NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Memorandum 33-301

Volume III

Tracking and Data System Support for Surveyor Mission V

N. A. Renzetti

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
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National Aeronautics and Space Administration

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 third 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 covers *Surveyor* Missions I and II. Volume II covers the support of *Surveyors III* and *IV*; and Volumes III, IV, and V 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:

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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.

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Abstract

This report covers the Tracking and Data System (TDS) activities for *Surveyor V*, 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 is the synopsis of the fifth *Surveyor* flight. 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 phase of the flight cover operations of the Goddard Space Flight Center, the Air Force Eastern Test Range, the Spacecraft Monitoring Facility at Cape Kennedy, and the Ascension Island Spacecraft Command and Guidance Station. Technical and statistical data concerning launch, trajectory, operating modes, tracking time, received-signal levels, command lockups, and data transmission and reduction are presented.

Tracking and Data System Support for *Surveyor*

Mission V

I. Introduction

This document provides a history of the Tracking and Data System (TDS) activities in support of *Surveyor* Missions A–G (identified after launch as *Surveyors I–VII*). 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 TDS performance evaluation summary. A brief description of the TDS for the *Surveyor* missions—as well as launch vehicles, spacecraft, and flight objectives—is also provided to convey an understanding of TDS activities.

The *Surveyor* Project was managed by the Jet Propulsion Laboratory for the NASA Office of Space Science and Applications. The project was supported by four major administrative and functional elements or systems:

(1) Launch Vehicle System.

(2) Spacecraft System.

(3) Tracking and Data System.

(4) Mission Operations System.

In addition to overall project management, JPL was assigned the management responsibility for the Spacecraft, Tracking and Data, and Mission Operations Systems. The Lewis Research Center was assigned the responsibility for the *Atlas/Centaur* Launch Vehicle System.

A. Summary of Significant Technical Activities Relating to Tracking and Data Acquisition Support for Surveyor

The *Surveyor* Project was the first space project to have its telecommunications function at S-band. When the project was initiated in 1960, those people responsible for the management of the frequency spectrum strongly recommended that there be no further L-band projects, such as *Ranger* and *Mariner II*, but that future projects such as *Surveyor* should be planned at S-band. In 1960, it was expected that the first flight of *Surveyor* would be in the fall of 1963. It subsequently became apparent that this objective could not be met (in fact, *Surveyor I* was not launched until May 1966). The first actual project to use S-band in flight was the *Mariner* Mars 1964 Mission.

The *Surveyor* Project provided the first spacecraft design that was wholly dependent upon commands from the ground stations of the Deep Space Network (DSN) for its inflight activities. It was significant that there was not much redundancy in the network for commanding at any single station. Thus, time-critical command activities were backed up by having other stations on line—rather than having, for example, such redundancy as two transmitter chains at each station. An example of the latter case is the Manned Space Flight Network (MSFN) configuration for the *Apollo* Project.

The *Surveyor* Project was the first deep space project to make extensive use of high bit rates, requiring the extensive use of high-speed data lines from the Deep Space Stations (DSSs) to the Space Flight Operations Facility (SFOF) in Pasadena, as a primary mode for the conduct of space flight operations. Considerable equipment was configured and experience obtained at bit rates up to 4400 bits/s from the Goldstone complex and up to 1100 bits/s from the overseas stations through the ground communications facility into data processing systems of the SFOF. Prior to this project, teletype circuits served as the primary means for transferring data and conducting spacecraft flight operations.

Additionally, the *Surveyor* Project was the first deep space project to make extensive use of real-time high-speed (greater than 50 bits/s) data processing with the IBM 7044–7094 computer system in the SFOF. This required, at times, two such computer strings to be fully operational for extended periods, especially during transit to the lunar surface. The support for this requirement was successfully provided, requiring however, many man-hours of hardware and software development and complex operational activities.

The *Surveyor* Project philosophy of highly centralized control of space flight operations required high reliability of communications circuits from the Deep Space Stations to the SFOF. This reliability was achieved by providing considerable redundancy, culminating in the first operational use of a communication satellite over the Atlantic Ocean for deep space data acquisition.

Development of the *Surveyor* spacecraft required the use of equipment and facilities for compatibility testing requiring an extensive series of tests at Goldstone with a telecommunication model of the *Surveyor* spacecraft. The availability of these facilities and the model spacecraft provided a basis for extensive training of network personnel in acquisition problems and the many varied communications procedures required to cope with the design of the *Surveyor* spacecraft. Furthermore, this project was one of the first to use the Cape Kennedy Deep Space Station (DSS 71). This station is located in the vicinity of the launch pad and checkout facilities, and was used in the final compatibility tests between the flight spacecraft and the Deep Space Network.

The *Surveyor* Project was the first to make use of the Ascension Island Deep Space Station (DSS 72), the Spacecraft Command and Guidance Station for near-earth telemetry coverage, tracking for early orbit determination, and at times, filling gaps between the coverage of other Deep Space Stations.

The *Surveyor* Project provided mission-dependent equipment at each of the Deep Space Stations for the functions of sending commands and processing telemetry and video data from the spacecraft. This equipment underwent considerable compatibility testing where it interfaced with mission-independent or network equipment. It was a source of many interface problems, not only in the hardware area, but in documentation, operations, and procedures. Stimulated, in part, by the need for extensive interface agreements because of the wide use of mission-dependent equipment throughout the TDS, procedures were developed to encompass interface structure and documentation, configuration control and documentation, as well as operational documentation for both mission-independent and mission-dependent equipment. The above procedures were developed to such a high degree that they have been implemented to support all subsequent flight projects. Furthermore, the project provided the personnel to maintain and operate this equipment, pending the training and transfer of responsibility to the on-site personnel. The project also provided on-site personnel for spacecraft control and data analysis in the event of a catastrophic failure in communications between the Deep Space Stations and the SFOF in Pasadena.

The DSN provided the support of its highest performance station, the Mars Deep Space Station (DSS 14) at Goldstone, to provide better signal-to-noise magnetic tape recordings of the strain-gage telemetry measurements during the *Surveyor I* touchdown. The *Surveyor* spacecraft, radiating from the moon, provided an excellent far field source for the Mars Station's 210-ft antenna pattern measurement (Fig. 1). The higher performance capability of this station was also used to return 4400-bit/s telemetry data during the trajectory correction maneuver of the spacecraft.

The *Surveyor* Project provided the first opportunity to demonstrate the capability to perform automatic data quality comparison in real-time on telemetry data received simultaneously from two Deep Space Stations. This function was accomplished by the telemetry processing system using two PDP-7 computers in the SFOF.

The project provided the first occasion for data commutations of pulse-code-modulated (PCM) telemetry data using a combination of hardware and software. This function was also accomplished in the telemetry processing system within the SFOF, and permitted automatic recognition of spacecraft data mode change from the telemetry system.

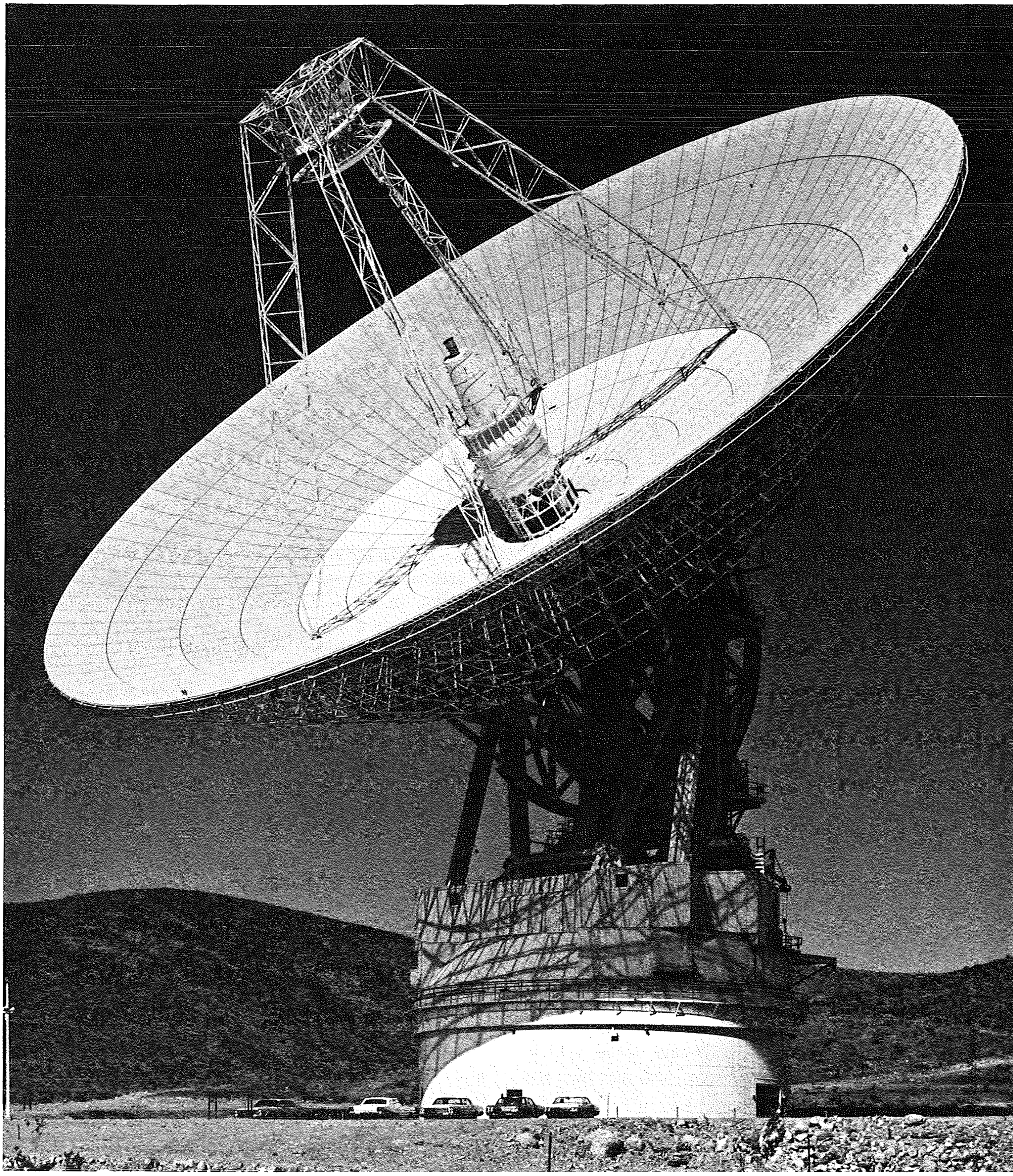


Fig. 1. Goldstone, Calif., Mars station (DSS 14), 210-ft antenna

The *Surveyor* Project was the first flight project wherein video information was received, retransmitted, processed, and displayed in real-time for operational decision making.

The *Surveyor* Project was the first project to share (with the *Mariner* Venus 67 Mission) the multiple project usage of a computer string.

The *Surveyor* Project was the first flight project that required the real-time transmission of spacecraft telemetry data from the near-earth phase network—i.e., from the Air Force Eastern Test Range (AFETR) ship and land stations and, in the later missions, from the MSFN station at Carnarvon to DSS 42. It brought together close working relationships between the three supporting networks: the AFETR, the MSFN, and the DSN. This integration was achieved to a degree never before attained for the support of a space flight program.

The *Surveyor* Project was the first to use: (1) real-time simulation of maneuvers with coordinated tracking and telemetry data, (2) video simulation, and (3) high-speed telemetry simulation data to overseas stations in real-time, by using the outgoing side of the high-speed data line to each of the Deep Space Stations.

B. Tracking and Data System

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

1. Air Force Eastern Test Range. This range 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 Air Force Base; actual missile launches and flight tests are conducted at Cape Kennedy Air Force Station (CKAFS) and over the downrange areas. Major instrumentation systems are used to support projects, programs, and organizations that use the AFETR launch facilities.

As a part of the Tracking and Data System, the AFETR performed tracking and data acquisition functions for the *Surveyor* missions during the countdown and launch phases of each flight. To meet its tracking and telemetry commitments for those missions, AFETR used land-based instrumentation sites, range instrumentation ships (RISs), and range telemetry aircraft.

2. Manned Space Flight Network. This network is under the direction of the GSFC, located at Greenbelt, Md. It is part of a worldwide network designed for supporting the near-earth manned space flight effort. The MSFN had 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 were monitored. By use of the switching communications and monitoring arrangements, voice operations and control were linked to all MSFN tracking stations committed to support the *Surveyor* missions.

All MSFN stations are tied together through common timing, geodetic, control systems, and communications coordination by GSFC. The worldwide NASA communications network designated NASCOM provided teletype, voice, and data links in support of *Surveyor.*

3. Deep Space Network. The DSN, established by the NASA Office of Tracking and Data Acquisition, is under the system management and technical direction of JPL. It is responsible for two-way communications with unmanned spacecraft from approximately 10,000 mi from earth to interplanetary distances. Present facilities permit simultaneous control of a newly launched spacecraft and one already in flight. In preparation for the increased number of U.S. space activities, 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 track spacecraft to, planets as distant as Jupiter.

The DSN is distinct from other NASA networks, such as the Space Tracking and Data Acquisition Network, which tracks earth-orbiting scientific and communications satellites, and the MSFN, which tracks the manned spacecraft of the *Gemini* and *Apollo* Projects.

The network supports (or has supported) the following NASA space exploration projects: (1) the *Ranger,* Mariner, and Surveyor 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 MSFN), 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 SFOF, which is the command and control center for DSN-supported projects.

The Deep Space Stations are situated so that three prime stations will always be approximately 120 deg apart in longitude so 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 critical flight maneuvers and nearly all of the picture-taking operations during each mission were commanded and recorded by DSS 11 during its view periods. A few picture sequences were obtained by DSSs 42 and 51, which served as prime stations for tracking and monitoring of engineering telemetry for *Surveyor I*. Deep Space Stations 12, 14 (with its 210-ft antenna), 61, and 72 were configured for monitoring and backup operations during the *Surveyor I* Mission.

Acquisition of a spacecraft signal may involve six different functions:

(1) Pointing the antenna at the spacecraft.

(2) Tuning 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).

(5) Synchronizing the telemetry system.

(6) In some cases, providing for immediate command transmission to the spacecraft.

Selected Deep Space Stations are equipped with acquisition aid antennas mounted on the 85-ft antennas to assist in the acquisition process. The acquisition aids

Table 1. Deep Space Station designations and locations

Location	DSS No.	Geodetic latitude, deg	Geodetic longitude, deg	Height above mean sea level, m	Geocentric latitude, deg	Geocentric longitude, deg	Geocentric radius, km
Pioneer Deep Space Station Goldstone, Calif.	11	35.38950 N	243.15175 E	1037.5	35.20805 N	243.15080 E	6372.0341
Echo Deep Space Station Goldstone, Calif.	12	35.29986 N	243.19539 E	989.5	35.11861 N	243.19445 E	6372.0176
Venus Deep Space Station Goldstone, Calif.	13	35.24772 N	243.20599 E	1213.5	35.06662 N	243.20507 E	6372.2599
Mars Deep Space Station Goldstone, Calif.	14	35.42528 N	243.12222 E	1160	35.24376 N	243.12127 E	6372.1341
Woomera Deep Space Station Island Lagoon, Australia	41	31.38314 S	136.88614 E	144.8	31.21236 S	136.88614 E	6372.5317
Tidbinbilla Deep Space Station Canberra, Australia	42	35.40111 S	148.98027 E	654	35.21962 S	148.98027 E	6371.6686
Johannesburg Deep Space Station Johannesburg, S. Africa	51	25.88921 S	27.68570 E	1398.1	25.73876 S	27.68558 E	6375.5415
Robledo Deep Space Station Madrid, Spain	61	40.429 N	355.751 E	800	40.238 N	355.751 E	6370.0868
Spacecraft Monitoring Station Cape Kennedy, Fla.	71	28.48713 N	279.42315 E	4.0	28.32648 N	279.42315 E	6373.2913
Spacecraft Command and Guidance Station Ascension Island, S. Atlantic	72	7.95474 S	345.67242 E	526.7	7.89991 S	345.67362 E	6378.2386

have beamwidths of approximately 16 deg and are accurately boresighted with the 85-ft antennas. They have angle-error outputs that 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. Tracking, telemetry, and control of the spacecraft are thus properly attained.

C. Surveyor Project

The *Surveyor* Project comprised seven flights—identified prior to launch as Missions A–G and after launch as *Surveyors I–VII*—that were conducted under the auspices of NASA. Essentially, the objectives were to accomplish successful soft landings on the moon (as demonstrated by the operation of the spacecraft subsequent to landing), to provide data on the performance of the spacecraft in the transit environment and basic knowledge of the moon's structure and environment in support of the *Apollo* Project.

1. Mission flight objectives. These objectives were ordered in three priorities: primary, secondary, and tertiary. Prior to *Surveyor I* launch, a launch-hold criterion established that all objectives must be capable of being met before launch would be permitted.

a. Primary flight objectives. Achievement of the primary objectives was required for the mission to be considered successful. When developmental or operational conditions existed that jeopardized or prevented achievement of the primary objectives, the launch was delayed or rescheduled. Further, nonstandard procedures, if required, were executed during flight operations in such a manner as to accomplish the primary objectives at the expense of the lesser objectives.

The primary flight objectives were to:

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

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

(3) 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.

b. Secondary flight objectives. Achievement of the secondary objectives was highly desirable; however, failure to achieve these objectives, although serious, was not regarded as mission failure. The scheduled launch would probably be delayed, or rescheduled if conditions existed that seriously jeopardized or prevented achievement of the secondary objectives—but a decision would be made at that time based on the circumstances.

The secondary flight objectives were to:

(1) Obtain inflight engineering data on all spacecraft subsystems used in the cruise phase of the flight.

(2) Obtain inflight engineering data on all spacecraft subsystems used during the midcourse maneuver, terminal-descent maneuver, and main retromaneuver phase.

(3) Obtain inflight engineering data on the performance of the closed-loop terminal-descent guidance and control system, consisting of the doppler velocity sensor and altitude marking radar, on-board analog computer, autopilot, and vernier engines.

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

c. Tertiary flight objectives. Achievement of the tertiary objectives was considered a bonus. If developmental, launch, transit, or lunar (e.g., landing-site lighting) readiness conditions that affected the accomplishment of the tertiary objectives were not satisfactory, the scheduled launch would proceed as planned without major delays.

The tertiary flight objectives were to:

(1) Obtain postlanding TV pictures of a spacecraft footpad and the immediately surrounding lunar surface material.

(2) Obtain postlanding TV pictures of the lunar topography.

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

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

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

d. Additional mission objectives. These objectives were to:

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

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

(3) Obtain engineering data regarding performance of the spacecraft system that would aid in future space exploration.

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

2. Flight description. The *Surveyor* spacecraft were launched from AFETR launch complex 36 at Cape Kennedy, Fla. *Atlas/Centaur* launch vehicles were used to boost the spacecraft to the required lunar-transfer trajectory. The ascent mode used for *Surveyor* was either by direct-ascent or parking-orbit trajectory. Direct-ascent trajectories are characterized by nearly continuous thrusting from liftoff to injection; parking-orbit trajectories are characterized by a coast period of up to 20-min duration followed by a second burn injecting the spacecraft into its lunar-transfer trajectory. A single-burn, direct-ascent trajectory was used for *Surveyors I, II,* and *IV. Surveyors III, V, VI,* and *VII* used a parking-orbit trajectory.

In the absence of a parking-orbit coast capability, injection is constrained to occur at an earth-centered, central angle of about 28 deg from the launch site. Consequently, the true anomaly at injection must be varied with launch time to satisfy the time-variant geometry requirements of the transfer trajectory. To vary the true anomaly at injection, the injection flight-path angle must be varied accordingly. Since payload capability is dependent upon injection flight-path angle, the true anomaly at injection cannot exceed the limits dictated by the payload requirement for a given mission. In general, the lower true anomaly limit will delay the opening of the launch window until the required geometry is obtained. This prevents use of the lower launch azimuths on certain days in the launch period.

A lunar trajectory is usually dependent upon four impact parameters: (1) speed, (2) selenographic latitude, (3) selenographic longitude, and (4) time of lunar impact. Other sets of four parameters can be used, but this set was the most useful for the *Surveyor* missions. Corresponding to the four impact parameters are four launch parameters by which the trajectory can also be specified. They are: (1) launch time, (2) launch azimuth, (3) injection flight-path angle, and (4) energy. In the trajectory design, the impact parameters are used as search variables; the launch parameters are the control variables.

An analytic direct-ascent *Atlas/Centaur* boost model was developed that computed the injection conditions of the translunar trajectory associated with a given set of launch parameters. When the injection conditions are obtained, the trajectory may then be computed.

The nominal *Surveyor* trajectories were selected on the basis of the launch and impact parameters previously described and the constraints imposed on them. The functional relationships involved in the selection of these parameters in trajectory design are presented in Fig. 2. This diagram shows the dependence of the parameters upon 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) upon these parameters is shown.

When all of 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. Injection into the required lunar-transfer trajectory occurs at *Centaur* main engine cutoff, approximately 680 s after liftoff. Shortly after injection, a *Centaur* programmer command deploys the spacecraft landing gear and omnidirectional antennas, and switches the spacecraft transmitter to high power. The spacecraft is then separated from the *Centaur.* At this time, *Centaur* executes a retromaneuver 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

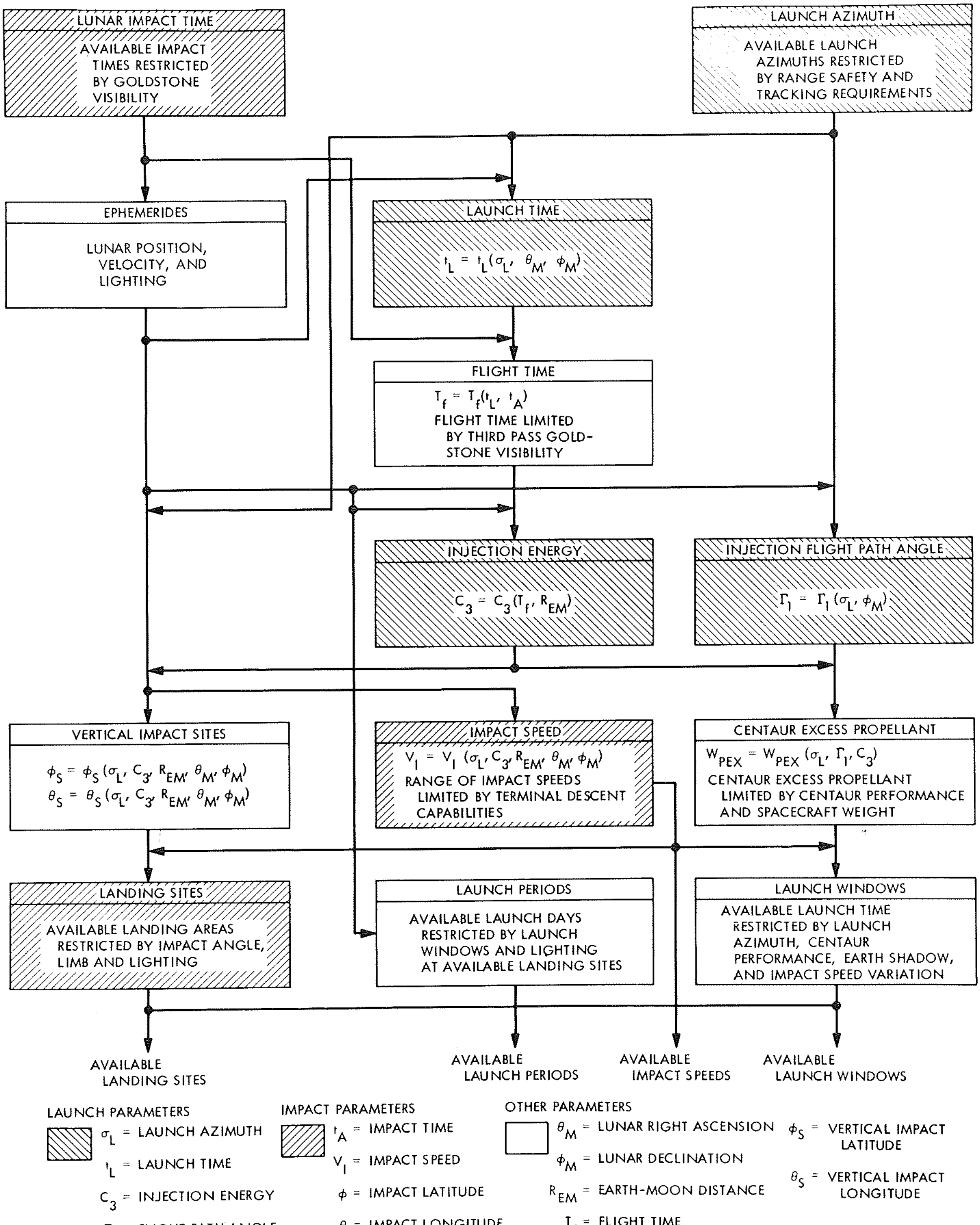


Fig. 2. Functional relationships between launch parameters, impact parameters, mission design constraints, and *Surveyor* trajectory design

perigee altitude is 90 nmi. Lunar encounter occurs at approximately one half the distance from perigee to apogee.

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

A trajectory correction maneuver, executed approximately 15 h after injection, provides the spacecraft with a trajectory that terminates at the desired point on the lunar surface and is called the terminal-descent maneuver. This maneuver is computed at the Space Flight Operations Facility from tracking information supplied by the DSIF.

The terminal-descent maneuver is initiated by pointing the vehicle thrust axis in a direction (precalculated at the SFOF) aligned with the predicted velocity vector at main retroignition for vertical approaches. For off-vertical angles, a small bias angle is sometimes introduced. Then, when distance to the lunar surface reaches a preset value (about 60 smi), 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 retroengine 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 the predicted impact. Following a command enabling signal to the trigger radar, the landing sequence is automatic.

The retroengine separates from the spacecraft after burnout at a nominal lunar altitude of 30,000 ft. 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. Postlanding TV sequences are then selected in real-time.

D. Surveyor Spacecraft

1. Design series. The *Surveyor* spacecraft were designed in two basic series. The A-21 series carried an engineering payload to demonstrate successful transit and soft 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 was a secondary objective for this series. The A-21A series of spacecraft used the same basic soft lunar-landing technology, but carried an additional payload consisting of various scientific instruments. The primary purpose of the A-21A series was the collection and transmission of scientific data relative to the lunar environment.

To ensure a minimum capability of lunar sunrise-to-sunset operations, a minimum predawn operation of 3 h for the A-21 and 20 h for the A-21A spacecraft (nonoperating mode), and a minimum postsunset operation of 150 h (nonoperating mode) were required with a 90-day period of operation as the desired objective.

2. Configuration. The general configuration of the *Surveyors V, VI,* and *VII* spacecraft and identification of its various elements are shown in Fig. 3. The spacecraft were composed of electronic and mechanical assemblies mounted on a basic spaceframe constructed of thin-walled aluminum alloy tubular members. Landing shock was absorbed by a crushable structure and by the tripod landing gear, which also maintained correct attitude after landing.

The equipment carried on the first four missions included flight control, propulsion, telecommunications, TV, and power subsystems. The flight control subsystem provided attitude stabilization and control during all phases of flight. The primary sun sensor and the Canopus sensor provided attitude reference during the coast phases of flight. Other elements of the flight control subsystem included gas jets, an inertial reference unit, and associated electronics. The altitude-marking radar initiated the terminal-descent phase by firing the vernier engines and main retromotor. The radar altimeter and doppler velocity sensor (RADVS) provided signals to control the rate of descent and attitude during the descent phase.

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

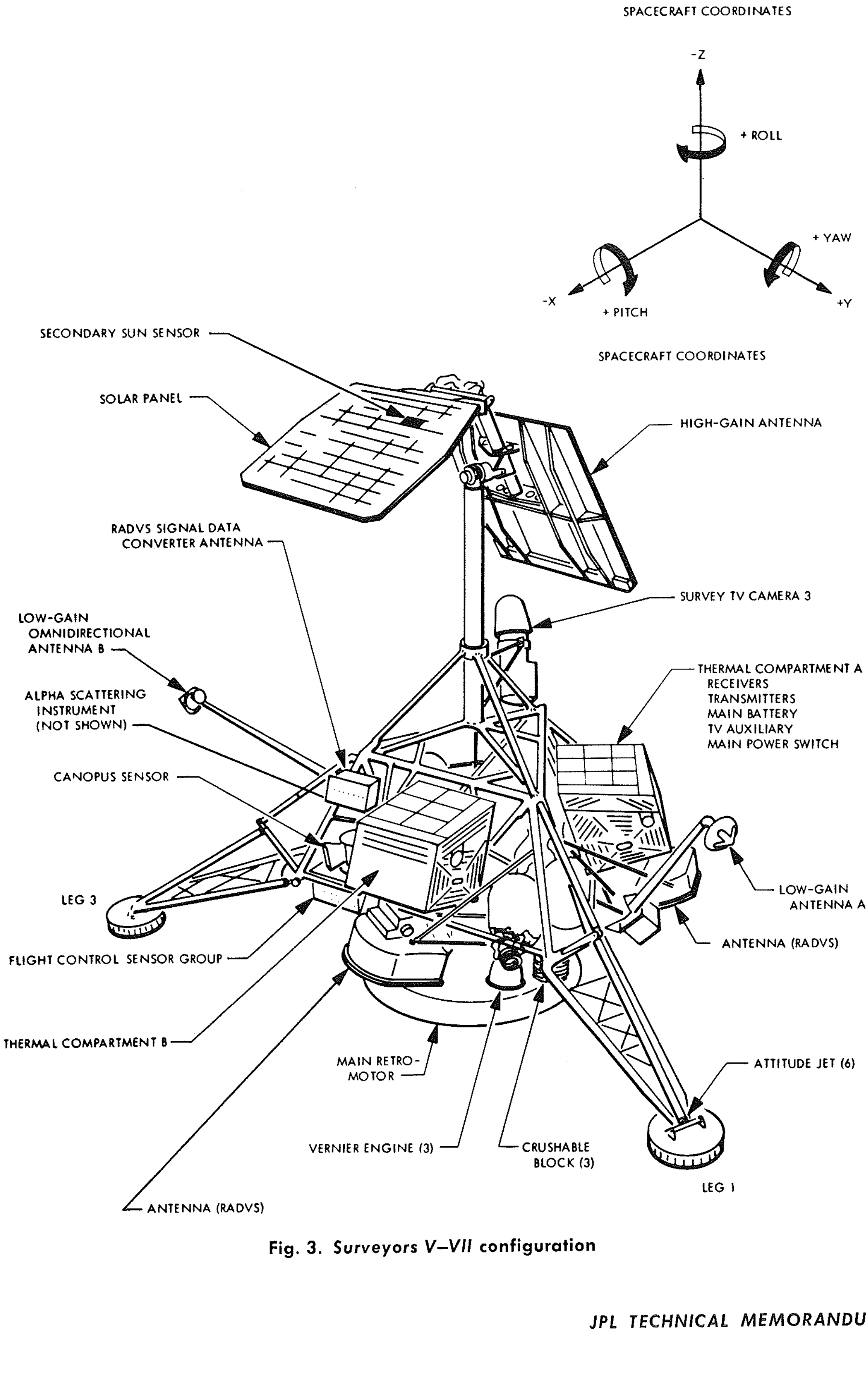


Fig. 3. ***Surveyors V–VII* configuration**

In addition to these subsystems, the *Surveyor* spacecraft carried an engineering payload. This payload consisted of an auxiliary battery, the television subsystem, accelerometers for measuring vernier engine thrust, strain gages for measuring main retrorocket 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 processed the sensor data for transmission.

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

The *Surveyor* spacecraft had a nominal separated weight of approximately 2200 lb and contained three extendable legs used for stability during touchdown on the lunar surface. The guidance system of each spacecraft maintained full attitude stabilization and directed the spacecraft through maneuvers in attitude and trajectory in response to commands from the ground. Cold gas jets were used to position and maintain the spacecraft in the required attitude. In the stabilized mode, the spacecraft used the sun and Canopus as reference objects.

The spacecraft contained two propulsion systems: a solid-propellant, main retroengine that provided 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 the terminal descent. During the terminal-descent sequence, the propulsion system was controlled automatically by a radar system that measured altitude and velocity components with respect to the lunar surface.

The spacecraft derived their electrical power from solar panels and from batteries for peak power requirements during transit, and after landing during the lunar night. Each had a two-way-communication S-band system that provided a method of telemetering information to the earth, provided command capability to the spacecraft, and provided angle tracking and one- or two-way doppler data for orbit determination.

E. *Atlas/Centaur* Launch Vehicle

The two-stage launch vehicle, shown in Fig. 4, consisted of an *Atlas* first stage and a *Centaur* second stage. Both stages were of a constant 10-ft diameter and used a stainless-steel shell construction that maintained its shape through pressurization without any internal stiffening. All main engines and the *Atlas* vernier engines were gimbaled for directional control. The gross weight of the 105-ft vehicle was approximately 300,000 lb at liftoff.

1. First stage. The first stage of the *Atlas/Centaur* vehicle was a modified version of the *Atlas D* used on many previous NASA and Air Force missions, such as *Ranger, Mariner,* and the *Orbiting Geophysical Laboratory (OGO).* The *Atlas* propulsion system consists of two booster thrust chambers rated at 165,000 lb thrust each, a single sustainer rated at 57,000 lb thrust, and two vernier thrust chambers rated at approximately 1000-lb thrust each. All engines burned a propellant combination of liquid oxygen and RP-1 kerosene that produced a total liftoff thrust of approximately 388,000 lb. The *Atlas* can be considered a 1½-stage vehicle because the booster section, weighing 6000 lb and consisting of the two booster engines together with the booster turbopumps and other equipment located in the aft section, was jettisoned after about 2.5 min of flight. The sustainer and vernier engines continued to burn until propellant depletion. A mercury manometer propellant utilization system was used to control mixture ratio for the purpose of minimizing propellant residuals at *Atlas* burnout.

