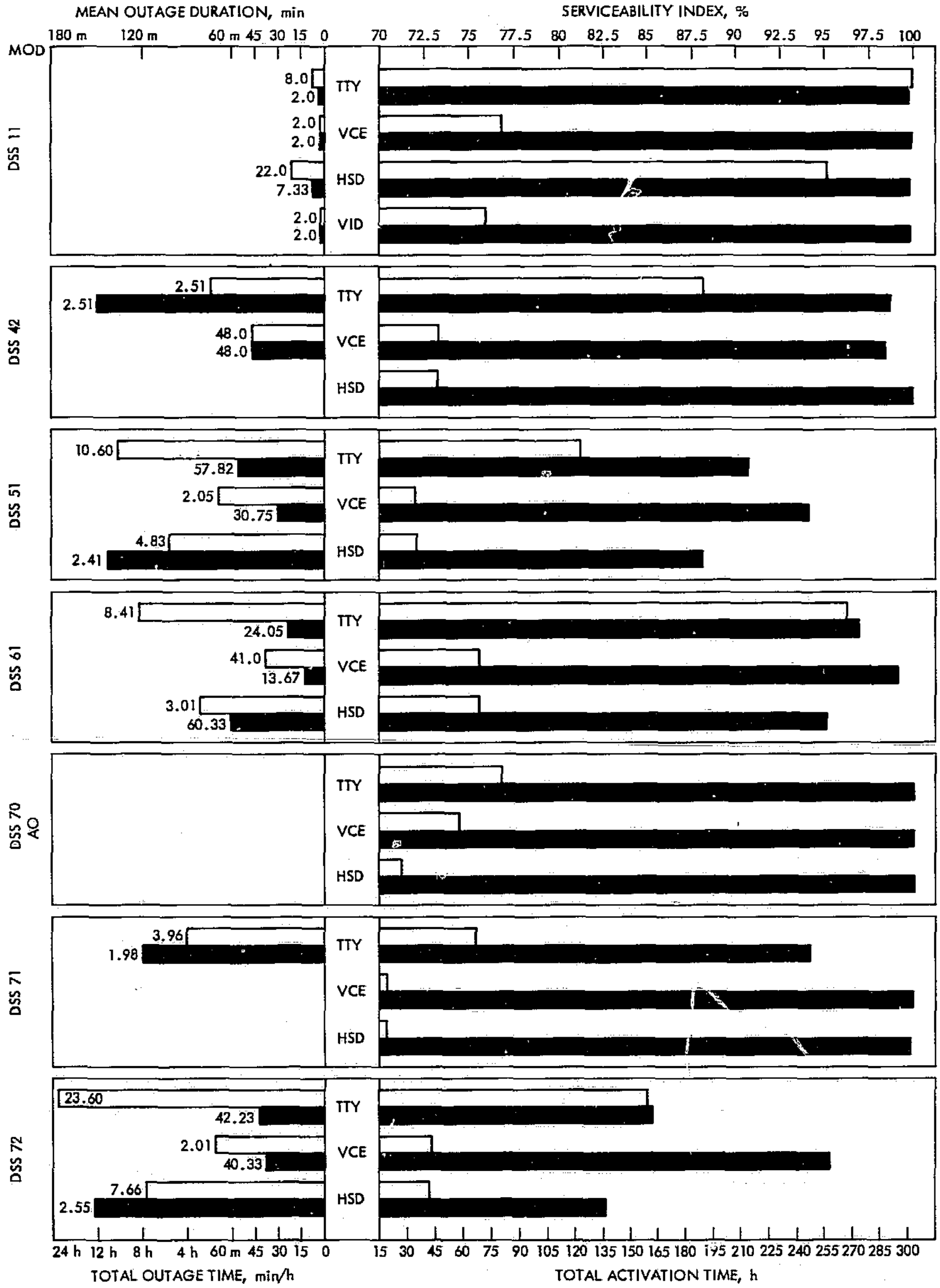


Fig. 105. GCS/NASCOM performance from launch through first lunar day

b. Data processing system. The overall performance of the DPS was consistent with previous mission performance. Special computer runs requested by the area directors were accommodated with no significant perturbation to the scheduled runs. The two PDP-7 computers were used extensively to process high-speed telemetry data for the mission. Data flow procedures, data transfer tests with the tracking stations, and DACON procedures and interfaces with TPS personnel caused the following:

Communications Error 1 problems. The most significant problem experienced during the *Surveyor* flight was the communications error 1 problems on the IBM 7044/7094 computer strings. Exhaustive diagnostic testing in May isolated this discrepancy to a software problem and this long-standing problem may now be closed out.

Communications/TPS patching. There was a great deal of confusion prior to the *Surveyor* flight as to the patching

Table 42. *Surveyor III* mission problems

Problem	Effect of mission	Real-time corrective action	Recommended permanent solution	Remarks
1. Communications problems between DSS 11 and Echo communications during several passes at DSS 11	Loss of data on 96-kHz line	Station investigated problem until it was corrected	Assign the responsibility of the Echo communications system to the GCS	Diverse philosophy between DSS 11 Manager and Communications Manager on responsibilities
2. SPAC–AGC recorder calibration, entire mission	DSS 11/SFOF integration slow and complicated	None	Simplify procedure and reduce the number of people involved	None
3. Loss of uplink for 17-min period. DSS 51, Pass 01. 107/17:00 to 17:17	No command capability or two-way doppler for time period	None	More specific procedures to cover this type of event be placed in the TIM	Transfer from DSS 61 to DSS 51. Lost uplink
4. Eighth digit in TDH-doppler was invalid. DSS 61, Pass 01. 107/15:24 to 19:32	Doppler data were invalid for the time interval	Repaired bad plug	None	Excessive time to repair, complicated by the preceding event and by having to give up the voice line to the station for commanding periods
5. IMP did not process three-way doppler, entire mission	Three-way doppler and deviations not documented as were one–way and two–way	None	Correct the IMP program	Program problem
6. Three erroneous commands transmitted by DSS 11, Pass 111/01:04	None	None	Better training of operators if this is the problem (perhaps better human engineering on CDC subsection)	None
7. Invalid telemetry made spacecraft temperatures unreliable and prevented DSIF from predicting best-lock frequencies of the spacecraft after touchdown	Probably operated outside the normal limit of SPE	Several best-lock frequency measurements were made and the predicts were biased accordingly	None	This would have been no problem had the telemetry been reliable
8. DSS 42 acquisition delayed due to radio frequency interference, 117/10:22 to 11:59	Delayed transfer from DSS 11 to DSS 42 scheduled for 10:55	Waited until the antenna was several degrees above the horizon and RFI disappeared	None	Station unable to identify source of RFI
9. DSS 11 switched TCP computers from primary to backup. Switching took 12 min, 110/06:06 to 06:18	Delayed commanding and loss of data for time period	Switched computers	Improvement in switching capabilities	Excessive time to switch computers due to equipment configuration and location at the station

of HSD between the communications center and TPS and the parties authorized to change this patching. This area has also been thoroughly investigated and the results indicate that revised SOPs identifying the standard configuration and procedures for operating this configuration are mandatory. Once these procedures are initiated and complied with, patching will no longer create adverse conditions to the project or DSN.

SFOF timing. A new timing system was implemented in the SFOF and used for the *Surveyor* mission. This system is synced with the Lab Standard each day and has demonstrated a deviation of 50–70 ms per day. On May 3, 1967, the oscillator was adjusted and the current deviation is on the microsecond level.

Table 42 shows *Surveyor III* mission problems encountered.

VII. *Surveyor IV* Mission Synopsis

A. Introduction

The *Surveyor IV* mission TDS consisted of those activities, agencies and organizations associated with the preparation, testing, and support of pre-launch, launch and flight operations.

For *Surveyor* missions the TDS performs tracking, in-flight control and data acquisition functions. To accomplish this task, the TDS is configured to include the launch facilities and tracking capabilities of the: (1) AFETR, (2) GSFC, MSFN, (3) the DSN, (4) SFOF at JPL, and (5) the GCF for transmitting the acquired tracking and telemetry data to the required organs within the tracking and data system.

B. Mission Synopsis

Following a very smooth countdown, with the exception of a 29 s *Centaur* stage hold at $T - 40$ s, and a possible receiver anomaly reported by the launch facilities at the AFETR, *Surveyor IV* was launched from launch pad 36A toward its target in the Central Bay (Sinus Medii) of the moon on day 195 at 11:53:29 GMT,* July 14, 1967. The mission was normal in all respects until terminal descent. At $L + 62{:}09{:}12$, (approximately 2 min and 20 s prior to the predicted touchdown time), all contact with the spacecraft was lost; less than 2 s remained before the expected retro engine burnout. Efforts to reestablish contact with the spacecraft were unsuccessful.

*All times are Greenwich Mean Time (GMT) unless otherwise noted.

Table 43. *Surveyor IV* mission milestones

Event	Date, PDT	Time: PDT	Time: Time after launch
Launch	July 14, 1967	04:53:29	0
Injection		05:04:50	11:21
Separation			
(1) Electrical disconnect		05:05:59	12:30
(2) Mechanical separation		05:06:05	12:36
Automatic sun acquisition completed		05:10:21	16:52
Automatic solar panel deployment completed		05:16:06	22:37
Spacecraft visibility at Ascension Island begins		05:04:53	16:24
Initial DSIF acquisition (2-way lock) confirmed		05:14:03	20:34
First ground command sequence initiated		05:29:46	36:17
Canopus verification started		10:51:27	5:57:56
Canopus acquisition completed		11:10:29	6:16:53
First pre-midcourse attitude maneuver initiated	July 15, 1967	19:15:29	38:22:00
Midcourse thrust executed		19:30:02	38:36:33
Sun reacquired		19:34:40	38:41:11
Canopus reacquired		19:40:57	38:47:28
First terminal descent attitude maneuver initiated	July 16, 1967	18:24:44	61:31:15
Retro thrust direction properly positioned		18:32:41	61:39:12
Final roll completed		18:35:56	61:42:27
Altitude marking radar mark generated		19:01:56.339	62:08:27.339
Vernier engine ignition		19:01:59.039	62:08:30.039
Retro engine ignition		19:02:00.139	62:08:31.139
Spacecraft signal disappeared		19:02:41.037	62:09:17.037

Table 43 is a timetable that indicates the time at which major milestones of the mission occurred. In order to accomplish all operations, 322 commands were sent to the spacecraft.

The launch vehicle, AC-11, was a direct-ascent vehicle and was the last of its type. This launch was accomplished during the second window; the first attempt was canceled due to a connector problem in the *Centaur* stage. All aspects of the mission went according to plan with no problems or anomalies interfering with the flight. It was decided to conduct the midcourse correction at $L + 39$ h instead of the nominal $L + 16$ h because calculations indicated that a higher degree of accuracy in attaining the landing site would be achieved by using the later midcourse correction time.

Injection, separation, sun acquisition, solar panel deployment, DSIF acquisition, initial commanding and interrogations, Canopus verification and acquisition, midcourse maneuvers and thrusting, and terminal maneuvers were all successfully executed and completed. Terminal descent proceeded normally through ignition and up to loss of signal during retro burn.

Throughout the transit phase through loss of spacecraft signal, the *Surveyor* mission was conducted during the period of July 14, 1967 (GMT day 195) through July 17, 1967 (GMT day 198) with the spacecraft correctly responding to 322 commands. The launch was delayed until the second opportunity on July 14, 1967, at 11:53:00 GMT, day 195. The final countdown of the *Atlas-Centaur/Surveyor* on pad 36A proceeded smoothly until approximately $T - 40$ s when an approximate 29 s hold was called to verify the liquid hydrogen level of the *Centaur* vehicle. Liftoff was accomplished at 11:53:29.215 GMT on day 195, with a launch azimuth of 103.82 deg. The performance of the *Atlas/Centaur* launch vehicle appeared excellent throughout its flight period as all *Mark* events occurred very close to the predicted times.

A summary of the mission profile is contained in Table 44. Injection of the spacecraft occurred at 12:04:57.2 GMT on day 195 on a trajectory that would have provided, with no midcourse correction, a total miss of approximately 110 mi from the target landing site within the Central Bay of 0.58 deg N and 0.83 deg W. All spacecraft programmed flight events (high power, extend landing legs and extend omnidirectional antennas A and B) were successfully completed and verified in real time. The *Surveyor IV* spacecraft was physically separated from the *Centaur* at 12:06:06.1 GMT. The sun was acquired, the sun sensor primary cell-lock-on indicated at approximately 12:10:21, and the automatic sun acquisition sequence completed at 12:11:04.

Table 44. Mission profile

Time[a]		Command sequence		Event
Time after launch, $L+$	GMT[b]	Major	Minor	
Mission phase: launch to separation				
0	11:53:29.215 (July 14, 1967)	—	—	Launch
11:57	12:05:26	—	—	Extend landing gears commanded by *Centaur*
12:09	12:05:38	—	—	Extend omni-antennas commanded by *Centaur*
12:35	12:06:04	—	—	Transmitter high voltage on commanded by *Centaur*
12:33	12:06:02	—	—	Spacecraft/*Centaur* electrical disconnect
		—	—	Separation
15.24	12:08:53	—	—	Sun acquisition cell illuminated (after 59-deg roll)
16:52	12:10:21	—	—	Sun lock-on achieved (primary sun sensor cell illuminated after 44-deg yaw)
18:30	12:11:59	—	—	Solar panel locked in transit position
22:37	12:16:06	—	—	Roll axis locked in transit position
		—	—	Initial DSIF acquisition completed (2-way lock)

Table 44 (contd)

Time[a]		Command sequence		Event
Time after launch, L+	GMT[b]	Major	Minor	
Mission phase: DSIF acquisition through star acquisition				
36:17	12:29:46	0040	0052	Initial 100 bits/s selection (change from 550 bits/s—low modulation index)
40:39	12:34:08	0040	0552	Turn off S/C high-power transmitter
44:45	12:38:14	0040	0050	Turn off accel. amplifiers and solar panel deployment logic
46:01	12:39:30	0040	0454	"Rocking" solar panel back and forth to seat locking pin
47:04	12:40:33	0040	0455	"Rocking" roll axis back and forth to seat locking pin
47:57	12:41:33	0040	0051	Mode 1 interrogation
50:11	12:43:40	0040	0055	Mode 4 interrogation
53:20	12:46:49	0040	0251	Mode 2 interrogation
56:20	12:49:49	0040	1356	Mode 6 interrogation
58:18	12:51:47	0040	1354	Return to Mode 5 for coast phase monitoring
3:29:18	15:22:47	0040	0054	Flight control commanded to cruise mode
5:33:29	17:26:58	0046	0250	Start of pre-star-verification engineering interrogation
5:33:37	17:27:06	0046	0250	Mode 4 interrogation
5:35:42	17:29:11	0046	0251	Mode 2 interrogation
5:37:34	17:31:04	0046	0252	Mode 1 interrogation
5:39:53	17:33:22	0046	0550	Return to Mode 5
5:51:21	17:44:05	0041	0652	Transmitter filament turn on
5:53:05	17:46:34	0041	0653	Transmitter high voltage turn on
5:54:17	17:47:47	0041	7B1	Selection of 4400 bits/s (change from 1100 bits/s)
5:56:34	17:50:04	0041	0654	Manual delay mode and positive angle maneuver commanded
5:57:57	17:51:27	0041	1251	Start of roll
6:14:29	18:07:59	0041	0655	Star acquisition mode commanded to permit automatic star lock on to occur
6:19:20	18:12:54	0041	0054	Cruise mode on
6:20:05	18:13:34		7A2	Return to 1100 bits/s
6:21:21	18:14:50	0041	0552	Turn off of transmitter high power
Mission phase: Coast I				
7:10:32	18:46:01	0041	0354	Initiate gyro drift check No. 1, 3 axis
9:00:45	20:54:14	0041	0054	Terminate gyro drift check
9:04:14	20:57:43		0354	Initiate gyro drift check No. 2, 3 axis
10:43:55	22:37:24		0054	Terminate gyro drift check
12:05:34	23:59:03	0046	0250	Mode 4 interrogation
12:09:13	00:02:42	0046	0251	Mode 2 interrogation
12:14:17	00:07:46	0046	0550	Return to Mode 5
12:15:56	00:09:25		0354	Initiate gyro drift check No. 3, 3 axis
14:15:55	02:09:24		0054	Terminate gyro drift check
14:25:23	02:18:52		0357	Initiate gyro drift check No. 4, roll axis only

Table 44 (contd)

Time[a]		Command sequence		Event
Time after launch, L+	GMT[b]	Major	Minor	
Mission phase: Coast I (contd)				
16:17:59	04:11:28		0250	Mode 4 interrogation
16:22:36	04:16:05		0251	Mode 2 interrogation
16:24:38	04:18:07		0550	Return to Mode 5
19:59:02	07:52:31		7B3	Reduce bit rate from 1100 to 550 bits/s
20:01:27	07:54:56		0054	Terminate gyro drift check
20:07:27	08:00:56		0354	Initiate gyro drift check No. 5, 3 axis
20:09:19	08:02:48		0250	Mode 4 interrogation
20:12:37	08:06:06		0251	Mode 2 interrogation
20:14:48	08:08:17		0550	Return to Mode 5
22:04:58	09:58:27		0054	Terminate gyro drift check
22:26:43	10:20:12		0354	Initiate gyro drift check No. 6, 3 axis
23:53:31	11:47:00		0054	Terminate gyro drift check
24:08:07	12:01:36		0250	Mode 4 interrogation
24:10:54	12:04:23		0251	Mode 2 interrogation
24:14:01	12:07:30		0550	Return to mode 5
28:06:21	15:59:50		0250	Mode 4 interrogation
28:10:27	16:03:56		0251	Mode 2 interrogation
28:13:44	16:07:13		0550	Return to Mode 5
28:15:04	16:08:33		0354	Initiate gyro drift check No. 7, 3 axis
29:45:04	17:38:33		0054	Terminate gyro drift check
30:09:48	18:03:17		0354	Initiate gyro drift check No. 8, 3 axis
31:49:07	19:42:36		0054	Terminate gyro drift check
33:46:20	21:39:49		0357	Initiate gyro drift check No. 9, roll only
34:33:57	22:27:26		0054	Terminate gyro drift check
36:17:58	00:11:27	0042	0250	Initiate premidcourse interrogation
36:18:05	00:11:34	0042	0250	Mode 4 interrogation
36:20:15	00:13:44	0042	0251	Mode 2 interrogation
36:22:17	00:15:46	0042	0252	Mode 1 interrogation
36:23:59	00:17:28	0042	0550	Return to Mode 5
Mission phase: midcourse correction				
36:24:56	00:18:25	0042	0350	Initiate gyro speed check
36:25:44	00:19:13	0042	0351	Select next gyro 3 times
36:28:29	00:21:58			Select next gyro one additional time
36:29:01	00:22:30	0042	0451	Gyro speed signal processing off and return to Mode 5
37:53:52	01:47:21	0043	0250	Initiate midcourse correction interrogation
37:53:59	01:47:28	0043	0250	Mode 4 interrogation
37:56:11	01:49:40	0043	0251	Mode 2 interrogation

Table 44 (contd)

Time[a]		Command sequence		Event
Time after launch, $L+$	GMT[b]	Major	Minor	
Mission phase: midcourse correction (contd)				
37:57:59	01:51:28	0043	0252	Mode 1 interrogation
38:07:05	02:00:34	0043	0652	Transmitter filament turn on
38:08:49	02:02:18	0043	0653	Transmitter high power turn on
38:09:48	02:03:17	0043	0253	Increase bit rate from 550 to 4400 bits/s
38:14:57	02:08:26	0403	1150	Command desired roll maneuver magnitude and direction (roll +72.5 deg)
38:22:00	02:15:29	0403	1251	Start of roll near zero crossing of Canopus error signal
38:25:05	02:18:34	0403	1151	Command desired yaw maneuver magnitude and direction (Yaw −64.3 deg)
38:27:41	02:21:10	0403	1253	Start of yaw near zero crossing of primary sun sensor error signal
38:30:32	02:24:01	0403	0251	Mode 2 interrogation
38:32:11	02:25:40	0403	0252	Return to Mode 1
38:32:41	02:26:10	0403	0751	Propulsion strain gage powered, inertial mode and reset, Group IV outputs commanded
38:33:56	02:27:25	0403	0750	Turn off cyclic loads SMSS, AMR, vernier line heaters
38:33:58	02:27:27	0740	0750	Pressurize vernier system (helium), unlock vernier engine No. 1
38:28:24	02:27:53	0043	0752	Thrust phase power on
38:34:48	02:28:17	0043	0753	Command desired thrust duration (10.475 s)
38:36:33	02:30:02	0043	0754	Execute midcourse thrust
38:36:46	02:30:15	0043.	0754	Command terminate thrust
38:37:01	02:30:30	0043	0754	Turn off thrust phase power
38:37:26	02:30:55	0043	0754	Turn off propulsion strain gage power
38:37:49	02:31:18	0043	0550	Operations to obtain coast mode data
38:38:21	02:31:50	0043	0755	Cyclic loads turned on. Vernier line, AMR, SMSS heaters
38:38:50	02:32:19	0043	1252	Command reverse yaw maneuver magnitude and direction (+64.3 deg)
38:39:24	02:32:53	0043	1253	Execute yaw (sun reacquired at 02:35:44)
38:42:58	02:36:27	0043	1250	Command reverse roll maneuver magnitude and direction (−72.5 deg)
38:43:56	02:37:25	0043	1251	Execute roll (Canopus reacquired at approximately 02:40:57)
Mission phase: Coast II				
38:47:54	02:41:23	0043	0157	Mode 2 interrogation
38:49:24	02:42:53	0043	0055	Mode 4 interrogation
38:50:54	02:44:23	0043	0550	Return to Mode 5
38:51:32	02:45:01	0043	0151	Reduce bit rate from 4400 to 550 bits/s
38:52:34	02:46:03	0043	0552	Turn off transmitter high power
40:22:29	04:15:58	0046	0354	Initiate gyro drift check No. 10, 3 axis
41:57:15	05:50:44	0046	0054	Terminate gyro drift check

Table 44 (contd)

Time[a]		Command sequence		Event
Time after launch, L+	GMT[b]	Major	Minor	
Mission phase: Coast II (contd)				
43:17:10	07:10:39	0046	0250	Mode 4 interrogation
43:19:43	07:13:12	0046	0251	Mode 2 interrogation
43:24:49	07:18:18	0046	0550	Return to Mode 5
44:04:48	07:58:17	0046	2053	Initial power mode cycling to determine load sharing of main and auxiliary batteries
44:57:30	08:50:59	0046	0357	Initiate gyro drift check No. 11, roll only
48:05:09	11:58:38	0046	0250	Mode 4 interrogation
48:08:27	12:01:56	0046	0251	Mode 2 interrogation
48:11:10	12:04:39	0046	0550	Return to Mode 5
49:09:02	13:02:31	0046	2054	Perform subsequent power mode cycling to determine battery load sharing and leave both batteries directly on line
50:42:49	14:36:18	0046	0054	Terminate gyro drift check
50:43:55	14:37:24	0046	1350	Vernier oxidizer tank No. 2 thermal control on
51:22:51	15:16:20	0046	0250	Mode 4 interrogation
51:26:29	15:19:58	0046	0251	Mode 2 interrogation
51:29:13	15:22:42	0046	0550	Return to Mode 5
51:47:06	15:40:35	0046	0354	Initiate gyro drift check No. 12, 3 axis
53:37:02	17:30:31	0046	0054	Terminate gyro drift check
53:46:13	17:39:42	0046	0354	Initiate gyro drift check No. 13, 3 axis
55:19:28	19:12:57	0046	0054	Terminate gyro drift check
55:30:35	19:24:04	0046	0250	Mode 4 interrogation
55:38:13	19:31:42	0046	0251	Mode 2 interrogation
55:47:57	19:41:26	0046	0550	Return to Mode 5
56:20:26	20:13:55	0046	2054	Subsequent power mode cycling
57:15:20	21:08:49	0046	1750	Survey TV electronics thermal control on
57:42:12	21:35:41	0046	0250	Mode 4 interrogation
57:45:08	21:38:37	0046	0550	Return to Mode 5
58:44:25	22:37:54	0046	0250	Mode 4 interrogation
58:46:46	22:40:15	0046	0251	Mode 2 interrogation
58:49:13	22:42:42	0046	0550	Return to Mode 5
59:52:08	23:45:37	0046	0250	Mode 4 interrogation
59:56:03	23:49:32	0046	0251	Mode 2 interrogation
59:58:03	23:51:32	0046	0252	Mode 1 interrogation
60:00:13	23:53:42	0046	0550	Return to Mode 5
Mission phase: terminal descent				
60:01:31	23:55:00	0046	0350	Initiate gyro speed check
60:02:25	23:55:44	0046	0351	Select next gyro 3 times
60:04:34	23:58:03	0046	0451	Return to Mode 5

Table 44 (contd)

Time[a]		Command sequence		Event
Time after launch, L+	GMT[b]	Major	Minor	
Mission phase: terminal descent (contd)				
60:07:28	00:00:57	0046	1050 1053	Narrow band VCXO check
61:06:00	00:59:29	0044	1355	Mode 6 interrogation
61:11:14	01:04:43	0044	0250	Mode 4 interrogation
61:12:45	01:06:14	0044	1757	Survey camera vidicon temperature control on
61:14:14	01:07:43	0044	0652	Transmitter filament turn on
61:15:51	01:09:26	0044	0653	Transmitter high power
61:16:26	01:09:55	0044	0255	Increase bit rate from 550 to 1100 bits/s
61:17:08	01:10:37	0044	2057	Pre-summing amplifier off
61:18:09	01:11:38	0044	0251	Mode 2 interrogation
61:19:35	01:13:04	0044	0550	Return to Mode 5
61:22:04	01:15:23	0044	1755	Propulsion strain gage power turned on
61:22:45	01:16:14	0044	1756	Touchdown strain gage power and SCOs turned on
61:23:40	01:17:09	0044	1050	Transponder power turned off and one way lock achieved
61:25:56	01:19:25	0044	1154	Cruise mode commanded
61:25:56	01:19:25	0044	1154	Roll maneuver magnitude and direction commanded (+80.9 deg)
61:31:15	01:24:44	0044	1251	Execute sun and roll at Canopus error signal null
61:34:23	01:27:52	0044	1155	Yaw magnitude and direction command (+92.7 deg)
61:36:05	01:29:34	0044	1253	Execute yaw at primary sun sensor yaw error null (retro thrust direction aligned properly)
61:39:40	01:33:09	0044	1157	Roll maneuver magnitude and direction commanded (−25.3 deg)
61:41:36	01:35:05	0044	1257	Roll executed
61:47:20	01:40:49	0044	1751, 1656	Vernier thrust level (200 lb) for retro phase and delay between AMR mark and vernier ignition (2.725 s) commanded
61:50:13	01:43:42	0044	1355	Command on Mode 6 data
61:51:34	01:45:03		1652	Command reset Group IV outputs
62:02:51	01:56:20	0044	1657	Retro sequence mode on commanded
62:03:11	01:56:40	0044	1752	Vernier lines and tanks SMSS, TV, and AMR thermal control commanded off
62:03:46	01:57:15	0044	1753	AMR on
62:04:46	01:58:15	0044	1754	Thrust phase power on
62:06:46	02:00:15	0044	2051	AMR enabled
62:08:25	02:01:54	0044	2051	Back-Up AMR mark commanded
		—	—	AMR mark
		—	—	Vernier ignition
		—	—	Retro ignition
62:08:27.339	02:01:56.339[c]	—	—	RADVS on
62:08:30.039	02:01:59.039[c]	—	—	RADVS
62:08:31.139	02:02:00.139[c]	—	—	RORA

Table 44 (contd)

Time[a]		Command sequence		Event
Time after launch, $L+$	GMT[b]	Major	Minor	
Mission phase: terminal descent (contd)				
62:09:57	02:03:26	0044	2152	Pre-summing amplifier on commanded (to get touchdown strain gage data)

[a]Times listed are from TM Data received in Performance Analysis Area at SFOF (i.e., Includes transit time from spacecraft to ground, SFOF processing delay, and commutation delay).

[b]Subtract 8 h from GMT values to obtain PST.

[c]Based on reduced data obtained directly from the 96 kHz microwave link data (1.21 s must be subtracted to account for RF propagation).

DSN stations utilized in a prime capacity were: DSS 11 (Pioneer) at Goldstone, California; DSS 42 (Tidbinbilla) at Canberra, Australia; DSS 51 at Johannesburg, So. Africa; DSS 61 (Robledo) at Madrid, Spain; DSS 71 (AFETR) at Cape Kennedy, Florida; and DSS 72 at Ascension Island. DSS 14 (Mars) was committed in real time to support the *Surveyor* program for the first time and was used during the terminal descent phase as a back up to DSS 11. DSS 12 (Echo) was employed, in addition to DSS 11 and 14, in an attempt to regain contact with the spacecraft after signal was lost by DSSs 11 and 14 during terminal descent.

During initial DSN acquisition one-way lock was accomplished by DSS 72 (Ascension Island) at 12:10:07 GMT with two-way lock established at 12:14:00 with a signal strength of −90 dBmW. DSS 51 acquired the spacecraft in one-way at 12:16:00 GMT with a signal strength of −113.6 dBmW. Initial spacecraft operations were started at 12:29:46 GMT with the increasing of the spacecraft bit rate to 1100 bits/s from 550 bits/s. This operation was a deviation from specifications in order to assure data for DSS 72. Transmitter high power was commanded off at 12:34:08 GMT after 28 min and 8 s of high power operation. Initial spacecraft operation was completed at 12:51:47 GMT with the spacecraft configured in low power, coast phase commutator on and transmitting at 1100 bits/s. The flight control cruise mode on command (0704) was not transmitted at the planned time due to a high-intensity signal indication in the Canopus intensity channel. However, cruise mode was transmitted, and receipt by the spacecraft verified at 15:22:47 GMT.

The real-time operational assessment indicated that the *Surveyor IV* performance as well as that of the entire TDS supporting the mission was practically flawless up to the moment of loss of signal during retro burn. At that time, an attempt was made to back up the flight control programmer with an emergency command sequence to ensure a soft landing in deference to working a possible data link/power anomaly. The standard command to turn-on strain gauge modulation preceded the emergency command and was transmitted in the blind according to a planned command countdown at 02:03:26.5 GMT. Spacecraft modulation was commanded off 66 s later to increase the chance of carrier detection by the tracking stations. This action reflected confidence in a soft landing and in a successful resolution of the telecommunications/power anomaly after touchdown.

During Coast Phase I and prior to star map some unidentified objects passed through the Canopus sensor field of view at approximately 15:27:00, 16:04:00, 16:16:00 and 16:36:20 GMT. Star map sequence was commenced at 17:51:26.9 and automatic Canopus acquisition was accomplished at 18:10:22 after some 572 deg of roll. During the star mapping sequence four stars (Eta Ursae Majoris, Delta Velorum, Gamma Cassiopeiae, and Canopus), the earth and the moon were positively identified. In addition to the above celestial bodies, one unidentified object was observed during the second roll of the star map. During the standard pre-midcourse project management conferences, it was decided by project management not to execute an $L + 15$ h midcourse but to delay the midcourse correction until $L + 39$ h. This decision was primarily based on the excellent injection conditions of the spacecraft and the expected overall landing site accuracy improvement obtained by executing the maneuvers at 39 h rather than 15 h.

During Coast Phase I, there were six standard engineering assessments, nine gyro drift checks and one gyro speed check. The spacecraft bit rate was reduced from 1100 to 550 bits/s at 07:52:47.2 on day 196 when DSS 42 reported a bit error rate of greater than 3×10^{-3}. Spacecraft data continuously gave indications that all subsystems were normal and within their predicted operational limits.

However, the temperature (P-15) of vernier oxidizer tank No. 1 showed an unexplainable and rapid increase (rate of 5 BCD per hour) at 19:24:00 GMT on day 196. At 20:19, the temperature stabilized at approximately 52°F, well within the upper temperature limit of 100°F.

Midcourse preparation was initiated at 01:47:21 GMT on day 197 with an engineering interrogation. The spacecraft was configured in high power and 4400 bits/s at 02:03:17. A pre-midcourse correction maneuver of a plus roll of approximately 72.497 deg (desired 72.5 deg) was successfully executed at 02:15:29 GMT and followed by a successful minus yaw of approximately 64.35 deg (desired 64.3 deg). The vernier engines system was pressurized (offset of 217 psi noted, as expected) and vernier engine No. 1 unlocked at 02:27:27 on day 197. Thrust phase power was commanded and verified at 02:27:53. Midcourse velocity correction was loaded and verified at 02:28:17. At 02:30:02.3 (the scheduled nominal time), the midcourse velocity correction was executed with a burn of approximately 10.5 s (desired 10.46 s) for a velocity change of 10.27 m/s. The SFOF TLM verification and doppler shift indicated that the velocity correction was as commanded. Following the midcourse thrust, the reverse maneuvers were commanded. Sun and Canopus lock on signals were obtained at 02:34:37 and 02:39:41 respectively on day 197. The midcourse maneuvers corrected the miss distance of the inflight lunar aiming points of 1°20'W and 0°25'N to a real-time calculated miss of 3–6 mi. It should be noted that during the pre-midcourse and post-midcourse maneuvers several unidentified and unexplained objects passed through the Canopus field of view. During the pre-midcourse maneuver execution, a new commanding technique was used with the objective of reducing the spacecraft pointing error: the gyro error limit cycle was observed and each maneuver executed when the respective gyro error was at zero or as near to zero as practical.

Following the post-midcourse maneuvers, the spacecraft was configured for Coast Phase II by returning to coast commutator low power and 550 bits/s (550 bits/s was used up to terminal descent as was the case with *Surveyor I*). Coast Phase II was very normal as four gyro drift checks, six engineering interrogations and one gyro speed check were performed. Initial power mode cycling was conducted at 07:58:17 on day 197 and subsequent power mode cycling was conducted at 13:02:32 and 20:13:55 on day 197.

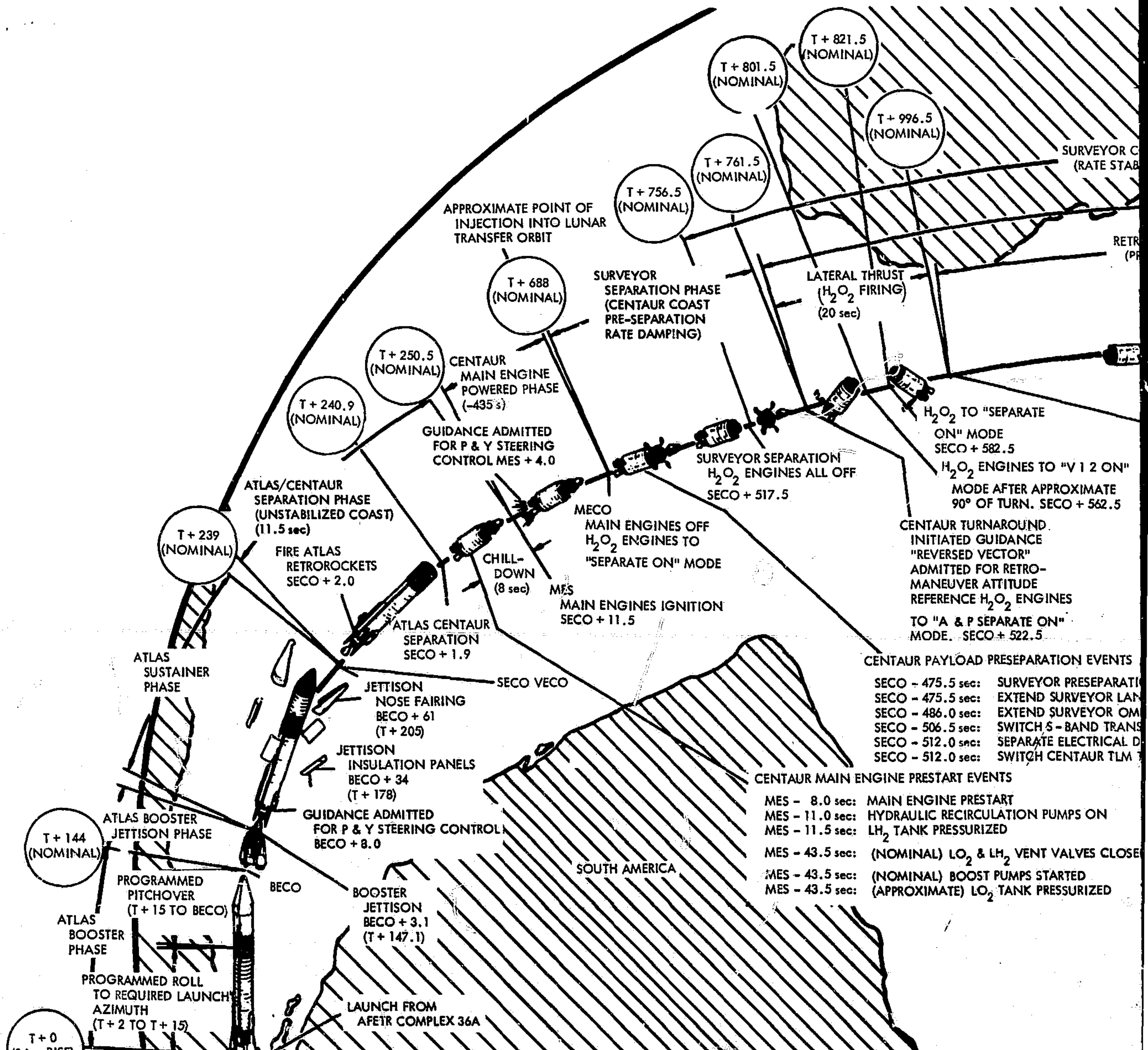
During the transit phase 13 gyro drift checks were performed; this relatively large number of drift checks was performed to refine the pitch gyro drift rate which indicated near or above specification. The final gyro drift rates supplied for utilization during the terminal descent were: (1) pitch −1.0 deg/h; (2) yaw +0.15 deg/h; and (3) roll −0.5 deg/h.

Terminal descent preparations were initiated during the DSS 11 pass at 00:00:57 on day 198 by turning the transponders off. The spacecraft was then assessed and configured as follows: (1) high power; (2) 1100 bits/s; (3) transmitter B; and (4) omnidirectional antenna B. The spacecraft was commanded and successfully performed the following three terminal maneuvers: (1) roll of +80.4 deg; (2) yaw of +92.7 deg; and (3) roll of −25.3 deg. These maneuvers were initiated at 01:24:44, 01:29:34 and 01:35:04 respectively on day 198. Once again, to more accurately align the thrust vector, the commanding technique used during midcourse was implemented to initiate the first two terminal maneuvers.

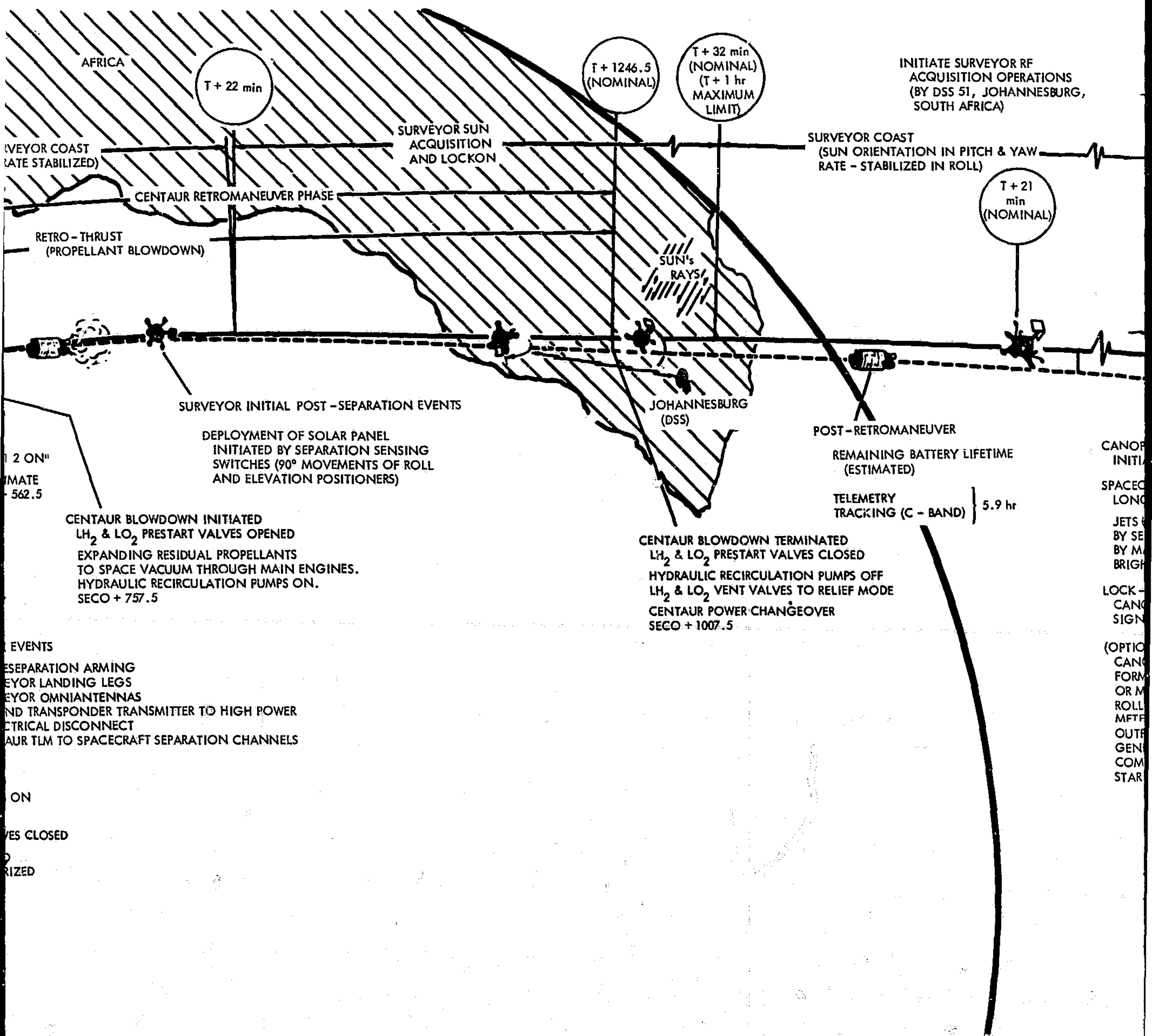
The DSIF signal strength at the end of the third maneuver was reported as −123.9 dBmW (the predicted signal strength at this time was within 0.2 dBmW), well within the −132.7 dBmW touchdown strain gauge turn-on criteria. The retro delay quantity of 2.725 s was loaded and verified at 01:41:53 GMT. The AMR power on was commanded at 01:57:14, thrust phase power on at 01:58:14 and enable AMR at 02:00:14.

The terminal descent maneuver started normally and continued very smoothly until 02:02:36 GMT on day 198 (Monday, July 17, 1967) when there was an abrupt loss of signal. Up to this point, the spacecraft had performed almost perfectly and had responded to 292 commands. The loss of signal occurred 40 s into the retro burn phase of the mission, just 2 s prior to retro burnout. At 02:02:41 DSS 11 reported an abrupt loss of spacecraft signal. The spacecraft signal was never reacquired by the DSIF and the mission was terminated.

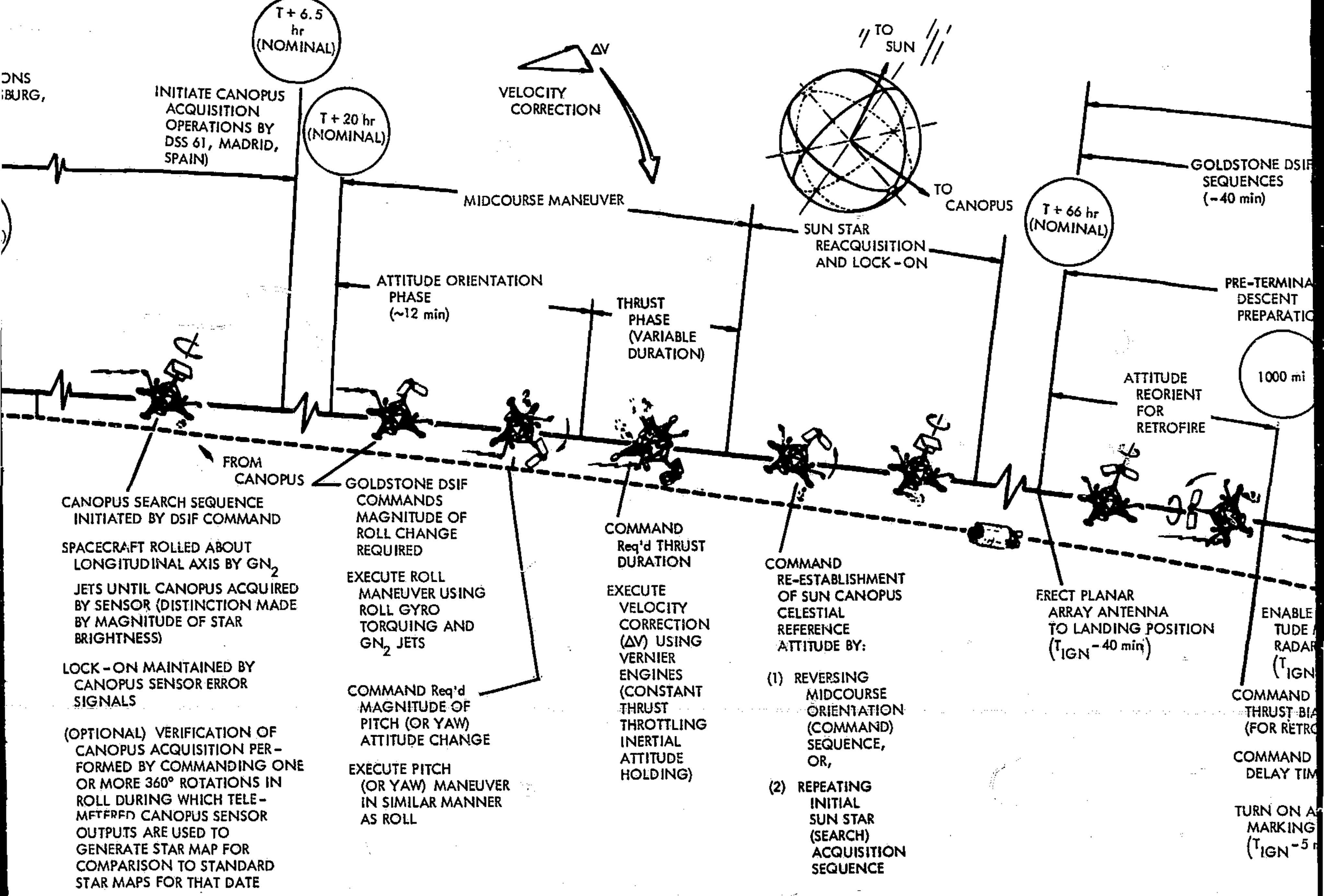
Figure 106 shows the *Surveyor IV* mission flight sequence in the direct ascent trajectory.



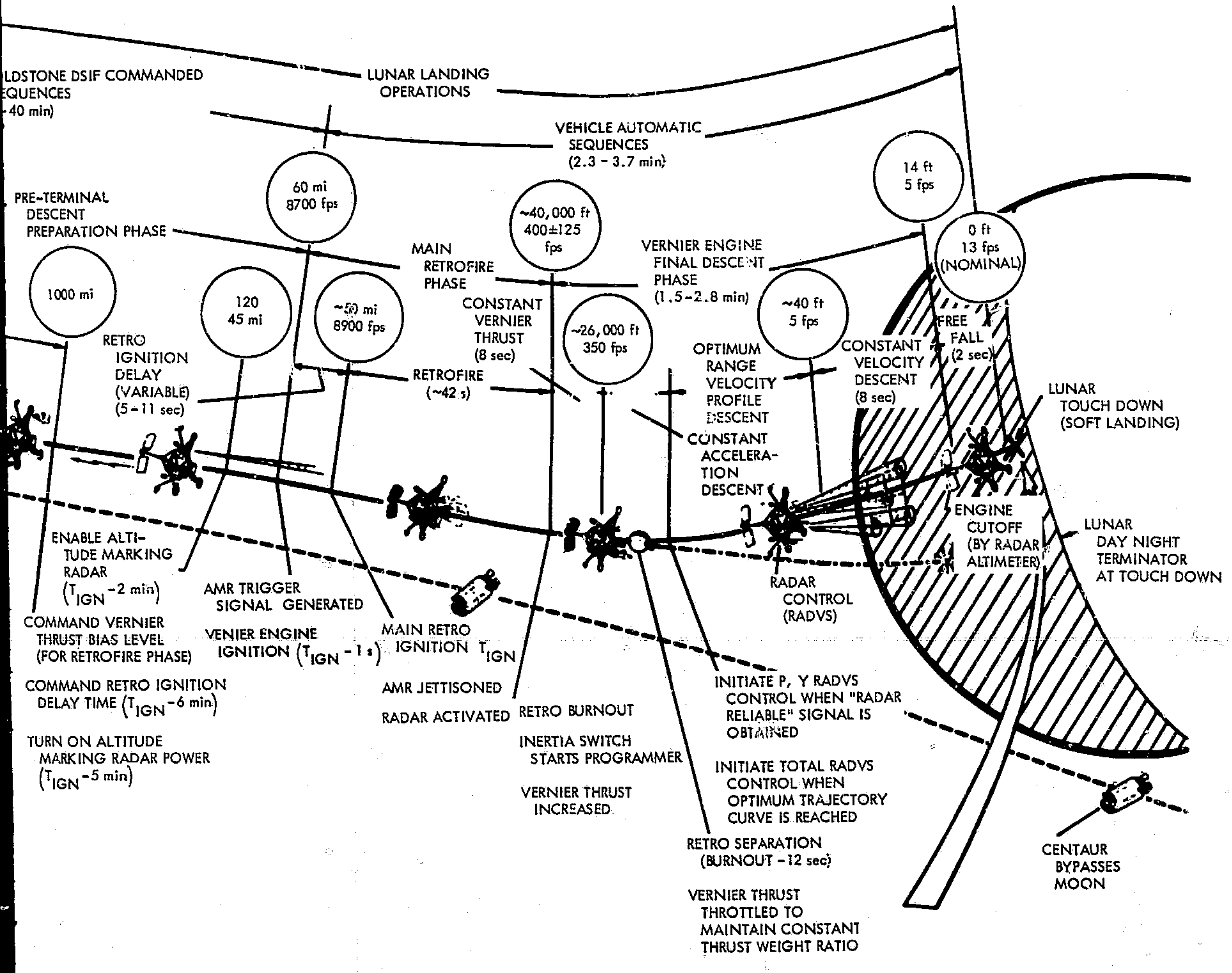
FOLDOUT FRAME



FOLDOUT FRAME 2



FOLDOUT FRAME 3



FOLDOUT FRAME 4 **Fig. 106.** ***Surveyor IV mission flight sequence***

PRECEDING PAGE BLANK NOT FILMED.

VIII. *Surveyor IV* TDS Mission Requirements

A. General

In general the TDS requirements for the *Surveyor IV* mission were the same as for *Surveyor III*; only the differences in requirements between the two missions are discussed in their related categories.

The *Surveyor IV* mission objectives were similar to those for *Surveyor III* and were as follows:

(1) Primary objectives were to:

  (a) Perform a soft landing on the moon within the *Apollo* landing zone and east of the *Surveyor I* landing site.

  (b) Obtain post-landing television pictures of the lunar surface.

(2) Secondary objectives were to:

  (a) Obtain information on lunar surface bearing strength, radar reflectivity and thermal properties.

  (b) Use the surface sampler to manipulate the lunar surface and observe the effects with the television camera.

The only landing site planned for the *Surveyor IV* mission was located at the center of the lunar disk; that is, at approximately 0.0 deg. This area is called Sinus Medii, a prime *Apollo* landing site, and is shown in Fig. 107. The potential *Apollo* landing sites are contained in the area bounded by ±45 deg in longitude and ±5 deg in latitude. The landing site assignments for particular *Surveyor* spacecraft, based on the success of the preceding missions, are also indicated in the above figure.

Except for the different landing site, the mission objectives of *Surveyor IV* were very similar to those of *Surveyor III*. The *Surveyor IV* spacecraft was equipped with a surface sampler; for the following two missions, *Surveyors V* and *VI*, the spacecraft will carry an alpha-scattering experiment in place of the surface sampler.

The ability of the TDS to satisfy the *Surveyor* project's tracking and telemetry coverage requirements was

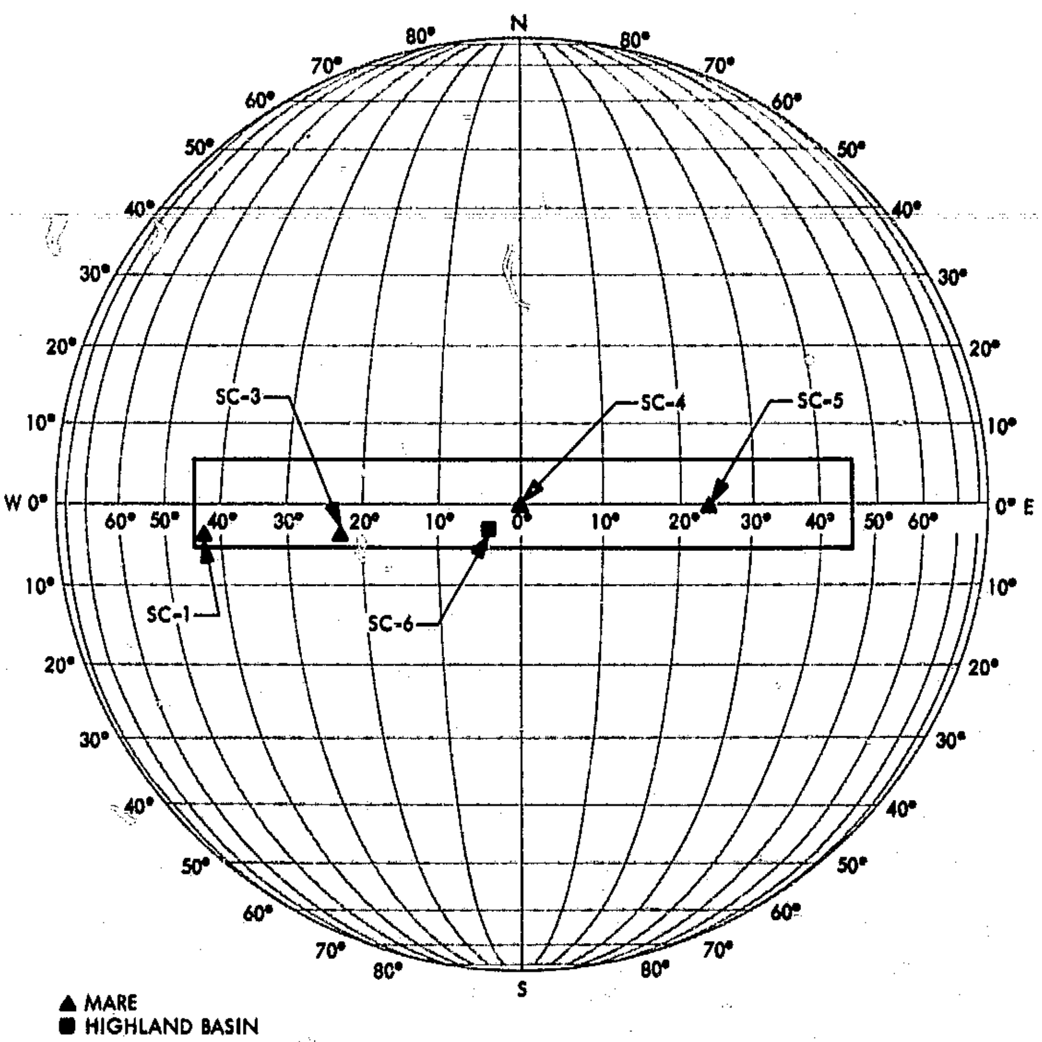


Fig. 107. *Surveyor* lunar landing sites

strongly dependent upon the characteristics of the trajectories, the availability of the TDS resources, and the capability of these resources.

B. Mission Constraints

If the TDS was to successfully provide the committed support to the *Surveyor IV* mission, it was necessary that certain mission constraints be observed.

1. Launch. For launch:

(1) The *Atlas/Centaur* boost vehicle was to be used in the direct ascent mode of operation.

(2) Launch was to take place from complex 36A of the Cape Kennedy facilities of the AFETR.

(3) Launch azimuth sectors were restricted between 85 deg and 120 deg E of true N.

(4) The launch countdown was to provide two built-in holds, one of at least 60-min duration at $T - 90$ min. The duration of the hold at $T - 5$ min was to be established.

2. Pre-injection. For pre-injection:

(1) The nose fairing was to be ejected prior to injection, but not until the value of the product of the atmospheric density and the earth-fixed velocity (ρV^3) was less than 1.0×10^4 lb/s^3.

(2) The 3-σ integrated value of ρV^3, from shroud jettison through the end of significant aerodynamic heating effects, was not to exceed 16,600 lb-min/s^3.

(3) Subsequent to 1 min after shroud ejection, the instantaneous 3-σ value of the aerodynamic heating parameter, ρV^3, was not to exceed 5020 lb/s^3.

(4) The instantaneous 3-σ value of ρV^3 was not to exceed 500 lb/s^3 during the period between 1 and 5 min after shroud ejection unless the total integral was less than 16,600 lb-min/s^3.

3. Post-injection. For post-injection:

(1) The *Centaur* retro maneuver was to be such that the *Surveyor/Centaur* separation distance at 5 h after injection would be at least 336 km.

(2) The targeted trajectories were to require no more than a 2 m/s midcourse maneuver at 20 h after injection to achieve the specified landing location, and a 4 m/s midcourse maneuver at 20 h after injection to achieve all specified target criteria.

4. Telecommunications. For telecommunications:

(1) No trajectory was to have an hour angle or declination rate in excess of 0.85 deg/s and acceleration in either hour angle or declination in excess of 5.0 deg/s^2 when station tracking was required.

(2) For the downlink initial acquisition phase following injection, there was to be 20 min of visibility (not in violation of item 1) and for which the spacecraft slant range would ensure at least 95% confidence in having the antenna gain required for zero minimum margin.

(3) For the uplink acquisition phase following injection, there was to be 20 min of visibility (not in violation of item 1) and for which the spacecraft slant range would ensure at least 99% confidence in having the antenna gain required for zero minimum margin.

(4) The spacecraft-centered angle between the sun and any DSIF station was not to exceed 175 deg to prevent degradation of the DSIF receiver sensitivity by solar noise. This constraint guaranteed that signal-to-noise ratios would not be degraded by more than 1 dB.

(5) The Mars station (DSS 14), the 210-ft disk at Goldstone, was required for telemetry acquisition during terminal descent phase.

5. Thermal control. For thermal control:

(1) The spacecraft was to be limited to a maximum of 42 min in the earth's shadow immediately after launch.

(2) The spacecraft was to be limited to a maximum of 30 min in the earth's shadow during any phase after initial sun acquisition.

(3) The spacecraft was to be limited to a maximum of 30 min at a random attitude to the sun during any phase between initial sun acquisition and lunar touchdown.

(4) The spacecraft was to be limited to a maximum of 30 min in the lunar penumbra shadow during any phase prior to touchdown.

(5) Initial spacecraft acquisition and the establishment of a command link were to occur no later than 1 h after the high power on command in order to permit switching the transmitter from high to low power to satisfy thermal constraints.

6. Midcourse maneuver. For midcourse:

(1) The spacecraft was to be capable of performing midcourse maneuvers at rates as great as 43 m/s. Nominal midcourse maneuver time was to be approximately 15 h after launch.

(2) A minimum midcourse maneuver would not be required.

(3) The landing accuracy goal was to be less than or equal to 30 km.

7. Lunar arrival. For lunar arrival:

(1) Flight time from injection to lunar impact was to be in the 63-h range.

(2) Transit trajectories were to be designed so that lunar arrival would occur no earlier than 2 h after DSS 11 (Goldstone, Pioneer Station) moonrise and no later than 3 h before DSS 11 moonset. (These constraints were to apply only to targeting. The visibility constraints to be used at midcourse were: earliest arrival, 80 min after DSS 11 rise; latest arrival, 3 h before DSS 11 set.) Furthermore, DSS 11 post-landing visibility was to be maximized.

(3) It was desired that landing occur before the sun elevation angle exceeded 25 deg at the landing site.

8. Terminal descent. For terminal descent:

(1) The incidence angle at unbraked impact was not to be greater than 45 deg from the vertical.

(2) The range of allowable nominal unbraked impact speed was from 2650 to 2662 m/s.

(3) The landed spacecraft roll orientation was to be when the sun azimuth was 14 deg past the −X axis in the direction of the −Y axis.

C. Trajectory Characteristics

The tracking and telemetry data requirements for the TDS were also dependent upon the following *Surveyor IV* trajectory characteristics and available launch windows.

1. Pre-injection. Of the remaining missions (*Surveyor IV–VII*) *Surveyor IV* was the only one to use the direct ascent launch mode. In this mode, the transfer orbit injection conditions are achieved with a single *Centaur*-powered phase; this (MECO) occurs at approximately $L + 680$ s.

The powered flight phase was shaped to maximize payload capability within the specified mission configuration

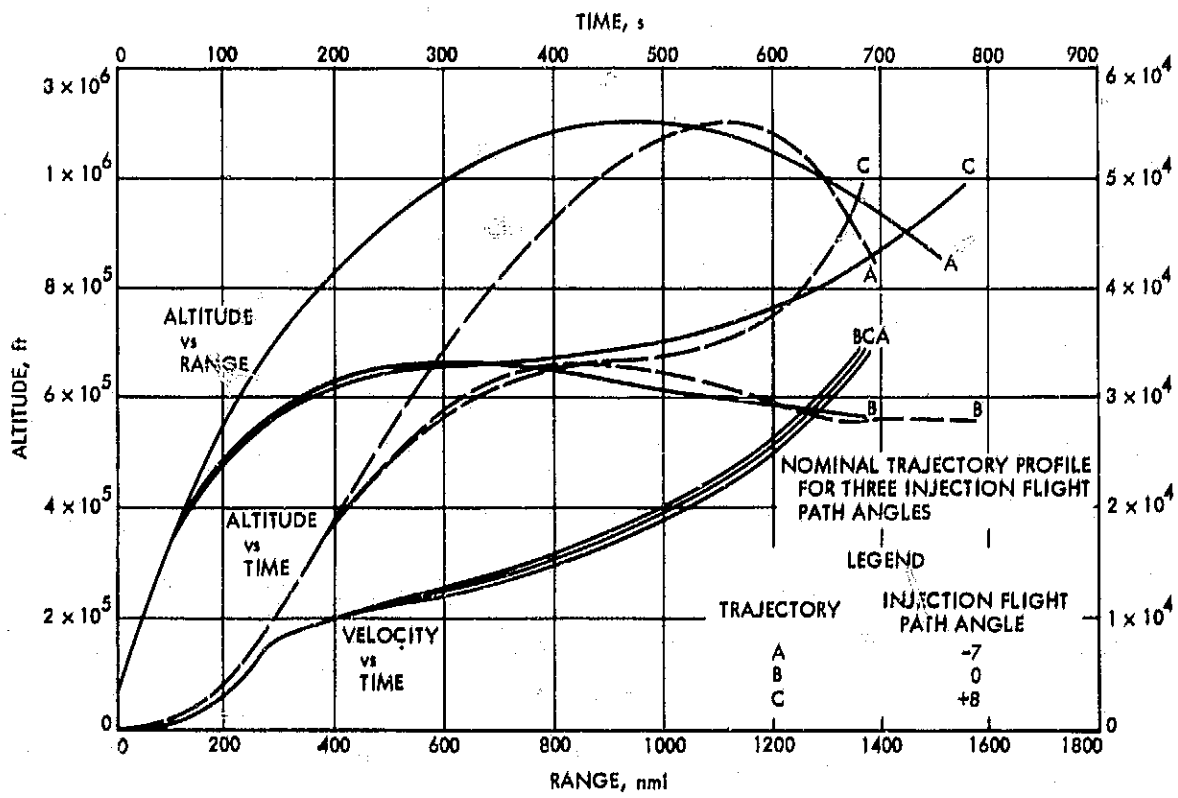


Fig. 108. Pre-injection trajectory parameters

Table 45. *Surveyor IV* mission target criteria

Launch date, GMT			Landing location selenographic		Impact speed, m/s	Arrival time constraints[a]									
						Earliest arrival					Latest arrival				
						Date			GMT		Date			GMT	
Day	Month	Year	Latitude, deg	Longitude, deg		Day	Month	Year	Hour	Min	Day	Month	Year	Hour	Min
13	July	1967	0.58N	0.83W	2650						16	July	1967	04	40
13	July	1967	0.58N	0.83W	2662	15	July	1967	23	56					
14	July	1967	0.58N	0.83W	2662	17	July	1967	01	10					
15	July	1967	0.58N	0.83W	2662	18	July	1967	02	25					
16	July	1967	0.58N	0.83W	2662	19	July	1967	03	42					
17	July	1967	0.58N	0.83W	2662	20	July	1967	04	46					
10	Aug	1967	0.58N	0.83W	2662	12	Aug	1967	23	01					
11	Aug	1967	0.58N	0.83W	2662	14	Aug	1967	00	16					
12	Aug	1967	0.58N	0.83W	2662	15	Aug	1967	01	32					
13	Aug	1967	0.58N	0.83W	2662	16	Aug	1967	02	39					
14	Aug	1967	0.58N	0.83W	2662	17	Aug	1967	03	34					
15	Aug	1967	0.58N	0.83W	2662	18	Aug	1967	04	14					

[a]Constraint specified only when applicable.

and trajectory constraints. Nominal ascent trajectory profiles are presented in Fig. 108. In Fig. 108, the three profiles represent three different injection flight path angles for the range of applicable values.

2. Post-injection. The transfer trajectories were highly elliptical earth orbits with injection conditions that satisfied arrival requirements specified by the target criteria listed in Table 45. These criteria consisted of the landing site defined by the selenographic latitude and longitude, the unbraked impact speed, and the earliest and latest arrival time for each launch day.

The range of values for the key injection parameters is given in Table 46. The more negative values of injection energy are applicable to the first day in the launch period and increase throughout the period.

Table 46. Key injection parameters

Inertial flight path angle	−3.40 to +7.20 deg
Injection energy	−1.54 to −1.22 km²/s²
Flight time	≈ 62.5 h

3. Launch windows. Table 47 lists the launch windows determined from the defined constraints. It should be noted that these windows do not reflect launch vehicle heating constraints or constraints due to inadequacies in the TDS support of class I tracking and/or telemetry coverage requirements. Specifically, the windows shown in the table are constrained by launch vehicle performance, by range safety launch azimuth constraints, and by the spacecraft impact speed constraint.

Requirements for tracking and data acquisition were placed in accordance with their importance to the successful accomplishment of the mission and were grouped into three classes. The classes were defined as follows:

(1) The class I requirements reflect minimum essential needs to ensure accomplishment of the primary flight objectives. These are mandatory requirements which if not met may result in the decision not to launch.

(2) The class II requirements define the needs to accomplish all stated flight objectives.

Table 47. July 1967 trajectory characteristics for *Surveyor IV*

Launch date, 1967 GMT	Launch window[a]							Landing conditions							
	GMT		PDT		Dur, min	Azimuth, deg		Site no.	Γ, deg	Hours from sunrise	Hours from sunset	Sun el, deg	Arrival window, h:min	Rise margin, h:min	Set margin, h:min
	Open, h:min	Close, h:min	Open, h:min	Close, h:min		Open	Close								
July 13	11:03	11:22	4:03	4:22	19	113.7	120.0[b]	1WIN	36	35	319	17	0:21	6:22	3:00
14	11:40	12:30	4:40	5:30	50	101.0	115.0	1WIN	32	56	298	29	1:31	2:46	4:52
15	12:32	14:02	5:32	7:02	90	90.2	115.0	1WIN	31	81	273	41	1:31	2:01	5:02
16	13:44	15:08	6:44	8:08	84	85.9	100.8	1WIN	29	106	248	54	0:01	2:00	6:00
17	14:43	16:10	7:43	9:10	87	84.3	97.5	1WIN	28	131	223	67	0:16	2:00	5:44

[a]Earth shadow constraint will not be violated during any launch window herein.

[b]120-deg closing launch azimuth not yet approved by AFETR range safety.

Note: Performance constraint: nominal excess propellant $\geq$ 235 lb.

Nomenclature

GMT: Greenwich Mean Time

PDT: Pacific Daylight Time (GMT −7 h)

Dur: duration of launch window

Site No.: landing site number

Γ: off-vertical unbraked incidence angle at landing site

Hours from sunrise: positive value indicates time elapsed since sunrise for a daylight landing; negative value indicates time remaining until sunrise for a night landing

Hours from sunset: positive value indicates time remaining until sunset

El: elevation of sun at landing site at time of landing

Arrival window: interval of time during which arrival might occur

Rise margin: minimum time from DSS 11 moonrise to lunar touchdown (constrained to be at least 2 h; relaxed to 80 min during flight)

Set margin: minimum time from lunar touchdown to DSS 11 moonset

(3) The class III requirements define the ultimate desired support. Such support should enable the project to achieve the flight objectives early in the program.

D. Near-earth Phase Requirements

The AFETR, MSFN and DSN elements of the T&DS were required to support tracking and telemetry requirements from launch to $L + 4$ h during the near-earth flight of *Surveyor IV*. The *Surveyor* project placed the near-earth tracking and data acquisition support requirements on those elements of the TDS to obtain a timely and continuing evaluation of the status of the mission during this phase. This early evaluation was used to aid in maximizing the probability of acquisition by the deep space stations and to provide information for the conduct of subsequent space flight operations.

The aforementioned class I near-earth TDS requirements of the *Surveyor IV* mission are shown in Fig. 109. Additionally, Fig. 110 shows the variable azimuth and direct ascent earth track.

1. AFETR. The AFETR was to provide pre-flight and in-flight support, including metric (C-band) and telemetry (VHF and S-band) data acquisition and recording, as well as real-time transmission from launch through injection into the transfer trajectory, until the spacecraft was acquired by the DSN.

Requirements for AFETR tracking and telemetry coverage were determined by: (1) *Surveyor* mission requirements; (2) launch vehicle requirements; and (3) configuration requirements. These requirements are defined in the following paragraphs.

a. Tracking. The AFETR and MSFN were required to track the C-band beacon on the *Centaur* stage. Continuous tracking of this beacon was required from launch to translunar trajectory injection. To establish the free-fall trajectories of the vehicles, it was required that the *Centaur* C-band be tracked continuously for at least 60 s between injection in the translunar orbit and start of the *Centaur* retro-maneuver. There was also a requirement that the C-band beacon be tracked continuously for at least 60 s after the end of the *Centaur* retro-maneuver to establish the final trajectory of the *Centaur*. The AFETR RTCS was to utilize these tracking data in computing the orbits of the spacecraft and the *Centaur*, and for orbit mapping to lunar encounter to permit an early evaluation of the trajectories. It was also required that the RTCS process these orbits in order to obtain in-flight acquisition data for the DSSs.

The AFETR was committed to provide class I tracking data from launch to insertion into the translunar trajectory. C-band (5–6 GHz) radars at Merritt Island, Cape Kennedy, Patrick AFB, Grand Bahama Island, Grand Turk, Trinidad, and Antigua were to provide data from launch, through *Atlas/Centaur* separation, to *Centaur* MECO. C-band radars at Antigua, Ascension Island and Pretoria were to provide real-time pre-retro and post-retro metric tracking data to JPL building AO. The data were then relayed to the SFOF for generation or orbital elements, injection conditions and DSIF acquisition data.