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

The *Atlas* contained a single VHF telemetry system that transmitted data on 118 first-stage measurements until *Atlas* separation. The system operated on a frequency of 229.9 MHz 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 were employed on the *Atlas* to provide the range safety officer with means

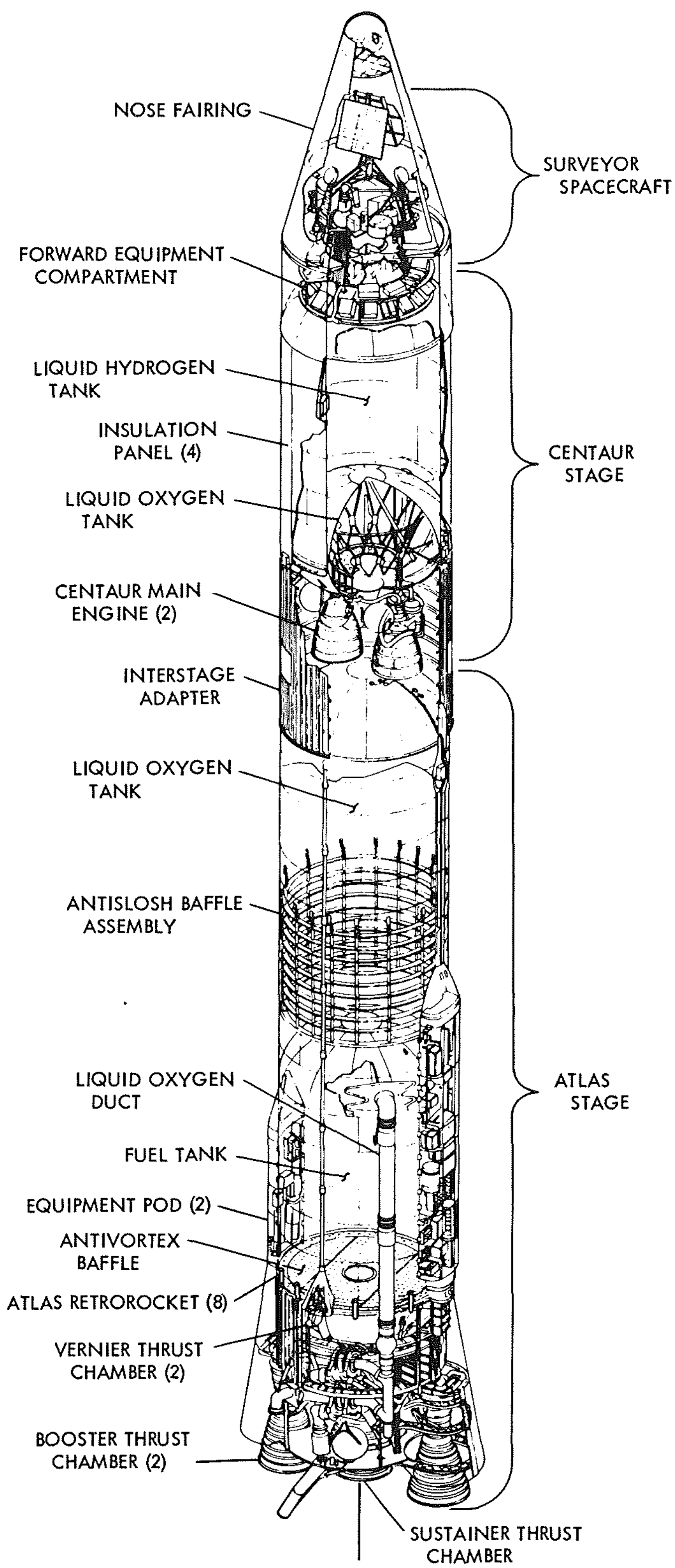


Fig. 4. ***Atlas/Centaur/Surveyor*** **space vehicle configuration**

of terminating the flight by initiating engine cutoff and destroying the vehicle. The system was inactive after normal *Atlas* staging occurred. Only the C-band tracking system was used on the *Centaur* stage.

2. Second stage. The *Centaur* second stage was the first vehicle to utilize liquid hydrogen/liquid oxygen, high-specific-impulse propellants. The cryogenic propellants required 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 was 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 to overcome a deployment control problem that had been suspected on previous vehicle development flights. Most of the *Centaur* electronic equipment packages were mounted on the forward tank bulkhead in a compartment that was air-conditioned before liftoff.

The *Centaur* was powered by two constant-thrust engines rated at 15,000-lb thrust each at vacuum conditions. Each engine could be gimbaled to provide control in pitch, yaw, and roll. Propellant was fed from each of the tanks to the engines by boost pumps driven with hydrogen peroxide turbines. In addition, each engine contained integral *bootstrap* pumps driven by the hydrogen propellant, which was also used for regenerative cooling of the thrust chambers. A propellant-utilization system was used on the *Centaur* stage to achieve minimum residual of one propellant upon depletion of the other. The system controlled 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 was 5:1 by weight.

The second-stage all-inertial guidance system contained an on-board computer that provided vehicle steering commands after jettison of the *Atlas* booster section. The *Centaur* guidance signals were 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 provided 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 employed 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 provided thrust to control the vehicle after powered flight. For small corrections in yaw, pitch, and roll attitude control, the system utilized six individually controlled, fixed-axis, constant-thrust, hydrogen peroxide reaction engines. These engines were mounted in clusters of three, 180 deg apart on the periphery of the main propellant tanks at the interstage adapter separation plane. Each cluster contained 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 were installed on the aft bulkhead, with thrust axes parallel with the vehicle axis. These engines were for use during retromaneuver and for executing larger attitude corrections (if necessary). The cluster engines were slightly modified from the design used on previous *Surveyor* flights in that a large aluminum B-nut on the thrust chambers was replaced with a steel flange joint to effect a more positive seal.

The *Centaur* stage utilized 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 provided 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 were employed on the *Centaur*, together with shaped-charge destruct units for the second stage and spacecraft. This provided 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 could be safed by a ground command normally transmitted by the range safety officer when the vehicle reached injection energy.

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

A C-band tracking system was contained aboard the *Centaur* that included a lightweight transponder, circulator, power divider, and two antennas located under the insulation panels. The C-band radar transponder provided real-time position and velocity data for the range safety instantaneous impact predictor program, as well as data for use in guidance and trajectory analysis.

F. Alpha Scattering Experiment

The *Surveyors V, VI,* and *VII* Missions carried an alpha scattering instrument package. Its function was to determine the chemical composition of the uppermost few microns of the moon's surface by an analysis of the characteristic manner in which nuclei reflect alpha particles. Additional discussion and the operational configuration of this experiment are discussed in Section IV.

II. *Surveyor V* Mission Synopsis

Surveyor V was launched on September 8, 1967, at 07:57:01.257 GMT[1] from launch complex 36B, Cape Kennedy, Fla. The launch vehicle (AC-13) was the second two-burn vehicle to be used in a *Surveyor* lunar mission. The flight sequence of *Surveyor V* was, in general, the same as that for *Surveyor III*, except that the inflight aiming point was in the Sea of Tranquility at 0.917 deg N and 24.083 deg E.

The objectives of *Surveyor V* were to:

(1) Obtain postlanding television pictures of the lunar surface.

(2) Conduct a vernier engine erosion experiment.

(3) Determine the relative abundance of the chemical elements in the lunar soil by operation of the alpha scattering instrument.

(4) Obtain touchdown dynamics data.

(5) Obtain thermal and radar reflectivity data on the lunar surface.

The performance of *Surveyor V*, but for the loss of helium pressure after the first midcourse correction, was flawless. The spacecraft responded successfully to all commands, standard and nonstandard, required to accomplish its soft landing at 00:46:45 on September 11, 1967.

[1]Unless otherwise noted, all references to time will be GMT.

The historic soft landing of *Surveyor V* can be attributed to the high level of technical skill of the *Surveyor* team, which was rapidly assembled into a task force directed by project management.

The *Surveyor V* spacecraft was launched after an uneventful countdown to $T - 5$ min, at which time the built-in hold of 10 min was extended approximately 18 min to resolve anomalous indications from the *Atlas* propellant utilization system. Liftoff was accomplished with a launch azimuth of 79.517 deg. Performance of the *Atlas/Centaur* launch vehicle was excellent; all *marks* occurred very close to the predicted times.

Injection of the spacecraft occurred at 08:16:26.8 on September 8 with a trajectory that would have provided, with no midcourse correction, a total miss of 46 km from the targeted landing site within the Sea of Tranquility at 0.83 deg N and 24.00 deg E. Normal preprogrammed spacecraft events occurred successfully [i.e., high power, landing legs extended, omnidirectional antenna extended, electrical disconnect from *Centaur*, automatic solar panel stepping, antenna and solar panel positioner (A/SPP) roll axis stepping, and automatic sun acquisition] and in the proper order.

The prime functions of telemetry recovery and command generation were accomplished at the Deep Space Stations. The Deep Space Stations utilized in a prime capability were DSS 11, DSS 42, DSS 51, DSS 61, and DSS 72 (see Table 1 for a breakdown of the Deep Space Stations by name and location) which was utilized as backup to DSS 51 upon initial spacecraft acquisition. As a backup to DSS 11, DSS 14 was committed in real-time to support the *Surveyor* program during the terminal-descent phase. Initial acquisition (one-way lock) was accomplished by DSS 72 at approximately 08:22 on September 8.

One-way lock was acquired at approximately 08:25 by DSS 51 and two-way lock established at approximately 08:29. Initial spacecraft operations were initiated at 08:36:59 by commanding off the transmitter high power. [See Table 4 for additional spacecraft performance analysis and command (SPAC) real-time decisions and outputs regarding mission details.] The star verification and acquisition sequence was initiated at 14:10:01 by commanding sun acquisition and roll maneuver; automatic Canopus acquisition was obtained at 14:27:52. During the star-mapping sequence, 10 star intensity signals (Zeta Ophiuchi, Antares, Tau Scorpii, Alnitak, Alnitam, Mintaka, Bellatrix, El Nath, Capella, and Polaris), in addition to those of Canopus and earth, were observed and identified.

Preparation of the spacecraft for the midcourse maneuver was initiated at 01:02:42 on September 9 with an engineering interrogation. The spacecraft was configured in high power and 4400 bits/s by 01:15:56. A premidcourse correction maneuver consisting of a +71.9-deg roll was successfully executed at approximately 01:35:20, followed by a successful −35.7-deg yaw. The vernier engine system was pressurized (offset of 232 psia noted, as expected) and vernier engine 1 unlocked at 01:42:26. Thrust phase power was commanded and verified at 01:43:17. The midcourse velocity correction was commanded and verified at 01:43:31. At 01:45:02.3 (the scheduled nominal time), the midcourse velocity maneuver was executed with a burn of 14.25 s that produced a velocity change of 14.0 m/s. Telemetry and doppler-shift data indicated that the velocity correction was as commanded.

During the postmidcourse sequence and while the spacecraft was in the commutator 1 mode, the SFOF propulsion specialists observed and reported possible helium pressure leakage. The standard postmidcourse sequence was terminated and the spacecraft was commanded back to mode 1 from mode 5. The helium pressure leak was verified, and it was established that: (1) the helium leak rate was approximately 10 psi/min, and (2) the probable cause of helium pressure loss was improper seating of the regulator valve.

The propulsion specialists advised that, to achieve a standard terminal descent, the helium pressure must be around 2500–3000 psia. In an attempt to reseat the helium regulator valve before the helium pressure reached this value, the engines were successfully reignited four times, but there was no indication of reseating. The spacecraft was placed in a partial transit configuration, (i.e., sun lockon at 1100 bits/s, low power, mode 5) at 02:56:50 with the helium still leaking. The normal transit configuration was obtained at 05:04:09 by obtaining sun and star lockon.

Mission Control then had to determine whether to: (1) fire the retroengine to place the spacecraft in an earth orbit to obtain TV pictures of the earth and alpha scattering data, or (2) redesign the terminal-descent sequence to attempt a soft landing. In anticipation that a soft landing might not be feasible, Mission Control directed that the spacecraft be prepared for placement in earth orbit. The TV and alpha scattering heaters were activated and the altitude-marking radar (AMR) heaters were deactivated at 05:48:45.

Further preparation of the spacecraft for placement in earth orbit was suspended until the response of the vernier engines at reduced pressure (825 psia) could be determined; it was expected that the helium vent valves would close and hold the pressure at this level. Since a soft landing appeared more feasible as a result of SFOF and program management test and analysis, Mission Control directed that the spacecraft be returned to the transit configuration. The AMR heater was activated and the TV and alpha scattering heaters deactivated at 06:39:39 on September 9.

As increasing amounts of test and analytical data supporting the feasibility of a soft landing were accumulated, project management directed that a soft landing be attempted instead of placing the spacecraft in an earth orbit.

The fifth midcourse vernier engine burn was initiated at 08:24:03 on September 9 to: (1) burn off propellants and lighten the spacecraft for the new soft landing dynamic criteria, and (2) redirect the spacecraft to the original landing site targeted during the initial midcourse correction maneuver. This maneuver returned the spacecraft to a landing point of 1.50 deg N and 23.19 deg E (original inflight aiming point was 0.917 deg N, 24.083 deg E), a miss of only 30 km. One final correction was made at 23:30:08 GMT on September 9 to further reduce fuel weight and correct a trajectory error.

In addition to the normal spacecraft operations in coast phase II, the alpha scattering instrument was operated successfully for calibration purposes, and 10 gyro drift checks were performed to provide accurate gyro-drift rates for use in the terminal-descent maneuver calculations. The gyro-drift rates were determined to be: (1) roll, +0.85 deg/h; (2) pitch, +0.60 deg/h; and (3) yaw, −0.60 deg/h.

The standard terminal-descent sequence timing was greatly revised as a result of extensive real-time analysis performed by the SFOF in order to attempt a soft landing. Basically, the terminal-descent sequence was modified by overriding the automatic sequence from retroignition on, and by ground command to adjust the retromotor burnout altitude from 38,000 to 4500 ft and the spacecraft velocity at burnout from 450 to 92 ft/s.

Terminal-descent operations were initiated during the DSS 11 (Goldstone) pass at 22:32:48 on September 10 with the performance of the last scheduled transit engineering interrogation. The spacecraft was commanded and successfully performed a roll of +73.9 deg and a yaw of −119.5 deg. A third maneuver was not required because the previous maneuvers yielded a spacecraft roll orientation that satisfied the RADVS and telecommunication terminal-descent constraints. Touchdown strain gages were activated at 00:21:38 on September 11 as the DSS 14 carrier signal level at the end of the second maneuver was reported as −117.1 dBmW, well within the turnon criteria of −130.5 dBmW for the touchdown strain gages. The retroignition delay quantity of 12.325 s was loaded and verified at 00:24:84 on September 11, AMR power was applied at 00:40:00, thrust phase power was turned on at 00:41:00, and the AMR was enabled at 00:43:00. The override command taped terminal-descent sequence was initiated at 00:44:43.9, and a soft landing was achieved at 00:46:45 on September 11. Touchdown strain-gage data indicated that leg 1 touched down first, followed by legs 2 and 3 at practically the same time. Communications were maintained with the spacecraft at all times during the terminal-descent phase. The post-landing shutdown sequences were initiated immediately after touchdown, the engineering assessment was performed, and the spacecraft was prepared for TV operations.

The transit phase of *Surveyor V* was conducted from September 8 through touchdown on September 11, 1967; the spacecraft responded successfully to 725 commands. Lunar operations began at touchdown and extended through September 28 at 23:56 PDT, when all *Surveyor V* first lunar day operations ended. A total of 18,006 good TV pictures (more than were received from *Surveyors I* and *III* combined) and 83 h of alpha scattering instrument data were obtained during this period.

A visual profile of the flight of *Surveyor V* is shown in Fig. 5. In addition, a detailed, time-ordered profile of the entire transit phase is contained in Table 2 (except for the daggered entries, all times listed are from telemetry data received in the spacecraft performance and analysis area at SFOF, and include delays due to transit, processing, and commutation). A summary of the important events is presented in Sections V and VI.

Table 2. *Surveyor V* mission profile summary

Time		Command sequence		Event
After launch	GMT	Major	Minor	
Launch to separation				
0	07:57:01.25 Sep 8, 1967			Launch
18:42	08:15:43			Extend Landing Gears commanded by *Centaur*
18:52	08:15:53			Extend Omniantennas commanded by *Centaur*
19:12	08:16:13			Transmitter High Voltage On commanded by *Centaur*
19:19	08:16:20			Spacecraft/*Centaur* electrical disconnect
19:24	08:16:25			Separation
25:38	08:22:39			Solar panel locked in transit position
31:02	08:28:03			Roll axis locked in transit position
31:35	08:28:36			Sun acquisition cell illuminated (after 342-deg roll)
31:59	08:29:00			Initial DSS acquisition completed (two-way lock)
32:11	08:29:12			Sun lockon achieved (primary sun sensor cell illuminated after 18-deg yaw)
DSIF acquisition through star acquisition				
39:59	08:37:00	0040	0552	Turn spacecraft high power transmitter off
45:20	08:42:21	0040	0050	Turn accelerometer amplifiers and solar panel deployment logic off
46:27	08:43:28	0040	0454	*Rocking* solar panel back and forth to seat locking pin
47:24	08:44:25	0040	0455	*Rocking* roll axis back and forth to seat locking pin
48:32	08:45:33	0040	0251	Mode 1 interrogation
49:49	08:46:50	0040	0052	Initial 1100 bits/s selection (change from 550 bits/s—low modulation index)
51:18	08:48:19	0040	0055	Mode 4 interrogation
54:00	08:51:01	0040	0251	Mode 2 interrogation
55:49	08:52:50	0040	1356	Mode 6 interrogation
1:03:59	09:00:00	0040	1354	Return to mode 5 for coast-phase monitoring
4:22:01	12:19:02			Select omniantenna A
5:50:45	13:47:46	0046	0250	Start pre-star-verification engineering interrogation
5:50:53	13:47:54	0046	0250	Mode 4 interrogation
5:54:15	13.51:16	0046	0051	Mode 2 interrogation
5:57:11	13:54:12	0046	0252	Mode 1 interrogation
6:02:16	13:59:17	0041	0652	Turn transmitter filament on
6:05:28	14:02:29			Solar panel switch on
6:06:27	14:03:28	0041	0653	Turn transmitter high voltage on
6:07:30	14:04:31			Select omniantenna B
6:08:39	14:05:40	0041	0253	Select 4400 bits/s (change from 1100 bits/s)
6:11:51	14:08:52		0654	Cruise mode commanded on
6:11:52	14:08:53	0041	0654	Manual delay mode and positive angle maneuver commanded
6:13:01	14:10:02	0041	1251	Start roll
6:28:35	14:25:36	0041	0655	Star-acquisition mode commanded to permit automatic star lockon
6:33:09	14:30:10	0041	0054	Cruise mode on
6:33:54	14:30:55		0550	Return to mode 5
6:35:37	14:32:38		0150	Return to 1100 bits/s
6:36:40	14:33:41	0041	0552	Turn transmitter high power off
7:11:25	15:08:26			Solar panel switch on

Table 2 (contd)

Time		Command sequence		Event
After launch	GMT	Major	Minor	
Coast phase I				
7:48:51	15:45:52	0041	0354	Initiate gyro drift check 1, three-axis
7:58:28	15:55:29			Solar panel switch on
8:45:14	16:42:15			Solar panel switch on
9:19:16	17:16:17			Solar panel switch on
9:25:05	17:22:06		11E4	Mode 4 interrogation
9:29:38	17:26:39		11D5	Return to mode 5
9:47:04	17:44:05			Solar panel switch on
10:19:27	18:16:28	0046	0054	Terminate gyro drift check
10:36:28	18:33:29			Solar panel switch on
10:37:27	18:34:28	0046	0354	Initiate gyro drift check 2, three axis
10:56:43	18:53:44			Solar panel switch on
11:37:23	19:34:24			Solar panel switch on
12:10:37	20:07:38			Solar panel switch on
12:19:01	20:16:02	0046	0054	Terminate gyro drift check
12:21:09	20:18:10		7B4	Reduce bit rate from 1100 to 137.5 bits/s
12:46:00	20:43:01		7D5	Reduce bit rate from 137.5 to 17.2 bits/s
13:41:54	21:38:55			Solar panel switch on
13:42:59	21:40:00		7E2	Increase bit rate from 17.2 to 1100 bits/s
13:46:57	21:43:58	0046	0357	Initiate gyro drift check 3, roll only
13:50:47	21:47:48	0046	0250	Mode 4 interrogation
13:56:23	21:53:24	0046	0251	Mode 2 interrogation
13:59:42	21:56:43	0046	0252	Mode 1 interrogation
14:03:57	22:00:58	0046	0550	Return to mode 5
15:43:32	23:40:33	0046	0054	Terminate gyro drift check
15:44:37	23:41:38	0042	0250	Initiate premidcourse interrogation
15:44:44	23:41:45	0042	0250	Mode 4 interrogation
15:48:45	23:45:46	0042	0251	Mode 2 interrogation
15:51:45	23:48:46	0042	0252	Mode 1 interrogation
15:56:47	23:53:48	0042	0550	Return to mode 5
Midcourse correction				
15:58:01	23:55:02	0042	0350	Initiate gyro speed check
15:59:37	23:56:38	0042	0351	Select next gyro three times
16:01:46	23:58:47	0042	0451	Gyro speed signal processing off and return to mode 5
17:02:38	00:59:39 Sep 9, 1967	0043	0250	Initiate midcourse correction interrogation
17:02:44	00:59:45	0043	0250	Mode 4 interrogation
17:05:41	01:02:42	0043	0251	Mode 2 interrogation
17:08:55	01:05:56	0043	0252	Mode 1 interrogation
17:16:25	01:13:26	0043	0652	Turn transmitter filament on
17:18:18	01:15:19	0043	0653	Turn transmitter high power on
17:18:55	01:15:56	0043	0253	Increase bit rate from 1100 to 4400 bits/s
17:28:10	01:25:11	0403	1150	Command desired roll maneuver magnitude and direction (+71.9 deg)
17:35:56	01:32:57	0403	1251	Start roll near zero crossing of Canopus error signal
17:39:25	01:36:26	0403	1151	Command desired yaw maneuver magnitude and direction (−35.7 deg)
17:41:05	01:38:06	0403	1253	Start yaw near zero crossing of primary sun sensor error signal
17:42:44	01:39:45	0403	0251	Mode 2 interrogation
17:43:45	01:40:46	0403	0252	Return to mode 1

Table 2 (contd)

Time		Command sequence		Event
After launch	GMT	Major	Minor	
Midcourse correction (contd)				
17:44:45	01:41:46	0403	0751	Propulsion strain-gage powered, inertial mode and reset group IV outputs commanded
17:45:23	01:42:24	0403	0750	Turn cyclic loads AMR, vernier line heaters off
17:45:26	01:42:27	0043	0750	Pressurize vernier system (helium). Unlock vernier engine 1
17:46:16	01:43:17	0043	0752	Thrust phase power on
17:46:30	01:43:31	0043	0753	Command desired thrust duration (14.25 s)
17:48:01	01:45:02	0043	0754	Execute midcourse thrust
17:48:18	01:45:19	0043	0754	Command terminate thrust
17:48:33	01:45:34	0043	0754	Turn thrust phase power off
17:48:54	01:45:55	0043	0754	Turn propulsion strain-gage power off
17:49:27	01:46:28	0043	0550	Operations to obtain coast mode data
17:51:05	01:48:06	0043	0755	Cyclic loads turned on vernier line, AMR
17:52:48	01:49:49		11E1	Mode 1 interrogation
17:55:49	01:52:50	0043	1252	Command reverse yaw maneuver magnitude and direction (+35.7 deg)
17:56:50	01:53:51	0043	1253	Execute yaw (sun reacquired at 02:00:09)
18:04:02	02:01:03	0043	1250	Command reverse roll maneuver magnitude and direction (−71.9 deg)
18:07:39	02:04:40[a]		0751	Propulsion strain-gage power on
18:07:45	02:04:46			Inertial mode on
18:08:00	02:05:01			Reset group IV outputs
18:08:56	02:05:57		0752	Thrust phase power on
18:10:38	02:07:39		0753	Command desired thrust duration (10.50 s)
18:15:01	02:12:02		0754	Execute midcourse thrust
18:15:13	02:12:14		0754	Command terminate thrust
18:15:38	02:12:39		0754	Turn thrust phase power off
18:15:55	02:12:56		0754	Turn propulsion strain-gage power off
18:18:48	02:15:49			Command sun mode on
18:20:43	02:17:44		11A5	Return to mode 5
18:22:19	02:19:20		1252	Command desired yaw maneuver magnitude (−180.1 deg)
18:23:21	02:20:22		11E1	Mode 1 on
18:27:32	02:24:33		1253	Start yaw
18:36:28	02:33:29		0751	Propulsion strain-gage powered, inertial mode and reset group IV outputs commanded
18:37:07	02:34:08		0752	Thrust phase power on
18:38:25	02:35:26		0753	Command desired thrust duration (23.05 s)
18:40:35	02:37:36		0754	Execute midcourse thrust
18:41:00	02:38:01		0754	Command terminate thrust
18:41:38	02:38:39		0753	Command desired thrust duration (23.05 s)
18:42:50	02:39:51		0754	Execute midcourse thrust
18:43:15	02:40:16		0754	Command terminate thrust
18:43:34	02:40:35		0754	Turn thrust phase power off
18:43:59	02:41:00		0754	Turn propulsion strain-gage power off
18:47:34	02:44:35		1252	Command desired yaw maneuver magnitude (−180.1 deg)
18:48:21	02:45:22		1253	Start yaw
18:56:23	02:53:24			Command sun mode on
18:57:55	02:54:56		7A2	Bit rate reduction—4400 to 1100 bits/s
18:58:40	02:55:41		0552	Turn transmitter high power off
18:59:49	02:56:50		0550	Operations to obtain coast mode data

[a]The remaining portion of this sequence differs from the standard sequence because of the helium pressure problem.

Table 2 (contd)

Time		Command sequence		Event
After launch	GMT	Major	Minor	
Midcourse correction (contd)				
20:02:58	03:59:59		1250	Command roll magnitude and direction to reacquired Canopus (−71.9 deg)
20:03:45	04:00:46		1251	Execute roll
20:07:17	04:04:18		0054	Cruise mode commanded and Canopus reacquired
20:07:54	04:04:55		1150	Command roll magnitude and direction (+68.5 deg)
20:08:54	04:05:55		1251	Start roll
20:11:44	04:08:45		1151	Command desired yaw maneuver magnitude and direction (−106.7 deg)
20:12:32	04:09:33		1253	Start yaw
20:16:37	04:13:38		11E1	Mode 1 on
20:17:19	04:14:20		0751	Propulsion strain-gage powered, inertial mode and reset group IV outputs commanded
20:18:22	04:15:23			Manual delay mode commanded on (so thrust could be timed manually)
20:19:14	04:16:15		0752	Thrust phase power on
20:21:47	04:18:48.4		0754	Execute midcourse thrust
20:22:00	04:19:00.5		0754	Command terminate thrust
20:22:01	04:19:01.5		0754	Execute midcourse thrust
20:22:01	04:19:02.0		0754	Command terminate thrust
20:22:02	04:19:03.0		0754	Execute midcourse thrust
20:22:03	04:19:03.5		0754	Command terminate thrust
20:22:21	04:19:22		0754	Turn thrust phase power off
20:22:49	04:19:50		0754	Turn propulsion strain-gage power off
20:59:37	04:56:38		1252	Command reverse yaw maneuver magnitude and direction (−106.7 deg)
21:01:12	04:58:13		1253	Execute yaw
21:05:59	05:03:00		1250	Sun acquisition mode on
21:06:29	05:03:30		1250	Command reverse roll maneuver magnitude and direction (−68.5 deg)
21:09:09	05:04:10		1251	Execute roll
21:10:50	05:07:51		0054	Command cruise mode on; reacquire Canopus
21:29:43	05:26:44		11A2	Mode 2 interrogation
21:35:51	05:32:52		0055	Mode 4 interrogation
21:46:55	05:43:56		0550	Return to mode 5
21:49:47	05:46:48		3056	Compartment C heater commanded on
21:51:44	05:48:45			AMR temperature control commanded off
21:53:44	05:50:45		1757	Survey camera electronics temperature control commanded on
22:08:45	06:05:46		11E4	Mode 4 interrogation
22:18:26	06:15:27		11D1	Mode 1 interrogation
22:32:11	06:29:12		11A4	Mode 4 interrogation
22:41:15	06:38:16		11D5	Return to mode 5
22:41:56	06:38:57			Compartment C temperature control commanded off
24:28:00	08:25:01		0754	Turn thrust phase power off
24:28:18	08:25:19		0754	Turn propulsion strain-gage power off
24:28:58	08:25:59		0550	Operations to obtain coast mode data
24:31:42	08:28:43		0755	Cyclic loads turned on vernier line heaters and AMR heater
24:28:57	08:29:58		11E1	Mode 1 selection
24:35:15	08:32:16		1252	Command reverse yaw maneuver magnitude and direction (−143.3 deg)

Table 2 (contd)

Time		Command sequence		Event
After launch	GMT	Major	Minor	
Midcourse correction (contd)				
24:36:50	08:33:51		1253	Execute yaw
24:38:26	08:39:27		1250	Sun mode commanded
24:42:53	08:39:54		1250	Command reverse roll maneuver magnitude and direction (−64.5 deg)
24:43:34	08:40:35		1251	Execute roll
Coast phase II				
24:47:26	08:44:27		0054	Cruise mode commanded
24:48:23	08:45:24		7A2	Bit rate reduction — 4400 to 1100 bits/s
24:49:50	08:46:51		0552	Turn transmitter high power off
24:52:12	08:49:13		3056	Turn compartment C heater on
25:11:31	09:08:32	0046	0354	Initiate gyro drift check 4, three-axis
25:24:02	09:21:03		11A4	Mode 4 interrogation
25:24:59	09:22:00		0151	Bit rate reduction — 1100 to 550 bits/s
25:58:11	09:55:12		1101	Mode 1 interrogation
25:59:49	09:56:50	0046	0054	Terminate gyro drift check
26:05:02	10:02:03		11A2	Mode 2 interrogation
26:08:39	10:05:40		1185	Mode 5 interrogation
26:14:09	10:11:10		11E4	Mode 4 interrogation
26:34:21	10:31:22		3D3	Transmitter B filament on
26:36:18	10:33:19		3D3	Turn transmitter high power on
26:37:43	10:34:44		7C6	Change telemetry from 550-bit/s normal to 550-bit/s low modulation index
26:39:47	10:36:48		3501	Alpha scattering power on
26:54:18	10:51:19		3515	Alpha detectors 1 and 2 off
26:54:28	10:51:29		3516	Proton detectors 1 and 2 off
26:54:35	10:51:36		3512	Proton detectors 3 and 4 off
26:58:17	10:55:18		3510	Calibration on
27:02:18	10:59:19		3507	Alpha detector 1 on
27:05:18	11:02:19		3515	Alpha detectors 1 and 2 off
27:05:32	11:02:33		3517	Proton detector 1 on
27:08:22	11:05:23		3523	Alpha detector 2 on
27:08:32	11:05:33		3516	Proton detectors 1 and 2 off
27:08:42	11:05:43		3513	Proton detector 2 on
27:11:25	11:08:26		3507	Alpha detector 1 on
27:11:33	11:08:34		3516	Proton detectors 1 and 2 off
27:11:44	11:08:45		3522	Proton detector 3 on
27:15:20	11:12:21		3512	Proton detectors 3 and 4 off
27:15:30	11:12:31		3511	Proton detector 4 on
27:18:31	11:15:32		3520	Calibration off
27:18:40	11:15:41		3517	Proton detector 1 on
27:18:49	11:15:50		3513	Proton detector 2 on
27:18:58	11:15:59		3522	Proton detector 3 on
27:30:42	11:27:43		3502	Alpha scattering power off
27:32:22	11:29:23		7F3	Change telemetry from 550-bit/s low modulation index to 550-bit/s normal
27:33:19	11:30:20		3C4	Transmitter B high power off
27:34:49	11:31:50			Compartment C heater off
27:35:50	11:32:51		11D1	Mode 1 interrogation
27:42:30	11:39:31		0354	Initiate gyro drift check 5, three-axis
27:47:17	11:44:18		11A5	Mode 5 interrogation
27:50:09	11:47:10		11E1	Return to mode 1
28:57:44	12:54:45		11A5	Mode 5 interrogation

Table 2 (contd)

Time		Command sequence		Event
After launch	GMT	Major	Minor	
Coast phase II (contd)				
29:02:45	12:59:46		11E1	Return to mode 1
29:18:28	13:15:29	0406	0054	Terminate gyro drift check
29:20:56	13:17:57	0406	0357	Initiate gyro drift check 6, roll only
29:56:27	13:53:28		11A4	Mode 4 interrogation
29:59:45	13:56:46		11D5	Mode 5 interrogation
30:04:05	14:01:06		11E2	Mode 2 interrogation
30:07:17	14:04:18		11B1	Return to mode 1
31:05:25	15:02:26		11A5	Mode 5 interrogation
31:11:08	15:08:09		0054	Terminate gyro drift check
31:13:40	15:10:41		0354	Initiate gyro drift check 7, three-axis
31:14:27	15:11:28		11E1	Mode 1 interrogation
32:07:26	16:04:27		11A4	Mode 4 interrogation
32:19:59	16:17:00		11D5	Mode 5 interrogation
32:27:23	16:24:24		11E1	Return to mode 1
33:15:19	17:12:20		11A5	Mode 5 interrogation
33:18:22	17:15:23		11E1	Mode 1 interrogation
33:21:07	17:18:08		0054	Terminate gyro drift check
34:02:57	17:59:58		0354	Initiate gyro drift check 8, three-axis
34:03:31	18:00:32		11A5	Mode 5 interrogation
34:14:12	18:11:13		11E4	Mode 4 interrogation
34:19:02	18:16:03		11D1	Return to mode 1
35:12:55	19:09:56		11A2	Mode 2 interrogation
35:15:46	19:12:47		11B5	Mode 5 interrogation
35:19:17	19:16:18		11E1	Return to mode 1
36:03:58	20:00:59		11A4	Mode 4 interrogation
36:08:25	20:05:26		11D5	Mode 5 interrogation
36:12:48	20:09:49		11E1	Return to mode 1
36:13:22	20:10:23		0054	Terminate gyro drift check
37:02:04	20:59:05		0354	Initiate gyro drift check 9, three-axis
37:02:43	20:59:44		11A5	Mode 5 interrogation
37:51:51	21:48:52		0054	Terminate gyro drift check
Midcourse correction				
38:37:09	22:34:10	0043	0250	Initiate midcourse correction interrogation
38:40:16	22:37:17	0043	0250	Mode 4 interrogation
38:38:37	22:35:58	0043	0251	Mode 2 interrogation
38:41:03	22:38:04	0043	0252	Mode 1 interrogation
39:07:17	23:04:18	0043	0652	Turn transmitter filament on
39:09:29	23:06:30	0043	0653	Turn transmitter high power on
39:10:15	23:07:16	0043	0253	Increase bit rate from 550 to 4400 bits/s
39:15:17	23:12:18	0043	1150	Command cruise mode on
39:15:28	23:12:29	0403	1150	Command desired roll maneuver magnitude and direction (—75.9 deg)
39:16:50	23:13:51	0403	1251	Start roll
39:21:17	23:18:18	0403	1151	Command desired yaw maneuver magnitude and direction (—100.5 deg)
39:22:35	23:19:36	0403	1253	Start yaw
39:26:49	23:23:50	0403	0251	Mode 2 interrogation
39:27:48	23:24:49	0403	0252	Return to mode 1
39:28:11	23:25:12	0403	0751	Propulsion strain-gage powered, inertial mode and reset group IV outputs commanded
39:28:43	23:25:44	0403	0750	Turn cyclic loads AMR, vernier line heaters, TV heaters off

Table 2 (contd)

Time		Command sequence		Event
After launch	GMT	Major	Minor	
Midcourse correction (contd)				
39:28:46	23:25:47	0740	0750	Pressurize vernier system (helium). Unlock vernier engine 1
39:29:05	23:26:06	0043	0752	Thrust phase power on
39:30:36	23:27:37	0043	0753	Commanded incorrect thrust duration (10.85 s)
39:34:48	23:29:22	0043	0753	Command desired thrust duration (5.45 s)
39:33:57	23:30:58	0043	0754	Execute midcourse thrust
39:34:05	23:31:06	0043	0754	Command terminate thrust
39:34:22	23:31:23	0043	0754	Turn propulsion strain-gage power off
39:34:28	23:31:29	0043	0754	Turn thrust phase power off
39:35:15	23:32:16	0043	0550	Operations to obtain coast mode data
39:36:18	23:33:19	0043	0755	Cyclic loads turned on. Vernier line, AMR
39:38:00	23:35:01	0043	1252	Command reverse yaw maneuver magnitude and direction (100.5 deg)
39:39:06	23:36:07	0043	1253	Execute yaw (sun reacquired at 23:42:12)
39:44:01	23:41:02			Touchdown strain-gage power off commands
39:46:02	23:43:03	0043	1250	Command reverse roll maneuver magnitude and direction (75.9 deg)
39:47:04	23:44:05	0043	1251	Execute roll (Canopus reacquired at approximately 23:46:35)
39:52:06	23:49:07			Cruise mode commanded
Coast phase II				
38:47:54	23:49:42	0043	0157	Mode 2 Interrogation
39:53:46	33:50:47	0043	0151	Bit rate reduction—4400 to 550 bits/s
39:54:34	23:51:35	0043	0552	Turn transmitter high power off
39:57:05	23:54:06	0046	1184	Mode 4 interrogation
39:59:46	23:56:47	0046	0550	Mode 5 interrogation
40:10:47	00:07:48 Sep 10, 1967		11E1	Return to mode 1
41:19:00	01:16:01		11A5	Mode 5 interrogation
41:24:59	01:22:00		11E4	Mode 4 interrogation
41:30:35	01:27:36		11D2	Mode 2 interrogation
41:37:16	01:34:17		11B1	Mode 1 interrogation
41:38:18	01:35:19		0354	Initiate gyro drift check 10, three-axis
42:01:23	01:58:24		11A5	Mode 5 interrogation
42:05:26	02:02:27		11E4	Mode 4 interrogation
42:09:51	02:06:52		11D1	Return to mode 1
42:49:24	02:46:25		11A5	Mode 5 interrogation
43:19:11	03:16:12		11E4	Mode 4 interrogation
43:26:35	03:23:36		11D2	Mode 2 interrogation
43:33:14	03:30:15		11B1	Return to mode 1
44:36:02	04:33:03		0054	Terminate gyro drift check
44:37:10	04:34:11		11A5	Mode 5 interrogation
44:45:39	04:42:40		11E4	Mode 4 interrogation
44:54:51	04:51:52		11D2	Mode 2 interrogation
45:01:35	04:58:36		11B1	Return to mode 1
46:08:35	06:05:36		11A5	Mode 5 interrogation
46:16:11	06:13:12		11E4	Mode 4 interrogation
46:23:07	06:20:08		1350	Vernier oxidizer tank 2 temperature control on
46:23:57	06:20:58		11D2	Mode 2 interrogation
46:27:36	06:24:37		11B1	Return to mode 1
47:11:14	07:08:15		11A5	Mode 5 interrogation

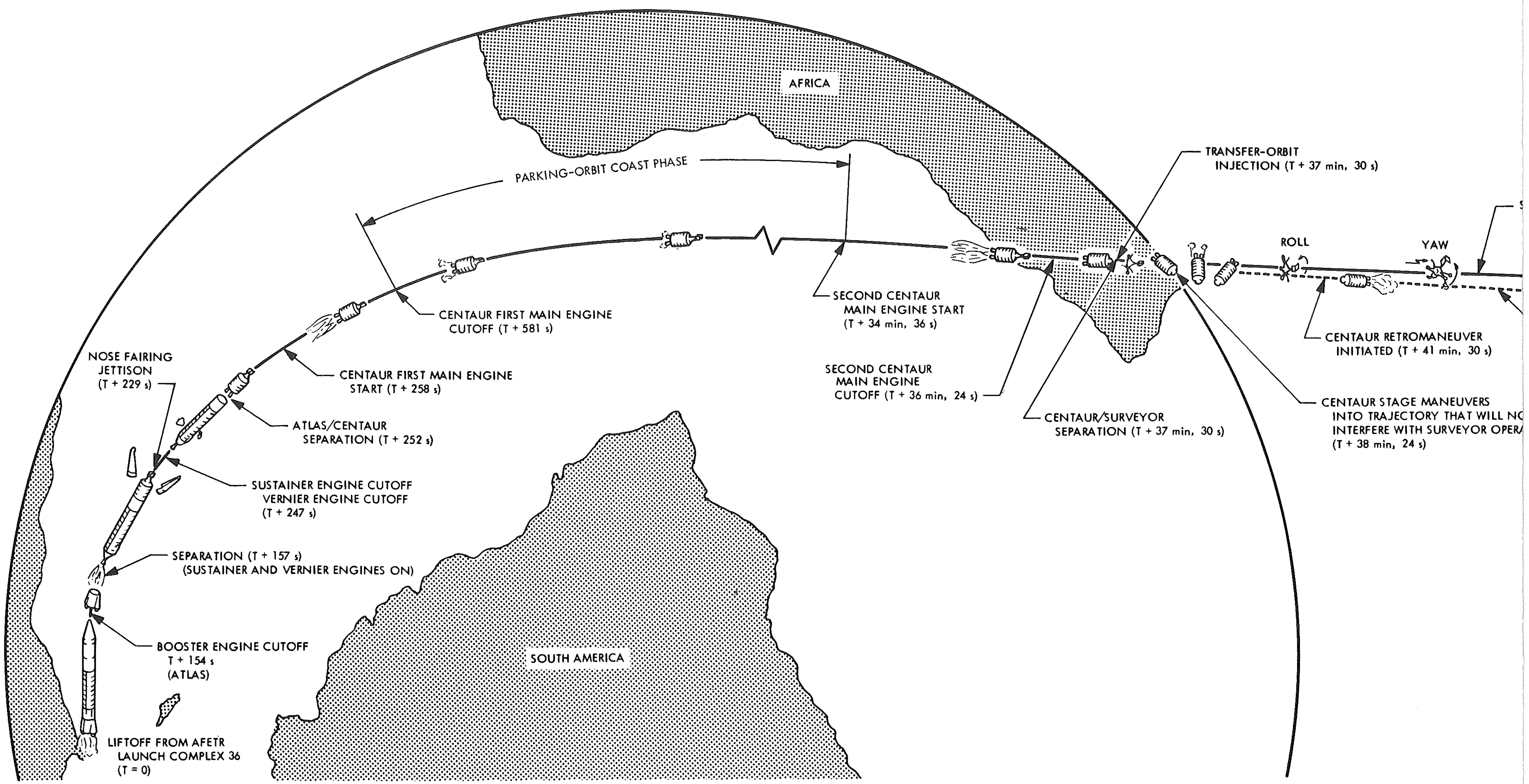
Table 2 (contd)

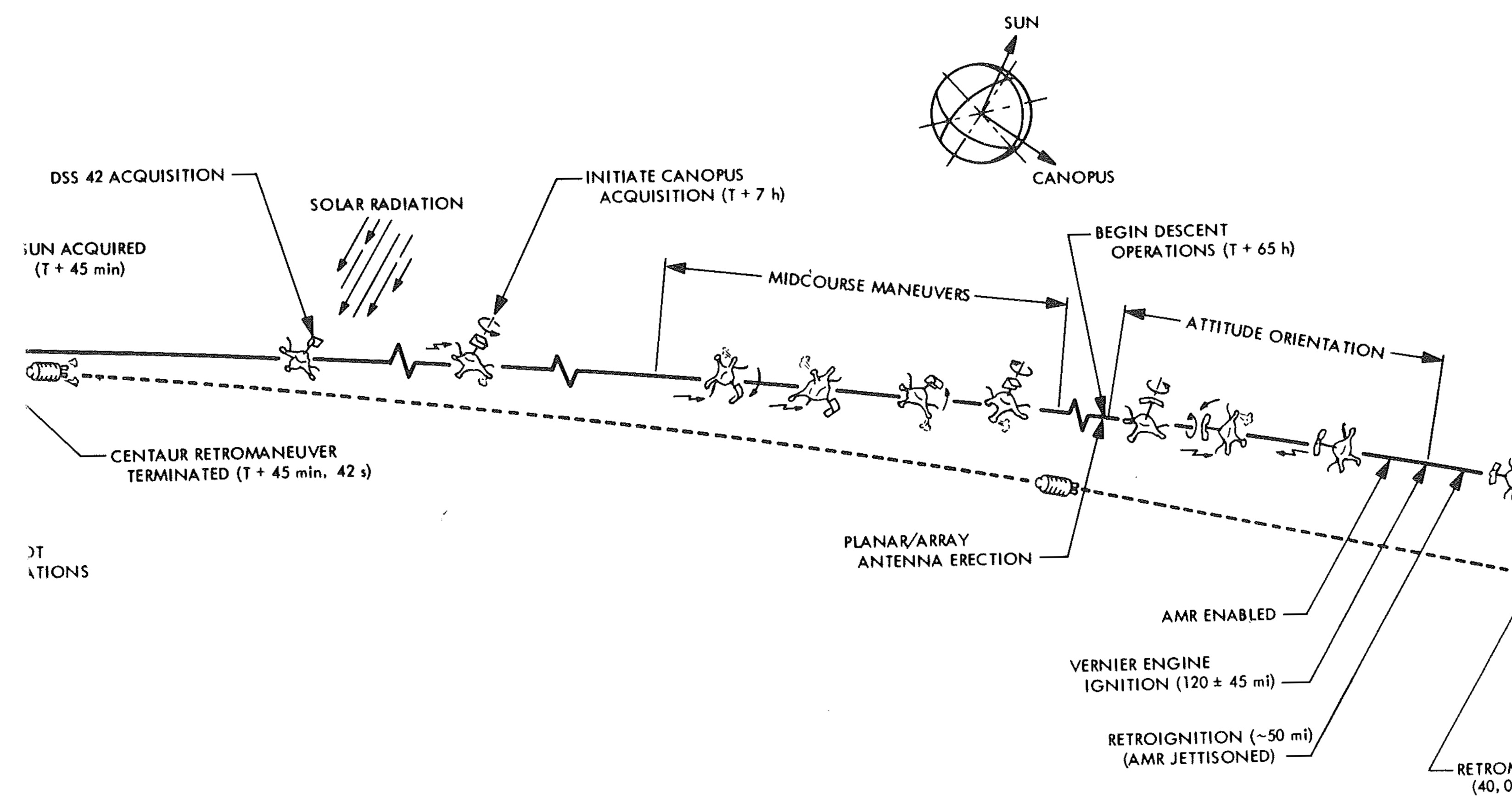
Time		Command sequence		Event
After launch	GMT	Major	Minor	
Coast phase II (contd)				
47:17:21	07:14:22		11E4	Mode 4 interrogation
47:20:40	07:17:41		11D2	Mode 2 interrogation
47:23:29	07:20:30		11B1	Return to mode 1
48:17:37	08:14:38		11A5	Mode 5 interrogation
48:25:34	08:22:35		11E4	Mode 4 interrogation
48:31:25	08:28:26		11D2	Mode 2 interrogation
48:33:16	08:30:17		11B1	Return to mode 1
49:20:35	09:17:36		11A5	Mode 5 interrogation
49:26:00	09:23:01		11E4	Mode 4 interrogation
49:28:11	09:25:12		9C4	Bit rate reduction—550 to 137.5 bits/s
49:30:55	09:27:56		9D3	Bit rate increase—137.5 to 550 bits/s
49:33:28	09:30:29		11D2	Mode 2 interrogation
49:35:45	09:32:46		11B1	Return to mode 1
50:19:41	10:16:42		11A5	Mode 5 interrogation
50:31:35	10:28:36		11E4	Mode 4 interrogation
50:33:33	10:30:34		11D2	Mode 2 interrogation
50:35:16	10:32:17		11B1	Return to mode 1
51:41:12	11:38:13		11A5	Mode 5 interrogation
51:44:06	11:41:07		11E4	Mode 4 interrogation
51:45:51	11:42:52		11D2	Mode 2 interrogation
51:47:24	11:44:25		11B1	Return to mode 1
52:55:28	12:52:29		11A5	Mode 5 interrogation
52:59:54	12:56:55		11E4	Mode 4 interrogation
53:02:36	12:59:37		11D2	Mode 2 interrogation
53:07:22	13:04:23		11B1	Return to mode 1
53:08:02	13:05:03		0357	Initiate gyro drift check 11, roll only
53:34:01	13:31:02		3054	Compartment A heater commanded on
54:08:43	14:05:44		11A5	Mode 5 interrogation
54:14:24	14:11:25		11E4	Mode 4 interrogation
54:18:05	14:15:06		11D2	Mode 2 interrogation
54:21:52	14:83:53		11B1	Return to mode 1
55:12:54	15:09:55		11A5	Mode 5 interrogation
55:17:17	15:14:18		11E4	Mode 4 interrogation
55:23:16	15:20:17		11D2	Mode 2 interrogation
55:25:33	15:22:34		11B1	Return to mode 1
55:27:12	15:24:13		0054	Terminate gyro drift check
55:30:07	15:27:08		0354	Initiate gyro drift check 12, three-axis
56:20:23	16:17:24		11A5	Mode 5 interrogation
56:26:23	16:23:24		11E4	Mode 4 interrogation
56:29:25	16:26:26		11D2	Mode 2 interrogation
56:33:13	16:30:14		11B1	Return to mode 1
57:27:58	17:24:59		11A5	Mode 5 interrogation
57:32:21	17:29:22		11E4	Mode 4 interrogation
57:37:31	17:34:32		11D2	Mode 2 interrogation
57:40:32	17:37:33		11B1	Return to mode 1
57:46:56	17:43:57		3056	Compartment C heater commanded on
58:02:41	17:59:42		0054	Terminate gyro drift check
58:13:36	18:10:37			Commanded desired yaw magnitude and direction (+179.9 deg)
58:15:15	18:12:16			Start yaw
58:25:09	18:22:10			Command desired yaw magnitude and direction (+180.1 deg)
58:25:51	18:22:52			Start yaw

Table 2 (contd)

Time		Command sequence		Event
After launch	GMT	Major	Minor	
Terminal descent				
62:48:19	22:45:20	0042	0350	Initiate gyro speed check
62:49:29	22:46:30	0042	0351	Select next gyro three times
62:53:43	22:50:44	0042	0352	Return to mode 5
62:56:46	22:53:47	0042	1050 1053	Narrowband voltage-controlled crystal oscillator check
63:43:33	23:40:34	0042	3054	Compartment A heater power off
63:44:26	23:41:27	0044	1757	Survey camera vidicon temperature control on
63:45:21	23:42:22	0044	1355	Mode 6 interrogation
63:47:32	23:44:33	0044	0250	Mode 4 interrogation
63:52:57	23:49:58	0044	0652	Turn transmitter filament on
63:54:40	23:51:41	0044	0653	Transmitter high power
63:55:17	23:52:18	0044	0255	Bit rate increase — 550 to 1100 bits/s
63:57:39	23:54:40	0044	2057	Presumming amplifier off
63:58:23	23:55:24	0044	0251	Mode 2 interrogation
64:00:04	23:57:05		1181	Mode 1 interrogation
64:02:05	23:59:06	0044	0550	Return to mode 5
64:03:30	00:00:31 Sep 11, 1967	0044	1755	Propulsion strain-gage power turned on
64:06:07	00:03:08	0044	1756	Touchdown strain-gage power and subcarrier oscillators turned on
64:07:20	00:04:21	0044	1050	Transponder power turned off and one-way lock achieved
64:11:57	00:08:58	0044	1154	Cruise mode commanded
64:11:58	00:08:59	0044	1154	Roll maneuver magnitude and direction commanded (+73.9 deg)
64:15:14	00:12:15	0044	1251	Execute sun and roll at Canopus error signal null
64:18:24	00:15:25	0044	1155	Yaw magnitude and direction command (+119.5 deg)
64:19:20	00:16:21	0044	1253	Execute yaw at primary sun sensor yaw error null (retromotor thrust direction aligned properly)
64:24:37	00:21:38	0044	2152	Presumming amplifier commanded on (to get touchdown strain-gage data)
64:26:17	00:23:18	0044	1654, 1656	Vernier thrust level (150 lb) for retrophase and delay between AMR *mark* and vernier ignition (12.325 s)
64:33:07	00:30:08	0044	1355	Command mode 6 data on
64:34:53	00:31:54		1652	Command reset group IV outputs
64:41:56	00:38:57	0044	1657	Retrophase sequence mode commanded on
64:42:10	00:39:11	0044	1752	Vernier lines and tanks, alpha scattering, TV, and AMR thermal control commanded off
64:42:59	00:40:00	0044	1753	AMR on
64:43:59	00:41:00	0044	1754	Thrust phase power on
64:46:00	00:43:01	0044	2051	AMR enabled
64:47:42.9	00:44:43.9	0044	2051	Backup AMR *mark* commanded
64:47:39.759	00:44:40.759†	—	—	AMR *mark*
64:47:52.067	00:44:53.067†	—	—	Vernier ignition
64:47:53.159	00:44:54.159†	—	—	Retroignition
	00:44:54.7†	—	—	RADVS on
		—	—	Reliable-operate doppler velocity sensor on
		—	—	Reliable-operate radar altimeter on

#1 of 2


AFRICA
SOUTH AMERICA
PARKING-ORBIT COAST PHASE
TRANSFER-ORBIT INJECTION (T + 37 min, 30 s)
ROLL
YAW
NOSE FAIRING JETTISON (T + 229 s)
CENTAUR FIRST MAIN ENGINE CUTOFF (T + 581 s)
CENTAUR FIRST MAIN ENGINE START (T + 258 s)
ATLAS/CENTAUR SEPARATION (T + 252 s)
SUSTAINER ENGINE CUTOFF VERNIER ENGINE CUTOFF (T + 247 s)
SEPARATION (T + 157 s) (SUSTAINER AND VERNIER ENGINES ON)
BOOSTER ENGINE CUTOFF T + 154 s (ATLAS)
LIFTOFF FROM AFETR LAUNCH COMPLEX 36 (T = 0)
SECOND CENTAUR MAIN ENGINE START (T + 34 min, 36 s)
SECOND CENTAUR MAIN ENGINE CUTOFF (T + 36 min, 24 s)
CENTAUR/SURVEYOR SEPARATION (T + 37 min, 30 s)
CENTAUR RETROMANEUVER INITIATED (T + 41 min, 30 s)


SUN
CANOPUS
DSS 42 ACQUISITION
SOLAR RADIATION
INITIATE CANOPUS ACQUISITION (T + 7 h)
(T + 45 min)
BEGIN DESCENT OPERATIONS (T + 65 h)
MIDCOURSE MANEUVERS
ATTITUDE ORIENTATION
CENTAUR RETROMANEUVER TERMINATED (T + 45 min, 42 s)
PLANAR/ARRAY ANTENNA ERECTION
AMR ENABLED
VERNIER ENGINE IGNITION (120 ± 45 mi)
RETROIGNITION (~50 mi) (AMR JETTISONED)

III. *Surveyor V* TDS Mission Requirements

A. General

This section details the requirements and support capabilities necessary for tracking and telemetry coverage of the *Atlas/Centaur/Surveyor V* space vehicle.

The TDA requirements necessary for the success of the mission were grouped in three classes and defined in the order of their importance to that objective:

Class I: These requirements represent the minimum necessary to accomplish the primary flight objectives. These requirements are mandatory and, if not met, may result in a decision not to launch.

Class II: These requirements define the support necessary to accomplish all stated flight objectives.

Class III: These requirements define the ultimate in desired support. Meeting these requirements should allow all flight objectives to be achieved early in the program.

The *Surveyor* Project placed the responsibility for near-earth tracking and data acquisition support on the AFETR, MSFN, and DSN elements of the Tracking and Data System. The TDS obtained current and continuous data on the status of the mission. This information was used as an evaluation aid in maximizing the probability acquisition by the Deep Space Stations and provided historical data for the support of future space flight operations.

The following constraints were placed on the TDS prior to the launch of *Surveyor V*.

*1. **Launch.*** The launch constraints were as follows:

(1) The *Atlas/Centaur* boost vehicle will be in a parking-orbit mode of operation for *Surveyor V*.

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

(3) Launch azimuth sectors are restricted to lie between 78 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. **Preinjection.*** The preinjection constraints consisted of:

(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 cube of the earth-fixed velocity ρV^3 is less than 19,000 lb/s^3.

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

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

*3. **Postinjection.*** The *Centaur* retromaneuver was to be such that the *Surveyor/Centaur* separation distance at 5 h after injection would be at least 336 km.

*4. **Telecommunications.*** The five telecommunications requirements were:

(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 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 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 Deep Space Station shall not exceed 175 deg to prevent the degradation of Deep Space Station receiver sensitivity by solar noise. This constraint guarantees that signal-to-noise ratios will not be degraded by more than 1 dB.

(5) DSS 14 (210-ft antenna) is required for telemetry acquisition during the terminal-descent phase.

5. Thermal control. These constraints consisted of the following:

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

(2) The spacecraft is limited to a maximum duration of 30 min in the shadow of the earth 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 acquision and lunar touchdown.

(4) The spacecraft is limited to a maximum duration of 30 min in the lunar penumbra 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 to permit switching the transmitter from high to low power to satisfy thermal constraints.

6. Midcourse maneuver. The following capabilities were required of *Surveyor:*

(1) The spacecraft shall be capable of performing midcourse maneuvers up to 46 m/s in magnitude. Nominal midcourse maneuver time is approximately 15–20 h after launch.

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

7. Lunar arrival. The lunar arrival requirements were:

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

(2) Transit trajectories are to be so designed that lunar arrival takes place not earlier than 2 h after DSS 11 moonrise and not later than 3 h before DSS 11 moonset.[2] Furthermore, DSS 11 postlanding visibility shall be maximized.

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

[2]These constraints applied only to targeting. The visibility constraints used at midcourse were: earliest arrival, 80 min after DSS 11 rise; latest arrival, 3 h before DSS 11 set.

8. Terminal descent. The following were required to ensure a successful soft landing:

(1) The incidence angle at unbraked impact shall not be greater than 45 deg from the vertical.[3]

(2) The range of allowable nominal unbraked impact speed is from 2630 to 2642 m/s.

(3) The spacecraft roll orientation constraints are presented in Fig. 6. The RADVS constraints shown encompass all possible launch dates. Two roll orientations were under consideration: sun azimuths at landing of +80 deg and −154 deg.

B. Air Force Eastern Test Range

The coverage capabilities and requirements presented herein are based upon the configuration of various land and ship stations. The capabilities of these ships are listed in Table 3. The ship positions were selected by the AFETR. Any change in the ship positions or any change in the availability of the four ships would necessarily indicate a change in coverage and, possibly a change in launch-window design.

Table 3. Range instrumentation ship capabilities

Ship	Capability		
	Cruising speed, knots	Tracking	Telemetry
Timber Hitch	10	—	VHF
Sword Knot	10	—	VHF/S-band
Coastal Crusader	10	—	VHF/S-band
Twin Falls	15	C-band (FPS-16)	VHF/S-band

The AFETR prepared to provide adequate coverage of all class I telemetry data receive and record requirements for the maximum launch windows. With the exception of a gap during the parking orbit, AFETR was to meet all spacecraft telemetry data real-time retransmission requirements over all of the maximum launch windows. Allowances were made for the anticipated gap in real-time data retransmission. Consequently, the telemetry support capability was not expected to constrain the launch windows.

[3]This constraint was waived for the September 8, 1967 launch date.

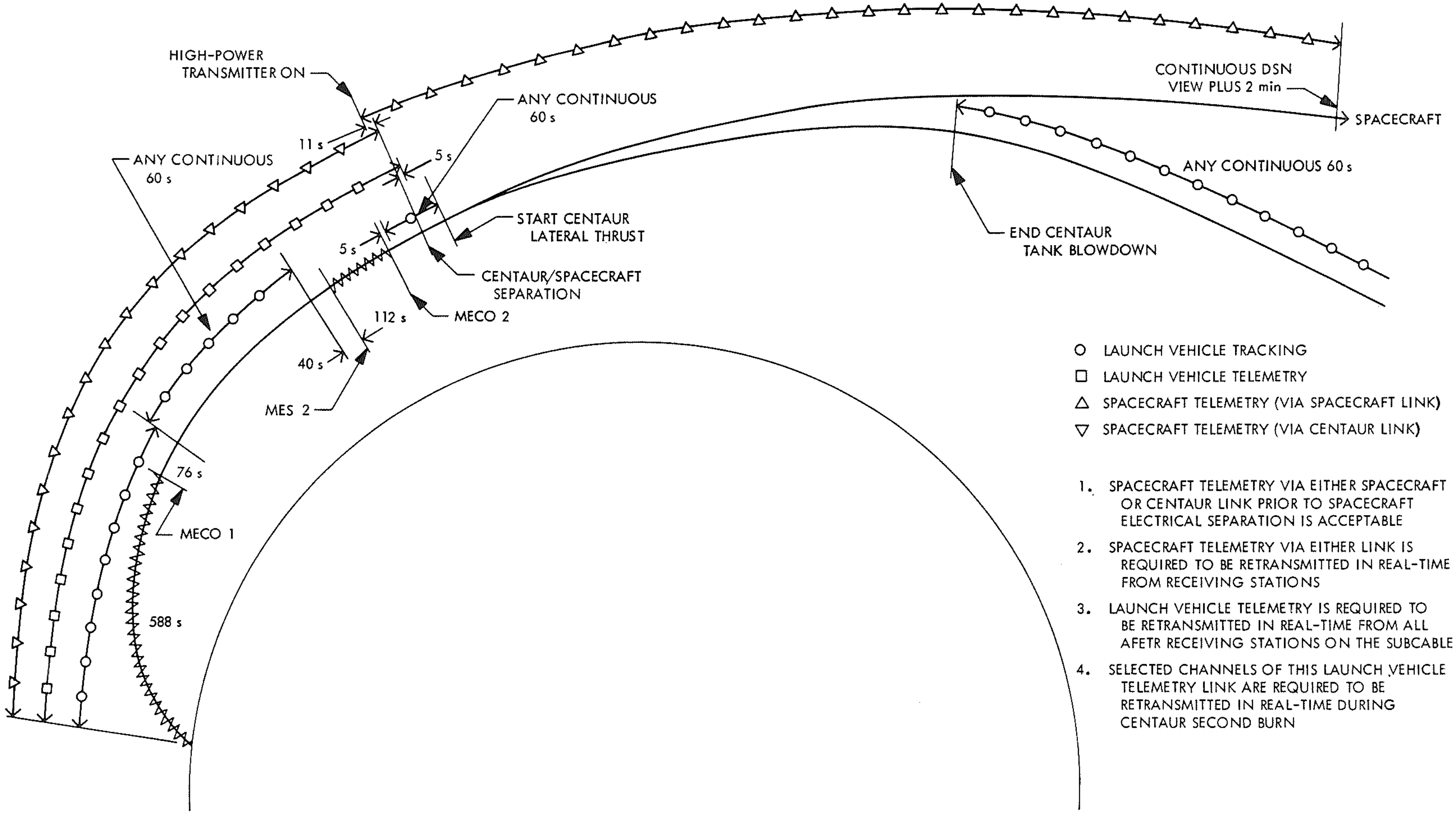


Fig. 6. *Surveyor V* class I TDA requirements for the near-earth phase

1. *Class I: overall coverage.* Table 4 presents the near-earth class I C-band, VHF, and S-band tracking coverage requirements. All of the stations indicated were not necessarily required for each launch date and azimuth. The overall uprange coverage is shown schematically in Fig. 7 for the *Surveyor* V Mission.

2. *Computer requirements.* Using the overall tracking coverage data provided as indicated in Table 4, the AFETR real-time computer system (RTCS) was to provide the following:

(1) Elements and injection conditions of:

(a) The parking orbit.

(b) The theoretical transfer orbit.

(c) The actual pre-retromaneuver transfer orbit.

(d) The actual post-retromaneuver transfer orbit.

(2) Mapping to lunar encounter—based on items (b), (c), and (d), above.

(3) DSN acquisition data.

(4) MSFN acquisition data.

(5) Decimal-formatted tracking data received from the AFETR and MSFN tracking radars.

3. *Real-time data transmission.* Real-time retransmission of spacecraft telemetry data to building AO and DSS 71 was required as follows:

(1) Via the *Centaur* 255. 7-MHz link, from $T - 10$ min to *Centaur/Surveyor* electrical disconnect.

(2) Via the spacecraft 2295-MHz link, from spacecraft high power transmitter on to continuous DSN view plus 2 min.

Real-time retransmission capability was to be provided by the same land and ship stations that provided the receive and record support. Since aircraft do not have the capability to retransmit telemetry data in real-time, some gaps in the real-time data were possible. However, the *Surveyor* Project allowed for the possibility of such gaps during the parking-orbit coast phase to optimize the coverage of the second burn and separation phases of the flight.

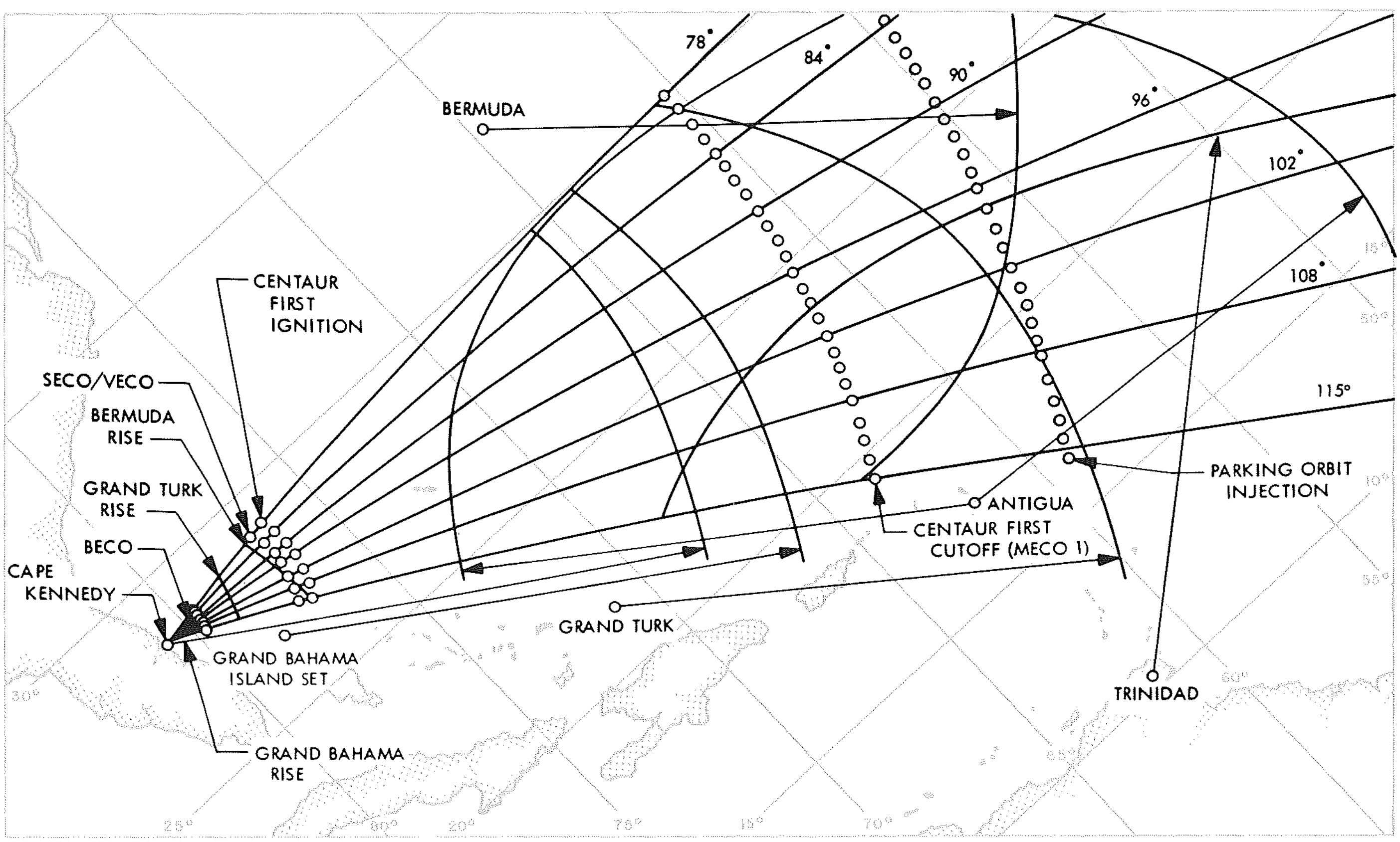


Fig. 7. *Surveyor V* uprange coverage

Table 4. *Surveyor V* class I near-earth phase coverage

Source	Coverage	Basis	Tracking station
Launch vehicle (C-band)	Launch to MECO 1[a]	Provides reasonable level of confidence for being able to track vehicle during parking-orbit coast phase Required by range safety until orbit, velocity acquired	Cape Kennedy Antigua
	Continuous 60 s from MECO 1 to MECO 1 + 136 s	Allows calculation of parking orbit, so that: (1) Early evaluation of powered flight can be made. (2) Inflight acquisition information can be provided to downrange stations, beginning with RISs and Ascension and MSFN stations. (3) DSN acquisition information can be generated, based on actual parking orbit and a theoretical second burn (constitutes first set of inflight predicts)	Antigua Bermuda
	Any 60 s of continuous tracking from MECO 2 + 5 s to retromotor start	Input data for calculation of actual transfer orbit, so that: (1) Early evaluation of transfer trajectory can be made, using lunar mapping technique. (2) Inflight acquisition data can be provided to DSN. (3) Acquisition information can be supplied to MSFN station at Carnarvon	Grand Canary *Twin Falls*
	Any 60 s of continuous tracking subsequent to power changeover switch	Establishes post-retromaneuver trajectory of *Centaur* to establish any possible interference with spacecraft star sensor	Ascension Pretoria
Launch vehicle (VHF) Spacecraft (S-band)	From launch to *Atlas/Centaur* separation	Provides *Atlas* performance data during its lifetime Establishes sustainer engine cutoff time, which is good indicator of what can be expected for *Centaur* burn duration Receipt of spacecraft telemetry via *Centaur* link and spacecraft S-band link	Cape Kennedy
	From *Centaur* MES 1[b] to MECO 1	Provides *Centaur* performance data during its first burn Establishes MES 1 and MECO 1 event times Receipt of spacecraft telemetry via *Centaur* link and spacecraft S-band link	Cape Kennedy Antigua
	From MECO 1 to MECO 1 + 76 s	*Centaur* propellants settled by thrusting two of the 50-lb vernier engines during this period Receipt of spacecraft telemetry via *Centaur* link and spacecraft S-band link	Antigua Bermuda
	From MECO 1 + 76 s to MES 2 − 40 s	*Centaur* propellants are retained at tank outlets during this period, by thrusting two of the 3-lb engines Receipt of spacecraft telemetry via *Centaur* link and spacecraft S-band link	Antigua Bermuda Telemetry ships
	From MES 2 − 40 s to MES 2	The following critical *Centaur* events take place: (1) Further propellant settling applied by firing two of 50-lb vernier engines.	Grand Canary Telemetry ships

[a]MECO = main engine cutoff. [b]MES = main engine start.