Listed in Table 48 are the class I tracking coverage requirements, the basis for levying these requirements, their ratings of relative importance, and the required supporting stations. Three rating categories were selected. These are referred to as critical (class I), highly

Table 48. Near-earth Class I tracking coverage requirements

Source	Class I tracking coverage requirements	Basis for requirements	Required tracking stations
Launch vehicle	From launch to MECO	(1) Provides a reasonable level of confidence for being able to track the vehicle after MECO (item 2)	Cape Kennedy
		(2) Required by Range Safety until orbital velocity is acquired	Antigua
	Any 60 s of continuous tracking from MECO + 5 s to retro start	Input data for calculation of actual transfer orbit so that: (1) Inflight acquisition data can be provided to the DSN (2) Acquisition information can be supplied to the AFETR station at Ascension Island (3) An early evaluation of the transfer trajectory can be made using lunar mapping technique	Antigua

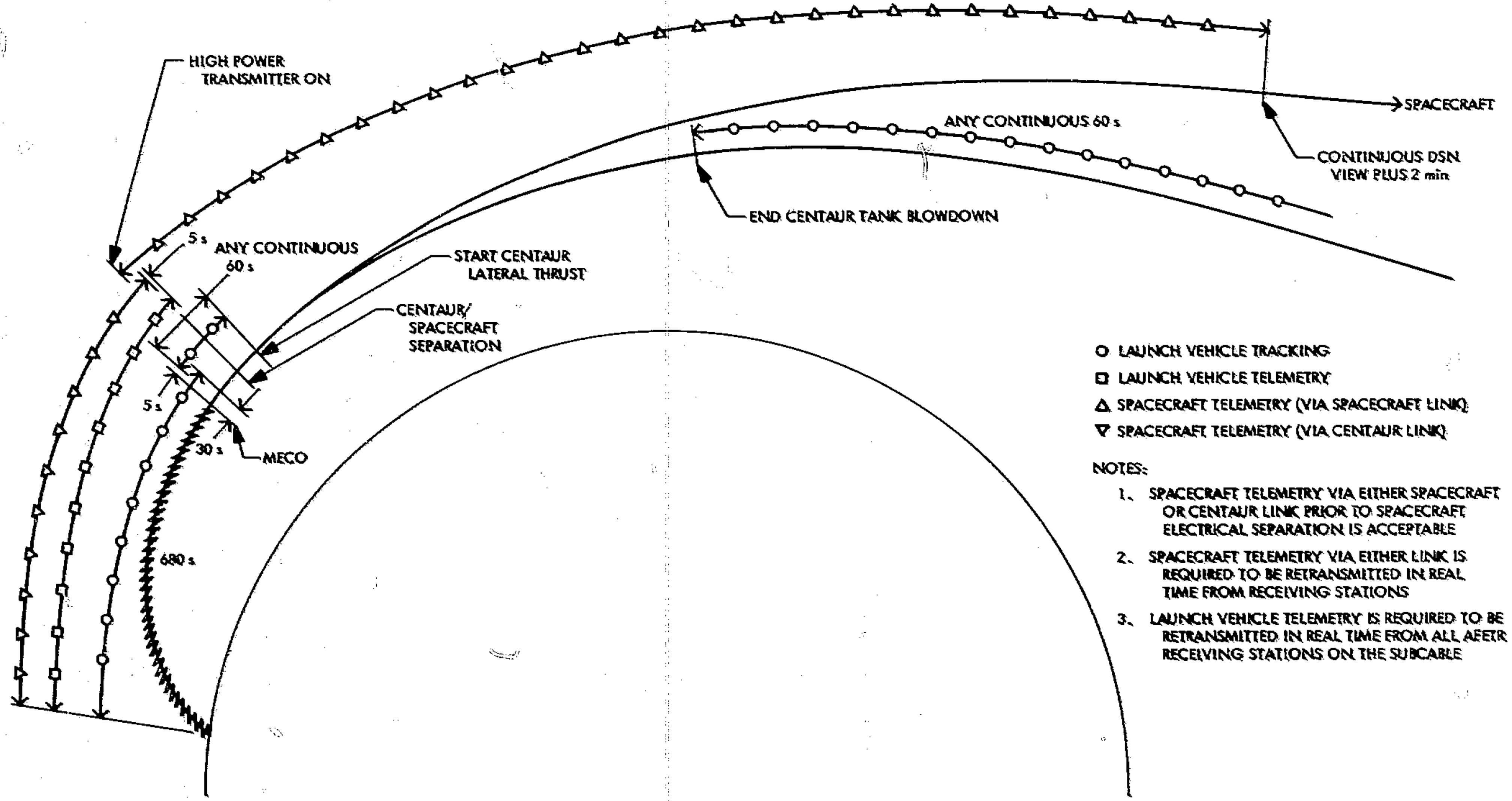


Fig. 109. Surveyor near-earth Class I tracking and data acquisition requirements for Mission IV

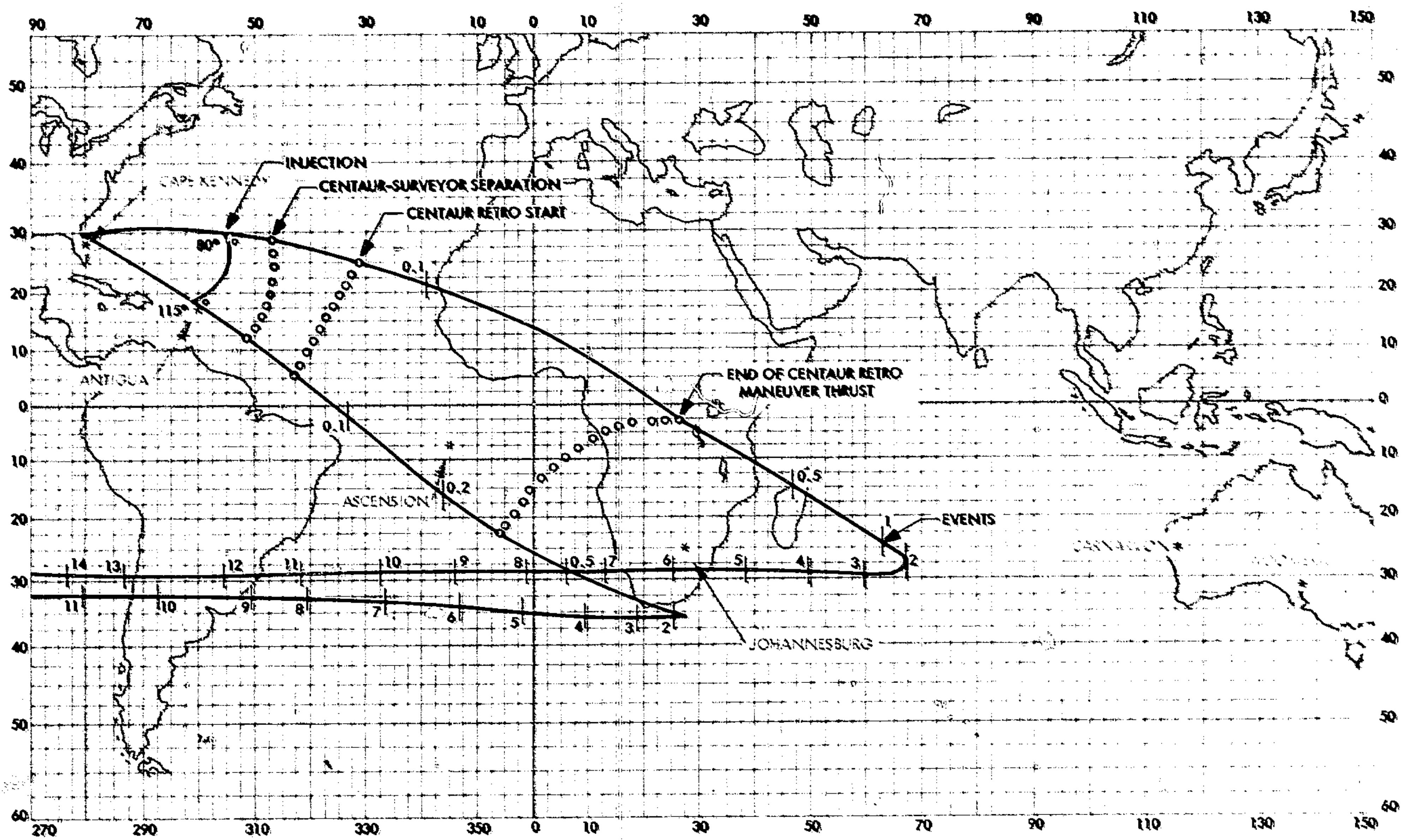


Fig. 110. Variable azimuth direct ascent earth track

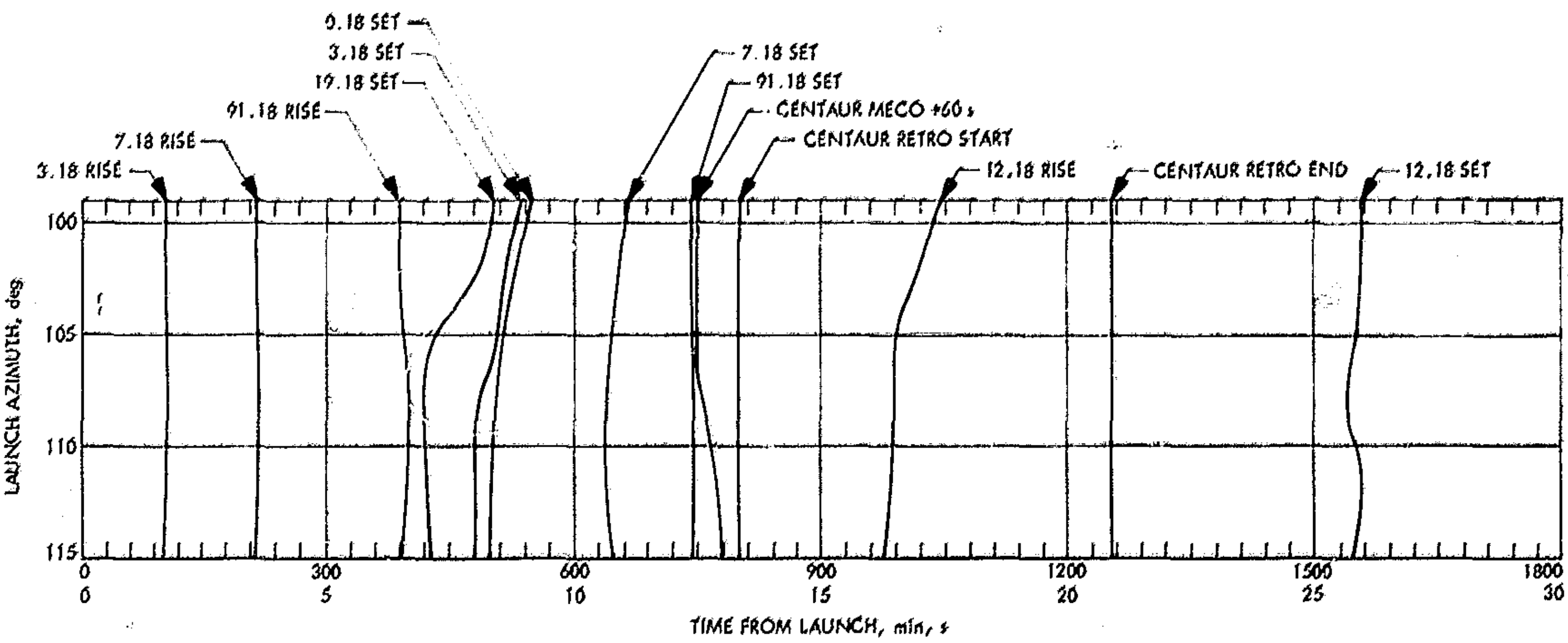


Fig. 111. Surveyor IV radar coverage, July 14, 1967

desirable (class II), and desirable (class III), in descending order of importance.

The estimated periods of time that supporting AFETR stations were to provide coverage, for the launch azimuth available on July 14, 1967, are shown in Fig. 111.

The *Surveyor IV* mission requirements for tracking coverage resulted from the need to calculate orbital elements and DSIF look angles as acquisition aids, and the need for raw data to contribute to the accuracy and reliability of the spacecraft orbit determination processes. Until separation, the orbits of the spacecraft and the *Centaur* were the same. At separation, a relative velocity of about 1 ft/s was imparted by a spring system. Since this separation velocity was small, the AFETR tracking of the *Centaur* stage, both before and after separation, was valuable in determining the spacecraft orbit and in checking other tracking systems. Even after the retro-maneuver of the *Centaur* stage (several minutes after separation), tracking information was helpful during flight.

It is clear that the processing of AFETR raw data after injection is involved with, and conditional upon, the telemetry identification of certain events. The relative weighting of the different AFETR data types (for example, range and angles with respect to DSIF data) was a task requiring more information than was available to AFETR and it was important that raw data be supplied to the DSN. Therefore, the requirements stating that the *Centaur* orbit would be determined by AFETR, and that raw tracking data would be furnished to the DSN during launch were very important.

Raw data can be defined as raw azimuth, elevation, and range points which have not been altered by smoothing, weighting, etc.; one exception was the correction of the raw data for the motion of the RIS. However, the range data of these ships is usually valuable even if their motion has not been removed. Thus, the AFETR data was to significantly improve the accuracy of the pre-midcourse orbit determination process. However, the data had to be more accurate for this process than for improving reliability. Table 6 shows the AFETR tracking data accuracy requirements for determination of the *Surveyor* orbit. Additional metric requirements included:

(1) Any continuous 60-s span between injection into transfer orbit and start of *Centaur* retro-maneuver.

(2) Any continuous 60-s span after completion of *Centaur* retro-maneuver.

(3) Delivery of data was requested in decimal format via teletype to building AO in near-real time.

(4) AFETR pre-flight and in-flight requirements included metric and telemetry data acquisition, and recording and real-time retransmission during particular intervals. In general, this data support included the period of launch through injection into the transfer trajectory, and the transition period until the spacecraft was acquired by the DSN. DSN provided the spacecraft tracking and commands required to support the mission objectives.

The AFETR was also required to generate accurate in-flight predictions to produce satisfactory look-angles for DSIF stations. In general, these accuracy requirements were met if class I data accuracy was met during the class I intervals specified. The DSIF look-angles had to be received at the site prior to the station view period. Thus, the AFETR operations were designed to provide these look-angles within a few minutes after receiving the raw tracking data.

Raw tracking data was required from AFETR for reliable and accurate determination of the spacecraft orbit. The reliability was closely correlated with the number of tracking stations contributing data. For example, an independent third data source can prove invaluable in resolving apparent discrepancies between two other data sources, both of which appear to be operating properly. Thus, RIS data would be invaluable under a variety of circumstances, and it was important to know the locations of the ships as accurately as possible.

The AFETR tracked the C-band beacon of the *Centaur* stage to provide metric data. Metric data requirements were as follows:

(1) Class I metric data requirements included tabulation of acceptable C-band beacon performance parameters and readouts, and S-band tracking.

(2) Metric orbital and space data requirements included mapping to lunar encounter (based on final post-retro orbit) in-flight TAER and related data.

(3) Transmission of in-flight trajectory data, by AFETR stations and appropriate RIS, was required from liftoff to LOS, as well as other raw data which was provided the DSN by 100 words/min TTY. Processing raw DSN tracking data was also necessary in real or near-real time. Table 7 lists the tracking data required by AFETR.

b. VHF telemetry requirements. To meet the class I telemetry requirements, the AFETR was to continuously receive and record *Atlas* telemetry (229.9-MHz link) from before liftoff until shortly after *Atlas/Centaur* separation, plus *Centaur* telemetry (225.7-MHz link) until shortly after spacecraft separation. Thereafter, *Centaur* telemetry was to be recorded as station coverage permitted until completion of the *Centaur* retro-maneuver. In addition to the land stations, the AFETR was to provide the RIS *Coastal Crusader.*

This data was required for evaluating overall launch vehicle performance, the monitoring and verification of important launch vehicle events (*mark* events), and post-flight analysis. Class I VHF telemetry coverage requirements for the AFETR are shown in Table 48.

The coverage requirements and UHF frequency band allocation which was to be used by the AFETR in support of the *Surveyor IV* mission were as follows:

(1) From $T - 300$ s to $T + 300$ s, 229.9 MHz (*Atlas* link): recordings and real-time analog stripouts.

(2) From $T - 300$ s to $T + 756$ s (*Surveyor* separation $+ 5$ s), 225.7 MHz (*Centaur* link): recordings; analog stripouts and real-time transmission of data from Antigua to building AO and to KSC; and transmission of data from Antigua after LOS.

(3) *Centaur/Surveyor* separation plus 5 s to end of *Centaur* retro-maneuver, 225.7 MHz; recording wherever coverage was available.

The estimated periods of time that supporting AFETR stations were to provide coverage are shown in Fig. 112.

c. S-band telemetry. The AFETR was required to receive, record and re-transmit *Surveyor* S-band (2295 MHz) telemetry in real time from spacecraft transmitter high-power-on until DSN continuous view plus 2 min. Class I S-band telemetry requirements placed on the AFETR are shown in Table 49. The S-band telemetry resources assigned to meet those requirements, and the estimated periods of time that coverage was to be provided are shown in Fig. 113. All primary S-band systems were used

Table 49. Near-earth Class I S-band coverage requirements

Source	Class I telemetry coverage requirement	Basis for requirement	Requirements rating	Required telemetry station
Spacecraft (S-band)	From Centaur/spacecraft electrical disconnect to DSN initial acquisition	Provides spacecraft status information	Critical for receive and record Highly desirable to retransmit in real time	Coastal Crusader Ascension Island

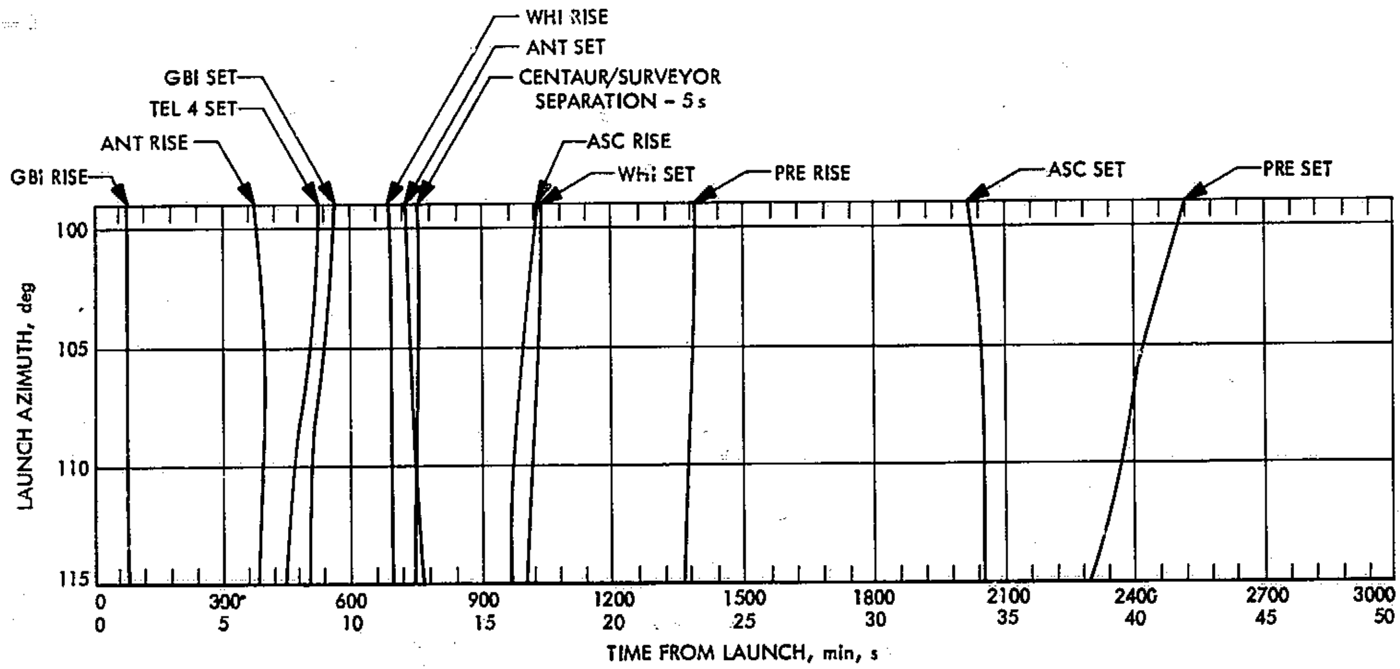


Fig. 112. *Surveyor IV* telemetry coverage, July 14, 1967

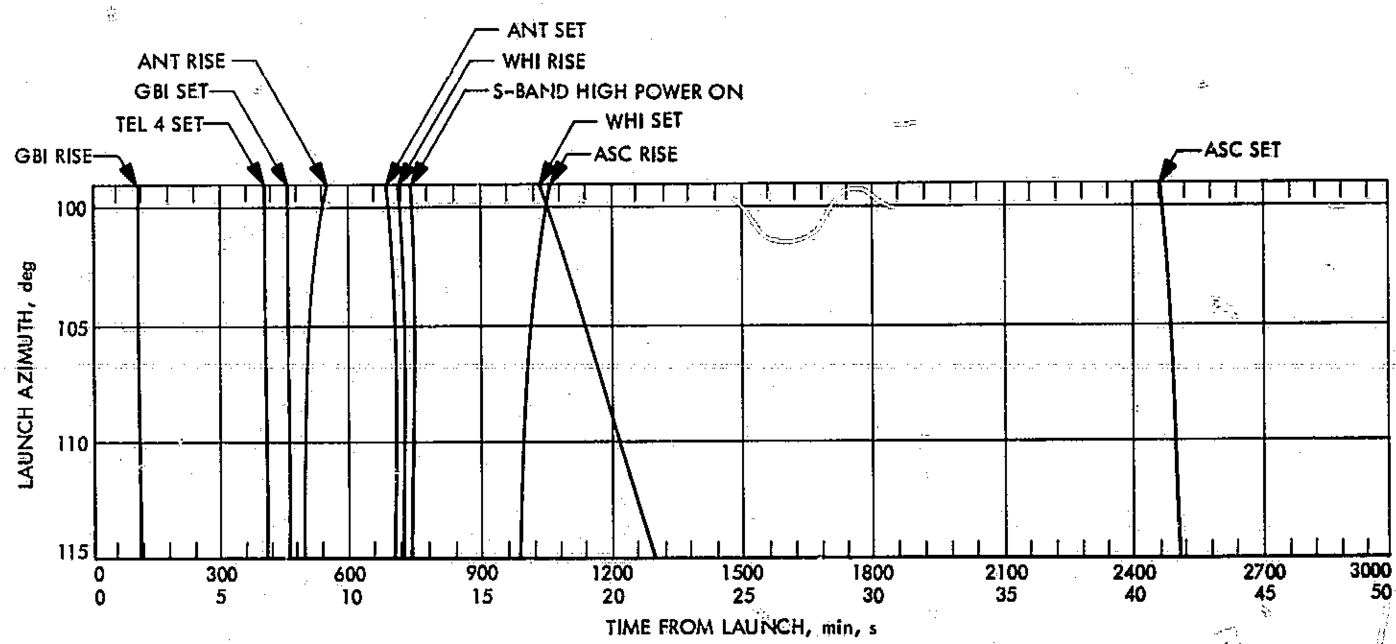


Fig. 113. *Surveyor IV* S-band telemetry coverage, July 14, 1967

on a limited commitment basis, since the *Centaur* vehicle was not roll-attitude stabilized and the aspect angle could not be predicted.

Spacecraft data was needed to confirm the occurrence of critical events during the near-earth phase. This telemetry would provide an early indication of the status of the mission and would be of particular value in the event of abnormal spacecraft performance.

The RIS *Coastal Crusader* was positioned at 15.0 deg N lat and 42.0 deg W lon on July 14, 1967 as an aid in meeting the aforementioned S-band requirements.

d. Computer requirements. The real time computer system (RTCS) was to provide computed data for the pre-retromaneuver and post-retromaneuver transfer orbits. The software was to be certified and the RTCS was to participate in joint operational readiness tests with the SFOF.

The computer data requirements for the pre-retromaneuver transfer orbit are summarized as follows:

(1) Single-station solution orbital elements and injection conditions. (Delivery requested via teletype to building AO in near-real time after receipt of data at the RTCS facility.)

(2) Multiple-station solution orbital elements and injection conditions. (Delivery requested via teletype to building AO within 2 h after delivery of item 1.)

(3) Orbital elements and injection conditions from telemetered *Centaur* guidance data. (Delivery requested via teletype to building AO within 30 min of receipt of data at RTCS facility.)

(4) Quick mapping (B-plane) to lunar encounter. (Delivery requested via teletype to building AO immediately following item 1.)

(5) Refined mapping to lunar encounter. (Delivery requested via teletype to building AO immediately following delivery of item 2.)

(6) AFETR inter-range vector (IRV). (Concurrent delivery to building AO and DSS 72 via teletype requested in near-real time after receipt of data at RTCS facility.)

(7) DSN acquisition data to station horizon break plus 14 h for any three of five stations. (Delivery requested via teletype to building AO in near-real time after receipt of data at RTCS. Concurrent data transmission went to DSS 72 and one of the three selected stations.)

The computer data requirements for post-retromaneuver transfer orbit are summarized as follows:

(1) Single-station solution orbital elements and injection conditions. (Delivery requested via teletype to building AO within 30 min of receipt of data at RTCS facility.)

(2) Multiple-station solution orbital elements and injection conditions. (Delivery requested via teletype to building AO within 2 h after delivery of item 1.)

(3) Orbital elements and injection conditions from telemetered *Centaur* guidance data. (Delivery requested via teletype to building AO within 30 min of data receipt at RTCS facility.)

(4) Quick mapping (B-plane) to lunar encounter. (Delivery requested via teletype to building AO immediately following delivery of item 1.)

(5) Refined mapping to lunar encounter. (Delivery requested via teletype to building AO immediately following delivery of item 2.)

(6) AFETR inter-range vector. (Concurrent delivery to building AO and DSS 72 via teletype requested within 30 min of receipt of data at RTCS facility.)

e. Communications requirements. The AFETR was required to have communication lines with the range tracking stations; these lines were particularly needed by *Surveyor IV* with its requirement of real-time transmission of spacecraft telemetry data. However, with the AFETR functioning as designed, the communications system would be adequate to support *Surveyor IV*. A possible exception would be a state of RF "blackout" between a station and the Cape; such an occurrence (only occasionally predictable) may cause a hold.

It was also required of the AFETR that the *Centaur* VHF signal or the spacecraft S-band signal carrying the spacecraft information be transmitted from each AFETR station to the allocated *Surveyor* facilities at Cape Kennedy in real-time. These data were then to be relayed to the SFOF for spacecraft evaluation. The launch vehicle and spacecraft discrete event information obtained at the AFETR stations was to be transmitted by voice lines to the *Surveyor* operations center at AFETR in real-time for relay to the SFOF. The spacecraft information recorded at the AFETR stations was to be forwarded to the *Surveyor* facilities at AFETR in non-real time.

Surveyor real-time data requirements were as follows:

(1) Coverage requirements:

(a) $T - 300$ s to Station 1 LOS.

(b) $T + 300$ s to $T + 1583$ s.

(2) Data source:

(a) VHF or S-band telemetry until S-band high power on.

(b) S-band telemetry after S-band high power on.

(3) Data delivery:

(a) 550-bits/s spacecraft data from up to three AFETR stations or ships were to be transmitted to building AO. One of the three 550-bits/s PCM signals being provided to building AO was to be decommutated by AFETR with six channels converted to analog and transmitted to building AO for display.

(b) Each station receiving or transmitting 550-bits/s spacecraft data was to decommutate the data train and convert specified channels to analog for monitoring or voice reporting of events as the status changed.

Table 50. GSFC network configuration

Location	Acquisition aid	VHF telemetry	C-band radar	SCAMA	Radar high-speed data	Real-time readouts
Bermuda	X	X	X	X	X	X
Grand Canary	X	X		X		X
GSFC				X	X	

Certain real-time voice communications requirements were also imposed upon the AFETR for the *Surveyor* mission. Included in these requirements was a report by voice in near-real time of the initial AOS and the final LOS of each station of the telemetry link containing spacecraft data. Reports were to be time tagged to the nearest minute. (Links to be reported would normally be the 225.7-MHz link prior to spacecraft high power on, and the 2295-MHz link after spacecraft high power on. Should there be a failure to acquire the 225.7-MHz link, reporting of the 2295-MHz link was to be substituted.) Report was also required by voice in near-real time of any anomaly or unexpected occurrence during the station's view period. (Examples included, but were not limited to, loss of modulation or unexpectedly low received signal level.) Spacecraft events and conditions, as observed at each station retransmitting spacecraft telemetry in real time, were also to be reported by voice.

The purpose of this voice reporting was to provide the SFOF with a backup to the real-time transmission of the spacecraft 550-bits/s PCM telemetry signal from the AFETR stations. Consequently, the requirement for voice reporting applied to each downrange station that received the spacecraft signal and transmitted it uprange in real time: specifically, Antigua, range instrumentation ships, Ascension and other stations assigned this function. These reports were very desirable at all times; they were of even greater importance if the quality of data being re-transmitted in real time was degraded for any reason.

2. *Goddard Space Flight Center.* The Manned Space Flight Network, managed by GSFC, was to support the *Surveyor IV* mission by performing the following functions:

(1) Tracking of the *Centaur* beacon (C-band).

(2) Receiving and recording *Centaur*-link telemetry.

(3) Providing real-time confirmation of certain *mark* events.

(4) Providing NASCOM support to all NASA elements for simulations and launch, and extending this communications support as necessary to interface with the combined worldwide network.

The GSFC tracking and telemetry facilities and equipment which were to support the *Surveyor IV* mission are listed in Table 50. GSFC was also to support the ORT prior to launch.

a. Tracking – metric data (C-band). Bermuda was to provide C-band radar beacon tracking, magnetic tape recording (at a minimum of 10 points/s) and real-time data transmission to GSFC and AFETR. The radar requirements imposed on the MSFN were:

(1) Bermuda was to provide beacon tracking of the *Centaur* from AOS to LOS and range safety backup support to AFETR.

(2) Bermuda was to provide real-time transmission of high-speed and low-speed radar data to GSFC and RTCS.

(3) Bermuda was to provide magnetic tape recordings, strip chart recordings and PLIM data sheets.

The required C-band radar coverage is shown in Table 51. Bermuda FPS-16 coverage was obscured by the FPQ-6 as follows:

Launch azimuth	Antenna azimuth	GET
99	178 to 143	0:08:54 to 0:10:42
102	178 to 148	0:08:54 to 0:10:30
105	178 to 157	0:08:58 to 0:10:06
108	178 to 165	0:09:03 to 0:09:43
111	178 to 174	0:09:08 to 0:09:20

Table 51. MSFN estimated radar coverage for July 14, 1967

Launch azimuth, deg	Station	GET		Range[a], kyd		Elevation, deg	
		AOS	LOS	AOS	LOS	AOS	LOS
99	BDA	0:04:34	0:10:56	1351	1561	3.0	3.0
	CRO	0:50:20	1:05:00	16215	19959	3.0	16.0
102	BDA	0:04:42	0:10:30	1342	1471	3.0	3.0
	CRO	0:52:40	1:03:00	17287	19945	3.2	11.9
105	BDA	0:04:50	0:10:06	1339	1412	3.0	3.0
	CRO	0:54:40	1:01:20	18221	19945	3.2	8.5
108	BDA	0:04:59	0:09:43	1341	1387	3.0	3.0
	CRO	0:56:40	1:00:00	19091	19956	3.2	5.7
111	BDA	0:05:08	0:09:20	1343	1361	3.0	3.0
	CRO	0:58:20	0:59:00	19814	19988	3.0	3.5
114	BDA	0:05:18	0:08:54	1352	1353	3.0	3.0

[a]Coverage is limited to track above 3 deg elevation and less than 20,000 kyd slant range.

Table 52. *Mark* events, Bermuda and Grand Canary

Station	*Mark* No.	Event	Time	Link/channel kHz/segment	Description
		Lift-off (2 in. motion)	0		2-in. motion from range
	1	*Atlas* BECO	02:23	229.9/.96 (continuous)	B-1 pump speed measurement goes out of band on low frequency side
	2	*Atlas* booster engine jettison	02:26	229.9/22	All booster section measurements go open
	3	*Centaur* insulation panel jettison	02:57	229.9/70 7 and 22 8 and 23	Segment levels change from ~ 11–74%. Each segment represents two panel sections
BDA	4	*Centaur* nose fairing jettison	03:24	225.7/3.0/24	Segment level changes from 50–67% at jettison
BDA	5	*Atlas* SECO and VECO	03:58	229.9/0.73 (continuous)	Sustainer pump speed measurement goes out of band on low frequency side
BDA	6	*Atlas/Centaur*	04:00	255.7/30.0 1 and 16	Segment should increase from 0–100% at separation
BDA	7	*Centaur* MEIG	04:09	225.7/0.96 (continuous)	C-2 chamber pressure goes from 0–75% of band
BDA	8	*Centaur* MECO (injection)	Refer to Para 1.5.6	225.7/0.96 (continuous)	C-2 chamber pressure goes from ~ 75–0% of band
BDA	9	*Surveyor* landing gear extend command sent	11:53	225.7/3.0/7	Segment should go from 0–100% for each signal segment integrated
	10	*Surveyor* omni antenna extend command sent	12:06	225.7/3.0/11	Same as *mark* 9
	11	*Surveyor* high power transmitter on	12:27	2295	Receiver AGC, indicates increased signal of 20 dB
	12	*Centaur/Surveyor* electrical disconnect	12:32	225.7/3.0/22	Measurement goes to 100%
	13	*Centaur/Surveyor* separation	12:37	225.7/14.5 22, 52.5 (continuous)	At release of payload, signal goes to 100%

Table 52 (contd)

Station	Mark No.	Event	Time	Link/channel kHz/segment	Description
	14	Begin *Centaur* turn-around maneuver	12:42	225.7/70.0 5, 6	Both gradually increase from 60–80%
CYI	15	Start blowdown (*Centaur* propellants)	16:37	225.7/70/12, 13, 18, & 22	Pump inlet pressure increases from 0–20%, approximately
CYI	16	End blowdown	20:47	As above	Pump inlet pressure decreases to 0%
CYI	17	Power change-over switch	20:47	225.7/.4	400-Hz frequency goes from 50% to open

Table 53. Estimated VHF telemetry coverage for July 14, 1967

Azimuth	STA	AOS		TLM lock		TLM unlock		LOS	
		GET	Azimuth	GET	Azimuth	GET	Azimuth	GET	Azimuth
99	BDA	03:50	252	04:20	249	11:10	137	11:20	134
	CYI	17:30	198	19:40	176	20:10	172	25:10	149
102	BDA	03:30	251	04:20	264	10:40	145	11:00	141
	CYI	18:00	195					26:40	150
105	BDA	03:50	250	04:30	246	10:20	153	10:50	148
	CYI	18:30	192					27:20	152
108	BDA	04:00	249	04:40	245	10:00	161	10:20	156
	CYI	19:20	188					25:50	156
111	BDA	04:00	248	04:20	243	09:40	169	10:10	161
	CYI	21:00	181					25:40	164
114	BDA	04:10	247	04:50	241	09:20	177	10:00	167
115	BDA	04:10	246	05:10	239	09:00	185	09:50	175

Acquisition aids at Bermuda and Grand Canary were to track the vehicle and provide RF inputs to the telemetry receivers from AOS to LOS. Performance recorders were to record AGC and angle errors for post-mission analysis. BDA was to track the *Atlas* 229.9-MHz link and the *Centaur* 225.7-MHz link. The acquisition aid at Grand Canary was to track the 225.7-MHz link.

b. VHF telemetry. Bermuda and Grand Canary were to receive, record and decommutate the *Centaur* telemetry link 225.7-MHz and confirm flight *mark* events. Bermuda was also to receive and record the *Atlas* telemetry link 229.9-MHz for range safety purposes.

Mark event readouts (Table 52) were required from both stations in real time or as near real-time as possible when the vehicle was in view of the station. The time periods in which the MSFN was to provide VHF telemetry coverage are shown in Table 53.

c. Computer requirements. The Goddard Space Flight Center DOB (Data Operations Branch) was to provide computing support for the MSFN stations during the prelaunch, launch and orbital phases of the mission. The computer requirements were as follows:

(1) To provide pointing data printouts for supporting MSFN station view periods for mission planning purposes.

(2) To generate and transmit nominal pointing data to participating MSFN stations, with the exception of Bermuda. Bermuda powered-flight data were to be supplied to GSFC by AFETR.

(3) To receive launch trajectory data from Bermuda and AFETR via the launch trajectory data system.

(4) To update and refine the orbit of the *Centaur*, based on low-speed TTY data received from participating C-band radars and to pass these parameters to the MSFN network controller.

(5) To use the refined orbital parameters to drive displays at the GSFC operations control center.

(6) To generate and transmit real-time acquisition messages to participating MSFN stations, based on post-injection tracking data.

(7) To reformat on magnetic tape the high-speed radar data received from AFETR in the tape format specified (XYZ and xyz) and to reformat on magnetic tape the low-speed TTY radar data received from AFETR and MSFN in the standard time, azimuth, elevation and range format for shipment to the *Centaur* Vehicle Office at Lewis Research Center.

(8) To reformat, on magnetic tape, the Bermuda high-speed raw radar data, including a list of the contents and formats, for shipment to the RCA Data Processing Requirements Group at Patrick Air Force Base, Florida.

d. Communications. Existing NASCOM facilities were to provide the required voice, teletype, and data circuits to participating stations.

The MSFN was to provide four TTY, eight voice and one high-speed data circuit, of the type and quantity indicated below:

Site	TTY	Voice	HSD
BDA	1	3	1
CYI	1	2	

E. Deep Space Network

The DSN was required to support the *Surveyor IV* mission with the integrated facilities of the DSIF, the GCF, and the SFOF. However, only the DSN facilities of the TDS were required to support the mission during the translunar and post-landing phases of the mission subsequent to the near-earth phase.

The DSN was required to provide a command and telemetry link with the spacecraft upon initial acquisition of spacecraft signals by a DSIF station; this would enable the DSIF station to control the spacecraft and furnish range rate, angular tracking data and real-time telemetry data to the SFOF. Continuous tracking and control was to be provided throughout the remainder of the mission by the prime DSIF stations designated to support the *Surveyor IV* mission.

Following the accumulation of sufficient tracking data by the SFOF, an orbit was to be determined that would predict the future path of the spacecraft. These data were required to allow the computation of a midcourse maneuver to compensate for injection errors.

The DSIF was required to command the midcourse maneuver, after which engineering telemetry and tracking data were to be gathered and transmitted via the GCF, to the SFOF, where the midcourse maneuver was to be evaluated and appropriate commands for the terminal maneuver were to be computed. After touchdown, DSIF stations were to receive video, and engineering and scientific telemetry data, as well as command the spacecraft during lunar operations.

1. Deep Space Instrumentation Facility. At least three prime DSIF stations were required to support the *Surveyor IV* mission; these were located approximately 120 deg apart girdling the earth. The following DSSs were required as prime stations for support of the *Surveyor IV* mission:

(1) DSS 11 – Pioneer, Goldstone Deep Space Communications Complex (DSCC), Barstow, Calif.

(2) DSS 42 – Tidbinbilla, Australia (near Canberra).

(3) DSS 51 – Johannesburg, S. Africa (transit phase coverage only).

(4) DSS 61 – Robledo, Spain.

(5) DSS 72 – Ascension Island (initial acquisition to DSS 11 acquisition + 1 h).

a. Tracking. Tracking data, consisting of antenna pointing angles and doppler (radial velocity) data, was to be supplied in near-real time via TTY to the SFOF and post-flight in the form of punched paper tape. Two-way and three-way doppler data were to be required full-time during the lunar flight, and also during lunar operations, at project request. The two-way doppler requirement implied a similar requirement for transmit capability at the prime stations.

The tracking coverage requirements are specified in Table 54. Also included in the table are the raw tracking data rates required and the form of the data (for example, one-way, two-way, or three-way doppler) and antenna pointing angles.

Table 54 below shows that the project requires continuous tracking of the spacecraft from injection to the end of the mission. This requirement is imposed to satisfy the data needs for the flight path analyses that are essential to the achievements of the selected landing sites. Furthermore, these data are necessary for determining the actual post-landing position. The required DSN configuration for achieving the tracking data needs is presented in Section IX.

b. Telemetry. Spacecraft telemetry data was to be received and recorded on magnetic tape. Baseband telemetry data was to be supplied to the CDC (mission-dependent equipment) for discrimination decommutation and real time readout. The DSIF also was to perform pre-communication processing of the decommutated data, using an on-site data processing computer. The data was then to be transmitted to the SFOF in near-real time, using high-speed data modems. It was required that continuous telemetry coverage be provided during the transit phase of the mission, and that such coverage be provided for the first lunar day and for 10 earth days of the first lunar night if landing was achieved. If landing was not achieved, continuous coverage would be required for no more than three earth days after encounter. Coverage of the mission beyond the time specified above was only required periodically.

Table 54. DSN tracking data requirements

Coverage and sampling rate	Data required
Track spacecraft from separation to first midcourse at 1-min sample rate (from initial DSIF acquisition to $L + 1$ h, the sample rate is 1 sample/10 s).	Doppler (two-way and three-way) and antenna pointing angles
Track spacecraft from first midcourse to touchdown at 1-min sample rate.	Doppler (two-way and three-way)
Track spacecraft from touchdown to end of mission at 1-min sample rate during 1 h following 10-deg elevation rise, during 1 h centered around maximum elevation, and during 1 h prior to 10-deg elevation set for DSS 11, 42, and 62.	Doppler (two-way and three-way) and antenna pointing angles
Track spacecraft during midcourse maneuver and terminal maneuver executions at 1/s sample rate, and transient data at a 10/s sample rate.	Doppler (two-way and three-way or one-way)

c. Commands. Command transmission was another function required of the DSIF. The transmission of approximately 250 commands to the spacecraft was required during the nominal sequence from launch to touchdown. This command requirement placed a second critical requirement for two-way communication with the spacecraft. Confirmation of the commands sent was to be processed by the OSDP computer and transmitted by TTY to the SFOF. The OSDP computer was also to be used to verify command tapes punched on-site from TTY instructions received from the SFOF.

d. Video. Video data was to be received and recorded on magnetic tape. This data was to be sent to the command and data handling console (CDC) and, at DSS 11 only, to the TVGDHS for photographic recording. In addition, video data from DSS 11 was to be sent in real time to the SFOF for magnetic and photographic recording by the TVGDHS.

e. Additional requirements. In addition to the above technical support, the DSIF was required to provide the following:

(1) Facilities support for mission-dependent equipment, including space for CDCs at all prime stations and for the TVGDHS at Pioneer (DSS 11).

(2) Maintenance and operation of all mission-independent equipment.

(3) Maintenance and operation of some mission-dependent equipment by negotiation with the *Surveyor* project. For example, DSIF operators were trained for maintenance and operation of the CDC. A similar agreement was to be negotiated for the TVGDHS at DSS 11.

(4) Logistic and spares support for mission-dependent equipment.

(5) At lunar landing, two receivers were to be used for different functions. One was to provide a signal to the CDC, the other to the TVGDHS. Signals for the latter system were a prime project requirement at that stage of the mission.

The following minimum capabilities were required from DSS 51 or 72:

(1) Acquisition and tracking of the *Surveyor IV* spacecraft.

(2) Generation and transmission of tracking data to the communications terminal equipment at the site.

(3) Acquisition, recording, decommutation, display, and processing of *Surveyor IV* spacecraft telemetry data.

(4) Transmission of processed telemetry data, both high speed and TTY, to the appropriate communications terminal equipment at the site.

(5) Generation and transmission of *Surveyor IV* spacecraft commands.

A high degree of probability was required that, at the start of DSS 61 visibility, the following minimum capabilities would be required of DSS 61:

(1) Acquisition and tracking of the *Surveyor IV* spacecraft.

(2) Generation and transmission of tracking data to the communications terminal equipment at the site.

(3) Acquisition, recording, decommutation, display, and processing of *Surveyor IV* spacecraft telemetry data.

(4) Transmission of processed telemetry data, both high speed and TTY, to the appropriate communications terminal equipment at the site.

(5) Generation and transmission of *Surveyor IV* spacecraft commands.

A high degree of probability was required that at the start of DSS 11 visibility, the following minimum capabilities would exist:

(1) Acquisition and tracking of *Surveyor IV* spacecraft.

(2) Generation and transmission of tracking data to the communications terminal equipment at the site.

(3) Acquisition, recording, decommutation, display, and processing of *Surveyor IV* spacecraft telemetry data.

(4) Transmission of processed telemetry data, both high speed and TTY, to the appropriate communications terminal equipment at the site.

(5) Generation and transmission of *Surveyor IV* spacecraft commands.

(6) Acquisition, recording, and processing of *Surveyor IV* spacecraft video data.

A high degree of probability was required that the following minimum capabilities would exist at DSS 42:

(1) Acquisition and tracking of the *Surveyor IV* spacecraft.

(2) Generation and transmission of tracking data to the communications terminal equipment at the site.

(3) Acquisition, recording, decommutation, display, and processing of *Surveyor IV* spacecraft telemetry data.

(4) Transmission of processed telemetry data, both high speed and TTY, to the appropriate communications terminal equipment at the site.

(5) Generation and transmission of *Surveyor IV* spacecraft commands.

2. *Ground Communications Facility.* The DSN GCF, a portion of the NASCOM, was required to support the *Surveyor IV* mission by providing communication paths between the various DSN tracking stations throughout the world and the SFOF. This communication system was to consist of landlines, undersea cables, and radio circuits and was to transmit teletype, voice, and high-speed data in real-time support of the *Surveyor IV* mission.

The DSN/GCF was to transmit tracking, telemetry, and command data from the DSIF to the SFOF; and control and command functions from the SFOF to the DSIF. The GCF was also to transmit simulated tracking data to the DSIF, and video data and base-band telemetry from DSS 11, Goldstone DSCC, to the SFOF.

a. Voice. The DSN/GCF was to provide a system of full-period, leased, four-wire, engineered, voice circuits to a majority of the sites in the network. Most of the voice circuits were to be routed via the GSFC switching center and comprise the signaling, conferencing, and monitoring arrangement. Circuits were to be routed by hardwire and microwave wherever possible. These circuits were to extend to overseas points through transoceanic cables, or by high-frequency radio links in those cases where cables were not available. Circuits were to terminate at the SFOF side of the first switching level: that is, the OVCS console. At the DSIF, the interface was to be at the DSS side of the first switching level.

b. Teletype. The DSN/GCF was to provide a system of full-period, full-duplex, leased links composed of leased and commercial facilities obtained from national, international, and foreign common carrier agencies. For purposes of reliability, overseas circuits were to employ undersea cables wherever possible, but were to be routed via radio facilities to reach certain locations. Circuits were to terminate at the SFOF (user) side of the Communications Processor (CP) System, except that the JPL nonoperational teletype message center and the equipment therein is a portion of the GCF at the DSIF; the interface was to be at the DSS side of the dc switching facility.

c. High-speed data. The DSN/GCF was to provide a system of full-period, leased, high-speed data circuits for the purpose of transmitting spacecraft telemetry requiring a higher bit rate than that of teletype. These circuits were to be assigned solely to operational traffic. Circuits were to terminate at the SFOF side of the dc switching/testing facility between the SFOF and the HSD transmission/monitoring facilities. For project-supplied data sets that used GCF circuits, the interface was to be at the SFOF side of the communications switching jacks equipment. At the DSIF, the interface was to be at the DSS side of the switching/testing facility between the DSS and the HSD transmission/merging/monitoring facilities (currently the dc patchfields in the HSD racks).

d. Wide-band. The DSN/GCF was to provide several full-period, leased, wide-band data circuits between the SFOF and the Goldstone DSSs. These circuits were to be used for operational traffic only. Circuits were to terminate at the SFOF side of the first-level switching and monitoring facilities (currently the wide-band jackfields in Room B3). At the DSIF, the interface was to be at the DSS side of the wide-band transmission, first-level switching and monitoring facilities (currently the station wide-band patch jacks). Figure 114 illustrates the configuration of the GCF in support of *Surveyor IV* and the type of data carried over these circuits.

e. Additional requirements. The NASCOM network was to provide 22 TTY, 9 voice, and 6 high-speed data circuits to the DSN/GCF for the *Surveyor IV* mission, as described in the following table.

Site	TTY	Voice	HSD
DSS 71	3	1	1
DSS 72	4	1	1
DSS 61	4	1	1
DSS 51	4	1	1
DSS 42	4	1	1
AFETR (AO)	3	4	1

One voice, one HSD and two TTY circuits serving the DSS 72 site were to be routed via the communication satellite; the remaining two TTY circuits were to be routed via HF radio to communications control at Cape Kennedy. JPL was to advise GSFC which of the four teletype circuits were the most critical.

DSS 51 circuitry was to be diversely routed over four paths: three TTY and one voice via London; one TTY and one HSD via Tangiers; one TTY via Perth; and one TTY and one voice via Ascension. The latter could be routed via the communication satellite, or directly to communications control at Cape Kennedy using HF radio.

The communication processors were not to be used during the launch and translunar phases of the mission; however, plans called for a switch to fill CP support at end of first DSS 11 pass after touchdown (approximately July 19).

NASCOM special coverage was to be implemented at $L - 6$ h through $L + 5$ h for all domestic stations. Overseas sites were to be covered as outlined below.

Site	Coverage time
DSS 51	$L - 2$ to $L + 11$ h (launch and first pass)
DSS 61	$L + 3$ to $L + 13$ h (first pass translunar) $L + 55$ to $L + 62$ h (touchdown and terminal)
DSS 72	$L - 2$ to $L + 4$ h (launch and first pass only)
DSS 42	$L + 18$ to $L + 24$ h (first pass translunar)

The NASCOM special coverage requirements were defined as follows: (1) an alerting message to switching centers involved in mission support, advising them of anticipated special event schedule during which uninterrupted communications are necessary and requesting that close supervision be given the circuits to stations involved; (2) dual communication processor operation; (3) immediate availability of programming personnel and UNIVAC engineering at each switching center; (4) low-speed monitoring of mission critical teletype circuits incoming from supporting sites to the communication processors; and (5) official modification to the commercial carriers and the request that priority be given to restoration/maintenance on equipment and circuits to specified critical tracking sites.

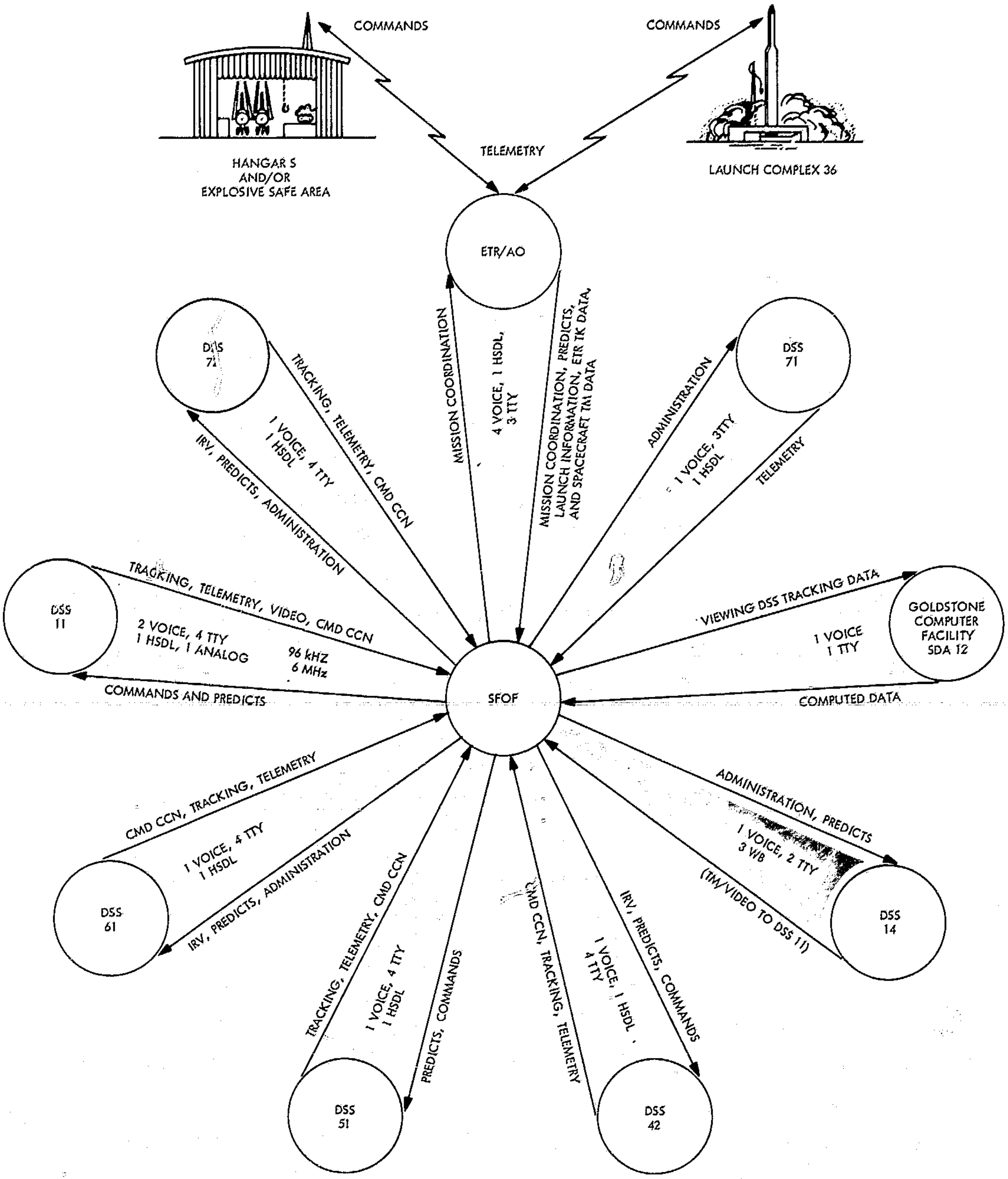


Fig. 114. DSN/GCF configuration diagram

HF propagation forecasts were to be provided for all HF radio circuits scheduled to support the mission. Forecasts were to cover the launch, mid-course and touchdown phases. The first forecast was to be issued at $L - 12$ h and was to cover the period $L - 8$ to $L + 20$ h. A touchdown forecast was to be issued at $T - 12$ h and was to cover the period $L + 58$ to $L + 66$ h.

*3. **DSN/SFOF.*** The SFOF was required to perform the functions of (1) tracking and telemetry data processing, (2) trajectory and performance computation, and (3) performance analysis in support of operational control of the *Surveyor IV* spacecraft during flight and lunar operations.

a. Data Processing System (DPS). The SFOF Data Processing System was required to perform the following functions for *Surveyor* missions.

(1) Computation of acquisition predictions for DSIF stations (antenna pointing angles and receiver and transmitter frequencies).

(2) Orbit determinations.

(3) Midcourse maneuver computation analysis.

(4) On-line telemetry processing.

(5) Command tape generation.

(6) Simulated data generation (telemetry and tracking data for tests).

The following minimum capabilities were required of the SFOF:

(1) One operational TPS 7288-7044 computer string in the Mode 3 configuration.

(2) Two operational 7094 computers in the Mode 4 configuration.

(3) Diesel generators as the power source for all SFOF computers committed to *Surveyor.*

(4) The OVCS system committed to *Surveyor* less its intercom capability.

(5) CCTV displays of TTY data and line status.

(6) Transmission of incoming telemetry data, both high speed and TTY, to the appropriate processing and display devices.

b. *DSN/ICS.* The DSN Intracommunications System (DSN/ICS) requirements were as follows:

(1) To provide an end terminal and switching capability for NASCOM and other special purpose circuits external to the SFOF. In this respect, the DSN/ICS was to be capable of the reception of voice, teletype, high-speed and wide-band data from the various data acquisition stations through the media of the DSN/GCF. In addition to these reception capabilities, the DSN/ICS was to be capable of transmitting voice, teletype, high-speed and wide-band data from the SFOF to various external terminals.

(2) To provide a facility whereby incoming data to the SFOF could be properly routed to user areas throughout the SFOF. In this respect, the DSN/ICS was to be capable of distributing such data by both audio and visual means.

(3) To provide a facility whereby user areas of the SFOF interconnected with each other. In this respect, the DSN/ICS was to be capable of providing both audio and video transmission and reception capabilities.

The DSN/ICS was to be composed of the internal circuits and equipment required to provide an integrated, multipurpose, internal communications network for the support of all space flight missions and simulations conducted in the SFOF. Both special purpose and conventional communications equipment were to be used. The majority of this communications equipment is owned by JPL; however, certain end items of equipment and nearly all audio equipment are leased from commercial sources.

The DSN Ground Communications Facility was required to provide the following:

(1) AFETR/SFOF

  (a) Two voice lines.

  (b) One high-speed data line building AO to SFOF or DSS 71 to SFOF.

  (c) One simplex TTY line from AFETR to SFOF.

(2) DSS 51 or 72

  (a) One voice line.

  (b) Two duplex TTY lines.

(3) DSS 61/SFOF — A high degree of probability was required that at the start of DSS 61 visibility, the following minimum communication capability would exist:

  (a) One voice line.

  (b) Two duplex TTY lines.

(4) DSS 42 — A high degree of probability was required that at the start of DSS 42 visibility, the following minimum communication capabilities would exist:

   (a) One voice line.

   (b) Two duplex TTY lines.

(5) DSS 11/SFOF — A high degree of probability was required that at the start of DSS 11 visibility, the following minimum communication capabilities would be operational:

   (a) One voice line.

   (b) One high-speed data line (1100 bits/s or 96 kHz).

   (c) One duplex TTY line.

IX. *Surveyor IV* TDS Flight Preparation

Tracking and data acquisition was an essential part of the *Surveyor IV* mission. This section summarizes the tracking and data system requirements and the manner in which the system was prepared for the *Surveyor IV* flight.

Table 55. AFETR, MSFN, and DSN station facilities

Station	Tracking capability (radar type)	Telemetry capability
	AFETR stations	
Cape Kennedy Area	C-band	VHF; S-band
Patrick AFB	0.18 (FPQ-6)	
Cape Kennedy	1.16 (FPS-16)	(Tel-2)
KSC	19.18 (TPQ-18)	(Tel-4)
Grand Bahama Island	C-band 3.16 (FPS-16) 3.18 (TPQ-18)	VHF; S-band
Eleuthera		VHF
Grand Turk	C-band 7.18 (TPQ-18)	VHF
Trinidad	UHF skin track 40.43 (FPS-43)	
Antigua	C-band 91.18 (FPQ-6)	VHF; S-band
Ascension Island	C-band 12.16 (FPS-16) 12.18 (TPQ-18)	VHF; S-band
Pretoria	C-band 13.16 (MPS-25)	VHF; S-band[a]
	AFETR ships	
Timber Hitch (10-knot cruising speed)	—	VHF
Rose Knot	—	VHF
Sword Knot (10-knot cruising speed)	—	VHF; S-band
Coastal Crusader (10-knot cruising speed)	—	VHF; S-band
Twin Falls (15-knot cruising speed)	C-band (FPS-16)	VHF; S-band
	MSFN stations	
Bermuda	C-band (FPS-16 & FPQ-6)	VHF; S-band
Grand Canary	C-band (MPS-26)	VHF; S-band
Tananarive, Malagasy	C-band (modified FPS-16) to be operational in third quarter of 1967	VHF
Carnarvon, Australia	C-band (FPQ-6)	VHF; S-band

Table 55 (contd)

Station	Tracking capability (radar type)	Telemetry capability
	DSN stations[b]	
Goldstone, Pioneer (DSS 11)	One, two, and three-way doppler and antenna angles	Full S-band 85-ft antenna with maser
Goldstone, Mars (DSS 14)	One, two, and three-way doppler and antenna angles	Full S-band 210-ft antenna with maser
Tidbinbilla (DSS 42)	One, two, and three-way doppler and antenna angles	Full S-band 85-ft antenna with maser
Johannesburg (DSS 51)	One, two, and three-way doppler and antenna angles	S-band 85-ft antenna with maser (not committed to Mission C)
Robledo (DSS 61)	One, two, and three-way doppler and antenna angles	Full S-band 85-ft antenna with maser
Cape Kennedy (DSS 71)	One-way doppler	Full S-band compatibility and launch support only (4-ft manual antenna)
Ascension Island (DSS 72)	One, two, and three-way doppler and antenna angles	Full S-band 30-ft antenna with paramp

[a]3-ft antenna only.
[b]DSS 11, 42, 51, 61, and 72 have CDC command capability; DSS 12 uses the DSS 11 CDC for commanding. The CDC at DSS 71 is used during prelaunch testing only.

A. Configuration

Based on trajectory data and other requirements, the TDS agencies selected the appropriate metric and telemetry data acquisition instrumentation from resources available at the sites listed in Table 55. Particular attention was given to class I intervals to assure a high probability of providing the required coverage.

1. AFETR. The overall AFETR configuration for the *Surveyor IV* mission is presented in Table 56 and Fig. 115. The configuration is similar to that of the *Surveyor III*, except that the only RIS supporting the mission was the *Coastal Crusader.*

a. Tracking. The AFETR configuration for acquiring, processing and transmitting metric data is shown in Fig. 116. As indicated in the figure, it was planned that the AFETR radars at Antigua, Ascension Island and Pretoria would provide real-time pre-retro and post-retro metric tracking data to JPL at building AO, for relay to the SFOF. For certain northerly azimuths, Bermuda would provide some post-injection data; however, the majority of Bermuda data would be obtained during the powered-flight phase.

In addition to relaying these data to JPL, the AFETR RTCS was configured to compute orbital elements and

Table 56. AFETR configuration for *Surveyor IV*

Station	C-band radar	VHF telemetry	S-band telemetry
KSC (Merritt Island)	X	X	X
Cape Kennedy	X	X	
Patrick AFB	X		
Grand Bahama Island	X	X	X
Grand Turk	X		
Antigua	X	X	X
Trinidad	X		
Coastal Crusader		X	X
Ascension Island	X	X	X
Pretoria	X	X	X

injection conditions (both pre-retro and post-retro) which were to be transmitted to JPL in the following formats:

(1) Standard JPL orbital message format.

(2) AFETR IRV.

(3) AFETR standard orbital parameter message (SOPM).

DSS acquisition information based on the pre-retro orbital computations was to be prepared by the RTCS and forwarded to JPL. In addition, AFETR was to transmit

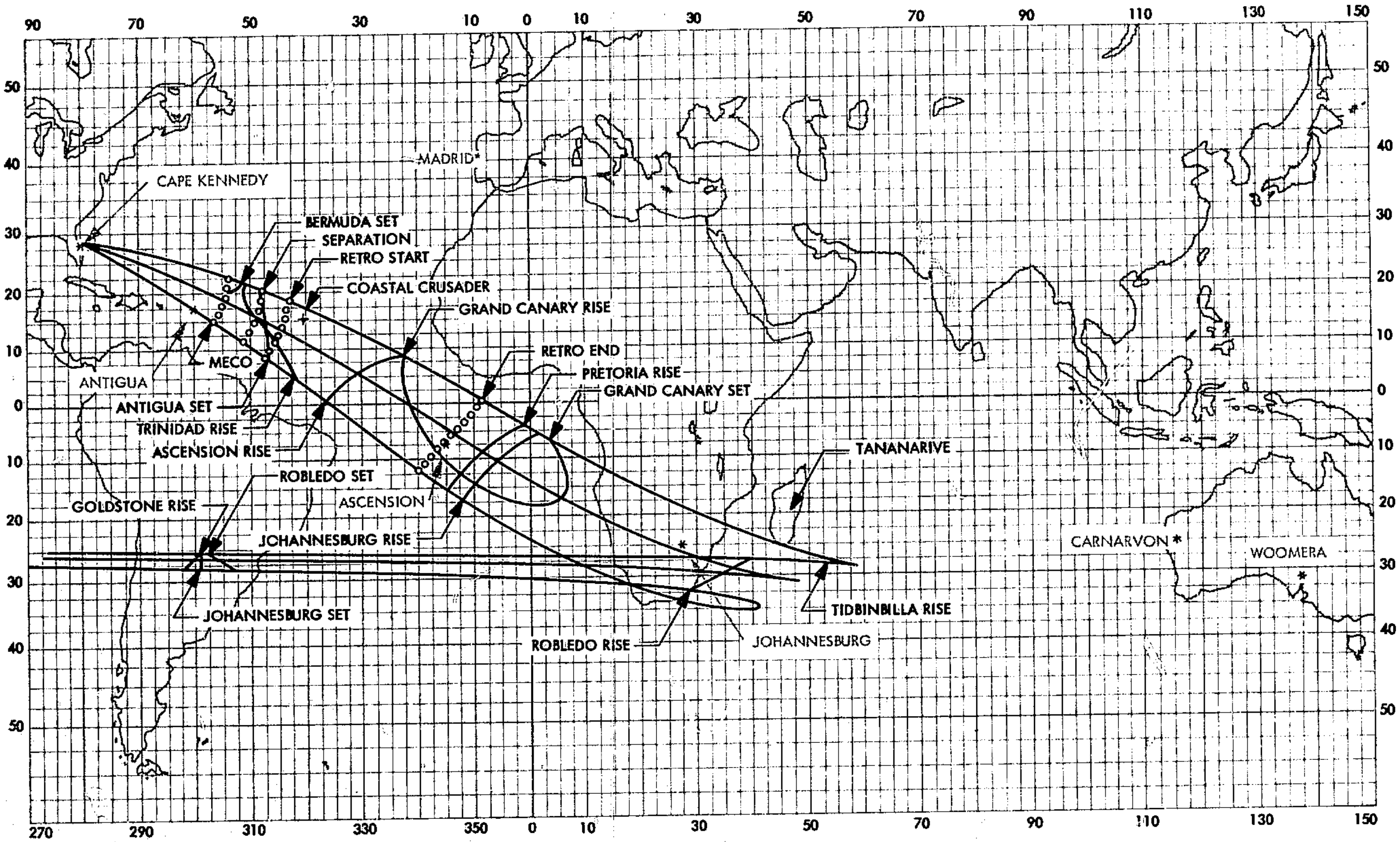
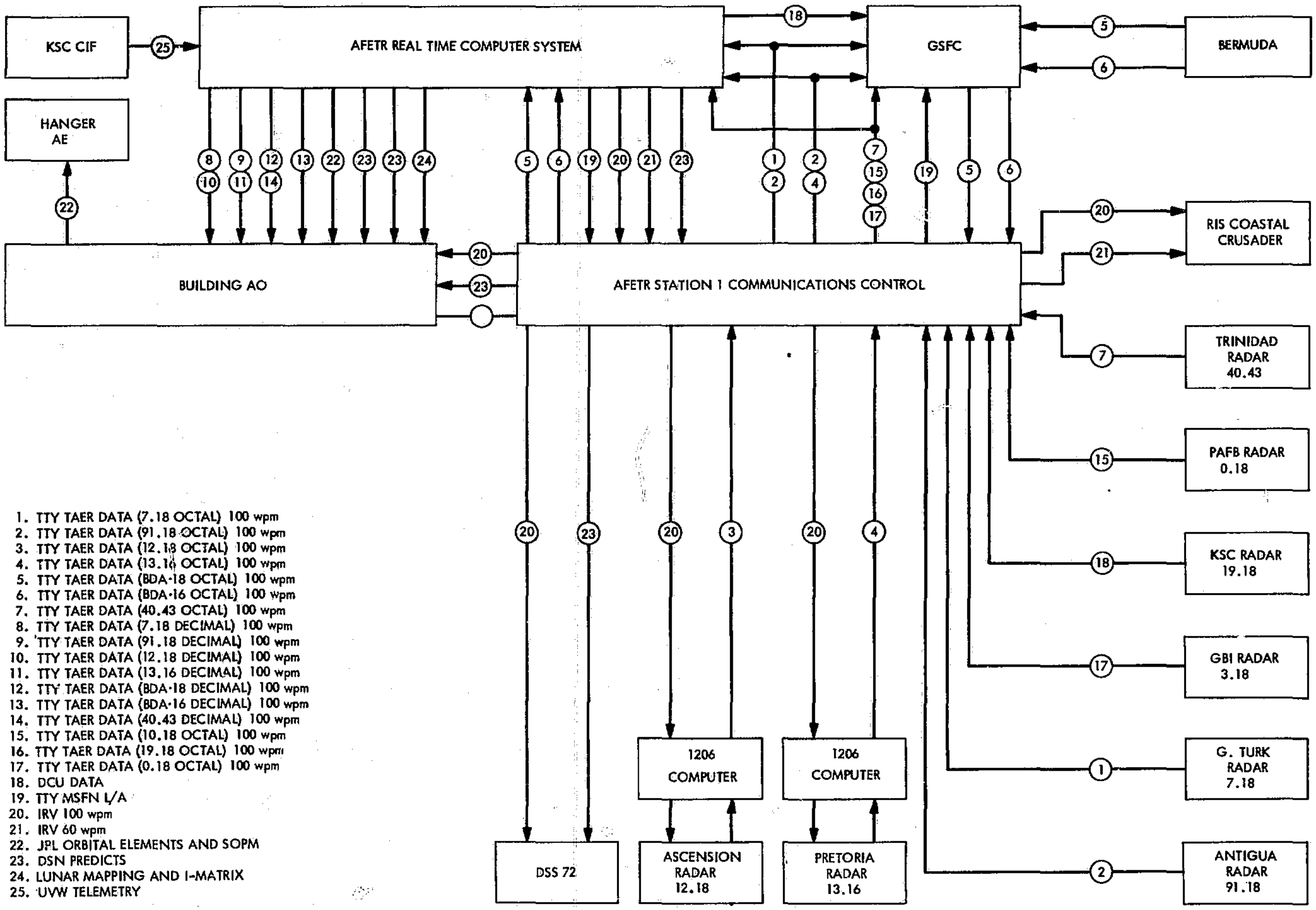


Fig. 115. Earth tracks and TDS station coverage, July 14, 1967



1. TTY TAER DATA (7.18 OCTAL) 100 wpm
2. TTY TAER DATA (91.18 OCTAL) 100 wpm
3. TTY TAER DATA (12.18 OCTAL) 100 wpm
4. TTY TAER DATA (13.16 OCTAL) 100 wpm
5. TTY TAER DATA (BDA-18 OCTAL) 100 wpm
6. TTY TAER DATA (BDA-16 OCTAL) 100 wpm
7. TTY TAER DATA (40.43 OCTAL) 100 wpm
8. TTY TAER DATA (7.18 DECIMAL) 100 wpm
9. TTY TAER DATA (91.18 DECIMAL) 100 wpm
10. TTY TAER DATA (12.18 DECIMAL) 100 wpm
11. TTY TAER DATA (13.16 DECIMAL) 100 wpm
12. TTY TAER DATA (BDA-18 DECIMAL) 100 wpm
13. TTY TAER DATA (BDA-16 DECIMAL) 100 wpm
14. TTY TAER DATA (40.43 DECIMAL) 100 wpm
15. TTY TAER DATA (10.18 OCTAL) 100 wpm
16. TTY TAER DATA (19.18 OCTAL) 100 wpm
17. TTY TAER DATA (0.18 OCTAL) 100 wpm
18. DCU DATA
19. TTY MSFN L/A
20. IRV 100 wpm
21. IRV 60 wpm
22. JPL ORBITAL ELEMENTS AND SOPM
23. DSN PREDICTS
24. LUNAR MAPPING AND I-MATRIX
25. UVW TELEMETRY

Fig. 116. Metric data flow

IRV messages and DSS 72 predictions directly to DSS 72. A "mapping to lunar encounter" message was to be prepared for both the pre-retro and post-retro orbits.

Following the single-station solutions, the RTCS was to compute and transmit to JPL pre-retro and post-retro orbit information. An I-matrix and a lunar mapping message based on each solution was to be included.

b. Telemetry. The AFETR configuration for acquiring, processing and transmitting telemetry data is shown in Fig. 117. As indicated in the figure, the AFETR stations that were expected to acquire and transmit spacecraft telemetry were: the Central Telemetry Facility at Station 1, Grand Bahama Island; Antigua; one RIS (*Coastal Crusader*); Ascension Island; and Pretoria. The Rixon 1, 2 and 3 lines on the diagram represent PCM telemetry data transmitted via direct HF radio links from the RIS, Ascension Island and Pretoria to Cape Kennedy. Pretoria data were to be relayed through Ascension and then by RF link directly to the Cape. The ship had an alternate route by RF link to Antigua and then up the subcable to the Cape. Not indicated on the drawing is the ability of Antigua to act as a relay for the other downrange stations. The lines on the diagram identified as DISC 1, 2, 3 and 4 represent four subcable data channels.

In addition to being fed directly to building AO, data from each of the Rixon sources was to be fed to central telemetry for selection as an input to the TDM-1. The TDM-1 is a time division multiplex system with a self-contained core memory. TDM parity and sync were to be displayed in the JPL/AFETR communications center to assist in selecting the best data source for retransmission to the SFOF.

The primary sync of the TDM-1 was to also provide reconstructed PCM data and data clock to building AO. These are listed as TDM DATA and TDM CLOCK on the diagram.

During the operation, the best data source was to be selected at the switch matrix in the JPL/AFETR communications center for transmission to the SFOF. The normal data path was to be through the switch matrix to the CDC, then back through the switch matrix to the bit synchronizer in the JPL/AFETR communication center. The bit sync was to condition the data stream for input to the bell modem and provide necessary control functions to the modem. The modem output was then to be transmitted over the high-speed data line to the SFOF. The bit sync also was to feed DSS 71 simultaneously with the bell modem.

In the event of a CDC failure, or if it was desired to bypass the CDC, the data stream could be sent directly from the switch matrix to the bit sync, from which it would follow the normal path as described above. An additional backup mode was available, wherein the TDM data from central telemetry could be routed directly from the switch matrix into the bell modem and out to the SFOF.

In the normal mode of operation, the data being transmitted to the SFOF was to be simultaneously monitored at the CDC, while the data quality display panel was to be evaluating the quality of the data being received from the next station downrange.

2. *GSFC.* The GSFC tracking and telemetry facilities and equipment used in support of the *Surveyor IV* are listed in Table 57.

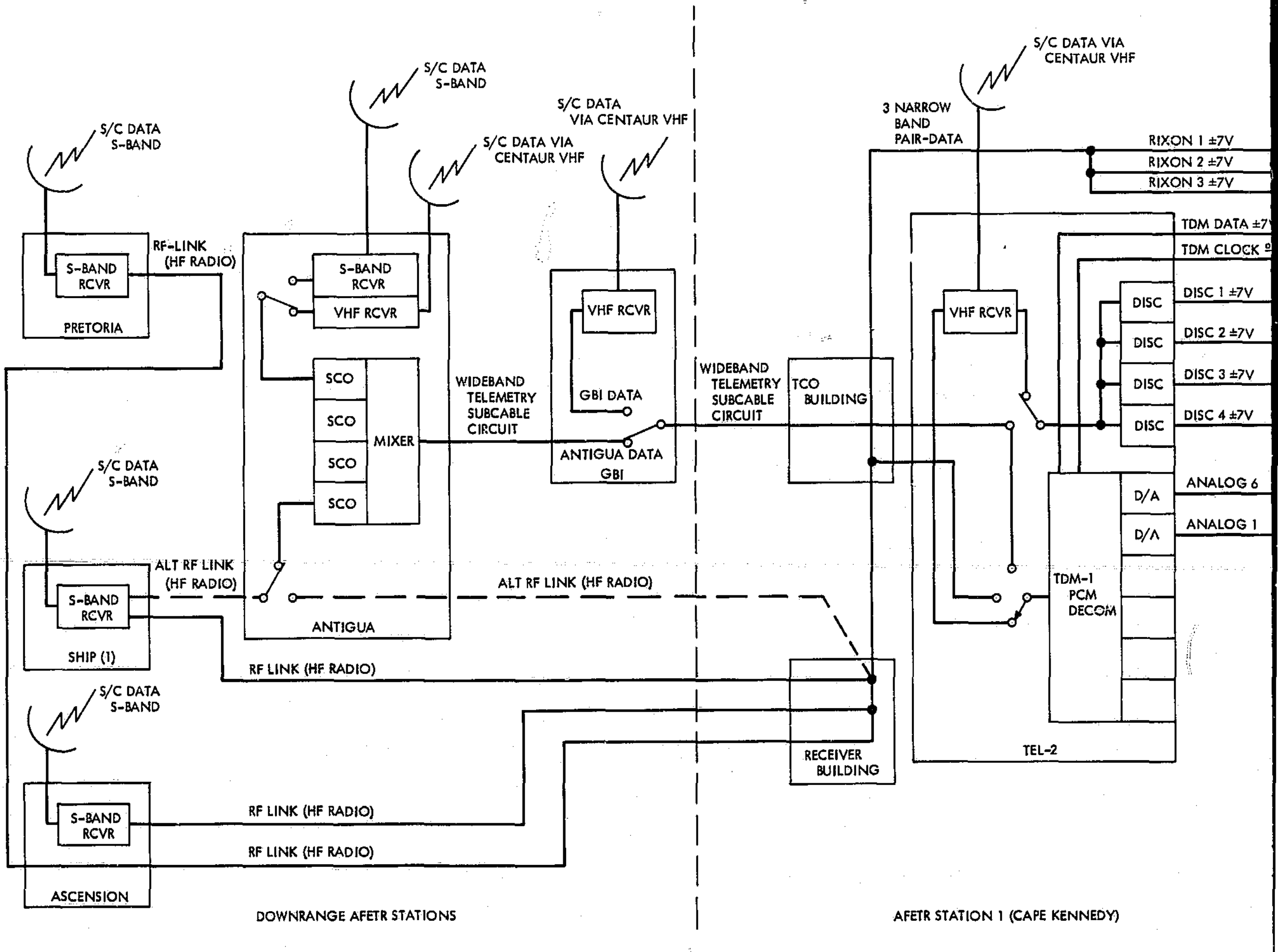
a. Acquisition aids. Stations at Bermuda and Canary were equipped with acquisition aids to track the vehicle and provide RF inputs to the telemetry receivers from AOS to LOS. Performance recorders were used to record AGC and angle errors for post-mission analysis.

b. Telemetry data. Bermuda and Canary were also equipped to decommutate, receive and record telemetry.

Table 57. GSFC configuration for *Surveyor IV*

Location	Acquisition aid	VHF telemetry	C-band radar	SCAMA	Radar high-speed data	Real-time readouts
Bermuda	X	X	X	X	X	X
Grand Canary[a]	X	X		X		X
GSFC				X	X	

[a]Grand Canary was not scheduled to support on July 13 or 14; however, the station was called up on a "best-obtainable" basis on launch day.



FOLDOUT FRAME

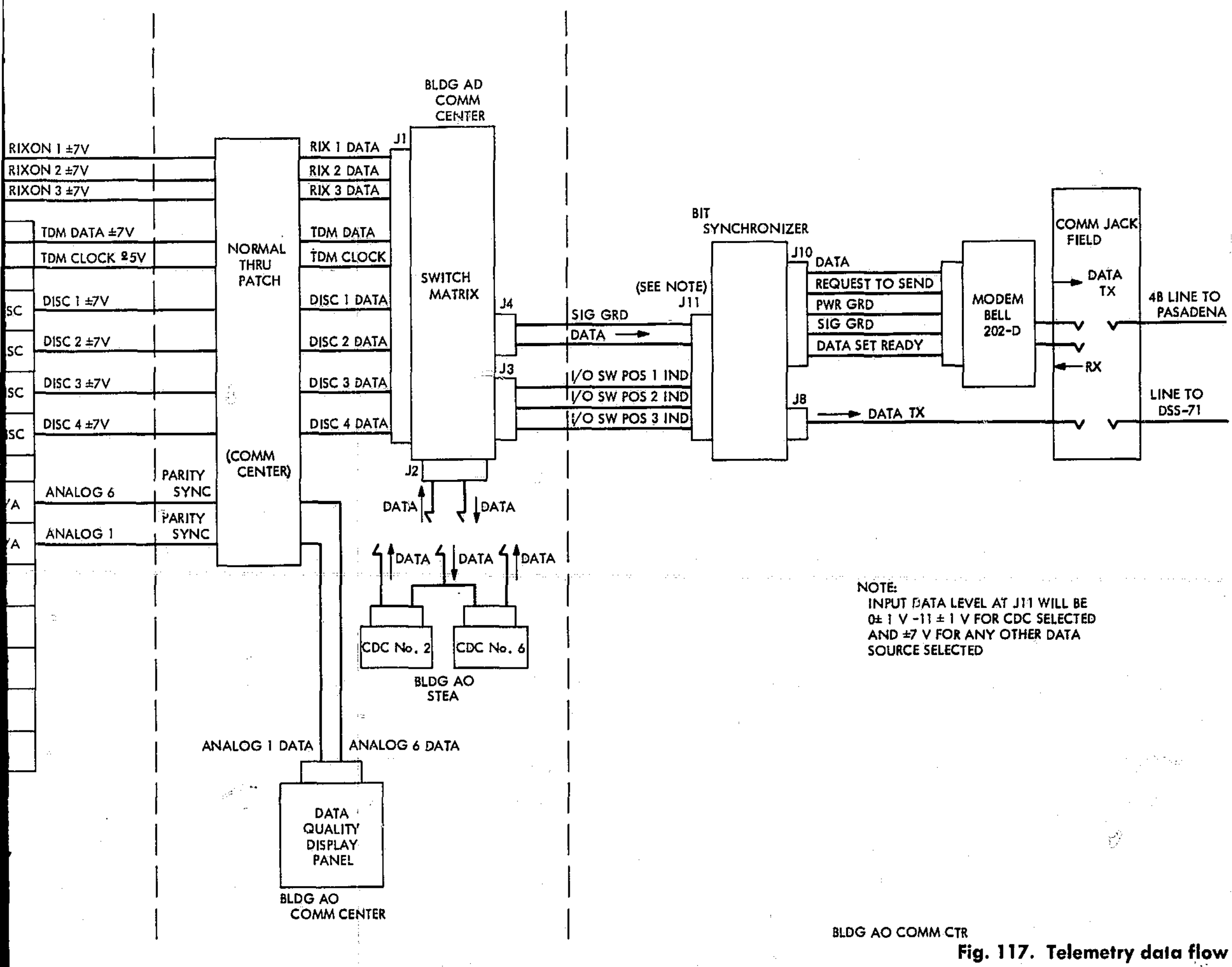


Fig. 117. Telemetry data flow

FOLDOUT FRAME 2

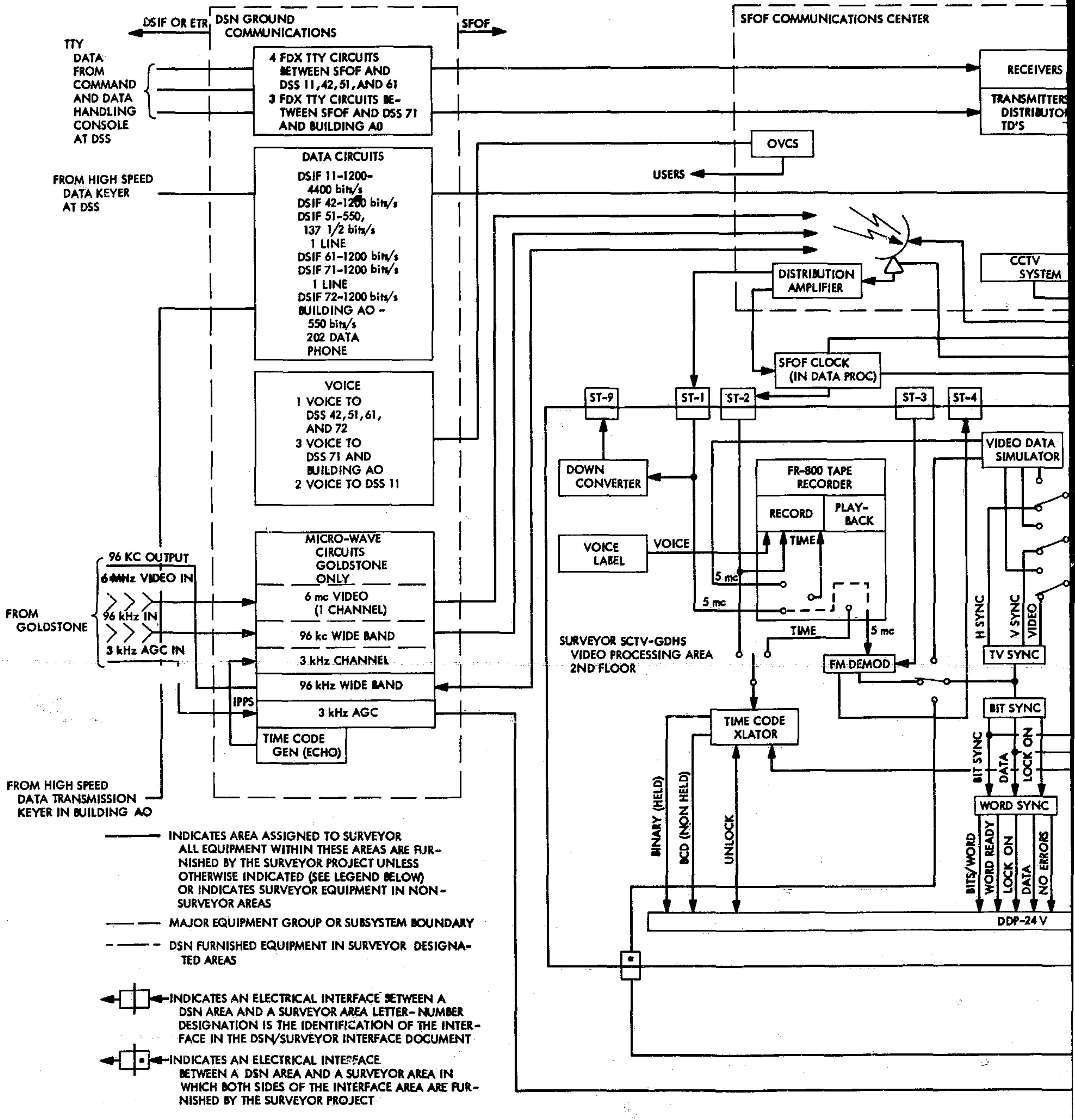
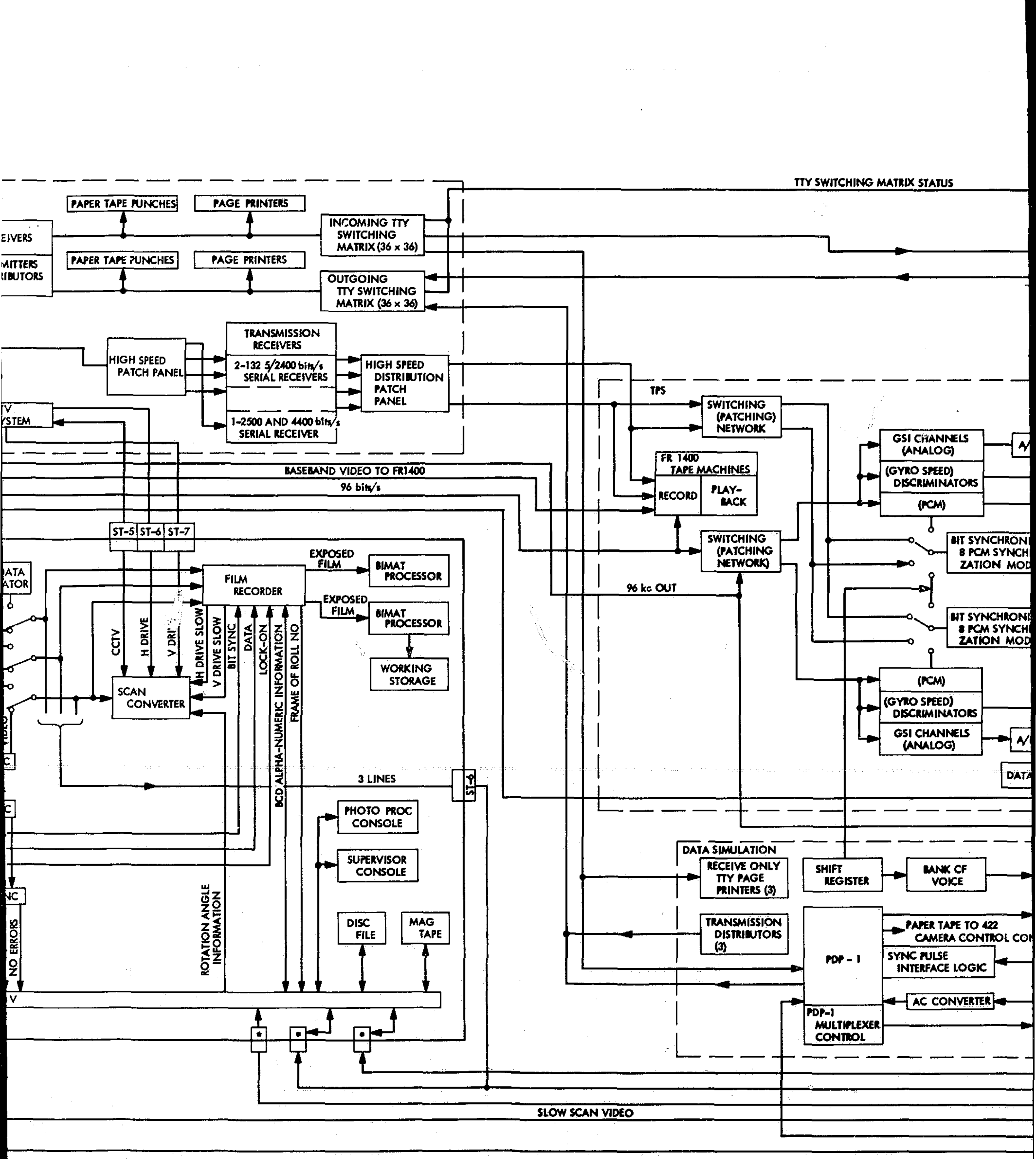
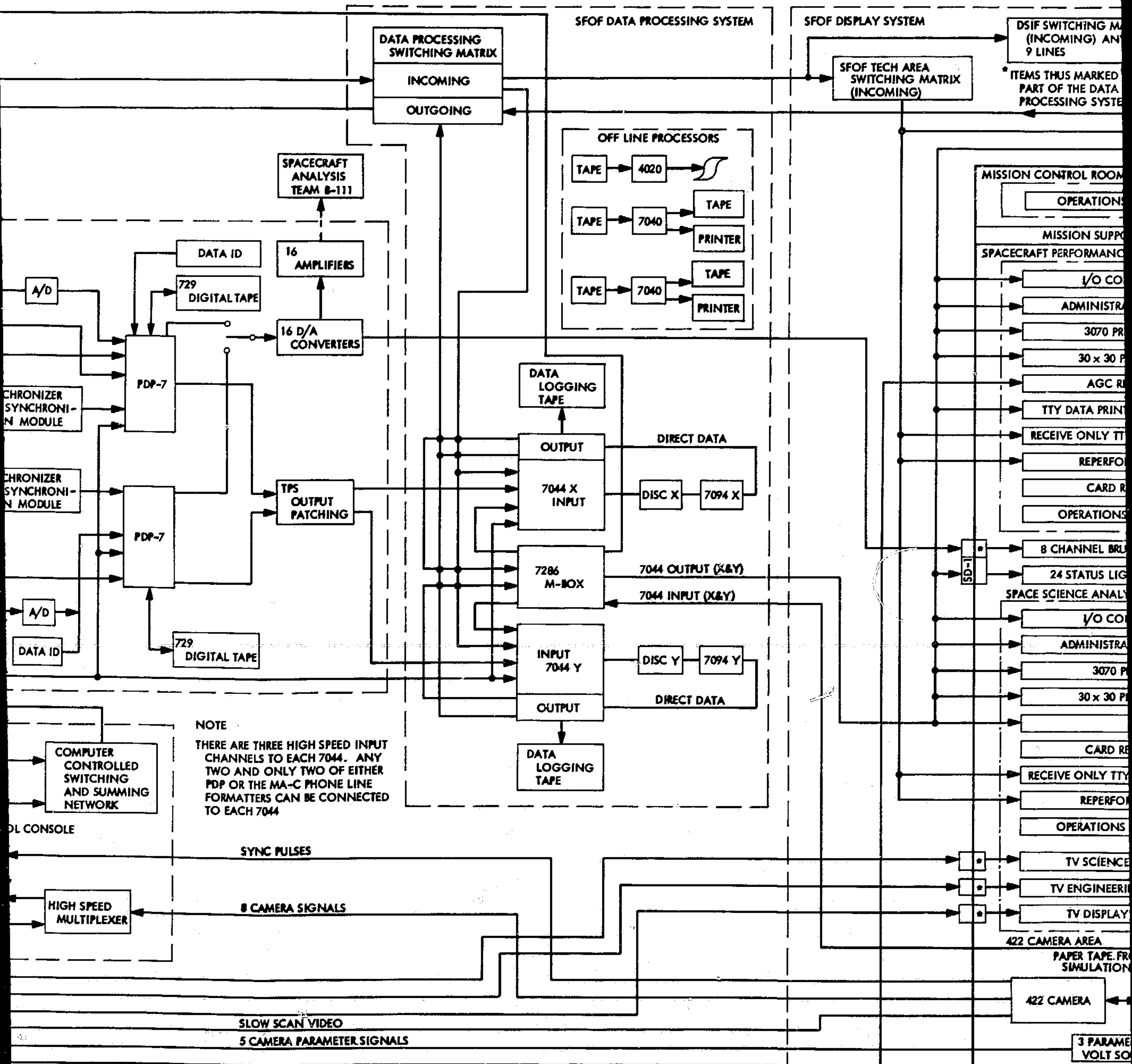


Fig. 118. Space Flight Operations Facility and DSN communications, block diagram

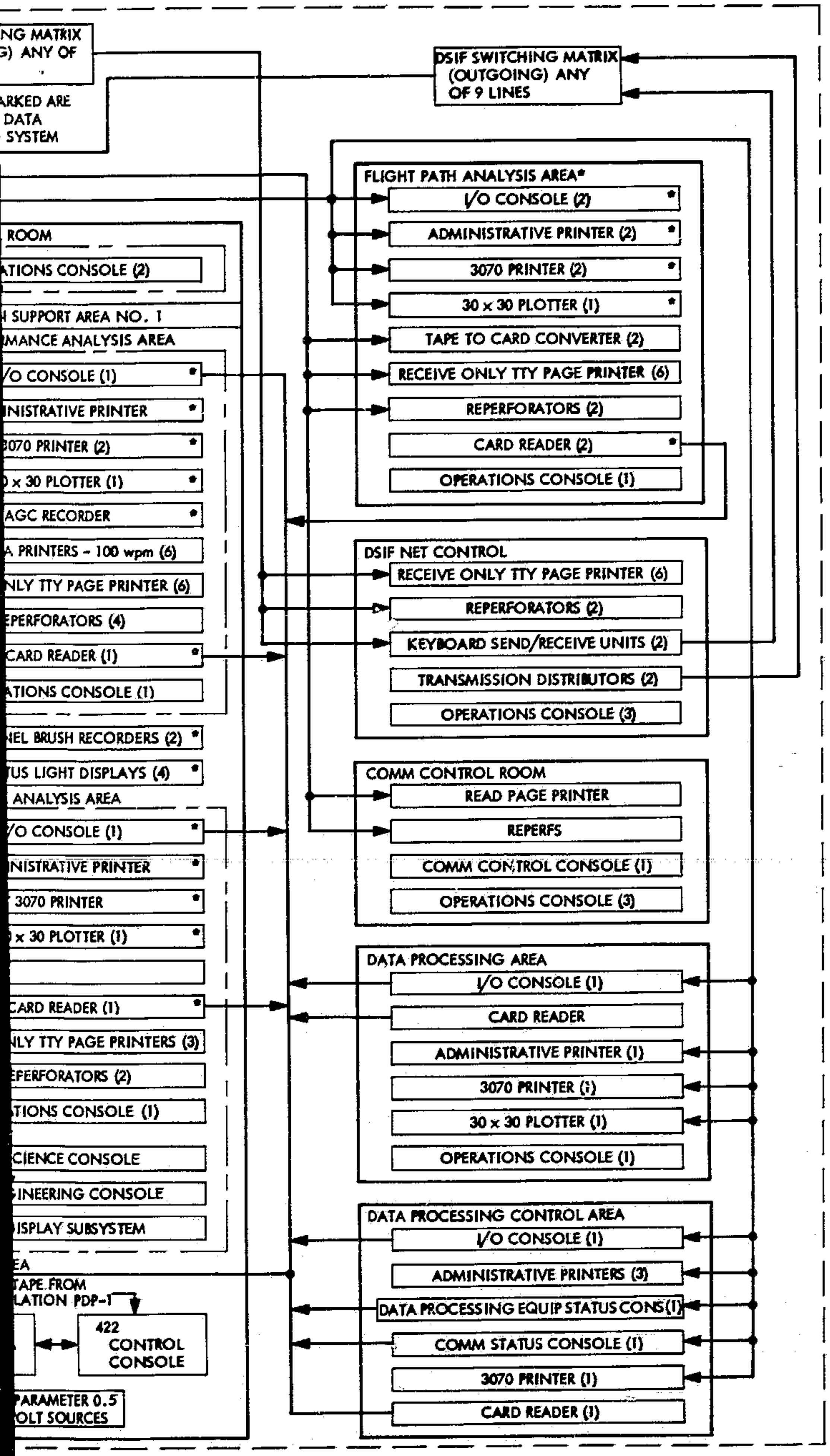
FOLDOUT FRAME 1



FOLDOUT FRAME 2



FOLDOUT FRAME 3



FOLDOUT FRAME 2

3. Deep Space Network. The DSN is the NASA facility for the two-way precision communication system designed to communicate with, and to permit the control of, the *Surveyor IV* spacecraft after it had travelled approximately 10,000 mi from earth. The DSN was required to perform four basic functions in support of *Surveyor IV* mission: (1) tracking-locating the spacecraft, measuring its distance, velocity, and position, and providing the data necessary for orbit determination; (2) acquisition of telemetry data from the spacecraft; (3) command; and (4) sending control instructions to guide the spacecraft in its flight to the moon, to direct the spacecraft in terms of when to perform required maneuvers and when to turn on instruments for performing certain operations, and determining trajectories from analysis of telemetry data from the DSIF, as well as from standard sequence of events.

The main elements of the DSN are:

(1) The DSIF with space communication and tracking stations located around the world.

(2) The GCF.

(3) The SFOF.

The DSIF, through precision radio tracking and communication, obtained angular position and velocity (doppler) of the spacecraft from the tracking stations as well as providing command control (up-link) and data reception (down-link) from the spacecraft. The Cape Kennedy DSS 71 supported the final checkout of the spacecraft prior to launch and verified telemetry and tracking compatibility between the DSN and the flight spacecraft during the prelaunch and first flight phases of the mission.

The GCF is that portion of the DSN which provides communications between all parts of the DSN through telephone, teletype, submarine cables, and high-speed and wideband microwave links.

The SFOF is the control center (from *Surveyor* launch through mission completion) for DSIF tracking and data-acquisition activities, spacecraft trajectory and orbit determinations, generation of commands transmitted to the spacecraft, and analysis and interpretation of the data received. It is equipped with control consoles, status and operation displays, computers, data processing and communication equipment. The SFOF provides communication by telephone and teletype throughout DSN, and internal communication at JPL by telephones, voice intercom units, public address systems, closed-circuit television, and other types of visual displays. Figure 118 is a block diagram depicting the SFOF and associated DSN/GCF for *Surveyor IV*.

a. Deep Space Instrumentation Facility. The following DSSs, all of which have 85-foot antennas, were committed as prime stations for the support of *Surveyor IV* mission:

(1) DSS 11, Pioneer, Goldstone DSCC, Barstow, California.

(2) DSS 42, Tidbinbilla, Australia.

(3) DSS 61, Robledo, Spain.

Due to the direct-ascent trajectory to be used for the *Surveyor IV* mission, initial acquisition was to be performed at either DSS 72, Ascension Island, or DSS 51, Johannesburg, depending upon the particular trajectory selected and upon station availability. The *Surveyor* project planned to use DSS 72 for initial acquisition. DSS 51 would also provide tracking support during the transit phase of the mission; that is, two-way tracking data would be provided upon request to assist in determining an accurate orbit.

DSS 71 coverage. DSS 71, Cape Kennedy, Florida, was committed to support RF compatibility tests between the *Surveyor IV* spacecraft located on the launch pad, and DSS 71. These tests were successfully completed on June 1 and 2, 1967. At time of launch DSS 71 would receive and record telemetry data from $L - 5$ min to loss of signal. In addition, DSS 71 would use its CDC and TCP computer to process AFETR range telemetry data for transmission to JPL via NASCOM high-speed data lines.

DSS 14 coverage. The DSIF was to use DSS 14, the 210-ft Mars station antenna, for backing up DSS 11 during the midcourse and terminal descent phases of the *Surveyor IV* mission. This would include on-site telemetry recording and availability of a backup transmitter if required for commanding. DSS 14 was to be available to the end of the touchdown pass.

b. Ground Communications Facility. The DSN Communications System is an integrated, operational, communications network and distribution system that was divided into two separately administered communications systems: (1) The DSN/GCF, external to the SFOF and technically controlled by Goddard Space Flight Center; and (2) the

SFOF Intracommunications System (ICS), internal to the SFOF and technically controlled by the JPL. The services thus provided are available 24 h per day and are controlled by the DSN Communications Center located in the basement of the SFOF. Figures 119–127 show the DSN/GCF circuits and SFOF nets configured to support the *Surveyor IV* mission.

DSN/GCF. The DSN/GCF is a particular configuration of the NASCOM which supports DSN space flight operations. Comprising teletype, voice, high-speed data and wide-band lines, the DSN/GCF consists mostly of NASCOM circuits including the Pasadena-Goldstone microwave link. Since NASCOM circuits are used to support many installations and activities, of which the DSN/GCF is but one part, circuit usage must be on a requested and scheduled basis from GSFC. Those circuits that do not pass through GSFC must also be scheduled to ensure their availability.

The DSN/GCF provided a system of full-period, leased, four-wire, engineered, voice circuits to a majority of the sites in the network. Most of the voice circuits were routed via the GSFC switching center and comprised the SCAMA. Circuits were routed by hardwire and microwave wherever possible. These circuits extended to overseas points through transoceanic cables, or by high-frequency radio links in those cases where cables were not available. Circuits terminated at the SFOF side of the first switching level; that is, the OVCS console. At the DSIF, the interface is at the DSS side of the first switching level.

The DSN/GCF also provided a system of full-period, full-duplex, leased links composed of leased and commercial facilities obtained from national, international, and foreign common carrier agencies. For purposes of reliability, intercontinental circuits utilized undersea cables wherever possible, but were necessarily routed via radio facilities to reach certain locations. Circuits terminated at the SFOF (user) side of the CP system, except that the JPL nonoperational teletype message center and the equipment therein is a portion of the GCF at the DSIF; the interface is at the DSS side of the dc switching facility.

A system of full-period, leased, high-speed data circuits for the purpose of transmitting spacecraft telemetry requiring a higher bit rate than that of teletype was also provided by the DSN/GCF. These circuits were assigned solely to operational traffic. Circuits terminated at the SFOF side of the dc switching/testing facility between the SFOF and the HSD transmission/monitoring facilities. For project-supplied data sets that used GCF circuits, the interface was at the SFOF side of the communications switching jacks equipment. At the DSIF, the interface was at the DSS side of the switching/testing facility between the DSS and the HSD transmission/merging/monitoring facilities.

In addition, the DSN/GCF provided several full-period, leased, wide-band data circuits between the SFOF and the Goldstone DSS. These circuits were used for operational traffic only. Circuits terminated at the SFOF side of the first-level switching and monitoring facilities. At the DSIF, the interface was at the DSS side of the wide-band transmission, first-level switching and monitoring facilities.

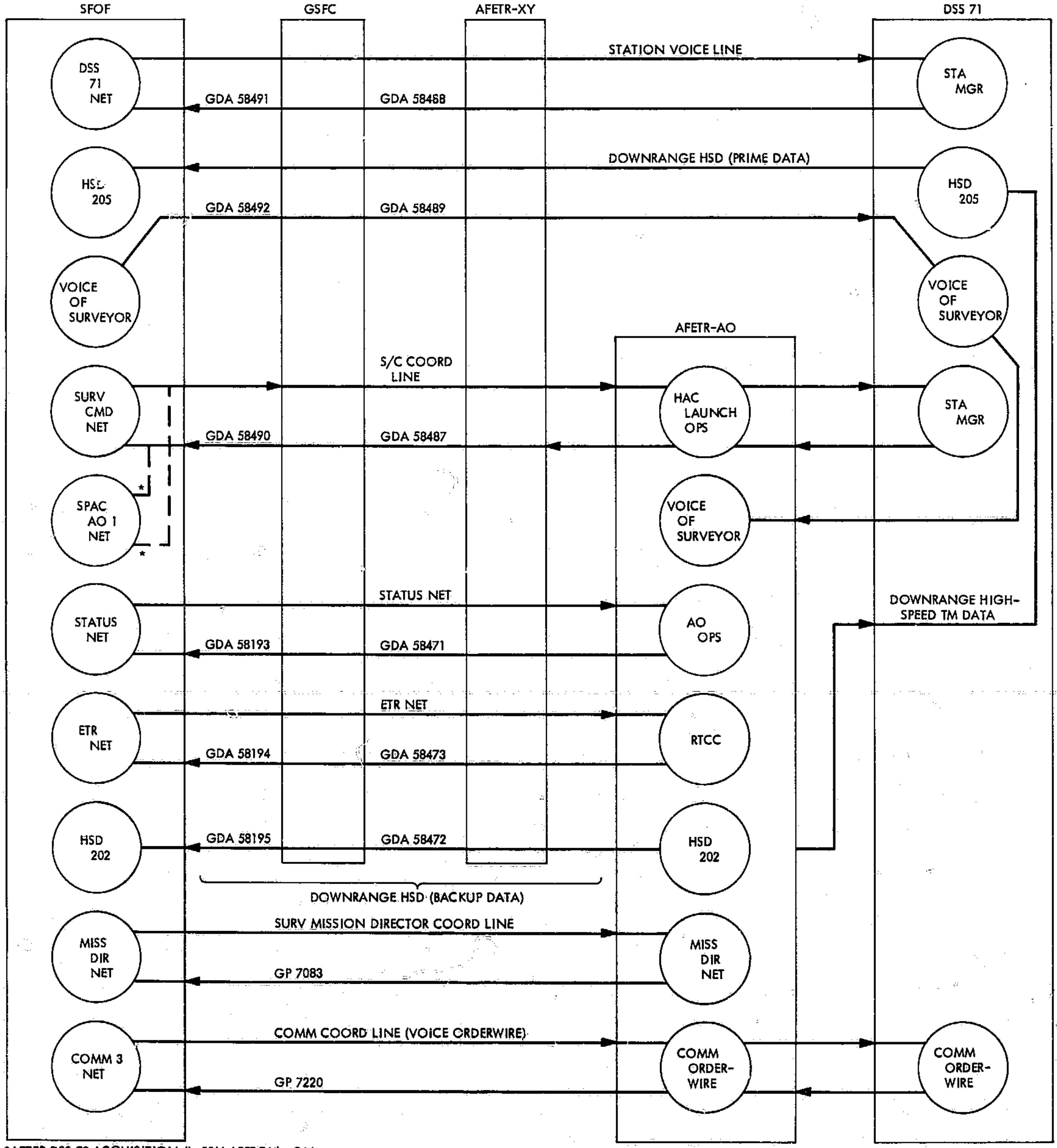
SFOF/ICS. The SFOF/ICS is composed of the internal circuits and equipment required to provide an integrated, multipurpose, internal communications network for the support of all space flight missions and simulations conducted in the SFOF. Both special purpose and conventional communications equipment are used. Most of this communications equipment is owned by JPL; however, certain end items of equipment and nearly all audio equipment are leased from commercial sources. Figures 128 and 129 show the DSN/ICS configuration in support of *Surveyor IV* mission.

The three functions of the SFOF/ICS were as follows:

(1) To provide an end terminal and switching capability for NASCOM and other special purpose circuits external to the SFOF. In this respect, the SFOF/ICS is capable of the reception of voice, teletype, high-speed and wideband data from the various data acquisition stations through the media of the DSN/GCF. The same capability exists in terms of transmitting from the SFOF to various external terminals.

(2) To provide a facility whereby incoming data to the SFOF may be properly routed to user areas throughout the SFOF. In this respect, the SFOF/ICS is capable of distributing such data by both audio and visual means.

(3) To provide a facility whereby user areas of the SFOF are interconnected with each other. In this respect, the SFOF/ICS is capable of providing both audio and video transmission and reception capabilities.



*AFTER DSS 72 ACQUISITION (L-30M APPROX), ON REQUEST OF ACE 1, VOICE LINE TO HAC LAUNCH OPERATIONS REVERTS FROM SURV CMD NET TO SPAC A/O NET.

Fig. 119. *Surveyor* Mission D voice/high-speed data configuration diagram, AFETR-AO and DSS 71

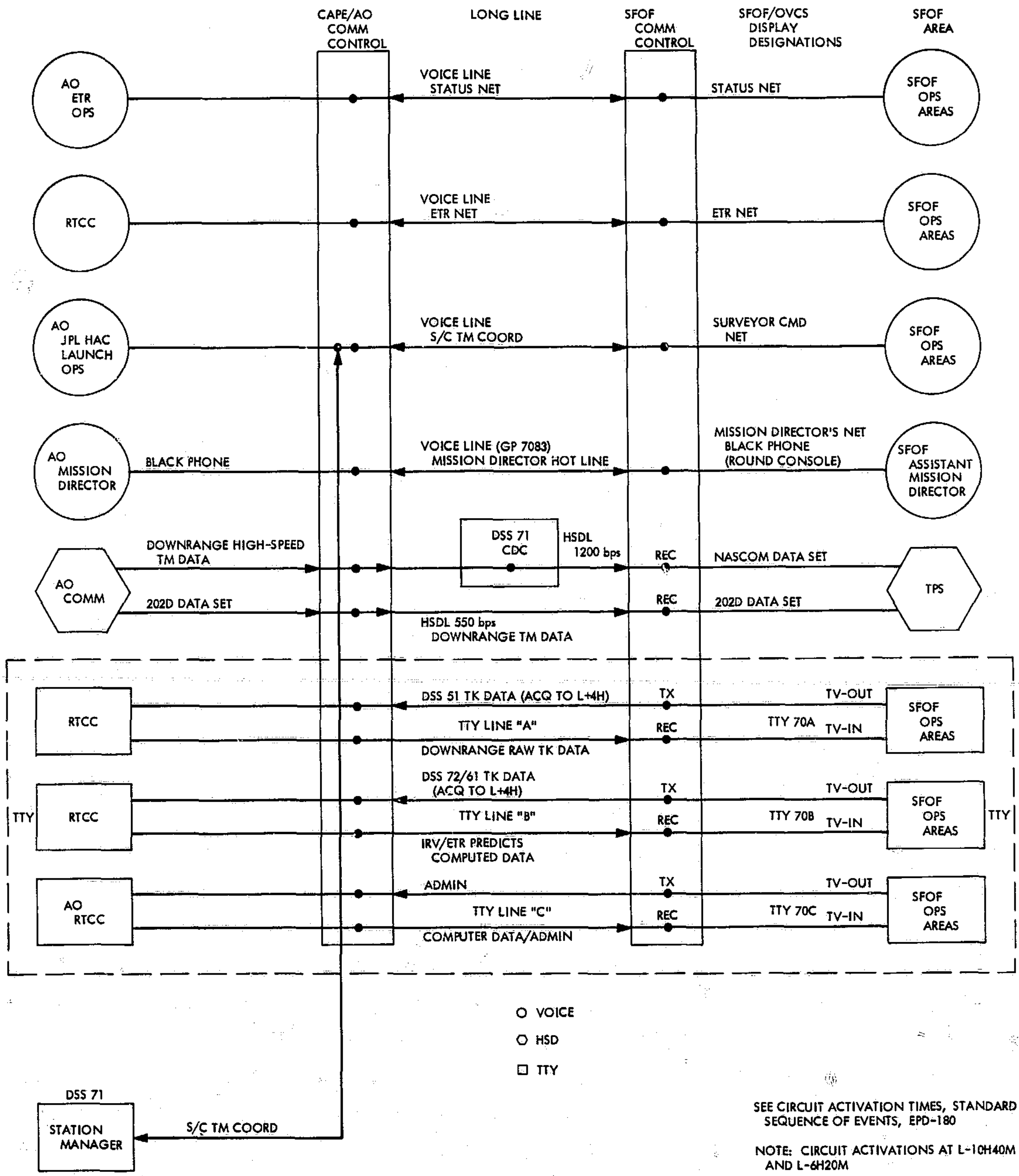


Fig. 120. SFOF/AFETR-AO initial circuit configuration diagram

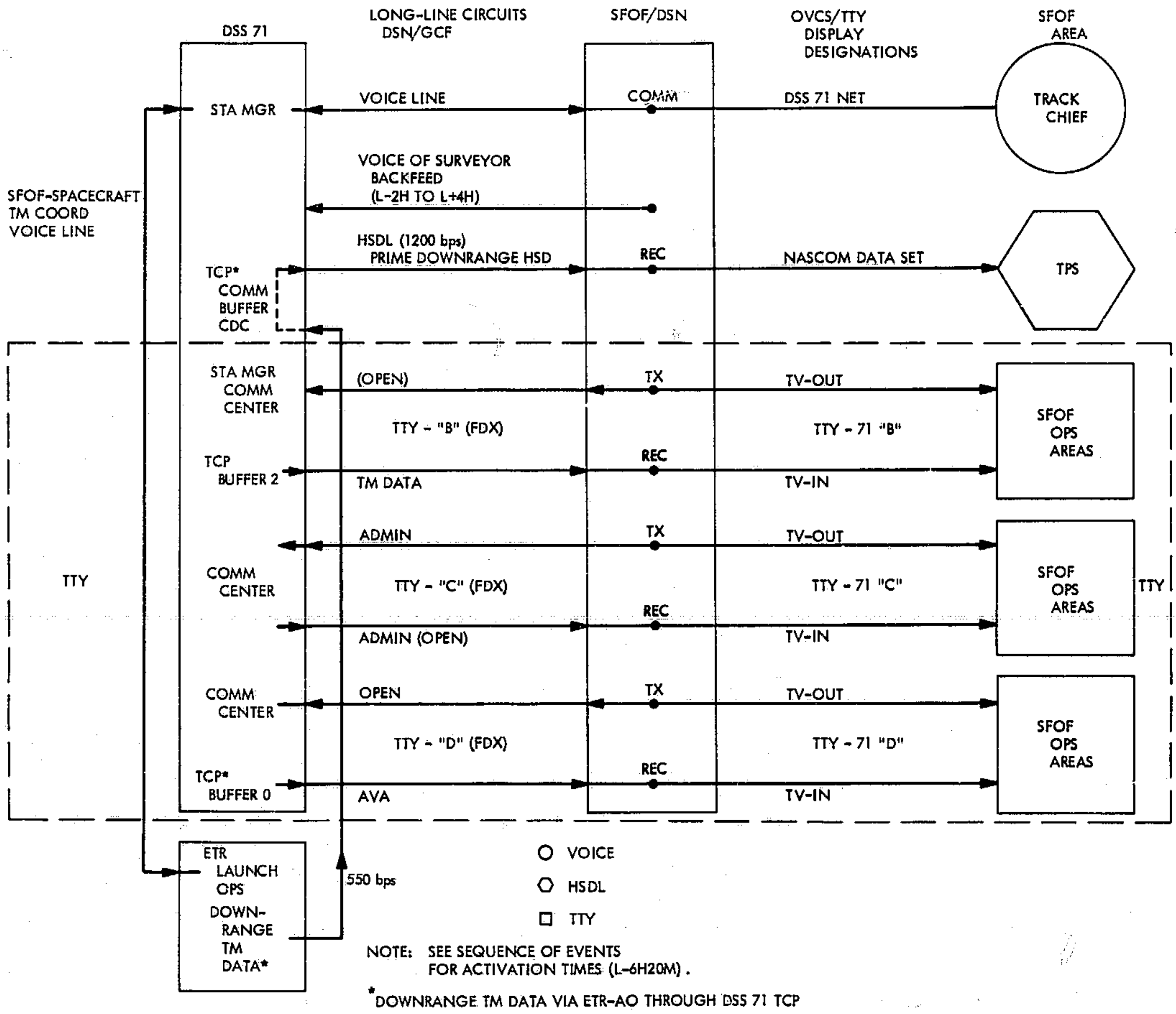


Fig. 121. SFOF/DSS 71 initial circuit configuration diagram

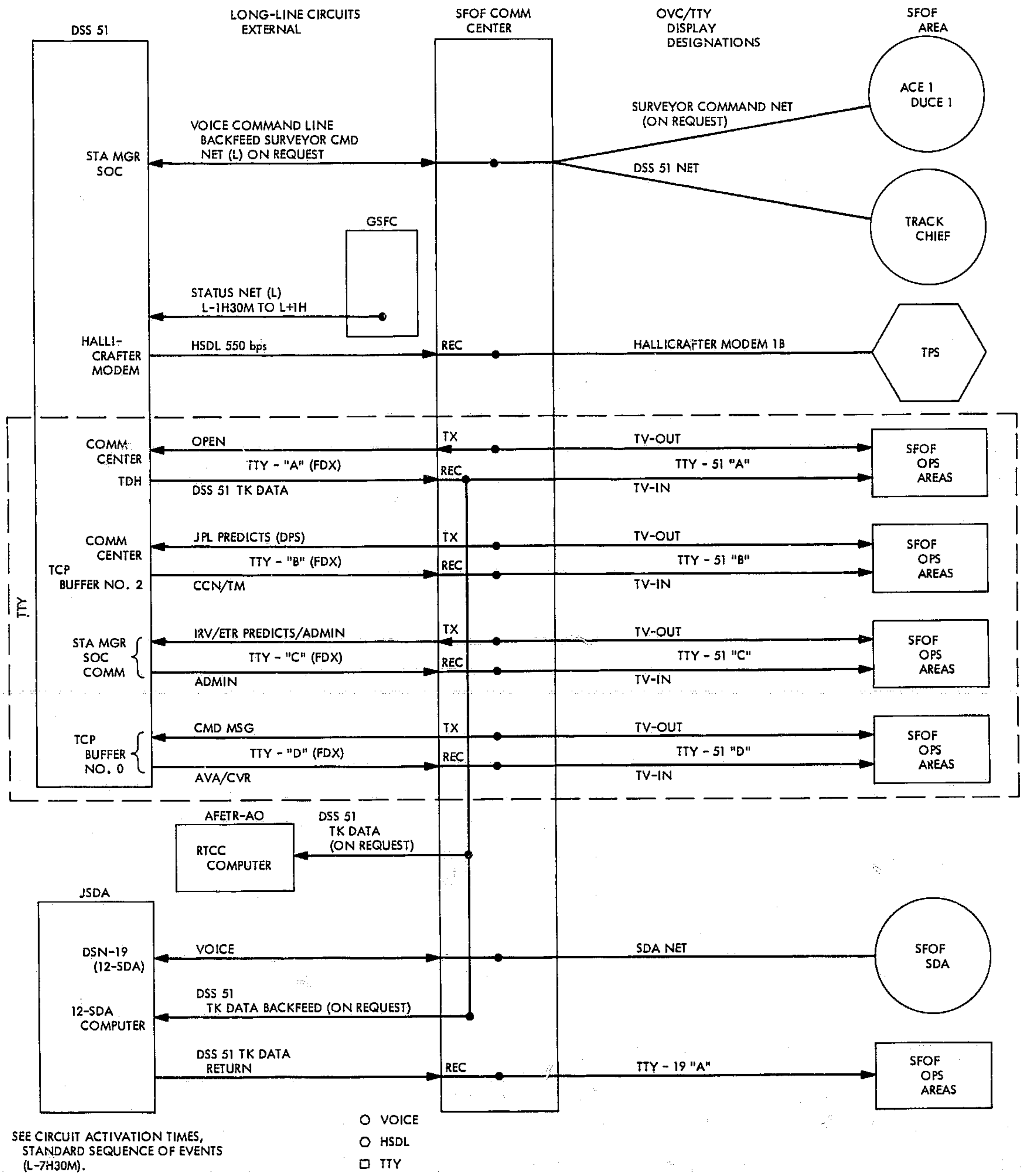


Fig. 122. SFOF/DSS 51 initial circuit configuration diagram

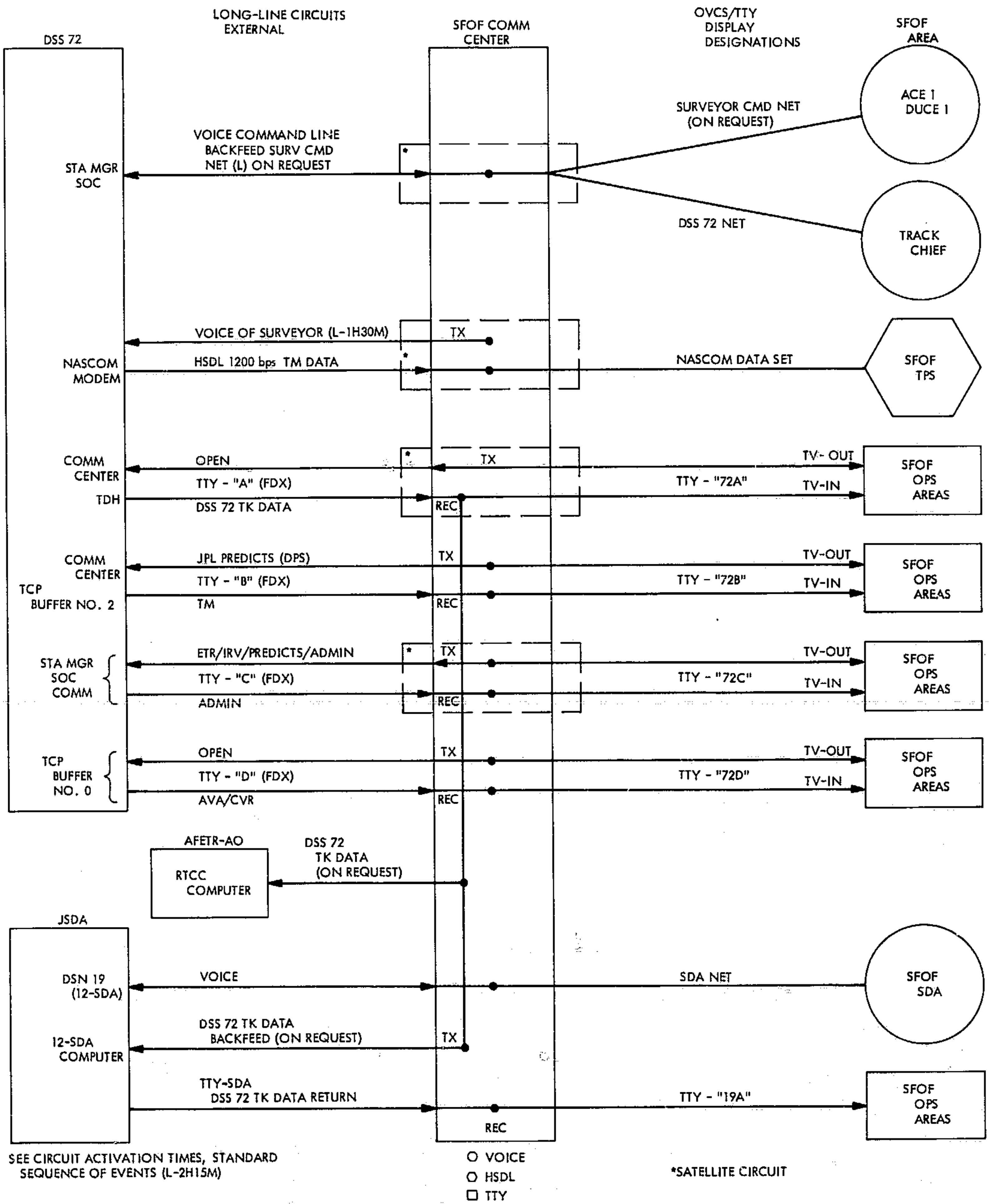


Fig. 123. SFOF/DSS 72 initial circuit configuration diagram

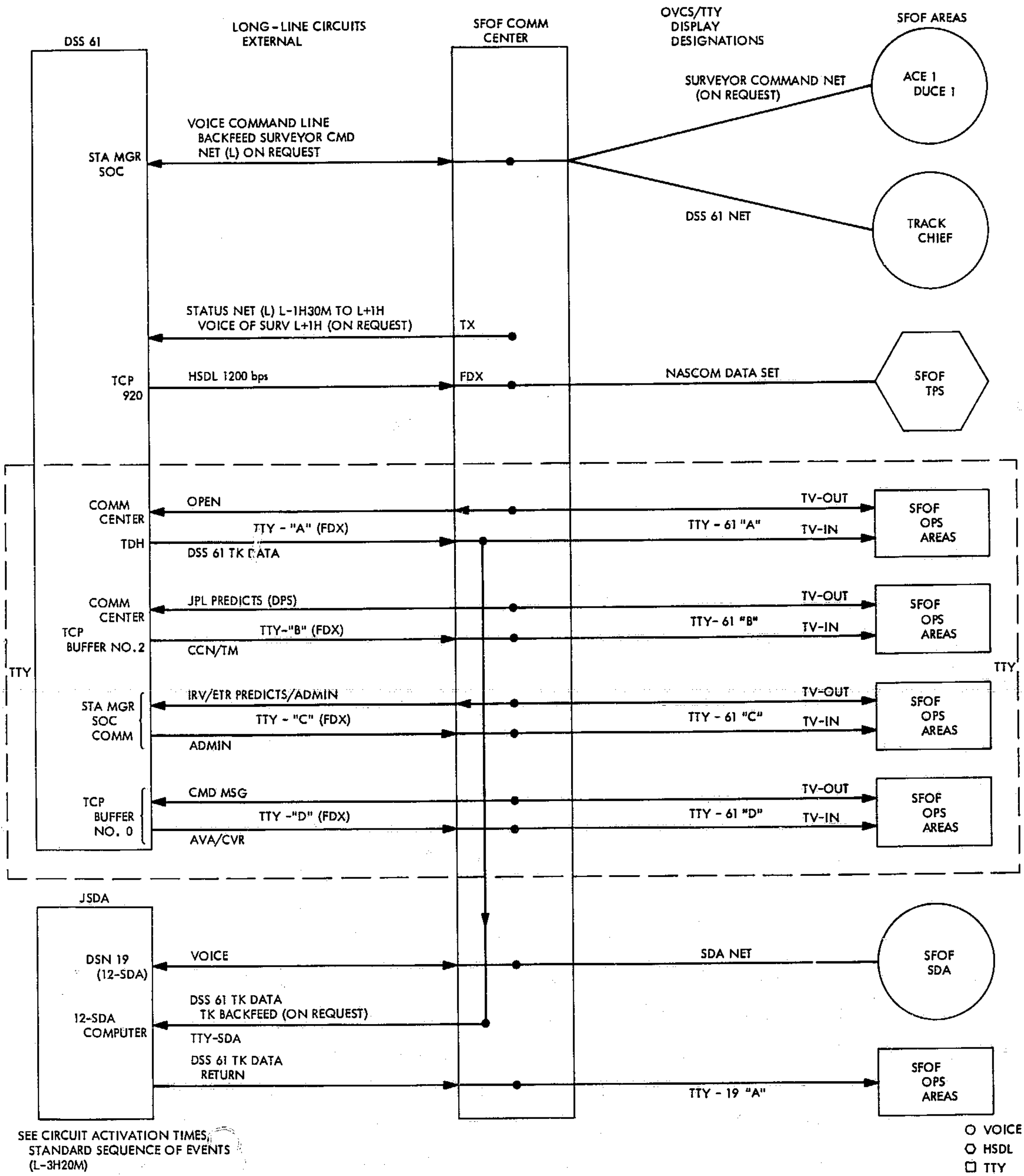


Fig. 124. SFOF/DSS 61 initial circuit configuration diagram

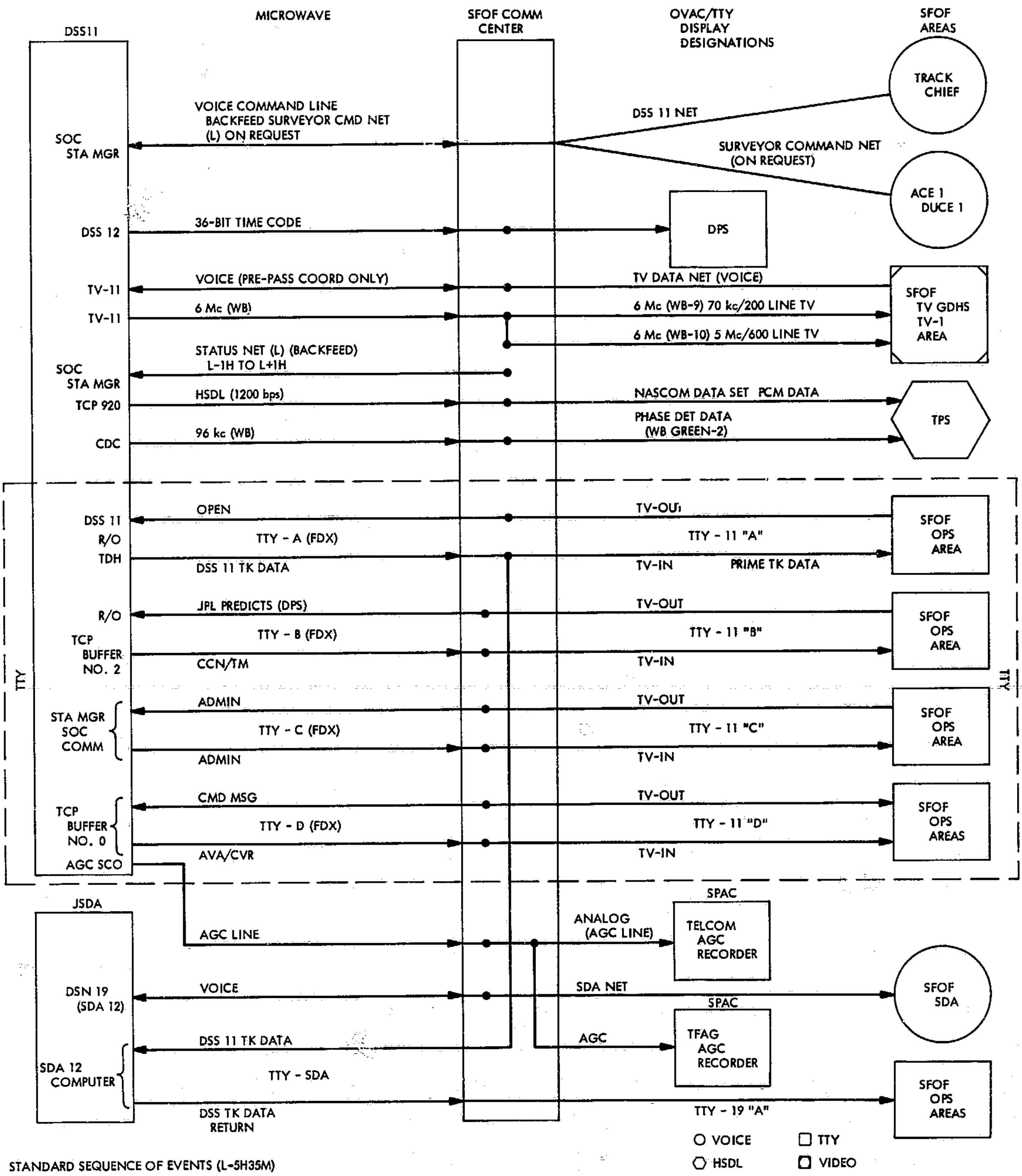


Fig. 125. SFOF/DSS 11 initial circuit configuration diagram

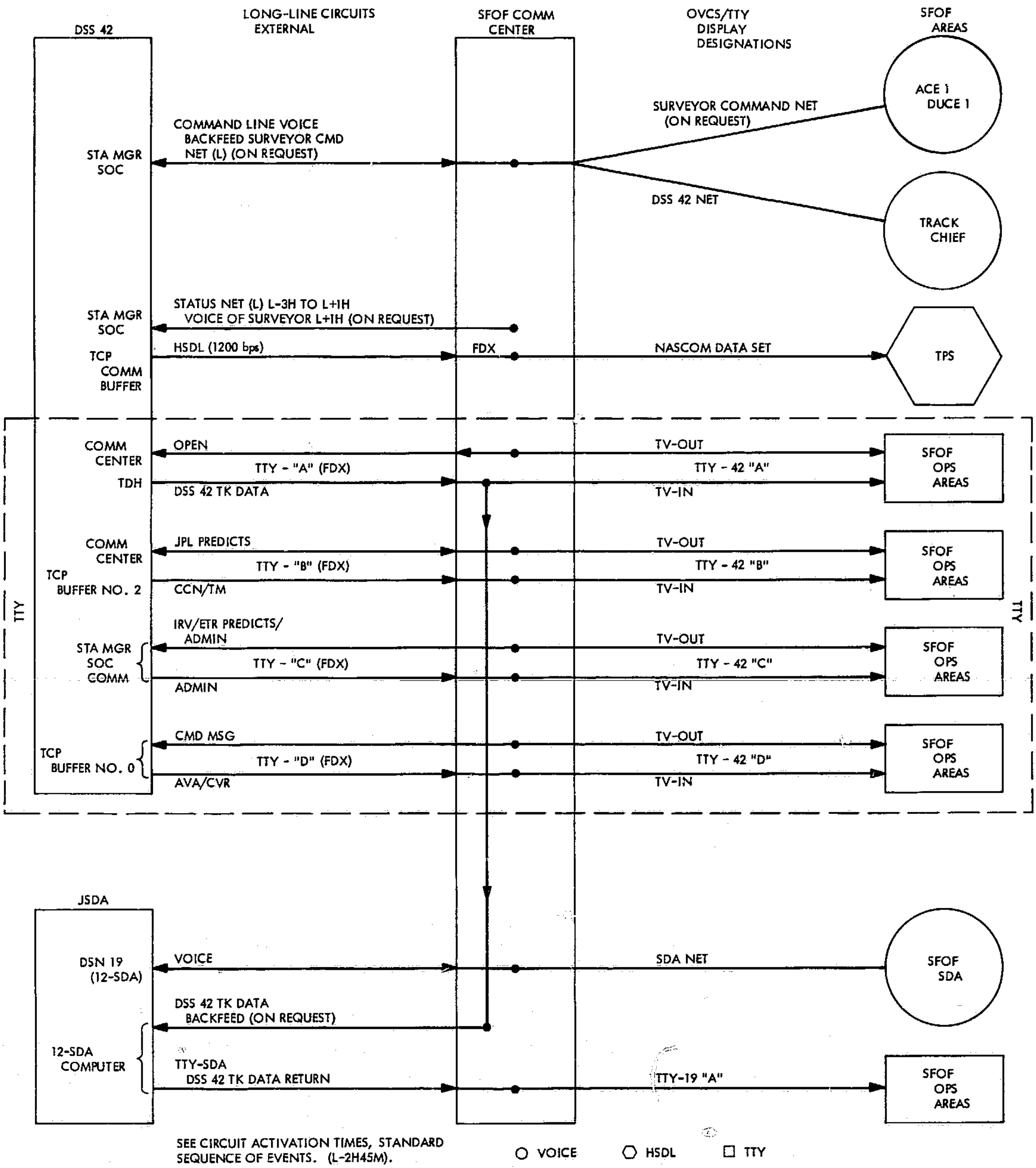
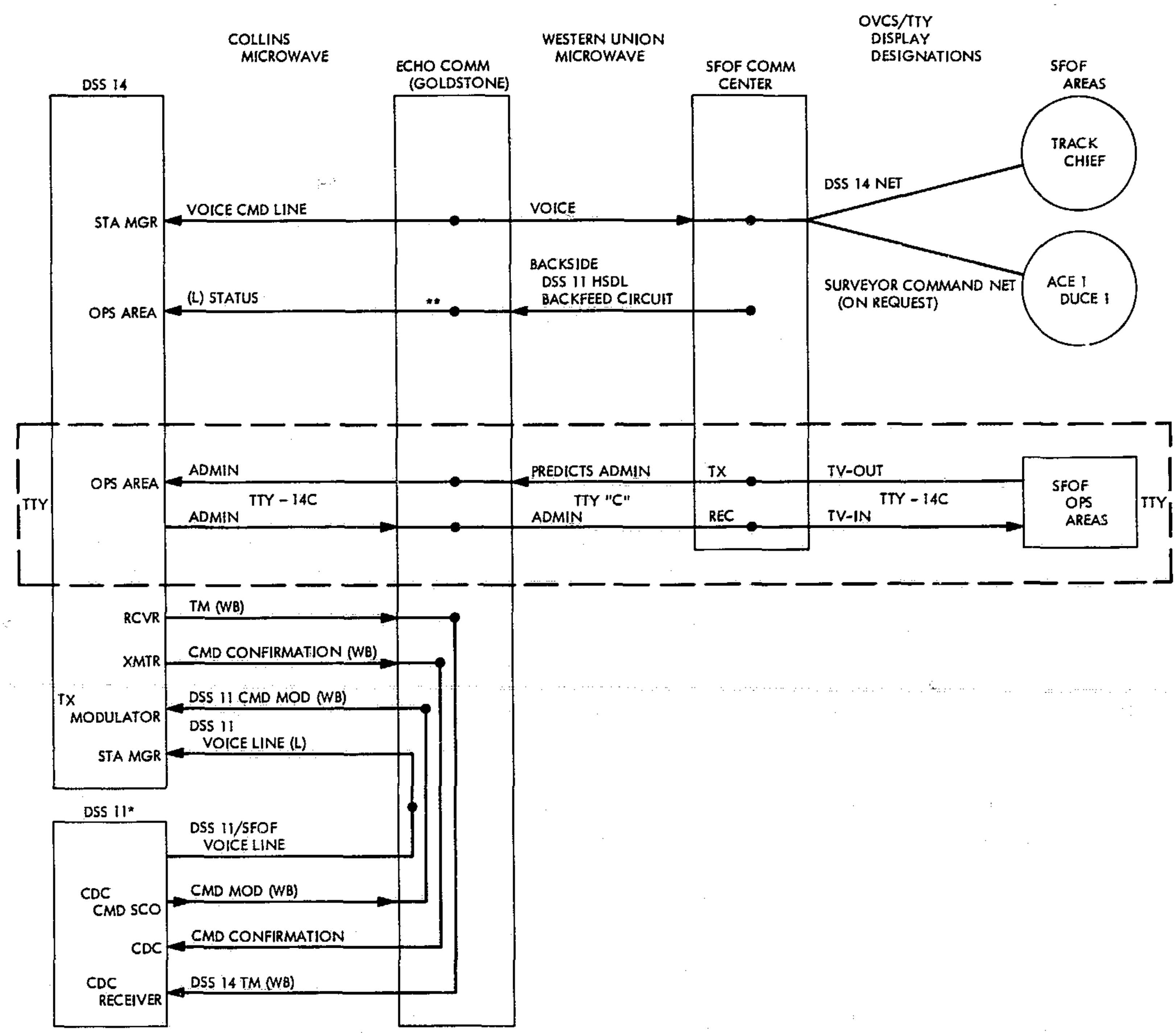


Fig. 126. SFOF/DSS 42 initial circuit configuration diagram



NOTE: DSS 14 PARTICIPATES IN M/C AND TERMINAL PHASES ONLY.

* SEE DSS 11 CIRCUIT CONFIGURATION DRAWING FOR OTHER DSS 11/SFOF CIRCUITS.

** STATUS NET BRIDGED TO GOLDSTONE OVERHEAD SPEAKERS AT ECHO COMM.

Fig. 127. SFOF/DSS 14 initial circuit configuration diagram

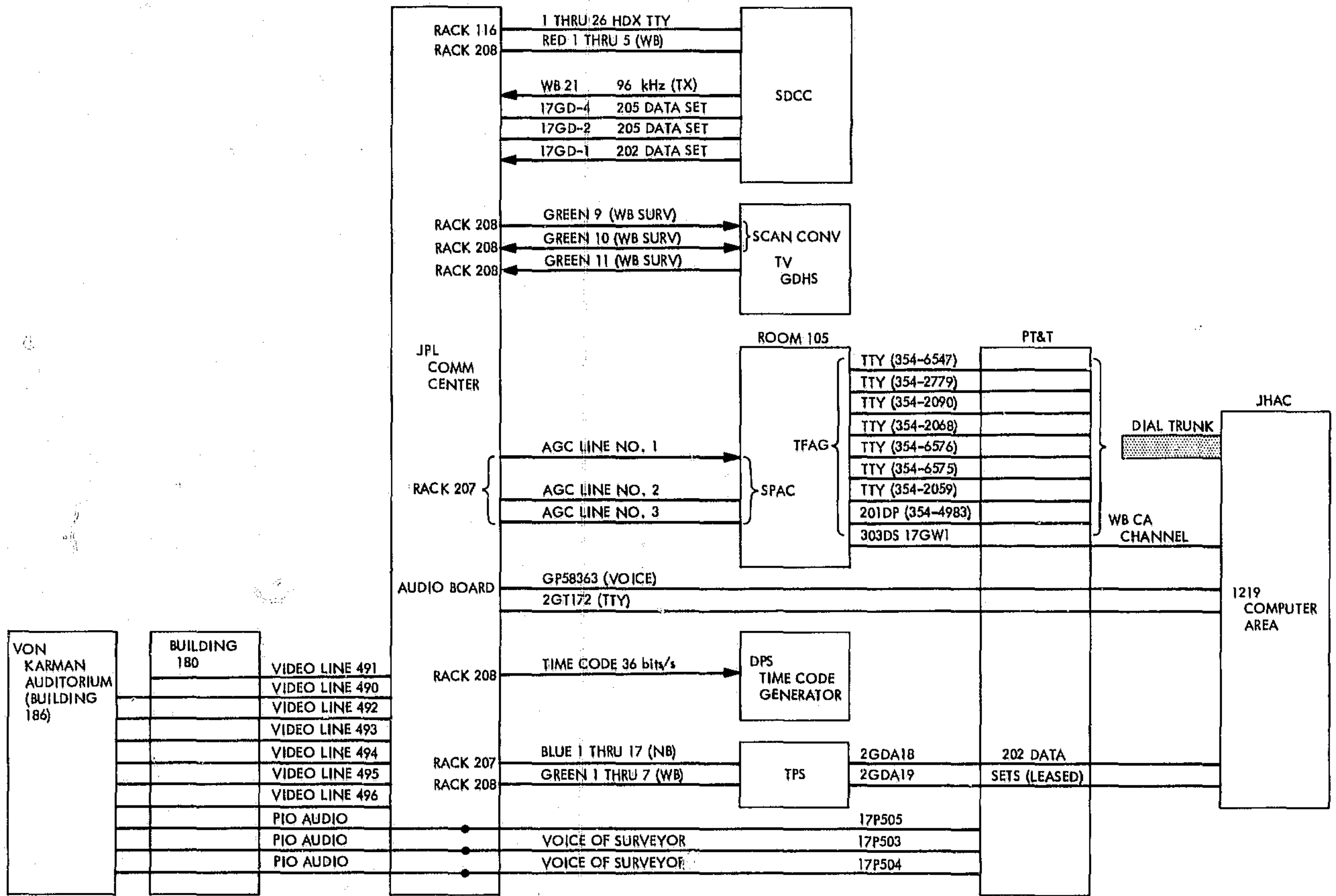
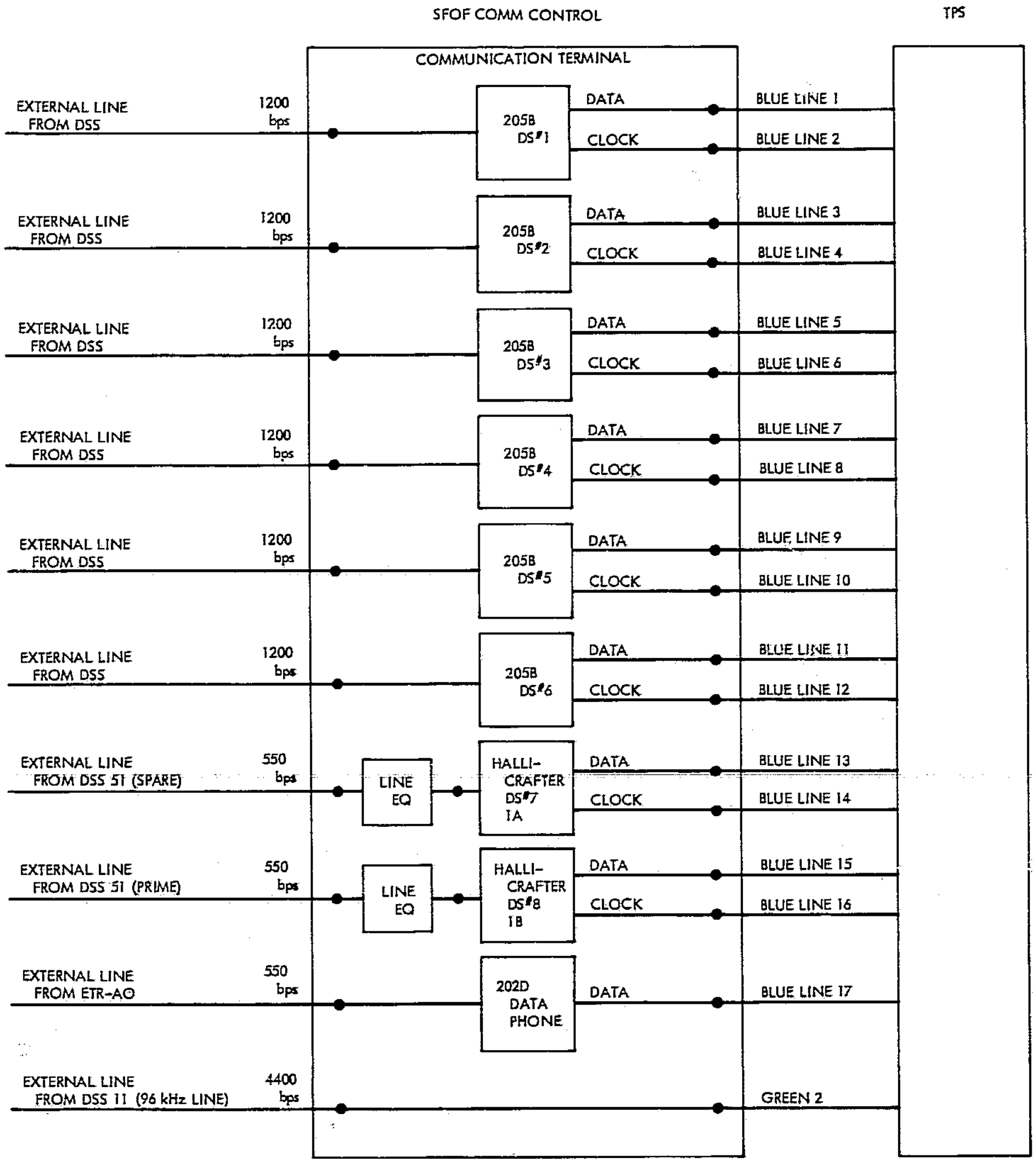


Fig. 128. SFOF/ICS line configuration supporting the *Surveyor IV* mission



NOTES:

1. NASCOM DATA SETS WILL BE USED TO ALL DSSs EXCEPT WHERE OTHERWISE ASSIGNED. COMM DPS LINE ASSIGNMENTS WILL BE IN ACCORD WITH THE LINE DRAWINGS.

2. WHEN HSDL IS ACTIVATED, COMM CHIEF WILL, IN REAL TIME, REQUEST DATA CHIEF TO DESIGNATE WHICH NASCOM 205 DATA SET WILL BE USED TO TERMINATE EACH HIGH-SPEED DATA LINE.

Fig. 129. Communications and data processing system high-speed data line assignments

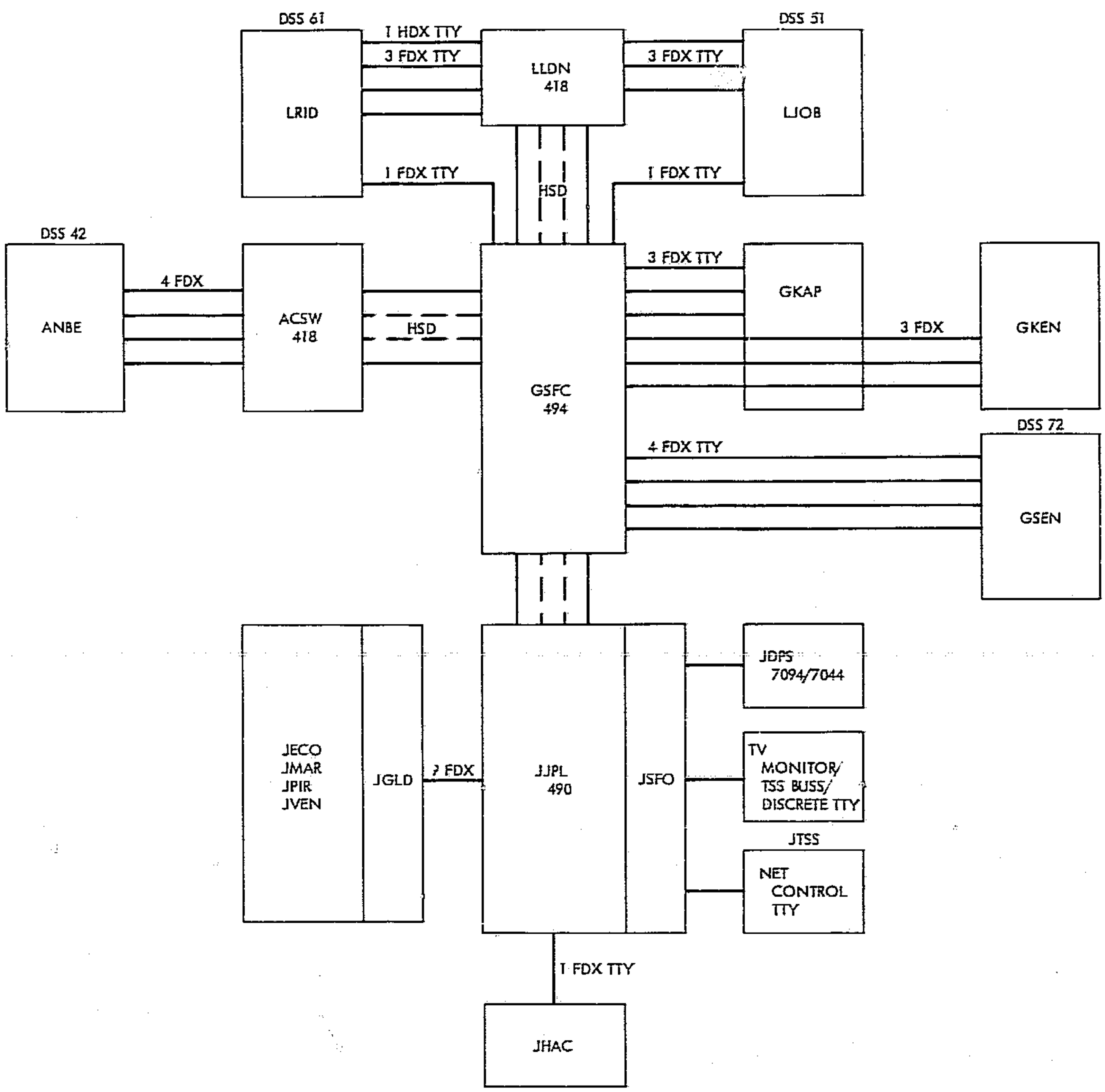


Fig. 130. DSN/GCF teletype communications processor configuration for supporting Surveyor IV mission

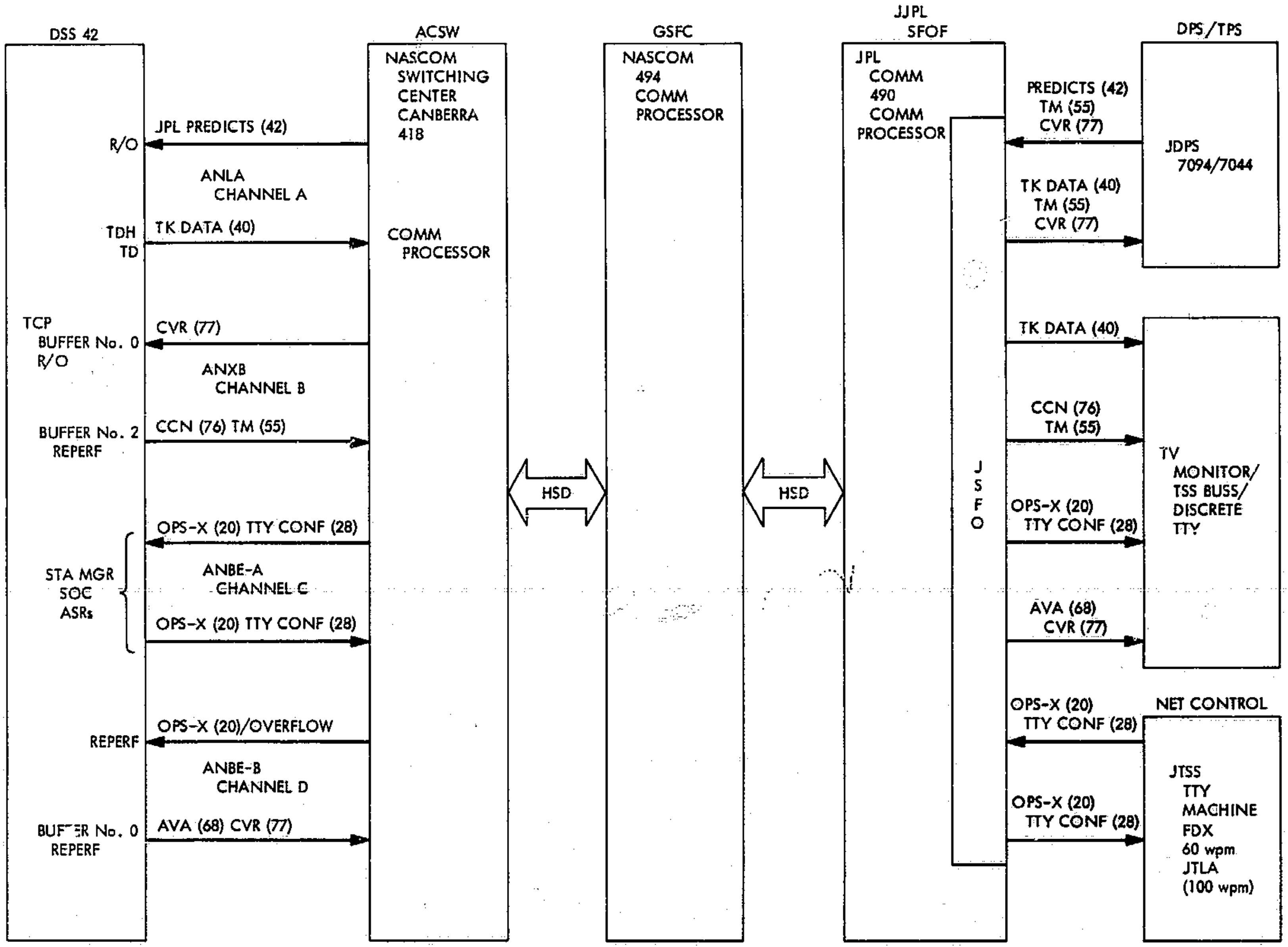


Fig. 131. SFOF/DSS 42 teletype communications processor traffic flow configuration diagram for the *Surveyor IV* mission

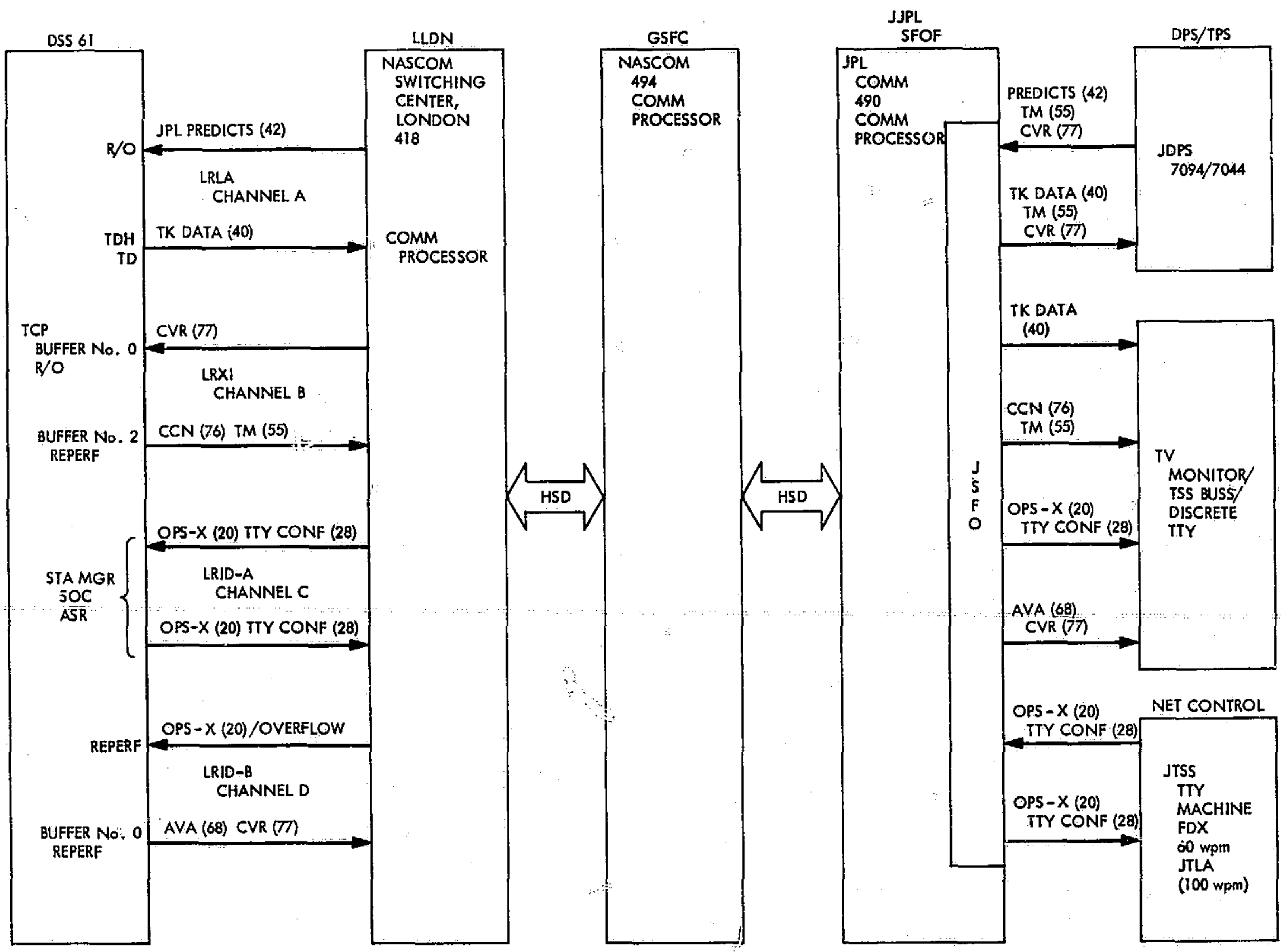


Fig. 132. SFOF/DSS 61 teletype communications processor traffic flow configuration diagram for the *Surveyor IV* mission