Table 4 (contd)

Source	Coverage	Basis	Telemetry station
Launch vehicle (VHF) Spacecraft (S-band) (contd)		(2) Boost pumps start. (3) Chilldown. (4) Receipt of spacecraft telemetry via *Centaur* link and spacecraft S-band link	
	From MES 2 to MECO 2	Provides *Centaur* performance data during its second burn Establishes MES 2 and MECO 2 event times Receipt of spacecraft telemetry via *Centaur* link and spacecraft S-band link	Grand Canary
	From MECO 2 to *Centaur*/spacecraft separation	The following major spacecraft events occur: (1) Spacecraft landing gear release. (2) Spacecraft omniantennas unlock. (3) Switch spacecraft transponder transmitter to high power. (4) *Centaur*/spacecraft separation	Grand Canary Ascension Telemetry ships
	From spacecraft high power on to DSN initial acquisition	Provides spacecraft status information	Ascension Pretoria Telemetry ships

It should be noted that RIS *Sword Knot* had updated its real-time telemetry system capability. This capability allowed the real-time retransmission of the spacecraft data and selected channels of the *Centaur* telemetry data. The project requested that the *Sword Knot* be positioned to cover the second main engine cutoff event. This would allow real-time guidance telemetry data to be input to the RTCS for orbital calculations. These computations can add confidence to those based upon radar data and provide a backup to these data.

4. Tracking data coverage. The only support that the range could provide for the transfer-orbit coverage requirement was with RIS *Twin Falls.* No other ship in the AFETR with C-band radar capability exists. Furthermore, it was determined that no AFETR land station was capable of providing coverage of this requirement. (It will be noted in Subsection C-1 that the MSFN station at Grand Canary could partially support the requirement.) Therefore, the positioning and resultant coverage capability of the *Twin Falls* was critical in the final launch window designs.

Indications were that the AFETR stations at Ascension and Pretoria could provide adequate coverage of the requirement for post-retromaneuver tracking data.

C. Manned Space Flight Network

The tracking and telemetry coverage requirements placed upon the MSFN (managed by GSFC) are discussed in this subsection.

1. Tracking. The MSFN was required to provide TDA support of *Surveyor V* with four stations: Bermuda, Grand Canary, Tananarive (Malagasy Republic), and Carnarvon (Australia). The configuration indicated that, after parking-orbit insertion, potential coverage by these stations existed. Figure 7 shows the Bermuda coverage of the *Centaur* first-burn phase and the insertion into the parking orbit.

a. Function. The stations at Bermuda and Grand Canary were to provide critical support of the northerly launch azimuth sectors during the September period. Bermuda's telemetry and radar coverage of the first burn was to complement the AFETR coverage of this phase. Grand Canary's telemetry and radar coverage of the transfer-orbit phase was also to complement the associated AFETR coverage. However, the Grand Canary coverage capability became degraded in the latter days of the period. In fact, on September 13, Grand Canary had no coverage of the critical phase from the second *Centaur* main engine cutoff to the start of the retromaneuver.

The MSFN stations at Tananarive and Carnarvon were to provide redundant coverage with the AFETR for launch vehicle telemetry data. Carnarvon was to provide redundant post-retromaneuver radar coverage with the AFETR and redundant S-band coverage with the DSN. However, if DSS 51 were not able to support the mission, the Carnarvon S-band coverage and real-time retransmission coverage could be very important. Indications were that the Carnarvon coverage could exceed the first pass view period of DSS 42.

Radars at Bermuda, Grand Canary, Tananarive, and Carnarvon were required to track the *Centaur* vehicle's C-band beacon. In addition, Bermuda was to provide range safety backup support for this mission. All stations were to provide real-time data, magnetic tape recordings of high-speed data, and verbal confirmation of the time (GMT) of acquisition of signal (AOS) and loss of signal (LOS) to the MSFN network controller.

b. Station requirements. The Bermuda station was to track the *Centaur* vehicle's C-band beacon in conjunction with AFETR until loss of the signal occurred. Magnetic tape recordings of the beacon, strip chart recordings, and postlaunch instrumentation message (PLIM) data sheets, as well as real-time transmission of high- and low-speed data to GSFC and the real-time computer system at AFETR were required. Bermuda also provided real-time verbal confirmation of the times of acquisition and loss of signal, and backup range safety support. Table 5 shows the prelaunch configuration of the MSFN stations and their radar types.

Table 5. *Surveyor V* MSFN station configuration

Station	C-band radar	VHF telemetry
Bermuda	FPQ-6/FPS-16	X
Grand Canary[a]	MPS-26	X
Tananarive	FPS-16	X
Carnarvon	FPQ-6	X

[a]Grand Canary was capable of real-time telemetry transmission.

Carnarvon, Grand Canary, and Tananarive provided the same types of information as Bermuda, except that Grand Canary and Carnarvon supplied real-time transmission of only low-speed data to GSFC, where it was to be reformatted and retransmitted to the real-time computer system at the AFETR. Tananarive was scheduled to have the capability to transmit low-speed data directly in the standard, RTCS-acceptable, 38-character radar data format by September 1. If this capability were not available, Tananarive data would also be routed through the GSFC.

*2. **Telemetry.*** The stations at Bermuda, Grand Canary Island, Tananarive, and Carnarvon, as well as portions of NASCOM and the GSFC/AFETR interface at Cape Kennedy, were to support this mission. Coverage of the *Centaur* 225.7-MHz link for receive, decommutate, and record was required from Bermuda, Grand Canary, and Tananarive. Carnarvon was to provide support on a best-obtainable basis. In addition, Bermuda was to receive and record the *Atlas* 229.9- and 232.4-MHz links.

Mark event readouts were required from all stations (except Carnarvon) in real-time or as near to real-time as possible when the vehicle was in view of a station.

All stations were to provide verbal confirmation in real-time of the time (GMT) of *mark* events (except at Carnarvon), acquisition and loss of signal to the network controller. Real-time transmission of telemetry data was required from Grand Canary.

The Bermuda station was required to provide real-time readout of *mark* events 4–11 and confirm them by teletype. Bermuda was also required to display range safety parameters on the *Atlas/Centaur* links and to accumulate magnetic tape recordings, strip chart recordings, and PLIM data sheets.

Tananarive was required to provide real-time readout of *mark* events 25 and 26 (with teletype confirmation) and accumulate magnetic tape recordings, strip chart recordings, and PLIM data sheets.

Grand Canary was required to retransmit channels 3–8 and 14 in real-time; and channels 16 (group II), 18 [segments 1–4, 9, and 10 (group III)], 22, and 23 in near-real-time. Grand Canary was also responsible for real-time readout of *mark* events 13–25.

Carnarvon participated on a best-effort basis and accumulated magnetic tape recordings, strip chart recordings, and PLIM data sheets.

There was no requirement for GSFC to provide S-band telemetry support for the *Surveyor V* Mission.

*3. **Computer requirements.*** The requirements levied on the Manned Space Flight Network, with respect to computer support, were to:

(1) Provide pointing data printouts to be used for mission planning and for committing MSFN station coverage.

(2) Generate and transmit nominal pointing data to all participating MSFN stations, except Bermuda. Bermuda's powered flight data to be supplied to Goddard by the AFETR.

(3) Receive launch trajectory data from Bermuda and AFETR via the launch trajectory data system.

(4) Update and refine the orbit of the *Centaur* stage based on low-speed teletype data received from participating C-band radars, and relay these data to the network controller.

(5) Use the refined orbital parameters to drive displays at the GSFC operations control center.

(6) Generate and transmit real-time acquisition messages to participating MSFN stations based on postinjection tracking data.

(7) Reformat Grand Canary and Carnarvon radar data to the standard 38-character radar data format for transmission to RTCS and AFETR. (In addition, Tananarive data were to be reformatted if the capability was not available to transmit data in the standard 38-character radar format.)

(8) Reformat on magnetic tape the high-speed radar data received from the AFETR in the tape format specified (XYZ and $\dot{x}\dot{y}\dot{z}$) and reformat on magnetic tape the low-speed teletype radar data received from the AFETR and MSFN in the standard time, azimuth, elevation, and range format for shipment to the *Centaur* Vehicle Office at the Lewis Research Center.

(9) Reformat on magnetic tape the high-speed raw data from Bermuda, including a list of the contents and formats, for shipment to the data processing requirements group at Patrick Air Force Base.

D. Deep Space Network

The DSN was required to support the *Surveyor V* Mission with the Deep Space Instrumentation Facility, the ground communication facility, and the DSN facilities in the Space Flight Operations Facility.

The DSN requirements included S-band tracking and two- and three-way doppler coverage. The responsibilities of the DSN were to obtain continuous spacecraft telemetry coverage from the first acquisition by DSS 42 to the end of the mission. Three Deep Space Stations (described in Subsection D-1) were required for this coverage. The full Goldstone duplicate standard (standard time reference) S-band system, in conjunction with the *Surveyor* telemetry system, was used at these stations.

The quality and type of tracking data required are defined in Tables 6 and 7. These tables specify the tracking coverage required to meet the orbit-determination accuracy requirements. Before presenting the tracking coverage requirements, however, the ground rules upon which the tracking coverage analysis was based will be defined.

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, and 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 achievement of a successful mission. Finally, the class III accuracy requirements did not have to be satisfied to ensure a mission success. Therefore, the greatest effort was directed toward 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 Deep Space Station supplying necessary data would, in fact, supply data of good quality. To ensure a supply of good quality data, it was highly desirable to assign additional Deep Space Stations to a tracking pattern for redundancy.

The requirements for allowable errors in orbit determination are specified by classes as follows:

Class I: The semimajor axis 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.

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

(1) The semimajor axis of the 1-σ ellipse must be $\leq$50 km using all tracking data available up to 6 h before DSS 51 set (approximately $T + 4$ h). A maneuver could then be executed during the DSS 51

Table 6. Deep Space Network tracking data accuracy requirements

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

pass, if desired, and still meet the required premidcourse orbit-determination accuracy.

(2) The semimajor axis of the 1-σ ellipse must be $\leq$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 value is to be contrasted with the value given for the class I requirement that assumed that a 45-m/s maneuver was performed.

Class III: The semimajor axis of the 1-σ ellipse must be $\leq$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 predicts.

This interface was supplied by the DSN to provide real-time transmission of downlink 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.

Table 7. Deep Space Network tracking data requirements

Coverage and sampling rate	Data required
Track spacecraft from separation to first midcourse maneuver at 1-sample/min rate (from initial DSS acquisition to $T + 1$ h, sample rate is 1 sample/10 s)	Doppler (two- and three-way) and antenna pointing angles
Track spacecraft from first midcourse maneuver to touchdown at 1 sample/min.	Doppler (two- and three-way)
Track spacecraft from touchdown to end of mission at 1-sample/min 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 DSSs 11, 42, and 61	Doppler (two- and three-way) and antenna pointing angles
Track spacecraft during midcourse maneuver and terminal maneuver executions at the 1-sample/s rate, and transient data at the 1-sample/10 s rate	Doppler (two- and three-way or one-way)

The DSN provided an interface for downlink telemetry from both VHF and S-band sources. The nominal switchover time was after S-band High Power On was commanded and the spacecraft's response.

This interface requirement was to provide early spacecraft orbit information to allow calculation of look angles for subsequent tracking. The Deep Space Stations could then effect proper initial acquisition with the aid of preflight prediction data and inflight prediction messages based upon actual spacecraft orbit determinations from AFETR. Subsequent acquisitions were made with prediction messages based upon orbits calculated to satisfy the need for a final premidcourse maneuver orbit.

Additional interface requirements included: (1) downrange telemetry data from building AO to the SFOF, (2) providing downrange spacecraft telemetry from both S-band and VHF, (3) a nominal switchover after S-band High Power On is the input to the command data console (CDC), and then to the GCF.

*1. **Deep Space Instrumentation Facility.*** The DSIF was required to provide coverage for the *Surveyor* V Mission, by at least three prime stations on a 24-h/day basis from launch to lunar landing, and for the first lunar day and night. The requirement for succeeding lunar days and nights was for 24-h/earth day coverage during the first three and last two earth days, and for 10 h/earth day in between.

The prime DSN coverage was to be provided by DSS 11 (California), DSS 42 (Australia), DSS 51 (South Africa), DSS 61 (Spain), and DSS 72 (Ascension). Additional DSN support was to be provided by DSS 14 (California), and DSS 71 (Florida). Deep Space Station 14 was to provide backup support to DSS 11 with its 210-ft antenna during the midcourse maneuver and terminal-descent phases. Prelaunch checkout and launch phase support of the spacecraft was provided by DSS 71. Deep Space Station 71 is also the key interface in relaying spacecraft telemetry data from the AFETR to the SFOF in Pasadena.

The initial Deep Space Station to acquire was to be DSS 51, with DSS 72 providing acquisition backup. Only DSSs 51 and 72 had view periods occurring early enough to provide command capability for switching the spacecraft transmitter to low power before the critical thermal limit was reached. In the event that DSS 51 was not able to support, the view periods of DSS 72 would have been the main constraint in establishing the launch windows. Certain launch window designs were the result of using DSS 72 to satisfy the spacecraft transmitter constraint. Also, DSS 72 was the only Deep Space Station that adequately covered the gap between DSSs 11 and 61. The anticipated configuration of the DSN did not impose any launch constraints. Coverage for the *Surveyor* V Mission by DSSs 51 and 72 is listed in Table 8.

Requirements for data handling by the prime Deep Space 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 by the SFOF and postflight data in the form of punched paper tape. Two- and three-way doppler data were required full-time during the lunar flight, and also during lunar operations at *Surveyor* Project Office request. The two-way doppler function implied a transmit capability at the prime stations.

(2) Spacecraft telemetry data were 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 computer. The data were then 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 on-site data processing computer and transmitted by teletype to the SFOF.

The definition of the various categories of received data are listed in Section III of Volume II of this report. Hard-copy *Surveyor* data required for authorized users are divided into three categories, and can also be found in the aforementioned volume.

a. Tracking. The DSIF tracking requirements were to:

(1) Supply three Deep Space Stations for prime tracking support.

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

(3) Supply antenna pointing angles.

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

(5) Supply tracking coverage.

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

(7) Supply tracking data in near-real-time via teletype to SFOF.

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

Deep Space Station raw tracking data requirements are given in Table 9.

b. S-band telemetry. The Deep Space Stations were required to obtain S-band telemetry from the *Surveyor V* spacecraft and to 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 on-site data processing computer. The data were then to be transmitted to the SFOF in near-real-time, using high-speed data modems.

The telecommunications system was designed to provide a two-way communication link between the DSIF and the *Surveyor* spacecraft. The Deep Space Station-to-spacecraft uplink signal was a PCM/frequency-modulated (FM)/phase-modulated (PM) system. The spacecraft-to-Deep Space Station downlink could be operated PCM/FM/PM (transponder mode), PCM/FM/FM, PCM/FM/PM, or direct FM throughout all phases of the mission. Transponder mode was employed during the transit phase to permit two-way doppler shift measurements.

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

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

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

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

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

Table 8. Deep Space Station coverage of *Surveyor V*

Phase	DSS coverage
Transit	24 h/earth day
Postlanding	
(1) First lunar day	24 h/earth day
(2) First lunar night	(1) 24 h/earth day for 3 days
	(2) 10-h pass/earth day for remainder of lunar night
(3) Second lunar day	(1) 10 h/earth day until spacecraft revival
	(2) 24 h/earth day for first 3 earth days after spacecraft revival
	(3) One 10-h pass/earth day until 48 h prior to sunset
	(4) 24 h/earth day for last 2 earth days prior to lunar sunset and first 48 h after sunset
(4) Second lunar night	Same as first lunar night
If landing were not achieved	(1) 24 h/earth day for not more than 3 earth days after encounter
	(2) 8 h/earth day for an additional 10 earth days, or for life of spacecraft, whichever is less

Table 9. Raw tracking data required from the Deep Space 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 maneuver at 1-sample/min rate (after first h, 1-sample/5 s rate to end of first h)	Doppler (2- and 3-way) and antenna pointing angles	A A	B B	C C	1. Teletype 2. Magnetic tape
2. Track spacecraft from midcourse maneuver to touchdown at 1-sample/min rate	Doppler (2- and 3-way)	A	B	C	1. Teletype 2. Magnetic tape
3. Track spacecraft from touchdown up to 90 days at 1-sample/min rate	Doppler (2- and 3-way)	A	B	C	1. Teletype 2. Magnetic tape

[a]Accuracy codes refer to the way that the data accuracies are broken down and are shown in Table 6.

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 on-site data processing computer and transmitted by teletype to the SFOF. The on-site data processing computer was capable of being used to verify command tapes punched on-site from teletype instructions received from the SFOF, but this function was not 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 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 TV Ground Data Handling System.

e. Additional requirements. It was necessary that certain minimum capabilities exist (with a high degree of probability) at DSSs 11, 42, 51 (or 72), and 61 during their view periods. In addition, acquisition, recording, and processing of *Surveyor* video data were considered a minimum capability for DSS 11. The general requirements for the Deep Space Stations follow:

(1) Acquisition and tracking of the *Surveyor* 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* spacecraft telemetry data.

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

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

2. *Ground communication facility/NASCOM.* The ground communication facility (GCF) is that portion of NASCOM that supported the *Surveyor V* Mission by providing communication paths between the various Deep Space Stations throughout the world and the SFOF. This communications system comprised the landlines, undersea cables, and radio circuits that carried teletype, voice, and high-speed data in real-time support of the *Surveyor V* Mission. Figure 8 illustrates the configuration of the GCF in support of *Surveyor V* and the type of data carried over these circuits.

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

a. Voice. The GCF 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 signaling, conferencing, and monitoring arrangement. The 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 cases where cables are not available.

b. Teletype. The GCF 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. Additional requirements. To ensure the success of the *Surveyor V* Mission, it was required (with a high degree of probability) that the following communications links exist:

(1) AFETR–SFOF:
- (a) Two voice lines.
- (b) One high-speed data line from building AO, or DSS 71, to SFOF.
- (c) One simplex teletype line from AFETR to SFOF.

(2) DSSs 51–72:
- (a) One voice line.
- (b) Two duplex teletype lines.

(3) DSS 61–SFOF:
- (a) One voice line.
- (b) Two duplex teletype lines.

(4) DSS 42:
- (a) One voice line.
- (b) Two duplex teletype lines.

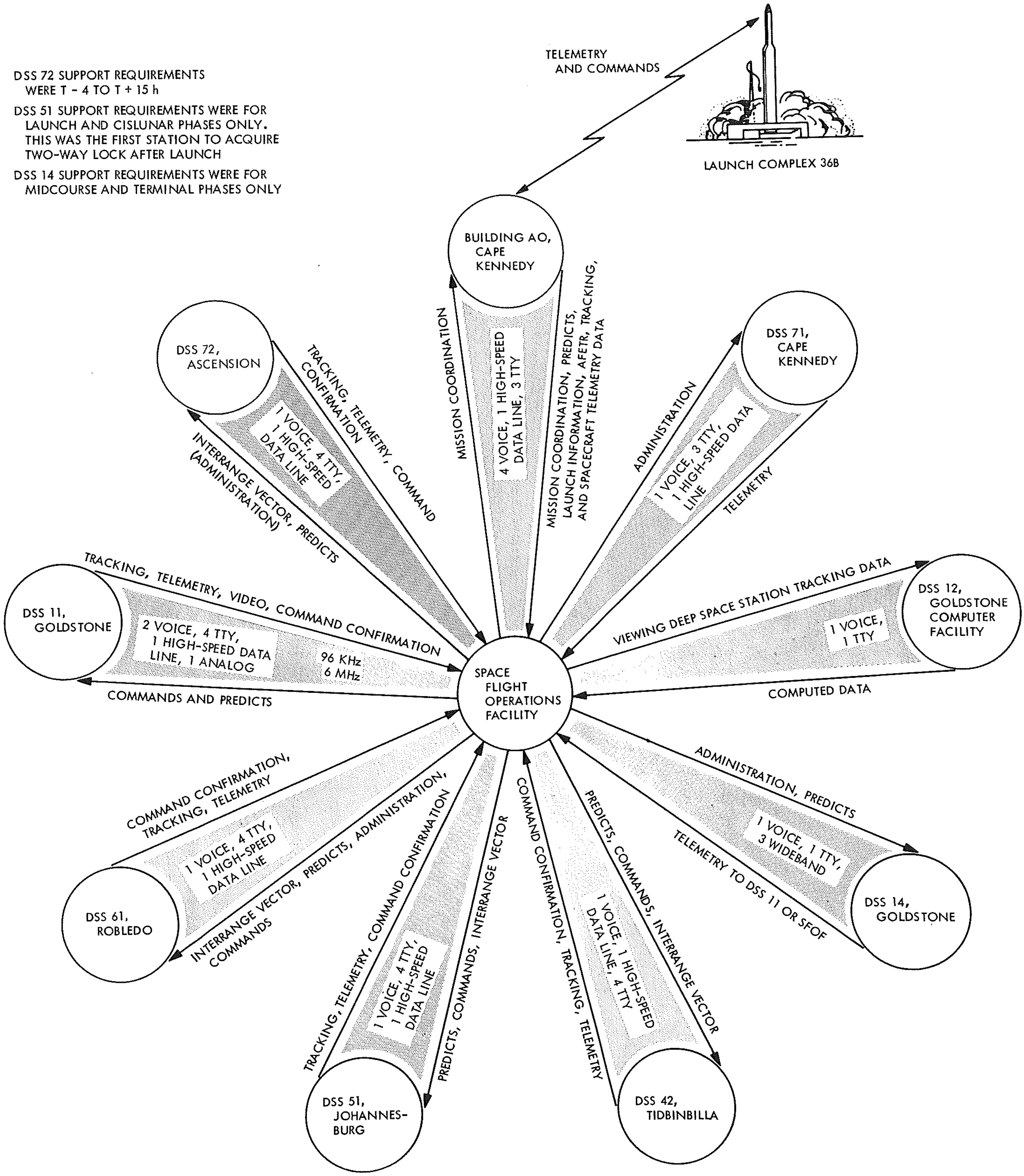


Fig. 8. Ground communications facility configuration for *Surveyor V*

(5) DSS 11–SFOF:

(a) One voice line.

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

(c) One duplex teletype line.

3. Deep Space Network/SFOF. The DSN/SFOF communications system was to provide the capability of transferring all of the necessary information required for spaceflight operations within the SFOF. This system was required to include: (1) all voice communication capabilities within the facility, (2) all closed-circuit television, (3) all teletype distribution, (4) all high-speed data distribution, and (5) all data received over microwave channels within the SFOF.

The Space Flight Operations Facility 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, assigned many of these mission-independent capabilities to support the *Surveyor III* Mission. These capabilities included such operating functions as communications, displays, and data processing.

a. Communications. The DSN intracommunications system (ICS) for the *Surveyor V* Mission consisted of those circuits, switching facilities, terminals, equipment, and personnel internal to the SFOF that were required to transmit, receive, and distribute various types of intelligence. The ICS was divided into nine subsystems, as follows:

(1) Operational voice communications subsystem.

(2) Operational status recording subsystem.

(3) Operational public address subsystem.

(4) Operational voice recording subsystem.

(5) Operational miscellaneous audio subsystem.

(6) Operational teletype communications subsystem.

(7) Television communications subsystem.

(8) High-speed data subsystem.

(9) Wideband communications subsystem.

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

(1) Operations Area.

(2) Flight Path Analysis Area.

(3) Mission Support Area 1A.

(4) Mission Support Area 1B.

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

(1) Computation of acquisition predictions for Deep Space 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. Additional requirements. The following minimum capabilities were required in the SFOF:

(1) One operational 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 operational voice communications subsystem committed to *Surveyor* less its intercom capability.

(5) Closed-circuit TV displays of teletype data and line status.

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

IV. *Surveyor V* TDS Flight Preparation

The TDS was responsible for tracking and data acquisition preparations for the flight of *Surveyor V.* Flight preparation was accomplished by the unique TDS configuration and testing discussed in this section.

A. Configuration

This subsection deals with the configuration of the elements comprising the TDS: the AFETR, the MFSN, and the DSN.

1. Air Force Eastern Test Range. The facilities of the AFETR were configured to give maximum coverage of the near-earth phase of the *Surveyor V* Mission. The committed station capabilities and configuration are shown in Table 10.

a. Tracking. The AFETR was to provide adequate C-band coverage of the powered flight and parking-orbit requirement with its uprange stations. The prelaunch TDS coverage (includes all committed TDS stations) for the September 8, 1967 launch date is shown in Fig. 9.

The RIS *Twin Falls* was positioned (20 deg N, 37 deg W,) to provide transfer-orbit coverage for the more southerly azimuths. The RISs *Coastal Crusader* and *Sword Knot* were positioned 19 deg N, 22 deg W, and 4.75 deg N, 0.50 deg W, respectively. The MSFN was to cover this interval with Grand Canary for the northerly azimuths. Ascension and Pretoria were to cover the post-retromaneuver tracking requirement.

b. Telemetry. Range telemetry aircraft, operating at VHF, were to be used to extend the windows during this launch. They were to cover the interval of *Centaur* second burn, thereby closing the gap in the interval between Antigua and the *Twin Falls*. The aircraft were to support near, or at, their maximum range, with staging out of Antigua.

Real-time transmission of VHF data was to be accomplished, using the subcable through Antigua, as on previous missions.

Table 10 shows the planned VHF telemetry configuration, along with the radar and S-band configuration, for the *Surveyor V* Mission.

Ascension, Pretoria, and RISs *Coastal Crusader* and *Sword Knot* were configured to satisfy the S-band telemetry requirements. The *Sword Knot* was to be positioned for prime coverage during Pretoria's view period. No coverage estimates were made for Pretoria because it was using a 3-ft antenna.

c. Real-time computer system. The AFETR radars at Grand Turk, Antigua, Ascension, Pretoria, and on the *Twin Falls* were to provide real-time parking, transfer, and post-retroignition-orbit metric tracking data to building AO for relay to the SFOF at JPL (Fig. 10). For certain northerly azimuths, Bermuda would provide some postinjection data; however, the majority of Bermuda data would be obtained during the powered-flight phase. Radar data from the MSFN radars at Grand Canary, Tananarive, and/or Carnarvon may also be used.

Table 10. Configuration and capabilities of AFETR stations

Station	Configuration		
	Radar		Telemetry capability
	Identification	Type	
Antigua	91.18	FPQ-6	VHF, S-band
Ascension	12.16 12.18	FPS-16 TPQ-18	VHF, S-band
CKAFS[a]	1.16	FPS-16	
Kennedy Space Center	19.8	TPQ-18	VHF, S-band
Patrick AFB	0.18	FPQ-6	
Grand Bahama	3.16 3.18	FPS-16 TPQ-18	VHF, S-band
Grand Turk	7.18	TPQ-18	VHF
Pretoria	13.16	MPS-25	VHF, S-band[b]
RIS *Twin Falls*	—	FPS-16	VHF, S-band
RIS *Coastal Crusader*	—	—	VHF, S-band
RIS *Sword Knot*	—	—	VHF, S-band
Audit 1[c]	—	—	VHF
Audit 2[c]	—	—	VHF

[a]CKAFS = Cape Kennedy Air Force Station.
[b]3-ft antenna only.
[c]Range telemetry aircraft.

In addition to relaying the data to JPL, the real-time computer system was to use the data to compute orbital elements and injection conditions (parking, transfer, and post-retroignition orbits), which would be transmitted to JPL in the following formats:

(1) Standard JPL orbital message.

(2) Interrange vector.

(3) Standard orbital parameter message.

The DSN and MSFN acquisition information, based on the parking-orbit plus theoretical second burn and actual pre-retroignition orbital computations, were to be prepared and forwarded by the RTCS. In addition, AFETR was to transmit interrange vector messages and DSS 72 prediction data directly to DSS 72.

A *mapping to lunar encounter* message was to be prepared for both the pre- and post-retromaneuver orbits. Following the single-station solutions, the RTCS was to compute and transmit to the SFOF, pre- and post-retroignition recursive cumulative orbits. An I-matrix

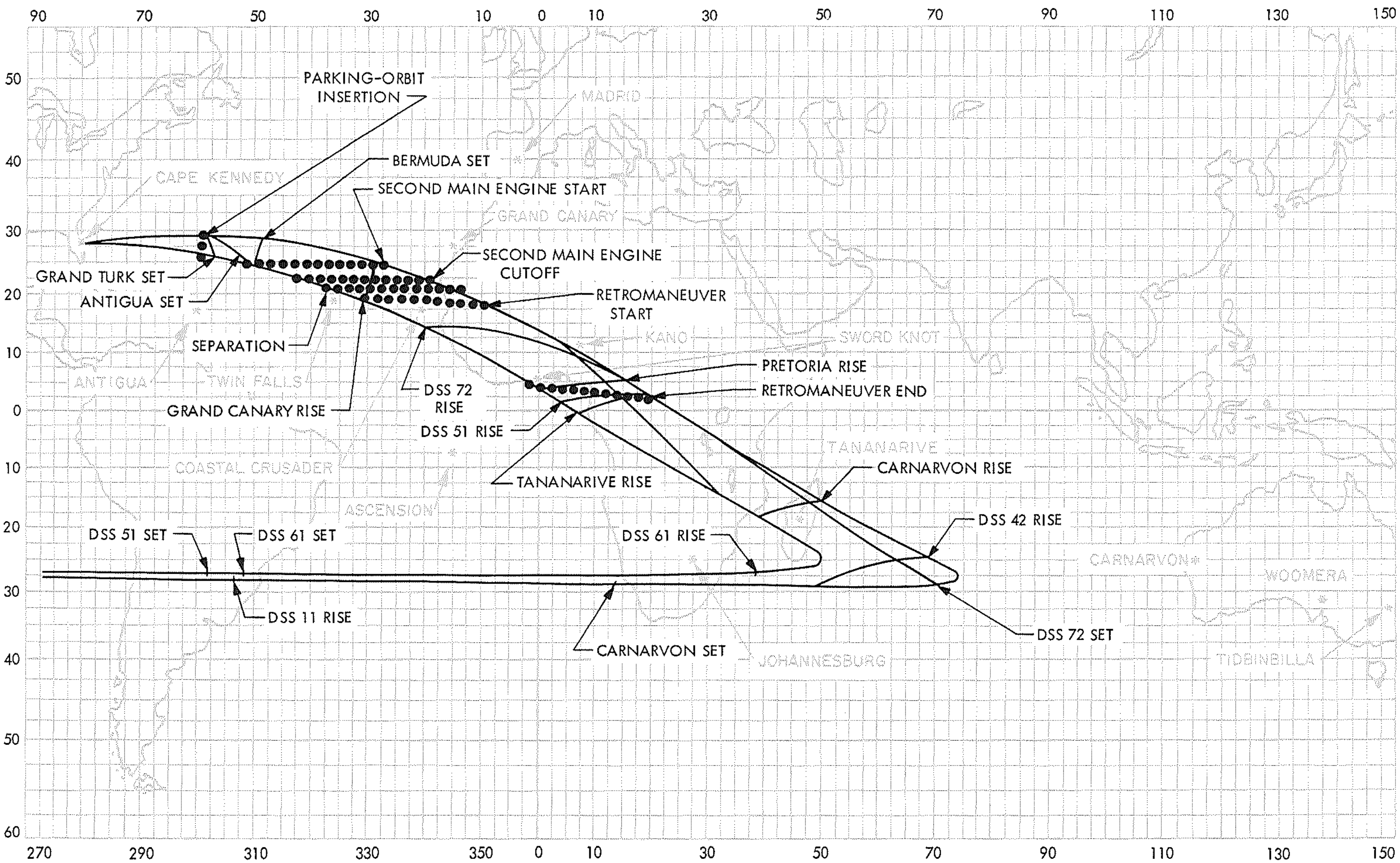


Fig. 9. Tracking and Data System coverage of the *Surveyor V* launch

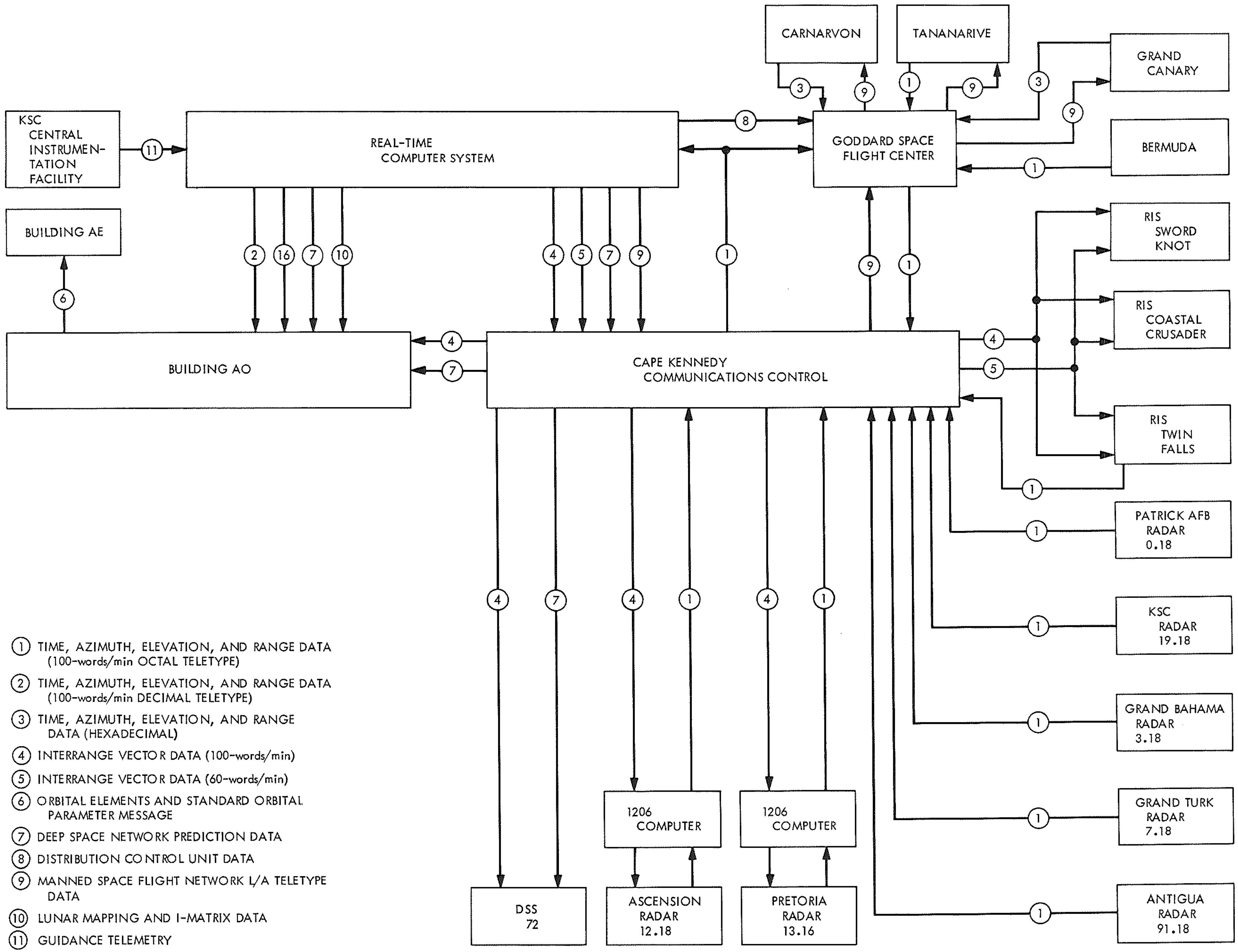


Fig. 10. Metric tracking and computed data flow

and a lunar mapping message based upon each solution would be included. Figure 10 also shows the planned configuration for the flow of metric data into and out of the RTCS.

d. Real-time data. The planned spacecraft telemetry data flow from the supporting AFETR stations to building AO and DSS 71 is shown in Figs. 11, 12, and 13. The following AFETR stations were expected to acquire and transmit spacecraft telemetry: Kennedy Space Center, Grand Bahama, Antigua, Ascension, and Pretoria. The Rixon 1, 2, and 3 lines in Fig. 11 represent PCM telemetry data transmitted via direct HF radio links from the RISs and Ascension to Cape Kennedy. Pretoria data were to be relayed through Ascension and then by RF link directly to Cape Kennedy.

The data were to be routed to Kennedy Space Center as shown in Figs. 11 and 12. There, after analysis by using the time-division multiplexers, the AFETR telemetry coordinator would select the best source for transmission to building AO and DSS 71 via modems. As shown in Fig. 13, there are two modem lines between Kennedy Space Center and the XY building to provide redundancy.

The modem lines are bridged at the XY building to provide two modem lines each to building AO and DSS 71. Deep Space Station 71 routed the data through a CDC and a telemetry and command processor for further transmission to the SFOF via a NASCOM high-speed data line. This is the prime route to the SFOF.

At building AO, the data were to be routed to the CDC for use by the spacecraft test team. The communication center in building AO would receive the data from the CDC for conditioning by the bit synchronizer, after which the data were to be routed, as a backup path, to the SFOF. In addition, an output is available from the bit synchronizer for routing data to DSS 71 during the spacecraft countdown, and as a backup to their modem lines from the XY building.

2. Manned Space Flight Network. The MSFN (managed by GSFC) was configured to support the *Surveyor V* Mission by providing tracking, telemetry, and computer support as shown in Fig. 14.

a. Tracking. The coverage of the C-band radars is discussed in Section III-C-1.

b. Telemetry. Telemetry coverage is discussed in Section III-C-2.

A keyer (circuit used to tone-burst guidance data over a communications line) was sent from building AE to GSFC for relay to Grand Canary in a further attempt to enable retransmission of *Centaur* guidance data from Grand Canary.

Although the keyer did not arrive at Grand Canary in time for support, the signaling, conferencing, and monitoring arrangements and teletype communications between GSFC and Grand Canary provided sufficient information to allow on-site fabrication of a keyer. Subsequent data-flow testing proved successful.

After successful Grand Canary data-flow tests, inquiries were made as to the possibility of obtaining *Centaur* guidance data from Bermuda. A keyer was shipped to Bermuda, and a data-flow test between Bermuda and building AE was successfully conducted on September 4, 1967.

The MSFN was to participate in S-band acquisition, on a noninterference basis, for unified S-band site training.

c. Computer. During the powered flight phase, GSFC computers were to receive launch trajectory data from Bermuda and the AFETR via the launch trajectory data system. The trajectory would be computed, and resulting parameters would be used to drive displays at the GSFC operations control center. Upon termination of the *Centaur* first burn, the data operations branch at Goddard was to pass orbital injection parameters to the MSFN network controller.

The GSFC computers receive low-speed data from the AFETR radars. Real-time acquisition messages were to be generated and transmitted to the participating MSFN stations, based upon the actual first-burn and nominal second-burn data. If time permitted, the station rise minus 5 min acquisition messages based on post-injection tracking data were to be generated and transmitted.

The low-speed teletype data from Grand Canary, Tananarive, and Carnarvon were to be reformatted to the standard 38-character radar data format by the GSFC computers, and retransmitted to the RTCS at AFETR.

At Grand Canary LOS, *Centaur* guidance data (channel 16) were to be transmitted to building AE for reconstruction of the 800-bit/s PCM data, in an attempt to compute an orbit from the guidance data.

d. Communications. Table 11 indicates the site, type, and quantity of communications circuits provided for support of the *Surveyor V* launch.

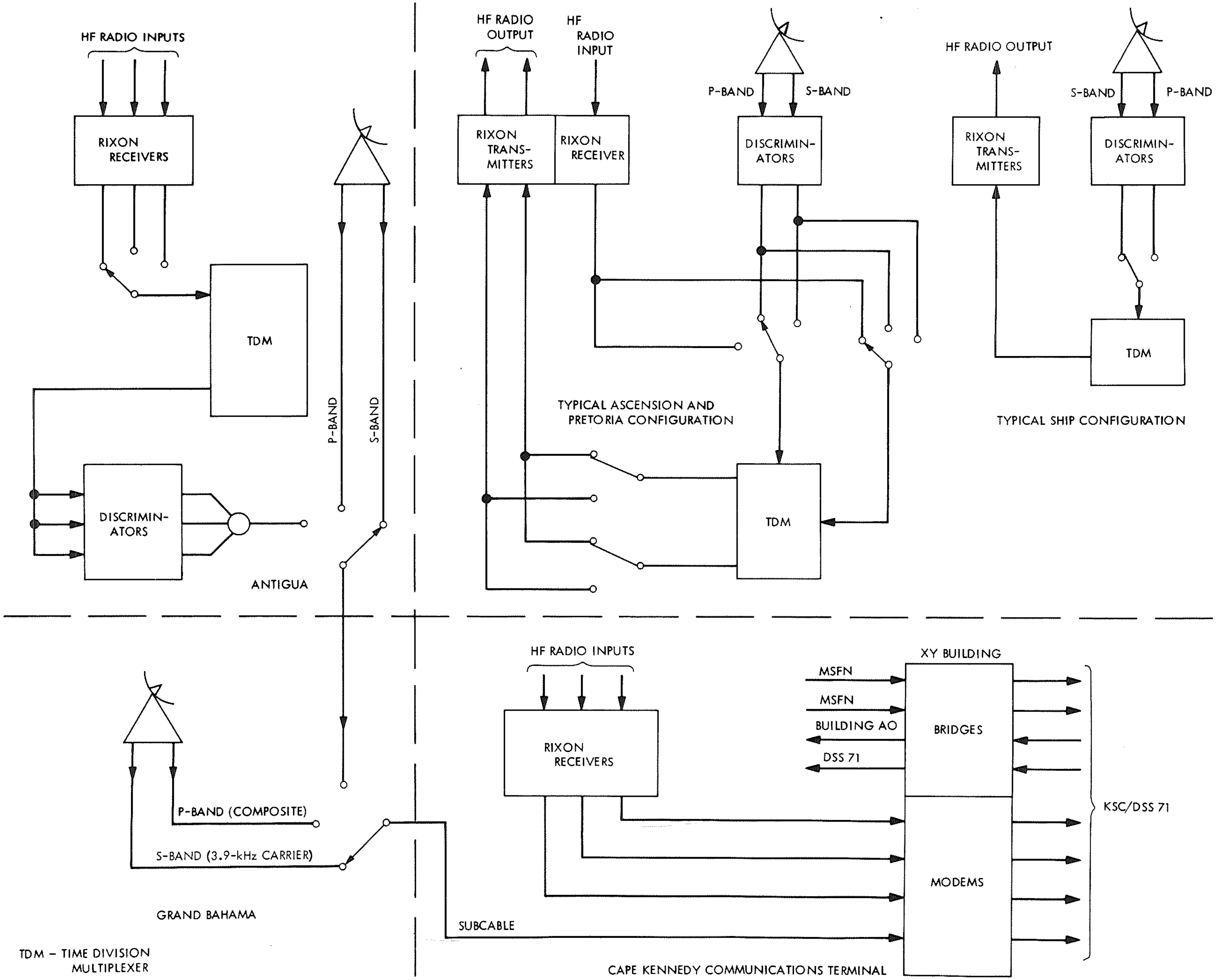


Fig. 11. Downrange telemetry data flow

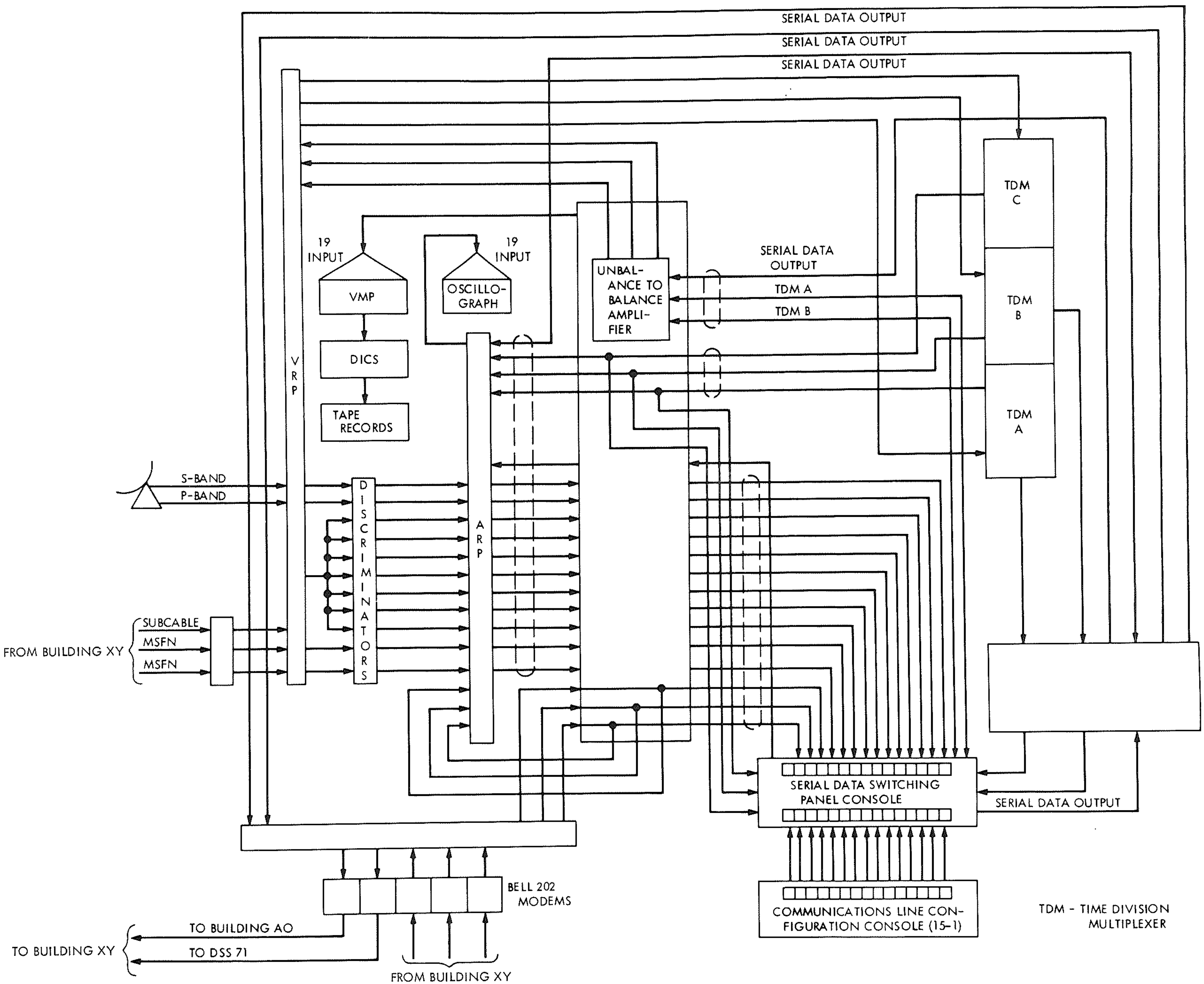


Fig. 12. AFETR serial data routing and switching system

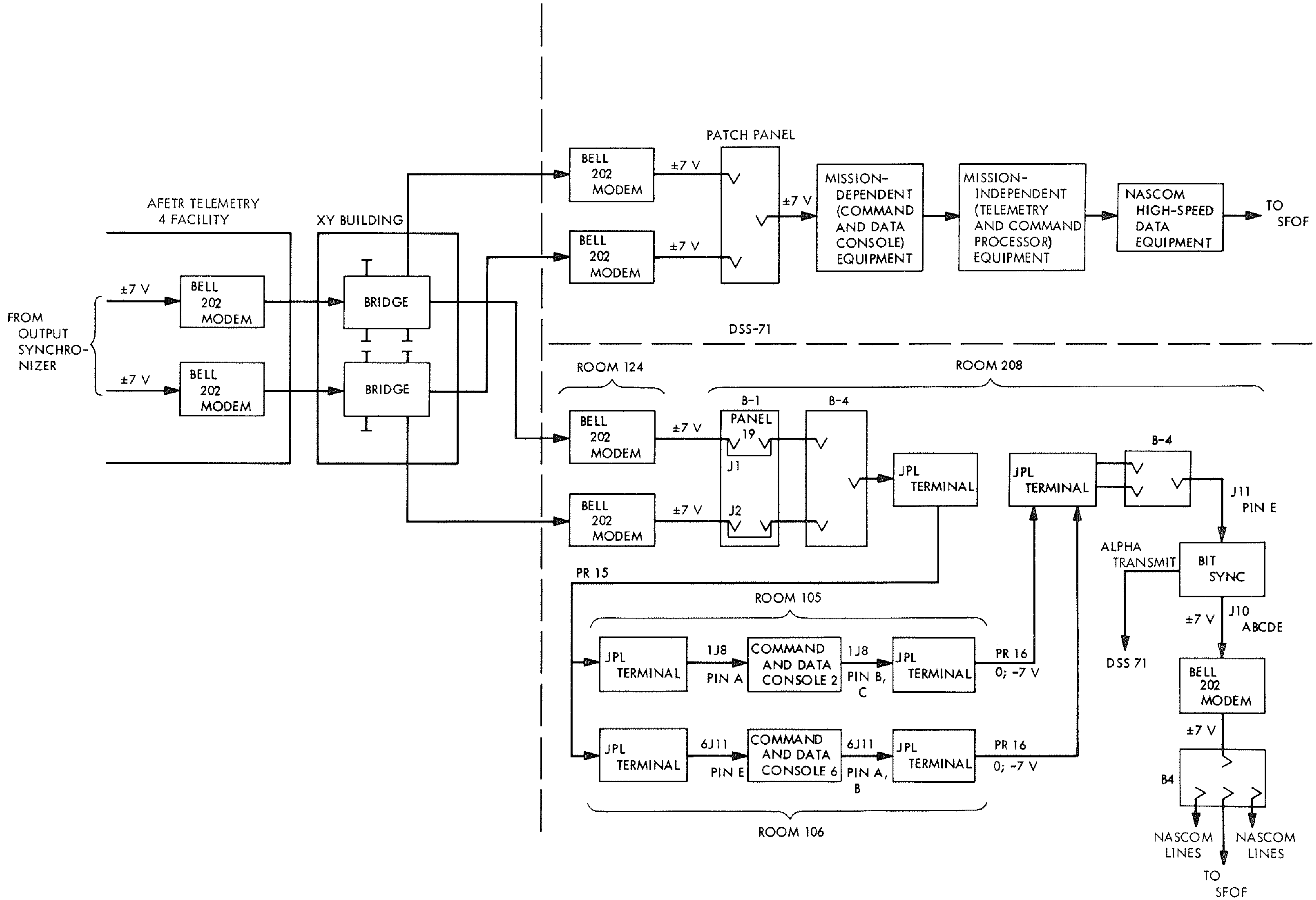


Fig. 13. Telemetry data distribution schematic (KSC–DSS 71)

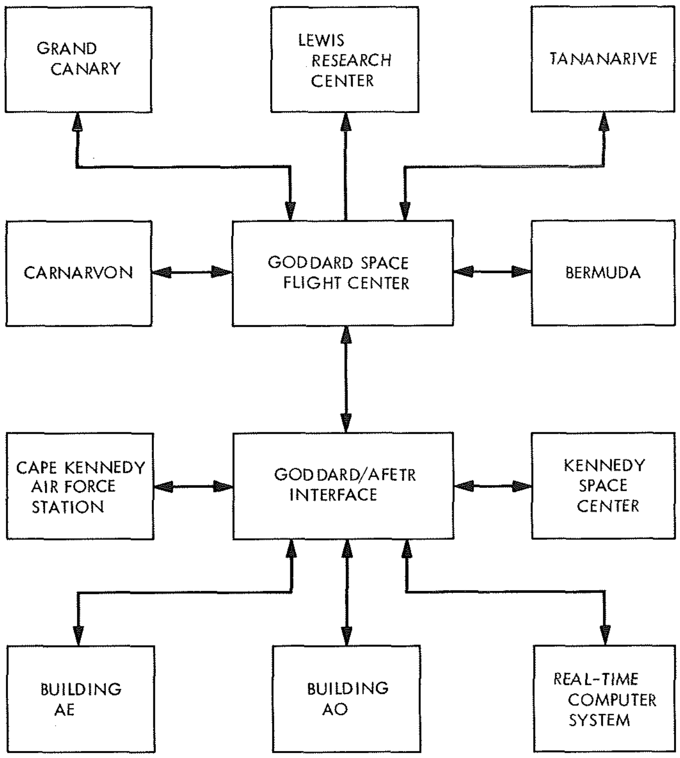


Fig. 14. Generalized ground communications configuration of the MSFN

e. Prelaunch near-earth phase coverage summary. A near-earth phase tracking summary of the elements of the TDS and their related stations is shown in Figs. 15–17.

Coverage intervals for the AFETR and MSFN stations, as well as station coverage estimates, significant *Centaur* and spacecraft events, and class I instrumentation coverage requirements are presented for contrast. The shaded areas on the various figures represent class I coverage. When they affect spacecraft coverage by S-band stations, the rise times for the Deep Space Stations are shown. The estimated coverage of the 2295-MHz radar, the S-band, and the P-band links are illustrated in Figs. 15–17, respectively.

3. Deep Space Network. The major elements of the DSN, configured to support *Surveyor V*, are the DSIF, the DSN communications system, and the SFOF.

a. Deep Space Instrumentation Facility. The DSIF coordinates the Deep Space Stations located around the world at intervals of about 120 deg in longitude. The Deep Space Stations are spaced so that, with a minimum of three operational stations, the antennas of one may continuously observe a spacecraft.

Table 11. *Surveyor V* NASCOM support

Deep Space Station	Number of circuits		
	Teletype	*Voice*	High-speed data
70	3	3	1
71	3	1	1
72	4	1	1
61	4	1	1
51	4	1	1
42	4	1	1

The prime Deep Space Stations committed to support *Surveyors V, VI,* and *VII* are:

(1) DSS 11 (California).

(2) DSS 42 (Australia).

(3) DSS 61 (Spain).

(4) DSS 71 (Florida).

(5) DSS 72 (Ascension Island).

Deep Space Stations that participated as supporting stations are:

(1) DSS 51 (South Africa).

(2) DSS 14 (California).

For a complete list of the Deep Space Stations and their locations, see Table 1.

Except for DSS 71, all prime Deep Space Stations are required to track during the assigned view periods. It was desirable that DSS 71 track and record telemetry as long as possible after launch. Deep Space Stations 14 and 51 were required to be capable of tracking and recording telemetry in accordance with scheduled assignments.

Coverage. In addition to the basic support discussed in Section I-D-1, DSS 14 was to provide support of the midcourse-maneuver and terminal-descent phases of the mission. This support was to include receiving and recording telemetry, availability as a backup transmitter for commanding (if required), real-time transmission of baseband telemetry data to the SFOF, and interface with a project-furnished down converter for predetection telemetry recording. The CDC at DSS 11 was to be available if any major problems were to occur.

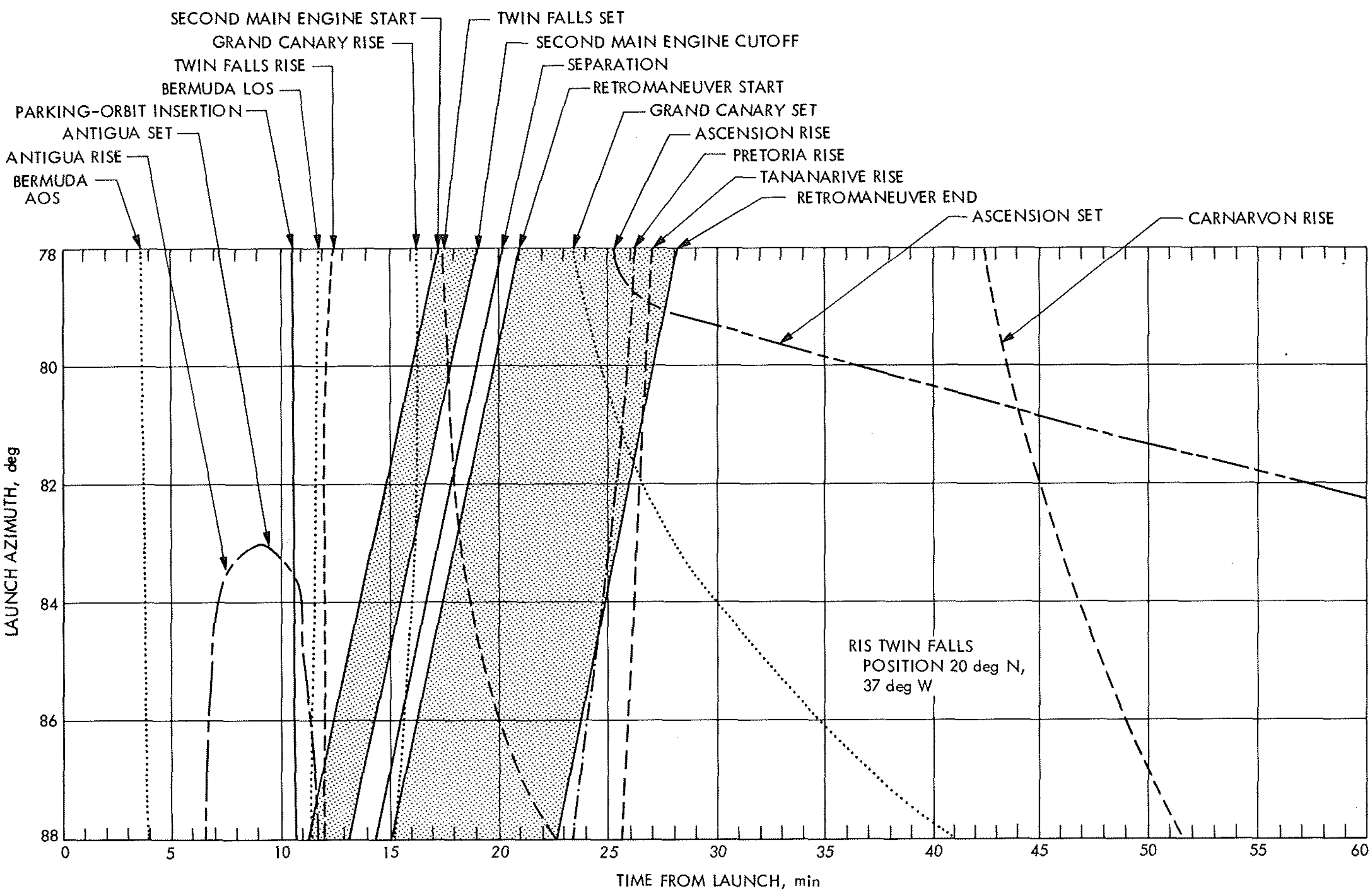


Fig. 15. Radar coverage for the *Surveyor V* launch date

Radio-frequency compatibility tests between the spacecraft on the launch pad and DSS 71 were successfully completed on July 29–30, 1967. The only anomaly was the transmitter A phase jitter problem. Telemetry data were to be received and recorded by DSS 71 from $T-5$ min to LOS. In addition, DSS 71 was to use its CDC and telemetry and command processor to process AFETR range telemetry data for transmission to JPL over NASCOM's high-speed data lines.

To ensure that the High-Power-Off commanding requirement is met, DSS 72 was to provide backup support to DSS 51 and provide early telemetry coverage. The on-site data processing function was to be performed by the digital instrumentation subsystem's SDS 920 computer. This change in configuration has been checked out at the site, and on-site data processing linkups with the SFOF were scheduled. No backup computer was available at DSS 72.

Video data. Because of the increase in video operations at DSSs 42 and 61, and the importance of the data to be obtained, the *Surveyor* Project requested special handling of the video data obtained at these stations. This included on-site verification of video magnetic tape recordings made during preliminary lunar operations, the first two passes after lunar touchdown, and expedited shipment (24- to 48-h delivery) of these recordings to JPL for further evaluation on a best-effort basis.

It is believed that the DSN can comply with all of these requirements except the 24- to 48-h delivery time from DSS 61 in Madrid. This cannot be accomplished through normal air freight channels; however, possible alternatives are under investigation.

Simulation data package. The simulation data package contains spacecraft telemetry and alpha scattering data recorded on seven-track magnetic tape. The simulated data are directly recorded at 15 in./s, and contains the data tabulated below.

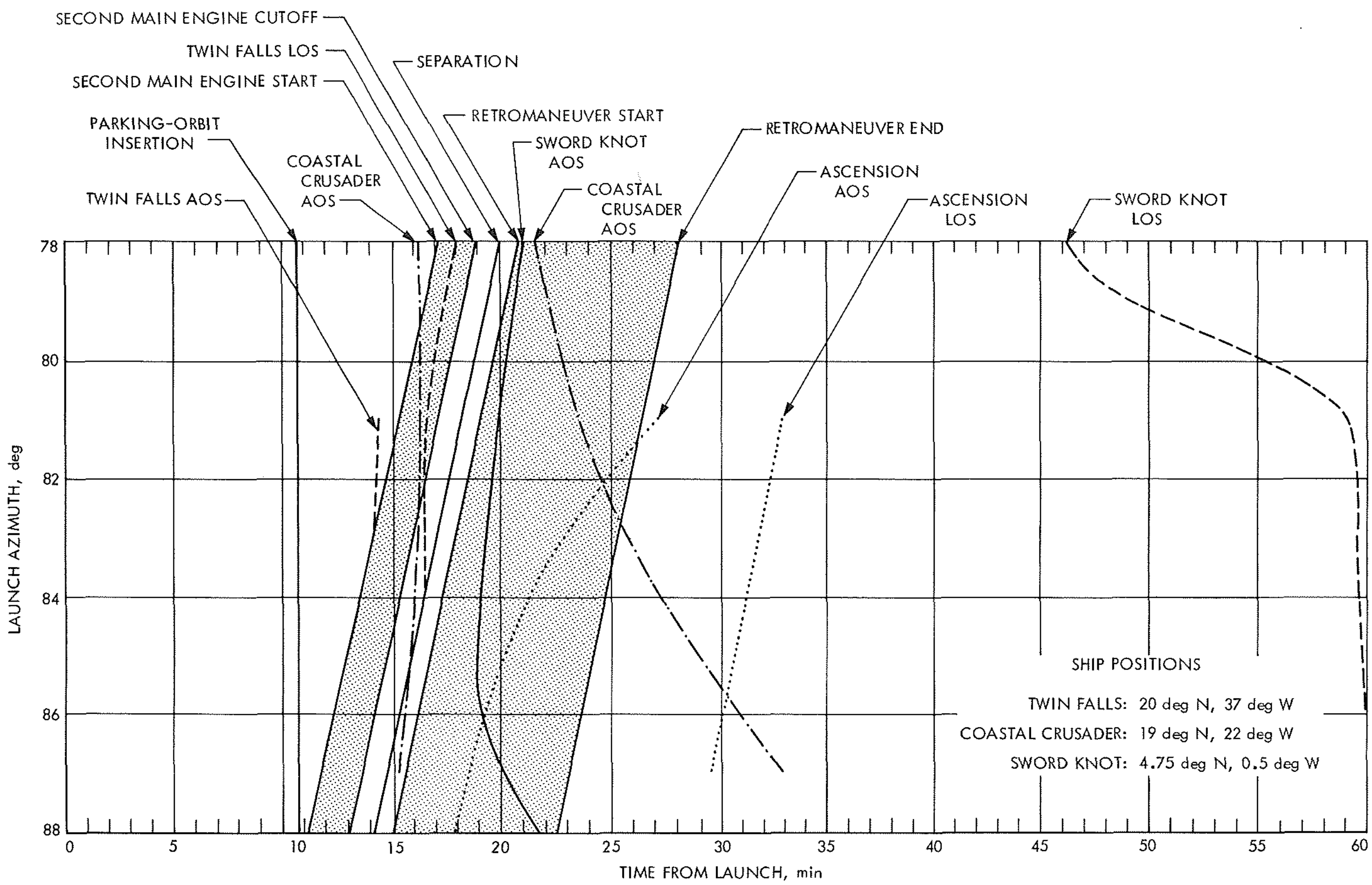


Fig. 16. Telemetry (S-band) coverage for the Surveyor V launch date

Track	Type of data
1	Voice
2	Alpha scattering data, 70-kHz subcarrier
3	Proton data, 5.4-kHz subcarrier
4	Composite telemetry
5	Composite data, alpha and proton only
6	NASA 36-bit time code
7	1-kHz standard tone

b. Communications system. The DSN communications system is composed of two major subsystems: The ground communication facility and the intracommunication system. The GCF provides communication links between the SFOF and all outside agencies (Fig. 18). The ICS provides all intra-SFOF communication links.

The DSN communication system was considered well prepared to support *Surveyor V*. Few significant changes were made since the flight of *Surveyor IV*. A complete discussion of the system is contained in Volume II of this report.

Ground communications facility. The only significant change from the *Surveyor IV* configuration was the implementation of a communications processing system to facilitate teletype transmission between the Deep Space Stations and the SFOF (Fig. 19). The use of the communications processor for total mission support added much to the system's capabilities, but certain procedural changes were required both at the SFOF and at the Deep Space Stations. Minor changes to the system are discussed in subsequent paragraphs.

A new teletype circuit was used as a backup to DSS 51 for the *Surveyor V* Mission. This circuit was used as a backup by GSFC during *Mariner* and *Lunar Orbiter* launches, and was fairly reliable. It is routed via satellite from Ascension to GSFC. Its use requires dropping one of the two DSS 72 satellite teletype channels.