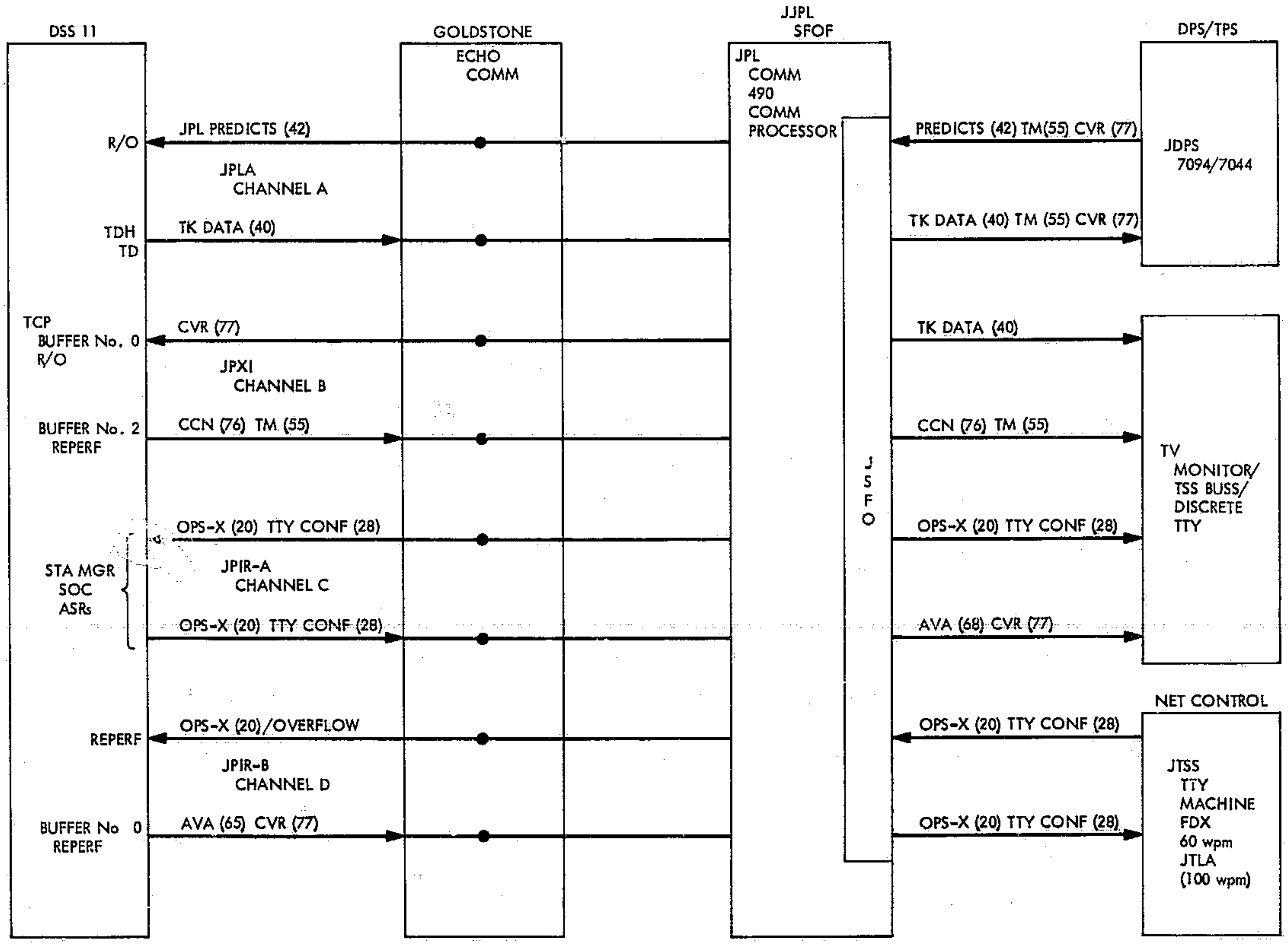


Fig. 133. SFOF/DSS 11 teletype communications processor traffic flow configuration diagram for the *Surveyor IV* mission

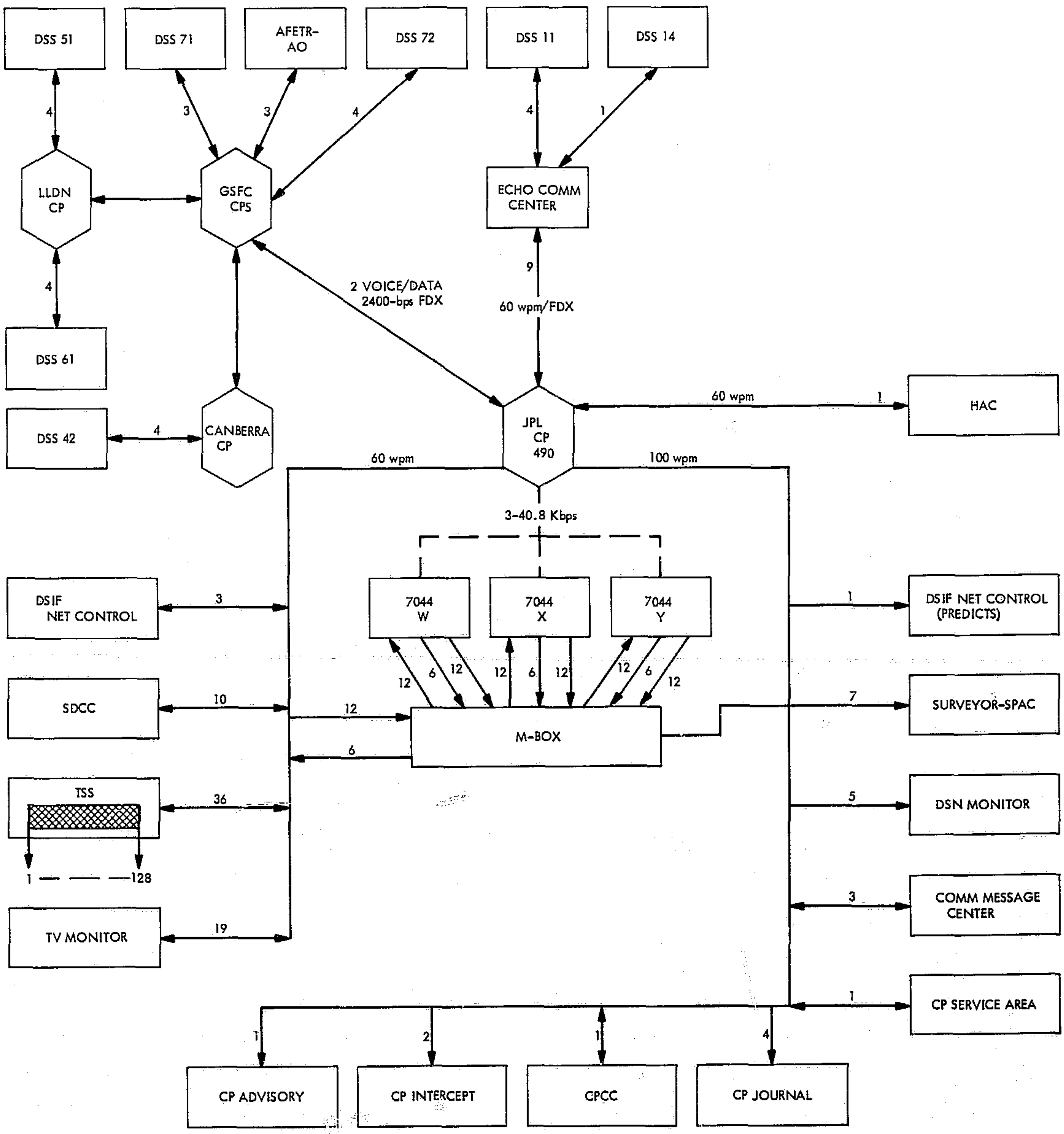


Fig. 134. *Surveyor*/Comm Processor/7044C GCF/SFOF circuit configuration diagram

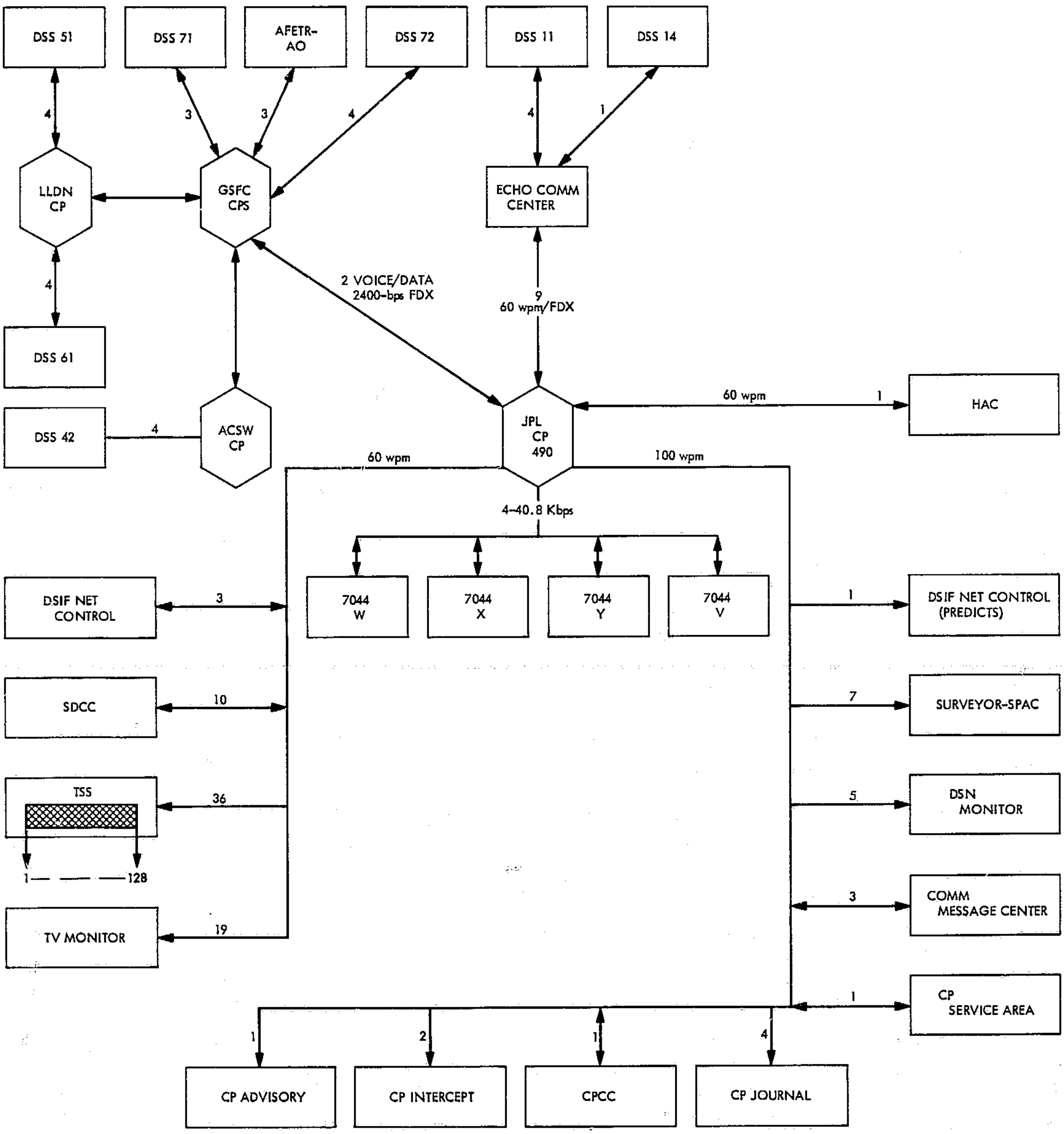


Fig. 135. Ground communications facility, SFOF, circuit configuration diagram for Surveyor

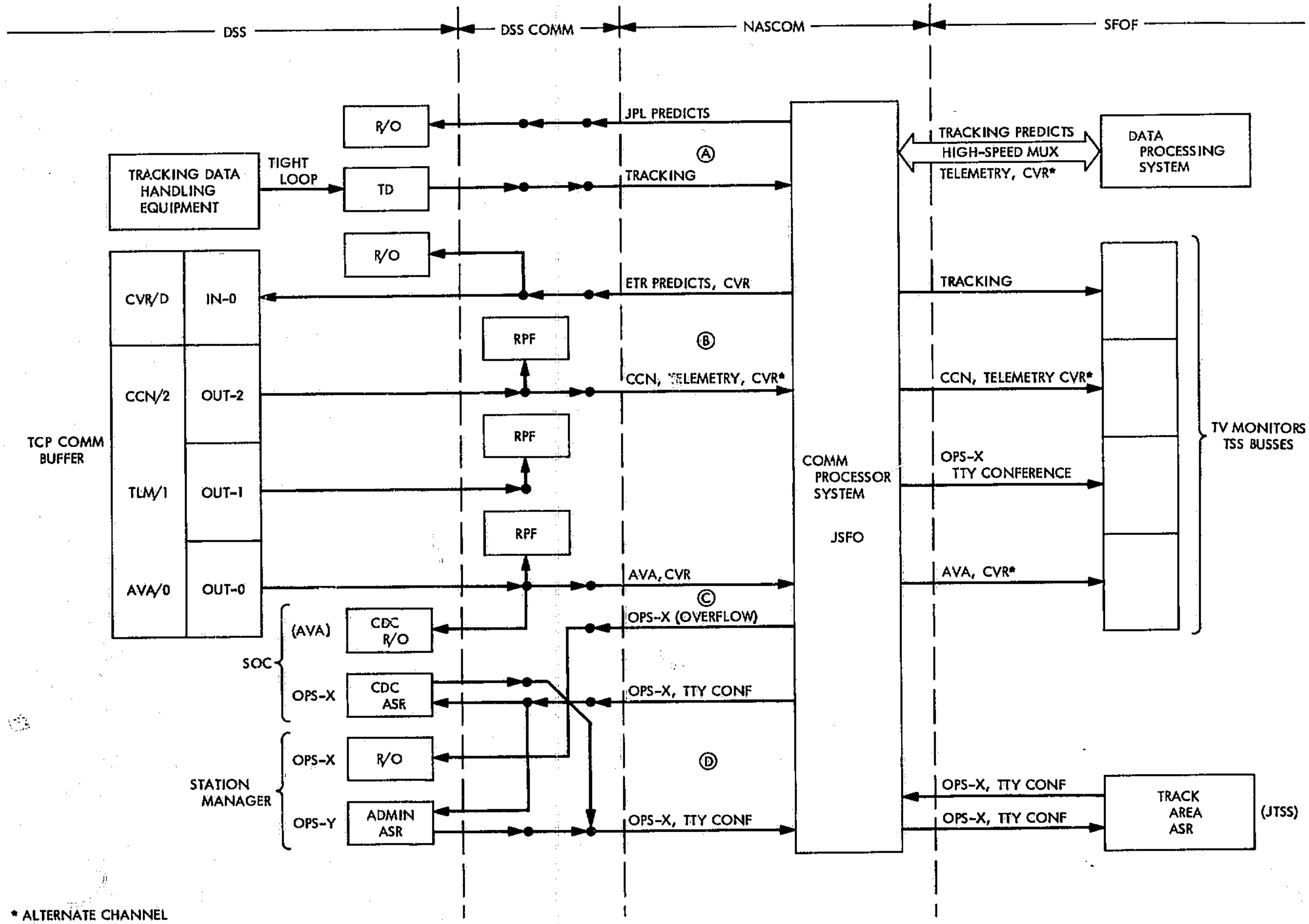


Fig. 136. Standard TTY channel configuration (functional requirements) for the *Surveyor IV* mission

The SFOF/ICS is composed of the following subsystems:

(1) Operational voice communications subsystem (OVCS).

(2) Operational status recording subsystem (OSRS).

(3) Operational public address subsystem (OPAS).

(4) Operational voice recording subsystem (OVRS).

(5) Operational miscellaneous audio subsystem (OMAS).

(6) Operational teletype communications subsystem (OTCS).

(7) Television communications subsystem (TVCS).

(8) High-speed data subsystem (HSDS).

(9) Wide-band communications subsystem (WBCS).

Displays. DSN communications control provides three status displays to provide information to users about communication circuits activated in support of flight projects. These displays are available on the TVCS and consist of the following:

(1) Teletype status display.

(2) Audio status display.

(3) Propagation status display.

Support readiness. Satellite voice circuits via Atlantic *Intelsat* was again provided to DSS 72 for ORT and mission critical launch phase. This path was used for the first time during Mission C and its quality and reliability proved excellent. *Intelsat* has 6 voice/data channel capability to DSS 72 at Ascension Island.

NASCOM has established a new voice backup circuit to DSS 51 via Ascension satellite or HF radio to Pretoria (USAF Station) by HF radio then to DSS 51 by cable. This circuit was used for the first time during the *Mariner* launch; however, the circuit did not prove very satisfactory on that first attempt.

TTY circuits remained the same as for the *Surveyor III* mission except for the new TTY backup circuit to DSS 51. This new NASCOM circuit uses the same Ascension routing as the new voice backup circuit mentioned above. This circuit was used as backup by GSFC during *Mariner* ORT and launch and proved to be quite reliable. This circuit is routed via satellite from Ascension to GSFC; however, its use required dropping one of the two DSS 72 satellite TTY channels.

There were no changes in the HSD system since the *Surveyor III* mission except in the SFOF/HAC 1219 computer interface where two new data phones were added.

No changes had been made to the JPL/Goldstone microwave system since the *Surveyor III* mission. Special maintenance coverage requested by the project for this system was as follows:

(1) Launch phase: none.

(2) Midcourse phase: $L+10$ h to $L+18$ h.

(3) Touchdown/terminal phase: $L+58$ h to $L+66$ h.

The CP from a communications standpoint was in the green and capable of supporting the *Surveyor IV* mission. Communications personnel were still in a phase of revising and completing the many new interface procedures and familiarizing user and support personnel with them; however, the CP had successfully supported the *Mariner* 1967 launch and mission and was supporting the lunar orbiter extended missions.

Except for the implementation of the CP system after touchdown there have been very few changes in project requirements or system capabilities for the GCF since the *Surveyor III* mission. An alternate voice and TTY circuit from DSS 51 through the Pretoria AFETR station via HF radio link to Ascension Island and the satellite circuit to the United States was to be available for *Surveyor IV*. Other communications facilities were to be provided as in previous *Surveyor* missions. Figures 130–136 show the *Surveyor IV* mission DSN/GCF communications processor circuits configuration.

Both the DSN GCF and the ICS were considered to be in excellent condition to support the *Surveyor IV* mission.

c. Space Flight Operations Facility. The SFOF had been assessed to be generally ready to support the *Surveyor IV* mission. At the *Surveyor* project request, two modifications were made to the SFOF. One change consisted of adding a full round console to the *Surveyor* mission control room to provide operational positions for the SFOD and other mission control personnel. The other change was the installation of a full duplex high-speed data circuit, using a 303 data phone, between the SFOF and Hughes Aircraft Co. (HAC), El Segundo, Calif. The 303 data phone would permit transmission of all *Surveyor* data rates (including 4400 bits/s) to Hughes for processing by the 1219 computer. In addition, this data phone would permit operation of a high-speed line printer in the SPAA remotely driven by the 1219 computer. The 303 data phone and associated microwave circuit were provided by the *Surveyor* project. The DSN provided interfaces to the two TPS strings, with the signals terminated in a switch in the SPAC area; the switch permitted *Surveyor* personnel to select which of the two TPS data streams would be sent to HAC for processing.

The implementation of the 7044 Redesign/CP for *Surveyor IV* mission was somewhat delayed because primary emphasis was placed on readying this system for the *Mariner V* launch. Therefore, it was decided early in June 1967, that the translunar portion of the *Surveyor IV* mission would be operated using the existing 7044 C system, with manually switched teletype lines. After touchdown *Surveyor* would switch to the 7044 Redesign/CP system to conduct lunar operations. This was necessary if a 7044 computer was to be shared with *Mariner V* and permit the required computer support for the *Lunar Orbiter V* mission. Tests were conducted to verify this capability.

An improvement was made to the CSC-94C system to correct spurious computer communications errors (COMM Error 1) which occurred throughout the *Surveyor III* mission. This improvement would not preclude COMM errors from occurring for other causes, but would eliminate the great majority of COMM errors which had been occurring.

Operational procedures were implemented for the TPS whereby operational control of the TPS through the data chief was waived for *Surveyor IV* mission to permit direct *Surveyor*/TPS interfaces.

A software modification was made to improve operation of card readers. Although card reader failures for mechanical problems were not affected, the reliability of card reader operation was substantially improved by the modification. A modification made to the Milgo plotters by the manufacturer included circuit elements which were substandard; those elements were replaced.

Since the *Surveyor III* mission, an operation and maintenance group directly responsive to SFOF Operation has been implemented for SFOF facilities operation. Support capabilities and response time to problems should be greatly improved for the *Surveyor IV* mission. Technical area staff has been augmented to accommodate any committed requirements for the *Surveyor IV* mission.

Two SFOF Operations briefings were planned for the *Surveyor* operations staff to provide additional training for Mission IV. One briefing was for the CP procedures and interfaces for post-touchdown operation and the second briefing for Data Processing System operations. The DACON operations area of the SFOF (Room 104) was implemented with the *Surveyor* requirements for post touchdown operations.

B. Tests.

To insure the successful launch and flight of *Surveyor IV* mission a great deal of preparation and compatibility testing was needed to determine the operational readiness of the mission. Thus, operational readiness tests were performed in an endeavor to assure a mission success.

1. AFETR. The facilities of the AFETR are under a constant state of testing. The preparation and testing of the T&DS, launch and near-earth phase support of the *Surveyor IV* mission was successfully accomplished in the following tests.

a. Test of June 26, 1967. The RTCS was unable to use the metric data from Antigua, due to a problem with the radar target acquisition (RATAC) system, which was subsequently fixed. Check-out of the telemetry circuits in the minus count was delayed due to a subcable problem at Grand Turk. This was worked around and telemetry data flow in the plus count was good.

b. Test of July 9, 1967. The telemetry tapes used for the simulation provided some problems but did not hamper the proper testing of the telemetry re-transmission system. The interface between building AO and JOPS at the SFOF was satisfactorily exercised. RF propagation was poor to fair in the minus count, with a continuous improvement for $T - 0$ and the plus count. Some of the DSN tracking data were delivered late to the AFETR, because of an operational problem at the SFOF; that problem was corrected before launch. There were no unresolved problems.

The telemetry tapes used for both of the above tests were apparently prepared without the 14.5-kHz data. This caused no difficulty during the tests, however, because the AFETR stations played back the 3.9-kHz spacecraft data instead.

c. S/C-4/TEL-2 compatibility test. The objective of this portion of the S/C-4/MOS compatibility test was to demonstrate the ability of a typical range receiver facility, represented by Tel-2, to receive, detect and transmit to building AO, the *Surveyor* S/C-4 telemetry data received via the *Centaur* VHF and spacecraft S-band and RF links.

The test objectives were met on a non-interference basis and required no special test configurations or procedures. The test was essentially a functional compatibility test for the purpose of demonstrating the ability of the STEA-CDC decommutator to acquire lock with the serial PCM obtained from either the *Centaur* or S/C-4 RF links via the Tel-2 VHF or S-band receivers, respectively. The signal to the decommutator was switched between the Tel-2 receiver output (after discrimination of the PCM from the subcarrier) and the reconstructed TDM-1 decommutator PCM output. At Tel-2, a tape recording was made of the telemetry subcarrier in the format specified in PRD 3400.

In general, if allowance is made for measurement uncertainties, the spacecraft and ground systems performed within specified limits in those cases where specifications were clearly defined. This was not an exhaustive test of all spacecraft and ground system parameters in all operating configurations. Rather, it was a spot check of those parameters and operating modes most pertinent to the mission. The spacecraft calibration data, used to obtain AGC, SPE and AFC corresponding to telemetered data numbers, was obtained from HAC documentation.

In this test the temperatures of the frequency determining elements were not available. Normally, the compartment A tray bottom temperature was used instead. It was apparent from the test data that there was a static offset between the tray temperature and the transmitter and receiver temperatures during static thermal periods.

VHF link telemetry. The STEA-CDC decommutator successfully acquired lock with the 550 bits/s serial PCM telemetry received via the Tel-2 receiver output and the TDM-1 decommutator. The DSN bit synchronizer was capable of maintaining lock with either the Tel-2 bit stream or the bit stream from the CDC decommutator. The data played back from tape was successfully processed by the Computer Data System.

The STEA-CDC decommutator successfully acquired lock with the spacecraft telemetry received via the *Centaur* VHF link. Data was not processed by the computer in real time. However, playback of recorded data was accomplished without difficulty.

S-band link telemetry. The STEA-CDC decommutator successfully acquired lock with the S/C-4 telemetry received via the spacecraft S-band link. The telemetry was received via the *Surveyor* spacecraft S-band RF link and the Tel-2 S-band receiver.

NBVCXO frequency drift. The maximum rate of change of the transmitter B system, NBVCXO, due to heating in the high power mode, was 5.6 Hz/s and 4.5 Hz/s for the A transmitter system.

WBFM telemetry. The frequency of transmitter B in WBVCXO mode was 2295.038048 MHz, and transmitter A 2294.989760 MHz. No spurious signals were observed in the spectrum. Frequency drifts noted in the high power mode were negligible.

SCO frequencies and telemetry error rate. All parity error rates were normal when link variations are considered. SCO offsets were noted, but were within specifications.

TV transmission frequencies. Transmitter frequencies at S-band corresponding to TV sync, porch, PCM one, and PCM zero were measured. All readings were satisfactory.

Spacecraft receiver phase-lock threshold. Both receivers exceeded threshold specifications at best lock. At ±70 kHz from best lock, receiver A threshold degraded by 13 dB while receiver B degraded 4 dB. No specification is known for the threshold at ±70 kHz.

Spacecraft receiver AFC threshold. Both receivers provided an AFC threshold which was satisfactory.

Spacecraft receiver phase lock tracking range. Both spacecraft receivers have adequate phase-lock tracking ranges for nominal mission requirements.

Spacecraft receiver best-lock frequency. Test results indicated that nominal best lock frequencies for receivers A and B were:

(1) 2113.309440 MHz for receiver A at 85°F.

(2) 2113.327968 MHz for receiver B at 84°F.

Table 58. Summary of tests conducted prior to the *Surveyor IV* mission

Test	May				June				July		
	6	13	20	27	3	10	17	24	1	8	15
B Tests—communications processor				Δ	Δ			Δ		Δ	
Lunar training test								Δ			
Flight training test								Δ			
Operational readiness test										Δ	
DSS 72 acquisition training test										Δ	

Spacecraft receiver center frequency. Test results indicated that the receiver center frequencies for receivers A and B were as follows:

(1) 2113.316592 MHz for receiver A at 85°F.

(2) 2113.335610 MHz for receiver B at 84°F.

2. *DSN.*

a. Operational readiness tests — general. Readiness of the mission operations personnel to support the *Surveyor IV* mission resulted from over 3 yr of training exercises and actual operations conducted jointly by JPL and HAC. This activity started about April, 1964, continued until 4 days prior to the actual launch of the *Surveyor IV* spacecraft, and included the *Surveyor I, II* and *III* missions. A summary of training exercises and tests conducted between the *Surveyor II* and *IV* missions is provided below with the schedule shown in Table 58. The operational test program consisted of the following test classes:

(1) Class A — internal testing.

(2) Class B — SFO/DSN functional compatibility tests.

(3) Class C — operational tests.

The broad objective of the class B tests was to ensure that the ground-based facilities were compatible with and capable of processing spacecraft command, telemetry, and video data. Class B tests were not performed in real time and did not require adherence to operational procedures.

The primary objective of the class C tests was to ensure that all elements of the SFO/DSN, including the technical and operational personnel, were capable of totally supporting the mission in accordance with the *Surveyor* space flight operations plan (SFOP). The class C tests:

(1) Utilized the full complement of personnel required for *Surveyor* flight operations.

(2) Included standard operational procedures and heavily emphasized nonstandard operational procedures.

(3) Required handling, processing, and interpretation of the full range of mission data under conditions of normal and degraded communications.

(4) Generally established the operational readiness of the SFO/DSN for the *Surveyor* mission.

b. Communications processor testing (B-tests). A series of three tests was conducted in an attempt to qualify the SFOF data system in the CP/7044R configuration (including the NASA communications processor computer and the redesigned real time program for the 7044 computer) for use during the *Surveyor IV* mission. Canned telemetry and tracking data were used along with selected test cases for the computer programs. A test command message was constructed, transmitted to each of the three participating DSIF stations (DSS 11, DSS 42 and DSS 61), punched on 7-level tape and played back for verification. Command confirmation network (CCN) data was generated by transmitting commands, at each of the stations, which were then routed through the system.

During the first two tests many problems were encountered in attempting to exercise most of the test functions. For example, telemetry data displayed on TTY machines ran from 20 s to 6 h behind real time, command messages were transmitted with extraneous characters added and several computer programs would not run. A general problem was the backlogging of data in the CP which could not be cleared without reinitialization of both the CP and the 7044.

During the third test the processing and display of telemetry data functioned at an acceptable level although data ran somewhat further behind real time than in the *Surveyor III* mission system. Command messages did not contain the extraneous characters found in the two previous tests but were somewhat garbled in the operator instruction section. Manual verification of a command tape was accomplished.

c. Personnel training — class C testing. The objectives of personnel training for class C testing are described in the following paragraphs.

Lunar training test. The objective of this test was to exercise the SFOF and DSS-11 personnel in the performance of a static firing of spacecraft vernier engines followed by a liftoff and translation of the spacecraft. Planning for this test was very good and the simulation data was considered the best witnessed. Several relatively minor problems were encountered in the scheduling of computer program usage and in the operational use of the engine firing command sequences. All of the problems, however, were resolved.

Flight training test. The objective of this test was to maintain and improve the efficiency of the personnel within the SFOF and selected portions of the DSN. Particular emphasis was placed on the critical portions of the mission which occur during the transit phase. The test was conducted in three segments covering the following parts of the transit sequence of events:

(1) Launch and acquisition: $L - 20$ min to $L + 2$ h, 20 min.

(2) Midcourse: first run, $M - 4$ h, 30 min to $M + 20$ min; second and third runs, $M - 50$ min to $M + 20$ min.

(3) Terminal: first run, $R - 2$ h, 30 min to $TD + 36$ min; second and third runs, $R - 1$ h, 10 min to $TD + 11$ min.

In each segment, spacecraft and/or SFOS anomalies were inserted by the test conductor. In the first segment of the test, the simulated problem was the failure of the flight control programmer (FCP) 20-Hz clock. The resulting failure of the spacecraft to perform an automatic sun acquisition was detected and corrective action taken in accordance with NSP 13. The exact malfunction was not pinpointed at this time, however, since the test did not include star identification and acquisition and there was no opportunity to exercise another clock timed function.

In the second segment of the test the simulated problem was carried over through the first run. After obtaining the information from mission control that the FCP clock should be considered to have failed to function during star verification, the SFOF responded by preparing a midcourse maneuver command tape designed to time the events from the ground. Some difficulty was encountered with the SCPS computer program, and the maneuver was slightly delayed but a successful midcourse maneuver was accomplished. In the second run of this segment, a failure in the TPS ground station was simulated which caused the flight control analog recorders to freeze on their current readings during a spacecraft maneuver. Since limit cycling of the flight control subsystem is not included in the normal data simulation, this malfunction was misinterpreted as the failure of the spacecraft to terminate the maneuver. The corrective action taken was not applicable to the problem and this run was terminated by mission control. In the third run, a shift in the gyro torque scale factor was simulated which resulted in a maneuver of half the required angle; this was recognized quickly and the proper corrective action taken.

The FCP clock problem was not carried over into the third segment of this test. The only anomaly detected on the first run was a downward shift of approximately 7% in all analog data. This did not appear to correlate with any known spacecraft malfunction and no action was taken. A successful touchdown was accomplished. During the second run several problems were detected encompassing the SFOS, the spacecraft, and simulation. Corrective action was taken to alleviate the more critical problems and the touchdown was successful. The third run was also characterized by multiple failures, including loss of star lock prior to terminal descent and failure of the FCP to accept the retro delay quantity. Mission control denied a request for a maneuver to verify roll attitude and directed that operations proceed under the assumption that roll attitude had not changed since loss of star lock. A successful touchdown was accomplished using the retro sequence emergency tape in accordance with the NASA support plan.

In general, the test objectives were achieved and in particular several nonstandard situations were encountered which had never before been simulated.

d. Operational readiness test. The objectives of this test were to exercise the total SFOS in the *Surveyor IV* mission activities preparatory to launching, and in the conduct of significant phases of the mission. Emphasis was on integrating all elements of the SFOS and exercising as many interfaces as possible among interacting elements. This was a final dress rehearsal for the mission and was intended to verify the flight readiness of the SFOS. The test was conducted in one continuous session consisting of the following two segments:

(1) Prelaunch through midcourse: $L - 13$ h, 20 min to $M + 40$ min.

(2) Terminal descent: $R - 3$ h, 19 min to $TD + 36$ min.

No anomalies were inserted in the system by the test conductor.

Several difficulties were encountered during the prelaunch phase of the test. For example, the 7044 initialization tapes prepared with S/C-4 coefficients would not function on the system and the emergency card deck had been lost. As a result, the test was started with obsolete coefficients. Other difficulties included missing or malfunctioning equipment and incorrectly simulated telemetry signals. From launch to after midcourse, operations were very nearly nominal with the exception of a timing error in the simulation of post separation events. The terminal descent segment started at a poor time since all management briefings had been deleted and no commanding was scheduled for approximately 2 h. When terminal operations were started, difficulties were encountered in maneuver simulations; however, after the third maneuver the remainder of the test progressed smoothly. In general the test objectives were met.

e. DSS 72 acquisition training tests. The objective of this test was to provide additional training in both standard and nonstandard acquisition procedures for the DSS 72 personnel, the SFOF track chief, and the command controller scheduled on duty at the time of initial spacecraft acquisition after launch.

One standard and two non-standard acquisitions were simulated and attempted. The NASA support plan for this exercise was used to isolate the simulated malfunctions and to develop corrective action. The test objectives were accomplished and performance was considered good.

f. Operational tests. Operational tests were divided between two major phases: (1) internal tests (A-series) and (2) mission operational tests (C-series) involving the stations and the SFOF. The internal tests primarily rehearsed the station crews for the C test. The mission, including several non-standard situations, was rehearsed with the complete DSN which included the SFOF during the C test.

g. S/C-4/DSS 71 compatibility test. The primary objective of this portion of the S/C-4/MOS compatibility test was to demonstrate the ability of a typical DSIF station, represented by DSS 71, to acquire a command configuration with the S/C-4. This involved measuring those spacecraft and ground RF system parameters that related to the command link. Such parameters include transmitter and receiver frequencies, receiver thresholds, and receiver acquisition and tracking ranges.

A secondary objective of this test was to obtain measurements of the S/C-4 telemetry modulation parameters, thereby gaining further confidence in the telemetry subsystem's performance predictions which are based on these numbers. During this test on June 1 and 2, 1967, the S/C-4 was encapsulated in the shroud, mounted on the launch vehicle on pad 36 and the entire assemblage enclosed by the service tower. The directional RF link between the service tower and building AO was operational. DSS 71, being within the beamwidth, thus communicated with the spacecraft through this link.

During the B system tests, RF link fluctuations normally ± 1.0 dB or less were observed. Test fluctuations for A system were normally less than ± 1.0 dB, but, variations to ± 5 dB were seen at the start of the test. The reason for link variations is unknown.

The DSS 71 configuration during performance of this test is shown in Fig. 137. The variable attenuators between the antenna and the transmitter and receiver were for performing threshold tests of the spacecraft and DSS 71 receivers. The printer was used to print out an apparent biased doppler frequency during the NBVCXO frequency drift test. The spectrum analyzer provided a means of observing the spectral content of the WBVCXO during the WBFM test. The wave analyzer and rms voltmeter (part of the wave analyzer) were used during the search for spurious signals and the carrier suppression and subcarrier sideband power tests. The magnetic recorder recorded all test sequences. The use of the DIS to control the DSS 71 transmitter frequency was devised by the station personnel. This technique was especially useful during the phase-lock tuning range test and the APC and AFC acquisition frequencies tests. The computer was programmed to slew the transmitter frequency linearly in time at a prescribed rate. In the phase-lock mode tests, the desired spacecraft reaction resulted in loss of down-link lock which automatically stopped the computer from further tuning the transmitter. In the AFC mode tests, the STEA telemetry engineer

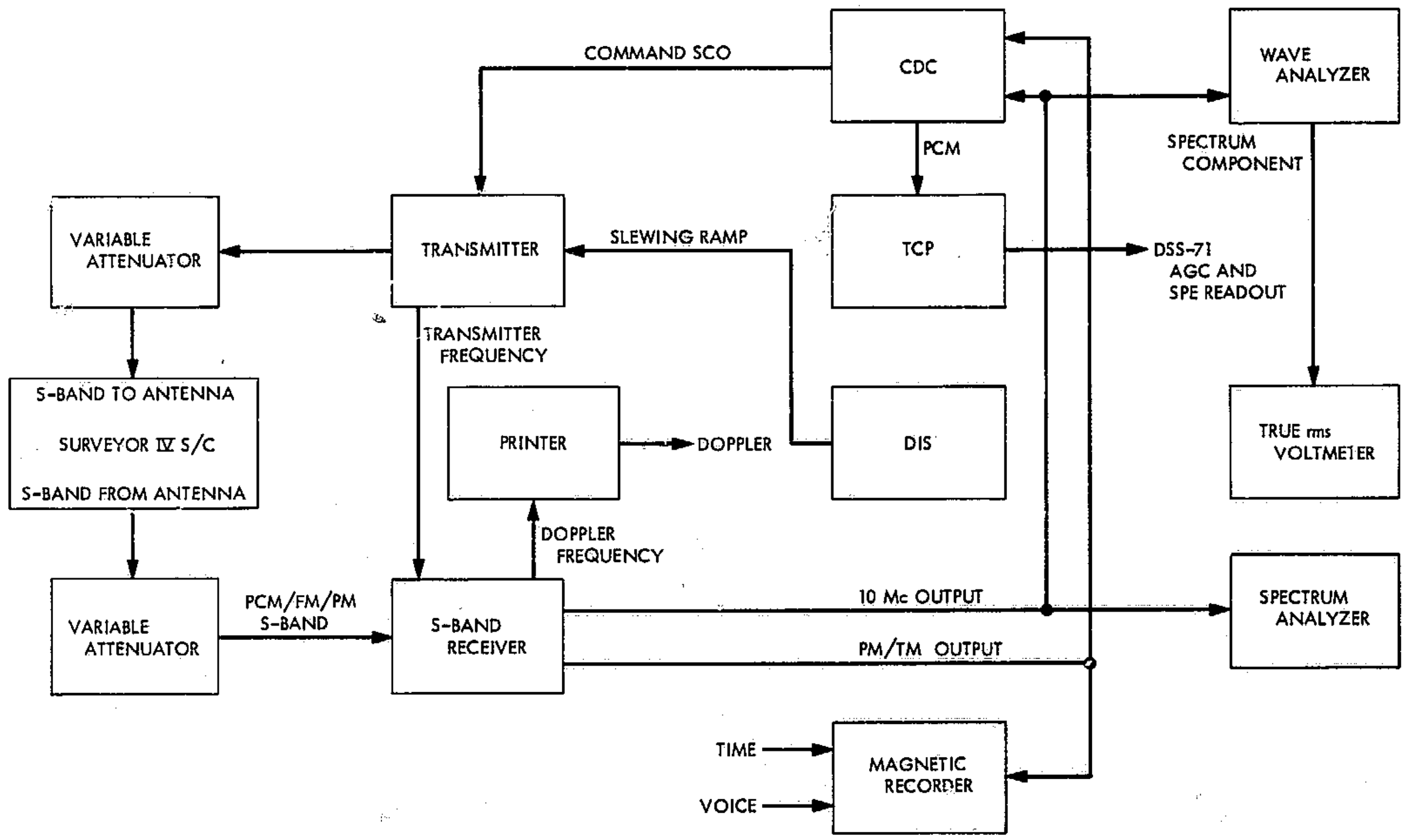


Fig. 137. *Surveyor IV DSS 71 test configuration*

reported the occurrence of the desired spacecraft response and the computer was stopped manually.

The CDC at DSS 71 was used during all test periods, except power turn on, to command the spacecraft. Command modulation was applied for all up-link tests except APC and AFC acquisition frequencies tests.

Down-link tests. Both transmitters were checked for spurious signals at signal levels down to 30 dB below the carrier level. No spurious signals were noted on either system.

The test plan specified searching for spurious signals in the down-link spectrum under the following three conditions:

(1) Two-way phase lock, high-power mode.

(2) One-way phase lock, high-power mode, transponder power on.

(3) One-way phase lock, high-power mode, transponder power off.

All tests were performed for both the A and B transmitters. Spurious signals that were 30 dB or more below the carrier level were ignored in all cases. All test results are listed in Table 59.

The only signals noted in the spectrum were carrier components or telemetry components. Variations in the observed frequencies were caused by carrier frequency drift of the transmitter while in the high power mode and not in two-way lock.

Carrier suppression and sideband power. If allowance is made for the measurement uncertainty due to RF signal fluctuations, the S/C-4 telemetry modulation parameters fell within the limits specified. There was no significant change in carrier suppression when the A/D converter was off (unmodulated subcarrier) as opposed to when it was on. The results of this test are presented in Table 60. The specified values of carrier suppression and P_s/P_t (total first order sideband power relative to the unmodulated carrier) are presented elsewhere. The results indicated that the S/C-4 modulation parameters fall within the specified bounds, if the measurement uncertainty is taken into account.

DSS receiver threshold. There was no apparent degradation in DSS receiver performance as a function of the

Table 59. Results of spurious signal test

Test step	DSS receiver frequency, MHz	Δf, kHz	Power, dBm	Relative power, dB	Remarks
Receiver—Transmitter A					
					Carrier at 2294.997632 MHz
002.006	2295.001568 2294.993120	+3.936 −4.512	−110 −110	−31 −31	TLM component TLM component
					Carrier at 2295.004448 MHz
002.017	2295.007136 2295.000224	+2.688 −4.224	−110 −110	−22 −22	TLM component TLM component
					Carrier at 2295.002432 MHz
002.021	2295.005696 2294.998112	+3.264 −4.320	−105 −110	−20 −25	TLM component TLM component
Receiver—Transmitter B					
					Carrier at 2295.018848 MHz
002.006	2295.022304 2295.015104	+3.456 −3.744	−100 −100	−24 −24	TLM component TLM component
					Carrier at 2294.986880 MHz
002.017	2294.991008 2294.983040	+4.128 −3.840	−101 −99	−25 −23	TLM component TLM component
					Carrier at 2294.986496 MHz
002.021	2294.989952 2294.982080	+3.456 −4.416	−100 −101	−24 −25	TLM component TLM component

Table 60. Carrier suppression and subcarrier sideband power test results

Test step	SCO center frequency, kHz	Sideband frequency		Carrier suppression		P_s/P_t		XMTR
		Lower, kHz	Upper, kHz	Measured[a] dB	Specified dB	Measured[a] dB	Specified dB	
002.029	3.9 SPA low power	3.693	3.694	Not measurable	$-0.2\ ^{+0.04}_{-0.03}$	−14 ±4	$-13.6\ ^{+0.8}_{-0.9}$	A
		3.693	3.693	0 ±1	$-0.2\ ^{+0.04}_{-0.03}$	−13.25	$-13.6\ ^{+0.8}_{-0.9}$	B
002.039	0.560	0.554	0.554	−5.5	$-5.3\ ^{+1.1}_{-1.6}$	−2.9	$-2.2\ ^{+0.3}_{-0.4}$	A
		0.554	0.554	−5.75 ±0.25	$-5.3\ ^{+1.1}_{-1.6}$	−1.75	$-2.2\ ^{+0.3}_{-0.4}$	B

Table 60 (contd)

Test step	SCO center frequency, kHz	Sideband frequency		Carrier suppression		P_s/P_t		XMTR
		Lower, kHz	Upper, kHz	Measured[a] dB	Specified dB	Measured[a] dB	Specified dB	
002.051	7.35, 0.96, 1.3, 1.7 multiplex	6964	6965	−6 ±1	−4.8 ±1	−7	$-7.4\ ^{+1.2}_{-1.3}$	A
		917 1255 1656	918 1256 1657			−10.8 −11.8 −10.8	−11.1 ±1.5	
		6964	6965	−4.5	−4.8 ±1	−7.75	$-7.4\ ^{+1.2}_{-1.3}$	B
		917 1255 1657	918 1256 1657			−11.0 −11.75 −11.25	−11.1 ±1.5	
002.072	33	31.392	31.680	−6	$-6.8\ ^{+1.6}_{-2}$	−1	$-1.9\ ^{+0.2}_{-0.3}$	A
		31.392	31.680	−6	$-6.8\ ^{+1.6}_{-2}$	−1	$-1.9\ ^{+0.2}_{-0.3}$	B
002.081	3.9 SPA high power	3607	3607	Not measurable	$-0.2\ ^{+0.04}_{-0.03}$	−13.8	$-13.6\ ^{+0.8}_{-0.9}$	A
		3608	3607	−0.5	$-0.2\ ^{+0.04}_{-0.03}$	−14.1	$-13.6\ ^{+0.8}_{-0.9}$	B

[a]Tolerances ±0.5 dB or as noted.

Table 61. DSIF receiver threshold test results

Test step	TM mode	Strong signal		Threshold		SC XMTR
		Attenuator dB	Pc/AGC, dBmW	Attenuator dB	P_c/Calc., dBm	
002.034	3.9 kHz SPA low power	23	− 95	75	−147	A
		23	− 95	76	−148	B
002.046	0.560 kHz low power	23	−102	71	−150	A
		23	−100	71	−148	B
002.057	7.35 kHz plus strain gages low power	23	−102	70	−149	A
		23	− 99	73	−149	B
002.075	33 kHz low power	23	−103	70	−150	A
		23	−100	70	−147	B
002.087	3.9 kHz SPA high power	23	− 76	91	−144	A
		23	− 74	95	−146	B

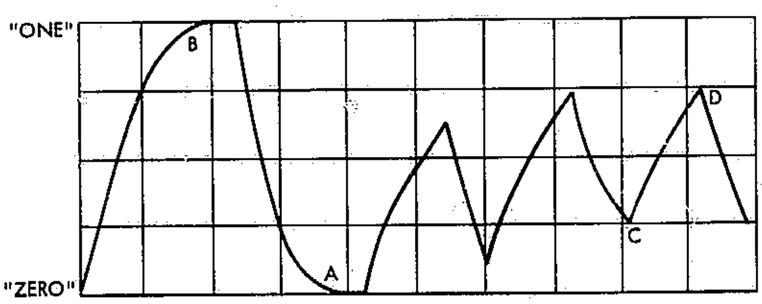
Table 62. Parity error rate measurements

Test step	XMTR	Mode	Discriminator bandpass signal to noise ratio, dB		Parity error rate (PER)		
			Calculated	Measured	Bits	Errors	Rate
005.010	A	7.35 kHz plus strain gages	12	11.3	100 K	3	3×10^{-5}
	B		12	11.5	100 K	287	2.87×10^{-3}
005.046	A	0.560 kHz	12	11.7	10.3 K	0	—
	B[a]		12	9.9	10 K	53	5.3×10^{-3}

[a]High PER on transmitter B due to RF link instability; errors occurred only when instability caused SNR to drop to low value.

spacecraft telemetry mode for any of the modes tested. The DSS 71 receiver threshold was measured in several down-link telemetry modes for both of the spacecraft transmitters. The results of these transmitter tests are shown in Table 61. The data indicates that the measured thresholds were approximately -2 dB to $+3$ dB below prediction, based on a definition of threshold as a zero dB signal-to-noise ratio in the receiver's phase-lock loop bandwidth. There was no evidence of any degraded performance by the receiver in any of the telemetry modes tested.

SCO frequencies and telemetry error rate. Parity error rates for PCM were measured in two modes for transmitters A and B. The data is presented in Table 62. Measured parity error rates for transmitter A were normal. For transmitter B, they were higher than anticipated. This higher error rate was due to link variations causing bursts of errors to occur periodically when the RF level dropped close to discriminator threshold. Several voltage levels at the PCM discriminator outputs were recorded as shown in Fig. 138; those voltage levels are tabulated in Table 63. From this data, offsets in SCO frequencies may be calculated. All measurements were within SCO center frequency tolerances.



STATED IN WORDS:

Voltage A = discriminator output voltage corresponding to binary 0 when two or more 0's in a row are transmitted

Voltage B = discriminator output voltage corresponding to binary 1 when two or more 1's in a row are transmitted

Voltage C = discriminator output voltage corresponding to binary 0 when alternate 1's and 0's are transmitted

Voltage D = discriminator output voltage corresponding to binary 1 when alternate 1's and 0's are transmitted

Fig. 138. PCM waveform test points

Table 63. Discriminator output voltages for PCM data

Mode	Voltages at test points				S/C XMTR
	A, negative	B, positive	C, negative	D, positive	
7.35 kHz SCO plus strain gages	3.0	2.8	1.1	1.1	A
	2.9	2.5	0.8	0.9	B
3.9 kHz SCO (SPA)	2.5	2.4	0.7	0.8	A
	2.6	2.4	1.0	1.0	B
0.560 kHz SCO	2.6	2.2	1.3	0.8	A
	2.6	2.2	1.2	0.8	B
33 kHz SCO	2.3	2.2	0.7	0.9	A
	2.7	2.5	1.0	0.9	B

NBVCXO drift. The results of this test are plotted in Figs. 139 and 140. The maximum rate of change of frequency indicated in the test data was 5.6 Hz/s, for transmitter B and 4.5 Hz/s, for transmitter A.

WBFM telemetry. First, the S-band frequency of each spacecraft transmitter was measured in the WBVCXO mode. For transmitter B, the frequency was 2295.038048 MHz. For transmitter A, the frequency was 2294.989760 MHz. No spurious signals were noted on the spectrum analyzer for either transmitter. Twenty

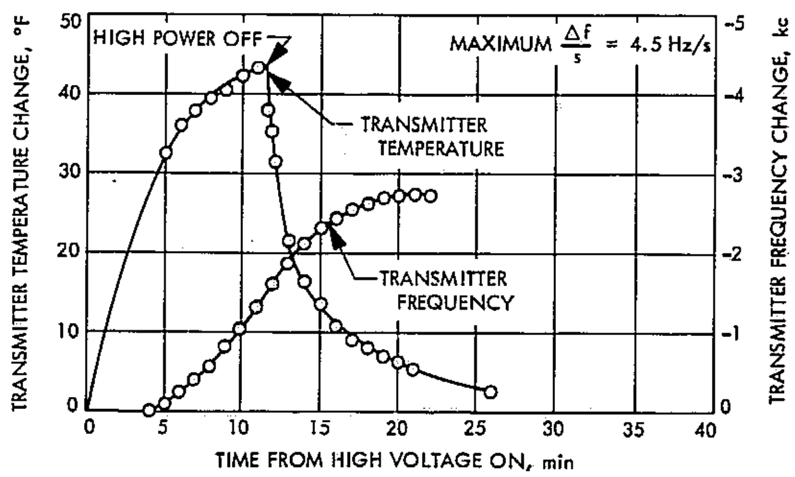


Fig. 139. SC-4 Transmitter A NBVCXD drift rate

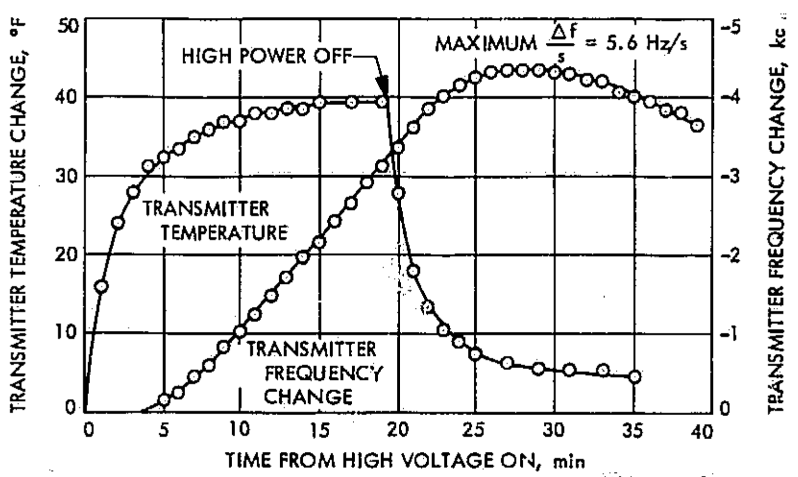


Fig. 140. SC-4 Transmitter B NBVCXO drift rate

minutes of high power operation caused frequency shifts of +0.192 kHz for transmitter A and −2.744 kHz for transmitter B.

The ability of the PCM discriminators and decommutator to lock-up in the following PCM-FM-FM downlink modes was then tested. All indications were normal.

(1) 33 kHz SCO at 4400 bits/s.

(2) 7.35 kHz SCO at 1100 bits/s.

(3) 3.9 kHz SCO at 550 bits/s.

Frequencies for 600-line TV. Spacecraft transmitter frequencies at S-band corresponding to TV sync, porch, PCM one, and PCM zero were measured. Before this measurement, the DSIF receiver was adjusted so that the 10 MHz output to the CDC was exactly 10 MHz with the spacecraft transmitter on WBVCXO, in high RF power mode, and survey TV camera power off. Measurement accuracy was approximately ±50 kHz. Both transmitter outputs were identical; the measured frequencies referenced to the 10-MHz output are shown below.

(1) Sync tip: +1.18 MHz.

(2) Porch: +0.75 MHz.

(3) PCM 1: −0.67 MHz.

(4) PCM 0: −1.18 MHz.

The transfer curve of the CDC FM demodulator used to measure the TV frequencies is shown in Fig. 141.

Spacecraft receiver phase-lock threshold. The results of this test, and of those tests for AFC threshold are given in Table 64. Receiver B met or exceeded the threshold specification at best-lock frequency and at ±70 kHz from best-lock receiver A met the threshold specification at best lock frequency only. The phase-lock threshold for receiver A degraded 13 dB at ±70 kHz while receiver B degraded only 4 dB at ±70 kHz. Although the degradation of receiver A seems severe, this magnitude of degradation has been observed on other *Surveyor* receivers. No specification for a threshold at ±70 kHz is known to exist. This test was conducted with command modulation applied.

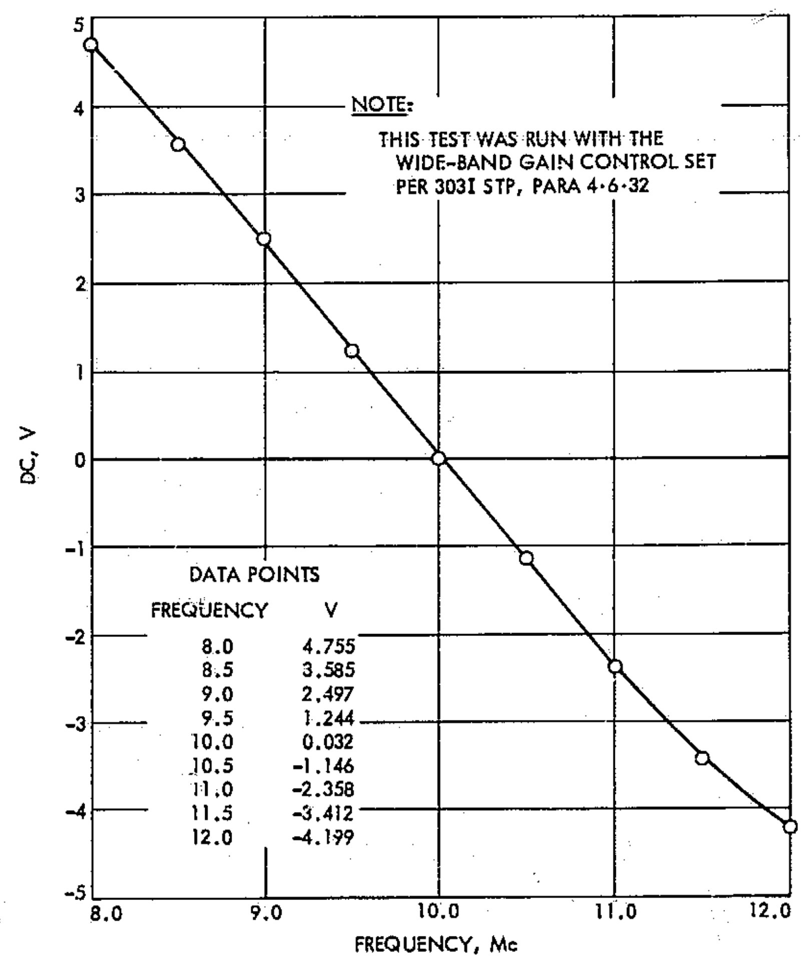


Fig. 141. Demodulator frequency response test, DSS 71

Table 64. Spacecraft receiver threshold test results

Test step	RCVR	Mode	Strong signal			Threshold			Remarks
			Attenuator, dB	RCVR, dB	AGC, dBm	Attenuator, dB	RCVR[a] in dBmW	Specified[b] dBmW	
003.007	A	APC	20	150	92	60	−132	−128.5 +2.3, −1.8	Best-lock frequency
	B		26	179	−105	53	−132		
003.010	A	APC	20	147	91	48	−119	None	+70 kHz from best lock
	B		26	175	−102.5	51	−127.5		
003.013	A	APC	20	147	91	48.5	−119.5	None	−70 kHz from best lock
	B		26	171	−103	51	−128.0		
003.037	A	AFC	6	103	− 75	47	−116	None	+50 kHz from center frequency
	B		26	167	−101	44	−119.0		
003.043	A	AFC	6	100	− 75	46.5	−115.5	None	−50 kHz from center frequency
	B		26	167	−101	44	−119.0		

[a]Total power
[b]Carrier power

Table 65. Spacecraft receiver phase lock tracking range test

Test step	Parameter	Receiver A	Receiver B
	Near threshold		
	Test conditions: 1. S/C RCVR temperature (V−16), °F 2. DSS-71 XMTR attenuator, dB 3. S/C RCVR input power, dBmW	 85 54 −126	 84 50 −129
003.018	Lower frequency limit, MHz	2113.285152	2113.307904
003.020	Upper frequency limit, MHz	2113.349760	2113.344864
	Strong signal		
	Test conditions: 1. S/C RCVR temperature (V−16), °F 2. DSS-71 XMTR attenuator, dB 3. S/C RCVR input power, dBmW	 85 6 −75	 84 26 −105
003.024	Lower frequency limit, MHz	2113.242720	2113.257792
003.026	Upper frequency limit, MHz	2113.383552	2113.398336

Note: Best-lock frequencies (per SC-4 test team) were: 2113.309440 MHz for receiver A; and 2113.327968 MHz for receiver B.

Receiver AFC threshold. The threshold of both receivers was satisfactory at ±50 kHz from receiver center frequency. As previously stated, the results of this test are listed in Table 64.

Spacecraft receiver phase-lock tracking range. The results of this test are summarized in Table 65 and are shown graphically in Figs. 142 and 143; the results of APC and AFC thresholds, acquisition frequencies and tracking ranges are superimposed. For receiver B, this test was conducted initially at 3 dB above threshold, then at strong signal. At near threshold, the tracking range was −20 kHz to +16.9 kHz. At strong signal, the tracking range was greater than 20 kHz. The weak signal test

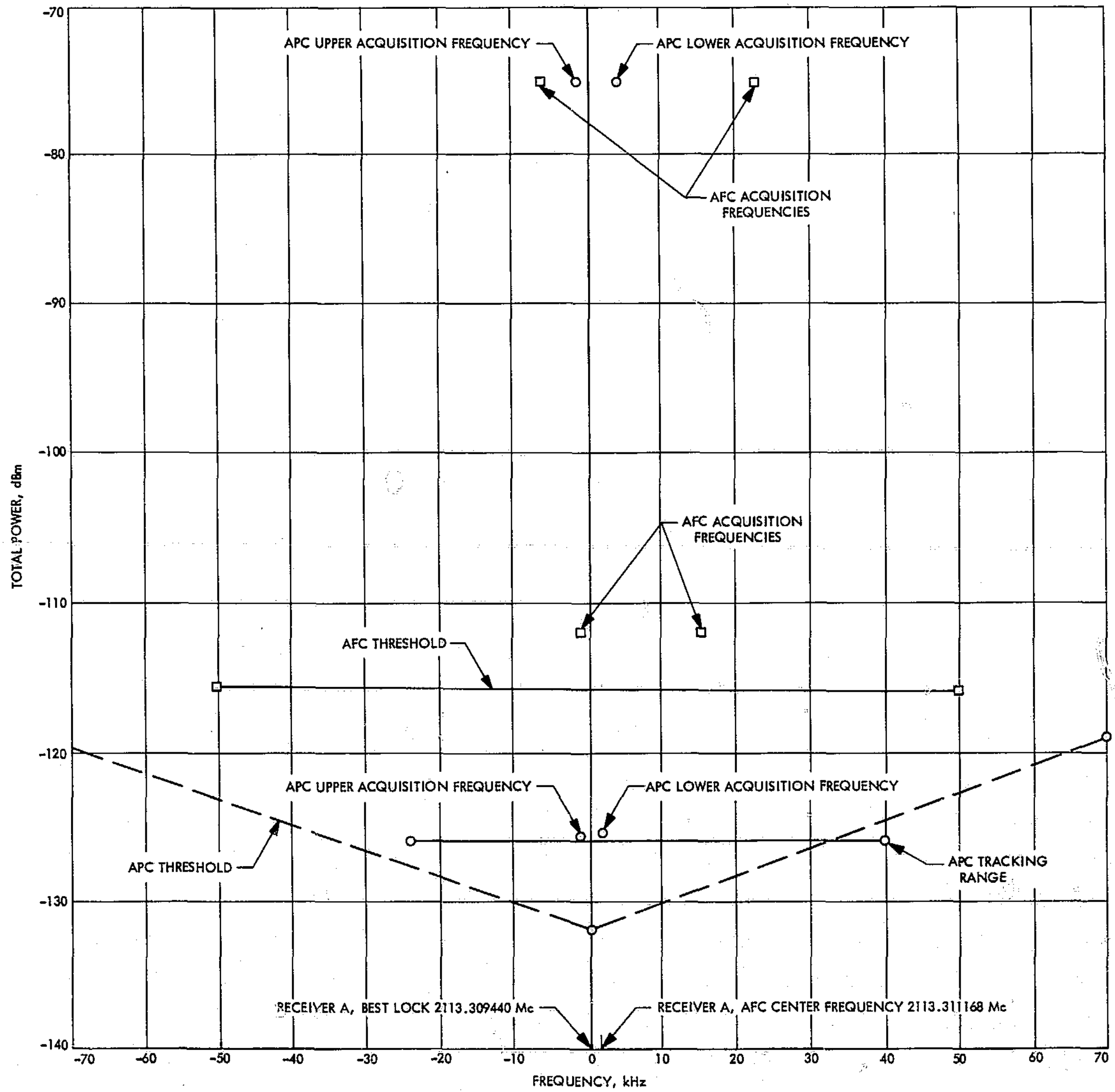


Fig. 142. SC-4 Receiver A AFC and APC acquisition and tracking frequencies

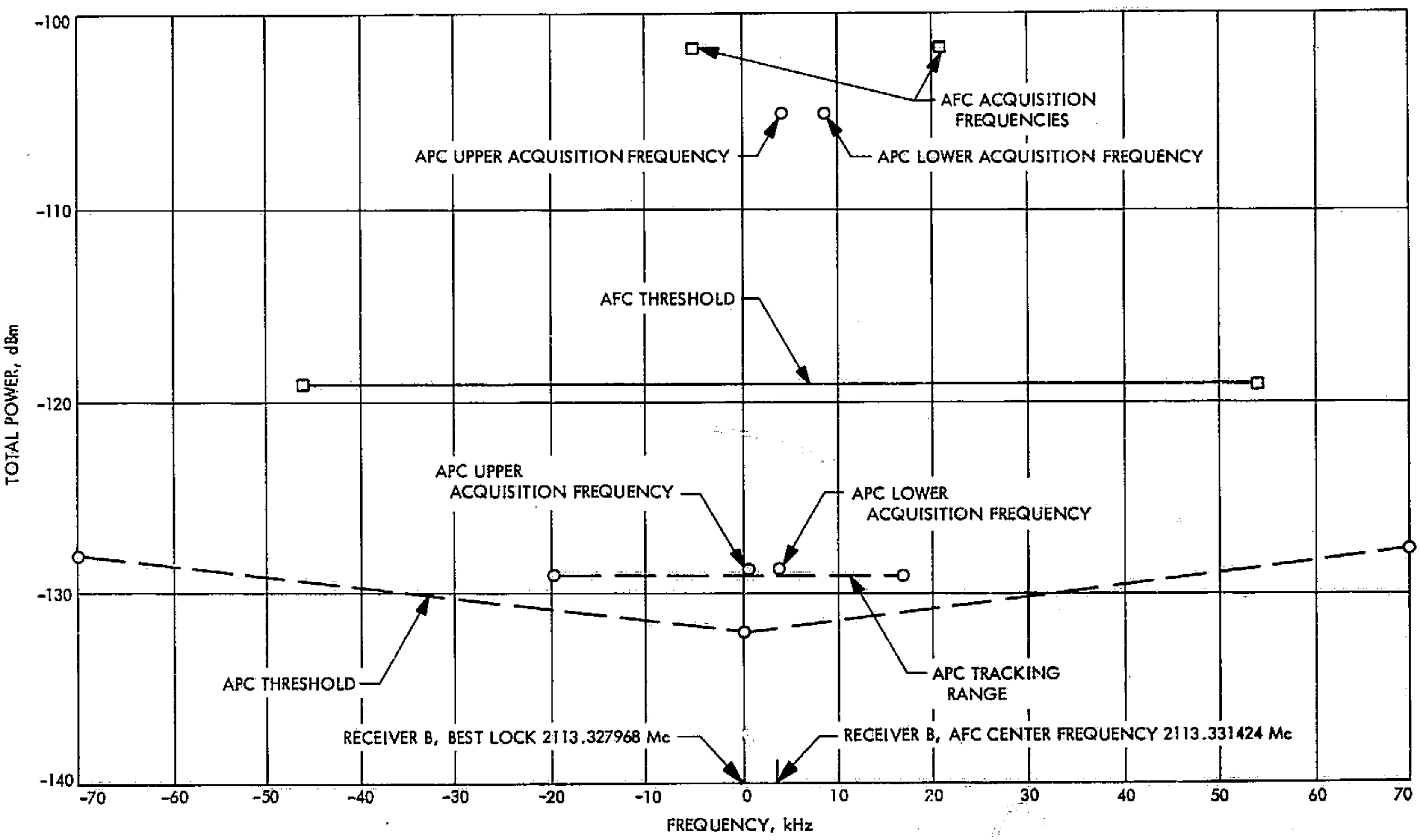


Fig. 143. SC-4 Receiver B AFC and APC acquisition and tracking frequencies

Table 66. Spacecraft receiver phase lock acquisition frequencies test results

Test step	Parameter	Receiver A	Receiver B
	Near threshold		
	Test conditions:		
	1. S/C RCVR temperature (V 16), °F	85	84
	2. DSS-71 XMTR attenuator, dB	54	50
	3. S/C RCVR input power, dBmW	−126	−129
003.019	Lower acquisition frequency, MHz	2113.311264	2113.331904
	S/C receiver AGC, dBmW	−125	−127.5
	S/C receiver SPE, kHz	−0.5	+2
	ACQ relative to best lock, kHz	+1.8	+3.9
003.021	Upper acquisition frequency, MHz	2113.308288	2113.328736
	S/C receiver AGC, dBm	−125	−127.5
	S/C receiver SPE, kHz	−3	−0.5
	ACQ relative to best-lock, kHz	−1.1	+0.8

Table 66 (contd)

Test step	Parameter	Receiver A	Receiver B
Strong signal			
	Test conditions:		
	1. S/C RCVR temperature (V 16), °F	85	84
	2. DSS-71 XMTR attenuator, dB	6	26
	3. S/C RCVR input power, dBmW	−75	−105
003.025	Lower acquisition frequency, MHz	2113.313280	2113.336608
	S/C receiver SPE, kHz	+1.5	+8
	ACQ relative to best-lock, kHz	+3.8	+8.6
003.027	Upper acquisition frequency, MHz	2113.310976	2113.332000
	S/C receiver SPE, kHz	−0.5	+2
	ACQ relative to best-lock, kHz	−1.5	+4

Note: Best-lock frequencies (per SC-4 test team) were: 2113.309440 MHz for receiver A; and 2113.327968 MHz for receiver B.

Table 67. AFC mode acquisition frequency test

Test steps	Parameters	Receiver A	Receiver B
Strong signal			
	Test conditions:		
	1. S/C RCVR temperature, V 16, °F	84	84
	2. DSS 71 transmitter attenuator, db	6	26
	3. S/C RCVR input power, dBmW	−75	−101.5
003.038	Lower acquisition frequency, MHz	2113.303584	2113.322592
	AFC at ACQ, kHz	−12	−15.5
003.044	Upper acquisition frequency, MHz	2113.332000	2113.348608
	AFC at ACQ, kHz	+17	+11
Weak signal			
	Test conditions:		
	1. S/C RCVR temperature, V 16, °F	84	84
	2. DSS 71 XMTR attenuator, dB	43	41
	3. S/C RCVR input level, dBmW	−112	−116.5
003.051	Lower acquisition frequency, MHz	2113.308384	Not available
	AFC at ACQ, kHz	−7	
003.055	Upper Acquisition frequency, MHz	2113.324800	Not available
	AFC at ACQ, kHz	+9	

Note: AFC center frequency (no signal AFC): 2113.311168 MHz for receiver A; 2113.331424 MHz for receiver B.

for receiver A was conducted 6 dB above threshold because of large link variations. At this signal level, the tracking range was −24 kHz to +40 kHz. At strong signal, the tuning range exceeded 70 kHz.

Spacecraft receiver phase-lock acquisition frequencies. The results of these tests are given in Table 66 and Figs. 142 and 143. The convention used is as follows. The lower acquisition frequency is the frequency at which the spacecraft transponder acquires lock, when the DSS transmitter is tuned toward best-lock from a frequency below best-lock. The upper acquisition frequency is obtained in a similar manner by tuning down from a frequency above best-lock. The usual overlap, wherein the lower acquisition frequency is higher than the upper acquisition frequency, was noted at both strong and weak signal levels. Results tend to confirm the best-lock frequencies of 2113.309440 MHz for receiver A and 2113.327968 MHz for receiver B, as obtained by the no-signal SPE measurement. Agreement with data preformulated was excellent.

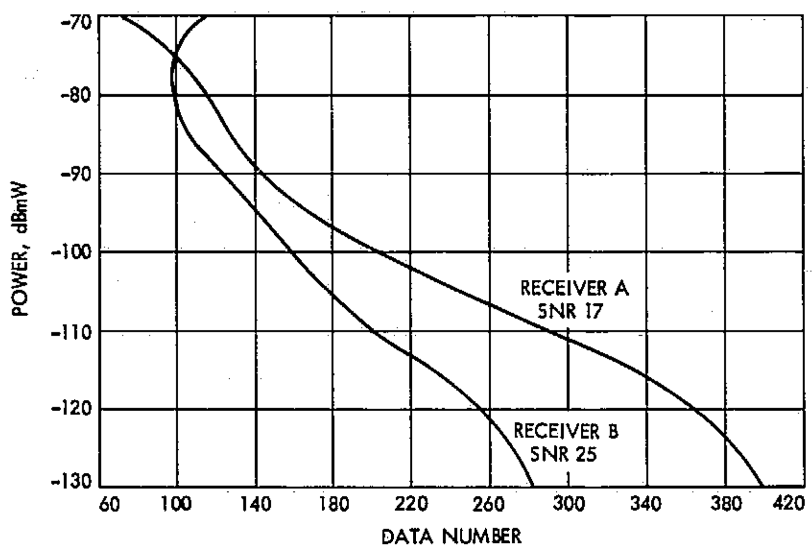


Fig. 144. AGC vs data number at 75°F

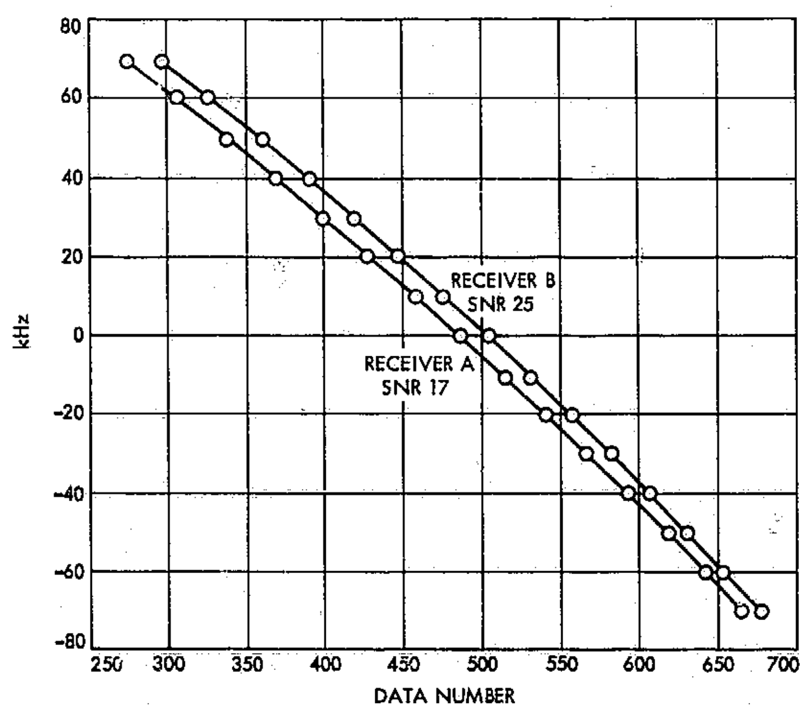


Fig. 145. SPE vs data number at 75°F

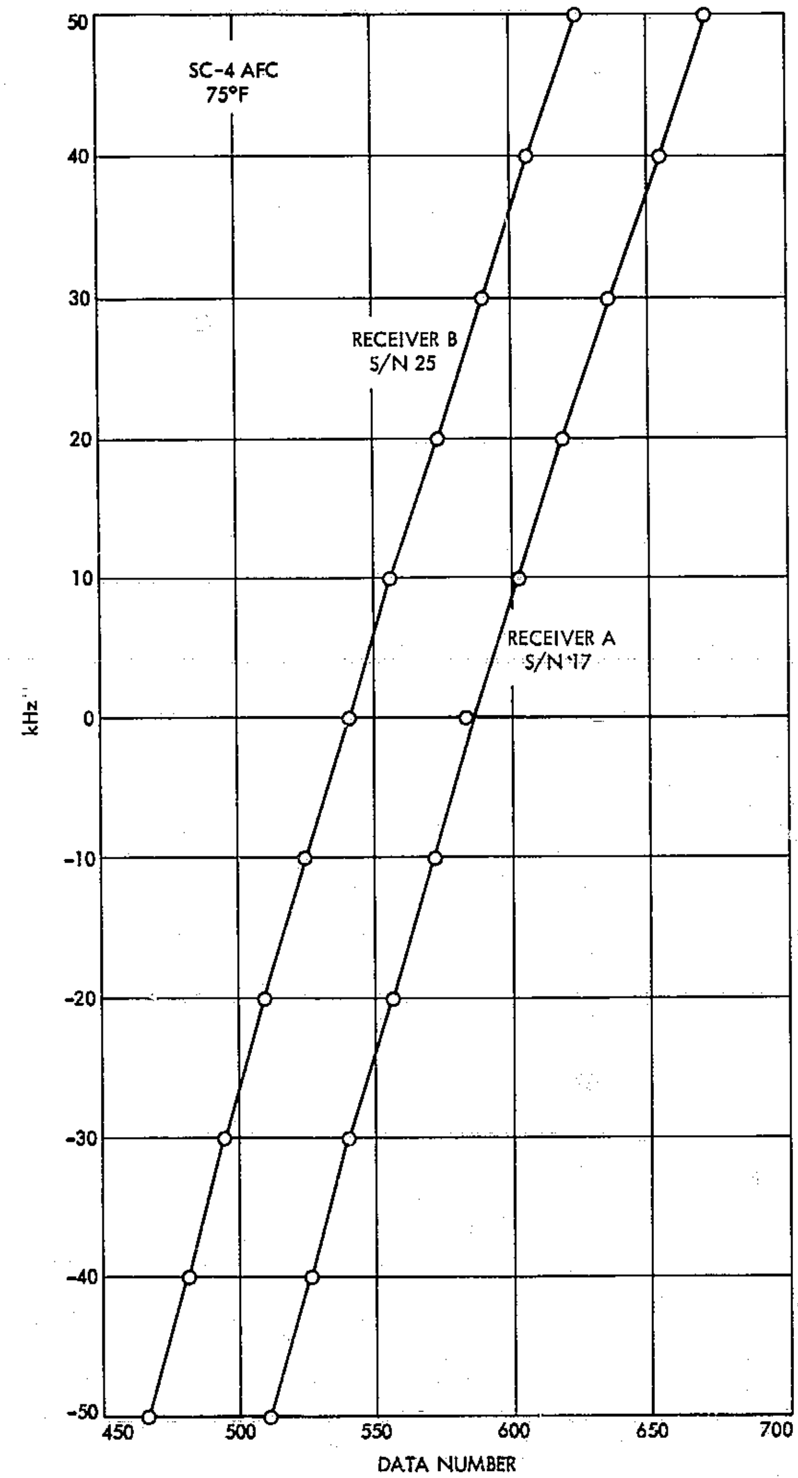


Fig. 146. AFC vs data number at 75°F

AFC tracking range. The tracking range at both strong and weak signal levels, was greater than ±50 kHz from the AFC center frequency for both receivers.