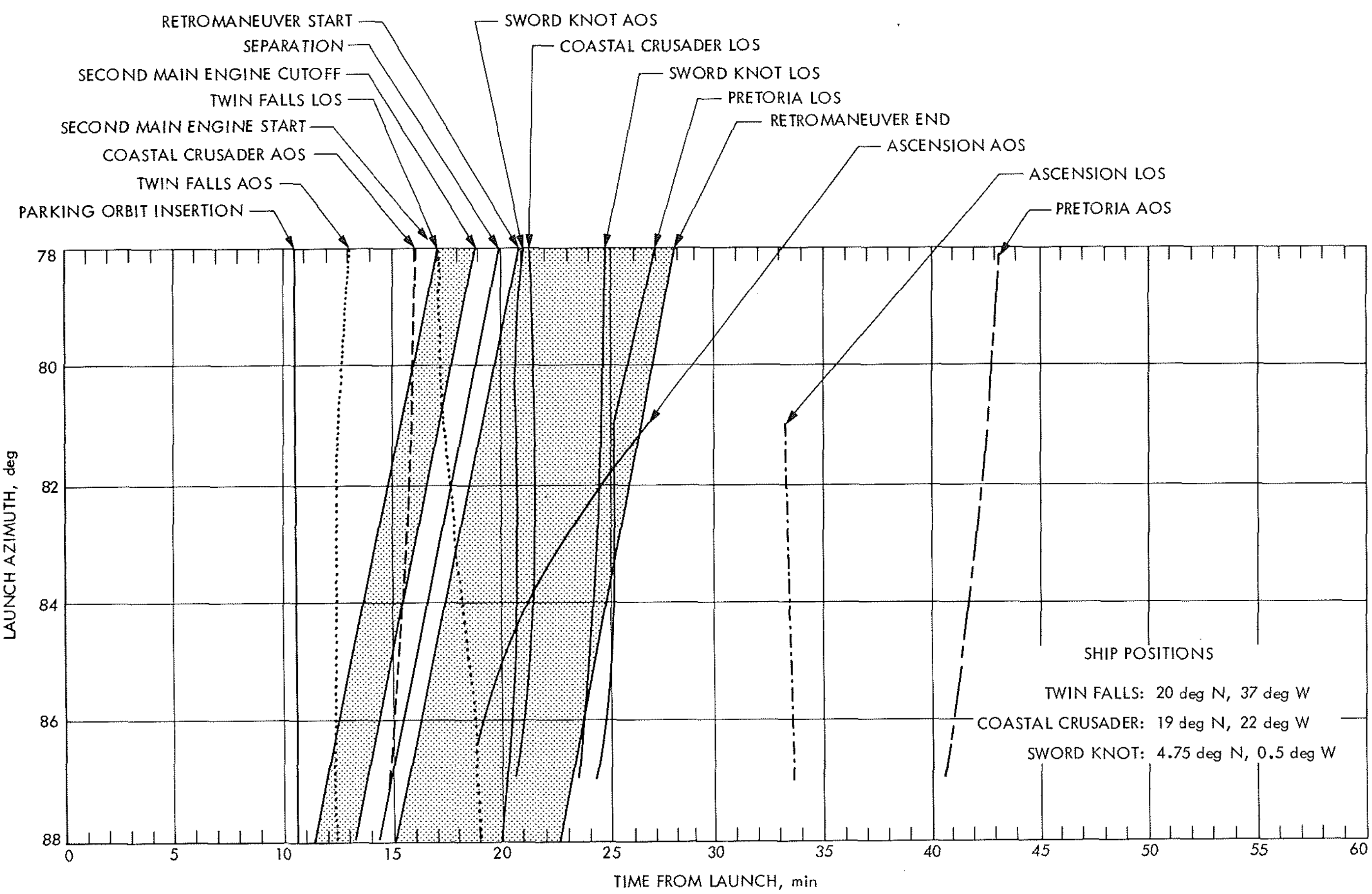


Fig. 17. Telemetry (P-band) coverage for the *Surveyor V* launch date

Two new dataphones have been installed at DSS 71 and building AO to receive high-speed data from the AFETR Telemetry 4 facility.

Project officials requested special maintenance coverage by the Goldstone microwave systems. The coverage requested was from $T + 12$ to $T + 20$ h during the midcourse phase, and from $T + 60$ to $T + 68$ h during the terminal phase.

Intracommunications system. The 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 is used. The majority of this equipment is owned by JPL; however, certain end items of equipment are leased from commercial sources.

Status information is provided by DSN communications control through three status displays of the TV communications subsystem. The communication circuits activity information is shown on the teletype status display, the audio status display, and the propagation status display.

Portions of the ICS are available for use 24 h/day; the use of other portions, however, must be scheduled in advance. The internal communications requirements should be stated together with the SFOF requirements when request for use is made. The ICS is configured to perform the following functions:

(1) Provide an end-terminal and switching capability for NASCOM and other special-purpose circuits external to the SFOF. In this respect, the ICS is

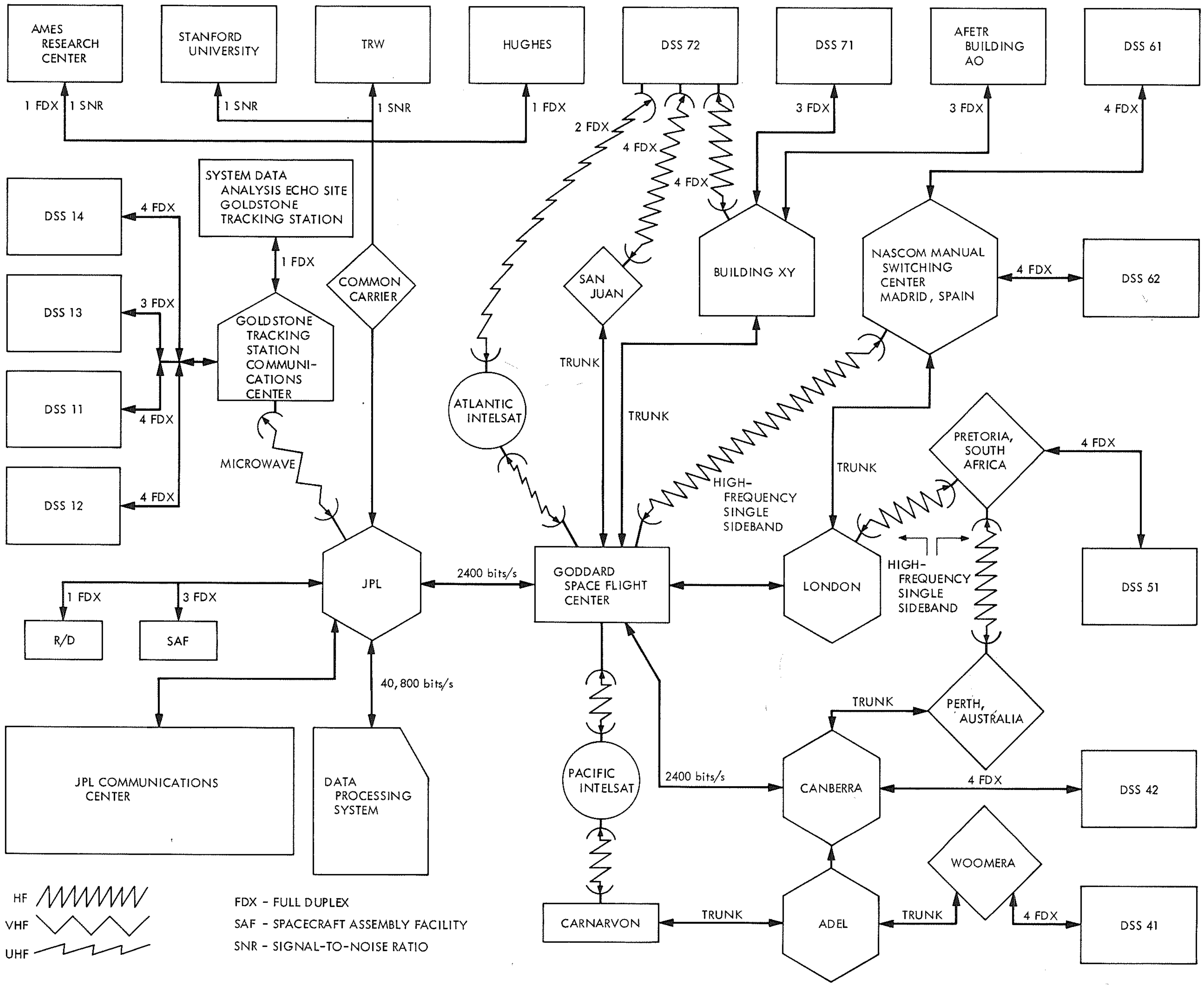


Fig. 18. Ground communications facility teletype routing

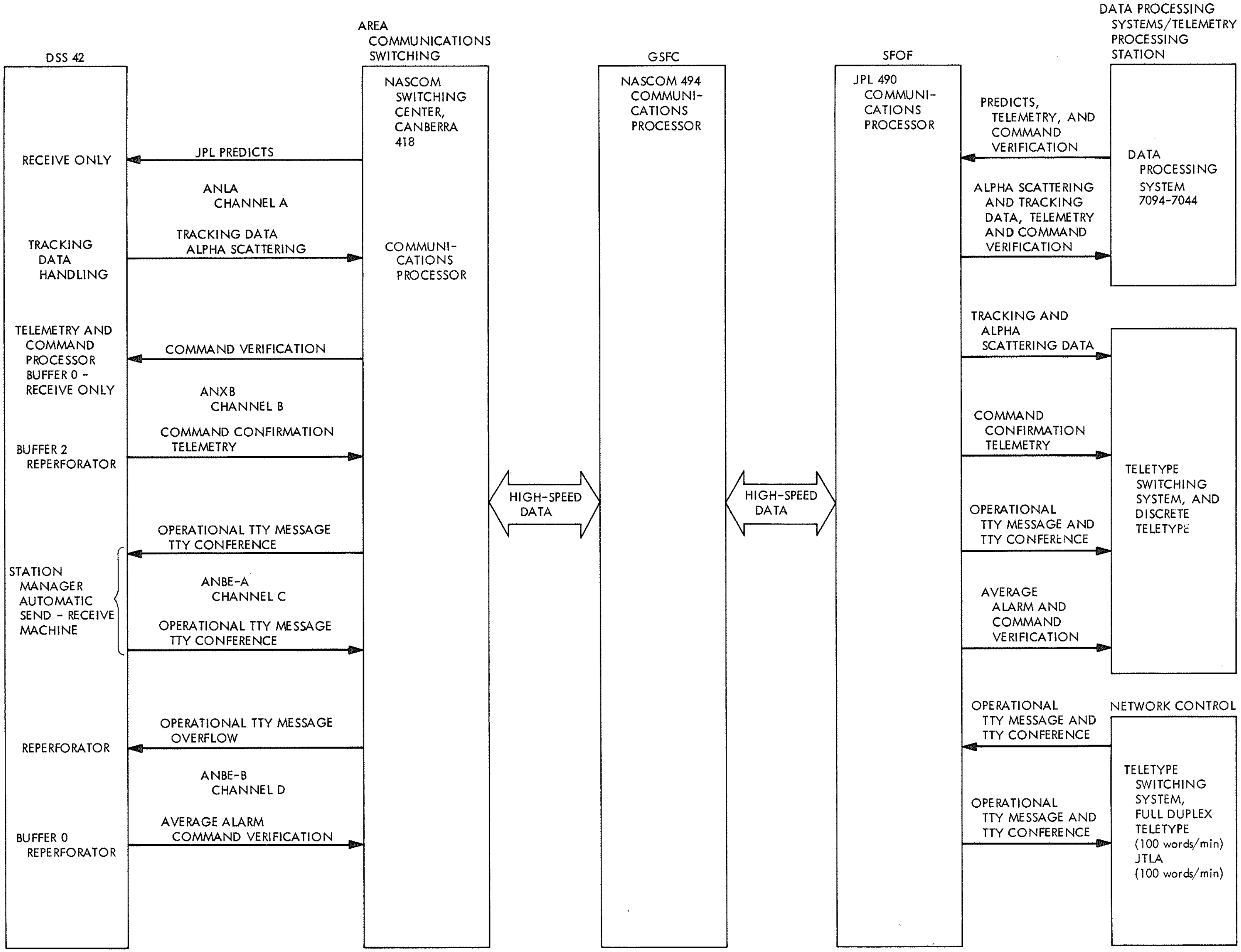


Fig. 19. Typical communications processor teletype data types and routing

capable of the reception of voice, teletype, high-speed, and wideband data from the various data acquisition stations through the media of the GCF. In addition to these reception capabilities, the ICS is capable of transmission of voice and teletype data from the SFOF to various external terminals.

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

(3) Provide a facility whereby user areas of the SFOF are interconnected. In this respect, the ICS is capable of providing both audio and video transmission and reception capabilities.

The ICS configuration consisted of the following subsystems:

(1) Audio subsystems: Operational public address subsystem, operational voice recording subsystem, operational voice communications subsystem, operational status recording subsystem, operational miscellaneous audio subsystem.

(2) Operational teletype communications subsystem: The teletype subsystems were configured to serve two prime functions: (a) the transmission and receipt of nonoperational traffic and (b) operational support.

(3) Television communications subsystem: This subsystem was configured in three sections: video inputs, central controls, and monitors. It performed the following functions: area surveillance, teletype presentation, status and hard-copy display, commercial TV display, and Goldstone 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 the operational traffic. The high-speed data subsystem provided a method of determining 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 telemetry processing station or the simulation data conversion center.

(5) Wideband communications subsystem: The DSN configured several wideband data circuits between the SFOF and the Goldstone Deep Space Communications Complex. These circuits were for operational traffic only. The wideband communications subsystem provided a method of patching external wideband data circuits to internal distribution circuits.

The DSN communications center was configured to interconnect the 96-kHz circuit to Goldstone (full duplex) and to several areas of the SFOF, including telemetry processing station/TV ground data handling system and the simulation data conversion center. In addition, the capability existed to interconnect the 6-MHz circuit to Goldstone (simplex) to the ground data handling area of the SFOF.

Interfaces. The DSN communications center has many operational interfaces consisting of various types and quantities of circuits with the following:

(1) NASCOM.

(2) User areas.

(3) Simulation data conversion center.

(4) Telemetry processing station.

(5) Data processing system.

(6) Television ground data handling system.

(7) Public information office.

Displays are provided for project use in each of the areas.

1. Operations area. Because of the construction of mission status board 1, only special time displays [countdown (up) clocks] will be available.

2. Flight Path Analysis Area. The displays in the flight path analysis area include:

(1) Maneuver board.

(2) Orbital and miss parameters board.

(3) Tracking data board.

(4) Trajectory display board.

(5) Chalk and/or bulletin boards.

3. Mission Support Area 1A. This is the location of the spacecraft performance analysis area. The displays in the spacecraft performance analysis area include:

(1) Spacecraft telemetry measurement display board (preformatted chalkboard).

(2) Chalk and/or bulletin boards.

4. Mission Support Area 1B. This is the location of the space science analysis area. The displays in the space science analysis area include:

(1) Television identification display board.

(2) Chalk and/or bulletin boards.

c. Space Flight Operations Facility. The SFOF, located at JPL, was the focal point of the DSN support of the *Surveyor V* Mission. All command, data processing, data analysis, communications, and support functions were controlled therein. The SFOF is a flexible facility in which areas and hardware can be configured to meet the needs of various projects. Figure 20 is a block diagram of the functional configuration of the SFOF.

Data processing system. The redesigned 7044 communications processor system shown in Fig. 21 will be used to support the *Surveyor V* Mission. Testing to qualify this system was continuous since the *Surveyor IV* Mission, and although no test was perfect, continuing progress was made until the system could be committed to support the flight. The final problems were with data slowdown in the 100-word/min SPAC teleprinters driven by the communications processor. A great deal of 7044R (the "R" is for *redesigned*) testing was done while sharing the computer with Mariner. During the mission, this mode was used only during lunar operations.

To ensure the continuous operation of SFOF from launch until touchdown, electrical power will be provided by the backup generators. After touchdown, the SFOF will switch back to commercial power (retaining the generators as a backup).

The operations control chief, J-OPS (ICS call designation for console operator), function has been incorporated into the sequence of events. This activity ceases 24 min after launch. The J-OPS group has participated in tests to qualify them for the launch phase.

The communications processor 7044 system has upgraded the capability of the 7044 program. However, the interfaces with the communications processor and operational interfaces as a result of the redesign have resulted in an overall degradation in confidence in the ability of the *Surveyor* Project to plan this mission. Some system constraints imposed by this system (i.e., format changes) are now difficult and spacecraft number changes now require days instead of hours.

1. Computer equipment. The computer equipment will be set up as follows:

(1) The W, X, and Y computer strings will be placed in the stand-alone condition.

(2) The extended memory switch on the 7044X and 7044Y will be placed in the 32K position.

Table 12 lists the computer equipment within the SFOF as of January 19, 1967.

Performance of data processing system operations and support personnel throughout the various segments of the premission phase [operational readiness tests (ORTs), data processing system checkout; and final count] reflected a proficient degree of capability; no outstanding personnel problems were encountered.

For the premission phase, the X and Y computer strings provided dual-mode, two-configuration support. Telemetry stations 1 and 2 and input/output (I/O) areas 5, 6, and 7 were also used to support this phase of the mission. Data for simulation and testing were provided from the simulation data conversion center.

Operational readiness tests were conducted with *Surveyor* on the X and Y computer strings to check out the "one-in" version of the *Surveyor* redesign system. This time was also used to familiarize operations personnel with the use of the system. Among the many problems encountered during this phase were software errors in the redesign system and lack of familiarity with the system by user and operational personnel. Some of these software problems remained with the system until touchdown of the spacecraft.

The telemetry processing station/simulation data conversion center maintenance started preparation for the *Surveyor V* Mission approximately 3 wk prior to the operational readiness test by scheduling extensive time for preventive maintenance. The 7044V computer also had preventive maintenance to ensure proper system operation. Preventive maintenance and checkout were also accomplished on both general-purpose stations and on all three PDP-7 computers in the telemetry processing station. Systems checkout was accomplished on all systems by the use of the test pattern generator program and the *Surveyor* program, using the PCM simulator as a source, and reading out data to the 7044. Maintenance personnel also checked out and adjusted all simulation data conversion center simulated equipment and equipment used by the *Surveyor* Project, including all Mark 200 brush recorders and the digital-to-analog system.

All simulation data conversion center and telemetry processing station systems and subsystems were operating properly at the beginning of the ORT.

Data systems maintenance ensured that an ample amount of operational spares were available, and that an adequate stock of operational supplies were available at SFOF stores.

Performance of the data processing system during the premission phase was adversely affected by numerous software problems. The problems in the *Surveyor* redesign system were evidenced by the large volume of discrepancy reports filed. This, when compared to other missions, pointed to the software deficiencies.

At 05:51 on September 5, 1967, the X and Y computer strings suffered recovery problems caused by an I/O problem in the 7094 on each string. Both 7094s appeared to receive I/O checks in their 7607 data channel. Software in the 7094s was unable to recover from the I/O checks and dropped communications with the 7044s. This problem occurred at the same time as the communications processor faulted. Preliminary investigation indicated that the communications processor fault and the X and Y string 7607 I/O check problem were coincidental. Software redesign engineers investigated the problem that caused these I/O checks.

A procedural interface problem occurred during the 7607 I/O check failures. The project data controller, in an attempt to bring the 7094s back up, found that the restart with SFOF "short deck" would not work. The 7094 operator was directed to use the "cold start" or "long deck" method to recover from the 7094 failure. Neither the data controller nor the 7094 operator informed the data chief of the "cold start" action. This method of starting the 7094 had resulted in the raw data pointers being reset to zero in that system. This resulted in the necessity for the data chief to reset the raw data pointers in the 7044s to complete the recovery action. Because the data chief was not informed of the "cold start," time was lost in getting the two strings operational. A procedure has been established to prevent this lack of communications from recurring.

At 15:44 on September 5, a paper tape read problem was encountered with PDP-7 No. 1 Station 1. This problem recurred at 07:10, September 6; at that time, PDP-7 No. 3 was changed to Station 1 configuration. This problem did not recur and the total delay of data was 10 min.

Disk problems were encountered on 7094Y at 01:15 on September 7, 1967. The Y string was taken, and a disk format check was run. The results of the format check indicated no disk problems. Later it was discovered that the project had called for the wrong ephemeris tape to be used. By 01:25:00 the Y string was operational. No problems other than continued recovery problems were encountered to alter support or processing capability of *Surveyor* until launch.

The seek and verify time was found to be slow on the 7094X. Rather than disassemble the disk, the data processing system went into the mission with the problem unsolved, as this would not affect the operation.

2. Input/output equipment. The I/O equipment consisted of:

(1) Message composer and status display.

(2) Administrative printer.

(3) 3070 bulk printer.

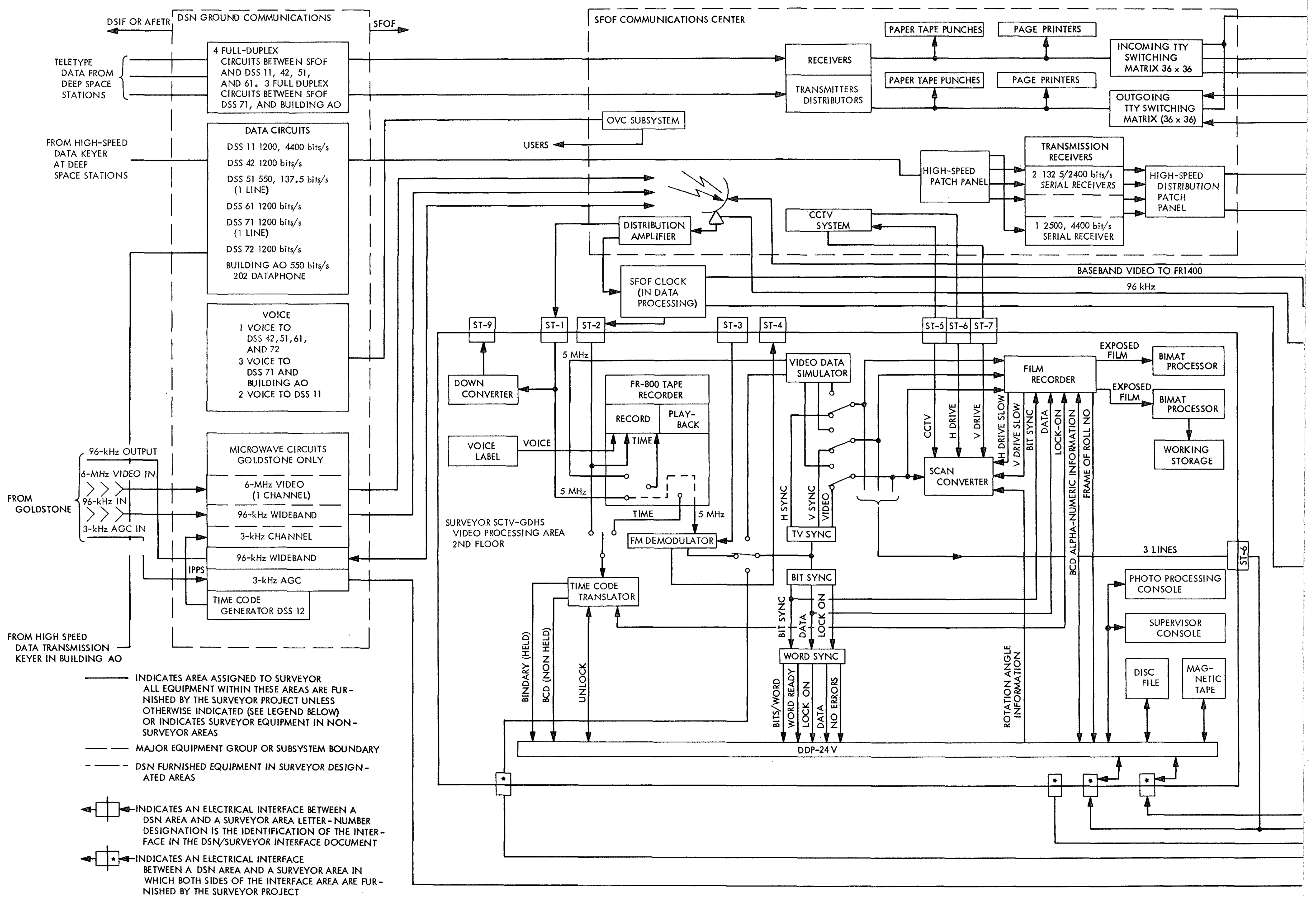
(4) 30 × 30-in. plotter.

(5) Card reader.

Table 13 shows the I/O equipment for various user areas.

3. Telemetry processing station equipment. Table 14 shows the telemetry processing station real-time operating equipment.

All of the area reconfigurations requested to support the alpha scattering experiment operations were completed. Some operational voice communications subsystem and electrical work remained to be completed in the TV ground data handling system area; however, all essential items were to be completed prior to the mission. All alpha scattering data were completed.


DSIF OR AFETR
DSN GROUND COMMUNICATIONS
SFOF
TELETYPE DATA FROM DEEP SPACE STATIONS
4 FULL-DUPLEX CIRCUITS BETWEEN SFOF AND DSS 11, 42, 51, AND 61. 3 FULL DUPLEX CIRCUITS BETWEEN SFOF DSS 71, AND BUILDING AO
FROM HIGH-SPEED DATA KEYER AT DEEP SPACE STATIONS
DATA CIRCUITS
DSS 11 1200, 4400 bits/s
DSS 42 1200 bits/s
DSS 51 550, 137.5 bits/s (1 LINE)
DSS 61 1200 bits/s
DSS 71 1200 bits/s (1 LINE)
DSS 72 1200 bits/s
BUILDING AO 550 bits/s 202 DATAPHONE
VOICE
1 VOICE TO DSS 42, 51, 61, AND 72
3 VOICE TO DSS 71 AND BUILDING AO
2 VOICE TO DSS 11
FROM GOLDSTONE
96-kHz OUTPUT
6-MHz VIDEO IN
96-kHz IN
3-kHz AGC IN
MICROWAVE CIRCUITS GOLDSTONE ONLY
6-MHz VIDEO (1 CHANNEL)
96-kHz WIDEBAND
3-kHz CHANNEL
96-kHz WIDEBAND
IPPS
3-kHz AGC
TIME CODE GENERATOR DSS 12
FROM HIGH SPEED DATA TRANSMISSION KEYER IN BUILDING AO
SFOF COMMUNICATIONS CENTER
OVC SUBSYSTEM
USERS
RECEIVERS
TRANSMITTERS DISTRIBUTORS
PAPER TAPE PUNCHES
PAGE PRINTERS
PAPER TAPE PUNCHES
PAGE PRINTERS
INCOMING TTY SWITCHING MATRIX 36 x 36
OUTGOING TTY SWITCHING MATRIX (36 x 36)
TRANSMISSION RECEIVERS
HIGH-SPEED PATCH PANEL
2 132 5/2400 bits/s SERIAL RECEIVERS
1 2500, 4400 bit/s SERIAL RECEIVER
HIGH-SPEED DISTRIBUTION PATCH PANEL
CCTV SYSTEM
DISTRIBUTION AMPLIFIER
SFOF CLOCK (IN DATA PROCESSING)
BASEBAND VIDEO TO FR1400
96 kHz
ST-9
ST-1
ST-2
ST-3
ST-4
ST-5
ST-6
ST-7
5 MHz
DOWN CONVERTER
VOICE LABEL
VOICE
FR-800 TAPE RECORDER
RECORD
PLAY-BACK
TIME
5 MHz
TIME
5 MHz
FM DEMODULATOR
VIDEO DATA SIMULATOR
H SYNC
V SYNC
VIDEO
TV SYNC
CCTV
H DRIVE
V DRIVE
SCAN CONVERTER
H DRIVE SLOW
V DRIVE SLOW
BIT SYNC
DATA
LOCK-ON
BCD ALPHA-NUMERIC INFORMATION
FRAME OF ROLL NO
FILM RECORDER
EXPOSED FILM
BIMAT PROCESSOR
EXPOSED FILM
BIMAT PROCESSOR
WORKING STORAGE
3 LINES
ST-6
SURVEYOR SCTV-GDHS VIDEO PROCESSING AREA 2ND FLOOR
TIME CODE TRANSLATOR
BIT SYNC
BIT SYNC
DATA
LOCK ON
WORD SYNC
BINDARY (HELD)
BCD (NON HELD)
UNLOCK
BITS/WORD
WORD READY
LOCK ON
DATA
NO ERRORS
ROTATION ANGLE INFORMATION
PHOTO PROCESSING CONSOLE
SUPERVISOR CONSOLE
DISC FILE
MAG-NETIC TAPE
DDP-24 V
INDICATES AREA ASSIGNED TO SURVEYOR ALL EQUIPMENT WITHIN THESE AREAS ARE FURNISHED BY THE SURVEYOR PROJECT UNLESS OTHERWISE INDICATED (SEE LEGEND BELOW) OR INDICATES SURVEYOR EQUIPMENT IN NON-SURVEYOR AREAS
MAJOR EQUIPMENT GROUP OR SUBSYSTEM BOUNDARY
DSN FURNISHED EQUIPMENT IN SURVEYOR DESIGNATED AREAS
INDICATES AN ELECTRICAL INTERFACE BETWEEN A DSN AREA AND A SURVEYOR AREA LETTER-NUMBER DESIGNATION IS THE IDENTIFICATION OF THE INTERFACE IN THE DSN/SURVEYOR INTERFACE DOCUMENT
INDICATES AN ELECTRICAL INTERFACE BETWEEN A DSN AREA AND A SURVEYOR AREA IN WHICH BOTH SIDES OF THE INTERFACE AREA ARE FURNISHED BY THE SURVEYOR PROJECT

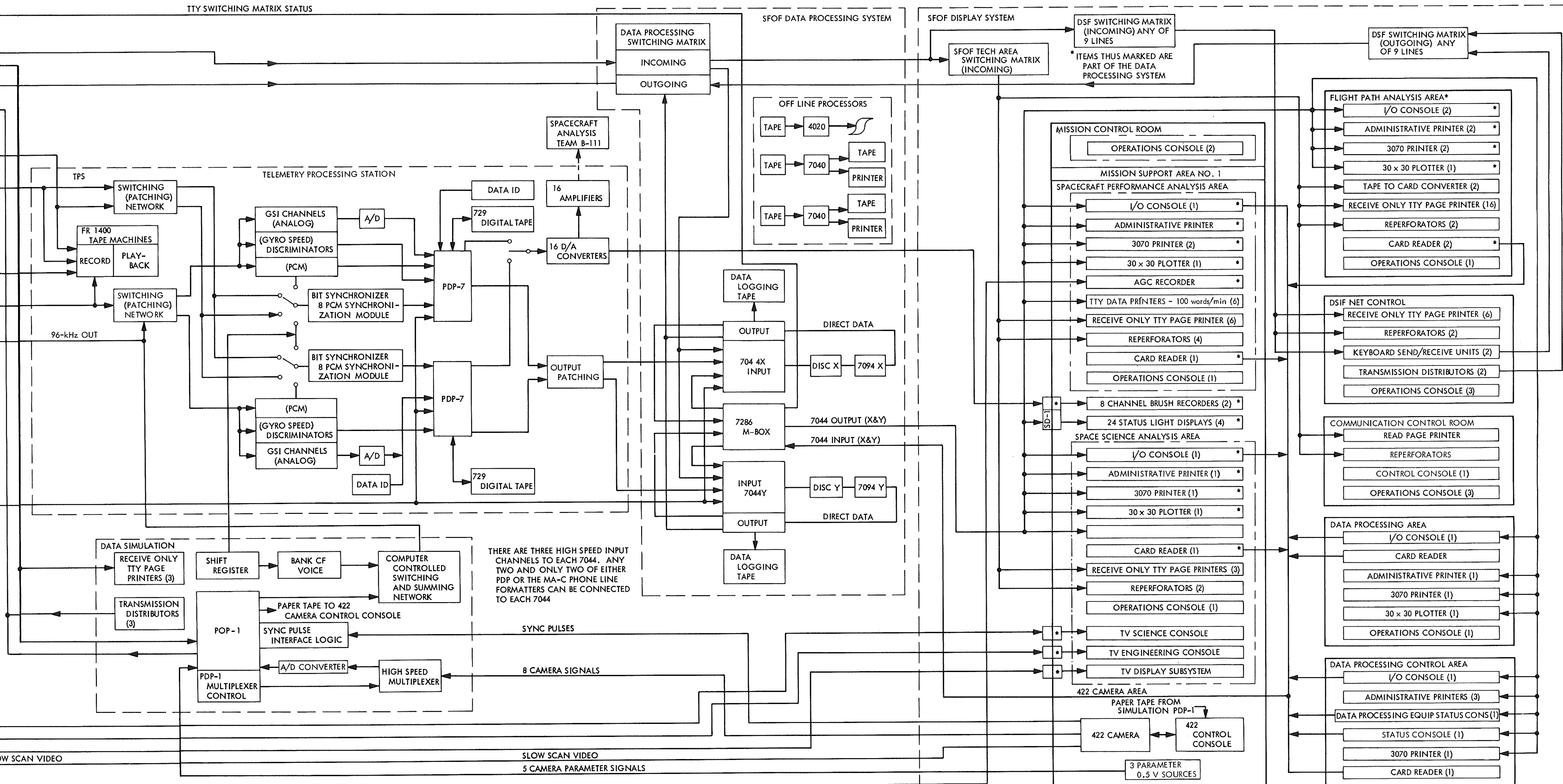


Fig. 20. Space Flight Operations Facility functional block diagram

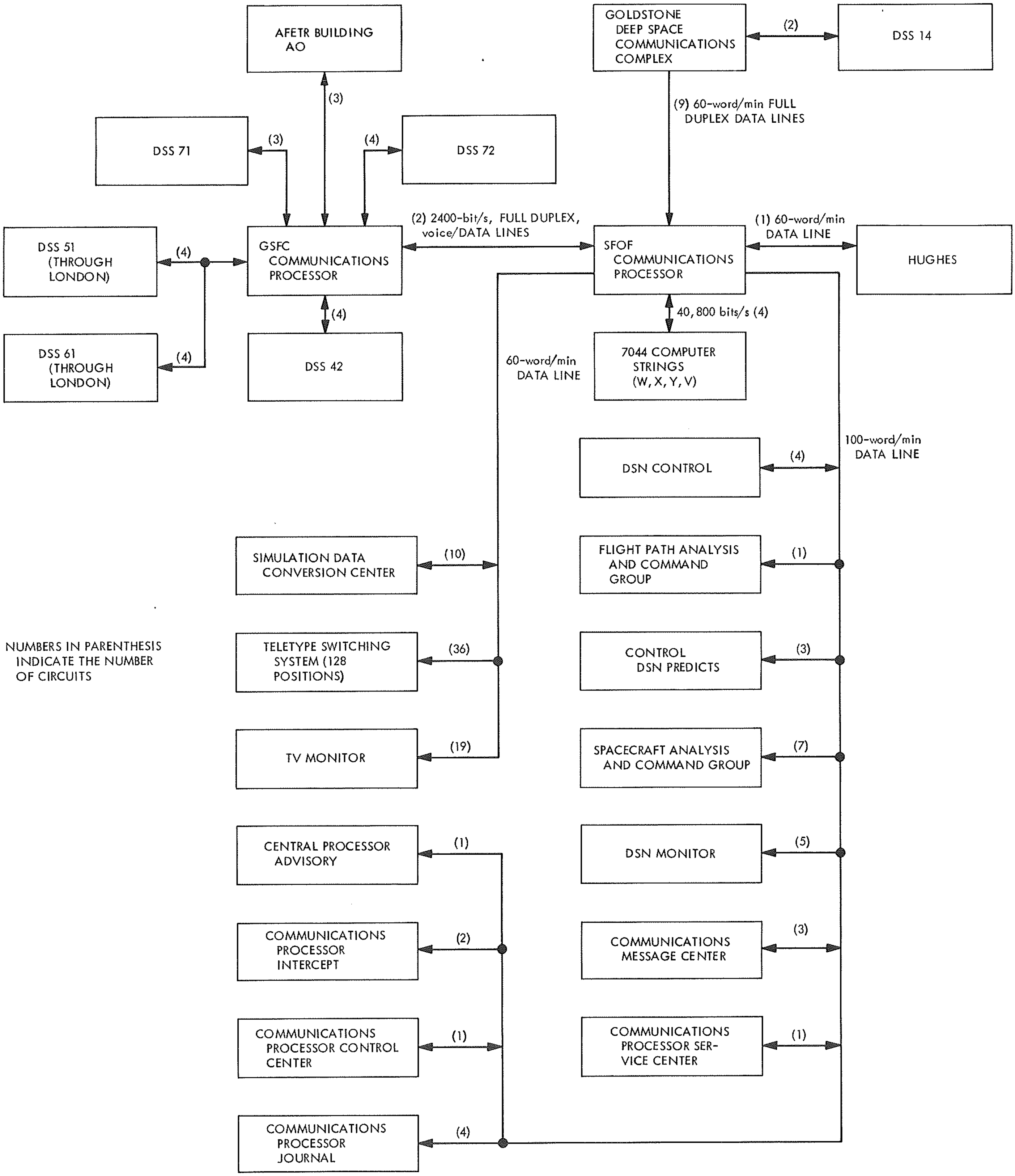


Fig. 21. Redesigned 7044 communications processing system

Table 12. Computer equipment at the SFOF (January 19, 1967)

Computer string	System	Model No.	Description	Quantity
X	7040	729 VI	Tape drives	2
		1014	Inquiry unit	1
		1301 II	Disk file	2
		1402 II	Reader punch	1
		1403	Printer	2
		1414 IV	I/O synchronizer	1
		1414 VII	I/O synchronizer	2
		1414 VIII	I/O synchronizer	1
		7106 IV	Processing unit	1
		7631 II	File control	1
X	7044	729 VI	Tape drives	8
		1301 II	Disk file	2
		1402 II	Reader punch	1
		1403	Printer	1
		1414 IV	I/O synchronizer	1
		1414 VII	I/O synchronizer	1
		7094	Data channel	1
		7107 III	Processing unit	1
		7257	Core storage	1
		7288	Data comm center	1
		7320	Drum	1
		7631 II	File control	1
		7631 IV	File control	1
X	7094	711	Card reader	1
		716	Printer	1
		729 VI	Tape drives	16
		4611	Tape switch	2
X	7094	7109	Arithmetic unit	1
		7111	Instruction processor	1
		7151	Console	1
		7302 III	Core storage	1
		7606 II	Multiplexer	1
		7607 IV	Data channel	2
		7608	Power converter	1
		7617	Data channel console	2
		7618	Power control	1
		7904	Data channel	1
		7904 II	Data channel	1
		7909	Data channel	1
Y	7040	729 VI	Tape drives	2
		1014	Inquiry unit	1
		1301 II	Disk file	2
		1402 II	Reader punch	1
Y (contd)		1403	Printer	2
		1414 IV	I/O synchronizer	1
		1414 VII	I/O synchronizer	2
		1414 VIII	I/O synchronizer	1
		7106 IV	Processing unit	1
		7631 II	File control	1
Y	7044	729 VI	Tape drives	8
		1301 II	Disk file	2
		1402 II	Reader punch	1
		1403	Printer	1
		1414 IV	I/O synchronizer	1
Y		1414 VII	I/O synchronizer	1
		7094	Data channel	1
Y	7044	7107 III	Processing unit	1
		7257	Core storage	1
		7288	Data comm center	1
		7320	Drum	1
		7631 II	File control	1
		7631 IV	File control	1
Y	7094	711	Card reader	1
		716	Printer	1
		729 VI	Tape drives	16
		4611	Tape switch	2
		7109	Arithmetic unit	1
		7111	Instruction processor	1
		7151	Console	1
		7302 III	Core storage	1
		7606 II	Multiplexer	1
		7607 IV	Data channel	2
		7608	Power converter	1
		7617	Data channel console	2
		7618	Power control	1
		7904	Data channel	1
		7904 II	Data channel	1
		7909	Data channel	1
Not applicable	7242	—	M-box	
		4612	Switch control	1
		4613	Inquiry multiplexer	1
		4614	Card reader multiplexer	1
		4615	Printer plotter	3
		4616	Status display multiplexer	1

Table 13. Space Flight Operations Facility I/O equipment

Description	Sub-channel	Unit select	Address	Quantity
I/O consoles	14	—	5, 7	2
Status displays	40	5, 7	1-4	2
Administrative printers	29	—	5, 7	2
Card readers	15	5, 7	—	2
3070 printers	20/22	—	—	2
30 × 30 plotter	32	—	—	1
Keypunches	—	—	—	2
I/O console	14	—	6	1
Status display	40	6	1-4	1
Administrative printer	29	—	6	1
Card reader	15	6	—	1
3070 printers	23/24	—	—	2
30 × 30 plotter	33	—	—	1
24-light status displays	40	6	5	5
8-Channel stripchart recorders	(Driven from the telemetry processing station)			2
Automatic gain control/static phase error display	(Driven from communications)			1
Keypunch	—	—	—	1
Status display	40	4	1-4	1
3070 printer	21	—	—	1
Teletype status console	—	—	—	1
3070 bulk printer	19	—	—	1
Administrative printers	29	Multiplexed		3
Input message composer and status display	14	Multiplexed		1
Equipment switching control	40	Multiplexed		1
Card reader	—	—	—	1
Insurance mode switching console	15	Multiplexed		1

Table 14. Telemetry processing station equipment

Model	Description	Quantity
28	Teleprinter	1
BERPE	Paper tape punch	2
—	EMR discriminators	—
3000	Analog-to-digital converters	2
—	Time code translator	2
—	Time code generator	1
219	PCM signal conditioner	2
—	PCM decommutator	2
4100	Line printer	2
3310	Line printer	1
PDP-4	Computer	1
PDP-7	Computer	1
—	Digital-to-analog converter	1
—	Brush recorders	3
FR-1400	Ampex tape decks	3
729 V	IBM tape decks	6

4. Alpha scattering experiment. The alpha scattering device was carried aboard *Surveyors V, VI,* and *VII*. The device (shown in Fig. 22) consists of an instrumented package to be placed on the lunar surface. The package contains sources of alpha particles aimed at the lunar soil and several alpha and proton detectors to measure the energy with which these respective particles are reflected. From this energy data, scientists hope to gain some insight into the atomic structure of the lunar top soil.

The on-board electronics package encodes these energy measurements into a 9-bit serial code word. This serial code consists of one "word sync bit" (always a binary *one*), seven data bits, and one parity bit (chosen so that the word, including sync bit, has odd parity). The 2200-bit/s alpha data bit stream is modulated onto a 70-kHz subcarrier; the 550-bit/s proton data bit stream will use a 5.4-kHz subcarrier. These two subcarriers are summed together with an existing engineering telemetry subcarrier, and the composite signal is then phase-modulated onto the spacecraft carrier for transmission to earth. (Mode 4 data were used during the alpha scattering operations because they contained certain engineering measurements from the alpha scattering package.)

It was planned to operate the experiment for a total of 40–60 h; however, the time could be conveniently broken into 3–5-h segments. The spacecraft was to be monitored by a Goldstone Deep Space Station for most of the first 10 h, with the remaining time distributed between DSSs 42 and 61. Alpha scattering experiment operations were to be completed within a few earth days after lunar landing.

Alpha scattering data would normally be sent to the SFOF using the alpha scattering teletype circuit (although this was an operational decision). During this period, tracking data would not be sent to the SFOF via teletype, but would be returned with the *Surveyor* data package.

A small possibility existed that the alpha scattering device would be operated during transit (before lunar landing) for calibration purposes. The station would not

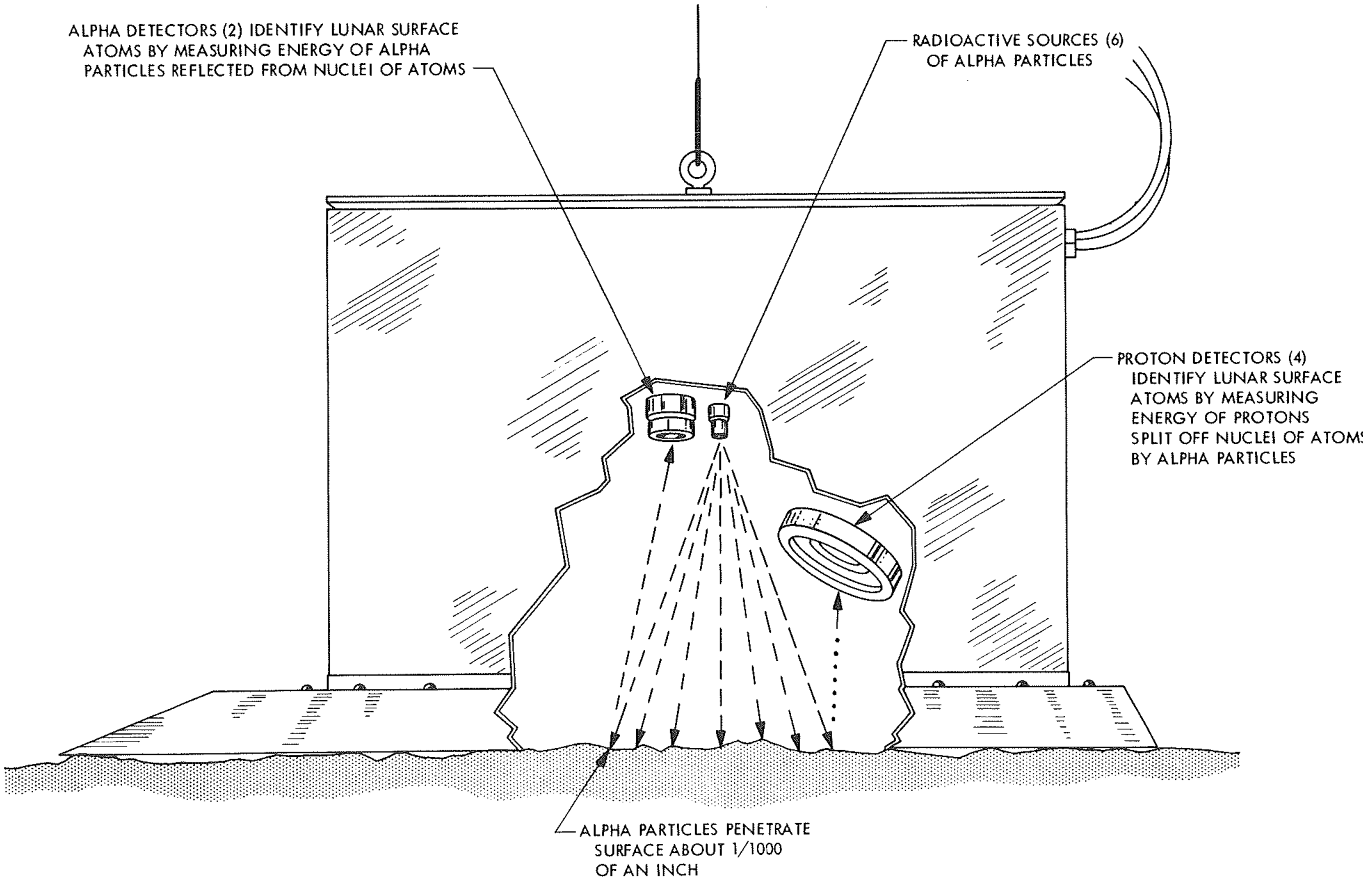


Fig. 22. Alpha scattering instrument

be configured to send the data in real-time to the SFOF, but the spectral accummulations would then be recorded on site.

a. Support and participation by the DSN. *Surveyor V* was the first spacecraft to carry the alpha scattering experiment, and preflight preparations have required DSN support and participation in the following areas:

(1) Deep Space Instrumentation Facility:

(a) CDC modifications and testing.

(b) Use of backup telemetry and command processor computer to process alpha data simultaneously with spacecraft telemetry processing in the prime computer.

(2) Space Flight Operations Facility:

(a) 7094 program checkout.

(b) Space sciences analysis and command group area modifications for alpha scattering operations.

(c) Monitor system support with tape-to-card converters.

(3) Simulation:

(a) Real-time system for transmission of alpha data from the JPL Lake Street annex to SFOF and Goldstone.

(b) ASI 6050 computer program to simulate a Deep Space Station for in-house training in SFOF.

(c) Simulation tapes for use by overseas stations.

(4) Testing:

(a) E-tests for equipment performance and interface testing.

(b) On-site alpha scattering linkups to verify the on-site alpha scattering program.

(c) B-tests to verify that hardware and software systems to support alpha scattering are operational.

(d) Lunar training tests to provide training for all alpha scattering operational personnel.

b. Operational configuration. The operational configuration for receiving, recording, processing, and retransmitting alpha scattering data is shown in Fig. 23. The *Surveyor* spacecraft signal is received and phase detected; resultant composite telemetry is then sent to the CDC and the FR-1400 for recording. These data paths are the same as those for earlier *Surveyor* missions.

Within the CDC, two new data paths have been implemented, one for the alpha data and one for the proton data. Each data path includes a subcarrier discriminator and bit synchronizer. These signals are then relayed into the backup telemetry and command processor via the patch panel and four unused interrupt lines. Residing within the backup telemetry and command processor is the on-site alpha scattering program. The program is the only software within this telemetry and command processor during alpha scattering operations. If either telemetry and command processor should fail during operations, a real-time operational decision would be made as to use of the remaining telemetry and command processor unit.

The on-site alpha scattering program decommutates the two serial bit streams by searching and locking to the repetitive sync (1) bits in the data. The parity is then checked on the data word, and identification of the type of data is made: (1) alpha data with correct parity, (2) proton data with correct parity, (3) alpha data with incorrect parity, or (4) proton data with incorrect parity. This allows determination of which of four blocks of storage is to be affected. The sample then causes one of 128 storage locations within this block to be incremented. (Seven data bits coming from the *Surveyor* spacecraft can represent 128 possible energy levels.) Thus, the storage locations indicate the number of times, within an accumulation period, that particles of a certain energy level hit the sensors. For example, a proton hit was encoded as energy at level 102. Under the supposition that the parity was good, the telemetry and command processor would then increment, by one count, channel 102 (a storage location) within the "good parity proton" section.

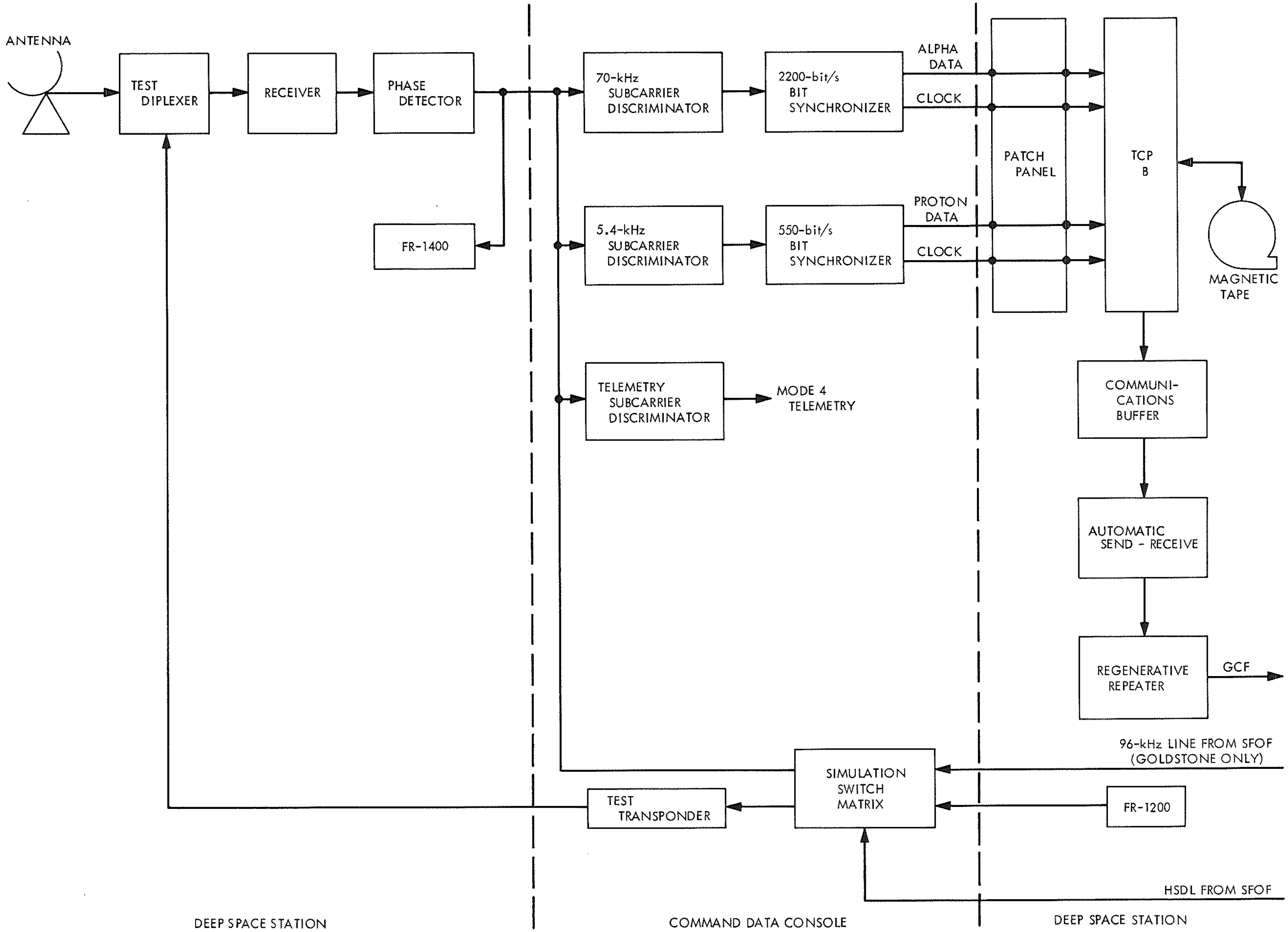
Upon operational command typed into the telemetry and command processor, the processor begins a new accumulation, dumps the old spectral totals onto magnetic tape, and initiates a teletype transmission of the old totals through the communications buffer to the SFOF. At a Deep Space Station, an automatic send–receive machine is placed in this outgoing teletype line. This machine is protected by a regenerative repeater—a relay that ensures line current on the machine regardless of the condition of the GCF. The automatic send–receive instrument produces a teletype page print and punched paper tape. Total send time for one spectral accumulation is about 10 min. Accumulation times were expected to average about 30 min.

If the GCF line fails during transmission, the teletype punched paper tape can be replayed, or the telemetry and command processor operator can command a readout of the old spectral totals from the magnetic tape (simultaneously with the accumulation of a new spectrum).

At the SFOF, these data are input to the data processing system, displayed on teletype page printers, and punched on teletype paper tape (a DSN monitor function). The teletype format is such that the spectral totals are visually readable, and can be used for real-time decisions. The 7044 logs the incoming data and places them on an area of disk reserved exclusively for alpha scattering data. The user programs on the 7094 high-speed computer pick up these data from the disk, run calibration checks, correct for known errors, and compare the received spectra to the spectra of known elements. The user program outputs consist of SC 3070 prints, F80 analog plots, and 35-mm film from the SC 4020 magnetic tape for prints on the 7040, and various program alarm messages routed through the 7044 computer to administrative printers.

The punched paper tape of the incoming teletype data can be used, if necessary, to punch cards containing the alpha scattering data using the tape-to-card punches in the DSN monitor area. These cards can then be entered directly into the data processing system. This mode of operation will only be used if the project scientist sees a need to manually edit the data entering the computers.

As with the previous *Surveyor* flights, composite telemetry [mixed subcarrier oscillators (SCOs)] is taken from the DSS 11 receiver and sent to the SFOF over the 96-kHz line for recording in the telemetry processing station. During alpha scattering operations, the recording speed of the FR-1400 recorders must be increased to 7½ in./s to accommodate the 70-kHz subcarrier. If needed, this FR-1400 magnetic tape can be duplicated, and the copy given to the project scientist for analysis of the raw data. This analysis would take place at Hughes



TCP = TELEMETRY AND COMMAND PROCESSOR

GCF = GROUND COMMUNICATIONS FACILITY

SFOF = SPACE FLIGHT OPERATIONS FACILITY

HSDL = HIGH-SPEED DATA LINE

Fig. 23. On-site alpha scattering data processing system

Aircraft Corp. in El Segundo, Calif. Therefore, it is considered an offline operation.

c. Data plan. The following forms of data are produced at each Deep Space Station and are returned each day with the *Surveyor* data package:

(1) Teletype punched paper tape.

(2) Handwritten log of engineering data (written by the CDC operator and used by the telemetry and command processor operator to affix engineering data to each accumulation).

(3) FR-1400 analog magnetic tape.

The following forms of data are produced at each Deep Space Station, and are kept on site until the end of the first lunar day, at which time they are sent to JPL document control:

(1) Digital telemetry and command processor magnetic tape.[4]

(2) Teletype page print.

(3) Telemetry and command processor typewriter output.

It is intended that these original data will be released directly to the project scientist in the same manner that video film recordings are released.

d. Alpha scattering simulation system. The alpha scattering simulation system, shown in Fig. 24, uses an actual alpha scatter device located within a vacuum chamber at the Lake Street annex of JPL. The two bit streams (alpha and proton) are sent to the simulation data conversion center via dataphone lines, with Bell model 202D data sets (modems) at each end. Because of the high phase jitter encountered with the use of the modems, bit synchronizers are needed to restore a stable time reference.

For "in-house" Space Flight Operations Facility simulation, these bit streams are routed to the 6050 computer, which performs the same functions as the telemetry and command processor at a Deep Space Station. The teletype output message is identical to the above, and can be used for operations training or experimental and program checkout.

[4]Only one tape per station will probably be produced per mission.

For DSN-wide simulation, the bit streams from the bit synchronizers are modulated onto their respective subcarriers, and either recorded on an FR-600 magnetic tape recorder or transmitted to DSS 11 in real-time via the 96-kHz line.

For tape verification, a return path to the Lake Street annex verification equipment is desirable. Since the normal mode for verifying recorded engineering data is to send the composite telemetry to the telemetry processing station for discrimination, this same path will be used for verifying alpha scatter data. The discriminated data, however, will be returned to the simulation data conversion center for transmission to the Lake Street annex. As the anticipated usage of this return path is very light, it will be possible to transport the bit synchronizers from the simulation data conversion center to Lake Street for this verification activity.

For the Deep Space Instrumentation Facility simulation, the composite telemetry signal is taken from the 96-kHz line (DSS 11 only) or from the playback of simulation tapes on the FR-1200 magnetic tape recorder. It is also possible for the CDC to receive engineering telemetry over the high-speed data line, and mix these data with the alpha and proton data reproduced from tape. The simulation signal is input to the CDC system tester to be used either as simulated phase detector output or to modulate the test transponder to exercise the entire receiver subsystem. The data then follow the normal operational path through the CDC, telemetry and command processor, communication lines, and the SFOF.

e. Simulation interfaces. At the Lake Street annex, the two bit streams (alpha and proton) pass from the alpha scattering device to the 202D modems at 2200 and 550 bits/s, respectively. The modem thresholds are at ± 3 V; the signals are a logical *one* at -4 ± 0.5 V and a logical *zero* at $+4 \pm 0.5$ V.

The simulation data conversion center modem/tape/96-kHz line interface data are routed from the modems (approximately ± 8 V) to bit synchronizers, then modulated on to the subcarriers at 70 and 5.4 kHz. These signals are mixed with a telemetry subcarrier and direct-recorded at 15 in./s on an FR-600 tape recorder. This composite telemetry can also be put on the 96-kHz line to Goldstone for real-time simulation. With an engineering subcarrier of 7.35 kHz, the actual spacecraft subcarrier modulation indexes are 1.4 and 9.935 for the 70-, 5.4-, and 7.35-kHz subcarriers, respectively (for

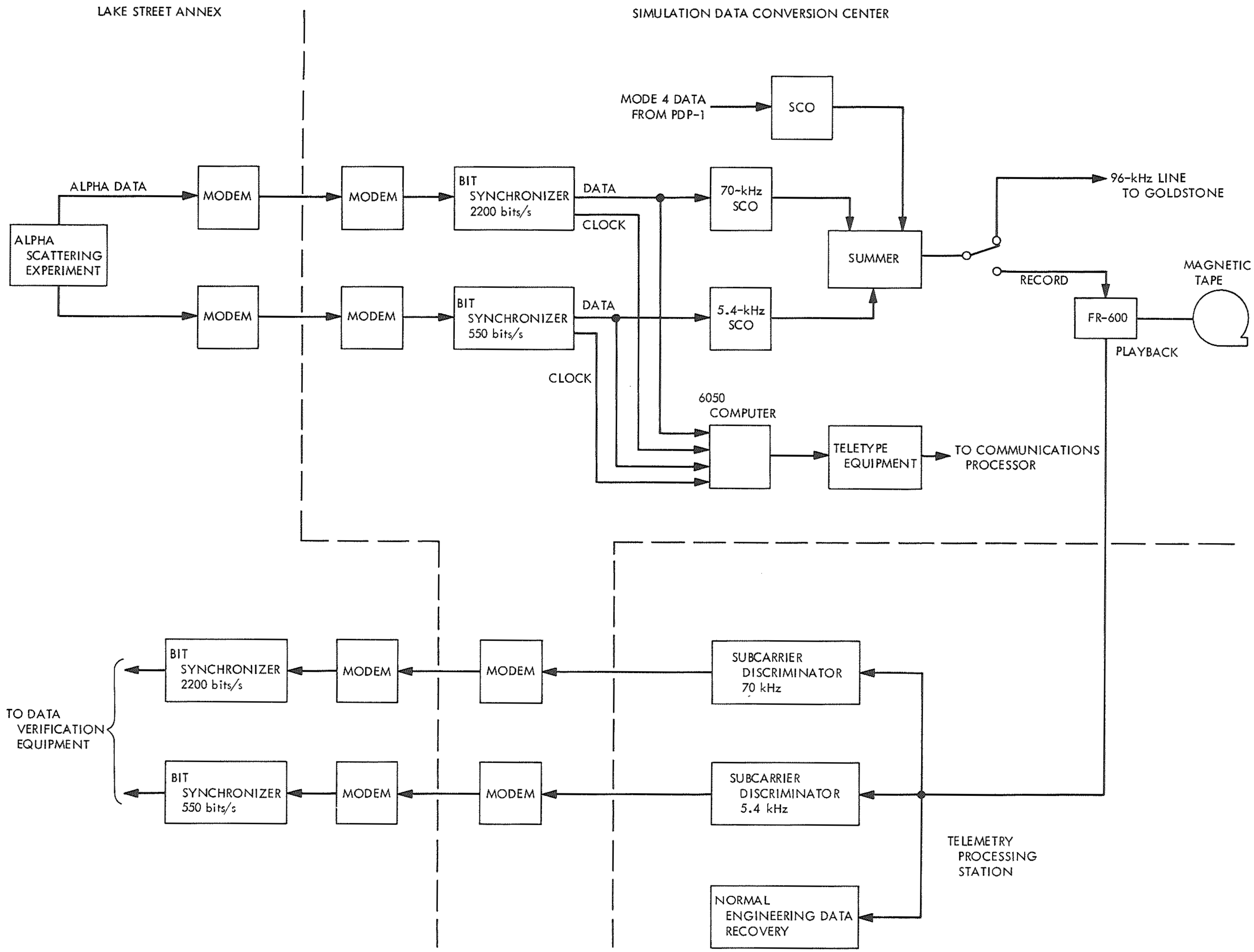


Fig. 24. Alpha scattering simulation system

other engineering subcarriers, the ratios would be somewhat different). The *relative* subcarrier voltage levels must be recorded in these same ratios. The absolute subcarrier voltages are adjusted to give a good tape recording.

An existing interface is used for sending simulation data conversion center PDP-1 computer engineering data via high-speed data lines to the sites in real-time.

An existing interface would be used to send the composite telemetry from the simulation data conversion center to the telemetry processing station during tape verification.

The discriminated alpha and proton bit streams will be returned to the simulation data conversion center from the telemetry processing station via existing trunks.

The PCM bit stream returned from the telemetry processing station during tape verification will be input to the 202D modems after any necessary inversion and/or amplification to greater than ±3 V.

The simulation data conversion center data and clock 202D modem outputs from both bit synchronizers will also be available to the 6050 computer.

The simulation data conversion center teletype output from the 6050 computer will be displayed on a page printer, and shall be sent to the communications processors as if from a Deep Space Station.

The simulation tape (15 in./s) is played on an FR-1200 tape recorder. The composite telemetry output from this recorder or from the 96-kHz line (from Goldstone only), and engineering telemetry (PCM) from the high-speed data line, can be input to the CDC, where it can be sent through the test transponder to enter the Deep Space Station as a simulated RF spacecraft signal. A description of the telemetry signal is contained in Table 15.

The output of the Deep Space Instrumentation Facility CDC test transponder to the receiver subsystem is the same as in previous *Surveyor* missions.

Table 15. Simulation tape telemetry characteristics

Signal	Modulation index	Rate, bits/s	Subcarrier oscillator		Presumming amplifier signal level, V rms
			Center frequency,[a] kHz	Deviation (±7.5 %), kHz	
1. Alpha	1.4	2200	70	±5.25	0.99
2. Proton	0.6	550	5.4	±0.405	0.424
3a. Mode 4	0.3	550	3.9	—	0.212
3b. Mode 4	0.94	1100	7.35	—	0.660

[a]In all cases, a downward shift of the subcarrier indicates a logical one.

B. Tests

To ensure the success of the *Surveyor V* Mission, a large amount of testing had to be accomplished. Space limits the ability to discuss at length all of the tests performed; however, this subsection will provide a basic knowledge of the major testing effort in support of *Surveyor*. The classes of tests performed are discussed below.

Class A: Facility internal tests. These tests were scheduled and conducted by each station on an individual basis. The standard sequence of events were used by the stations as countdown exercises. There were two phases of class A tests; one phase prepared the station for class B tests and the other for class C tests. Both test phases developed the ability of station personnel to use the proper procedures and hardware within a given time constraint. All prime stations completed sequences of class A tests for practice, station countdown, and training of personnel.

Class B: Functional compatibility tests. These tests were designed to ensure that the ground-based facilities were capable of processing telemetry data (and video data at DSS 11) as received from the spacecraft. Command capability was verified in all configurations and modes of operation. The sequence of events was incorporated into this series. Class B tests were not conducted in real-time, and it was not necessary to rigidly adhere 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 by the SFOF was required. (Class B tests were conducted in conjunction with DSS 61 only.)

Class C: Operational tests. The primary objective of these tests was to ensure that all support systems and facilities, including technical and operational personnel, were capable of totally supporting the *Surveyor V* Mission. These tests used the full complement of personnel actually required for *Surveyor* flight operations. Heavy emphasis was placed upon nonstandard operational procedures and the handling, processing, and interpretation of a full range of data under normal and degraded conditions.

Compatibility tests. These tests were run between the test spacecraft and the prime Deep Space Stations, the Deep Space Communication Complexes (each composed of several Deep Space Stations), the CDC, and the SFOF to establish mutual compatibility between all of these elements of the network. They included RF tests, command tests, and telemetry tests.

Training tests. Deep Space Station backup and stations under engineering cognizance conducted training tests for the operator crews. The T-21 (test model) spacecraft was used for space science analysis and command group/spacecraft performance analysis and command group lunar-sequence training and as a data source for class B and C tests with DSS 11 only.

Surveyor on-site computer program integration tests. These tests were designed to prove the on-site computer program and to verify data that could be transmitted from a Deep Space Station and processed there. The software tests were run on a regular basis at each prime station. These tests were concluded with a checkout of the final version of the on-site computer program.

1. Air Force Eastern Test Range. The testing of facilities as regularly used as those of the AFETR/GSFC in support of *Surveyor V* is so routine as to require little comment. The following information is to provide a general knowledge of the AFETR/GSFC prelaunch status for *Surveyor V* Mission support.

a. Compatibility and verification tests. The Grand Canary/Carnarvon/RTCS data handling test to verify the digital demodulation program at GSFC was successfully conducted on August 16, 1967. (Data-flow tests to determine the feasibility of transmitting 800-bit/s *Centaur* guidance data from Bermuda and Grand Canary to building AE were also conducted.)

b. Operational readiness tests. The objectives of the ORTs were to exercise the total Space Flight Operations System in support of *Surveyor V* Mission activities before launch and during significant phases of the mission. The emphasis was on integrating all elements of the Space Flight Operations System and exercising as many interfaces as possible among the interacting elements. This was a final dress rehearsal for the mission, and was intended to verify system flight readiness.