AFC acquisition frequencies. The results of this test are given in Table 67, and Figs. 142 and 143. In the AFC mode, there was no crossover of upper and lower acquisition frequencies as there was in the APC mode. Acquisition frequencies indicate the receiver center frequencies are higher than the no-signal AFC values by 5 kHz for receiver A and 4 kHz for receiver B. This places the center frequencies for a temperature of 85°F at 2113.316592 MHz for receiver A and 2113.335610 MHz for receiver B.

Conclusion. The S/C-4 spacecraft and DSS 71 systems met, or exceeded, specifications or requirements of the mission in all areas tested.

Spacecraft calibration data. A graphic presentation of S/C-4 spacecraft calibration data is given in Figs. 144–146.

X. TDS Flight Support

A. General

The TDS for the *Surveyor IV* mission included selected resources of the AFETR, the MSFN, the DSN, and the NASCOM. This section is limited to the support provided by the TDS during the pre-launch countdown, near-earth flight phase, and deep space phase of the *Surveyor IV* mission.

B. Countdown

The launch of *Surveyor IV* was delayed until the second day of the launch window. Originally scheduled to be launched on July 13, 1967, launch was delayed until July 14, 1967 to permit an anomalous condition in the booster's fuel oxidizer system to be corrected. The one RIS supporting the launch was reported on station. This ship (*Coastal Crusader*) was committed for telemetry coverage between Antigua set and Ascension rise.

There was a planned 60-min hold at $T-90$ min and a 15 min hold at $T-5$ min. All operations progressed normally until $T-40$ s at which time a hold was called to complete liquid hydrogen topping in the *Centaur*. This unscheduled hold lasted for approximately 29 s. Table 68 is a summary of countdown events.

Table 68. Countdown time summary

Event	Time	GMT
Started range countdown	$T-335$ min	05:03
Started 60 min BIH	$T-90$ min	09:08
End BIH; resumed count	$T-90$ min	10:08
Started 15 min BIH	$T-5$ min	11:33
End BIH; resumed count	$T-5$ min	11:48
Started momentary hold	$T-40$ s	11:52
Resumed count	$T-40$ s	11:52
Liftoff	$T-0$	11:53:29

The first AFETR RF propagation forecast for $T-0$ was received at $T-360$ min, at 04:38. This report forecast a Condition 3[a] for all downrange RF circuits. Subsequent forecasts, which were received at $T-240$, $T-180$, $T-88$ and $T-22$, continued to predict a Condition 3 for all circuits.

As noted in Table 67, the range countdown was started on schedule at $T-335$ min (05:03 GMT). At $T-320$, the 3100 computer at the RTCS, which is used in reformatting the metric tracking data from octal to decimal format, was declared NOR (Not Operationally Ready). It was estimated by AFETR that the computer would be down for 5 h; however, the 3100 was declared operational and returned to service at $T=282$. The difficulty was identified as a minor software problem.

The 3.18 radar at Grand Bahama Island was declared NOR at 07:34 (at $T-184$ min) because of a faulty azimuth servo valve in the hydraulic system. It was estimated that the radar could be back in service 1 h after the necessary parts were received; however, no spare parts were available and the radar remained down throughout the launch. The 19.18 radar on Merritt Island (KSC) experienced problems with the pulse transformer, and was placed in a nonoperating condition at $T-116$ min, at 08:42. Again, the necessary parts were not at the site. The required spares were on site at 10:09, and the radar was operational at 11:05, at $T-32$ min.

The 60-min built-in hold at $T-90$ began at 09:08, and the count was resumed on schedule at 10:08. The 13.16 radar at Pretoria, South Africa was not committed to the launch, however, it did support and provided post-retro

[a]RF propagation conditions are defined as follows: Condition 5—excellent; Condition 4—good; Condition 3—fair; Condition 2—unusable; and Condition 1—circuit out.

tracking data in addition to that received from the Ascension Island radar.

During the countdown the expected *mark* event times were updated on a preflight nominal trajectory corresponding to the liftoff time of 11:53 GMT and the actual launch azimuth. At $T-30$ min, AFETR reported that the prime data routes from the *Coastal Crusader* and Ascension Island would be direct to the Cape.

The second built-in hold was entered at $T-5$ minutes. The hold duration was 15 min, with the count resumed on schedule at 11:48. All operations progressed normally down to $T-40$ s, when a 29-s hold was required to complete hydrogen topping in the *Centaur*. Liftoff occurred at 11:53:29.215 GMT, with a flight azimuth of 103.820 deg.

C. Liftoff to DSIF Acquisition

Surveyor IV was successfully launched at 11:53 GMT on July 14, 1967, on a flight azimuth of 103.820 deg. The Near Earth phase of the flight was very nominal. Following a smooth direct ascent launch, the spacecraft was very accurately injected into the transfer orbit. The occurrence of space vehicle *mark* events was reported in near-real time followed up with a report of the times at which they occurred. *Mark* event times are shown in Table 69.

During the powered flight phase (from launch to MECO) a real-time evaluation of the launch vehicle performance was received from the launch vehicle telemetry laboratory via the AFETR intercommunication system (MOPS). This evaluation is based upon real-time launch vehicle telemetry received at JPL. Also, a real-time commentary was monitored over the MOPS from AFETR

Table 69. *Mark* events

Mark event	Day	GMT	ID	GMT	ID	GMT	ID
Liftoff	195	1153:29.215	Cape[a]				
1	195	1155:51.100	Cape				
2	195	1155:54.600	Cape				
3	195	1156:25.400	Cape				
4	195	1156:52.600	Cape				
5	195	1157:28.900	Cape	1157:27.2	BDA		
6	195	1157:31.950	Cape	1157:30.8	BDA		
7	195	1157:41.000	Cape	1157:41.1	BDA		
8	195	1204:57.100	Cape	1204:52.2	ANT[b]		
9	195	1205:25.000	Cape	1205:24.6	ANT	1204:24.5	CRU[c]
10	195	1205:24.600	ANT	1205:34.5	CRU		
11	195	1206:00.100	ANT	1205:55.2	CRU		
12	195	1206:00.100	ANT	1206:00.5	CRU		
13	195	1206:06.100	CRU				
14		No report					
15	195	1210:06.100	CRU	1210:00.6	ASC		
16	195	1214:00.800	ASC	1214:16.8	CYI		
17	195	1214:00.800	ASC	1214:16.8	CYI		
Mid-course	197	0230:00.00					
Retro	198	0201:57.823					
Signal lost	198	0202:40 (Approx.)					

[a]Cape Kennedy
[b]Antigua
[c]RIS *Coastal Crusader*

central control giving the status of the trajectory as it was plotted on the range safety present-position charts. The voice reports from both of these sources indicated a nominal mission up through MECO.

Presented in Table 70 are the expected nominal *mark* event times, as well as the actual times determined by post-flight analysis of the recorded telemetry data. The only deviation from the nominal significant enough for comment occurred in the *Centaur* burn duration. As can be seen from Table 68, the burn duration was 6.0s longer than the expected nominal. However, this duration had been averaging about 4.5 s longer than expected on previous flights when adjusted for all known anomalies. Therefore, the additional 6.0 s of *Centaur* burn on the flight (real-time *mark* event times indicated 5.1 s) was not of particular concern since it did not in itself indicate abnormal performance. It is worthwhile to note that the low chamber pressure in the *Centaur* engines, experienced on some of the previous flights and resulting in larger burn dispersions from the nominal, apparently did not occur on this flight.

Table 70. Comparison of *Surveyor IV* preflight and actual event times

Event	Programmer time, s	Preflight time, s	Actual time, s
Booster engine cutoff	BECO	$T+143.7$	$T+141.9$
Jettison booster package	BECO + 3.1	$T+146.8$	$T+145.4$
Jettison insulation panels	BECO + 34	$T+177.7$	$T+175.8$
Fire thruster bottles	BECO + 61	$T+204.7$	$T+202.9$
Sustainer engine cutoff; vernier engine cutoff; start *Centaur* programmer	SECO	$T+238.2$	$T+239.4$
Separate (1st and 2nd stage)	SECO +2.0	$T+240.2$	$T+241.4$
Centaur main engine ignition	SECO + 11.5	$T+249.7$	$T+250.8$
Centaur main engine cutoff	MECO	$T+680.7$	$T+687.8$
Preseparation arming signal; extend landing gear signal	SECO + 475.5	$T+713.7$	$T+714.8$
Unlock omni antennas on signal	SECO + 486.0	$T+724.2$	$T+724.8$
High-power transmitter on signal	SECO + 506.5	$T+744.7$	$T+745.4$
Electrical disconnect	SECO + 512	$T+750.2$	$T+751.4$
Spacecraft separate	SECO + 517.5	$T+755.7$	$T+756.9$
Begin *Centaur* orientation maneuver	SECO + 522.5	$T+760.7$	$T+762.0$
Start *Centaur* tank blowdown	SECO + 757.5	$T+995.7$	$T+996.9$
End *Centaur* tank blowdown	SECO + 1007.5	$T+1245.7$	$T+1247.6$
Energize power changeover	SECO + 1007.5	$T+1245.7$	$T+1247.6$

With the telemetry ship (*Coastal Crusader*) providing spacecraft telemetry coverage between that provided by AFETR Antigua and Ascension telemetry stations, continuous spacecraft telemetry was received, either via the *Centaur* link or spacecraft link from launch until loss of lock at Ascension, and transmitted to the SFOF in near-real time. The LOS experienced at Ascension occurred at approximately 4 min following the initial two-way lock at DSS 72. The AFETR S-band station at Antigua had some trouble maintaining lock and consequently was locked up only about 30% of the time during its view. However, this did not result in a gap in spacecraft telemetry coverage since the Antigua VHF station received solid launch vehicle telemetry during this period through *Centaur*/spacecraft separation. Thus, spacecraft telemetry was received via the *Centaur* link until separation and *Coastal Crusader* S-band coverage overlapped the separation event. The actual S-band and VHF telemetry coverages provided by each of the supporting stations are included in Section XI.

The uprange AFETR tracking stations provided continuous tracking of the vehicle from launch to about 100 s beyond MECO, at which time the Antigua radar lost track ($L + 779$ s). Post-MECO Antigua tracking data was used by the RTCS to compute the first transfer orbit. The solution was considered only fair by the RTCS because of the low elevation angle of the Antigua data. This solution did indicate, however, that the orbital elements were close to nominal. Mapping the transfer orbit out to the moon indicated the spacecraft would have impacted the moon without a midcourse correction (the radius of closest approach calculated to be approximately 866 km).

The radar at Trinidad did skin-track the vehicle subsequent to MECO, but the data was very noisy because of the low elevation at which the station viewed the vehicle during this time period. As a result, it was not usable for transfer orbit calculations.

Based on the initial transfer orbit computations, DSN acquisition predictions were generated for DSS 72, 61 and 51 and sent out. The predictions for DSS 72 arrived a few minutes subsequent to their rise due to the short interval of time between MECO and DSS 72 rise (approximately 4 min). Since DSS 72 had acquired in one-way lock at about 1 min after their rise and before the arrival of the AFETR Ascension Island Station predictions, the latter were only of academic interest in this situation.

A post-retro orbit was computed by the RTCS using tracking data from the AFETR radars at Ascension Island and Pretoria, South Africa. The fit to the orbit was considered good and the orbital elements appeared to be nominal, indicating a nominal retro maneuver had been performed by the *Centaur* stage.

Both DSS 72 and DSS 51 tracking data were back-fed to the RTCS for their use in transfer orbit computations. During the first 36 min, approximately, of two-way lock at DSS 72, the operators had trouble holding the uplink in lock. It was subsequently learned that this was apparently caused by the antenna driving off of the spacecraft in the azimuth direction. The situation was further confused by the coincidence that at the time of the loss of the uplink, the one-way doppler and two-way doppler predictions were almost identical, thus preventing the receiver operators from immediately recognizing the loss of the uplink.

The RTCS computed a preliminary DSN solution of the transfer orbit using 10 min of DSS 72 data. This solution was considered a poor fit to the data and a second attempt was made. This second solution, completed at approximately $L + 100$ min, was deemed good and the orbit was mapped out to the moon.

The first *Centaur* guidance telemetry vector was not received by the RTCS until approximately 67 min after launch. After evaluation of this first vector, it was determined to be unusable and a second one was requested. The second one was received at about 112 min after launch and appeared to be good. The transfer orbital elements resulting from calculations based on the guidance vector further enhanced the conclusion that the spacecraft trajectory was nominal. The impact point was predicted as a result of mapping to the moon.

The last transfer orbit computed by the RTCS was based on DSS 72 and DSS 51 tracking data. The orbit solution was an excellent fit to the data. DSS 72 mean residuals for range rate were 0.0003 ft/s, and 0.0007 ft/s for DSS 52. The orbital elements and encounter conditions as calculated from the DSS 72 and DSS 51 data are presented in Section X. Also included are the orbital and encounter data computed at $L + 35$ h (last pre-midcourse orbit computations) by FPAC. By comparing the conditions from the two sources, it can be seen that they are in close agreement. The FPAC encounter conditions indicate that the launch vehicle injected the spacecraft such that its unbraked impact would only miss the target point by about 172 km.

The required midcourse corrections at $L + 38$ h to correct miss was 2.47 m/s and to correct miss plus time of flight was 4.78 m/s. These corrections are based upon an aiming point of 0.467° N latitude and 358.91° E longitude.

The near-earth phase of the flight was nominal, both in launch vehicle and spacecraft performance and in the support provided by the TDS. The problems experienced by elements of the TDS did not significantly affect the overall TDS support.

D. DSIF Acquisition to Midcourse Maneuver

Initial DSIF acquisition was obtained at 12:10 GMT by DSS 72, followed by the initial two-way lock at 12:21. The automatic sun acquisition sequence was completed at 12:11. Spacecraft command operations were initiated from DSS 72 at 12:29. The spacecraft data rate was increased to 1100 bits/s, transmitted power was reduced to the low-power mode, and initial spacecraft operations were completed at 12:53 GMT.

Johannesburg DSS 51 established one-way lock with the spacecraft at 12:16 GMT; a station transfer from DSS 72 to DSS 51 was made at 13:10 in accordance with the planned transfer schedule. The flight control cruise mode was not commanded on until 15:22 due to saturation of the Canopus intensity channel. Subsequently, transfer was made to DSS 61 at 17:00.

Because of a doppler resolver problem at DSS 61, it was decided to return control of the spacecraft to DSS 51 to minimize loss of two-way tracking data. This resulted in accomplishing the star acquisition maneuver somewhat earlier than planned. The command sequence was initiated by DSS 61 at 17:44 GMT. A nonstandard bit rate of 4400 bits/s was used to ensure a higher sampling rate of sensor signals than could be expected at 1100 bits/s and, following one roll on omnidirectional antenna B, the cruise mode was resumed at 18:13. The Canopus lock-on was confirmed at 18:15. Station transfer to DSS 51 was accomplished at 18:30, about 1½ hours earlier than planned. An approximate 5-min gap in coverage between DSS 51 and DSS 11 was covered by DSS 72 tracking the carrier one way.

Standard gyro speed and drift tests and engineering assessments during the first portion of the coast phase indicated completely nominal spacecraft performance. Minor anomalies – such as temperature variations which brought about a drop in helium pressure and higher battery power than had been predicted – were determined to have no adverse effect on the mission. No errors were indicated and there were no known anomalies during the second coast phase. The pre-terminal interrogation, conducted from 23:45 to 00:04 day 198 GMT, brought data indicating spacecraft performance was still completely nominal.

At 00:10, the final terminal message was sent to DSS 11, and the terminal descent sequence was commanded at 00:56. The SFOF confirmed initiation of the terminal sequence at 01:07; and, after it was determined that spacecraft status remained satisfactory, the sequence was continued.

E. Midcourse Maneuver to Mission Termination

A decision was made to execute the midcourse correction at approximately $L + 39$ h because of the relatively small miss distance of about 150 km from the initial target point of 1°20′W, 25′N, in Sinus Medii. The objective was to reduce the spacecraft's burnout velocity, increase maneuvering accuracy, and achieve a touchdown about half an hour earlier than nominal.

The midcourse correction was started at 01:46, day 197 GMT, with DSS 11 in two-way lock. At 02:00 GMT, the spacecraft was reconfigured for high power and 4400 bits/s. Premidcourse maneuvers were a positive roll of 72.5 deg and a negative yaw of 64.3 deg. Flight control thrust power was on at 02:27, and at 02:30 midcourse thrust was executed. Thrust duration was 10.3 s. With thrust power off, the reverse attitude maneuvers were started at 02:32. Canopus lock-on was then completed at 02:39, high transmitter power was commanded off, and the midcourse sequence was successfully completed at 02:46. At this point, there were no known anomalies and calculations indicated the Mission IV landing probably would be within 9 km of the aiming point.

The first terminal maneuver, an 81 deg positive roll, was started at 01:24 GMT and completed at 01:27. The second terminal maneuver, involving a 92.4 deg yaw, began at 01:29 and ended at 01:32. The third terminal maneuver, a 20.3 deg negative roll, was initiated at 01:35 and finished at 01:35:58.

From 01:36 to 01:42, auxiliary and main battery temperatures were 80°F and 78°F, respectively, and all subsystems were responding satisfactorily.

The retro sequence mode was commanded on at 01:56, and AMR power-on at 01:57 GMT. Other terminal events were: (1) thrust-phase power on at 01:58; (2) AMR enable at 02:00:15; (3) AMR mark at 02:01:55; (4) main retro ignition at 02:01:58 GMT.

The terminal descent maneuver was started normally and continued very smooth until 02:02:36 on day 198 (Monday, July 17, 1967) when there was an abrupt loss of signal. Up to this point, the spacecraft had performed almost perfectly and had responded to approximately 292 commands. The loss of signal occurred 40 s into the retro burn phase of the mission, only 2 s prior to retro burnout. To date, no cause of the abrupt loss of signal has been identified although a number of reasons have been advanced.

The DSIF Stations DSS 14, DSS 12, and DSS 11 lost the spacecraft signal at 02:02:41 GMT. Estimated time of touchdown was 02:05:11. At 02:05 GMT, DSS 11 and 14 reported a signal, below threshold (−172 dBmW), which was too weak to be positively identified. Subsequent attempts to contact *Surveyor IV* were unsuccessful.

Efforts to contact *Surveyor IV* were continued through July 18, 1967 (day 199 GMT). Then, because every feasible technique had been exhaustively tried, the *Surveyor IV* mission was terminated.

F. Summary of DSIF Station Operations

1. Ascension Island (DSS 72). Ascension Island DSS 72 was committed as the initial acquisition station for Mission IV. DSS 72 acquired the spacecraft at 12:10:13 with a decommutator lock at 12:10:41. Two-way lock by the station occurred at 12:21:46. Command Modulation was turned on at 12:26:41.

a. Initial acquisition. Initial spacecraft acquisition was performed by DSS 72 (Ascension Island). Significant events occurring during this phase are tabulated in

Table 71. Acquisition events

Events	GMT (day 195) h:min:s	Comments
Transmitter B high power on	12:05:55.18	Spacecraft commanded to high power by *Centaur*
DSS 72 acquires spacecraft in one-way mode on SAA (acquisition aid antenna)	12:09:56	
DSS 72 switch from SAA to SCM (30-foot antenna)	12:12:08	
DSS 72 transmitter turn on	12:12:24	
Signal in passband of both spacecraft receivers	12:12:31	(From telemetry) receiver B not phase locked. Receiver A in AFC capture
Receiver B phase locked	12:13:52	From telemetry
DSS 72 reports two-way	12:14:06	
DSS 72 auto tracking on SCM	12:18:50	
DSS 51 reports one-way lock	12:19:00	
DSS 72 turned on command modulation	12:19:22	DSS-72 could not confirm two-way. Telemetry data indicated receiver B not phase-locked at 12:17:24
DSS 72 turned off command modulation	12:20:50	Accomplished to reacquire the spacecraft in two-way.
DSS 72 reacquired 2-way	12:21:46	Telemetry indicates receiver B phase locked at 12:21:43
DSS 72 reported momentary out of locks	12:25:48 12:28:52	
DSS 72 reported good two-way lock	12:26:10	Solid two-way acquisition in 32 min and 41 s from launch
DSS 72 turned on command modulation	12:26:41	
Spacecraft command to 1100 bits/s data	12:29:58	Necessary for low-power data reception at DSS-72
Transmitter B high power off		Spacecraft was in high power for 30 min and 34 s for initial acquisition phase (1 h maximum allowed)

Table 71. With the exception of the antenna pointing problem, the initial spacecraft acquisition was nominal. The predictions indicated a *Surveyor IV* rise at DSS 72 at 12:09:45 GMT, on July 14. Ascension Island DSS 72 reported one-way doppler at 12:10:03 (rise + 01:18), auto-track on the SAA (acquisition-aide antenna) at 12:11:04 (rise + 01:19), auto-track on the SCM (antenna main beam) at 12:13:48 (rise + 04:03) and good two-way data at 12:16:23 (rise + 06:38). Previous experience with the acquisition procedure indicated that the above acquisition sequence which occurred at DSS 72 was smooth and quite nominal.

For instance, during the initial acquisition of *Surveyor III* at DSS 42, good two-way data was taken at rise + 06:55. The DSS 72 acquisition was marred, however, by the loss of up-link at 12:17:03, which was subsequently reacquired at 12:21:46. It is curious to note that the DSS 72 tracking data between 12:17:03 and 12:20:53 is labeled as good (in lock), two-way data, when it was, in fact, good one-way data. Investigation of the predictions indicate that at 12:17:00, the one-way doppler (which is a function of the ground VCO frequency) and the two-way doppler were almost identical – hence a possible explanation why the down link was not lost and why it was not immediately recognized at DSS 72 that the up-link had been lost.

There was one unexplained loss of two-way lock by the station. The station started the first command sequence at 12:29:46 and terminated commanding at 12:51:47Z. The station continued to track the spacecraft in three-way lock until DSS 11 rise plus 1 h. There were no spacecraft or CDC anomalies during DSS 72 participation.

b. View period summary – first pass. The *Surveyor IV* was launched at 11:53:29.2. Ascension Island DSS 72 acquired the spacecraft at 12:10:13 with a decommutator lock at 12:10:41. Initial spacecraft telemetry indications were normal with all *mark* events verified. The station was green for commanding and turned over to BUSS Chief for commanding of major sequence 0040, modified for DSS 72 telemetry threshold limitations.

Minor sequence 0052 was initiated at 12:29:46. The remainder of the minor sequences of major 0040 were transmitted with the exception of minor sequence 0054, which was delayed due to a strong Canopus sensor signal, and minor sequence 1054 which was not required. The final command was sent at 12:51:47. The CDC telemetry data became unusable at 12:49:00. The station continued to track the spacecraft through station transfers to DSS 51, DSS 61, DSS 11, and was released from track at 23:50.

2. *Goldstone operations (DSS 11).* The *Pioneer* site of Goldstone tracking station was used to track *Surveyor IV.* Backup tracking was provided by the Mars site with its 210-ft diameter antenna. Provision had been made to switch the CDC at the *Pioneer* site from the *Pioneer* site antenna to the Mars site antenna for either commanding the spacecraft or receiving telemetry from the spacecraft or both.

Midcourse maneuver and terminal descent were the two major events of the *Surveyor* mission to be commanded from Goldstone. The midcourse maneuver was delayed from the first Goldstone view period to the second view period in order to improve the accuracy of the final trajectory. This was possible because of the near perfect initial trajectory of the spacecraft. No problems occurred in the midcourse maneuver as both ground equipment and spacecraft performed perfectly.

During terminal descent everything continued to function normally through retro ignition and 40 s of retro burn; the signal from the spacecraft was then lost. Several attempts to revive the spacecraft were unsuccessful, and the best guess to date of the cause of failure is that the retro engine exploded near the end of its normal burn.

There were no failures or anomalies in the CDC during the mission. See Table 72 for a summary of the Goldstone CDC operations.

Table 72. Summary of CDC operations

Pass	Date	No. of CMDs	Problems	TFR No.	Affected mission
			GOLDSTONE		
1	July 15	13	None		
2	July 16	87	None		
3	July 17	497	None		
4	July 18	176	None		
			CANBERRA		
1	July 15	19	(1) DECOMM analog output channel 4 gave wrong indications	34127	No
			(2) SOC console light 3 indicated incorrectly	34130	No
2	July 16	20	None		
3	July 17	0	None		
4	July 18	1972	Note: Number of commands transmitted is estimate		
			JOHANNESBURG		
1	July 14	5	None		
2	July 16	11	None		
3	July 17	28	None		
			ASCENSION		
1	July 14	49	None		
			MADRID		
1	July 14	24	None		
2	July 15	0	None		
3	July 16	0	None		

a. View period summaries — first pass. The first pass at DSS 11 went very well although an improper acquisition procedure was used. Acquisition occurred at 23:15 GMT and end of track was at 07:27. There were 13 commands transmitted to the spacecraft. Ten of these were to perform two engineering interrogations, and the other three were to change flight control modes in order to perform gyro drift measurements.

A bit rate of 1100 bits/s was maintained throughout the pass. Parity errors were measured five times and increased from 0.22 errors per 1000 bits early in the pass to 4.24 errors per 1000 bits about 0.5 h prior to end of track. There were no spacecraft or CDC anomalies during this pass. No CDC problems were encountered during the countdown, but there was a failure in the Beta computer which was repaired prior to acquisition.

b. View period summary — second pass. Acquisition for pass 2 at DSS 11 occurred at 23:20 GMT and end of track was at 08:06 GMT. During this pass, 87 commands were transmitted. Most of these were required to perform the midcourse maneuver and return the spacecraft to normal coast phase configuration and attitude. In addition, two engineering interrogations and one gyro speed check were performed. The bit rate was 550 bits/s for the entire pass except during the midcourse maneuver when the transmitter high power was on and the bit rate increased to 4400 bits/s. One parity error measurement was made at 03:26 GMT. The DSIF receiver signal level was −142.3 dBmW, and the bit error rate was 6×10^{-5}.

The CDC input was transferred to Station 14 for telemetry during this pass, and the signal level increased 8.5 dB. There was a delay in this transfer because of incorrect patching of the telemetry communication lines. This would have caused loss of data if the transfer had been required by some failure to obtain a satisfactory signal from DSS 11. There were no spacecraft or CDC problems during this pass. Also no CDC failures or other problems were encountered in the countdown.

c. View period summary — third pass. The third DSS 11 pass acquisition occurred at 23:20 GMT. Events progressed normally into terminal descent. Pre-terminal maneuvers were executed and retro ignition occurred in a normal manner. The spacecraft remained stable through 40 s of retro burn, and then the signal from the spacecraft was lost at 02:02:41 GMT. Up to this time, 66 commands had been sent to the spacecraft. An additional 431 commands were sent after loss of downlink signal in an unsuccessful attempt to re-acquire a signal from the spacecraft. The CDC equipment continued to operate without difficulty.

d. View period summary — fourth pass. Goldstone DSS 11 participated in a fourth pass for Mission IV in an attempt to revive the spacecraft. The ground transmitter was on from 00:29:17 GMT to 05:41:40 GMT. During this time, 176 commands were transmitted. Again no CDC problems were encountered.

3. Canberra (DSS 42). During Mission IV, Station 42 had two tracking periods prior to the loss of spacecraft carrier during terminal descent. The station was in two-way lock with the spacecraft for 9 h 5 min during the first pass and 9 h during the second pass. A total of 39 commands were transmitted to the spacecraft during the transit phase. No significant problems with either the spacecraft or ground equipment were encountered during the tracking periods.

Two special command tapes for the static firing were transmitted to Station 42 approximately 5 h prior to rise time on the pass preceding touchdown. A special training session was scheduled to ensure SOC and command generator operator familiarity with the tape; station personnel were also briefed on their activities during this sequence.

Several RF loop TV tests were scheduled prior to the mission with all personnel participating to ensure adequate preparation for the station's increased TV commitment during Mission IV. A summary of the Canberra CDC operations is given in Table 72.

a. View period summary — first pass. Spacecraft acquisition occurred at 03:05 GMT with firm decommutator lock at 03:11. The end of track occurred at 16:17 GMT. Station transfer from DSS 11 occurred at 05:04 GMT. Transfer to DSS 51 was at approximately 14:09 GMT. Both transfers utilized a modified form of the "lost communications" procedure. In this procedure, the transmitter power of the station controlling the uplink is reduced to 1 kW and the three-way station turns on its transmitter to 10 kW when the telemetry indicates the controlling station has reduced its power. Unfortunately, both transfers caused the uplink (and hence the downlink) to go out-of-lock when the controlling station turned off its transmitter. The problem appears to be that the acquiring station tuned into the receiver bandpass, but did not phase-capture the receiver.

Nineteen commands were transmitted to the spacecraft. The spacecraft responded normally to all commands. The command sequences consisted of:

(1) Two engineering interrogations.

(2) Termination of a roll gyro drift check (initiated at DSS 11).

(3) Two three-axis gyro drift checks.

(4) A bit rate reduction from 1100 to 550 bits/s.

No spacecraft anomalies were observed, although R-18 was observed to be fluctuating. It was later noted that this is normal behavior with the RADVS off according to the SC-5 signature list. During the pass, four particles were observed to go through the Canopus sensor field of view. One particle even caused a momentary loss of star lock.

b. View period summary – second pass. Pass 2 for DSS 42 lasted from acquisition at 03:40 GMT to antenna prelimits at 16:34. Station transfer from DSS 11 occurred at 06:00 and our transfer to DSS 51 was at 15:00.

Twenty commands were transmitted to the spacecraft; the spacecraft responded normally to all commands. The command sequences consisted of:

(1) Two engineering interrogations.

(2) Initial power mode cycling (minor sequence 2053).

(3) A roll gyro drift check.

(4) The subsequent power mode cycling.

(5) Turn on the oxidizer tank No. 2 temperature control (CMD 0615).

c. View period summary – third pass. At 03:53 GMT the moon was in view of the TV monitor. The DSS receivers searched ±60 kHz about 2295 MHz from 03:53 until the end of the DSS 11 command sequence to shut down the spacecraft at 08:06. At 08:16 DSS 42 was relieved for the remainder of the pass.

d. View period summary – fourth pass. At 04:29 GMT the moon came into the station view. The DSS receivers tuned ±60 kHz about 2295 MHz while DSS 11 was commanding per NSP-32. At 05:45 GMT the DSS 42 transmitter was turned on and tuned ±20 kHz. After a full receiver search (±60 kHz about 2295 MHz) commanding commenced per NSP-32, Point 6. The NSP was then followed from Points 7 through 15, 19 through 24, and 28 through 29.

After completing the normal NSP-32 effort, it was proposed and the SFOD approved, to make an attempt to position the planar array and determine if a signal could be detected with various planar array look angles. In accordance with this concept, the following actions were taken:

(1) Turn-on sequence.

  (a) 0305 – Enable OTC.

  (b) 0607 – Unlock roll axis (Interlocked).

  (c) 0634 – Unlock elevation axis (Interlocked).

  (d) 0635 – Unlock solar panel.

  (e) 0117 – XMTR A to P/A.

  (f) 0126 – XFER switch on low power.

  (g) 0101 – XMTR A low power on.

  (h) 0112 – NBVCXO on.

(2) Initial PA/SP POSITIONING.

  (a) 0403 – 1280 times (at 100 CMD intervals followed by 0402 at 50 CMD intervals).

  (b) 0402 – 640 times. This resulted in the P/A being at an angle of −10 deg from the horizontal and the solar panel being horizontal. A receiver search was then conducted over the entire band.

(3) From the initial conditions described above, a receiver search was conducted with the planar array at −10, −5, 0, and +6 deg from the horizontal. At each of the above four conditions, a receiver search was also conducted with the elevation axis set at −10, 0, and +10 deg. During the P/A positioning the solar panel was maintained in a position corresponding to the transit position.

(4) The final conditions at which the turn-off sequence was initiated were:

  (a) Solar panel position: 170 deg.

  (b) Polar axis: +96 deg (or 6 deg over the horizontal).

  (c) Elevation axis: −10 deg.

At 12:15 GMT the spacecraft shutdown sequence was initiated. This consisted of commands 0111, 3617 and 0314 repeated 4 times and interspersed with modulation interrupts after each group of three commands.

4. Johannesburg (DSS 51). Station 51 was more active in the *Surveyor IV* mission than had been anticipated. Scheduled only as a backup station, it became the primary station for the transit phases.

The spacecraft was monitored from DSS 51 for three passes from $L + 24$ min to approximately retro minus 2 h.

During the launch phase the command line from Station 72 was patched on a spare SCAMA line to Station 51 (listen only). This was in addition to the normal line to the SFOF and the voice of *Surveyor* line. This allowed keeping up with events in real time as DSS 51 acquired the spacecraft less than 10 min after Station 72.

Voice communications to and from Station 51 were fairly good for the first two passes but were quite bad for part of pass No. 3. The TTY conference mode worked very well during pass No. 3, and a little commanding of the spacecraft was accomplished using this means for instructions.

There were no operational or equipment problems in the CDC area during the complete mission. See Table 75 for a summary of the Johannesburg CDC operations.

a. View period summary – first pass. Initial spacecraft acquisition was performed by DSS 72. Two-way lock, tuned to sync frequency, and command modulation were all reported prior to downlink acquisition by DSS 51. No change in status was reported; therefore, based on this information, DSS 51 acquired the spacecraft in three-way at 12:16:53. Solid decommutator lock was accomplished at 12:19 as the antenna main lobe locked onto the spacecraft. The spacecraft telemetry data showed that receiver B did not have a signal in its passband, was not phase-locked, and that the spacecraft was not receiving command modulation. This information was reported to track and at 12:21:39 DSS 72 reinitiated two-way acquisition of the spacecraft. This action resulted in the DSS 51 receiver and decommutator being out of lock from 12:21:39 to 12:22:05 and again from 12:24:20 to 12:26:16. During this pass the receiver and decommutator were momentarily out of lock at three other times. These occurred at 21:34:14 when the spacecraft was commanded to low power, at 18:05:47 when the decommutator went out of lock during the star map because of an omniantenna null, and at 18:14:51 when the spacecraft was again commanded to low power. There was no visibility overlap with DSS 11, so the spacecraft was monitored until it went over the horizon with no station transfer. End of pass occurred at 23:39:41.

During this pass, the following transfers occurred:

From	To	GMT
DSS 72	DSS 51	13:10
DSS 51	DSS 61	17:02
DSS 61	DSS 51	18:30
DSS 51	Over horizon	23:39:41

Five commands were transmitted from DSS 51 during this pass. These consisted of cruise mode on and initiating and terminating two gyro drift checks.

At 16:10 it was necessary to reload the SOCP program due to an incompatibility between it and the interim monitor program (IMP). The IMP is used to monitor various switch positions and AGC of the station ground receiver. The IMP was withdrawn from operation and a DSS-TFR written. At DSS 51 there is only one computer setup rather than separate computers for these programs.

At 12:41:39 an engineering interrogation of Mode 1, 2, and 4 data was performed. Mode 6 data was interrogated at 12:49:55, and a second engineering interrogation of Mode 1, 2, and 4 data was performed at 17:27:20. The telemetry data during these mode interrogations showed the spacecraft performance to be nominal. With the exception of these interrogations, the spacecraft was operated in Mode 5 and average alarm printouts of all telemetry signals in this mode were used to verify spacecraft performance. At 15:15 significant transitory changes in FC-12 and FC-14 were observed. It was concluded that these changes were due to a particle passing in front of the Canopus sensor. These observations and the probable cause were transmitted to BUSS-1 who later relayed the information that SFOF reached the same conclusion. At 15:30 P-1 had decreased 5 BCDs from its previous values. This change represents 30 psi and was not related with the tank temperature which remained constant during this time. This information was transmitted to BUSS-1.

During this pass, star verification and Canopus acquisition occurred. This was monitored at DSS 51 while the commands were transmitted from DSS 61. Both the star map and the automatic Canopus lock-on were nominal.

Prior to Canopus lock-on, the signal level to the spacecraft receiver A was −80 dBmW. After Canopus lock-on this signal level was −106 dBmW, and approximately an hour later had decreased to −118 dBm on the average alarm printout. BUSS-1 reported that decoder indexing had occurred during this period indicating that at times the signal level decreased to −126 dBmW, the indexing level of this receiver. This low signal level was attributed to an omni antenna pattern null, and BUSS-1 relayed the information that the SFOF agreed with this conclusion. This condition lasted for approximately 2 h, after which the signal level increased to −99 dBmW and followed the predicted levels for the remainder of the pass.

b. View period summary—second pass. Pass 2 for DSS 51 lasted from acquisition at 11:58:50 to loss of signal at 23:52:40. During the period, the following station transfers occurred:

From	To	GMT
DSS 42	DSS 51	14:08:12
DSS 51	DSS 11	23:35:02

The transfer from DSS 42 to DSS 51 attempted to use the emergency transfer procedure whereby the upcoming station "steals" the spacecraft from the outgoing station. The steal was considered unsuccessful as both uplink and downlink phase lock were lost in the process.

After DSS 42 had reduced its transmitter power to 1 kW, DSS 51 turned on its transmitter at 10 kW at a frequency approximately 20 kHz below the DSS 42 S-band frequency. The DSS 51 transmitter was then tuned upwards in frequency at a rate of approximately 500 Hz/s at S-band until the spacecraft AGC indicated that the DSS 51 transmitter had entered the passband of receiver B; tuning of the DSS 51 transmitter was continued upwards in frequency until the downlink phase lock was lost. (Until this time, the SPE of receiver B had remained constant, which indicated the uplink was still locked to the DSS 42 transmitter.) When the downlink was reacquired on the DSS 51 receiver, the spacecraft telemetry indicated that receiver B was not phase-locked to either the DSS 42 or 51 transmitter.

The DSS 51 transmitter upward tuning was then resumed until the downlink phase lock was again lost. When the DSS 51 receiver again reacquired the spacecraft, the telemetry indicated phase-lock of transponder B.

An interesting aspect of this experience is that the DSS 51 transmitter broke the DSS 42 uplink without uplink being acquired on the DSS 51 transmitter. From the start of the "steal" until uplink-lock was finally achieved, the DSS 51 transmitter was tuned in only an upward direction.

Eleven commands were transmitted to the spacecraft from DSS 51 during this pass. These involved one engineering interrogation, two standard gyro drift checks and one gyro drift check in roll only. During this pass engineering interrogations of Mode 2 and 4 data were performed at 12:02 by BUSS-42 and at 16:00 by DSS 51. These interrogations and the mode 5 data showed that the spacecraft performance was nominal during this pass.

c. View period summary—third pass. Pass 3 for DSS 51 lasted from acquisition at 12:06:56 to loss of signal at 00:02:00. During this pass the following station transfers occurred:

From	To	GMT
42	51	15:00:00
51	11	23:30:02

Twenty-eight commands were transmitted to the spacecraft from DSS 51 during this pass. These consisted of 4 engineering interrogations, 2 gyro drift checks, 1 power mode cycle, and turning the temperature control of camera 3 on.

Communications during the last portion of this pass were very poor and voice circuits in particular were out a good deal of the time. Of the commanding accomplished during this pass 50% was by way of TTY conference mode and worked very well.

During this pass, engineering interrogations of Modes 2 and 4 data occurred at 15:16:11, 19:24:14, and 22:37:53. An engineering interrogation of Mode 1, 2, and 4 data occurred at 23:46, and an interrogation of Mode 4 data at 21:35:50 after turning on the auxiliary battery mode, high current mode, and the Camera 3 heater. These interrogations and the Mode 5 data showed that the spacecraft performance was nominal during this pass.

5. Madrid (DSS 61). Prior to the mission, local studies had been accomplished to analyze what use might be made of the backup computer during its long periods of inactivity. From these studies it was decided that automatic conversion of raw telemetry counts to engineering units would be of most value. For this purpose a special program was written to use average alarm data routed from the prime computers and to output engineering unit conversions on TTY.

This program was successfully used during Mission IV; during the third pass this data rather than average alarm data was routed to SPAC with their concurrence for review and comments.

DSS 61 tracked *Surveyor IV* for the three transit phase view periods. The station was in two-way lock with the spacecraft for slightly less than 2 h. Twenty-four commands were transmitted and the spacecraft responded accurately to them all. These commands were executed during the first pass and involved an engineering interrogation, star map, and star acquisition.

For the greater portion of the transit phase Station 61 was in three-way lock in conjunction with Station 51. This was due to the relatively low antenna elevation angles from 61 and certain antenna servo problems. All aspects of the CDC crew and equipment performed flawlessly.

Surveyor IV was tracked from DSS 61 for the three transit phase passes. Total tracking time was 21 h, 8 min of which 1 h, 30 min was two-way. A total of 24 commands was transmitted to the spacecraft from DSS 61 during the 1 h 30 min period of two-way tracking which occurred during the first pass. The remainder of the tracking period was three-way tracking with DSS 51 having control of the uplink.

a. View period summary—first pass, July 14, 1967. The track began with acquisition at 15:23Z and lasted for 7 h, 35 min, ending with loss of signal at 22:58 GMT. The spacecraft was acquired in mode 5 at 1100 bits/s, at a signal level of −132.5 dBm. Transfer from DSS 51 occurred at 17:00 GMT. An engineering interrogation of modes 4, 2, and 1 with return to mode 5 was initiated at 17:27 GMT.

An early star verification and acquisition sequence was initiated at 17:51 GMT after going to 4400 bits/s with the spacecraft transmitter operating in high power. During the roll maneuver AGC voltage readings were taken at 10 s intervals along with a GMT every fifth reading. The CDC DECOMM lost lock twice during the roll, each time at the same roll angle. The received signal level at the beginning of the roll maneuver was −119.1 dBm and fell to a low of −147.9 dBm at the severest omni null. Automatic Canopus lock-on occurred at 18:10:33 GMT at a down-link signal level of −114.0 dBm. Following Canopus lock-on, the spacecraft was commanded to low power. AGC voltage readings obtained during the star map were converted to received signal strength in dBm and sent by TWX to OPS-X *Surveyor IV* by request of SFOF personnel. Transfer back to DSS 51 took place at 18:30 GMT.

During the remainder of the pass, several gyro drift checks were monitored and rates of drift were calculated. No equipment failures occurred and all personnel performed satisfactorily. A total of 24 commands were sent during uplink control of the spacecraft by DSS 61. The pass ended at 22:58 GMT.

b. View period summary—second pass, July 15, 1967. The second pass lasted 5 h, 48 min. The scheduled tracking period was 8 h, but due to a hydraulic failure in the antenna servo system, track was prematurely terminated at 21:52 GMT. During the pass, several gyro drift checks were made and rates of drift were calculated. All spacecraft signals available were routinely checked against predicted values. No spacecraft or CDC anomalies were noted. DSS 51 had control of the up-link during the entire pass; therefore, no commands were sent from DSS 61. The receiver went out of lock at 21:50 GMT due to an antenna servo problem, and the station was released from track at 22:35.

c. View period summary—third pass, July 16 and 17, 1967. Acquisition occurred at 16:15 GMT with the spacecraft in mode 5 at 550 bits/s. DSS 51 again had up-link control of the spacecraft during the entire pass. The entire pass was spent monitoring data checking against predicted values. At approximately 21:00, the SOC asked and received permission from the BUSS Chief to send average alarm data already converted to engineering units. A program written by one of the DSS 61 personnel had been generated which allows converting spacecraft telemetry counts directly to engineering units in the backup computer, and outputting this to the page printer for immediate analysis. Track ended at 00:04 on July 17.

G. Space Flight Operations Facility

The contents of this report reveal the only major problem encountered during the *Surveyor IV* mission was a power failure that occurred on the second floor of the SFOF that caused complete shut-down of the X and Y computer strings. The failure occurred when the mission was in the launch phase at the specific of 19:08, July 13, 1967, 16 h and 45 min prior to launch. Full operational capacity was achieved on the X and Y computer strings after 2 h and 7 min. The power failure occurred during a lull period when diagnostic tests were being conducted on IBM equipment and had no adverse effects on mission performance. The power to computer strings X and Y was replaced with individual feeders and circuit breakers to prevent a recurrence of the problem.

During the SFOF computer checkout on July 13, an SFOF power system failure dropped both computer strings off line; this occurred at 19:08 GMT. A power surge from the facility generator power system was first suspected; however, the cause was later isolated to a faulty circuit breaker.

At 23:45, the X-string 7044 computer was still experiencing problems in two areas. One was a direct data channel problem (high parity errors) from the 7044 to the 7094. The second was associated with the output driver sub-channel to the *Surveyor* SPAC Area.

The Y string, which had been re-established and checked out previously, was turned over to the *Surveyor* project at 01:45 on July 14. At this time, the X string was still not operational in Mode 2 (7044/7094), but was operating properly in Mode 3 (one 7044) and Mode 4 (one 7094). The project requirements, which were one Mode 3, plus two Mode 4, could be met with the X string and Y string in the present configuration. In addition, the W string was made available to the project from $L - 5$ h through launch. The X string was checked out and turned over to the *Surveyor* project in a go condition at 04:00.

All other problems encountered were of a minor nature and were expeditiously resolved. These had little or no significance in the overall support of the mission. Aside from the normal radio propagation problems experienced by the DSN ground support facilities, there was no loss of data due to malfunctions of down time of equipment in the SFOF.

The time period covered by this report includes the following phases:

(1) Pre-mission phase: From beginning of first operational readiness test (ORT) to launch phase (21:39, July 8, 1967, to 11:53, July 12, 1967).

(2) Launch phase: From liftoff minus 48 h to acquisition by the first DSN station (11:53, July 12, 1967, to 12:09, July 14, 1967).

(3) Mission phase: From acquisition by the first DSN station to loss of signal plus 38 h (12:09, July 14, 1967, to 14:02, July 18, 1967).

The five functions in the SFOF that supported the *Surveyor IV* mission described below are: (1) Data Systems Operations; (2) Data Processing System Support; (3) SFOF Communications; (4) SFOF Operations; and (5) SFOF Support.

*1. **Data systems operations.*** The functions of the data system operation in support of the *Surveyor IV* mission were the real-time computer operations and data flow support. Figure 147 shows the SFO generalized data flow.

a. Pre-mission performance. No major problems were encountered during the ORT. During the pre-launch checkout phase, electrical power to the mission dependent X and Y strings, computers failed at 19:08, July 13, 1967. Electrical power capability was restored to the computers and a power-up sequence on X and Y strings was implemented. All computers were restored to full operational capacity at 21:15. No anomalies were experienced during the diagnostic checkout of the equipment and sequence of events which followed.

b. Launch phase performance. There were no problems encountered during the launch phase of sufficient magnitude to degrade support for the project, and performance was highly reliable.

c. Mission phase performance. There were no problems of sufficient magnitude to degrade support for the project, and performance was highly reliable.

d. System anomalies. During pre-mission, the X and Y computers were red from 19:08, July 13, 1967, to 21:15, July 13, 1967, due to a primary power problem. No major problems were encountered during either the launch or mission phases.

2. Data processing system support. The SFOF data processing support provided pre-launch testing and support of *Surveyor IV* in the simulated data control center (SDCC), Telemetry Processing System (TPS), input/output (I/O) user areas, and operational control of these areas at the data processing control area (DPCA).

a. Pre-mission performance. Two problems occurred and were resolved during pre-mission checkout which caused a delay in the checkout of the DPS. Other problems were minor, having no significant effect on the pre-mission phase.

b. Launch phase performance. One minor problem was encountered during this phase.

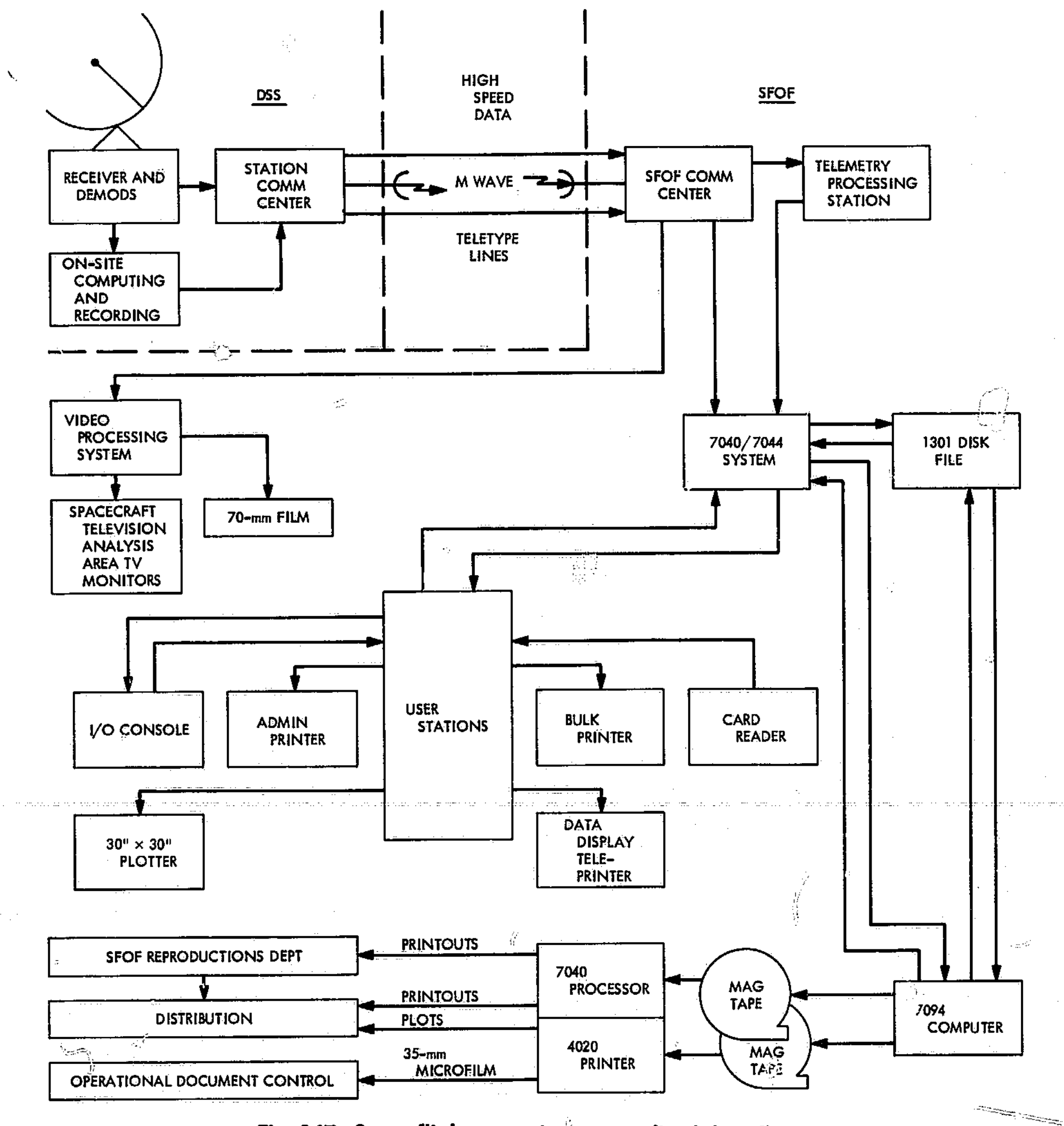


Fig. 147. Space flight operations generalized data flow

c. Mission phase performance. Some minor problems occurred up to the time spacecraft data was lost; however, there was no degradation of mission performance.

d. System anomalies. Pre-mission anomalies consisted of the following:

(1) At 13:30, July 12, 1967, PDP-7 computer of System No. 1 developed an intermittent problem in the output buffer, while running the test pattern generator diagnostic program.

(2) At 16:20, July 12, 1967, the PDP-7 computer of System No. 3 had been checked out and was configured to System No. 1 for launch.

(3) At 19:40, July 12, 1967, the PDP-7 computer of System No. 1 had been repaired and checked out on the V string.

(4) At 19:08, July 13, 1967, loss of power was experienced on the X and Y strings.

(5) At 20:23, July 13, 1967, power was restored to the DPS and the equipment was powered-up one piece at a time.

(6) At 21:15, July 13, 1967, all equipment was on line at full operational capacity.

The following anomalies occurred during the launch phase

(1) At 02:59, July 14, 1967, the administration printer in Flight Path Analysis Area 1 (FPAA 1) was replaced because of paper jamming.

(2) At 03:57, July 14, 1967, the bulk printer in FPAA was replaced because of printing problems.

3. Surveyor IV mission discrepancy report summary. The primary purpose of the DSN discrepancy report summary (DRS) is to provide a controlled closed-loop method for systematically reporting and correcting operational failures or problems to ensure that the DSN is properly prepared to support SFO of succeeding missions. The system also supplies an operations effectiveness measurement for specific DSN committed support. The period covered by this summary is May 16, 1967 through July 19, 1967. Minute details are omitted for the sake of brevity.

Discrepancies which occurred during the mission phase were as follows:

(1) At 17:34, July 14, 1967, the administration printer in FPAA 1 was replaced due to loss of first character of each line. A time delay occurred in the replacement action; this was at the convenience of *Surveyor* personnel.

(2) At 09:30, July 15, 1967, the bulk printer in the Spacecraft Performance Analysis Area (SPAA) was replaced because of bad output data.

Since all problems were of a minor nature and were easily corrected without degradation of mission performance, no recommendations for improving the operations were made.

4. SFOF/DSN/ICS. In support of the *Surveyor IV* mission, the DSN Intracommunications System (ICS) provided a communications system capable of receiving, switching and distributing all voice, teletype, high speed data (HSD) and closed circuit television to all users with the SFOF.

a. Pre-mission performance. All modes of communications (teletype, voice, and HSD) performed well with high reliability during the phases of ORT. The DSN/ICS encountered no major troubles during the ORT. Minor equipment failures within the DSN/ICS were corrected in real-time with no actual loss of data to the project.

b. Launch phase performance. During the launch phase, the DSN/ICS performed well. There were no problems of sufficient magnitude to degrade operational support to the project.

c. Mission phase performance. The DSN/ICS performed well. The usual radio propagation problems were experienced by DSN/ground control facilities (DSN/GCF) causing minimal loss of data and operational circuit time.

d. System anomalies. Throughout the ORT, the usual short duration radio propagation conditions were encountered by DSN/GCF. This created minor problems which resulted in minimal loss of data in the SFOF/ICS. There were no major problems during the launch phase; poor radio propagation that occurred from time to time caused minimal loss of data. During the mission phase there were no major problems and close surveillance and prompt reaction to a few minor problems resulted in a high degree of reliability with minimal loss of data due to radio propagation.

5. Computer performance. The computer configuration performed satisfactorily throughout all phases of the mission. All support functions performed nominally except for a circuit breaker failure (during the launch phase) supplying power to the X and Y strings.

a. System anomalies. During the launch countdown, 16:35, July 13, 1967, the local commercial power carrier reported that possible thunderstorms might occur in the area. As a result, a decision was made to place the SFOF on generator power during this period. The generator switch was accomplished at 17:20, July 13, 1967. At 20:23, July 13, 1967, commercial power was restored and the equipment was gradually powered-up. At 21:47, July 13, 1967, generator power was restored.

At 19:08, July 13, 1967, a power failure occurred on the second floor, which caused both the X and Y computer strings to go down. It was determined that a shift in the load on the second floor had caused an overload at a power panel where the main 400 A breaker was located. A new breaker was installed with a factory rating of 400 A and a redistribution of some of the load was made. The current was monitored throughout the mission and no overloads developed. No problems were encountered during either the launch or mission phase.

b. Recommendations for improvement of operation. Since no major problems occurred in the SFOF/ICS, no recommendations for operations improvement were made.

6. SFOF operations. In support of the *Surveyor IV* mission, the SFOF Operations Group performed the following tasks: prepared and operated the display and monitoring system; provided internal access control; operated the data flow and distribution system; operated the facility control area; provided technical area assistants as required; and operated the discrepancy reporting system and equipment-failure reporting system.

a. Mission performance. Mission performance during various phases of the mission was as follows:

(1) Pre-mission: The ORT was satisfactory from a support standpoint.

(2) Launch phase: All operations were normal and no major problems were encountered.

(3) Mission phase: A few minor problems occurred that were resolved in real-time and performance was entirely satisfactory until loss of signal.

b. System anomalies. All required support was provided to the *Surveyor* project during the pre-launch testing with no significant problems being encountered. During the launch phase, at 19:08, July 13, 1967, a power failure occurred on the second floor causing both the X and Y strings to go down. At 20:23, July 13, 1967, electrical power was restored to the X and Y computer strings and a power-up sequence was implemented at that time. At 21:15, July 13, 1967, X and Y computer strings were restored to full operational capacity.

In the mission phase, a discrepancy occurred in the data distribution system in that repro copies were not run on Orbit Determination Programs. This was not a serious problem as the Flight Support Group had 1403 NCR output available. Repro copies of the program were later made from the 35 mm film from Operational Documentation Control.

Posting of the display boards in the SPAA area was more time consuming than originally anticipated; however, the necessary manpower was provided and the work completed satisfactorily.

c. Recommendations for operations improvement. No major problems were encountered pertaining to the support provided by the SFOF Operations Group; therefore, no recommendations for improvement were made.

7. SFOF support. In support of the *Surveyor IV* mission, the support group performed the following: operated the reproduction operations facility and maintained the Facility Support Systems, including the electrical, air conditioning, and diesel sub-systems.

All pre-mission support of the *Surveyor IV* mission was nominal. A complete pre-mission checkout of the physical plant equipment was conducted without any major anomalies in the system. It was necessary to change the injectors in the No. 1 generator between the completion of the ORT and launch; however, there was no loss of power to mission support equipment.

XI. TDS Performance Evaluation

A. Near-Earth Flight Phase

The AFETR provided coverage for tracking (metric) data, *Atlas/Centaur* telemetry (VHF), and *Surveyor* telemetry (VHF and S-band)—using land stations, an RIS, and aircraft. Aside from the fact that the only RIS supporting the mission was the *Coastal Crusader,* the AFETR configuration was the same as for *Surveyor III* and *IV* mission. Continuous tracking coverage was provided to $L + 779$ s by stations from Cape Kennedy to Antigua, and this was followed by Ascension Island and Pretoria tracking from $L + 1142$ to $L + 2976$ s. The azimuth servo valve on the antenna pedestal of the TPQ-18 radar at Grand Bahama Island failed during the countdown, and remained down through the launch. But sufficient redundant coverage was provided by other stations during the Grand Bahama Island interval.

The FPS-16 radar at Cape Kennedy had a 13-s dropout at $L + 464$ s, which was 114 s after the end of the estimated coverage interval, and provided an additional 73 s of data after the dropout. The Grand Turk TPQ-18 radar also had a short dropout near the end of its coverage interval, being off from $L + 579$ to $L + 600$ s; but it thereafter provided data until LOS at $L + 675$ s. Redundant data were obtained from other stations during both of the latter dropouts.

Atlas telemetry (229.9-MHz link) was continuously received and recorded from before liftoff until after *Atlas/Centaur* separation; *Centaur* telemetry (225.7-MHz link), until shortly after spacecraft separation. Thereafter, *Centaur* telemetry was recorded as station coverage allowed until completion of the *Centaur* retro maneuver. Thus, continuous and substantially redundant VHF telemetry data was received from the beginning of the countdown through Pretoria LOS at $L + 3570$ s. Besides meeting all requirements, this was greater than predicted coverage.

Continuous S-band coverage was obtained from liftoff to Ascension Island LOS at $L + 2444$. The Tel-4 antenna dropped receiver phase lock between $L + 197$ and $L + 270$ s, but Grand Bahama Island maintained lock and provided redundant coverage throughout this period. Antigua exceeded the estimated coverage interval, but maintained phase lock for only 30% of the time. Coverage from Grand Bahama Island and the *Coastal Crusader* overlapped most of the Antigua view, but from $L + 495$ to $L + 673$ s, Antigua was the only station in phase lock. Receiver phase lock was maintained continuously by the *Coastal Crusader* and then Ascension Island from $L + 673$ to $L + 2197$ s, and Pretoria provided redundant coverage during this interval with receiver phase lock from $L + 1377$ to $L + 1698$ s.

In meeting real-time telemetry data requirements, spacecraft telemetry via the VHF link was transmitted to the SFOF from liftoff to spacecraft high-power-on. Then, as planned, AFETR switched to real-time transmission of spacecraft telemetry data received via the S-bank link and the data flow was very good. In addition, all *mark* events (except *mark* 14) were read out and reported.

The RTCS provided trajectory computations based on tracking data and telemetered vehicle guidance data, and computed six orbits—including a pre-retro orbit from Antigua data, a second pre-retro orbit from *Centaur* guidance telemetry data, a post-retro orbit using Ascension Island and Pretoria data, two spacecraft orbits from DSS 72 data, and a spacecraft orbit using DSS 72 and DSS 51 data. This last orbit was a very good solution, and compared favorably with the final premidcourse computation generated by the SFOF.

MSFN facilities supporting *Surveyor IV* included acquisition aids, VHF telemetry, and real-time readouts at Bermuda and Grand Canary; C-band radar at Bermuda; SCAMA at GSFC, Grand Canary, and Bermuda; and radar high-speed data at Bermuda and GSFC. GSFC also supported the ORT prior to launch.

Problems and anomalies:

(1) Grand Canary reported a maximal telemetry-data signal strength of -103 dBmW, which was just above threshold, and there were numerous dropouts during the last 2 min of track—although the decommutator maintained lock long enough to confirm *mark* event 16.

(2) Two seconds of Bermuda FPQ-6 radar data were lost at 12:01:08 GMT, due to phasing separation.

(3) The range safety impact prediction plot became erratic at approximately $L + 8$ min, and investigation revealed a possible problem in the 4101 computer program. This may have been due to the improper smoothing of elevation data.

*1. **AFETR.*** The overall AFETR estimated coverage vs requirements vs actual coverage is shown in Fig. 148.

AFETR and MSFN support of the launch vehicle tracking and data acquisition requirements was completely satisfactory. All Class I and Class II requirements were met. Real-time evaluation of the launch vehicle performance, through spacecraft separation, was made possible because of the direct ascent mission profile and the use of subcable *Centaur* VHF telemetry data through Antigua LOS after spacecraft separation. The AFETR and MSFN reporting of *mark* events was proper and timely. All launch vehicle systems performed satisfactorily and no anomalies were encountered.

The AFETR method of predicting coverage intervals for S-band low-power is still not accurate and needs further refinement.

a. Tracking. The estimated vs actual coverage is shown in Fig. 149. The class I requirements were met and exceeded, with AFETR stations downrange to Antigua providing continuous coverage to $L + 779$ s, and with Ascension Island and Pretoria providing continuous coverage from $L + 1142$ to $L + 2976$ s.

The TPQ-18 radar at GBI experienced a failure with the azimuth servo valve on the antenna pedestal during the countdown. The radar remained down through the launch and did not support. Redundant coverage during the GBI interval was provided by other stations.

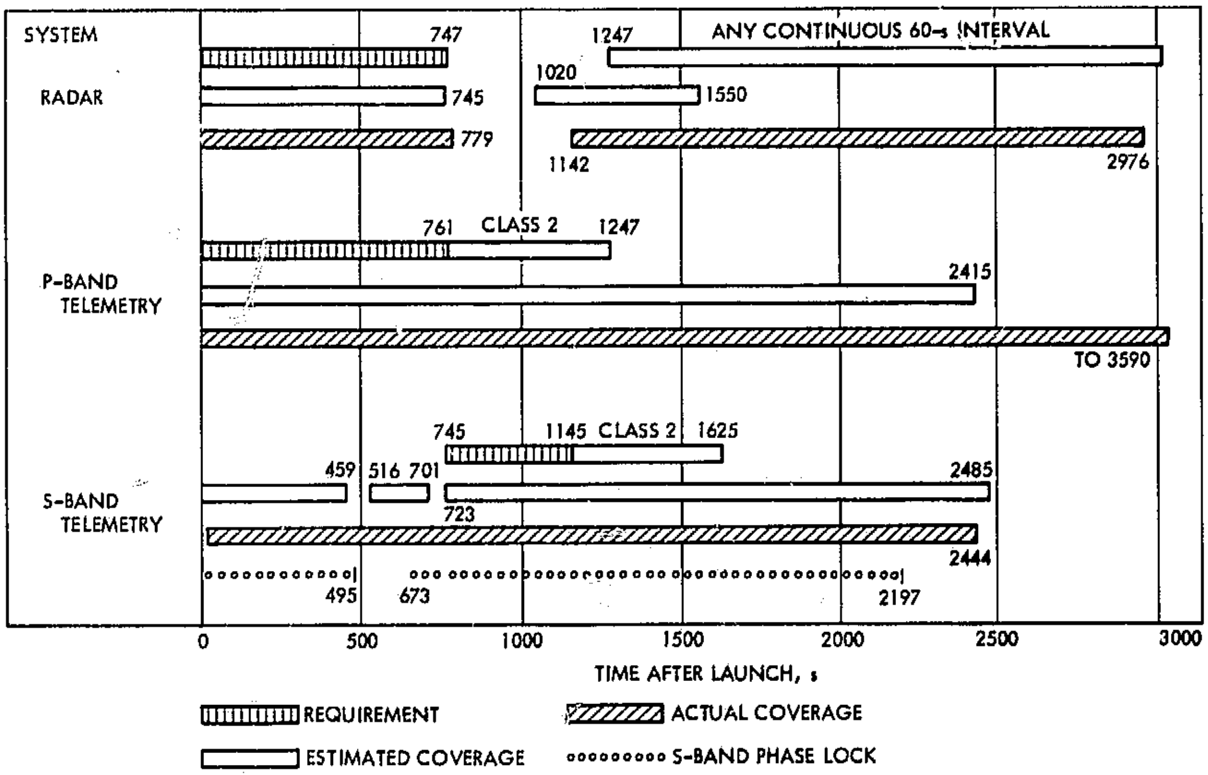


Fig. 148. Summary of AFETR coverage

The FPS-16 radar at Cape Kennedy experienced an unexplained 13-s dropout at $L + 464$ s; however, this occurred 114 s after the end of their estimated coverage interval. Following the dropout, they provided another 73 s of data.

The Grand Turk TPQ-18 radar also experienced a short dropout toward the end of their coverage interval. The radar was off track from $L + 579$ to $L + 600$ s, then provided data until LOS, at $L + 675$ s. This dropout was attributed to the balance-point shift problem. Redundant data from other stations were provided during both of the dropout periods.

The actual coverage provided by Ascension Island did not meet the estimated interval; however, long periods of intermittent track were provided by both Ascension Island radars following initial loss of lock.

The Pretoria data were noisy throughout, because of the low signal level, but were not intermittent.

b. Metric. Project metric requirements were any continuous 60 s of radar track between MECO and start of Retro. The launch vehicle requirement was continuous coverage from launch to MECO + 30 s, and any continuous 60 s after Retro.

Project computation requirements were: (1) computation of the pre-retro orbit; (2) generation of predicts for the DSN from this orbit; and (3) mapping to encounter for this orbit.

The launch vehicle computation requirements were computation of the *Centaur* pre- and post-retro orbits. Table 73 gives the orbital computations performed, and lists the parameters from one of the RTCS multi-station solutions (DSS 72 and DSS 51 inputs) and one of the final pre-midcourse computations at the SFOF.

Table 73. Orbital computations

Parameters	SFOF—$L + 35$ h track	RTCS—72/51 2 h track
Epoch, GMT	7/14/67 12:05:06.4805	7/14/67 12:04:53.8
SMAA, km	285977.43	285843.4
ECC	0.97711195	0.9771036
INC, deg	30.560181	30.58551
C_3, km^2/s^2	−1.3938207	−1.39
LAN	275.80161	275.7766
APF	142.75164	142.75046
Epoch, GMT	7/16/67 02:11:42.121	7/16/67 02:11:06.4
B[a], km	1784.1903	1781.0436
B • TQ[b], km	1554.0911	1616.0602
B • RQ[c], km	−876.43370	−748.64269
Latitude	−2.0061469	−4.7807944
Longitude	354.07456	354.48327

[a]B, magnitude of the impact parameter.
[b]B • TQ, projection of the impact parameter B upon the vector T.
[c]B • RQ, projection of the impact parameter B upon the vector R.

All metric requirements were met.

The RTCS made the following computations from AFETR radar, *Centaur* guidance telemetry, and DSN data:

(1) An initial pre-retro orbit was computed using Antigua (91.18) data. The solution was considered only fair by the RTCS, because of the low elevation angle of the data used. An IRV, SOPM, orbital elements and moon mapping were provided from these data. The FPAC stated that the RTCS orbital elements were close to nominal. The DSN site predicts were provided by the RTCS to DSSs 72, 61 and 51.

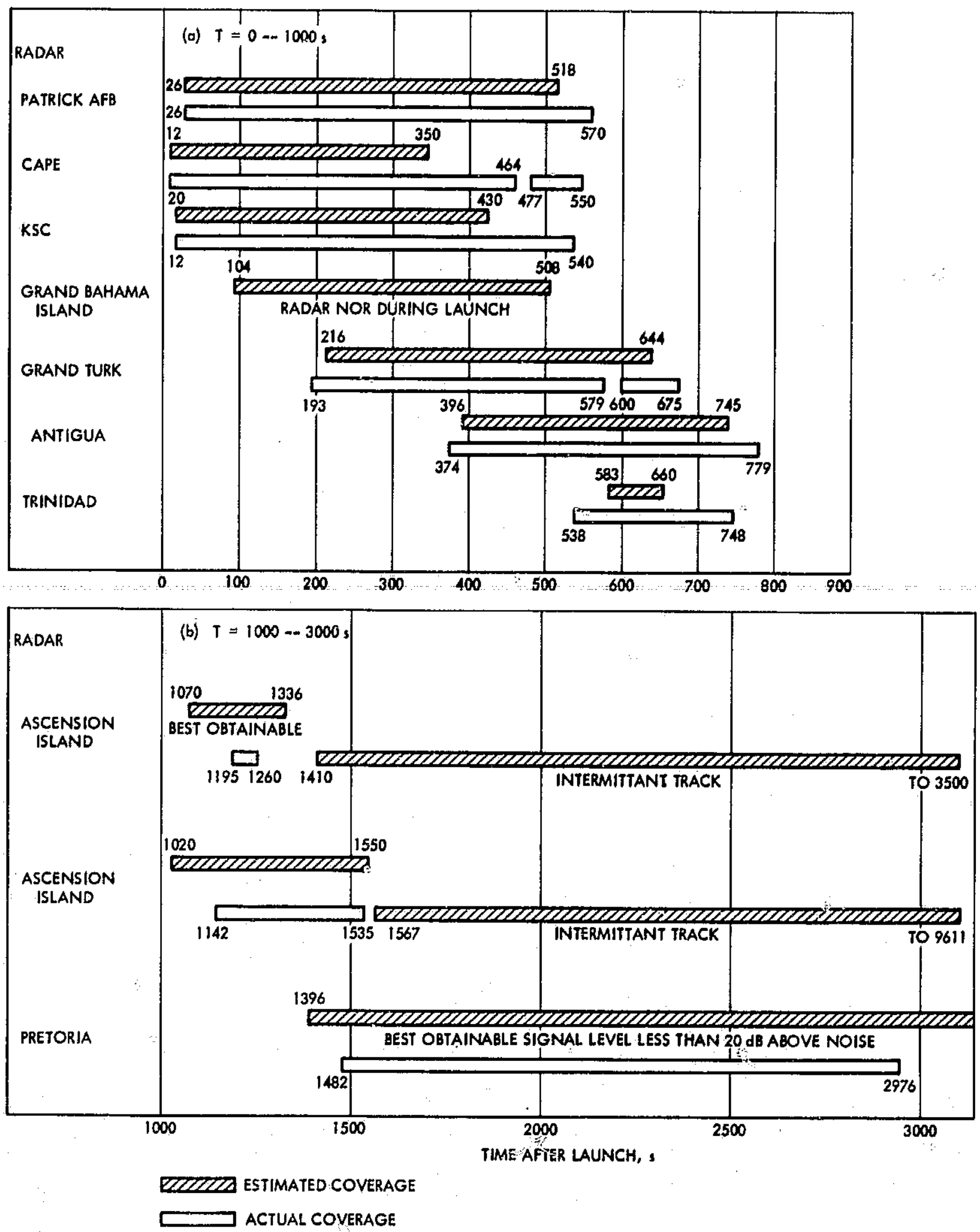


Fig. 149. AFETR C-band radar coverage

(2) A post-retro orbit was computed using Ascension Island (12.18) and Pretoria (13.16) data. The RTCS used these data to compute an IRV, SOPM, orbital elements, moon mapping and an I-matrix. The fit on these data was considered good by the RTCS, and FPAC indicated that the elements looked nominal.

(3) The DSS 72 data received by the RTCS had intermittent lock until 12:50. The RTCS computed a preliminary DSN solution of the spacecraft orbit, using 10 min of DSS 72 data. The computer solution was considered a poor fit. An IRV, SOPM and orbital elements were computed from these data. Moon mapping was not done because of the poor fit.

(4) A second DSN solution of the spacecraft orbit was computed from DSS 72 data. This solution was considered good by the RTCS and an IRV, SOPM; orbital elements and moon mapping were provided. The FPAC stated that the moon mapping parameters provided from this solution were quite close to nominal values. The FPAC could not give the RTCS a comparison on RTCS elements, because the FPAC did not have a DSN solution at that time.

(5) The first *Centaur* guidance telemetry (UVW) vector was not received from the Kennedy Space Center until approximately $T + 67$ min. After evaluation by the RTCS, this vector was determined to be unusable. A second guidance telemetry vector was received by the RTCS about $T + 112$. This vector appeared to be valid and an IRV, SOPM, JPL elements and moon mapping were provided.

(6) The last spacecraft orbit was computed from DSS 72 and DSS 51 data. An IRV, SOPM, orbital elements, moon mapping and an I-matrix were provided from these data. This solution was considered to be very good. In this solution, the DSS 72 mean residuals for range rate were 0.0003 ft/s and the DSS 51 mean residuals for range rate were 0.0007 ft/s.

Table 74. Metric raw data coverage

Station	Estimated coverage, s	Actual coverage, s
1.16	12–152[a]/200–350	0–550
19.18	20–82[b]/96–200[b]/260–440	12–540
0.18	26–525	26–570
3.16	96–161[a]	Not committed
3.18	104–510 (clutter)	NOR for A3 servo valve
7.18	216–646	193–579/600-675
Trinidad	586–652	538–748
67.16	275–530 (clutter)	Passive
67.18	275–645	241–247/271–673
91.18	394–742	374–779
12.18	1005–1550	1142–1535/1567–8611
12.16	1075–1330 best obtainable	1195–1260/1410–3500
13.16	1400 best obtainable, signal less than 20 dB	1483–3625

[a]Expected loss of track as a result of cross-polarization or antenna patterns.
[b]Expected rough track as a result of antenna pattern.

Table 74 indicates the metric tracking data estimates and the actual coverage that was provided.

c. S-band. The S-band requirements were from spacecraft high-power on to DSN continuous view plus 2 min.

Real-time transmission. This requirement was met.

The RIS was selected as the data source at $T + 11{:}40$, when the JPL Telemetry Coordinator observed ship S-band AOS. Ascension Island data were selected at approximately $T + 36$, when Ascension Island reported that modulation had disappeared from the S-band carrier.

First DSN acquisition occurred at DSS 72 with one-way acquisition at 12:10:18. The received signal level was reported as -90 dBmW on Receiver 1 and -102 dBmW on Receiver 2. The transmitter was turned on at 12:12:30. After twice dropping receiver lock when modulating the command transmitter, two-way lock was achieved at 12:50:12. DSS 51 acquired one-way lock at 12:16:55 and transfer from DSS 72 to DSS 51 occurred at 13:10.

Receive and record. This requirement was met.

Table 75 presents a tabulation of the coverage plan vs actual coverage for S-band telemetry.

Table 75. AFETR S-band telemetry

Radar site	Estimated coverage, s	Actual coverage, s			
		AOS	Lock	Unlock	LOS
Tel-4	0–405	−2100	—	—	+362
Station 3	116–458	48	60	495	521
Station 91	520–697	339	Locked 30% of view		720
Coastal Crusader	1027–2480	657	673	1214	1214
Station 12	722–1120	975	975	2197	2444

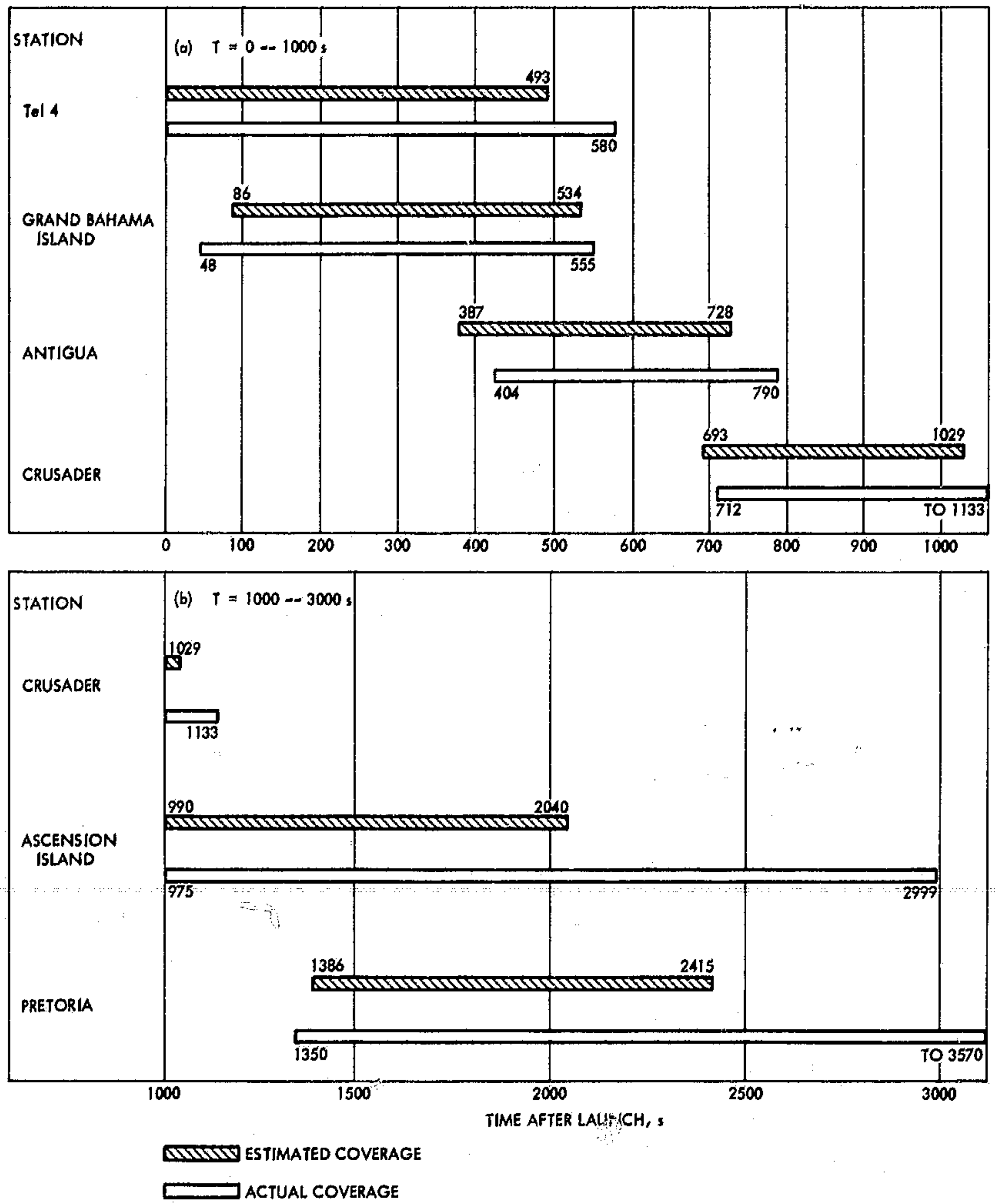


Fig. 150. AFETR VHF telemetry coverage

d. VHF telemetry. VHF telemetry requirements and coverage are shown in Fig. 150.

All requirements were met, since continuous and substantially redundant VHF telemetry data were received beginning with the countdown and through Pretoria LOS, at $L + 3570$ s. Coverage was greater than predicted. *Mark* event times that were received and read out are shown in Table 76.

There was a project requirement for spacecraft VHF coverage via the *Centaur* link, from launch to separation. There was also a launch vehicle requirement for *Centaur* VHF telemetry from launch to spacecraft separation plus 5 s.

All requirements were met.

Real-time transmission. At $T - 10$, Tel-2 P-band data were selected. The data were excellent. The selection

Table 76. Atlas/Centaur mark event readouts

Event	Time, GMT	Readout from
Liftoff	11:53:29.215	Cape
Mark 1	11:55:51.100	Cape
Mark 2	11:55:54.600	Cape
Mark 3	11:56:25.400	Cape
Mark 4	11:56:52.600	Cape
Mark 5	11:57:28.900 11:57:27.2	Cape Bermuda
Mark 6	11:57:31.950 11:57:30.8	Cape Bermuda
Mark 7	11:57:41.000 11:57:41.1	Cape Bermuda
Mark 8	12:04:57.100 12:04:57.2	Cape Antigua
Mark 9	12:05:25.000 12:05:24.6 12:05:24.5	Cape Antigua Crusader
Mark 10	12:05:34.600 12:05:34.5	Antigua Crusader
Mark 11	12:06:00.100 12:05:55.2	Antigua Crusader
Mark 12	12:06:00.100 12:06:00.5	Antigua Crusader
Mark 13	12:06:06.100	Crusader
Mark 14	Not reported	
Mark 15	12:10:06.100 12:10:00.6	Crusader Ascension
Mark 16	12:14:00.800 12:14:16.8	Ascension Canary
Mark 17	12:14:00.800 12:14:16.8	Ascension Canary

Table 77. AFETR VHF telemetry

Radar site	Estimated coverage, s	Actual coverage, s	
		AOS	LOS
Tel-2	0–500	−2100	551
Tel-4	0–500	−2100	580
Station 3	86–540	15	591
BDA	230–650	214	666
Station 91	385–725	304	790
Coastal Crusader	692–1030	713	1134
Station 12	1000–2035	975	2999
Station 13	1380–2450	1351	3571
CYI	960–1940	981	1897

remained with Tel-2 until approximately $T + 6{:}30$, when Antigua P-band data were selected. This procedure bypassed GBI data, even though GBI data were excellent, since there was a considerable overlap between Tel-2 LOS and Antigua AOS.

Receive and record. Table 77 presents a tabulation of the coverage plan versus actual coverage for VHF telemetry.

At $T - 10$, Tel-2 P-band data were selected. The data were excellent. The selection remained with Tel-2 until approximately $T + 6{:}30$, when Antigua P-band data were selected. This procedure bypassed GBI data, even though GBI data were excellent, since there was a considerable overlap between Tel-2 LOS and Antigua AOS.

All real-time VHF retransmission requirements were met. Good quality data were received at the SFOF, although not as good as on previous missions.

e. S-band telemetry. The S-band telemetry requirements and coverage are shown in Fig. 151. As indicated in the figure, continuous coverage was obtained from liftoff to Ascension LOS at $L + 2444$ s.

Tel-4 dropped receiver lock between $L + 197$ and $L + 270$ s; however, GBI maintained lock throughout this period and provided redundant coverage.

The Antigua coverage interval was quite a bit in excess of the estimated coverage, but phase lock was maintained for only 30% of their actual coverage interval, with 6 RH (right hand) periods of lock and 7 LH (left hand) periods. Coverage from GBI and the *Coastal Crusader* overlapped most of the Antigua view; however, during the interval from $L + 495$ to $L + 673$ s, no station other than Antigua was in receiver lock. The *Coastal Crusader* position had been adjusted approximately 30 s to provide better coverage of the spacecraft high-power up interval.

Receiver lock was maintained continuously, by the *Coastal Crusader* and then Ascension Island from $L + 673$ to $L + 2197$ s. Pretoria provided redundant coverage during this interval, with receiver lock from $L + 1377$ to $L + 1698$ s. No estimated coverage interval was given for Pretoria because of the small antenna and the expected signal level.

The AFETR method of predicting coverage intervals for S-band low-power is still not accurate and needs further refinement.

The RIS was selected as the data source at $T + 11{:}40$, when the JPL Telemetry Coordinator observed ship S-band AOS. Ascension Island data were selected at approximately $T + 16$ min. Continuous data were received until approximately $T + 36$, when Ascension Island

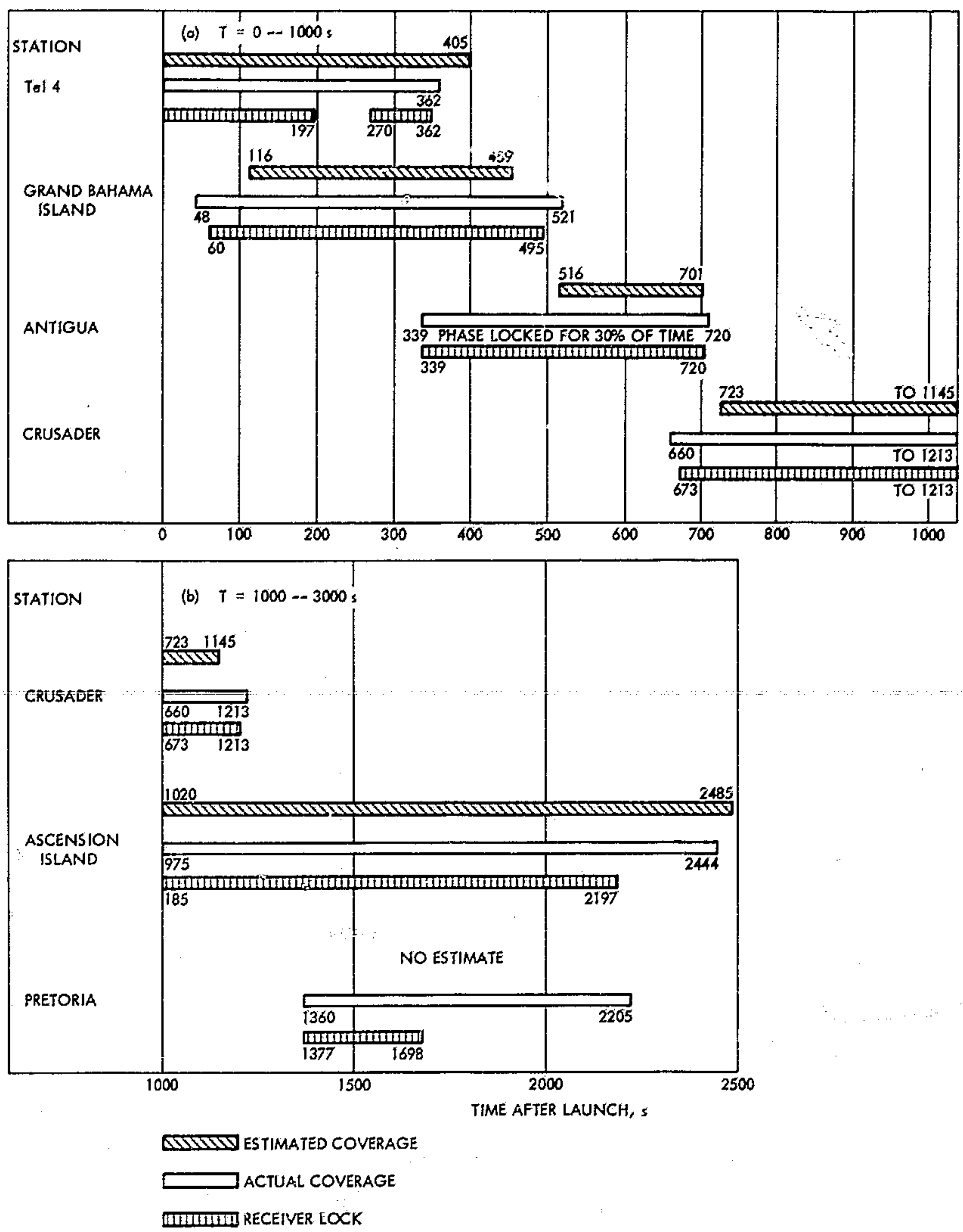


Fig. 151. AFETR S-band telemetry coverage

reported that modulation had disappeared from the S-band carrier.

All real-time S-band retransmission requirements were met.

The RTCS computations performed and the nominal and actual times of delivery are shown in Table 78.

Table 78. AFETR real-time computer support

Nominal, T	Actual, T	Operation
+ 20	+ 17	Transmit pre-retro IRV, SOPM and orbital elements
+ 25	+ 20	Transmit pre-retro DSN predicts for DSSs 72, 61 and 51
+ 25	+ 62	Receive DSN data from Building AO
+ 25	+ 62	Receive guidance data (UVW) from KSC
+ 35	+ 33	Transmit pre-retro moon map
+ 38	+ 35	Transmit post-retro IRV, SOPM & orbital elements
+ 45	+ 42	Transmit post retro moon map
+ 48	+ 121	Transmit IRV, SOPM and orbital elements based on UVW data
+ 53	+ 62	Start processing DSN data
+ 55	+ 46	Transmit post-retro I-matrix
+ 80		Transmit IRV, SOPM and orbital elements based on DSN data
	+ 74	Preliminary solution
	+ 101	Updated solution
	+ 142	Final solution
+ 85		Transmit moon map based on DSN data
	+ 104	Based on updated solution at $T + 101$
	+ 151	Based on final solution at $T + 142$
+ 95		Transmit I-matrix based on DSN data
	+ 109	Based on updated solution at $T + 101$
	+ 162	Based on final solution at $T + 142$
	+ 147	Transmit moon map based on UVW data
Deleted at $T + 59$		Pre-retro recursive IRV, SOPM, orbital elements, moon map and I-matrix

2. *GSFC.*

a. Tracking. The Bermuda FPQ-6 radar achieved 402 s of valid auto-track data; however, 2 s of FPQ-6 data were lost at 12:01:08 GMT, due to phasing separation. The FPS-16 radar tracked passively, with no data taken.

The range safety impact prediction plot became erratic at approximately $L + 8$ min. Investigation revealed a possible problem in the 4101 computer program. This problem may have resulted in improper smoothing of the elevation data, thereby causing the rough impact prediction plot.

The predicted versus actual coverage is shown in Fig. 152.

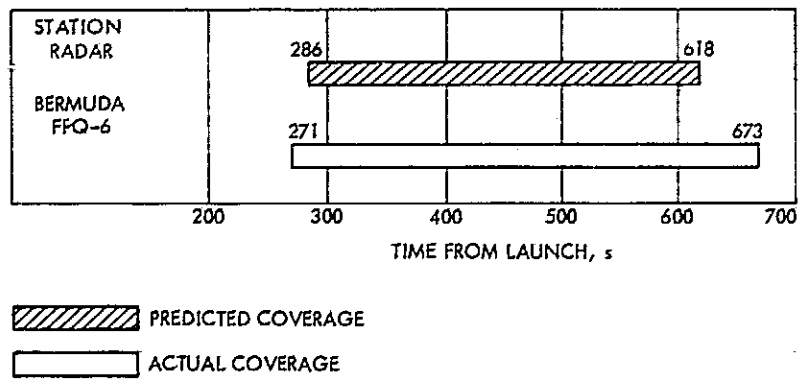


Fig. 152. MSFN radar coverage

b. VHF telemetry. All requirements for MSFN telemetry support, except from Bermuda and Grand Canary were deleted prior to launch day. Grand Canary was not required to support on launch days 1 or 2; however, they were called-up on launch day to support on a best-obtainable basis.

The telemetry systems at Bermuda and Grand Canary performed all required functions. Bermuda received and recorded range safety parameters and *mark* events 5, 6 and 7. Grand Canary reported *mark* events 16 and 17, attitude rates and propellant ullages.

No problems were encountered; however, Grand Canary reported a maximum signal strength of -103 dBmW, which was just above threshold. Numerous dropouts occurred during the last 2 min of track; however, the decommutator maintained lock long enough to confirm *mark* event 16. The predicted versus actual coverage is shown in Fig. 153.

c. Computer support. The GSFC DOB provided all required support. Because Grand Canary was not scheduled for support on July 13 or 14 and was called up for support on a *best-obtainable* basis on launch day, the DOB generated and transmitted nominal pointing data to Grand Canary during the minus count on launch day.

B. Deep Space Network Phase

From the time of two-way acquisition by DSS 72 until the loss-of-signal during the retro-maneuver, the DSN

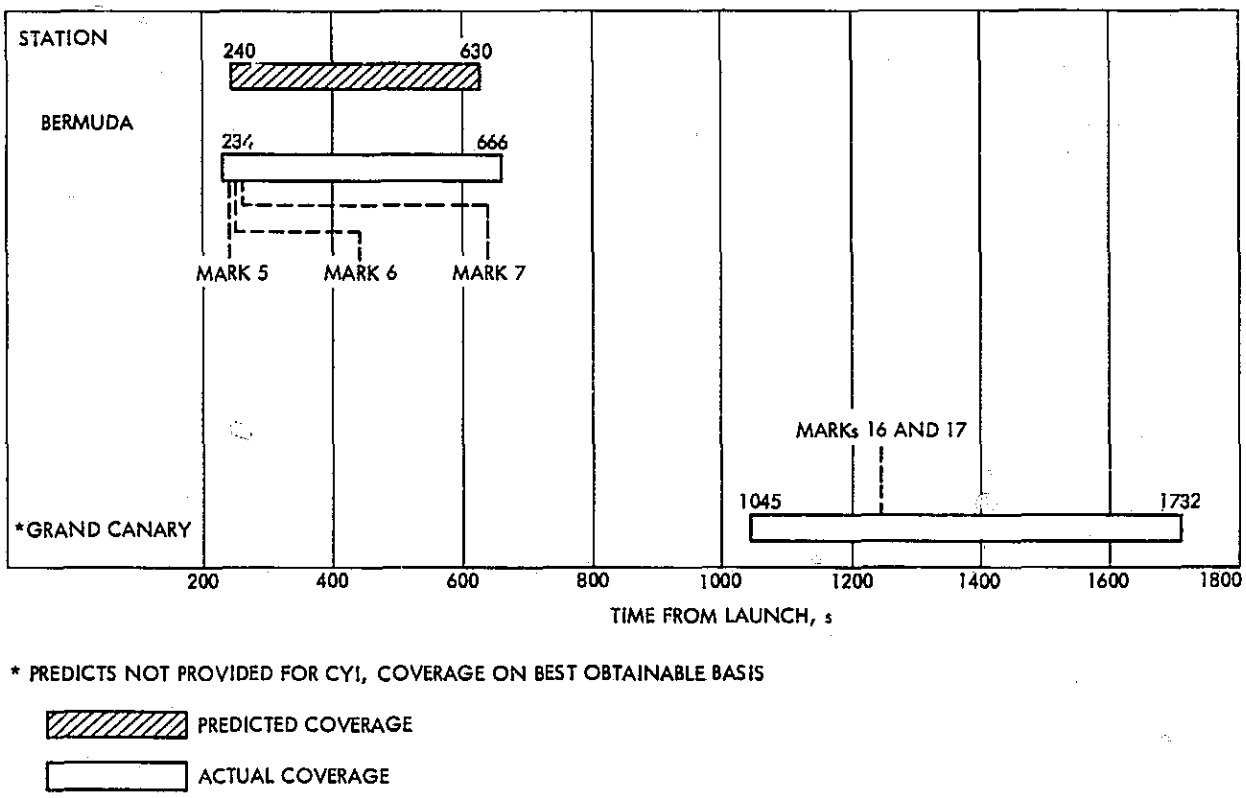


Fig. 153. MSFN VHF telemetry coverage (225.7 MHz)

tracked the *Surveyor* spacecraft in the two-way mode with only minor exceptions, and in general returned high quality two-way doppler data. The most serious loss of two-way doppler data occurred at DSS 61 during their first pass when approximately one and a half hours worth of data was lost because of a dropped eight bit in the least significant digit of the doppler counter. Transfer of the spacecraft was made to DSS 51 and DSS 61 repaired the counter. Minor losses of data occurred during the initial acquisition at DSS 72 when a loss of the up-link was responsible for a 10-min loss of prime early data, and during the second pass at DSS 11, when an intermittent loss of the most significant digit of the doppler counter accounted for a 30-min loss of data. Finally, the initial acquisition (first pass) at DSS 11 took approximately 20 min, this unnecessarily long time being due in large part to the failure of DSS 11 to use the standard acquisition procedure. Figure 154 shows the *Surveyor IV* DSN earth track.

Early analysis of the *Surveyor IV* trajectory indicated a midcourse maneuver during the second pass over DSS 11 would be most advantageous. Therefore, the midcourse maneuver was executed during that pass. Engine ignition was programmed for July 16 02:30 GMT, with a total burn time of 10.46 s.

In an attempt to more accurately align the spacecraft Z-axis with the desired midcourse thrust direction, the attitude rotations were initiated at limit-cycle nulls. It was hoped that approximately 20% improvement in landing site accuracy could be achieved with this method of minimizing pointing errors. Actual telemetry results indicated that attitude rotations were begun within 0.1-deg null on each axis.

Final in-flight calculations by the Orbit Determination Group indicated retroignition on July 17 02:01:57 GMT. Loss-of-signal occurred shortly before retro engine shutoff at 02:02:41 GMT.

1. DSIF. The following DSIF stations performed tracking and data acquisition functions in support of the *Surveyor IV* mission:

(1) Prime:
- (a) DSS 11
- (b) DSS 42
- (c) DSS 51—Tracking support only during cislunar phase
- (d) DSS 61
- (e) DSS 71—Pre-launch support and track to loss of signal
- (f) DSS 72—Tracking from acquisition to DSS 11 first pass plus 1 h

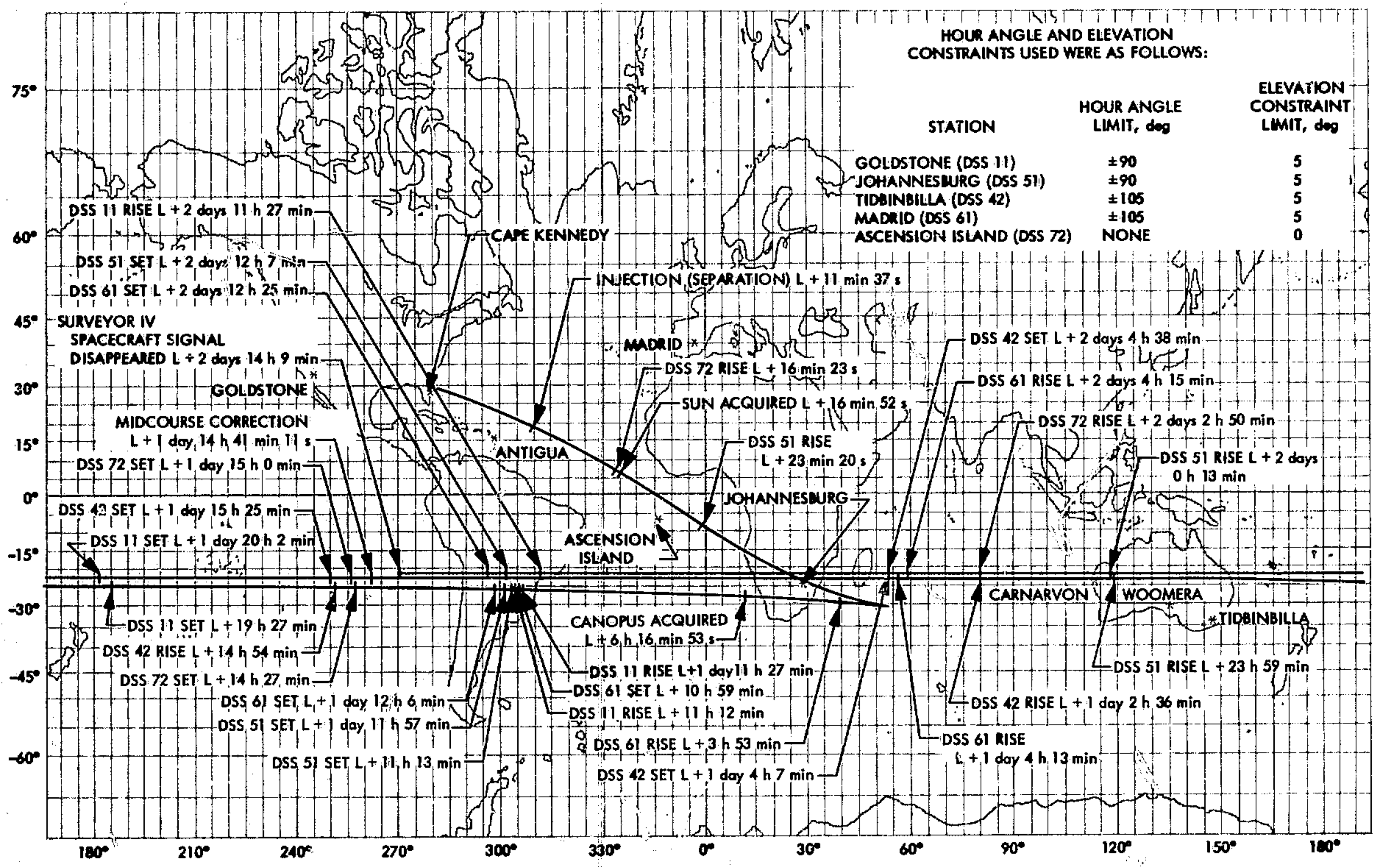


Fig. 154. *Surveyor IV* earth-track DSN phase

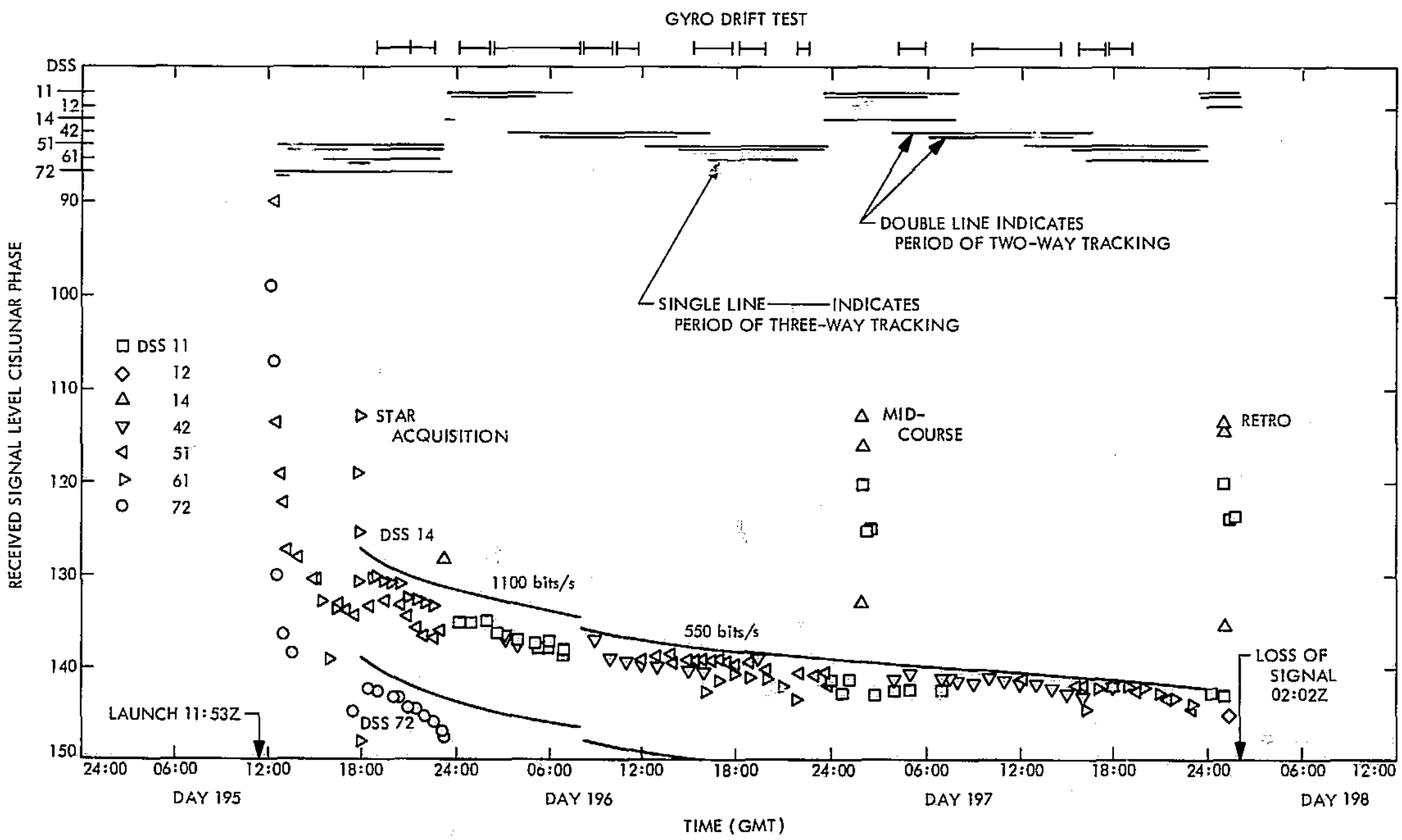


Fig. 155. DSIF received-signal levels and tracking periods

(2) Recording and transmitter backup station (DSS 14):
   (a) Provided recording backup during midcourse and retro phases
   (b) Provided transmitter backup to DSS 11 during midcourse and retro phases

The DSIF received-signal levels are shown in the attached Fig. 155 and compare favorably with predicted values. The positive and negative tolerances are shown with solid lines. The predicted signal level range is adjusted for the various telemetry SCO modulation indexes for each data bit rate. No level predictions are made before star acquisition because prior to this time the spacecraft is not roll stabilized and the spacecraft antenna gain can vary significantly. This can produce variations in the station received signal of 20 dB. This, together with the varying spacecraft look angle, makes signal level prediction of limited usefulness in evaluating station performance.

The periods of high power during star acquisition, midcourse, and terminal descent indicate a nominal 20-dB increase over the low power signal level. This is the expected performance for the spacecraft.

The telemetry bit rate was reduced from 1100 to 550 bits/s at $L + 25$ h.

The telemetry bit rate change occurred within ± 2 dB of the predicted telemetry thresholds (not shown).

Gyro drift tests were conducted as indicated on top of the plot. The random drift and subsequent spacecraft antenna pattern variations produced a spread in the received signal levels of approximately ± 3 dB. These variations can be observed in the plot.

Ascension Island DSS 72 signal level is very close to 10 dB below DSS 51. These two stations were quite consistent; however, they differed from DSS 61 significantly. The 10 dB between DSS 51 and DSS 72 is expected because of the difference in the diameter of their two antennas, i.e., 85 vs 30 ft.

Throughout the cislunar phase of the mission 1- to 3-dB difference in received signal levels are observed between stations. These signal level differences are within the spacecraft antenna gain variations due to the small difference in look angle between widely separated stations.

The stations view periods are shown on the bottom of the plot in Fig. 155. The single line indicates the period of three-way tracking and the double line indicates the periods of two-way tracking.

The DSIF support for the *Surveyor IV* mission differed from that for previous missions primarily in individual station commitments resulting from trajectory considerations. Specific information on the configuration, operational procedures, and preflight predictions for each station may be obtained from the DSIF Tracking Instruction Manual.

DSIF stations provided all support needed for the *Surveyor IV* mission. There were some minor anomalies, but they caused no significant loss of data to the project. Prime station support was given by DSSs 11, 42, 51, 61, and 72. DSS 71 provided pre- and post-launch telemetry data processing, while DSS 14 was configured for command backup and telemetry reception during Goldstone visibility periods.

After the loss of spacecraft signal, the DSIF provided all requested support for spacecraft turn-on attempts—using DSSs 11, 14, and 42.

a. DSS 11—Goldstone (Pioneer), California. The Pioneer site of Goldstone tracking station was used to track *Surveyor IV*. Backup tracking was provided by the Mars site with its 210-ft diam antenna. Provision had been made to switch the CDC at the Pioneer site from the Pioneer antenna to the Mars antenna for commanding the spacecraft, receiving telemetry, or both.

Midcourse maneuver and terminal descent were the two major events of the *Surveyor* mission commanded from Goldstone. The midcourse maneuver was delayed from the first Goldstone view period to the second view period to improve the accuracy of the final trajectory. This was possible because of the near-perfect initial trajectory of the spacecraft performed perfectly. In the midcourse maneuver, both ground equipment and spacecraft performed perfectly.

Since the FR-800 video recorder at DSS 11 was not fully operational, DSS 12 provided backup coverage at touchdown using the FR-900 recorder and one receiver. This meant that, at the time the *Surveyor IV* signal was lost (approximately 02:02:40 GMT, July 17), there were five receivers—utilizing three different antennas—monitoring the spacecraft at the Goldstone complex. This provided immediate and positive indication that the loss of signal was not due to a ground system failure.

Problems and anomalies were:

(1) For the first acquisition, DSS 11 used an improper acquisition procedure which caused a delay of approximately 20 min in obtaining two-way lock.

(2) There were several hardware problems, which did not affect the mission.

(3) Doppler data was intermittent during Pass 2 and 10 min of Pass 3 because the TDH doppler counter was intermittently dropping the most significant digit.

(4) The video verification test for the TVGDHS was not completed during two countdowns.

(5) Changes in established calibrations and recording procedures were requested by the TVGDHS.

(6) Split authority and responsibility, and a nonstandard method of providing communications support were problems, although not as severe as in the past, due to a verbal agreement that was reached during the *Surveyor IV* mission.

b. DSS 14—Goldstone (Mars), California. DSS 14 provided midcourse and terminal-phase support, using the 210-ft antenna. Project-furnished equipment was installed on a best-efforts basis to permit pre-detection recording at DSS 14. Also, at touchdown, the baseband telemetry output of the DSS 14 prime receiver was transmitted to SFOF.

c. DSS 42—Canberra, Australia. During the *Surveyor IV* mission, DSS 42 had two tracking periods prior to the loss of the spacecraft RF carrier during terminal descent. It was in two-way lock for 9 h and 5 min during the first pass and 9 h during the second pass. A total of 39 commands was transmitted to the spacecraft during the transit phase.

Canberra DSS 42 had no significant problems with either the spacecraft or ground equipment during its two tracking intervals.

After terminal descent, DSS 42 performed spacecraft revival attempts during passes 3 and 4 without success.

d. DSS 51—Johannesburg, South Africa. Johannesburg DSS 51, was more active in the *Surveyor IV* mission than anticipated, due to problems at DSS 61 and the trajectory which favored DSS 51 view. The latter station tracked *Surveyor IV* for three passes from $L + 24$ min, to approximately Retro $- 2$ h.

During the launch phase, the command line from DSS 72 was patched on a spare SCAMA line to DSS 51 (listen only) in addition to the normal SFOF and Voice of *Surveyor* lines. This allowed keeping up with events in real time in acquiring the spacecraft less than 10 min after DSS 72.

Voice communications to and from DSS 51 were fairly good for the first two passes, but quite bad for part of pass 3. The TTY conference mode worked very well during pass 3, and considerable commanding of the spacecraft was accomplished in this mode.

Other problems and anomalies:

(1) Due to a non-standard station configuration, the IMP interfered with the SOCP program and had to be discontinued. This had no effect on the mission.

(2) An insulation breakdown and consequent short in the primary switch caused a delayed acquisition of the spacecraft for about 3 min during Pass 2.

(3) The Tracking Instruction Manual (TIM) procedure for loss of communications was not followed.

e. DSS 61—Madrid, Spain. Prior to the mission, local studies were made to determine what might be done with the backup computer during its long periods of inactivity. It was decided that automatic conversion of raw telemetry counts to engineering units would be of most value. For this purpose, a special program was written to utilize average alarm data routed from the prime computers and to output engineering unit conversions on TTY. This program was successfully utilized during the *Surveyor IV* mission and, during the third pass, resultant data—rather than average alarm—was routed to SPAC for review and comment.

The Madrid DSS 61 tracked *Surveyor IV* during the three transit-phase view periods, and was in two-way lock with the spacecraft for slightly less than 2 h. Twenty-four commands were transmitted, to which the spacecraft responded accurately. These commands were executed during the first pass and involved an engineering interrogation, star map, and star acquisition.

For the greater portion of the transit phase, DSS 61 was in three-way lock in conjunction with DSS 51, due to the relatively-low antenna elevation angles from DSS 61 and certain antenna-servo problems.

Problems and anomalies were:

(1) The TDH doppler readout was improper during Pass 1, because 8 or 9 in the least-significant digit was not printing due to a bad connector pin. Accordingly, there was no doppler data from 17:17 to 20:26 GMT.

(2) An operator error resulted in an improper doppler resolver count during Pass 1, and no doppler resolver data was obtained from 17:17 to 20:26 GMT.

(3) The spacecraft was lost for a short time during Pass 2 due to a leak in an antenna hydraulic system.

f. DSS 71—Cape Kennedy, Florida. Cape Kennedy (DSS 71) support for the *Surveyor IV* mission involved one operational readiness test, two spacecraft countdowns, and the launch. The operational readiness test consisted of processing Tel-2 data from building AO through the DECOMM/SOCP back to the SFOF via TTY and HSDL. The spacecraft countdown and launch were supported in the same manner. However, the DSS 71 RF receiver equipment was in lock with the spacecraft and available at all times if it had been needed.

The AFETR Tel-2 data consisted of downrange data (including *Centaur* link data received at AFETR tracking stations), and data from DSS 72 at Ascension. During all three situations mentioned above, the data were usable. But there were numerous parity errors at times and occasional decommutator out-of-lock conditions. During launch, the Tel-2 data was continued until approximately $L + 38$ min.

g. DSS 72—Ascension Island. As initial acquisition station for the *Surveyor IV* mission, DSS 72 acquired the spacecraft at 12:10:13 GMT with a decommutator lock at 12:10:41 GMT. Two-way lock by the station was at 12:21:46 GMT. Command modulation was turned on at 12:26:41 GMT.

The first command sequence was started at 12:29:46 GMT and terminated at 12:51:47 GMT. Transfer to DSS 51 was accomplished at 13:10 GMT and DSS 72 continued to track the spacecraft in three-way lock until DSS 11 rise plus 1 h in accordance with the station commitment.

Problems and anomalies were:

(1) An antenna hardware problem resulted in loss of the spacecraft during initial acquisition, and *Surveyor IV* had to be reacquired.

(2) At the time of launch there was a CEC oscillograph recorder malfunction, which resulted in none of these recordings during the first DSS 72 acquisition.

h. Conclusion. Tracking data retrieval for the *Surveyor IV* mission was approximately 5% better than the *Surveyor III* mission, with 94.1% of the total tracking data samples usable. Communication garbling caused losses of approximately 2.5% of the total data, and the remaining data losses were due to bad data condition codes (DCCs) generated during the course of normal operational procedures.

The DSN performed all the functions required by the *Surveyor IV* Project with no major problems or equipment malfunctions. All data requested by the *Surveyor IV* personnel was provided.

Table 79 gives a complete report of the total tracking data for the *Surveyor IV* mission. Table 80 provides a total tracking data summary.

2. *Ground communications facility*

a. Introduction. The DSN/GCF is that portion of NASCOM that provides communication between the various DSN tracking stations through the world and the SFOF in Pasadena, California. This communications system comprises the land lines, undersea cables, and high-frequency radio circuits that carried TTY, voice, and HSD in real time support of the *Surveyor IV* mission. The performance of the NASA Communications Network used to support the *Surveyor IV* mission was considered excellent, again demonstrating its high degree of reliability. Goddard circuit restoration support was considered excellent. The DSN/GCF configuration for support of the *Surveyor IV* mission is given in Fig. 114.

b. High-speed data lines. This portion of the Communications System performed exceptionally well during both the testing and mission phases. Both data-set types (NASCOM and Hallicrafter) were used.

The transmit side of the lines was used during testing to transmit data to the stations and during the mission to backfeed various voice nets as required.

DSS 72 data circuit was via satellite during the ORT and the mission and performed flawlessly.

c. Teletype circuits. The teletype circuit operation was highly reliable. There were outages due to propagation on the DSS 51 circuits and the DSS 72 circuits which were by high-frequency radio path. During the mission, the A and B circuits were via satellite and suffered no outage.

A TTY circuit via satellite to Ascension, then radio path through Pretoria to DSS 51, was activated during the ORT but did not prove satisfactory due to propagation problems from Ascension Island to Pretoria.

d. Voice circuits. The NASCOM voice circuits provided for the *Surveyor IV* mission tests performed well within expectations. The *Surveyor* Command Net was patched at all times to the active DSS Voice Net. The Voice of *Surveyor* was patched via GSFC to all scheduled activities plus some which came up in real-time. There were no particular problems noted except some routine voice circuit outages.

The DSS 72 voice circuits were routed by satellite during the ORT test, and the mission performed exceptionally well.

A voice circuit via satellite to Ascension Island, then radio path through Pretoria to DSS 51 was activated as a backup voice during the mission launch phase. This circuit was used when the normal voice circuit failed.

e. Special NASCOM support. Special circuit coverage was activated during the Launch, Midcourse and Touchdown phases. During Midcourse and Touchdown, all JPL/Goldstone microwave relay points and terminals were manned by Western Union. No circuit failures occurred on microwave.

NASCOM provided nine additional teletype and five additional voice circuits between the SFOF and Goddard to support the mission and tests. There were not enough permanent circuits to support multi-mission requirements.

f. Deep Space Network Intra-Communications System (DSN/ICS)

Introduction. The DSN/ICS provides the capability of receiving, switching and distribution to designated areas of users within the SFOF, all types of information required for Space Flight Operations. The system includes all voice communication capabilities within the SFOF, TVCS, TTY, HSD, and data received over the microwave channels. This system DSN/ICS performed in an exceptional manner with only minor problems noted.

Table 79. Total tracking data, *Surveyor IV* mission

Day	Station	Pass	Data received		At	Rate	Total received	Good DCC	Sampling		Total samples				Remarks
			From	Thru					From	Thru	Good DCC	Bad DCC	Garbled	Usable	
195	73	1	115630	115924	2 min 54 s	6 s	30	2	115642	115924	28	2	0	28	AFETR, Grand Turk
195	73	1	121906	121954	48 s	6 s	9	2	121936	121954	4	5	0	4	
195	74	1	115948	120348	4 min	6 s	41	2	115948	120348	41	0	0	41	AFETR, Antigua
			120400	120618	2 min 18 s	6 s	24	2	120400	120618	24	0	0	24	
195	85	1	121245	120533	2 min 48 s	6 s	29	2	120245	120533	29	0	0	29	AFETR, Trinidad
195	79	1	121230	133706	11124 min 36 s	6 s	846	2	121230	133700	845	1	7	838	AFETR, Ascension Island
195	76	1	121812	124348	25 min 36 s	6 s	257	2	121812	124348	257	0	3	254	AFETR, Pretoria
195	72	1	121103	124503	34 min	10 s	205	8040	121623	124504	145	60	4	141	DSS
			124602	143902	11153 min	1 min	114	8040	124602	131502	23	8	4	20	
								8060	131602	143802	78	5	2	76	
						Sum	319				246	73	10	237	80.4%
195	51	1	121831	124451	26 min 20 s	10 s	159	8060	121831	124451	141	18	1	140	
			124602	230902	101122 min	1 min	623	8060	124602	130402	18	1	0	18	
								8040	131402	170002	227	9	1	227	
								8060	170202	182602	85	3	2	83	
								8040	183302	230502	270	8	30	240	
								8050	230702	230802	2	0	1	1	
						Sum	782				743	39	35	709	91.21%

Table 79 (contd)

Day	Station	Pass	Data received		At	Rate	Total received	Good DCC	Sampling		Total samples				Remarks
			From	Thru					From	Thru	Good DCC	Bad DCC	Garbled	Usable	
195	61	1	152302	193302	41110 min	1 min	251	8160	152302	153002	8	0	0	8	
			193352	195352	20 min	10 s	121	8060	153102	170002	89	0	15	74	
			195402	202802	34 min	1 min	35	8040	170102	182502	85	3	7	78	
			202832	203352	5 min 20 s	10 s	33	8060	182702	193302	66	0	0	44	22 Lost line outage
			203402	230002	21126 min	1 min	147	8060	193352	195352	181	0	0	121	
								8060	195402	202802	35	0	2	33	
								8060	202832	203352	33	0	0	33	
								8060	203402	230002	147	0	1	146	
						Sum	587				584	3	25	537	89.08%
195	72	1	192302	234902	41126 min	1 min	267	8060	192302	234902	265	2	5	260	97.38%
196	11	1	233802	072702	71149 min	1 min	470	8040	233802	045702	320	0	1	319	
								8060	045802	072702	135	15	0	135	
						Sum	470				455	15	1	454	96.59%
196	42	1	030902	161602	13117 min	1 min	788	8060	030902	045802	110	0	2	108	
								8040	051502	140002	528	14	7	527	
								8160	141202	141602	5	11	0	5	
								8060	141702	161602	120	0	0	120	
						Sum	788				763	25	9	760	96.45%
196	61	2	160302	215002	51147 min	1 min	348	8160	160302	162002	18	0	1	17	
								8060	162102	215002	330	0	10	320	
						Sum	348				348	0	11	337	96.84%

Table 79 (contd)

Day	Station	Pass	Data received		At	Rate	Total received	Good DCC	Sampling		Total samples				Remarks
			From	Thru					From	Thru	Good DCC	Bad DCC	Garbled	Usable	
196	51	2	120102	235302	111152 min	1 min	713	8060	120102	140802	116	12	8	111	
								8040	140902	233502	563	4	29	535	
								8060	233602	235302	14	4	1	14	
						Sum	713				693	20	38	660	92.57%
197	11	2	231802	021002	21152 min	1 min	173	8160	231802	234002	9	14	3	9	
			021045	024024	29 min 39 s	10 s	179	8040	234102	020702	147	0	0	147	
			024202	080202	51120 min	1 min	321	8140	020802	025002	190	1	2	188	
								8040	025102	060002	184	6	15	169	
								8060	060102	080202	119	3	14	105	
						Sum	673				649	24	34	618	89.69%
197	42	2	034102	163402	121153 min	1 min	774	8060	034202	055402	133	1	0	133	
								8040	060302	145402	532	8	9	523	
								8060	150302	163302	91	9	0	91	
						Sum	774				756	18	9	747	96.51%
197	61	3	160702	162402	17 min	1 min	18	8160	160702	162402	18	0	0	18	
			162446	163452	10 min 6 s	10 s	62	8160	162426	163452	62	0	1	61	
			170402	181902	11115 min	1 min	76	8060	170402	181902	76	0	2	74	30 min data lost by doppler counter problem
			181932	182522	5 min 50 s	10 s	36	8060	181932	182502	36	0	0	36	
			182602	001502	51149 min	1 min	350	8060	182602	001502	344	6	6	338	
						Sum	542				536	6	9	527	96.95%
197	51	3	120802	000002	111152 min	1 min	713	8160	120802		1	0	0	1	
								8060	120902	145402	166	0	3	163	
								8040	150302	232402	502	8	22	480	
								8060	232302	000002	28	8	2	26	
						Sum	713				697	16	27	670	93.97%
197	11	3	233302	014102	2118 min	1 min	129	8040	233302	010802	92	4	1	91	
			014137	020246	21 min 9 s	10 s	128	8140	010902	011702	8	1	0	8	
								8150	011902	014102	23	1	0	23	
								8150	014137	020246	128	0	0	128	
						Sum	257				251	6	1	250	95.33%

Table 80. Total tracking data summary

Data	AFETR	DSS 11	DSS 42	DSS 51	DSS 61	DSS 72	Total
Total data samples	1236	1400	1562	2208	1477	586	8469
Total good data	1218	1322	1507	2039	1401	497	7984
Total bad DCC	8	45	43	75	9	75	255
Total garbled samples	10	36	18	100	45	15	224
Percentage of Usable Data[a]	98.54	93.87	96.48	92.58	94.29	93.97	94.11
Percentage of total with bad DCC[a]	0.64	3.36	2.75	3.46	0.71	5.54	2.74
Percentage of total data garbled[a]	0.80	2.77	1.15	4.81	3.55	1.68	2.46

[a]Sample rate compressed to 1 min samples for % computation.

Communications status display. This display performed satisfactorily.

NASCOM data sets. The NASCOM data sets were used with all stations except DSS 51 and the reliability was very high. Set Numbers 1 and 12 were dedicated to *Surveyor* only. This gave some problem during launch when several stations were active and caused some problems switching sets for each station to run data transfer tests. DSS 51 used the Hallicrafter data sets, and the normal circuit problems due to propagation were experienced but no equipment problems.

Communications/TV ground data handling system (COMM/TVGDHS) 6-MHz video line. Extensive tests were conducted prior to the mission and no problems were experienced on this interface.

Television communications subsystem. Only minor equipment problems were experienced on this system and they were all repaired in real time. *There was a shortage of TTY/TV monitors during launch phase.* All available monitors were assigned to the *Surveyor* Project. The output of the Scan Converter was normalled through to PIO at all times and no problems were encountered.

g. Evaluation of COMM support for the Surveyor IV mission. In general, all communications support provided for this mission including NASCOM, DSN/GCF, DSN/ICS, SFOF communications and other contractor-furnished communications was considered excellent to outstanding with communications imposing no constraints or major problems affecting the mission. New, highly reliable, satellite circuits provided by NASCOM to DSS 72 (one VCE, one HSDL, two TTY) during final test and launch phases are considered the spectacular change from earlier missions. A performance analysis of communications for *Surveyor IV* mission is shown in Fig. 156.

h. Outstanding COMM problems for Surveyor IV mission. Table 81 gives the outstanding communications (COMM) problems experienced for *Mission IV*:

(1) SFOF/Echo COMM/DSS 11 COMM support problems to be resolved.

(2) Lack of appropriate documentation of COMM line turn up and end-to-end checkout procedures.

Table 81. Outstanding COMM problems for the *Surveyor IV* mission

No.	Problem	Cause	Remarks
1	DSS 11 COMM support problem	Split authority and responsibility and non-standard way of providing COMM support to DSS 11	Some progress on this problem had been made through meeting and verbal agreement on this subject held during the *Surveyor IV* mission
2	Integration of COMM processor		Mission Control and Support Area personnel were still weak on COMM Processor procedures as system was still new to *Surveyor* support personnel
3	Lack of appropriate documented COMM line turn up and end-to-end checkout procedure	Lack of agreement as to appropriate document or documents which would carry these procedures	

3. Space flight operations facility. *Mission IV* support from SFOF was generally good. Personnel were provided as requested and also on a standby basis. Internal access control, special access control, and documentation services were available when needed.

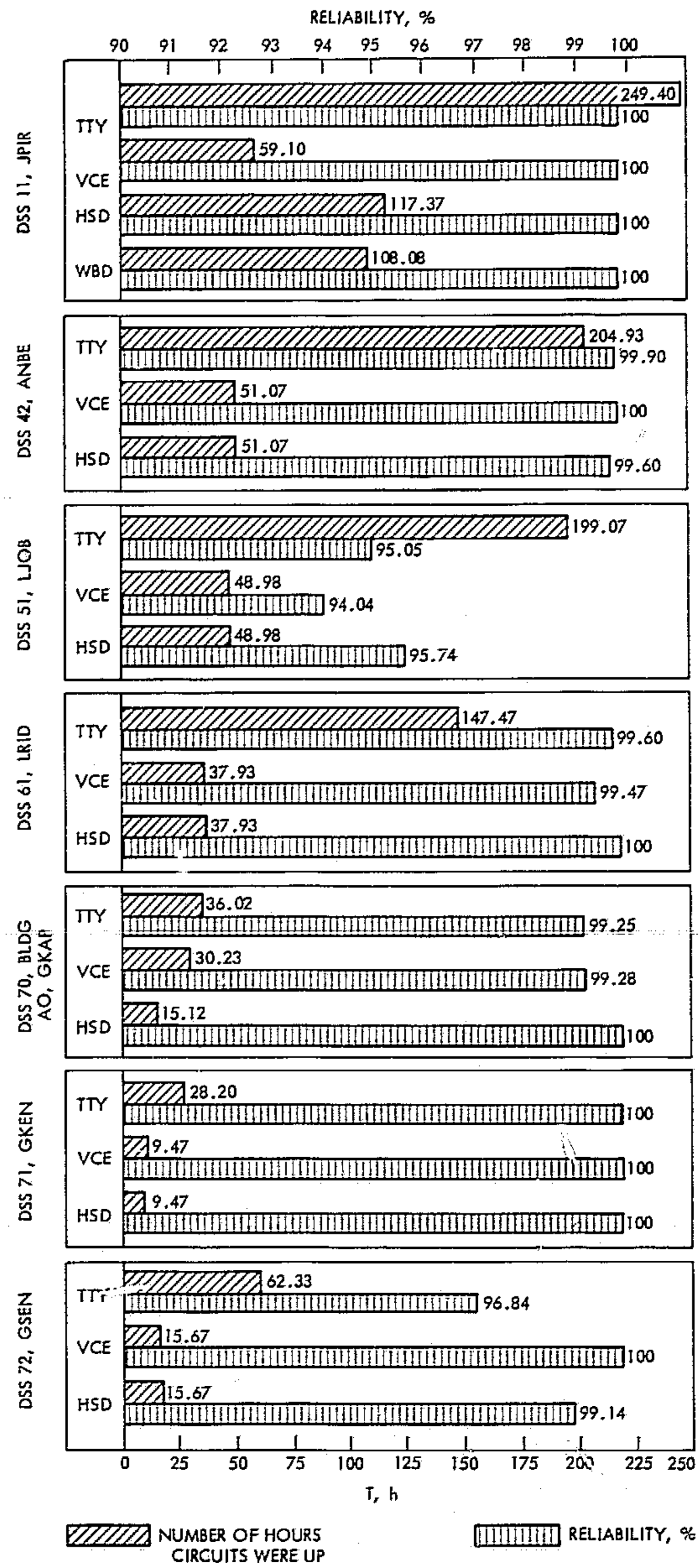


Fig. 156. Communications performance analysis, *Surveyor IV* mission

SFOF problems deserving special mention were:

(1) The data distribution list was not provided to the support group until after the ORT was complete; and, when received, it had errors that caused difficulty during the mission.

(2) Standby generator support was initiated before the scheduled time due to a local thunderstorm. A power failure occurred on the second floor at 19:12 GMT on Day 194 bringing the X- and Y-computer strings down. It was determined at 19:18 GMT on Day 194 that an apparent shift in load between the second floor and generators had taken place. The probable cause was an overload at the second floor panel which blew a circuit breaker. A new breaker rated at 400 A was installed. The breaker had not been tested to hold this amperage, except at the factory. A redistribution reduced the load to approximately 360 A. This breaker load was monitored continuously afterward, but no further problems occurred in this area during the remainder of time to completion of the mission.

a. Television ground data handling system. The TVGDHS in the SFOF was not used in a real-time operation, other than to make a real-time decision to attempt an FR-800 baseband recording as soon as signal loss was reported in the final maneuver, due to the early termination of the *Surveyor IV* mission. The recording effort yielded no useful data, but brought into focus a capability that could facilitate mission evaluations, since an FR-800 baseband recording might be made for each critical maneuver.

Problems occurred in the TV-1 scan-converter driver and film-recorder systems during pre-launch and pre-DSS 11 countdowns. These were cleared prior to terminal descent, and the systems were fully operational for post-touchdown operations.

b. Data processing system. The DPS was manned by a sufficient number of qualified and experienced personnel, and their performance in general was excellent.

There were no major changes in DPS computers and peripheral equipment, and hardware in general functioned in a satisfactory manner.

A new computer program, HOPS, for lift-off and translation of the spacecraft, was certified and used in a lunar training test.

Significant DPS deviations from planned sequences or procedures were:

(1) The first midcourse maneuver took place at $L + 38$ h (approximately). At $L + 16$ h, the program running sequences were reissued by Mission Control. These caused no problems in operations procedures.

(2) A position in Mission Control was staffed by the Data Processing Project Engineer (DPPE) during launch, midcourse, and terminal phases of flight.

Performance problems deserving special mention were:

(1) Due to a series of misunderstandings, the checkout of computer strings prior to launch did not take place.

(2) A master circuit breaker in the SFOF gave way at $L - 20$ h (approximately). The computers did not turn off normally, necessitating a major system checkout by computer maintenance engineers. The Y-string came up at $L - 10$ h; the X-string, at $L - 6$ h.

(3) Programmed Data Processor 7, No. 3 (PDP-7, No. 3) Computer did not perform properly during the program diagnostic checkout. PDP-7 (No. 1) was substituted and used for flight.

(4) Erratic performance of X- and Y-strings was observed during the first 10 h after launch. Tracking data and cards input from user areas would not read into the 7094 computers, and computer programs did not appear to run correctly. In some instances, the 7094 would go *non-shared.* The computer memories were cleared, and programs were read from disk storage.

(5) As in past flights, the SC 3070 computers, card readers, and administrative printers performed poorly.

4. Spacecraft center frequencies. So that spacecraft predictions might be generated and supplied to the DSN tracking stations for purposes of spacecraft acquisition, aided track, and station-to-station transfers of the spacecraft, it was essential that the spacecraft transmitter (one-way) center frequency and spacecraft transponder (two-way) center frequency be accurately known. The nominal values for these frequencies were 2295.000000 MHz (at carrier level) for the transmitter center frequency and 22.013670 MHz (at station VCO level) for the transponder center frequency. Normally, these frequencies were measured months before the mission for use in the Preflight Prediction Document, and then they were measured several times in the last 10 h of the countdown for use in real time predictions.

The frequencies which were used in the Preflight Prediction Document were:

2294.998200 (one-way, transmitter A, at 95° F)

2294.990400 (one-way, transmitter B, at 95° F)

22.013642 (two-way, transponder A, at 85° F)

22.013872 (two-way, transponder B, at 85° F)

These frequencies were abstracted from preflight data. During the countdown, frequency measurements were made and sent to the SFOF at $T - 555$, $T - 494$, $T - 274$, $T - 90$, $T - 49$, and $T - 23$ min, respectively, approximately as called for in the Sequence of Events, and these measurements were used to adjust the Preflight frequency versus temperature curves by a constant bias in frequency (see Figs. 157–160). Finally, using temperature predictions for *Surveyor IV,* tables of the appropriate frequencies to be used throughout the mission were constructed and incorporated in the various inflight prediction sets (see Table 82). The one deviation from this sequence was the predict set for initial acquisition at DSS 72 and DSS 51, which utilized special initial acquisition frequencies (2294.994959 MHz and 22.013847 MHz, for transponder B).

Table 82. *Surveyor IV* frequency corrections

Unit	Time	Temperature, °F	Frequency, MHz
Transmitter A	L to $L+30$	75	2295.015050
	$L+30$ to $L+65$	65	2295.020550
	$L+65$ to $L+68$	72.5	2295.016850
Transmitter B	L to $L+3$	110	2294.985225
	$L+3$ to $L+30$	97.5	2294.989225
	$L+30$ to $L+65$	85	2294.996625
	$L+65$ to $L+68$	105	2294.986625
Transponder A	L to $L+4$	92.5	22.013625
	$L+4$ to $L+30$	85	22.013628
	$L+30$ to $L+65$	80	22.013643
	$L+65$ to $L+68$	87.5	22.013626
Transponder B	L to $L+4$	92.5	22.013768
	$L+4$ to $L+30$	85	22.013814
	$L+30$ to $L+65$	80	22.013839
	$L+65$ to $L+68$	87.5	22.013799

As can be seen by examining Figs. 157–160, the countdown frequency vs temperature measurements correlate rather poorly with the preflight data. In addition, the inflight acquisition frequencies show little agreement with either the preflight data or the countdown data. For instance, at 12:21:46, on July 14, DSS 72 reacquired Transponder B (actual temperature at this time, 90° F) at a frequency of 22.014495 MHz, which, after removing the doppler, indicates a Transponder B center frequency of 22.013914 MHz, and at 23:33:00, on July 14, DSS 11 acquired Transponder B (actual temperature at this time, 80°F) at a frequency of 22.014075, which, after correcting for doppler, yields a Transponder B center frequency of 22.013941 MHz. These two frequencies are approximately 60 Hz above the preflight data (see Fig. 160). Table 83 presents the various Transmitter B one-way frequencies reduced from the one-way data recorded during the *Surveyor IV* mission. These values can be compared to the data presented in Figs. 157 and 158.

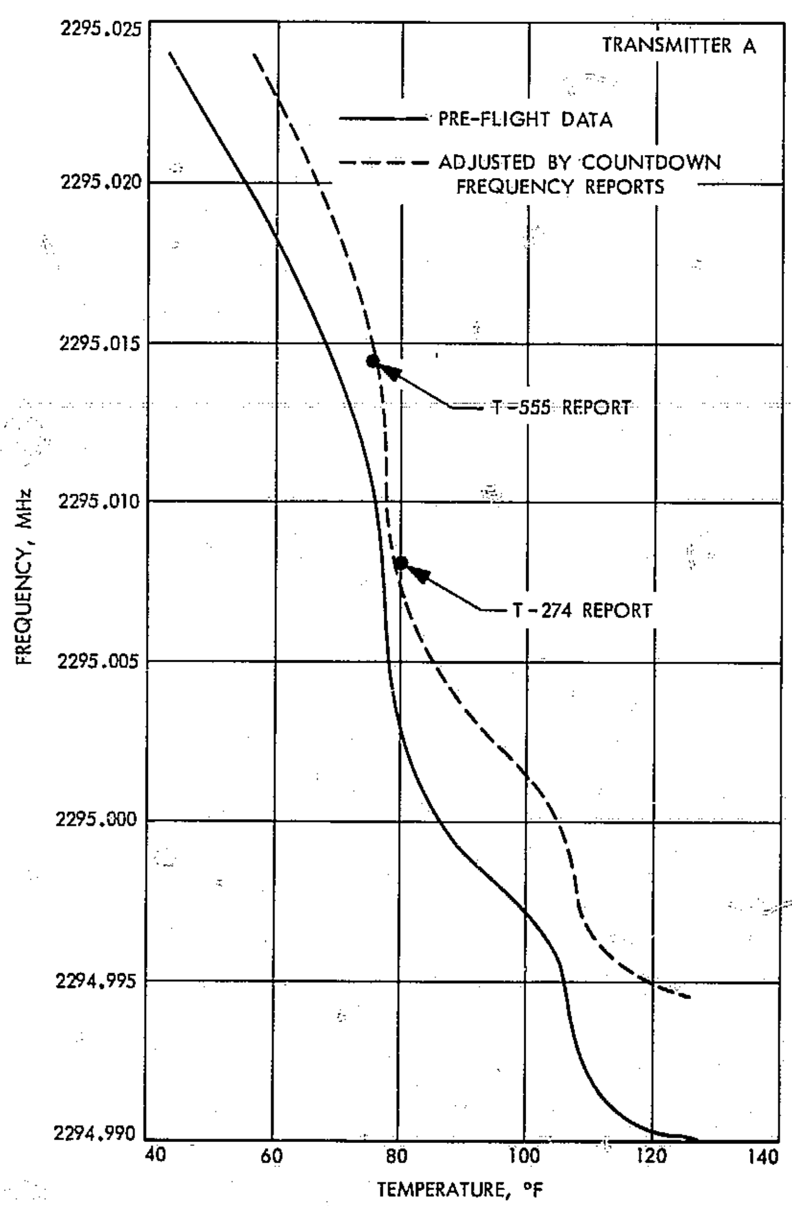


Fig. 157. Preflight frequency reports, transmitter A

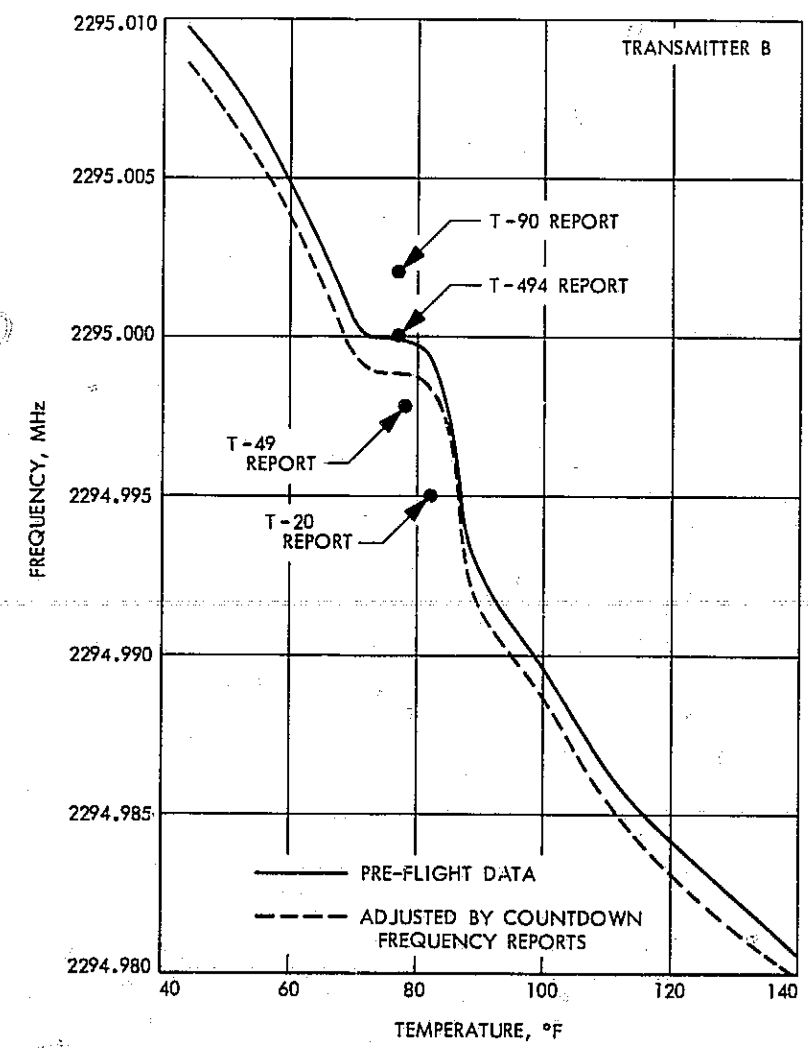


Fig. 158. Preflight frequency reports, transmitter B

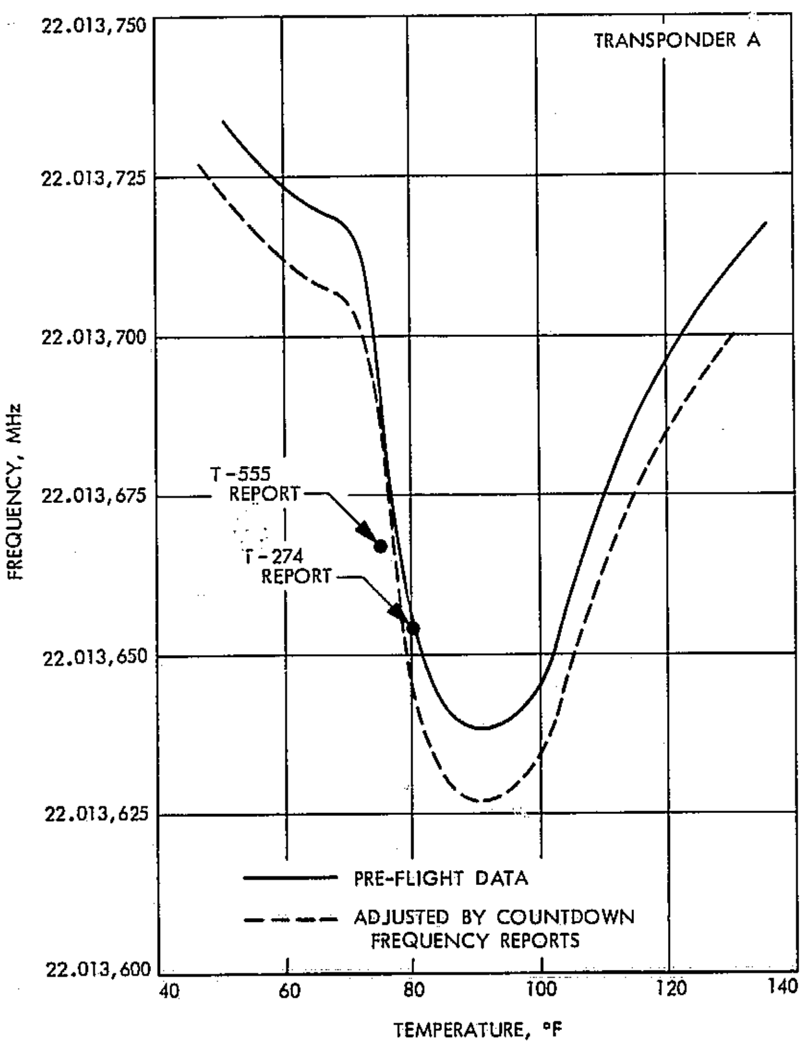


Fig. 159. Preflight frequency reports, transponder A

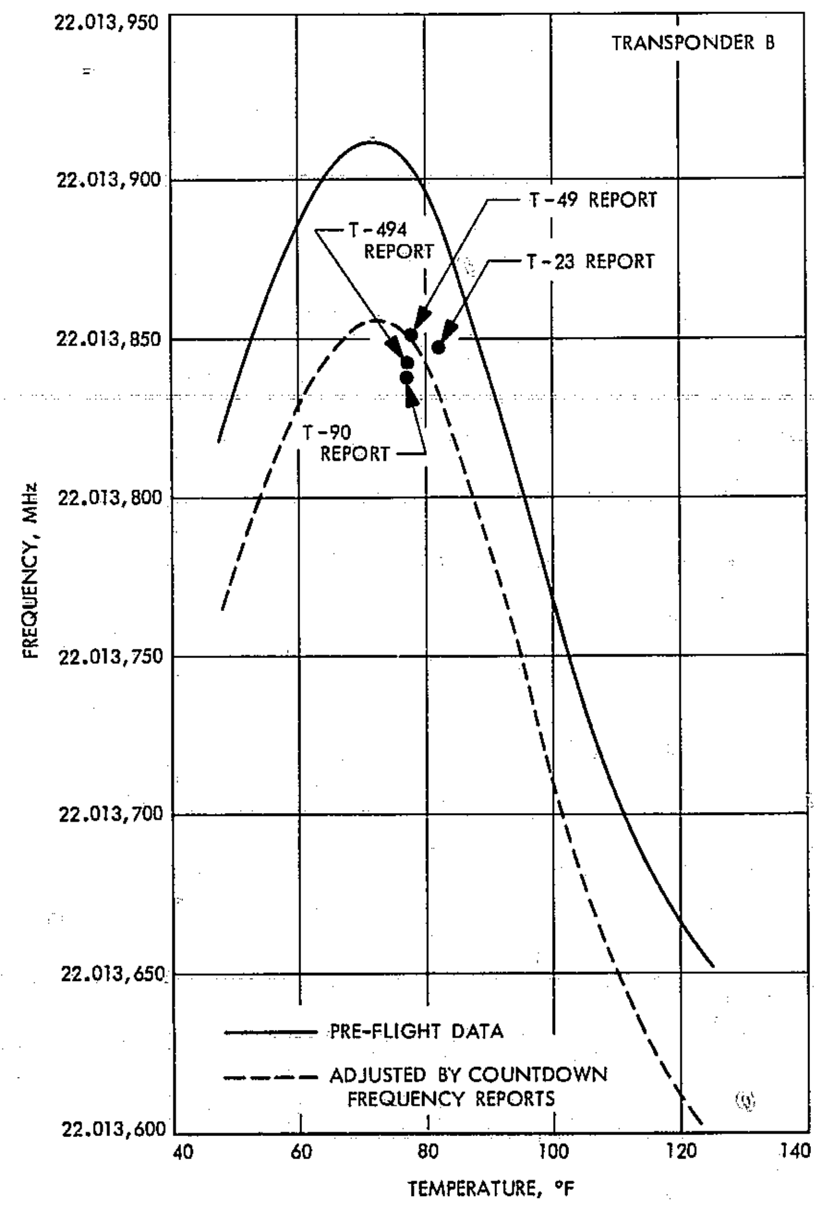


Fig. 160. Preflight frequency reports, transponder B

Table 83. Transmitter B one-way frequencies

DSS 51 PASS 1 14 JULY 1967
START TIME=230632.00 GMT. END TIME=230732.00 GMT.

GMT	AUX OSC FREQUENCY
230632.00	2294998351.73
230732.00	2294998379.08

FREQUENCY AVERAGE=2294998365.41
VCO=22014010.
SAMPLE RATE=60.
MULTIPLIER=1

DSS 72 PASS 1 14 JULY 1967
START TIME=121058.00 GMT. END TIME=121208.00 GMT.

GMT	AUX OSC FREQUENCY
121058.00	2294995538.84
121108.00	2294995529.95
121118.00	2294995522.75
121128.00	2294995515.41
121138.00	2294995374.27
121148.00	2294995634.89
121158.00	2294995493.52
121208.00	2294995485.23

FREQUENCY AVERAGE=2294995511.84
VCO=22013298.
SAMPLE RATE=10.
MULTIPLIER=2

Table 83 (contd)

DSS 72 PASS 1 14 JULY 1967
START TIME=121628.00 GMT. END TIME=122048.00 GMT.

GMT	AUX OSC FREQUENCY
121628.00	2294998455.22
121638.00	2294997547.08
121648.00	2294996747.94
121658.00	2294996045.48
121708.00	2294995428.70
121718.00	2294994922.94
121728.00	2294994694.42
121738.00	2294994609.31
121748.00	2294994551.62
121758.00	2294994509.11
121808.00	2294994470.84
121818.00	2294994428.53
121828.00	2294994400.02
121838.00	2294994368.77
121848.00	2294994338.25
121858.00	2294994307.45
121908.00	2294994276.53
121918.00	2294994247.06
121928.00	2294994212.02
121938.00	2294994186.52
121948.00	2294994158.17
121958.00	2294994130.95
122008.00	2294994098.08
122018.00	2294994070.17
122028.00	2294994038.08
122038.00	2294994005.47
122048.00	2294993981.03

FREQUENCY AVERAGE=2294994786.22
VCO=22014180.
SAMPLE RATE=10.
MULTIPLIER=2

Table 83 (contd)

DSS 72 PASS 1 14 JULY 1967
START TIME=230732.00 GMT. END TIME=233132.00 GMT.

GMT	AUX OSC FREQUENCY
230732.00	2294998380.44
230832.00	2294998418.23
230932.00	2294998456.87
231032.00	2294998494.09
231132.00	2294998533.11
231232.00	2294998568.64
231332.00	2294998606.47
231432.00	2294998640.55
231532.00	2294998676.41
231632.00	2294998708.19
231732.00	2294998740.70
231832.00	2294998771.59
231932.00	2294998801.83
232032.00	2294998832.83
232132.00	2294998862.50
232232.00	2294998890.14
232332.00	2294998921.12
232432.00	2294998948.34
232532.00	2294998973.66
232632.00	2294998999.61
232732.00	2294999024.66
232832.00	2294999047.27
232932.00	2294999070.06
233032.00	2294999093.08
233132.00	2294999116.45

FREQUENCY AVERAGE=2294998783.00
VCO=22013990.
SAMPLE RATE=60.
MULTIPLIER=2

Table 83 (contd)

DSS 11 PASS 3 17 JULY 1967
START TIME=011832.00 GMT. END TIME=013332.00 GMT.

GMT	AUX OSC FREQUENCY
011832.00	2294997593.87
011932.00	2294997548.16
012032.00	2294997503.17
012132.00	2294997454.27
012232.00	2294997401.08
012332.00	2294997339.12
012432.00	2294997271.98
012532.00	2294997199.06
012632.00	2294997119.58
012732.00	2294997033.89
012832.00	2294996943.67
012932.00	2294996849.52
013032.00	2294996749.50
013132.00	2294996648.86
013232.00	2294996541.44
013332.00	2294996433.48

FREQUENCY AVERAGE=2294997101.87
VCO=22013967.
SAMPLE RATE=60.
MULTIPLIER=1

Table 83 (contd)

DSS 11 PASS 3 17 JULY 1967
START TIME=014151.00 GMT. END TIME=015731.00 GMT.

GMT	AUX OSC FREQUENCY
014151.00	2294995421.89
014201.00	2294995398.81
014211.00	2294995377.28
014221.00	2294995356.06
014231.00	2294995335.28
014241.00	2294995312.53
014251.00	2294995288.45
014301.00	2294995266.16
014311.00	2294995245.95
014321.00	2294995222.45
014331.00	2294995201.55
014341.00	2294995177.95
014351.00	2294995158.67
014401.00	2294995135.56
014411.00	2294995112.72
014421.00	2294995089.36
014431.00	2294995067.92
014441.00	2294995042.72
014451.00	2294995017.12
014501.00	2294994993.47
014511.00	2294994972.73
014521.00	2294994951.36
014531.00	2294994926.92
014541.00	2294994903.12
014551.00	2294994882.48
014601.00	2294994860.27
014611.00	2294994838.06
014621.00	2294994814.89
014631.00	2294994792.39
014641.00	2294994770.84
014651.00	2294994747.00
014701.00	2294994722.84
014711.00	2294994702.16
014721.00	2294994677.67
014731.00	2294994658.58
014741.00	2294994636.87
014751.00	2294994613.20
014801.00	2294994591.14
014811.00	2294994567.30
014821.00	2294994543.87
014831.00	2294994521.89
014841.00	2294994499.94
014851.00	2294994476.64
014901.00	2294994451.59
014911.00	2294994431.59
014921.00	2294994406.66
014931.00	2294994383.72
014941.00	2294994359.94
014951.00	2294994340.73
015001.00	2294994317.25
015011.00	2294994293.77
015021.00	2294994271.48
015031.00	2294994249.03
015041.00	2294994222.89
015051.00	2294994200.92
015101.00	2294994176.86

Table 83 (contd)

015111.00	2294994156.36
015121.00	2294994134.33
015131.00	2294994110.78
015141.00	2294994087.52
015151.00	2294994063.86
015201.00	2294994040.59
015211.00	2294994019.16
015221.00	2294993992.72
015231.00	2294993970.75
015241.00	2294993949.42
015251.00	2294993926.30
015301.00	2294993903.59
015311.00	2294993880.44
015321.00	2294993857.44
015331.00	2294993834.50
015341.00	2294993810.78
015351.00	2294993787.39
015401.00	2294993765.20
015411.00	2294993741.78
015421.00	2294993716.77
015431.00	2294993694.66
015441.00	2294993670.37
015451.00	2294993646.47
015501.00	2294993625.70
015511.00	2294993601.05
015521.00	2294993576.81
015531.00	2294993554.80
015541.00	2294993533.34
015551.00	2294993509.06
015601.00	2294993486.89
015611.00	2294993462.73
015621.00	2294993439.72
015631.00	2294993417.00
015641.00	2294993393.87
015651.00	2294993368.28
015701.00	2294993343.56
015711.00	2294993322.42
015721.00	2294993301.22
015731.00	2294993279.95

FREQUENCY AVERAGE=2294994357.34
VCO=22013967
SAMPLE RATE=10.
MULTIPLIER=1

Table 83 (contd)

DSS-11 PASS 3 17 JULY 1967			
START TIME=015700.50 GMT.	START EXTRAPOLATION TIME=020157.50 GMT.		END EXTRAPOLATION TIME=020244.50 GMT.
GMT	AUX OSC FREQUENCY	AUX OSC FREQUENCY CURVE FIT	R DOT KM/SEC
015700.50	2294993345.89	2294993347.86	.16569115E 01
015701.50	2294993342.02	2294993345.64	.16577098E 01
015702.50	2294993341.16	2294993343.44	.16585126E 01
015703.50	2294993337.30	2294993341.22	.16593153E 01
015704.50	2294993336.44	2294993339.00	.16601180E 01
015705.50	2294993334.61	2294993336.78	.16609229E 01
015706.50	2294993331.78	2294993334.58	.16617299E 01
015707.50	2294993329.98	2294993332.36	.16625392E 01
015708.50	2294993327.17	2294993330.14	.16633484E 01
015709.50	2294993325.39	2294993327.92	.16641599E 01
015710.50	2294993324.59	2294993325.72	.16649713E 01
015711.50	2294993322.84	2294993323.50	.16657871E 01
015712.50	2294993317.08	2294993321.28	.16666007E 01
015713.50	2294993316.33	2294993319.06	.16674187E 01
015714.50	2294993316.59	2294993316.84	.16682367E 01
015715.50	2294993312.87	2294993314.62	.16690568E 01
015716.50	2294993310.17	2294993312.41	.16698792E 01
015717.50	2294993308.47	2294993310.20	.16707015E 01
015718.50	2294993306.78	2294993307.98	.16715261E 01
015719.50	2294993304.11	2294993305.77	.16723528E 01
015720.50	2294993300.44	2294993303.55	.16731795E 01
015721.50	2294993299.78	2294993301.33	.16740083E 01
015722.50	2294993298.14	2294993299.11	.16748394E 01
015723.50	2294993296.50	2294993296.89	.16756705E 01
015724.50	2294993294.87	2294993294.67	.16765037E 01
015725.50	2294993293.28	2294993292.45	.16773392E 01
015726.50	2294993289.69	2294993290.23	.16781768E 01
015727.50	2294993289.09	2294993288.02	.16790144E 01
015728.50	2294993286.53	2294993285.80	.16798542E 01
015729.50	2294993283.95	2294993283.58	.16806940E 01
015730.50	2294993280.42	2294993281.36	.16815381E 01
015731.50	2294993276.89	2294993279.14	.16823823E 01
015732.50	2294993276.36	2294993276.92	.16832286E 01
015733.50	2294993275.84	2294993274.70	.16840749E 01
015734.50	2294993271.34	2294993272.48	.16849235E 01
015735.50	2294993269.84	2294993270.27	.16857742E 01
015736.50	2294993269.37	2294993268.05	.16866270E 01
015737.50	2294993264.91	2294993265.81	.16874799E 01
015738.50	2294993264.45	2294993263.59	.16883350E 01
015739.50	2294993262.02	2294993261.37	.16891922E 01
015740.50	2294993259.59	2294993259.16	.16900516E 01
015741.50	2294993259.17	2294993256.94	.16909111E 01
015742.50	2294993253.77	2294993254.72	.16917727E 01
015743.50	2294993253.37	2294993252.48	.16926365E 01
015744.50	2294993253.00	2294993250.27	.16935002E 01
015745.50	2294993250.62	2294993248.05	.16943662E 01
015746.50	2294993250.27	2294993245.83	.16952344E 01
015747.50	2294993246.94	2294993243.59	.16961047E 01
015748.50	2294993244.61	2294993241.37	.16969772E 01
015749.50	2294993240.30	2294993239.16	.16978497E 01
015750.50	2294993239.98	2294993236.94	.16987244E 01
015751.50	2294993237.70	2294993234.70	.16996013E 01
015752.50	2294993234.41	2294993232.48	.17004782E 01
015753.50	2294993234.14	2294993230.27	.17013572E 01
015754.50	2294993230.89	2294993228.03	.17022384E 01

Table 83 (contd)

015755.50	2294993227.66	2294993225.81	.17031219E 01
015756.50	2294993223.42	2294993223.59	.17040053E 01
015757.50	2294993220.20	2294993221.36	.17048931E 01
015758.50	2294993219.00	2294993219.14	.17057808E 01
015759.50	2294993216.81	2294993216.91	.17066708E 01
015800.50	2294993213.62	2294993214.69	.17075608E 01
015801.50	2294993211.48	2294993212.47	.17084551E 01
015802.50	2294993211.33	2294993210.23	.17093494E 01
015803.50	2294993207.19	2294993208.02	.17102459E 01
015804.50	2294993204.06	2294993205.78	.17111446E 01
015805.50	2294993201.95	2294993203.56	.17120433E 01
015806.50	2294993199.86	2294993201.33	.17129463E 01
015807.50	2294993199.77	2294993199.11	.17138494E 01
015808.50	2294993197.70	2294993196.87	.17147546E 01
015809.50	2294993193.62	2294993194.66	.17156598E 01
015810.50	2294993191.59	2294993192.42	.17165694E 01
015811.50	2294993187.56	2294993190.20	.17174790E 01
015812.50	2294993186.53	2294993187.97	.17183908E 01
015813.50	2294993183.53	2294993185.75	.17193048E 01
015814.50	2294993182.55	2294993183.52	.17202209E 01
015815.50	2294993179.56	2294993181.28	.17211370E 01
015816.50	2294993180.61	2294993179.06	.17220575E 01
015817.50	2294993180.66	2294993176.83	.17229780E 01
015818.50	2294993174.72	2294993174.61	.17239007E 01
015819.50	2294993175.80	2294993172.37	.17248256E 01
015820.50	2294993172.87	2294993170.14	.17257504E 01
015821.50	2294993170.98	2294993167.92	.17266797E 01
015822.50	2294993169.11	2294993165.69	.17276089E 01
015823.50	2294993165.23	2294993163.45	.17285403E 01
015824.50	2294993163.37	2294993161.22	.17294739E 01
015825.50	2294993160.55	2294993159.00	.17304096E 01
015826.50	2294993158.72	2294993156.77	.17313476E 01
015827.50	2294993155.91	2294993154.53	.17322855E 01
015828.50	2294993156.11	2294993152.31	.17332257E 01
015829.50	2294993155.33	2294993150.08	.17341702E 01
015830.50	2294993152.56	2294993147.84	.17351147E 01
015831.50	2294993150.80	2294993145.61	.17360591E 01
015832.50	2294993148.06	2294993143.37	.17370080E 01
015833.50	2994993143.34	2994993141.16	.17379590E 01
015834.50	2294993140.62	2294993138.92	.17389101E 01
015835.50	2294993138.92	2294993136.69	.17398633E 01
015836.50	2294993136.25	2294993134.45	.17408209E 01
015837.50	2294993132.58	2294993132.22	.17417785E 01
015838.50	2294993131.92	2294993129.98	.17427382E 01
015839.50	2294993125.27	2294993127.75	.17436980E 01
015840.50	2294993120.66	2294993125.53	.17446621E 01
015841.50	2294993120.03	2294993123.30	.17456262E 01
015842.50	2294993120.45	2294993121.06	.17465947E 01
015843.50	2294993117.86	2294993118.83	.17475632E 01
015844.50	2294993116.30	2294993116.59	.17485339E 01
015845.50	2294993113.73	2294993114.36	.17495067E 01
015846.50	2294993113.20	2294993112.12	.17504818E 01
015847.50	2294993109.69	2294993109.89	.17514590E 01
015848.50	2294993104.19	2294993107.66	.17524384E 01
015849.50	2294993103.69	2294993105.42	.17534199E 01
015850.50	2294993104.20	2294993103.19	.17544015E 01
015851.50	2294993101.75	2294993100.95	.17553874E 01
015852.50	2294993099.30	2294993098.72	.17563712E 01
015853.50	2294993096.87	2294993096.48	.17573615E 01
015854.50	2294993096.47	2294993094.25	.17583540E 01
015855.50	2294993092.06	2294993092.02	.17593465E 01

Table 83 (contd)

015856.50	2294993091.67	2994993089.77	.17603411E 01
015857.50	2294993089.31	2294993087.53	.17613380E 01
015858.50	2294993086.95	2294993085.30	.17623370E 01
015859.50	2294993081.61	2294993083.06	.17633360E 01
015900.50	2294993078.28	2294993080.83	.17643394E 01
015901.50	2294993076.98	2294993078.59	.17653450E 01
015902.50	2294993074.69	2294993076.36	.17663506E 01
015903.50	2294993073.41	2294993074.11	.17673605E 01
015904.50	2294993072.16	2294993071.87	.17683726E 01
015905.50	2294993068.91	2294993069.64	.17693847E 01
015906.50	2294993068.67	2294993067.41	.17703990E 01
015907.50	2294993066.47	2294993065.17	.17714177E 01
015908.50	2294993062.27	2294993062.92	.17724363E 01
015909.50	2294993063.08	2294993060.69	.17734572E 01
015910.50	2294993060.94	2294993058.45	.17744824E 01
015911.50	2294993058.78	2294993056.20	.17755076E 01
015912.50	2294993054.64	2294993053.97	.17765349E 01
015913.50	2294993053.53	2294993051.73	.17775645E 01
015914.50	2294993050.42	2294993049.50	.17785962E 01
015915.50	2294993048.36	2294993047.25	.17796323E 01
015916.50	2294993045.28	2294993045.01	.17806663E 01
015917.50	2294993044.23	2294993042.78	.17817067E 01
015918.50	2294993041.20	2294993040.53	.17827472E 01
015919.50	2294993039.19	2294993038.30	.17837899E 01
015920.50	2294993038.19	2294993036.05	.17848347E 01
015921.50	2294993036.20	2294993033.81	.17858817E 01
015922.50	2294993033.23	2294993031.58	.17869309E 01
015923.50	2294993029.28	2294993029.33	.17879823E 01
015924.50	2294993027.34	2294993027.09	.17890358E 01
015925.50	2294993027.42	2294993024.84	.17900916E 01
015926.50	2294993026.55	2294993022.61	.17911517E 01
015927.50	2294993024.66	2294993020.36	.17922118E 01
015928.50	2294993019.78	2294993018.12	.17932741E 01
015929.50	2294993019.94	2294993015.87	.17943385E 01
015930.50	2294993017.11	2294993013.64	.17954052E 01
015931.50	2294993016.30	2294993011.39	.17964762E 01
015932.50	2294993011.50	2294993009.16	.17975472E 01
015933.50	2294993006.72	2294993006.91	.17986204E 01
015934.50	2294993004.97	2294993004.67	.17996979E 01
015935.50	2294993002.22	2294993002.42	.18007755E 01
015936.50	2294993000.48	2294993000.17	.18018552E 01
015937.50	2294992999.78	2294992997.94	.18029393E 01
015938.50	2294992999.08	2294992995.69	.18040234E 01
015939.50	2294992994.41	2294992993.45	.18051119E 01
015940.50	2294992990.77	2294992991.20	.18062025E 01
015941.50	2294992993.11	2294992988.95	.18072931E 01
015942.50	2294992991.48	2294992986.72	.18083881E 01
015943.50	2294992988.89	2294992984.47	.18094853E 01
015944.50	2294992988.31	2294992982.22	.18105847E 01
015945.50	2294992985.73	2294992979.98	.18116862E 01
015946.50	2294992984.19	2294992977.73	.18127899E 01
015947.50	2294992979.67	2294992975.48	.18138980E 01
015948.50	2294992977.16	2294992973.23	.18150061E 01
015949.50	2294992977.66	2294992971.00	.18161164E 01
015950.50	2294992972.19	2294992968.75	.18172310E 01
015951.50	2294992967.72	2294992966.50	.18183457E 01
015952.50	2294992965.28	2294992964.25	.18194647E 01
015953.50	2294992960.86	2294992962.02	.18205837E 01
015954.50	2294992962.47	2294992959.77	.18217092E 01
015955.50	2294992960.08	2294992957.52	.18228347E 01
015956.50	2294992957.72	2294992955.27	.18239625E 01

Table 83 (contd)

015957.50	2294992956.36	2294992953.02	.18250924E 01
015958.50	2294992948.05	2294992950.77	.18262266E 01
015959.50	2294992945.73	2294992948.52	.18273609E 01
020000.50	2294992943.45	2294992946.28	.18284995E 01
020001.50	2294992943.19	2294992944.03	.18296403E 01
020002.50	2294992939.94	2294992941.78	.18307833E 01
020003.50	2294992937.70	2294992939.53	.18319285E 01
020004.50	2294992933.48	2294992937.28	.18330758E 01
020005.50	2294992931.30	2294992935.03	.18342275E 01
020006.50	2294992930.11	2294992932.78	.18353793E 01
020007.50	2294992928.97	2294992930.53	.18365353E 01
020008.50	2294992926.83	2294992928.28	.18376936E 01
020009.50	2294992921.72	2294992926.03	.18388540E 01
020010.50	2294992918.61	2294992923.78	.18400167E 01
020011.50	2294992918.55	2294992921.53	.18411836E 01
020012.50	2294992915.48	2294992919.28	.18423506E 01
020013.50	2294992912.45	2294992917.03	.18435220E 01
020014.50	2294992911.44	2294992914.78	.18446955E 01
020015.50	2294992909.44	2294992912.53	.18458712E 01
020016.50	2294992905.47	2294992910.28	.18470513E 01
020017.50	2294992902.50	2294992908.03	.18482313E 01
020018.50	2294992900.56	2294992905.78	.18494158E 01
020019.50	2294992897.66	2294992903.52	.18506024E 01
020020.50	2294992895.77	2294992901.27	.18517934E 01
020021.50	2294992893.89	2294992899.02	.18529843E 01
020022.50	2294992891.03	2294992896.77	.18541797E 01
020023.50	2294992889.20	2294992894.52	.18553772E 01
020024.50	2294992890.39	2294992892.27	.18565769E 01
020025.50	2294992887.59	2294992890.00	.18577788E 01
020026.50	2294992885.83	2294992887.75	.18589850E 01
020027.50	2294992885.08	2294992885.50	.18601935E 01
020028.50	2294992882.34	2294992883.25	.18614041E 01
020029.50	2294992878.64	2294992881.00	.18626191E 01
020030.50	2294992875.94	2294992878.73	.18638340E 01
020031.50	2294992874.28	2294992876.48	.18650534E 01
020032.50	2294992871.62	2294992874.23	.18662749E 01
020033.50	2294992869.02	2294992871.98	.18675008E 01
020034.50	2294992867.42	2294992869.72	.18687288E 01
020035.50	2294992865.83	2294992867.47	.18699591E 01
020036.50	2294992863.27	2294992865.22	.18711915E 01
020037.50	2294992861.73	2294992862.95	.18724283E 01
020038.50	2294992857.22	2294992860.70	.18736672E 01
020039.50	2294992855.72	2294992858.45	.18749084E 01
022040.50	2294992854.23	2294992856.19	.18761517E 01
020041.50	2294992851.80	2294992853.94	.18773994E 01
020042.50	2294992851.36	2294992851.67	.18786493E 01
020043.50	2294992846.95	2294992849.42	.18799035E 01
020044.50	2294992845.58	2294992847.17	.18811599E 01
020045.50	2294992843.22	2294992844.91	.18824185E 01
020046.50	2294992839.86	2294992842.66	.18836793E 01
020047.50	2294992835.55	2294992840.39	.18849444E [illegible]
020048.50	2294992835.25	2294992838.14	.18862117E 01
020049.50	2294992829.98	2294992835.87	.18874834E 01
020050.50	2294992831.72	2294992833.62	.18887551E 01
020051.50	2294992826.50	2294992831.36	.18900331E 01
020052.50	2294992825.30	2294992829.11	.18913116E 01
020053.50	2294992822.11	2294992826.84	.18925942E 01
020054.50	2294992819.97	2294992824.59	.18938811E 01
020055.50	2294992816.81	2294992822.33	.18951681E 01
020056.50	2294992816.70	2294992820.06	.18964594E 01
020057.50	2294992814.62	2294992817.81	.18977551E 01

Table 83 (contd)

020058.50	2294992814.55	2294992815.55	.18990529E 01
020059.50	2294992810.50	2294992813.30	.19003530E 01
020100.50	2294992809.48	2294992811.03	.19016574E 01
020101.50	2294992806.50	2294992808.77	.19029640E 01
020102.50	2294992805.52	2294992806.52	.19042727E 01
020103.50	2294992802.56	2294992804.25	.19055859E 01
020104.50	2294992801.64	2294992801.98	.19069012E 01
020105.50	2294992798.73	2294992799.73	.19082208E 01
020106.50	2294992794.86	2294992797.47	.19095427E 01
020107.50	2294992793.00	2294992795.20	.19108667E 01
020108.50	2294992790.17	2294992792.95	.19121973E 01
020109.50	2294992789.37	2294992790.69	.19135301E 01
020110.50	2294992785.58	2294992788.42	.19148628E 01
020111.50	2294992782.83	2294992786.16	.19162021E 01
020112.50	2294992780.11	2294992783.91	.19175436E 01
020113.50	2294992773.39	2294992781.64	.19188873E 01
020114.50	2294992776.70	2294992779.37	.19202353E 01
020115.50	2294992775.05	2294992777.11	.19215855E 01
020116.50	2294992775.42	2294992774.84	.19229401E 01
020117.50	2294992779.81	2294992772.59	.19242990E 01
020118.50	2294992771.22	2294992770.33	.19256580E 01
020119.50	2294992768.67	2294992768.06	.19270235E 01
020120.50	2294992766.12	2294992765.80	.19283889E 01
020121.50	2294992763.62	2294992763.53	.19297610E 01
020122.50	2294992761.16	2294992761.27	.19311352E 01
020123.50	2294992761.69	2294992759.00	.19325115E 01
020124.50	2294992760.25	2294992756.73	.19338901E 01
020125.50	2294992757.84	2294992754.48	.19352752E 01
020126.50	2294992756.47	2294992752.22	.19366625E 01
020127.50	2294992753.12	2294992749.95	.19380542E 01
020128.50	2294992750.78	2294992747.69	.19394480E 01
020129.50	2294992749.48	2294992745.42	.19408462E 01
020130.50	2294992748.22	2294992743.16	.19422466E 01
020131.50	2294992743.97	2294992740.89	.19436513E 01
020132.50	2294992742.73	2294992738.62	.19450583E 01
020133.50	2294992739.55	2294992736.36	.19464695E 01
020134.50	2294992736.37	2294992734.09	.19478852E 01
020135.50	2294992735.23	2294992731.83	.19493030E 01
020136.50	2294992732.12	2294992729.56	.19507252E 01
020137.50	2294992728.02	2294992727.28	.19521496E 01
020138.50	2294992727.95	2294992725.02	.19535783E 01
020139.50	2294992724.94	2294992722.75	.19550114E 01
020140.50	2294992722.92	2294992720.48	.19564467E 01
020141.50	2294992721.94	2294992718.22	.19578863E 01
020142.50	2294992719.97	2294992715.95	.19593282E 01
020143.50	2294992718.06	2294992713.69	.19607765E 01
020144.50	2294992718.16	2294992711.42	.19622249E 01
020145.50	2294992713.28	2294992709.14	.19636776E 01
020146.50	2294992707.44	2294992706.87	.19651369E 01
020147.50	2294992704.62	2294992704.61	.19665984E 01
020148.50	2294992702.83	2294992702.34	.19680598E 01
020149.50	2294992704.08	2294992700.08	.19695300E 01
020150.50	2294992700.34	2294992697.80	.19710024E 01
020151.50	2294992696.66	2294992695.53	.19724791E 01
020152.50	2294992695.97	2294992693.27	.19739580E 01
020153.50	2294992693.33	2294992691.00	.19754413E 01
020154.50	2294992691.72	2294992688.72	.19769289E 01
020155.50	2294992686.12	2294992686.45	.19784187E 01
020156.50	2294992684.56	2294992684.19	.19799129E 01
020157.50	2294992682.03	2294992681.91	.19814114E 01

Table 83 (contd)

GMT	AUX OSC FREQUENCY EXTRAPOLATED	R DOT KM/SEC
020157.50	2294992681.91	.19813962E 01
020158.50	2294992679.64	.19825370E 01
020159.50	2294992677.37	.19836778E 01
020200.50	2294992675.09	.19729284E 01
020201.50	2294992672.83	.19472919E 01
020202.50	2294992670.56	.19203466E 01
020203.50	2294992668.28	.18923542E 01
020204.50	2294992666.02	.18626670E 01
020205.50	2294992663.73	.18314115E 01
020206.50	2294992661.47	.17989803E 01
020207.50	2294992659.19	.17656329E 01
020208.50	2294992656.92	.17318951E 01
020209.50	2294992654.66	.16978977E 01
020210.50	2294992652.37	.16635055E 01
020211.50	2294992650.11	.16283324E 01
020212.50	2294992647.83	.15930262E 01
020213.50	2294992645.56	.15568061E 01
020214.50	2294992643.28	.15201934E 01
020215.50	2294992641.00	.14829284E 01
020216.50	2294992638.73	.14448804E 01
020217.50	2294992636.45	.14059163E 01
020218.50	2294992634.19	.13660381E 01
020219.50	2294992631.91	.13252461E 01
020220.50	2294992629.64	.12831496E 01
020221.50	2294992627.36	.12398730E 01
020222.50	2294992625.08	.11954230E 01
020223.50	2294992622.81	.11497994E 01
020224.50	2294992620.53	.11033883E 01
020225.50	2294992618.25	.10555420E 01
020226.50	2294992615.98	.10066530E 01
020227.50	2294992613.70	.95697662E 00
020228.50	2294992611.42	.90612450E 00
020229.50	2294992609.16	.85370840E 00
020230.50	2294992606.87	.80011441E 00
020231.50	2294992604.59	.74560428E 00
020232.50	2294992602.31	.68952800E 00
020233.50	2294992600.05	.63227819E 00
020234.50	2294992597.77	.57293654E 00
020235.50	2294992595.48	.51267874E 00
020236.50	2294992593.20	.45072392E 00
020237.50	2294992590.92	.38720075E 00
020238.50	2294992588.66	.32263712E 00
020239.50	2294992586.37	.25728387E 00
020240.50	2294992584.09	.19180410E 00
020241.50	2294992581.81	.13050147E 00
020242.50	2294992579.53	.11478973E 00
020243.50	2294992577.25	.15015260E 00
020244.50	2294992574.97	.15377352E 00

STANDARD DEVIATION OF FIT CURVE 2.74
A=.0000959 B=-2.214 C=334.74
AVERAGE OF ACTUAL FREQUENCY 2294993015.34
AVERAGE OF EXTRAPOLATED FREQUENCY 2294992628.33
TOTAL FREQUENCY AVERAGE 2294992961.66

5. *Spacecraft predictions*

a. Types of predictions. Spacecraft predictions, which are composed of time-tagged station observables such as pointing angles, one-way doppler, two-way doppler, best lock ground transmitter frequency, etc., are more or less routinely provided to the DSN tracking stations to ensure the success of spacecraft acquisitions, aided track, and station handovers of the spacecraft. However, during the launch phase the provision of accurate predictions to DSS 72 and DSS 51 and other tracking stations becomes a critical matter because of the crucial need for early acquisition and commanding of the spacecraft. For first two-way acquisition at DSS 72 and DSS 51 there are three distinct sets of predictions available: 1) Preflight Prediction Document, 2) $L - 5$ m predictions based on actual launch azimuth, and 3) AFETR predictions based on actual post-injection tracking data.

Although both the preflight predictions and $L - 5$ min predictions are generated before launch, the $L - 5$ min predictions have two important advantages over the preflight predictions in that they are based on updated frequency information and they are generated for the exact actual launch azimuth. Because of these two factors the $L - 5$ min predictions were generated and sent to DSS 72 and DSS 51, with the advisement that they be used instead of the Preflight Prediction Document. Because of the special nature of the July 14 launch window (it had an extremely short duration) a 30-s hold occurred between $T - 5$ min and launch, thus causing a 30-s time error in the $L - 5$ min predictions (although the launch azimuth remained exact); DSS 72 and DSS 51 were notified of this and were instructed to make the appropriate time bias to their $L - 5$ min predict sets. DSS 72 acknowledged receipt of the $L - 5$ min predicts approximately 10 min before rise and were able to successfully acquire *Surveyor IV* using these predicts. At about $L + 20$ min, predicts from AFETR based on actual post-injection tracking data were received at JPL which very closely matched the $L - 5$ min predict set (corrected for the 30-s time bias), thereby verifying that DSS 72 and DSS 51 predicts to acquire *Surveyor IV* in the three-way mode with DSS 72, with no difficulties being encountered.

During the cruise phase, predictions were routinely supplied to all participating DSS stations. No problems were encountered in the generation of accurate (trajectory-wise) predictions, although moderate errors were introduced into the ground transmitter VCO prediction (X_A) and the one-way doppler prediction (D1) because of the inadequacy of frequency data and temperature predictions as supplied by Hughes Aircraft Company.

b. Initial two-way acquisition at DSS 72. Predictions indicated a *Surveyor IV* rise at DSS 72 at 12:09:45 GMT, on July 14. DSS 72 reported one-way doppler at 12:10:03 (rise + 00:18), auto-track on the SAA at 12:11:04 (rise + 01:19), auto-track on the SCM, the antenna main beam, at 12:13:48 (rise + 04:03) and good two way data at 12:16:23 (rise + 06:38). The above sequence, culminating in the acquisition of good, two-way doppler data, was, in light of previous experience with the current acquisition procedure, smooth and quite nominal. For instance, during the initial acquisition of *Surveyor III* at DSS 42, good two-way data was taken at rise + 06:55. The acquisition was marred, however, by the loss of up-link at 12:17:03, which was subsequently reacquired at 12:21:46. The loss appears to have been caused by an antenna malfunction wherein the antenna temporarily *drove off* the spacecraft azimuth. The actual azimuth at DSS 72 during this period can be seen plotted against the predicted azimuth in Fig. 161. The DSS 72 tracking data between 12:17:03 and 12:20:53 is labeled as good (in lock), two-way data, when it was, in fact, good, one-way data. Investigation of the predictions indicate that at 12:17:00, the one-way doppler (which is a strongly-dependent function of the ground VCO frequency) and the two-way doppler were almost identical—hence a possible explanation why the down link was not lost and why it was not immediately recognized at DSS 72 that the up-link had been lost.

All two-way tracking data taken during the *Surveyor IV* mission was computer monitored in near real time, which resulted in the timely discovery of a faulty bit in the doppler counter during the first pass of DSS 61, and the immediate discovery of the intermittent lost digit in the doppler counter during the second pass at DSS 11.

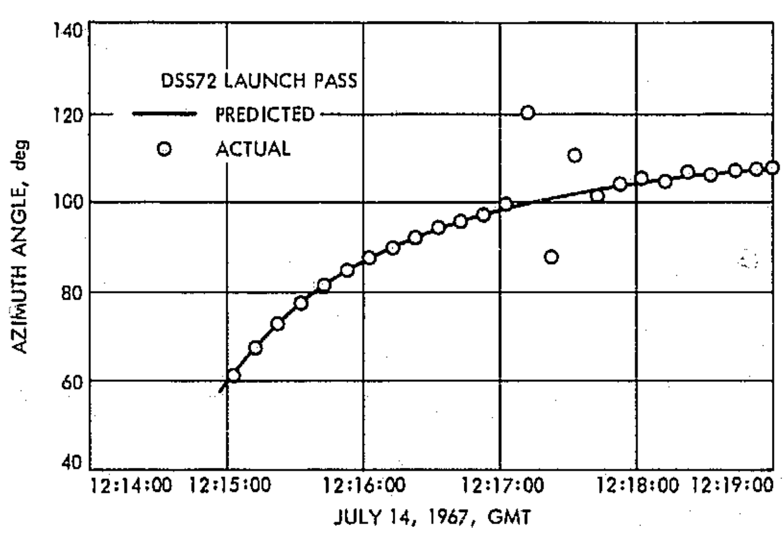


Fig. 161. Predicted vs azimuth, DSS 72

6. *Tracking performance*

a. General. The DSN provided continuous angular and doppler tracking of the *Surveyor IV* spacecraft from initial one-way acquisition by DSS 72 at 12:10:03 on July 14, 1967 until loss of signal during the retro phase, at 02:02:41.001 on July 17. In general the overall quality of the tracking data taken during the *Surveyor IV* mission can be described as very good. Data types used during flight in the ODP were angular data taken during the first pass over DSS 72 and DSS 51, two-way doppler data taken during the first pass over DSS 72 and DSS 61, and two-way doppler taken during all passes over DSSs 42, 51, and 11. A summary of the data used in the ODP, together with data statistics, is given in Table 84. The relative quality of the tracking data taken at each station can be obtained by comparing the standard deviations, the root-mean-squares, and the first moments of the data as listed in the table. Changes in the quality of the same data as reflected in different orbits are largely attributable to the particular selection criteria of each orbit is determined by the Orbit Determination Group. Orbit identifications are as follows:

Predict orbit	= PROR
Injection condition evaluation orbit	= ICEV
Preliminary pre-midcourse orbit	= PREL
Data consistency orbit	= DACO
Nominal midcourse orbit	= NOMA
Last pre-midcourse orbit	= LAPM
Pre-midcourse cleanup orbit	= PRCL
Post flight analysis orbit	= POST
N^{th} post midcourse orbit	= N POM
Final in-flight orbit	= FINAL
Computer string X	= X
Computer string Y	= Y

In general, DSIF station operations during the *Surveyor IV* mission were effectively implemented. This is best judged by the fact that the DSN was able to provide high quality data to the Orbit Determination Group such that they were able to meet all orbital accuracy requirements for such events as the Midcourse Maneuver, Retro Motor Ignition backup, etc. From the time of first acquisition of the spacecraft over DSS 72 until the time of loss-of-signal, the spacecraft was almost continuously in two-way lock, and station transfers were rapid and efficiently executed. During the first pass of *Surveyor IV*, a gap in coverage of about 5 min occurred between DSS 51 set and DSS 11 rise. DSS 72 filled the gap by taking one-way doppler data; however, this necessitated an initial two-way acquisition at DSS 11. Predictions indicated a *Surveyor IV* rise (first pass) at DSS 11 at 23:12:34 on July 14. DSS 11 did not acquire the spacecraft until 23:36:02, or approximately rise + 24 min. This unnecessarily long time in the acquisition of *Surveyor IV* by DSS 11 is in large part due to the failure of DSS 11 to use the standard acquisition procedure. Had DSS 11 used the standard acquisition procedure, this acquisition would probably have been completed within 10 min.

The most serious loss of two-way doppler data during the *Surveyor IV* mission occurred during the first pass at DSS 61. DSS 61 began taking two-way doppler data at 17:03:02 on July 14 and approximately 20 min later the results of the data monitor program indicated excessive noise in the DSS 61 doppler data. The problem was traced to a dropped 8 bit in the least significant digit of the doppler counter. A transfer to DSS 51 could not be effected until 18:30:00 on July 14, at which time DSS 51 reacquired good two-way doppler data. This problem at DSS 61, which resulted in the loss of approximately 1½ h of two-way doppler parallels almost exactly the problem which occurred during the first pass of DSS 61 of the *Surveyor III* mission.

Minor losses of data occurred during the initial acquisition at DSS 72, when a loss of the up-link was responsible for a 10-min loss of prime early data, and during the second pass at DSS 11, when an intermittent loss of the most significant digit of the doppler counter accounted for a 30-min loss of data. The resultant effect from these data losses on the mission was negligible.

b. Pre-midcourse phase.

Angular tracking. In general, doppler data yields far greater accuracy in the determination of a spacecraft orbit than does angular data and is therefore used almost exclusively in the orbit determination process during most of the mission. The one exception is the launch phase, when little doppler data is available and a quick determination of the orbit necessitates the use of both doppler and angle data. During the *Surveyor IV* mission, angle data from DSS 72 and DSS 51 was used in the orbit determination program during the pre-midcourse phase of the mission. In order to improve the quality of the angular data to be used in the orbit determination program, it is first corrected for OPE. The OPE is determined by having the DSS stations optically track several stars at the expected,

Table 84. Premaneuver DSIF tracking data used in *Surveyor IV* orbit computations

Orbit identification	DSS	Data type	Beginning data (month/day-GMT)	End data (month/day-GMT)	No. of points	Standard deviation	Root mean square	Mean error	Sample rate, s
AFETR X	91	Az	7/14-12:05:12	7/14-12:06:18	10	0.0126	0.0217	0.0177	6
		El	7/14-12:05:12	7/14-12:06:06	9	0.0139	0.0298	−0.0263	6
		Range	7/14-12:05:12	7/14-12:06:18	9	0.00343	0.00906	0.00839	6
	77	Az	7/14-12:05:15	7/14-12:05:33	4	0.0198	0.0928	−0.0906	6
		El	7/14-12:05:15	7/14-12:05:33	4	0.123	0.446	0.428	6
		Range	7/14-12:05:15	7/14-12:05:33	4	0.0487	0.111	−0.0999	6
PROR YA	72	CC3	7/14-12:26:08	7/14-13:04:32	118	0.136	0.144	−0.0478	10
		Az	7/14-12:16:23	7/14-13:17:02	149	0.0223	0.0292	−0.0189	10
		El	7/14-12:16:23	7/14-13:17:02	154	0.0323	0.0367	0.0174	10
	51	HA	7/14-12:42:11	7/14-13:04:02	35	0.0175	0.0202	−0.0100	60
		Dec	7/14-12:42:11	7/14-13:04:02	35	0.00456	0.0141	−0.0133	60
		CC3	7/14-13:14:32	7/14-13:16:32	3	0.0392	0.179	−0.174	60
		HA	7/14-13:14:02	7/14-13:17:02	4	0.00102	0.00905	−0.00900	60
		Dec	7/14-13:14:02	7/14-13:17:02	4	0.00240	0.00255	−0.000865	60
PROR XA	72	CC3	7/14-12:26:08	7/14-13:04:32	113	0.0926	0.0944	−0.0183	10
		Az	7/14-12:26:53	7/14-13:37:02	135	0.0186	0.0386	−0.0338	10
		El	7/14-12:26:53	7/14-13:37:02	134	0.0239	0.0454	0.0387	10
	51	HA	7/14-12:42:11	7/14-13:04:02	152	0.0114	0.0181	0.0140	60
		Dec	7/14-12:42:11	7/14-13:04:02	152	0.0136	0.0217	−0.0169	60
		CC3	7/14-13:14:32	7/14-13:35:32	18	0.0744	0.0744	0.00255	60
		HA	7/14-13:14:02	7/14-13:36:02	19	0.00283	0.0182	0.0180	60
		Dec	7/14-13:17:02	7/14-13:36:02	19	0.00147	0.00330	−0.00295	60
ICEV YA	72	CC3	7/14-12:26:08	7/14-13:04:32	115	0.0797	0.0801	−0.00810	10
		Az	7/14-12:26:53	7/14-14:16:02	182	0.0177	0.0332	−0.0280	10
		El	7/14-12:26:53	7/14-14:16:02	182	0.0227	0.0482	0.0425	10
	51	CC3	7/14-13:14:32	7/14-14:14:32	61	0.0259	0.0262	−0.00382	60
		HA	7/14-12:42:11	7/14-14:15:02	97	0.0111	0.0128	0.00641	60
		Dec	7/14-12:42:11	7/14-14:15:02	97	0.00912	0.0103	0.00479	60
ICEV XA	72	CC3	7/14-12:26:08	7/14-13:04:32	110	0.0353	0.0355	−0.00400	10
		Az	7/14-12:26:53	7/14-14:16:02	165	0.0169	0.0372	−0.0332	10
		El	7/14-12:26:53	7/14-14:16:02	164	0.0238	0.0513	0.0455	10
	51	HA	7/14-12:18:51	7/14-12:26:21	28	0.00559	0.0355	0.0351	60
		Dec	7/14-12:18:51	7/14-12:26:21	27	0.00689	0.0351	−0.0344	60
		CC3	7/14-13:18:32	7/14-14:15:32	53	0.0293	0.0294	0.00254	60
		HA	7/14-12:26:31	7/14-14:16:02	180	0.0102	0.0195	0.0166	60
		Dec	7/14-12:26:31	7/14-14:16:02	180	0.0157	0.0189	−0.0106	60
PREL XB	72	CC3	7/14-12:26:48	7/14-13:04:32	101	0.0212	0.0212	−0.000387	10
	51	CC3	7/14-13:18:32	7/14-15:24:32	115	0.00725	0.00729	−0.000713	60
PREL YB	72	CC3	7/14-12:26:48	7/14-13:04:32	96	0.0208	0.0208	0.0000509	10
	51	CC3	7/14-13:18:32	7/14-16:13:32	164	0.00775	0.00776	−0.000408	60
DACO XB	51	CC3	7/14-13:18:32	7/14-16:59:32	199	0.0514	0.0514	−0.0000810	60

Table 84 (contd)

Orbit identification	DSS	Data type	Beginning data (month/day-GMT)	End data (month/day-GMT)	No. of points	Standard deviation	Root mean square	Mean error	Sample rate, s
DACO XB	61	CC3	7/14-12:26:48	7/14-13:04:32	96	0.0207	0.0207	−0.000346	60
DACO YB	51	CC3	7/14-12:26:48	7/14-16:58:32	205	0.00788	0.00788	−0.000119	60
	61	CC3	7/14-17:03:32	7/14-17:46:32	33	0.0190	0.0190	−0.000163	60
DACO YC	72	CC3	7/14-12:26:48	7/14-13:04:32	96	0.0268	0.0273	0.00545	10
	51	CC3	7/14-13:18:32	7/14-16:58:32	205	0.0104	0.0134	−0.00837	60
	51	CC3	7/14-18:33:32	7/14-20:27:32	61	0.0102	0.0103	−0.00183	60
	61	CC3	7/14-17:03:32	7/14-18:23:32	39	0.0135	0.0342	0.0314	60
DACO XF	72	CC3	7/14-12:26:48	7/14-13:04:32	96	0.0208	0.0208	0.00107	10
	51	CC3	7/14-13:18:32	7/14-16:58:32	205	0.00928	0.00931	0.000724	60
	51	CC3	7/14-18:33:32	7/14-22:24:32	145	0.00837	0.00843	−0.00099	60
DACO XH	11	CC3	7/14-23:38:32	7/14-23:57:32	20	0.00824	0.0209	−0.0193	60
	51	CC3	7/14-13:18:32	7/14-16:38:32	205	0.0106	0.0108	−0.00201	60
	51	CC3	7/14-18:33:32	7/14-23:04:32	172	0.00767	0.00771	−0.000713	60
NOMA YA	11	CC3	7/14-23:38:32	7/14-00:42:32	65	0.00958	0.0118	0.00684	60
	13	CC3	7/14-12:26:48	7/14-13:04:32	96	0.0358	0.0368	0.00838	60
	51	CC3	7/14-13:18:32	7/14-16:58:32	205	0.0108	0.0111	−0.00231	60
	51	CC3	7/14-18:33:32	7/14-23:04:32	215	0.00809	0.00809	−0.000357	60
NOMA YD	72	CC3	7/14-12:28:08	7/14-13:04:32	95	0.0308	0.0324	0.0100	10
	42	CC3	7/14-23:38:32	7/15-11:30:32	373	0.00840	0.00842	−0.000586	60
	51	CC3	7/14-13:18:32	7/14-16:58:32	205	0.0114	0.0118	−0.00301	60
	51	CC3	7/14-18:33:32	7/14-23:04:32	215	0.00860	0.00867	0.00109	60
NOMA YE	72	CC3	7/14-12:28:08	7/14-13:04:32	95	0.0262	0.0268	0.00599	10
	11	CC3	7/14-23:38:32	7/15-04:56:32	317	0.00782	0.0101	0.00644	60
	42	CC3	7/15-05:13:32	7/15-11:30:32	373	0.00707	0.0114	0.00899	60
NOMA YF	72	CC3	7/14-12:28:08	7/14-13:04:32	95	0.0316	0.0340	0.0125	10
	11	CC3	7/14-23:38:32	7/15-04:56:32	317	0.00822	0.00895	0.00354	60
	42	CC3	7/15-05:13:32	7/15-13:15:32	478	0.00786	0.00795	−0.00121	60
	51	CC3	7/14-13:18:32	7/14-16:58:32	205	0.0115	0.0126	−0.00504	60
	51	CC3	7/14-18:33:32	7/14-23:04:32	215	0.00839	0.00854	0.00158	60
LAPM XA	42	CC3	7/15-08:00:32	7/15-13:59:32	355	0.00700	0.00712	−0.00131	60
	51	CC3	7/15-14:15:32	7/15-19:59:32	324	0.00762	0.00787	−0.00197	60
LAPM YB	72	CC3	7/14-12:28:08	7/14-13:04:32	95	0.0292	0.0299	0.00652	10
	11	CC3	7/14-23:38:32	7/15-04:56:32	299	0.00815	0.00817	−0.000523	60
	42	CC3	7/15-05:13:32	7/15-13:59:32	519	0.00689	0.00700	−0.00126	60
	51	CC3	7/14-14:00:32	7/14-16:58:32	162	0.0102	0.0103	−0.00134	60
	51	CC3	7/14-18:33:32	7/14-23:04:32	220	0.00910	0.00948	−0.00265	60
	51	CC3	7/15-14:15:32	7/15-21:58:32	425	0.00881	0.00885	−0.000793	60
LAPM XC	42	CC3	7/15-08:00:32	7/15-13:59:32	355	0.00719	0.00719	−0.000287	60
	51	CC3	7/15-14:15:32	7/15-21:53:32	429	0.0133	0.0133	0.000228	60
LAPM XE	42	CC3	7/15-08:00:32	7/15-13:59:32	355	0.00711	0.00711	−0.00217	60
	51	CC3	7/15-14:15:32	7/15-22:29:32	441	0.00730	0.00730	0.000117	60

Table 84 (contd)

Orbit identification	DSS	Data type	Beginning data (month/day-GMT)	End data (month/day-GMT)	No. of points	Standard deviation	Root mean square	Mean error	Sample rate, s
LAPM YC	72	CC3	7/14-12:28:08	7/14-13:04:32	95	0.0288	0.0296	0.00707	10
	11	CC3	7/14-23:38:32	7/15-04:56:32	299	0.00805	0.00810	0.000873	60
	42	CC3	7/15-05:13:32	7/15-13:59:32	519	0.00694	0.00694	−0.000270	60
	51	CC3	7/14-14:00:32	7/14-16:58:32	162	0.0105	0.0105	0.000193	60
	51	CC3	7/14-18:33:32	7/14-23:04:32	220	0.00967	0.00997	−0.002243	60
	51	CC3	7/15-14:15:32	7/15-22:50:32	454	0.00917	0.00931	0.00158	60
1 POM YC	11	CC3	7/16-02:30:19	7/16-02:40:19	50	0.0498	0.0508	−0.0101	10
	11	CC3	7/16-02:43:32	7/16-05:53:32	149	0.00662	0.00666	0.000670	60
	42	CC3	7/16-06:03:32	7/16-09:01:32	166	0.00711	0.00711	−0.0000287	60
1 POM XE	11	CC3	7/16-02:30:19	7/16-02:40:19	50	0.0498	0.0511	−0.0166	10
	11	CC3	7/16-02:43:32	7/16-05:53:32	148	0.0067	0.00672	0.000576	60
	42	CC3	7/16-06:03:32	7/16-10:13:32	235	0.00715	0.00715	0.0000291	60
1 POM YE	11	CC3	7/16-02:30:19	7/16-02:40:19	49	0.0516	0.0539	−0.0156	10
	11	CC3	7/16-02:43:32	7/16-05:53:32	149	0.00690	0.00690	0.00109	60
	42	CC3	7/16-06:03:32	7/16-10:34:32	256	0.00718	0.00718	0.0000057	60
1 POM XF	11	CC3	7/16-02:30:19	7/16-02:40:19	50	0.0498	0.0512	−0.0117	10
	11	CC3	7/16-02:43:32	7/16-05:53:32	148	0.00669	0.00671	0.000610	60
	42	CC3	7/16-06:03:32	7/16-11:39:32	315	0.00723	0.00723	−0.0000093	60
2 POM XA	11	CC3	7/16-02:30:19	7/16-02:40:19	48	0.0507	0.0530	−0.0155	10
	11	CC3	7/16-02:43:32	7/16-05:53:32	148	0.00682	0.00689	0.00101	60
	42	CC3	7/16-06:03:32	7/16-12:18:32	353	0.00728	0.00728	0.0000145	60
2 POM YA	11	CC3	7/16-02:30:19	7/16-02:40:19	49	0.0517	0.0543	−0.0168	10
	11	CC3	7/16-02:43:32	7/16-05:53:32	149	0.00689	0.00698	0.00116	60
	42	CC3	7/16-06:03:32	7/16-14:09:32	462	0.00725	0.00725	0.00000766	60
2 POM XC	11	CC3	7/16-02:30:19	7/16-02:40:19	48	0.0508	0.0532	−0.0159	10
	11	CC3	7/16-02:43:32	7/16-05:53:32	148	0.00684	0.00690	0.000958	60
	42	CC3	7/16-06:03:32	7/16-13:39:32	428	0.00721	0.00721	−0.0000074	60
2 POM YC	11	CC3	7/16-02:30:24	7/16-02:40:19	48	0.0509	0.0550	−0.0208	10
	11	CC3	7/16-02:43:32	7/16-05:53:32	149	0.00668	0.00674	0.000927	60
	42	CC3	7/16-06:03:32	7/16-14:53:32	505	0.00722	0.00722	0.000220	60
	51	CC3	7/16-15:03:32	7/16-16:42:32	90	0.00754	0.00757	−0.000677	60
3 POM YA	11	CC3	7/16-02:30:24	7/16-02:40:19	48	0.0508	0.0549	−0.0208	10
	11	CC3	7/16-02:43:32	7/16-05:53:32	149	0.00669	0.00673	0.000749	60
	42	CC3	7/16-06:03:32	7/16-14:53:32	505	0.00722	0.00723	0.000369	60
	51	CC3	7/16-15:03:32	7/16-20:20:32	291	0.00731	0.00732	−0.000343	60
3 POM YC	11	CC3	7/16-02:30:24	7/16-02:40:19	48	0.0509	0.0550	−0.0208	10
	11	CC3	7/16-02:43:32	7/16-05:53:32	149	0.00666	0.00668	0.000495	60
	42	CC3	7/16-06:03:32	7/16-14:53:32	505	0.00722	0.00723	0.000421	60
	51	CC3	7/16-15:03:32	7/16-21:39:32	352	0.00815	0.00816	−0.000248	60
3 POM XB	11	CC3	7/16-02:30:24	7/16-02:40:19	52	0.0590	0.0638	−0.0242	10
	11	CC3	7/16-02:43:32	7/16-05:53:32	148	0.00663	0.00671	0.000985	60

Table 84 (contd)

Orbit identification	DSS	Data type	Beginning data (month/day-GMT)	End data (month/day-GMT)	No. of points	Standard deviation	Root mean square	Mean error	Sample rate, s
3 POM XB	42	CC3	7/16-06:03:32	7/16-14:53:32	501	0.00726	0.00727	0.000526	60
	51	CC3	7/16-15:03:32	7/16-21:39:32	356	0.00775	0.00777	−0.000453	60
3 POM YD	11	CC3	7/16-02:30:24	7/16-02:40:19	48	0.0508	0.0552	−0.0216	10
	11	CC3	7/16-02:43:32	7/16-05:53:32	149	0.00708	0.00711	0.000601	60
	42	CC3	7/16-06:03:32	7/16-14:53:32	505	0.00751	0.00751	0.0000147	60
	51	CC3	7/16-15:03:32	7/16-22:38:32	418	0.00942	0.00942	0.000239	60
FINAL XA	51	CC3	7/16-20:21:32	7/16-22:06:32	80	0.00696	0.00696	0.0000641	60
FINAL XD	11	CC3	7/16-23:33:32	7/16-23:54:32	22	0.00557	0.00558	0.000139	60
	51	CC3	7/16-20:21:32	7/16-23:23:32	174	0.00738	0.00738	−0.0000182	60
FINAL YA	11	CC3	7/16-23:33:32	7/17-00:10:32	29	0.00724	0.00724	0.0000210	60
	51	CC3	7/16-20:21:32	7/16-23:23:32	171	0.00742	0.00742	0.000124	60
FINAL XE	11	CC3	7/16-23:33:32	7/17-00:13:32	32	0.00770	0.00770	0.00000381	60
	51	CC3	7/16-20:21:32	7/16-23:23:32	174	0.00736	0.00736	−0.0000982	60
FINAL YB	11	CC3	7/16-23:33:32	7/17-00:22:32	41	0.00841	0.00841	0.000134	60
	51	CC3	7/16-20:21:32	7/16-23:23:32	171	0.00743	0.00743	−0.00002	60
FINAL YC	11	CC3	7/16-23:33:32	7/17-00:37:32	56	0.00771	0.00771	0.000142	60
	51	CC3	7/16-20:21:32	7/16-23:23:32	171	0.00741	0.00741	−0.0000514	60
FINAL XH	11	CC3	7/16-23:33:32	7/17-00:58:32	72	0.00814	0.00814	0.0000559	60
	51	CC3	7/16-20:21:32	7/16-23:23:32	174	0.00735	0.00735	−0.0000379	60
FINAL YE	11	CC3	7/16-23:33:32	7/17-01:01:32	75	0.00840	0.00840	0.0000309	60
	51	CC3	7/16-20:21:32	7/16-23:23:32	171	0.00740	0.00740	0.00000428	60
FINAL YF	11	CC3	7/16-23:33:32	7/17-01:15:32	87	0.00989	0.00990	0.000281	60
	51	CC3	7/16-20:21:32	7/16-23:23:32	171	0.00744	0.00744	−0.000136	60
POST 1	11	CC3	7/16-02:30:24	7/16-02:40:19	52	0.0590	0.0647	−0.0267	10
	11	CC3	7/16-02:43:32	7/16-05:53:32	149	0.00787	0.00793	0.000957	60
	11	CC3	7/16-23:33:32	7/17-01:16:32	88	0.0105	0.0106	0.000610	60
	42	CC3	7/16-06:03:32	7/16-14:53:32	505	0.00796	0.00796	−0.000198	60
	51	CC3	7/16-15:03:32	7/16-23:23:32	462	0.00964	0.00965	0.000420	60

mission dependent, spacecraft declinations. A polynomial curve fit is then made to the differences between the refraction corrected Ephemeris values of the star positions and the observed values as read from the antenna angle encoders. The correction coefficients used in the *Surveyor IV* mission inflight orbit computations can be seen in Table 85.

Experience gained in past missions has shown that the OPE correction coefficients do not remove all systematic pointing errors. This is reasonable since the RF and optical axis of the antenna are not necessarily the same. That is, the RF axis is a function of the position of the quadripod feed, whereas the optical axis is not. Thus, if there is a quadripod deflection (due to thermal effect and/or gravitational loading) at some given instant of time, the optical error and the RF error would not be the same. Furthermore, the optical refraction and the RF refraction are not the same due to the difference in respective wavelengths. In addition to these effects, the RF pointing error is also a function of feed alignment, received signal-to-noise ratio, and received polarization angle (since the antenna null pattern does not have the same slope at all polarization angles).

Since DSS 72 was the initial acquisition station, the angular data taken by it was the most important angular data for use in the early orbits. This data, when fit through the final post flight orbit, shows a bias of +0.046 deg in

Table 85. *Surveyor IV* antenna correction coefficients

Coefficient	Correction	Coefficient	Correction
A_{00}	−2.823094562E − 02	B_{00}	1.529098827E − 02
A_{01}	5.353777033E − 05	B_{01}	3.410829831E − 04
A_{02}	−3.082597437E − 05	B_{02}	−4.336071801E − 06
A_{03}	−6.626461141E − 07	B_{03}	6.109815447E − 07
A_{10}	−3.171398689E − 04	B_{10}	−1.559484352E − 04
A_{11}	9.542137245E − 06	B_{11}	−2.032267916E − 06
A_{12}	−3.367726933E − 07	B_{12}	5.779247847E − 08
A_{13}	−8.201321554E − 09	B_{13}	−2.831355530E − 10
A_{20}	1.589100967E − 06	B_{20}	−1.186130483E − 05
A_{21}	1.835756063E − 07	B_{21}	−5.239010283E − 08
A_{22}	3.851291638E − 09	B_{22}	−2.152496155E − 10
A_{23}	−8.191144217E − 11	B_{23}	−4.436567279E − 11
A_{30}	4.599327736E − 08	B_{30}	−2.298149026E − 08
A_{31}	3.344301616E − 09	B_{31}	8.193320409E − 10
A_{32}	1.386713245E − 10	B_{32}	−1.910069905E − 11
A_{33}	1.816077278E − 12	B_{33}	−7.276751867E − 13

[a]These corrections are useful for elevations greater than 15 deg, and declinations between N 30 and S 35 deg.

azimuth and +0.097 deg in elevation. Based on these biases the DSS 72 angle data can be judged quite poor, a conclusion more easily appreciated in light of the fact that the azimuth angle standard deviation was 0.210 deg. This angular data matches the very poor angular data taken by DSS 72 during their first pass of *Surveyor III*, in contrast to the better angular data taken by DSS 72 on AC-9 and *Surveyor II*. DSS 72 angular residuals are presented in Figs. 162–164. First pass angular data from DSS 51, Figs. 165 and 166, when fit through the final post flight orbit, shows biases of +0.028 deg in HA and −0.018 deg in Dec. These values are consistent with the Orbit Determination Group study of DSS 51 correction coefficients and also correlate well with past experience on the *Surveyor* Project. For instance the DSS 51 HA and Dec biases averaged over AC-9, *Surveyor II*, and *Surveyor III* were +0.028 and −0.020 deg, respectively. DSS 51 angular residuals can be seen in Figs. 167 and 168. Finally, it should be noted that efforts are under way to use RF sources (post touchdown *Surveyor* data) to generate new, and hopefully more accurate, correction coefficients.

Doppler tracking. Ascension Island DSS 72, the first prime station to see the spacecraft after injection, began taking good two-way, 10-s count doppler data at 12:16:23 on July 14, 1967. However, two-way lock was lost at 12:17:03 and was not recovered until 12:25:54. At this time DSS 72 returned to taking good 10-s count two-way doppler data. The sample rate was changed to 60 s at 12:45:02 and the spacecraft was transferred to DSS 51 at 13:11:02. This early data from DSS 72 was quite acceptable, showing a standard deviation of 0.026 Hz. The two-way doppler residuals for this initial pass over DSS 72 may be seen in Fig. 162, while three-way doppler residuals from DSS 72 are seen in Figs. 163 and 164. DSS 51 returned good 60-s count two-way doppler from 13:11:02 to 17:00:02 and from 18:30:02 to 23:05:02, on July 14, 1967. The first pass data from DSS 51 showed a standard deviation of 0.009 Hz—a quite nominal figure for this period. On the second pass DSS 51 did slightly better, showing a standard deviation of 0.007 Hz. First pass two-way doppler residuals from DSS 51 are seen in Figs. 165 and 166, while second pass residuals are seen in Figs. 169 and 170. As was already mentioned, a malfunction of the DSS 61 doppler counter caused the two-way doppler data from 17:00:02 to 18:30:02 to be bad. This data can be seen in Fig. 171. Three-way doppler data taken during the first pass at DSS 61 can be seen in Fig. 172, while three-way doppler data taken during the second pass at DSS 61 is presented in Fig. 173. Both DSS 11 and DSS 42 took very good two-way doppler data during their pre-midcourse passes. Two-way doppler data from DSS 11 showed a standard deviation of 0.008 Hz and can be seen in Figs. 174 and 175. DSS 42 two-way doppler showed a standard deviation of 0.007 Hz and is presented in Figs. 176 and 177, while Fig. 178 shows three-way doppler and angles taken at DSS 42.

c. Midcourse maneuver. Early analysis of the *Surveyor IV* trajectory indicated a midcourse maneuver during the second pass over DSS 11 would be most advantageous, and therefore, the midcourse maneuver was executed during this pass. Engine ignition was programmed for July 16, at 02:30:00 GMT, with a total burn time of 10.46 s. Results of the maneuver as seen in the two-way doppler data over DSS 11 are presented in Fig. 179. As can be seen in the data, the midcourse maneuver resulted in a doppler shift over DSS 11 of approximately +76.1 Hz.

d. Post-midcourse phase. All post-midcourse orbit computations used only two-way doppler from the prime stations, DSS 11, DSS 42, and DSS 51. Very good two-way doppler data was obtained throughout the post midcourse phase without exception. The doppler data from all stations indicated a standard deviation of 0.007 Hz during this period, and any biases in the data were miniscule.

Goldstone DSS 11 residuals during the post-midcourse phase are shown in Figs. 180 and 181, DSS 42 residuals are seen in Figs. 182 and 183, and DSS 51 residuals are presented in Figs. 184 and 185.

e. Retro-phase. Final in-flight calculations by the Orbit Determination Group indicated retro-ignition on July 17, at 02:01:57.8 GMT. Loss-of-signal occurred shortly before retro engine shut-off, at 02:02:41.001. Results of the retro engine burn as seen in the one-way doppler data over DSS 11 are presented in Fig. 186. An extrapolation of the spacecraft one-way center frequency (transmitter B) through the burn period and the resultant radial velocity (referenced to DSS 11) are shown in Table 83.

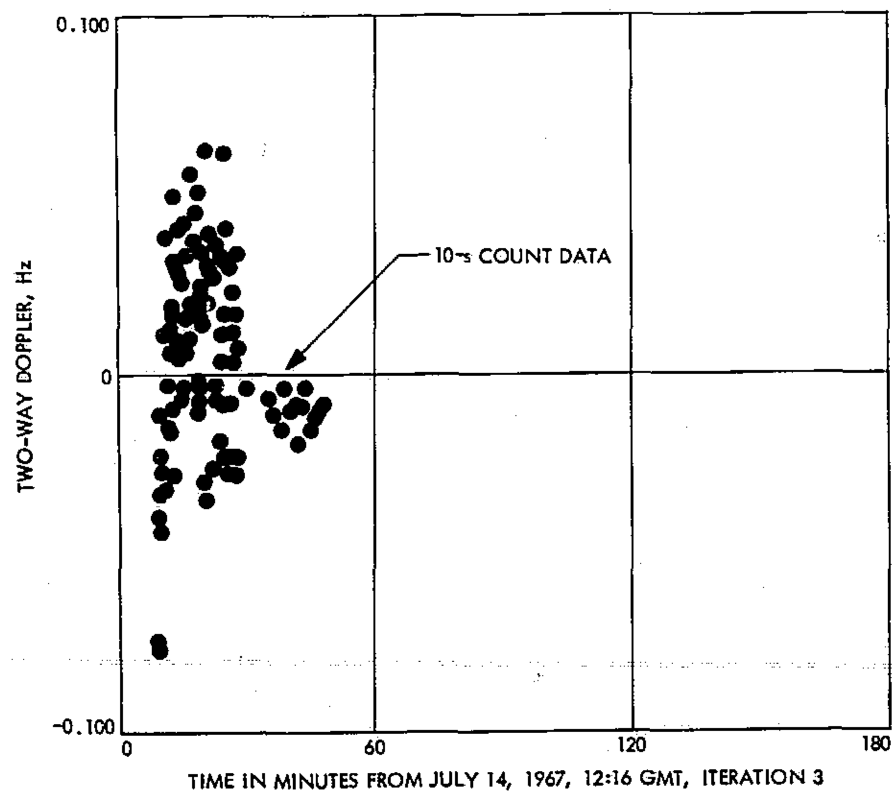


Fig. 162. Two-way doppler residuals, DSS 72, pass 1

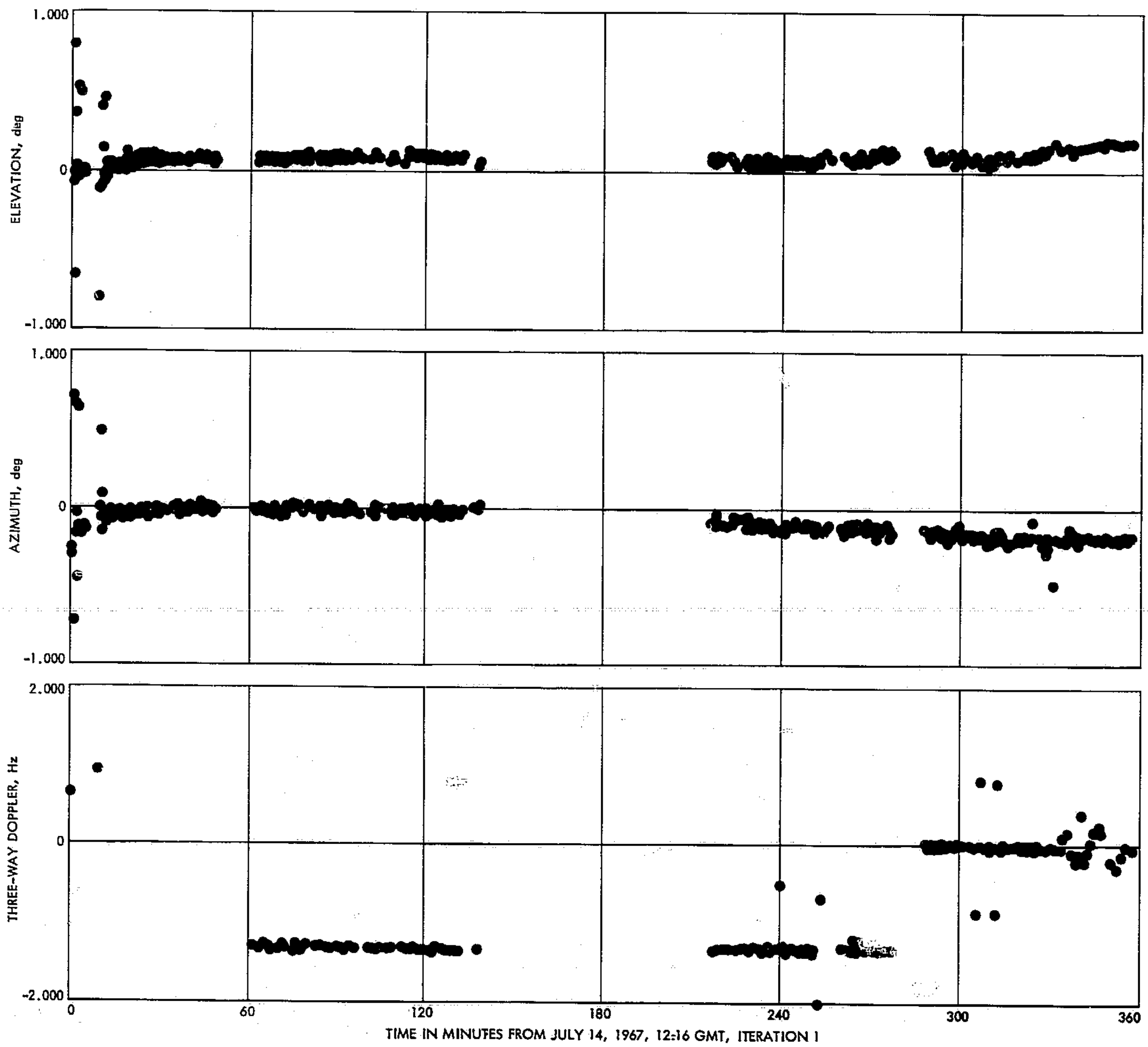


Fig. 163. Three-way doppler residuals, DSS 72, pass 1, from 12 h

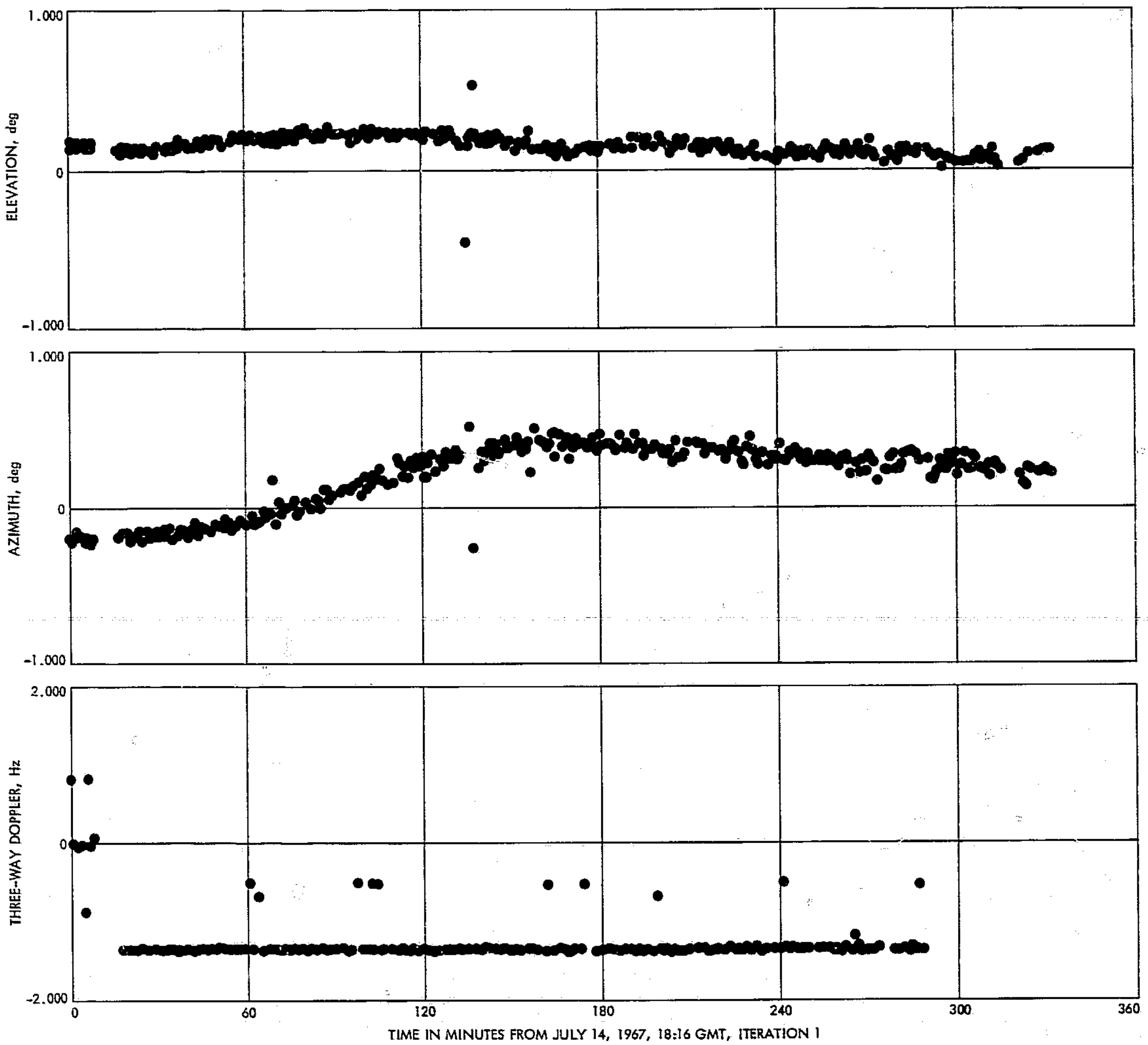


Fig. 164. Three-way doppler residuals, DSS 72, pass 1, from 18 h

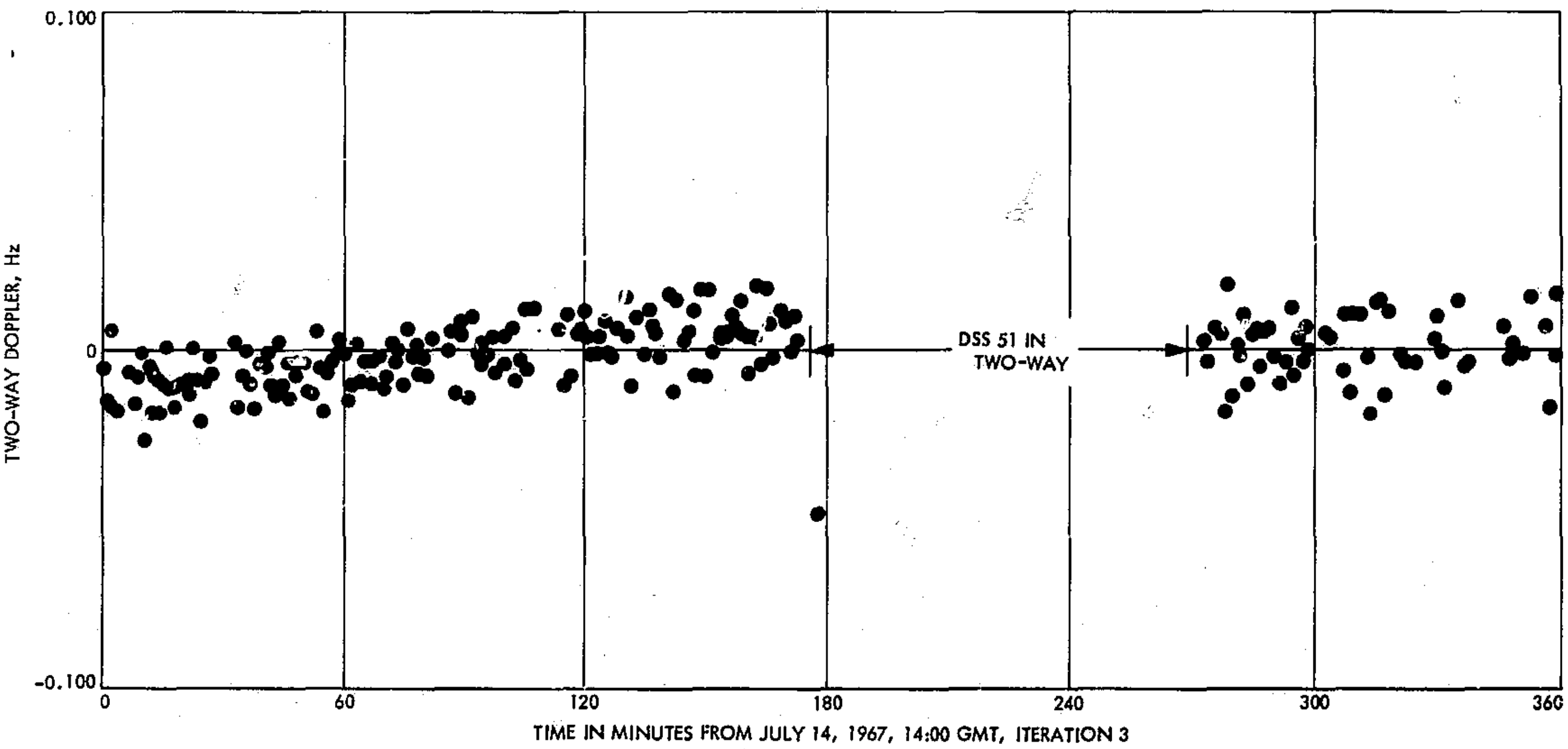


Fig. 165. DSS 51 angular residuals, pass 1, from 14 h

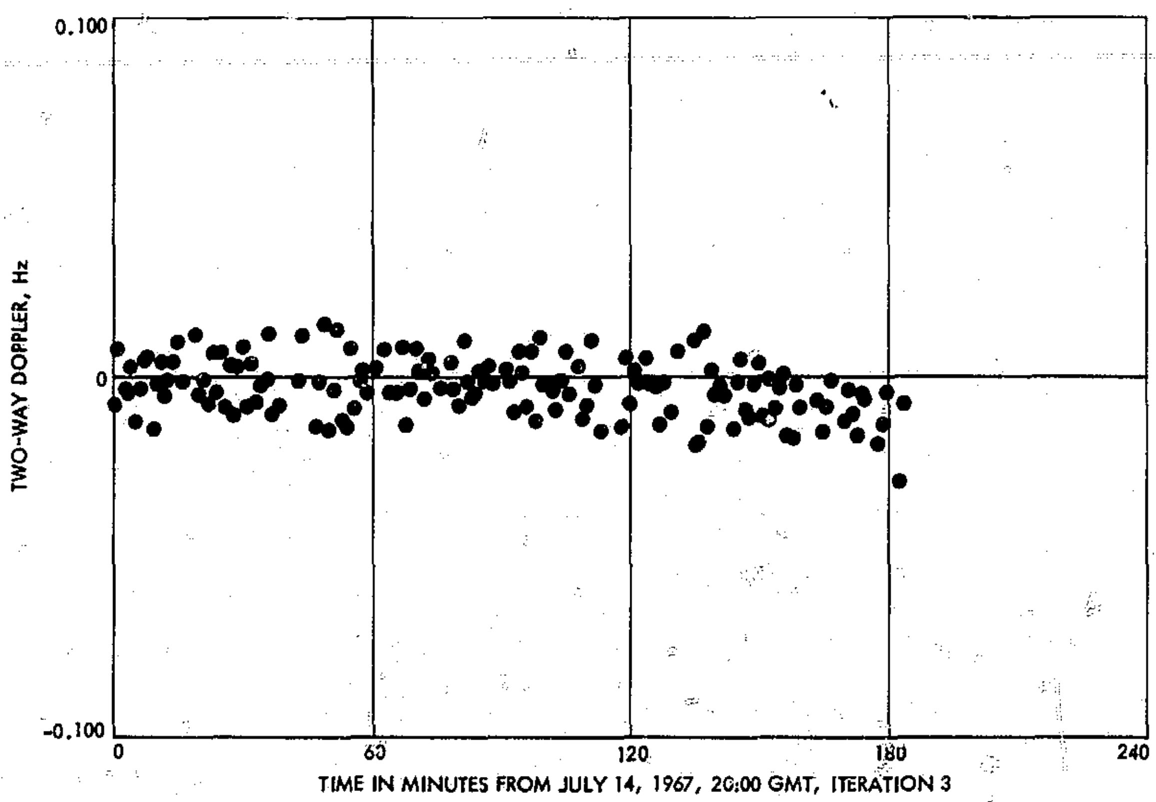


Fig. 166. DSS 51 angular residuals, pass 1, from 20 h

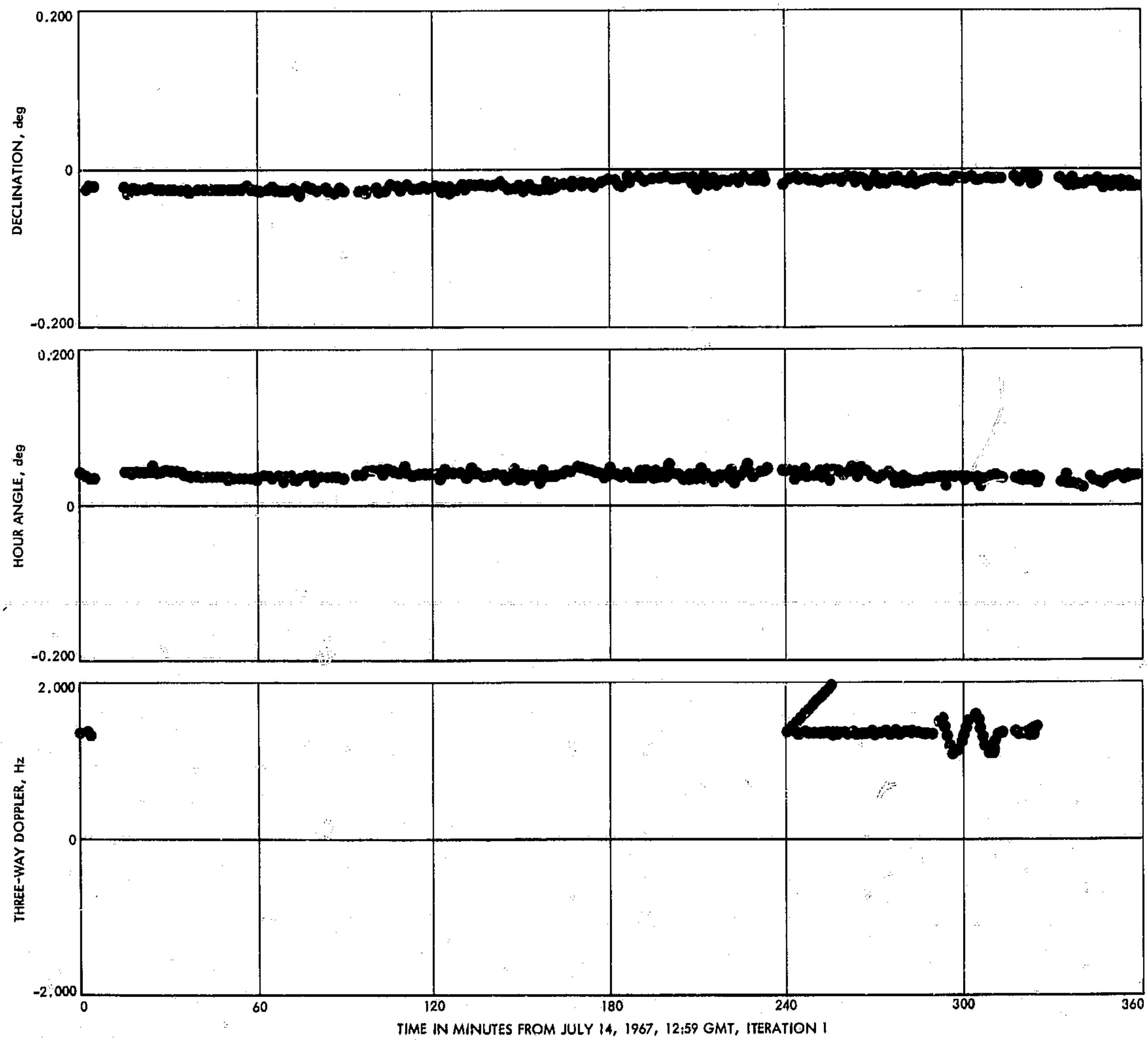


Fig. 167. DSS 51 angular residuals, pass 1, from 12 h

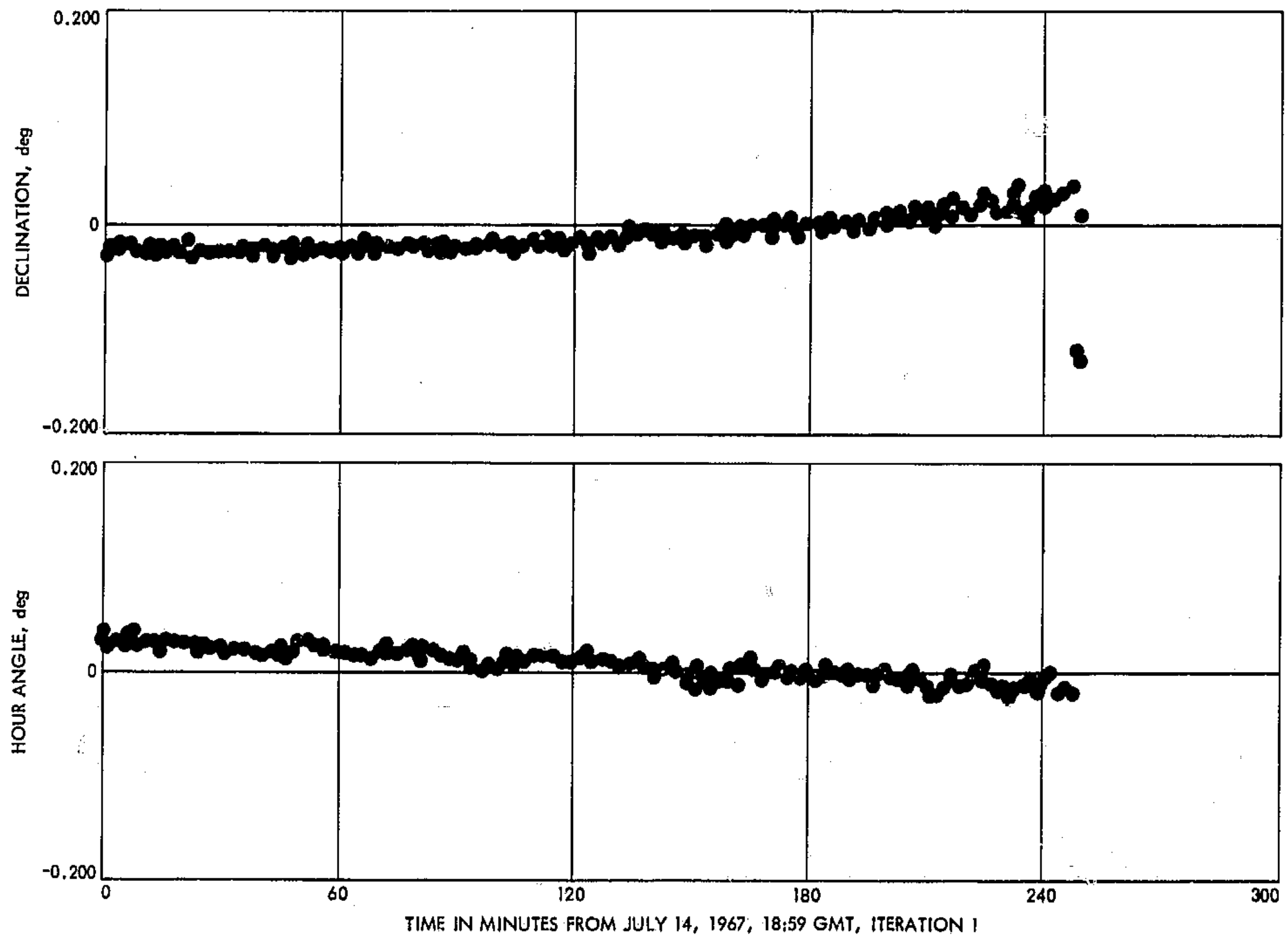


Fig. 168. DSS 51 angular residuals, pass 1, from 18 h

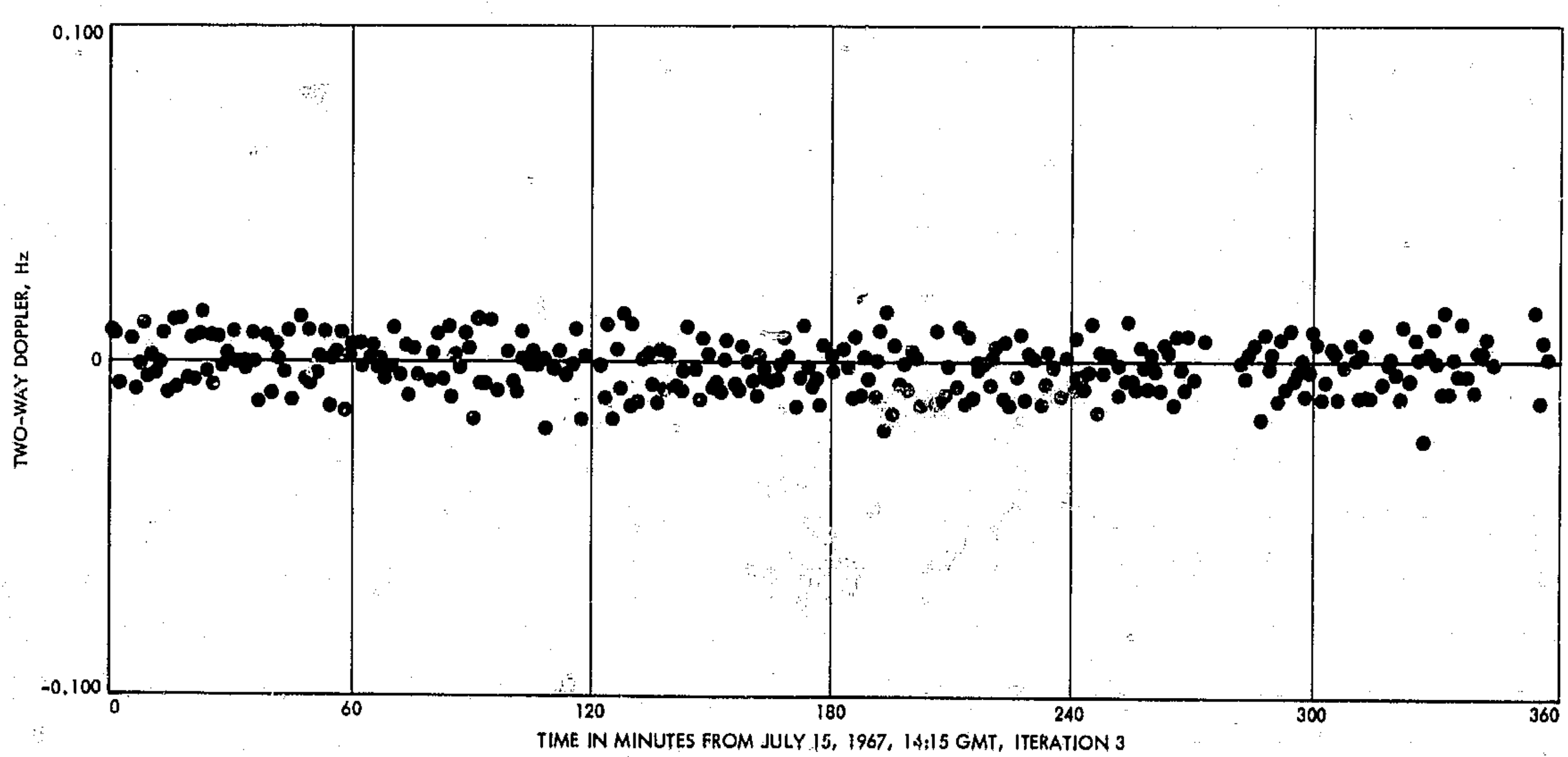


Fig. 169. DSS 51 angular residuals, pass 2, from 14 h

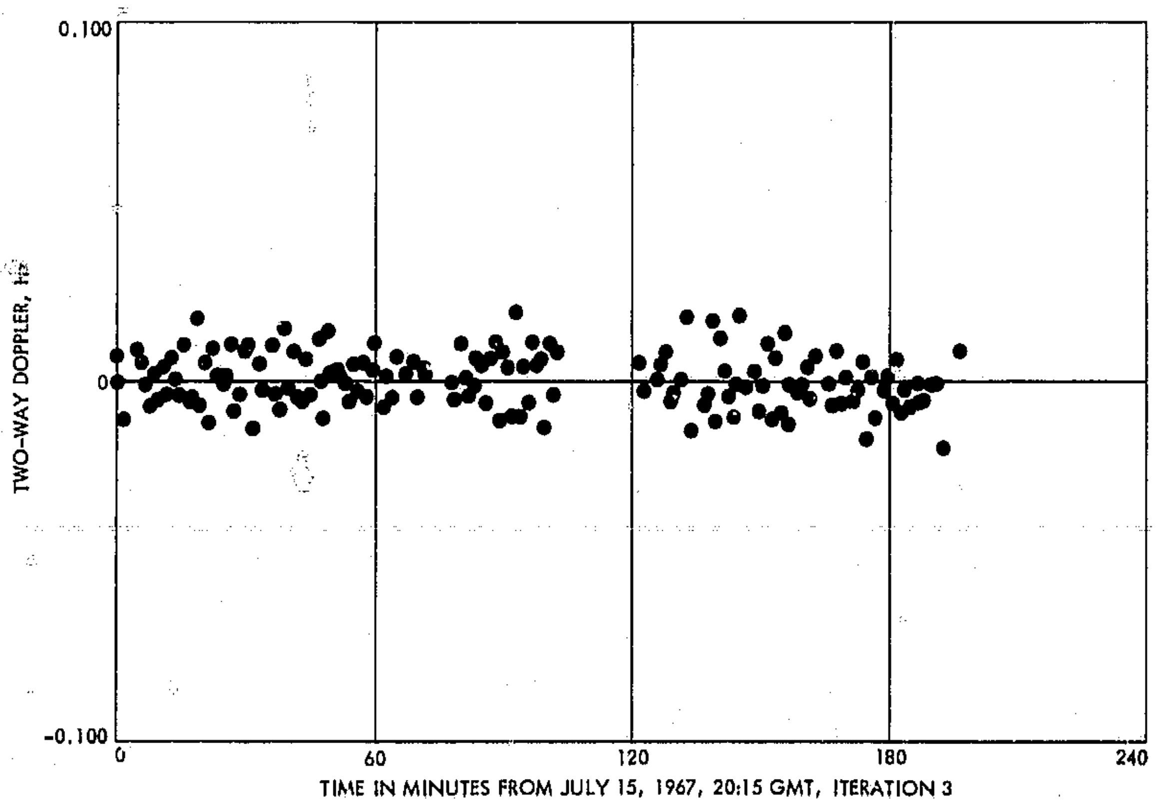


Fig. 170. DSS 51 angular residuals, pass 2, from 20 h

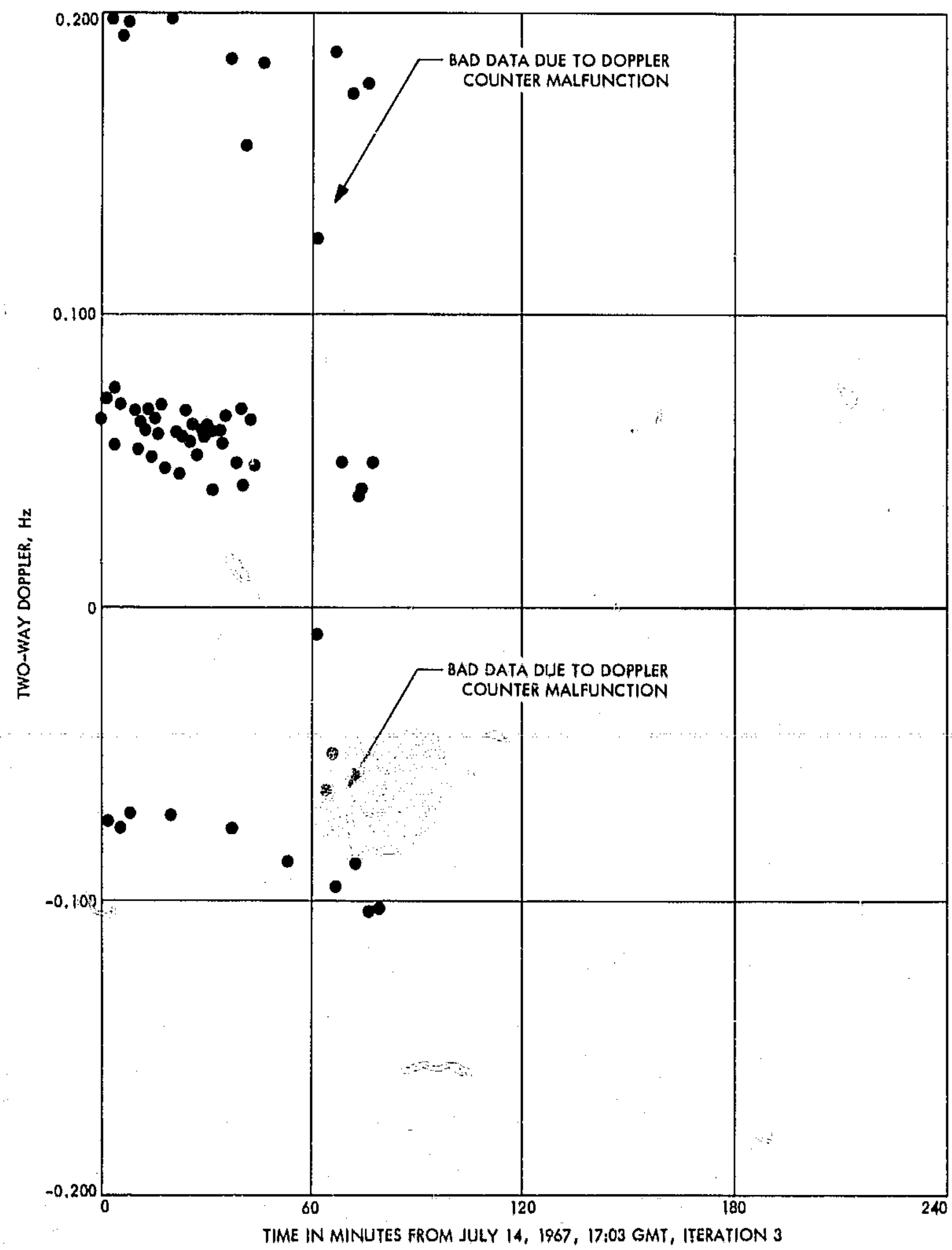


Fig. 171. DSS 61 angular residuals, pass 1, from 17 h

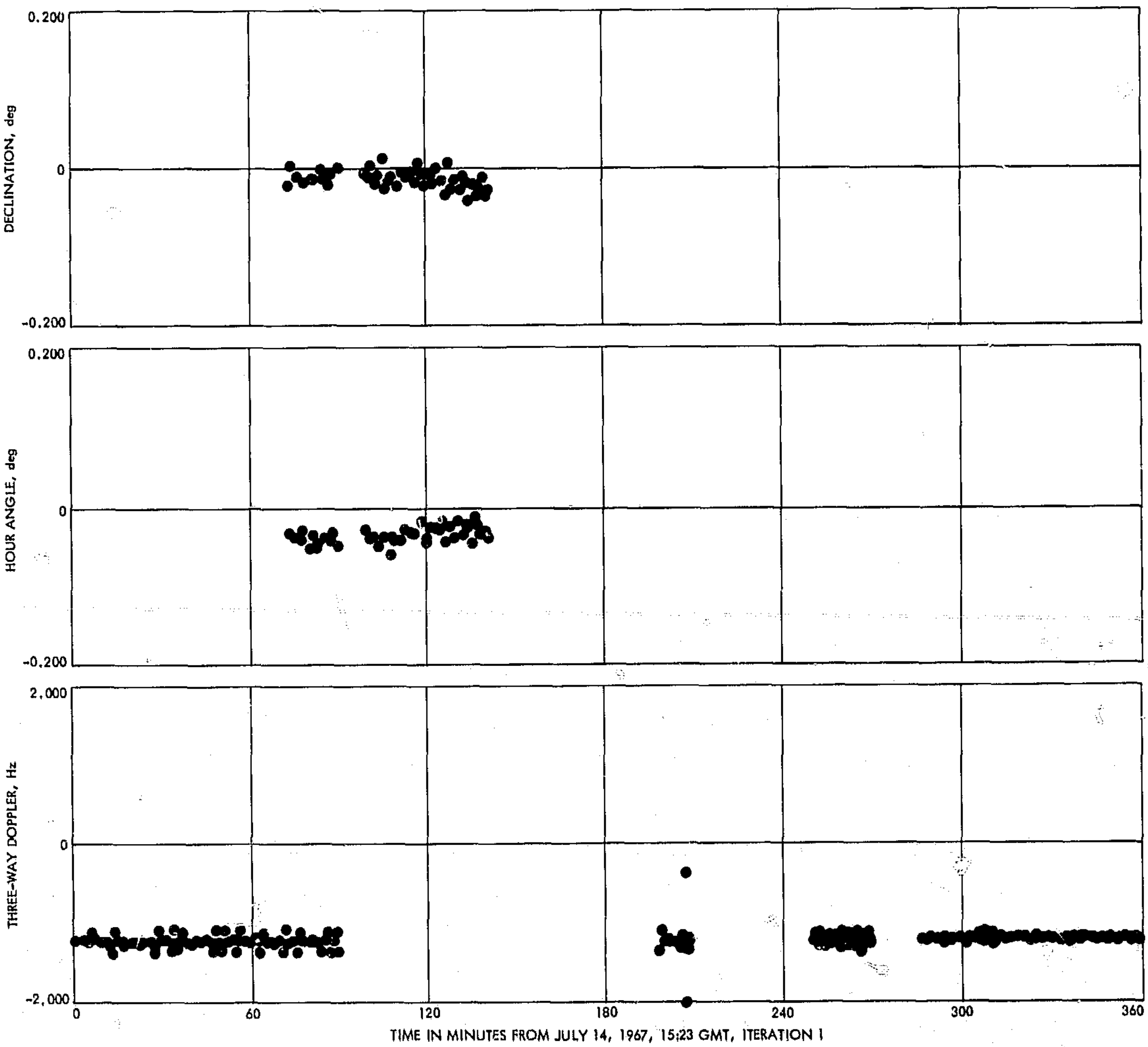


Fig. 172. DSS 61 angular residuals, pass 1, from 15 h

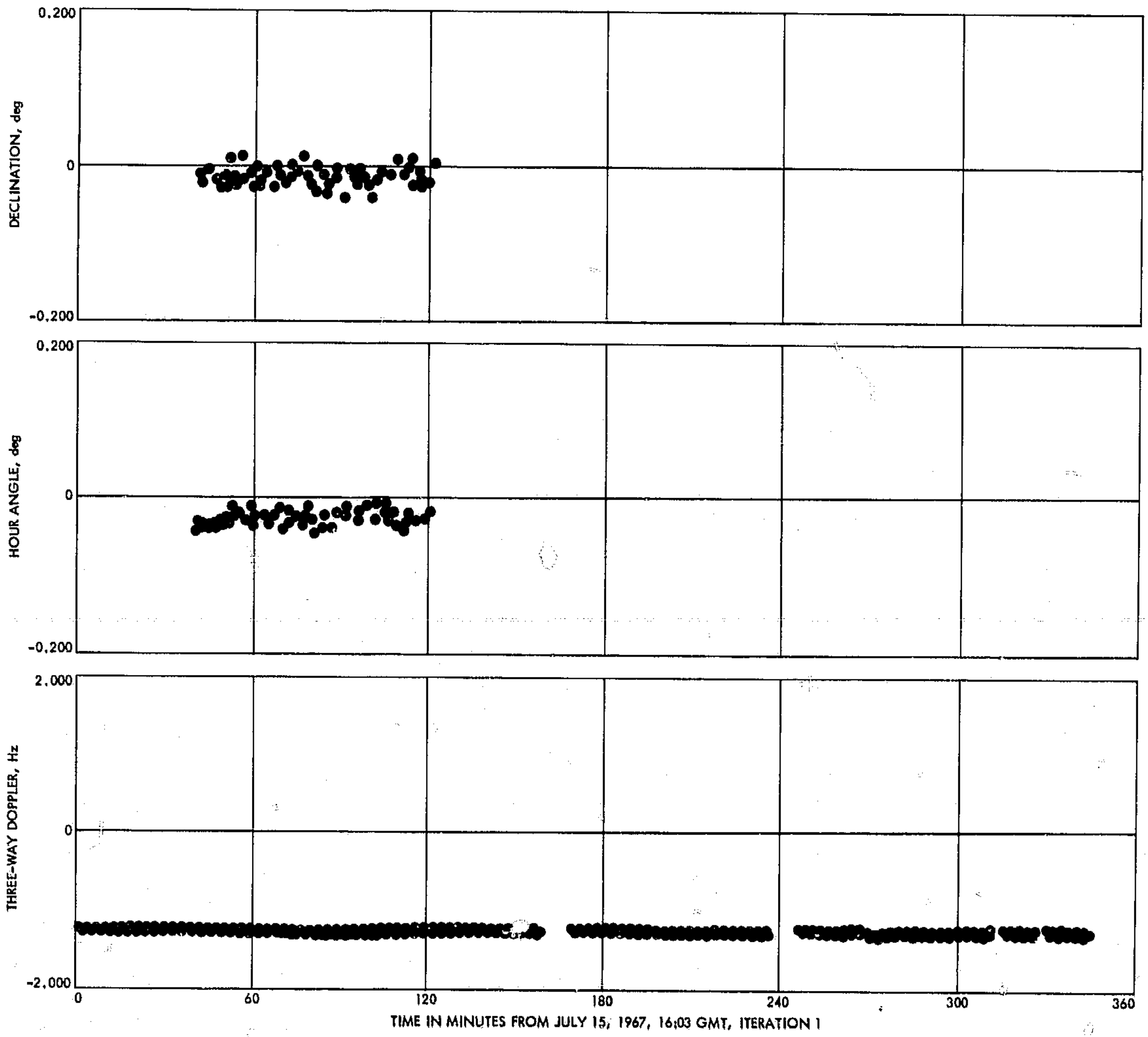


Fig. 173. DSS 61 angular residuals, pass 2

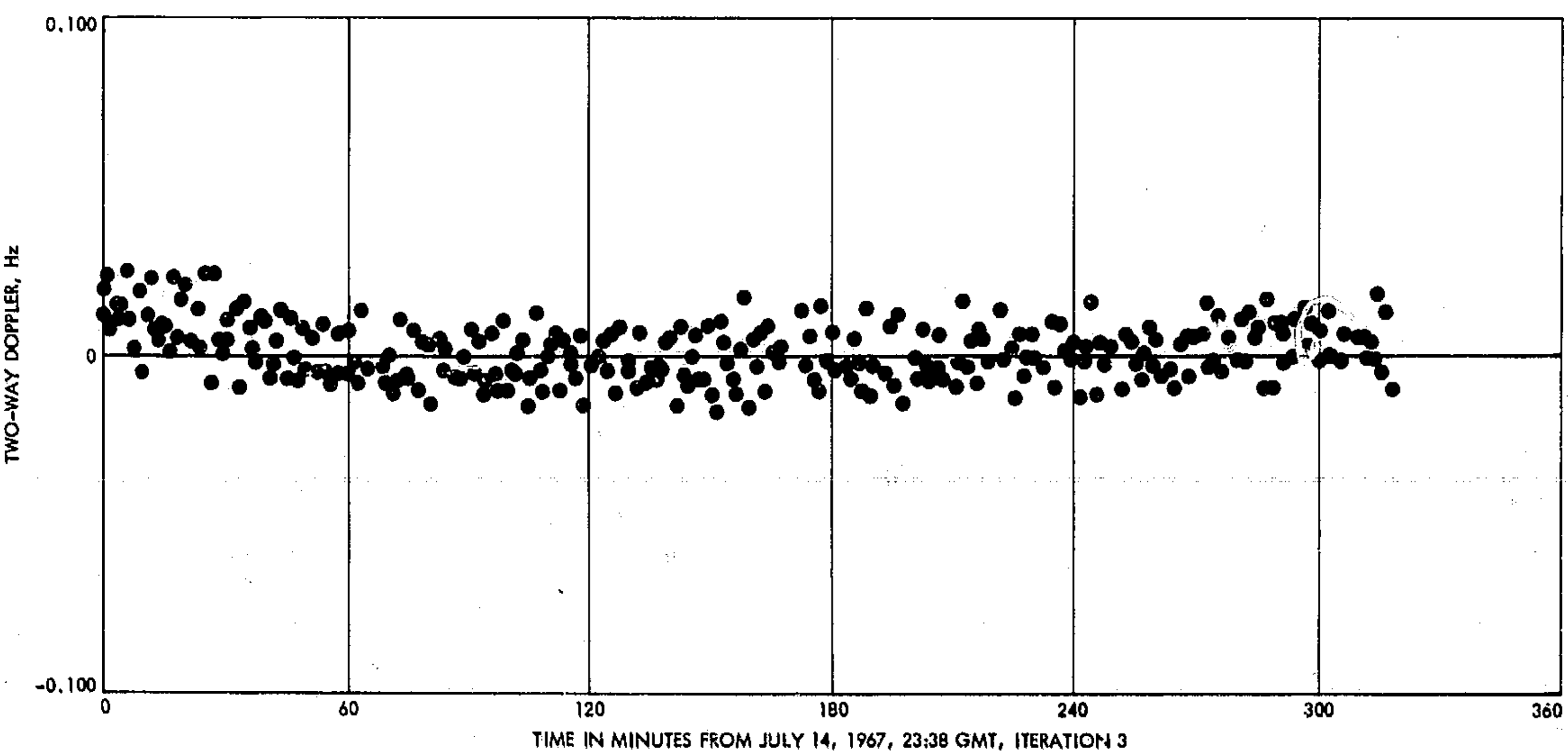


Fig. 174. DSS 11 angular residuals, pass 1

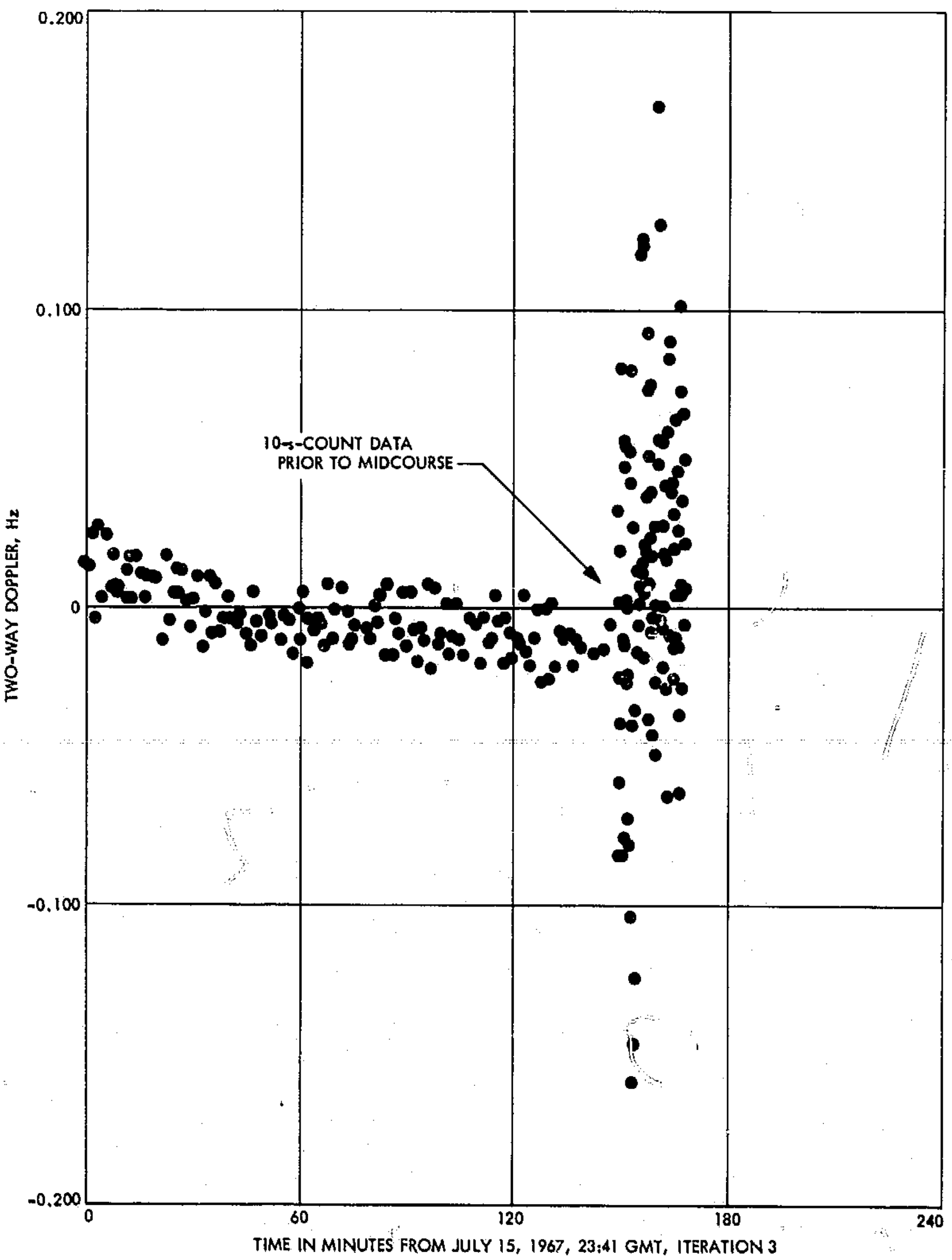


Fig. 175. DSS 11 angular residuals, pass 2

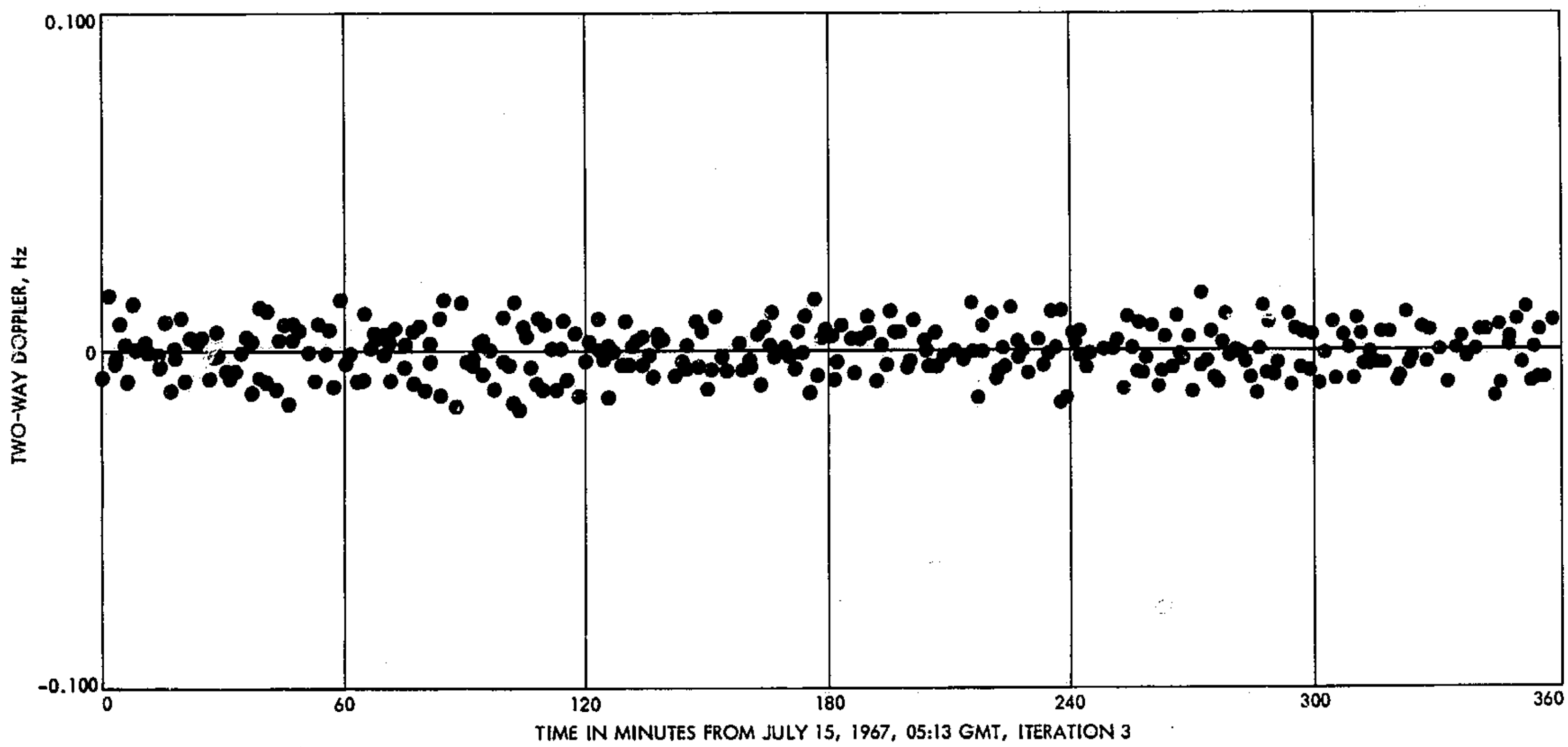


Fig. 176. DSS 42 angular residuals, pass 1, from 5 h

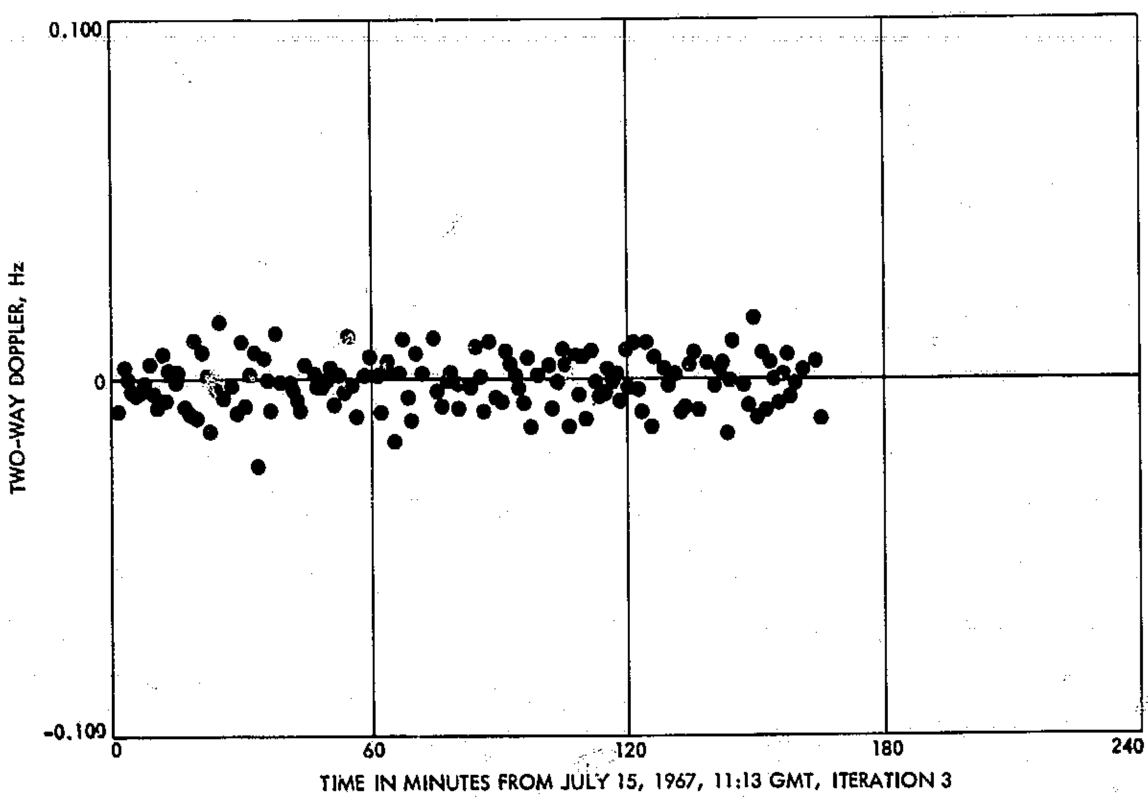


Fig. 177. DSS 42 angular residuals, pass 1, from 11 h

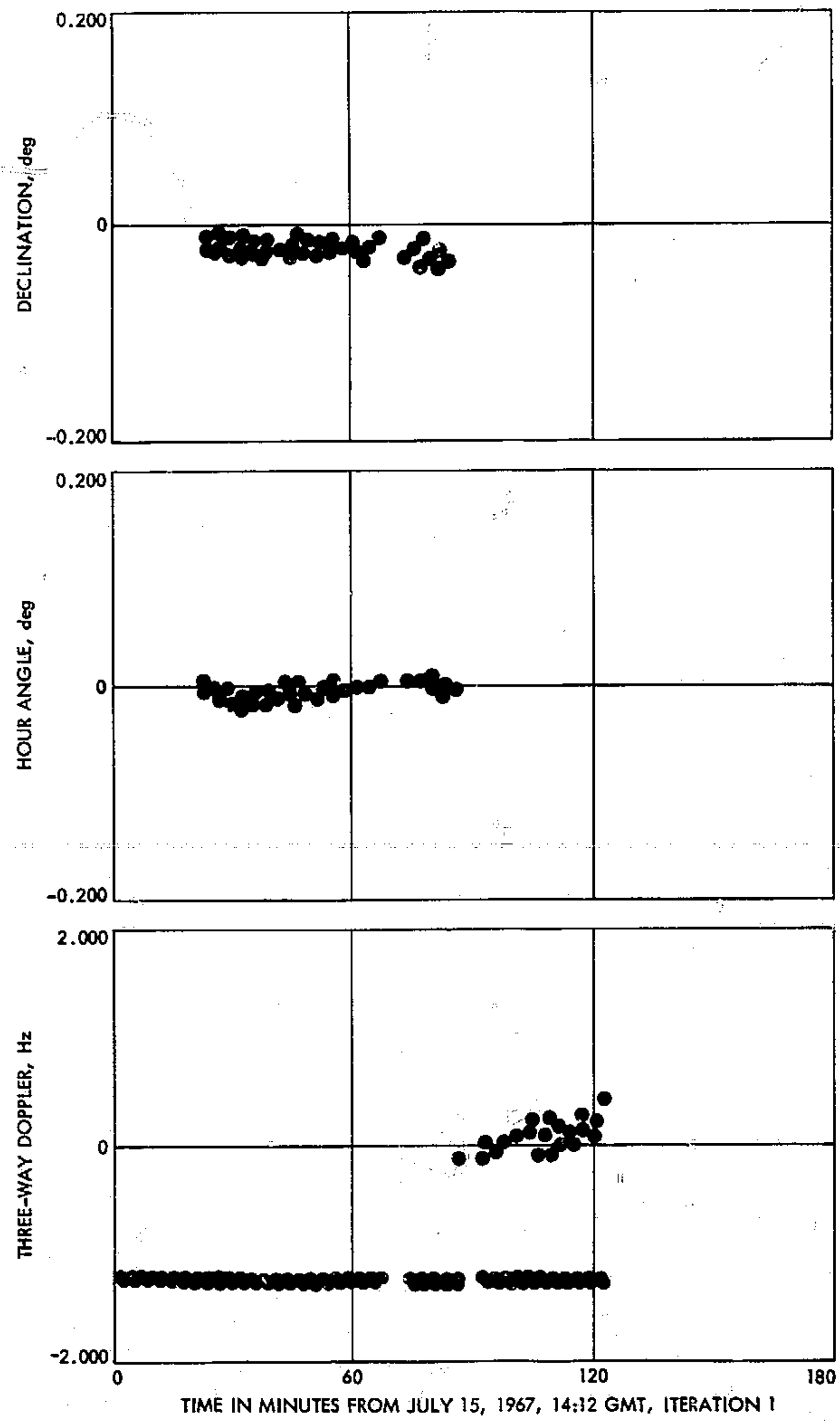


Fig. 178. DSS 42 angular residuals, pass 1, from 14 h

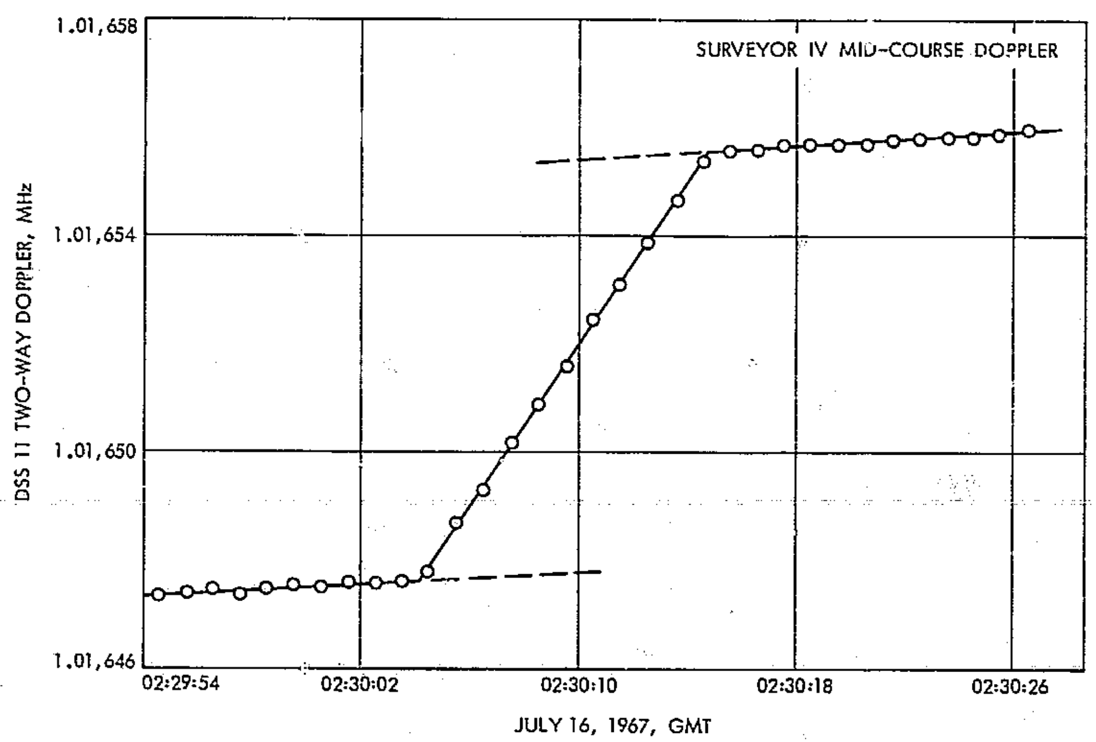


Fig. 179. Two-way doppler, DSS 11

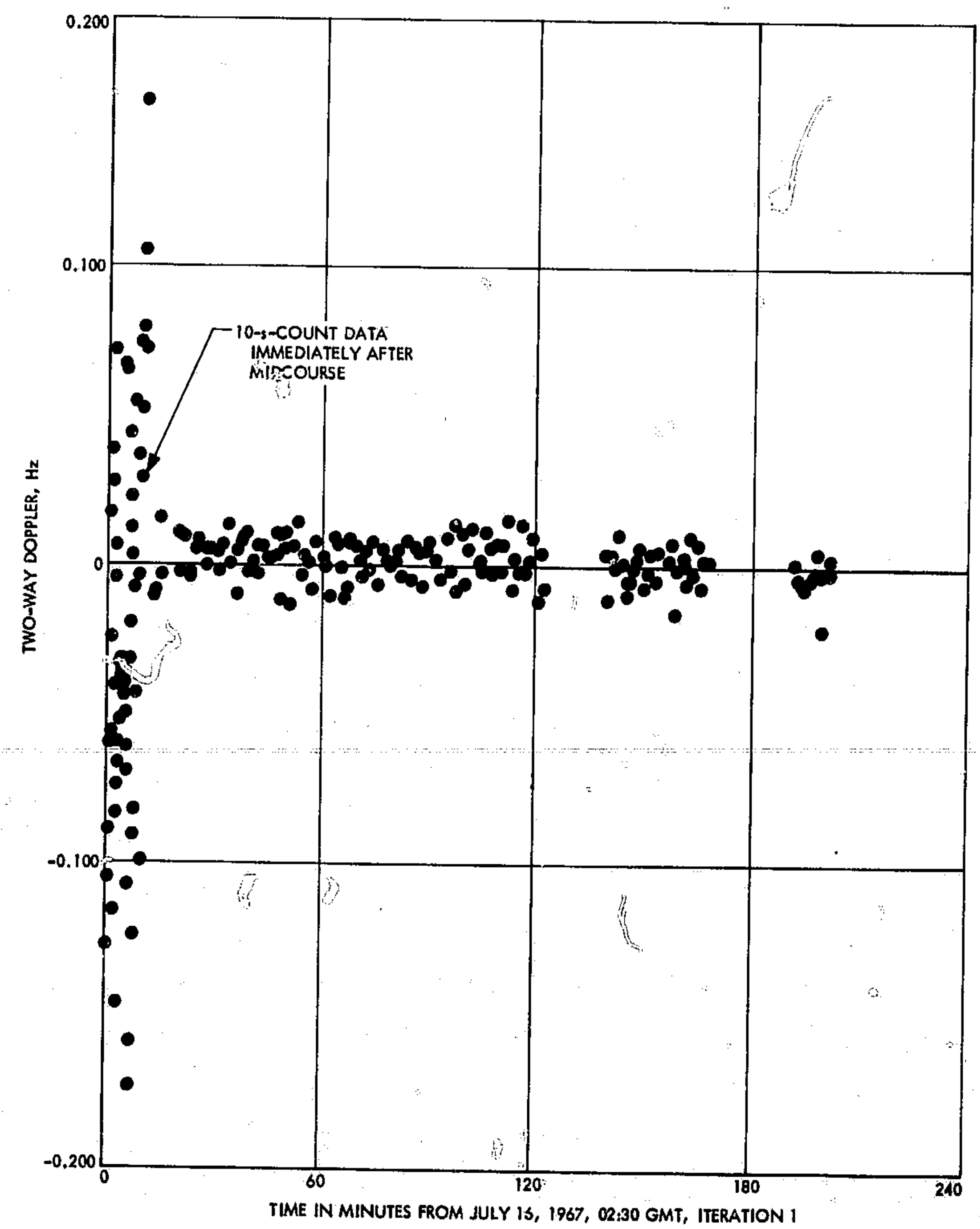


Fig. 180. DSS 11 residuals, post-midcourse phase, pass 2

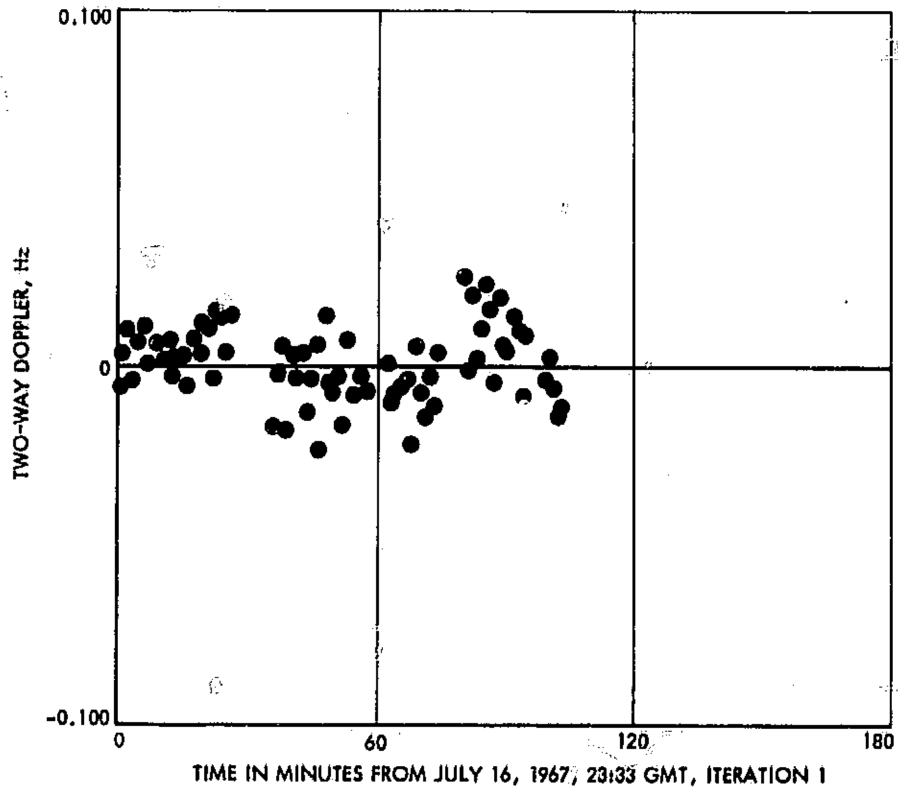


Fig. 181. DSS 11 residuals, pass 3

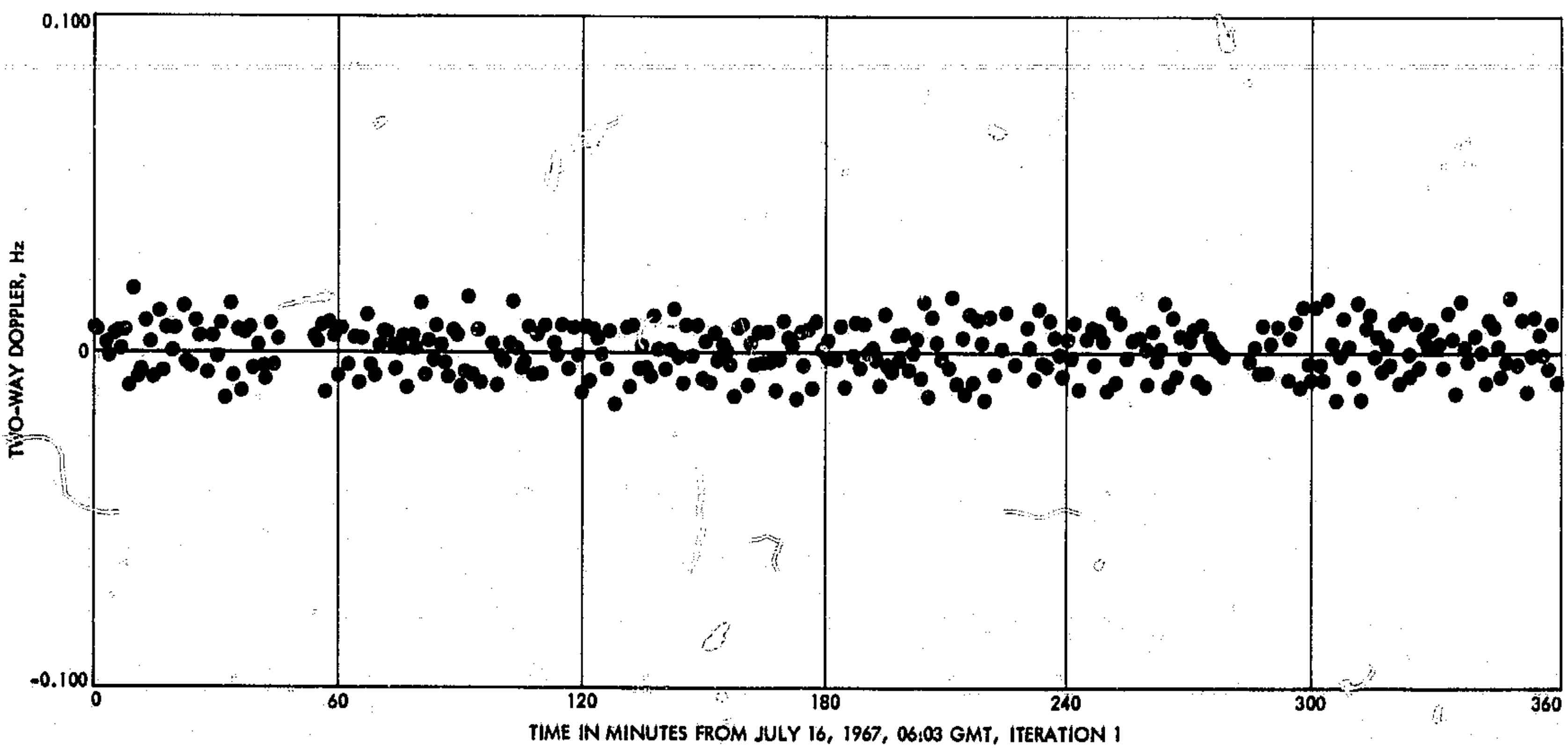


Fig. 182. DSS 42 residuals, post-midcourse phase, pass 2, from 6 h

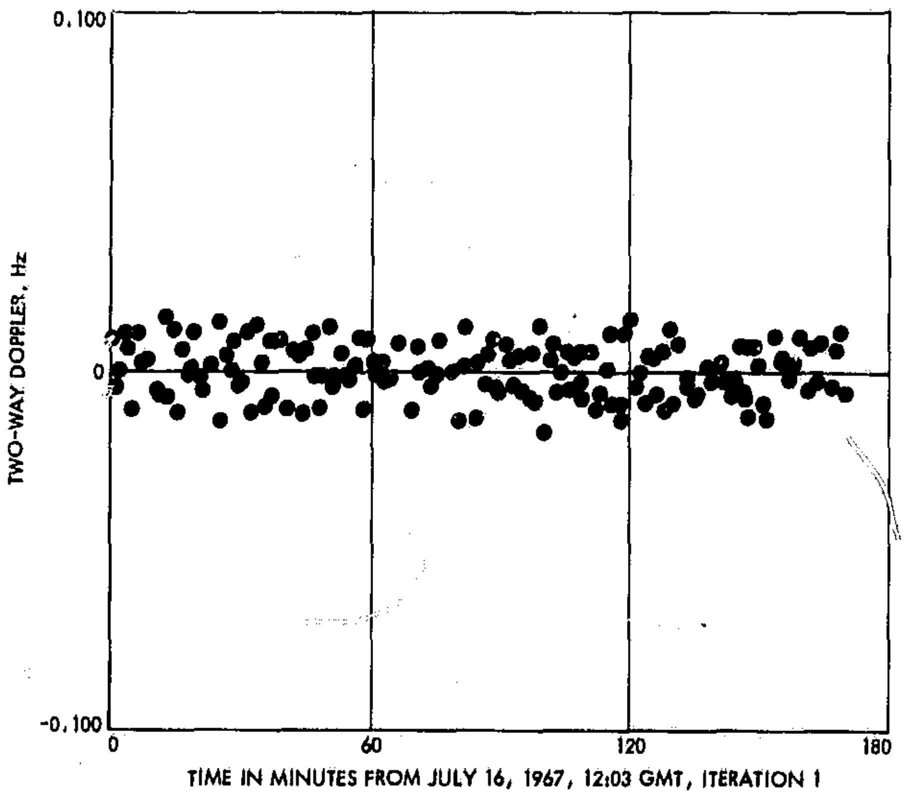


Fig. 183. DSS 42 residuals, post-midcourse phase, pass 2, from 12 h

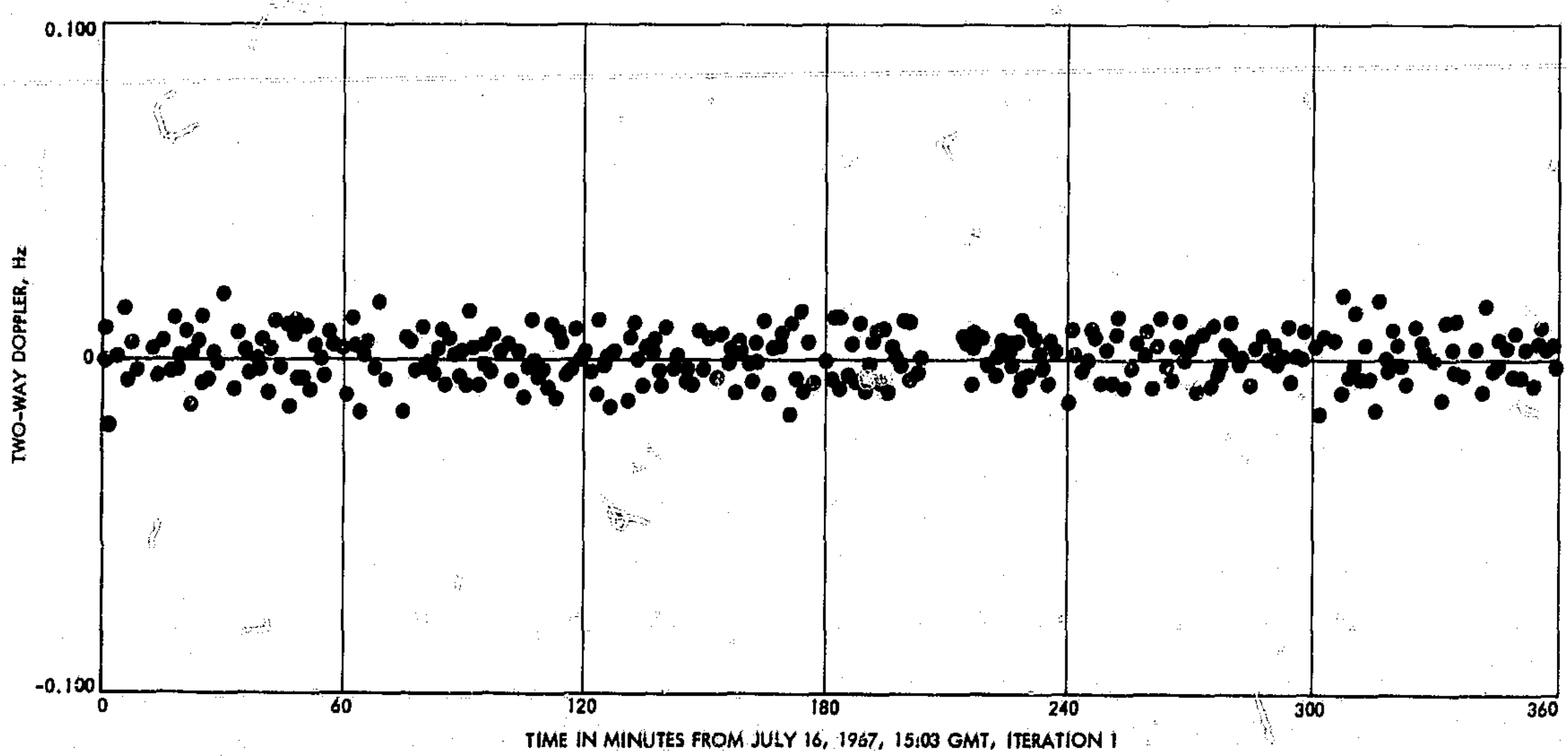


Fig. 184. DSS 51 residuals, post-midcourse phase, pass 3, from 15 h

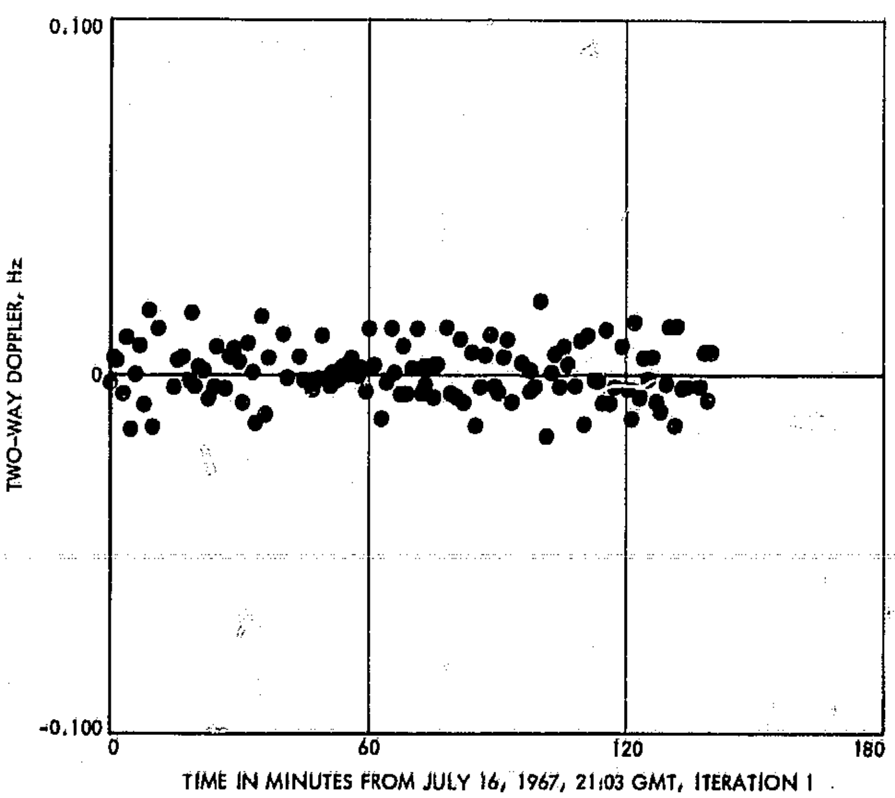


Fig. 185. DSS 51 residuals, post-midcourse phase, pass 3, from 21 h

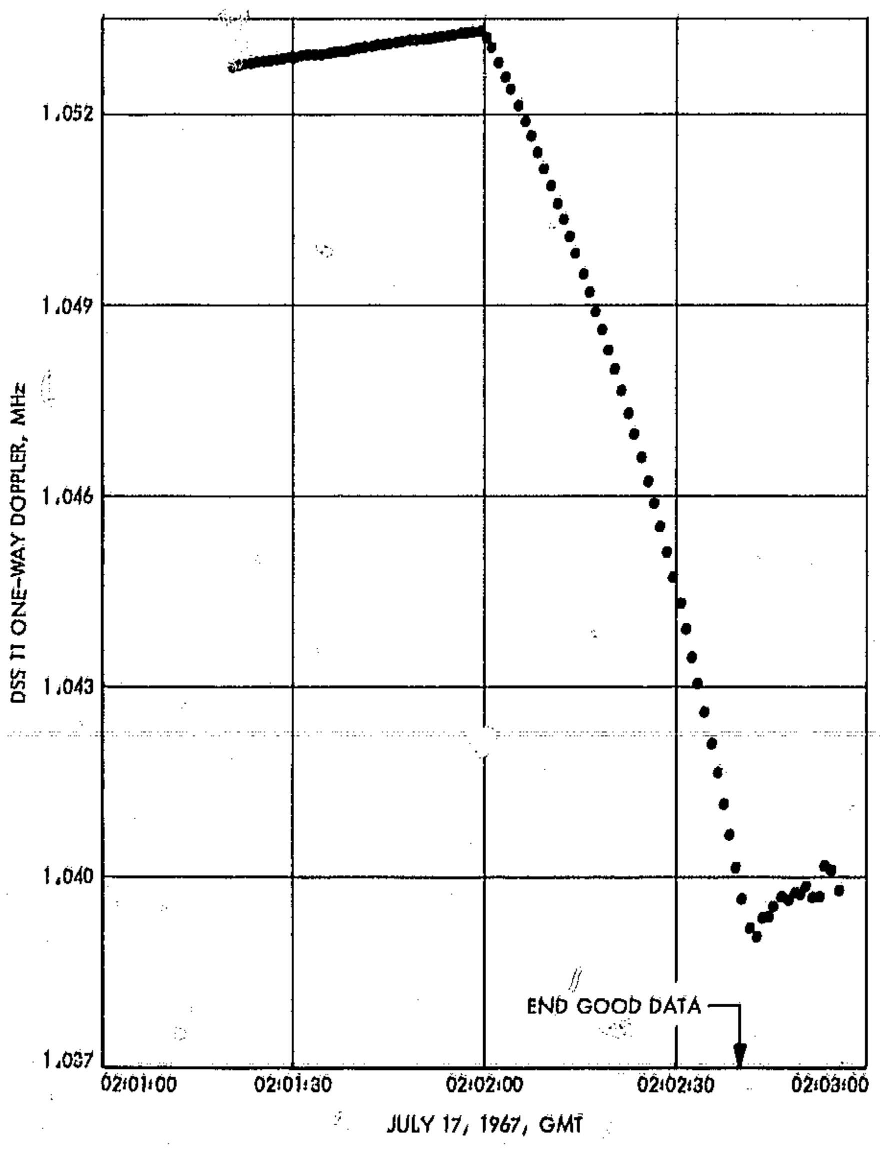


Fig. 186. *Surveyor IV* retro phase doppler, DSS 11

Glossary

AADE TTY communications routing indicator (Adelaide)

A/C *Atlas/Centaur*

ACSW TTY communications routing indicator (Canberra)

A/D analog-to-digital

AFC automatic frequency control

AFETR Air Force Eastern Test Range

AGC automatic gain control

AIS analog instrumentation subsystem

AMR altitude marking radar

ANBE TTY communications routing indicator (DSS 42, Tidbinbilla)

ANB2-A TTY communications routing indicator (DSS 42, Tidbinbilla)

ANLA TTY communications routing indicator (DSS 42, Tidbinbilla)

ANXB TTY communications routing indicator (DSS 42 Tidbinbilla)

AO building AO (AFETR checkout facility)

AOS acquisition of signal

APC automatic phase control

APF argument of pericenter

ASC Ascension Island

A/SPP antenna and solar panel positioner

ASR automatic send and receive (TTY equipment)

AT&T American Telephone and Telegraph Co.

AVA average alarm (data edit mode)

AVA/CVR average alarm/command verification (data edit mode)

AZUSA A short-baseline, continuous-wave, phase-comparison, single-station, tracking system operating at C-band and giving two-direction cosines and slant range which can be used to determine space position and velocity

BCD binary-coded decimal

BDA Bermuda

BECO booster engine cutoff

BER bit error rate

BIH built-in hold (during countdown)

BUSS-1 Communications Chief

C-band radio frequency band in the 5- to 6-gHz region

CCN Central Command Network

CCN/TM Central Command Network telemetry

CCTV closed-circuit television

CC3 Command Control two-way tracking mode

CDC command and data-handling console

CEC Consolidated Electrodynamics Corp.

CKAFS Cape Kennedy Air Force Station

CMD command

CMDMSG command message

CNB Canberra

COMM communications

CONF configuration

CP communications processor

CPCC Communications Processor Conversion Center

CRO Carnarvon

C/S *Centaur/Surveyor*

CVR command verification

CVR/D command verification/drop (data exit mode)

CYI Grand Canary Island

DACO data consistency orbit

DACON Data Control

DCC data condition code

DDC direct data channel

dec declination

Glossary (contd)

DECOMM decommutation
DIR Director
DIS digital instrumentation subsystem
DME distance measuring equipment
DOB data operation branch
DPPE Data Processing Project Engineer
DP data processing
DPS data processing system
DS a communications routing channel
DSCC Deep Space Communication Complex
DSIF Deep Space Instrumentation Facility
DSN Deep Space Network
DSS Deep Space Station
E engineering
ECC eccentricity
EQ equalizer
FCP flight control programmer
FDX full duplex, two-way
FM frequency modulation
FPAA Flight Path Analysis Area
FPAC Flight Path Analysis and Command
FPQ-6 precision missile tracking radar
FPS fixed-point station (type of radar)
FR-800 Ampex video tape recorder
FR-1400 Ampex tape recorder
GAMR TTY communications routing indicator (AFETR COMM Center, Cape Kennedy)
GBI Grand Bahama Island
GBUR TTY communications routing indicator (Johannesburg)
GCF Ground Communications Facility
GDA line number for U. S. Government TTY circuit
GDHS Ground Data Handling System
GET ground elapsed time (since liftoff)
GKAP TTY communications routing indicator (DSS 70, JPL/AFETR, Bldg AO, Cape Kennedy)
GKEN TTY communications routing indicator (DSS 71, Cape Kennedy)
GM ground mode
GP galactic probe
GSEN TTY communications routing indicator (DSS 72)
GSFC Goddard Space Flight Center
GT line number for U. S. Government TTY circuit
GTS Goldstone Tracking Station
GWM Guam
HA hour angle
HAC Hughes Aircraft Company
HAW Hawaii
HD/LD half duplex/data loss
HDX half duplex, one way
HOPS computer program
HSD high-speed data
HSDL high-speed data line
HSDS high-speed data subsystem
ICEV injection condition evaluation orbit
ICS Intra-Communication System
IDC internal document control
IMP interim monitoring program
INC inclination (in deg)
Intelsat a communications satellite
I/O input-output
IRIG Interrange Instrumentation Group
IRV interrange vector

Glossary (contd)

ISO	isolation
JDPS	TTY communications routing indicator
JECO	TTY communications routing indicator (DSS 12, Goldstone)
JGLD	TTY communications routing indicator (Deep Space COMM Complex, Goldstone)
JHAC	TTY communications routing indicator (Hughes Aircraft, El Segundo)
JJPL	TTY communications routing indicator (JPL COMM Center, Pasadena)
JMAR	TTY communications routing indicator (DSS 14, Goldstone)
JOPS	TTY communications routing indicator
JPIR	TTY communications routing indicator (DSS 11, Goldstone)
JPL	Jet Propulsion Laboratory
JPLA	TTY communications routing indicator (DSS 11, Goldstone)
JPXI	TTY communications routing indicator (DSS 11, Goldstone)
JSDA	TTY communications routing indicator
JSFO	TTY communications routing indicator (JPL SFOF)
JTLA	TTY communications routing indicator
JTSS	TTY communications routing indicator
JVEN	TTY communications routing indicator (DSS 13, Goldstone)
KSC	Kennedy Space Center
LAN	longitude of the ascending node
LAPM	last pre-midcourse orbit
LCP	left circular polarization
LeRC	Lewis Research Center
LF	low frequency
LH	left hand
LJOB	TTY communications routing indicator (DSS 51, Johannesburg)
LLDN	TTY communications routing indicator (London)
LMAD	TTY communications routing indicator (Madrid)
LOS	loss of signal
LRID	TTY communications routing indicator (DSS 61, Madrid)
LRLA	TTY communications routing indicator (DSS 61, Madrid)
MA	Mission Analyst
MAD	Madrid
MC	midcourse
MCC-K	Mission Control Center–Cape Kennedy
MECO	main engine cutoff (*Centaur*)
MEIG	main engine ignition (*Centaur*)
MOPS	missile operations paging system
MOS	Mission Operations System
MPS	main power switch
MSFN	Manned Space Flight Network
MUX	multiplexer
MWAVE	microwave
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications System
NBVCXO	narrow-band voltage-controlled crystal oscillator
NCR	National Cash Register Co.
NOMA	nominal midcourse orbit
NOP	Network Operations Plan
NOR	not operationally ready
N POM	*n*th post midcourse orbit
NR	number
NRT	near real time
NRZ	non-return-to-zero
NSO	Network Support Office

Glossary (contd)

NSP (13)	NASA Support Plan
NTSA	NASA Testing Support for *Atlas/Agena*
NTSC	NASA Testing Support for *Centaur*
OD	orbit determination
ODP	Orbit Determination Program
OGO	*Orbiting Geophysical Observatory*
OMAS	operational miscellaneous audio subsystem
OPAS	operational public address system
OPE	optical pointing error
OPSCON	Operations Control Center
OPS-X	operational teletype message
ORT	Operational Readiness Test
OSDP	on-site data processing
OSRS	operational status recording subsystem
OTC	Overseas Telecommunications Corp.
OTCS	operational teletype communications subsystem
OVCS	operational voice communications subsystem
OVRS	operational voice recording subsystem
P/A	path angle
PAFB	Patrick Air Force Base
PAM	pulse-amplitude modulation
PA/SP	positioner antenna and solar panel
PCM	pulse code modulation
PDP	programmed data processor
PDP-7	Programmed Data Processor 7 Computer
PER	parity error rate
PIO	Public Information Office
PLIM	postlaunch instrumentation message
PM	phase modulation
POM	see N POM
POST	post flight analysis orbit
PRCL	pre-midcourse cleanup orbit
PRD	Program Requirements Document
PRDX	Prediction Program
PREL	preliminary pre-midcourse orbit
PROR	predict orbit
PS	program supplier
PT&T	Pacific Telephone and Telegraph Co.
RADVS	radar altimeter and doppler velocity sensor
RATAC	radar target acquisition (system)
RCP	right circular polarization
RCVR	receiver
[illegible]	recording system
REPERF	reperforation
RFI	radio-frequency interference
RFP	request for programming
RH	right hand
RIS	range instrumentation ship
RO	receive only (teletype machine)
RORA	reliable operate radar altimeter
RT	real time
RTCC	Real-Time Computer Complex
RTCF	Real-Time Computer Facility
RTCS	Real-Time Computer System
SAA	S-band acquisition aid antenna (Deep Space Stations)
S-band	radio frequency band
SC-1	*Surveyor I* spacecraft
SC 3070	a computer
SCAMA	signaling, conferencing, and monitoring arrangement
SCCG	Station Communications Control Group
SCM	S-band Cassegrain monopulse antenna (Deep Space Stations)

Glossary (contd)

SCO	subcarrier oscillator
SCPS	station communications processor subsystem
SCSM	Station Communications Systems Manager
SDA	Systems Data Analyst
SDCC	Simulated Data Conversion Center
SECO	sustainer engine cutoff
SFO	Space Flight Operations
SFOD	Space Flight Operations Director
SFOF	Space Flight Operations Facility
SFOP	space flight operations plan
SFOS	Space Flight Operations System
SMAA	semimajor axis
SM/SS	soil mechanics/surface sampler
SN	serial number
SOC	*Surveyor* Operations Chief
SOCP	*Surveyor* on-site computer program
SOPM	~~standard orbital parameter message~~
SP	space character (TTY symbol)
SPA	signal processing auxiliary
SPAA	Spacecraft Performance Analysis Area
SPAC	Space Performance Analysis and Command
SPE	static phase error
SRT	supporting research and technology
SSAA	space science analysis area
SSAC	Space Science Analysis and Command
STADAN	Space Tracking and Data Acquisition Network
STA MGR	Station Manager
STEA	System Test Equipment Assembly
TAER	time-azimuth-elevation rate
TAN	Tananarive
T&FA	Tracking and Flight Analysis
TCD	telemetry and command data
TCP	telemetry and command processor
TD-1	TTY Tape Distributor No. 1
TDA	Tracking and Data Acquisition
TDH	tracking data handling system
TDM	time division multiplex
TDS	Tracking Data System
Tel-2	Telemetry Bldg at AFETR
TEX	Texas
TFAG	Technical Flight Number Analysis Group
TFR	tuneable frequency range
TIM	Tracking Instruction Manual
TK	tracking data
TLM	telemetry
TM	telemetry mode
TPQ-18	a type of radar
TPS	Telemetry Processing Station
TSS	teletype switching system
TTY	teletype
TV	television
TVCS	television communications subsystem
TVGDHS	television ground data handling system
TX	transmit
TXR	DSIF transmitter subsystem
USB	unified S-Band
VCE	voice
VCO	voltage-controlled oscillator
VCXO	voltage-controlled crystal oscillator
VECO	vernier engine ~~cutoff~~
WBCA	wide-band communications line
WBCS	wide-band communications subsystem
WBFM	wide-band frequency modulation

Glossary (contd)

WBVCXO	wide-band voltage-controlled crystal oscillator
WWV	National Bureaus of Standards time broadcasting station, Boulder, Colo.
X	X computer string
XA, XB, XC, XD, XF	designators for different runs of same program on X string
X_A	ground transmitter VCO frequency setting for specific time
XFER	transfer
XMTR	transmitter
Y	Y computer string
YA, YB, YC, YD, YE	designators for different runs of same program on Y string
7.18	Grand Turk radar
9.1	Antigua (original designation for Antigua Station 91)
12	Ascension Island designation
91.18	Radar on Antigua, Station 91
$	TTY symbol