Operational readiness test 1. Test 1 was conducted on August 22, 1967, and marked support of the AFETR and MSFN only. Good overall results were obtained.

1. Telemetry. Propagation problems from Cape Kennedy and Ascension in the minus and plus counts resulted in only partially usable data. The test was run with a $T = 0$ of 17:00 GMT. There was no checkout with the *Sword Knot* during the minus count because of a Rixon problem. However, the *Sword Knot* provided good data during the plus count.

The Antigua data were inverted; analysis of the test indicated a change to operational setup at KSC. There was no impact on the launch setup.

The exercise of the telemetry coordination network usage between KSC, building AO, and DSS 71 was very good.

Grand Canary successfully transmitted vehicle telemetry data to building AE. The guidance data retransmission was not attempted during this test.

2. Metric. Grand Canary simulated data did not provide a solution consistent with the test conditions. Tananarive simulated data had a bias in ranging. The B computer at the RTCS failed at approximately $T + 60$ min. Computed data were delayed about 25 min. The computer was back on line at $T + 140$ min. The GSFC did not deliver rise minus 5 min look angles to Grand Canary.

Centaur guidance data, transmitted from Antigua to the central information facility and provided to the RTCS for guidance data orbit computations, were exercised successfully.

3. Problems and solutions. The simulation data from Grand Canary and Tananarive were corrected. The problem with GSFC computer was corrected to ensure that the look angles prior to rise would be produced for Grand Canary.

Operational readiness test 2. This ORT was project sponsored, and was the final test conducted prior to launch. The test simulation was for a launch azimuth of 80.632 deg at 06:21:09 on September 7, 1967. Although this was no longer a possible launch azimuth (the first day of the launch period had been deleted), it was considered a suitable simulation condition.

For this azimuth, the AFETR stations at Antigua and Ascension would not have view for spacecraft and C-band data, so their participation was deleted. In the first ORT, the ability of those station's to retransmit spacecraft telemetry had been satisfactorily demonstrated.

The same launch azimuth was simulated in ORT 1. The main items unresolved from this test were poor metric data sent from Grand Canary and Tananarive. In addition, the GSFC computed look angles, scheduled for transmission at 5 min before Grand Canary rise, had not been demonstrated.

1. Telemetry. Checkout of the AFETR telemetry stations with building AO and DSS 71, which was to start at $T - 300$ min, was extremely slow getting underway, and it was not until $T - 175$ min that the checkout began in earnest. There was a problem with checkout of the data modem lines between KSC and DSS 71. No trouble was found, and the checkout continued.

Concurrent with this effort, KSC was setting up with the participating downrange stations; namely, RISs *Coastal Crusader, Sword Knot,* and *Twin Falls,* and Pretoria and Grand Bahama. This checkout proceeded rapidly, hampered only by HF propogation, which invalidated portions of the data.

By $T = 0$, the only station not satisfactorily checked out was the RIS *Twin Falls.* The problem with the *Twin Falls* data seemed to be repetitive in nature (losing sync). The Rixon equipment was investigated, but by $T = 0$ no satisfactory checkout had been accomplished with the ship. The retransmission of spacecraft data from AFETR was good except for the data from the *Twin Falls.* A post-test checkout revealed that a secondary route through Antigua, not available during the test, provided good data.

2. Metric. The checkout of the metric data circuit progressed satisfactorily and on schedule. Tananarive did not provide a static point message.

The updated inputs for the AFETR prediction data were received from the flight path analysis and command group in a timely manner by voice, but the teletype confirmations were slow.

The $T - 40$ min report arrived at $T - 11$ min, and the $T - 20$ min report was received at $T - 7$ min, 30 s. In a launch count, the AFETR, having received the inputs this late, would have completed predicts on a best-obtainable basis.

At $T - 90$ min, the PDP-1 at the SFOF was to transmit simulated spacecraft data to building AO for use by the building AO system test equipment assembly and retransmission to the SFOF, via building AO and DSS 71, to simulate the spacecraft countdown. The receive line of the high-speed data line from Pasadena to building AO was open between building AO and the AFETR XY building. This was corrected at $T - 71$ min by patching to a spare line.

The plus count appeared normal, until the SFOF reported that the liftoff message, parking-orbit message, theoretical transfer orbit, and interrange vector were not received after they had been transmitted by building AO at the proper time.

After some false starts, the problem was attributed to queuing in the communications processor at JPL. The message from building AO carried an identification of 23 or 24. It was found that using an identification of 20 cleared them out of the processor faster.

Using Grand Canary simulated data produced a pre-retromaneuver transfer orbit that was incorrect. To create the illusion of what would happen in similar circumstances during a launch, the requirements for pre-retromaneuver transfer-orbit predicts, interrange vector, moon map, and I-matrix were also deleted.

A report from J-Ops (ICS call designation) that building AO would not receive data feedback from the DSN also resulted in operations deleting requirements for computations based upon DSN data. Subsequently, the data were received (at $T + 62$ min), and the requirement for calculations was reestablished with the supervisor of range operations.

Transmission of guidance data from the central information facility to the RTCS was faulty on the first try, with numbers instead of letters in the copy. A subsequent retransmission was satisfactory.

3. Problems and solutions. Simulated metric data from Grand Canary and Tananarive, though usable, were incorrect for ORTs 1 and 2. The resolution was an assurance that it was a software problem for generation of simulation data (simulation problem) at GSFC, and that Grand Canary radar was ready to support the launch.

The GSFC did not provide Grand Canary with the rise minus 5 min acquisition message during ORT 1 because of an operational error. The problem was resolved for ORT 2.

During ORT 2, the AFETR telemetry data support was excellent, with the exception of insufficient HF relay units at Antigua. The problem was considered to be resolved with AFETR assurances that a sufficient number of data links via Antigua would be available for launch.

Many outages were experienced on the voice and teletype circuits to DSS 51 via London. However, both the Tangiers and Perth routes performed without interruption. One voice circuit was released to the station at Johannesburg for support of a pass by an *Explorer* satellite because of the difficulty in maintaining reliable voice communication with DSS 51.

The voice circuit was lost because of poor HF propagation then reacquired. At this time, a teletype conference line was established to DSS 51, utilizing the noninterrupt mode of operation. This conference proved satisfactory, and remained in operation until a reliable voice circuit became available.

Because of the inability to obtain a good transmitter at Pretoria for the DSS 51 voice circuit, no success was realized via this route. The teletype data were marginal throughout most of the test, but they were declared acceptable shortly before termination of the test. However, this circuit was never used as a traffic channel.

2. ***Deep Space Network.*** The DSN supported the *Surveyor* Project test plan, which included various operational compatibility and integration tests. System readiness tests (SRTs) were scheduled during the week of August 28, 1967, to verify the readiness of the DSN to enter the ORT prase of prelaunch preparations. The SRT results were characterized by operational problems attributable to the introduction of the communications processors with the consequent need for special message-heading procedures. The following discussion defines the tests conducted in preparation for the flight of *Surveyor V*.

a. Operational readiness testing. The objectives of the ORT are discussed in Subsection B-1-b. The ORT was conducted in one continuous session consisting of the following three phases:

(1) Prelaunch through initial operations: $T - 14$ h to $T + 1$ h, 40 min.

(2) Midcourse maneuver: $T - 2$ h, 45 min to $T + 40$ min.

(3) Terminal descent: $T - 2$ h, 45 min to $T + 28$ min.

No anomalies were inserted in the system by the test conductor. All three phases were relatively uneventful, except for numerous data outages and computer breakdowns. As in the flight training test, the Univac 1219 at Hughes Aircraft Co. (HAC), El Segundo, proved to be a very valuable backup to the SFOF data system.

Functional compatibility testing of the 7044R computer began during the week ending August 5 and ended during the week ending August 19. Flight training tests were conducted during the weeks ending August 19 and 26. The ORTs began during the last week of August.

b. Communications processing system functional compatibility testing. Two tests were conducted that resulted in the qualification of the SFOF data system in the 7044R configuration (including the NASA communications processor computer and the redesigned real-time program for the 7044 computer) for use during the *Surveyor V* Mission. Prerecorded telemetry and tracking data were used, along with selected test cases for the SPAC computer programs. A test command message was constructed and transmitted to each of the two participating Deep Space Stations (DSSs 11 and 61). Command confirmation network data were generated by transmitting commands at each of the stations and routing them through the system.

During the first test, all computer programs were run successfully, and accurate (although somewhat slow) operation of the command confirmation data handling was verified. A command message was constructed correctly, transmitted to DSS 11, punched on 7-track tape, played back, and manually verified. Numerous attempts were made over a 4-h period to transmit the same message to DSS 61. None was successful because of the frequent breakdown communications processing system and the 7044R throughout that period.

Telemetry data displays contained errors and omissions that were generally considered correctable. Backlogging of data occurred, but was much less severe than in previous tests.

Tests conducted by DSS 71 were designed to verify spacecraft compatibility with the DSIF prior to launch. With the exception of excessive phase jitter in transmitter A, SC-5 (prelaunch serial designation) was considered compatible.

The second test was oriented to training personnel and proving the telemetry displays supposedly corrected since the previous test. This test was terminated early to allow JPL personnel to troubleshoot a backlog of mission telemetry data that developed and could not be cleared. In addition, the expected update of telemetry formats had not been accomplished. The 7044R system was nevertheless declared operational for the flight.

c. Flight training test. The objective of this class C test was to maintain and improve the efficiency of personnel within the SFOF and selected portions of the DSN. Particular emphasis was placed upon the critical portions of the mission that occur during the transit phase. The test was conducted in three phases covering the following parts of the transit sequence of events:

(1) Prelaunch to initial operations: $T - 20$ min to $T + 1$ h.

(2) Midcourse maneuver: first run, $T - 2$ h, 45 min to $T + 1$ h; second and third runs, $T - 50$ min to $T + 20$ min.

(3) Terminal descent: first run, $T - 2$ h, 45 min to $T + 36$ min; second and third runs, $T - 1$ h, 10 min to $T + 11$ min.

The *Surveyor IV* Technical Review Board recommendations implemented were: (1) creation of a backup command tape for loss-of-data-link during time-critical mission periods such as terminal descent, and (2) development of a nonstandard procedure to implement such a taped sequence.

The first two phases were conducted during a single day of testing. The terminal-descent phase was accomplished 10 days later. During each phase, spacecraft and/or Space Flight Operations System anomalies were inserted by the test conductor. These were sometimes obscured or confused by actual problems with the 7044R system.

In the prelaunch and initial operations phase, a failure of the automatic sun-acquisition sequence was simulated. The failure was promptly detected and the proper corrective action taken.

The midcourse maneuver segment of the test was divided into three runs. During the first run, a backlog of data and I/O difficulties with format changes caused an abort. In the second run, the data system operation was satisfactory except for the failure of the flight control analog recorder, which was an intentional failure caused by the test conductor. The maneuvers and burn were accomplished using the remaining data. The simulated burn time was longer than the commanded duration because of an error in simulation. During the third run, a major data outage forced the HAC Univac 1219 computer in El Segundo to be the prime data source. In spite of this, a successful midcourse maneuver was accomplished.

The terminal-descent phase actually consisted of four runs instead of the three planned runs. In the first three phases, the same anomaly (error in sync pattern on commutator 6) was introduced, resulting in loss of decommutator lock. Various attempts were made to solve the problem, but none was successful. The fourth phase was significant in that there was a loss of data at $T - 6$ min. A special command tape designed to regain data in certain critical situations was used, and data were regained. (It should be noted that the 1219 regained data, but the SFOF system did not lock up, possibly because of the loss of data identification from the station.) The test was considered successful and fulfilled the requirements of the Space Flight Operations Director, the SPAC Director, and the *Surveyor IV* Technical Review Board.

In general, test objectives were achieved and useful experience was gained. It was also demonstrated that: (1) the 7044R configuration of the SFOF data system provides considerably less data handling capability than the previous configuration, and (2) if necessary, a midcourse correction can be accomplished using only the analog recorders and the Univac 1219.

d. Coordination and simulation. To control and execute the class A, B, and C tests in accordance with the objectives and directives stated in the test plans, a joint JPL/HAC test coordination team was formed in July 1964. The basic responsibility of the test coordinator was to create the total test environment. The most important function of the HAC test coordinator was to gather and specify in detail the data simulation requirement for each test, and to plan for a timely and realistic display presentation to the operations personnel. To carry out these functions, the test coordination team was divided into telemetry, tracking, science, and TV simulation groups.

The prime responsibilities of the test coordinator and his staff were: (1) to plan the telemetry and tracking data packages (including problems) about 2 mo prior to the scheduled test; (2) to prepare and mail data package kits (including trajectory specification) to AFETR and FR-600 telemetry simulation tapes to AFETR and the Deep Space Stations for use and playback during scheduled tests; and (3) to control, during the test, the playback of the telemetry and tracking data, which included problems of producing a smooth-flowing, realistic mission simulation.

Because of the lead time required to prepare the data packages for *Surveyor V*, it was necessary to start the test planning and test design while the *Surveyor IV* Mission was still in progress. The data packages produced in support of *Surveyor V* were for the class A tests, the NASA communication processor checkout tests, and the ORT. All of these packages were mailed and delivered on time to AFETR and the Deep Space Stations for the scheduled tests.

The ORTs for *Surveyor V* were constructed without nonstandard spacecraft indication in the telemetry and tracking data. The selected trajectory closely matched the actual launch time and data for *Surveyor V*. The significant simulation difference over the previous mission's ORT was the playback of telemetry data for AFETR and DSS 51. As during previous operational readiness tests, telemetry data were prerecorded on FR-600 data tape and mailed to AFETR for playback during the actual test. During the *Surveyor V* Mission, a dataphone circuit between SFOF and building AO at the AFETR was used to transmit prelaunch data to building AO.

A special initial acquisition tape (major sequence 0040) was provided DSS 51 that was not previously used in other ORTs.

Operational tests were divided between two major types: internal tests (class A) and mission ORTs involving the Deep Space Stations and the SFOF. The internal tests primarily rehearsed the station crews for the ORT. The mission, including several nonstandard situations, was rehearsed with the complete DSN, which included the SFOF during the ORT.

e. Equipment preparation. The following major tasks were accomplished between the flights of *Surveyors IV* and *V*:

(1) Installation and checkout of approximately 19 modification kits for *Surveyor V*.

(2) Performance of the CDC unit/subsystem/system and compatibility tests necessary to confirm proper operation of the equipment.

(3) CDC selloff at the Goldstone, Madrid, and Johannesburg Deep Space Communications Complexes obtained final JPL approval. The data packages for all sites were completed and submitted.

(4) A special activity was accomplished that concerned the conduct of *Development Test Request Bulletin* for alpha scattering simulation tapes (conducted at DSS 11 only).

V. Tracking and Data System Flight Support

A. General

The near-earth (less than 10,000 mi) phase of the *Surveyor V* Mission was supported by the AFETR, the MSFN, the DSN, and NASCOM. This section comprises a summary of significant events, a narrative description of countdown activities, and a presentation of actual mission performance through touchdown. The data were assembled from material presented at preflight and postflight reviews of the Tracking and Data System which supported the *Surveyor V* Mission.

B. Countdown

The planned countdown for September 7 and 8, 1967, included two built-in holds; one of 60-min duration at

$T - 90$, and a second 10-min hold at $T - 5$. Liftoff was scheduled for 07:39 GMT on September 8, with a flight azimuth of approximately 78 deg and a launch window duration of 110 min. The actual countdown is summarized in Table 16.

Table 16. *Surveyor V* countdown summary

Event	Time	
	Before launch, min	GMT
Start system readiness test	—	19:03[a]
End system readiness test	—	00:14
Start vehicle countdown	335	00:54
Start 60-min built-in hold	90	04:59
Start spacecraft countdown	90 (during hold)	05:35
End built-in hold; resumed count	90	05:59
Start 10-min built-in hold	5	07:24
Hold extended; launcher stabilization	5	07:33
Resume count	5	07:52
Liftoff	0	07:57

[a]September 7, 1967; subsequent times are September 8.

The teletype noninterrupt mode of operation was established at 17:00 GMT on September 7. All high-speed transmissions were paralleled with low-speed input. These low-speed lines terminated in the facility control section at the Goddard Space Flight Center where they could be used by JPL in the event of a communications processor failure.

The spacecraft system readiness test was started on schedule at 19:03 on September 7. The first spacecraft frequency report was transmitted verbally to the SFOF at 19:45, followed by teletype confirmation. A total of six frequency reports were sent during the test and countdown. The test progressed normally until the start of the alpha scattering checks, at 21:45, when the test was suspended pending completion of another launch. This was necessary because the launch complex alpha scattering checks would have been disrupted if the switchover occurred during the test. The complex was placed on critical power, and the test resumed at 22:43. The SRT was satisfactorily completed at 00:14.

Special NASCOM coverage was implemented at 01:00 GMT on September 8. A special propagation forecast was provided effective from $T - 8$ to $T + 20$ h for all HF circuits.

The DSS 51 teletype circuit via Pretoria was activated and was of good quality but this circuit was not called for and it was used as an orderwise by GSFC throughout the launch phase. The voice circuit via the same route was not available due to class I *Surveyor V* commitments at the AFETR site at Pretoria.

The two prime teletype circuits to DSS 72 were routed via the communication satellite.

It was requested that Goddard backfeed the DSS 51 command net to DSS 72; however, this was not accomplished because of circuit limitations at DSS 72 (i.e., only two voice/data circuits may be terminated at that site at any given time).

The first RF propagation forecast was received from AFETR at $T - 360$ min. Seven of these forecasts, each of which predicted the propagation conditions for $T = 0$, were provided. The last two of these forecasts also predicted the propagation conditions until $T + 30$ min. Table 17 lists the forecast conditions.

The vehicle countdown was started on schedule at $T - 335$ min, at 00:54. All operations progressed normally until $T - 115$ min, when several problems with AFETR sites were reported. The Grand Bahama radar (3.18) was not operationally ready because of encoder problems. This could have affected the launch/hold criteria, but the Patrick Air Force Base and KSC radars covered the potential gap. It was confirmed by the range operations supervisor that this did not represent a hold condition. The Grand Bahama radar was returned to operation at $T - 26$ min.

From 02:08 through 07:00 GMT on September 8, numerous outages were experienced on HF circuits to DSS 51 via London. However, no outages were encountered via Tangiers or Perth. At 05:38, a high error rate occurred on the GSFC/JPL 2400-bit/s circuit. An alternate circuit was provided at 05:44.

Table 17. *Surveyor V* HF propagation forecasts

Time received, min before launch	*Sword Knot*/ Ascension		Pretoria/ Ascension		Ascension/ Cape Kennedy		*Coastal Crusader*/ Antigua		*Twin Falls*/ Antigua		*Twin Falls*/ Cape Kennedy	
	$T-0$	$T+30$	$T-0$	$T+30$	$T-0$	$T+30$	$T-0$	$T+30$	$T-0$	$T+30$	$T-0$	$T+30$
360	Fair[a]		Fair		Fair		Fair		Fair		Fair	
240	↑		↑		↑		↑		↑		↑	
180												
120												
90												
70	↓	Fair	↓	Fair	↓	Fair	↓	Fair	↓	Fair	↓	Fair
15	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair

[a]On scale of excellent, good, fair, unusable, and circuit out.

The radar at Antigua (91.18), was also not operationally ready because of a supercharger pump failure in the hydraulic system. The time division multiplexer on the *Coastal Crusader*, the pulse amplitude modulation/pulse duration modulation converter, the 100-word/min receiver, and both S- and P-band antenna systems on the *Sword Knot* were not operationally ready.

The Carnarvon radar FPQ-6 was also considered in the *red,* because of a faulty klystron which required operation on reduced power, but planned to support on a limited basis. This could have affected the class I requirement for a definition of the post-retromaneuver orbit of the *Centaur*, but Pretoria/Ascension were prepared to cover this phase and this did not represent a hold condition.

With the exception of those of Antigua and Carnarvon, all of these problems were cleared before launch.

During the minus count, the downrange telemetry stations and ships were checked for data communication quality. The HF communication from Ascension and Pretoria was consistently good throughout the minus count (there was only one communication circuit for these two stations).

The *Twin Falls* had one HF path available, into Rixon 1 at Cape Kennedy. However, shortly before launch Rixon 1 indicated poor operation and the *Twin Falls* data were assigned to Rixon 2 at Cape Kennedy, along with the Ascension and Pretoria data.

The *Coastal Crusader* data communication path, which was HF to Antigua and then sent over the subcable to KSC, was good during most of the minus count. This was the only communication path available for this ship.

The *Sword Knot* data communication path, which was HF to Cape Kennedy via Ascension, was excellent throughout the minus count.

All subcable data channels from Antigua and Grand Bahama were good.

The operation of RTCS computer B had been intermittent since 18:30 on September 7. Because of this, an alternate plan, using only one computer for support had been developed. Fortunately, the problem was isolated and corrected and the B computer was declared operational at 04:50 on September 8. The problem was identified as a faulty timing card.

The real-time computer system did not perform the scheduled static point checks with Antigua because the Antigua radar was not able to support these checks.

The static point-3 check from the *Twin Falls* was garbled at the RTCS when transmitted at 100 words/min. This point was usable when transmitted at 60 words/min.

The 60-min built-in hold at $T-90$ min began on schedule at 04:59, and the count was resumed at 05:59. At the start of the $T-90$ hold, the decision was made to launch at the opening of the window. This decision emphasized the role of the Canary radar, and the *Coastal Crusader* S-band receive-and-record capability. The *Coastal Crusader* was also prime for real-time delivery of S-band telemetry. Propagation forecasts were therefore

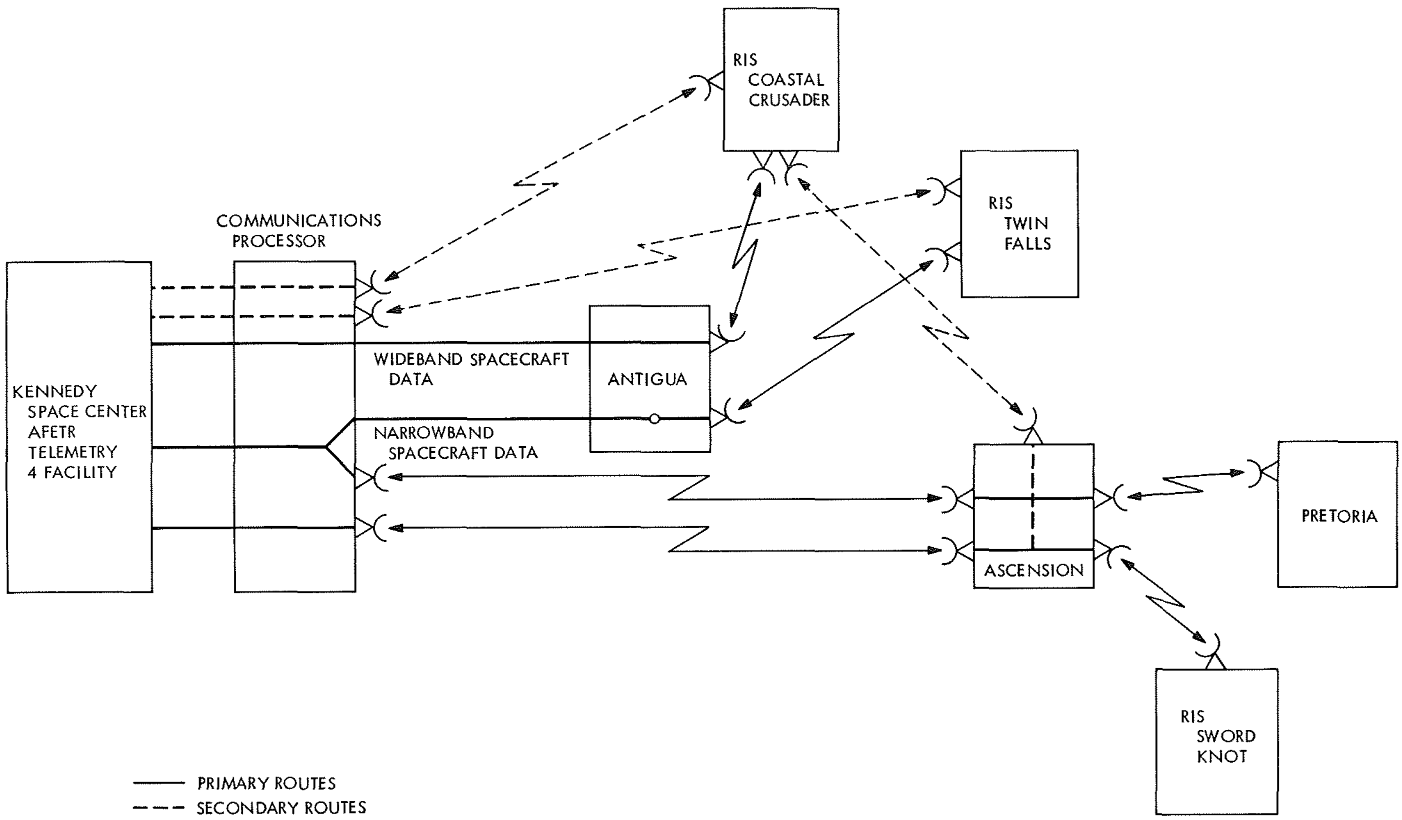


Fig. 25. Real-time telemetry circuits

watched very closely in an effort to anticipate real-time transmission capability during flight.

The DSS 42 radar was reported malfunctioning at 05:23 because of a motor problem. The problem was cleared and the station returned to operation at 06:12.

The spacecraft countdown was started at 05:35, during the built-in hold. All spacecraft countdown operations progressed normally through launch.

The left-hand side of the antenna system at Grand Bahama was reported not operationally ready at $T - 42$ and clear by $T - 26$ min.

At $T - 40$ min, the range reported that the prime routes selected for return of spacecraft telemetry data were by HF routes as follows:

(1) *Sword Knot:* through Ascension.

(2) Pretoria: through Ascension.

(3) Ascension: direct to Cape Kennedy.

(4) *Coastal Crusader:* to Antigua/subcable to Cape Kennedy.

(5) *Twin Falls:* direct to Cape Kennedy.

Late in the count, the range operations supervisor reported that the prime route for *Twin Falls* data had been changed to HF through Ascension. At the postlaunch debriefing, it was learned that the route had not changed; however, the Rixon assignment at Cape Kennedy had been changed (Fig. 25).

At $T - 10$ min the blockhouse light indicating acceptable launcher stabilization pressure extinguished, pointing to either a loss of instrument air or less than 2410 psi on the stabilization system. The light cycled on again but went out at $T - 5$. The planned 10-min built-in hold at $T - 5$ min, which was started on schedule at 07:24, was extended an additional 18 min to evaluate the problem. The analysis indicated an operational stabilization system, and a decision was made to continue the count. The count was resumed at 07:52, and proceeded without incident through liftoff.

Throughout the countdown, the TDS was considered ready to provide the required support.

C. Liftoff to DSIF Acquisition

The fifth *Surveyor* spacecraft was launched from launch complex 36B at Cape Kennedy, Fla., at 07:57:01.257 GMT on September 8, 1967 by an *Atlas/Centaur* launch vehicle. Two seconds after liftoff, the launch vehicle began a 13-s programmed roll that oriented the vehicle from a pad-aligned azimuth of 105 deg to a launch azimuth of 79.517 deg. At $T + 15$ s, a programmed pitch maneuver was initiated. The nominal and actual *mark* times for the *Atlas/Centaur* boost phase events are summarized in Table 18. Times for *mark* events 12, 22, and 23 were never made available during the mission. All *mark* times were nominal with the exception of events 10 and 21. There was some question of the validity of these *mark* times but postflight data showed that the times received were in error and the events were, in fact, nominal. The support provided by the near-earth phase was less than nominal, but did not compromise the success of the mission.

Separation of *Surveyor* from *Centaur* occurred at 08:16:26.8 on September 8, at an approximate geocentric

Table 18. *Mark* events

Mark	Event	Actual GMT	Time from launch		Nominal time from separation, s
			Actual, s	Nominal, s	
	Liftoff	07:57:01.257	0.0	0.0	
1	*Atlas* BECO[a]	07:59:34.65	153.4	153.5	
2	*Atlas* booster engine jettison	07:59:38.05	156.8	156.6	
3	*Centaur* insulation panel jettison	08:00:19.65	198.4	198.5	
4	*Centaur* nose fairing jettison	08:00:49.9	228.6	228.5	
5	*Atlas* SECO[b] *and* VECO[c]	08:01:07.7	246.4	248.2	
6	*Atlas/Centaur* separation	08:01:10	248.7	250.2	
7	*Centaur* MES 1[d]	08:01:20.3	259.0	259.7	
8	*Centaur* MECO 1[e]	08:06:48.3	587.0	579.2	
9	100-lb thrust on	08:06:51.3	590.0	579.2	
10	100-lb thrust off	08:08:15.2	673.9	655.6	
11	6-lb thrust on	08:08:06	664.7	655.6	
12	100-lb thrust on	—	—	946.5	−216.0
13	*Centaur* MES 2 engine C 2	08:13:32.2	990.9	986.5	−176.0
14	*Centaur* MES 2 engine C 1	08:13:32.2	990.9	986.5	−176.0
15	*Centaur* MECO 2	08:15:25.2	1103.9	1099.4	−63.1
16	Extend landing gear	08:15:45.5	1124.2	1120.5	−42.0
17	Unlock omnidirectional antenna	08:15:55.7	1134.4	1131.0	−31.5
18	*Surveyor* high power transmitter on	08:16:16	1154.7	1146.0	−11.0
19	*Centaur/Surveyor* electrical disconnect	08:16:22.2	1160.9	1157.0	−5.5
20	Spacecraft separation (injection)	08:16:26.8	1165.5	1162.5	0.0
21	Begin *Centaur* turn around maneuver	08:17:29.8	1228.5	1167.5	5.0
22	Start *Centaur* lateral thrust	—	—	1207.5	45.0
23	End *Centaur* lateral thrust	—	—	1227.5	65.0
24	Start *Centaur* tank blowdown	08:20:26.8	1405.5	1402.5	240.0
25	End *Centaur* tank blowdown	08:24:37.2	1655.9	1652.5	490.0
26	Power changeover switch	08:26:16.5	1755.2	1752.5	590.0

[a]BECO = booster engine cutoff. [b]SECO = sustainer engine cutoff. [c]VECO = vernier engine cutoff. [d]MES = main engine start. [e]MECO = main engine cutoff.

latitude and longitude of 21 and 344 deg, respectively. The spacecraft was in the shadow of the earth during the first 11.5 min of the ascent phase and parking orbit but left the shadow prior to separation and remained out of the shadow during the transit trajectory. Approximately 1 min after separation, automatic acquisition of the sun began. The trajectory group had predicted a sun acquisition maneuver of +23-deg yaw. The actual maneuver was −342.5-deg roll and +18-deg yaw. No prediction was made for the roll maneuver since the *Centaur* was not roll stabilized. Canopus was acquired 6 h, 31 min after launch with a roll maneuver of +179 deg. The roll maneuver predicted by the trajectory group was +221 deg.

D. Acquisition to Midcourse Maneuver

Solid one-way spacecraft signals were reported by DSS 71 for 4 min, 39 s after liftoff. Signal levels varied from a −71 dBmW on the pad to −156 dBmW at loss of lock.

Initial one-way spacecraft acquisition was performed by DSS 72. This station had visibility and tracked for 12 min (08:20–08:32) during the launch pass. DSS 72 did not go two-way with the spacecraft during this pass.

Initial two-way acquisition was performed by DSS 51. The station was in two-way lock with the spacecraft at 08:31 with command modulation on. The period from receipt of the first spacecraft signal to command modulation on was slightly less than 7 min.

The predicted view periods for the four committed tracking stations and the first two passes over DSS 72 are shown in Table 19. This summary is a compilation of pre- and post-midcourse maneuver trajectories. The rise and set criteria are included under the event column.

At 08:25:10 GMT ($T + 28$ min, 9 s), the spacecraft became visible to DSS 51, which achieved one-way lock at this time. At $T + 31$ min, 9 s, the acquisition was completed when two-way lock was established between DSS 51 and the spacecraft.

The first ground-controlled sequence (initial spacecraft operations) was initiated at $T + 39$ min, 59 s by commanding off the transmitter high voltage and filament power. In addition, commands were sent to the spacecraft to turn off other equipment required only for launch-to-DSIF-acquisition phase (e.g., solar panel deployment logic off and analog-to-digital isolation amplifier off) to seat the solar panel and roll axis locking pins securely (i.e., by rocking the axes back and forth), to switch from the 500-bit/s low-modulation-index mode to the 1100-bit/s normal-modulation-index mode, and to interrogate telemetry communicator modes so that the overall condition of the spacecraft could be assessed. All spacecraft responses to commands were normal.

The pre-star verification engineering interrogation was initiated at $T + 5{:}30{:}54$. During the interrogation of

Table 19. Predicted view period summary

DSS	Event						Time (GMT), h:min
	Rise			Set			
	0-deg el	5-deg el	270-deg HA	0-deg el	5-deg el	90-deg HA	
72	X						Sep 8 8:21
51		X					8:24
72	X						8:33
42		X					9:12
72	X						10:29
42					X		12:38
61	X						13:38
61					X		20:20
51						X	20:52
11		X					21:02
72				X			Sep 9 00:07
42		X					00:18
11					X		04:46
51			X				09:35
72	X						12:10
61		X					14:14
42					X		14:19
61					X		21:18
11		X					21:24
51					X		21:35
72				X			Sep 10 00:41
42		X					00:47
11					X		05:20
51			X				09:52
72	X						12:25
61		X					14:21
42					X		14:34
11		X					21:29
61					X		21:37
51						X	21:47

mode 4, the solar panel switch tripped off since the battery voltage had built up to over 27 V. It was recommended that time (approximately 15 min) be allowed to permit the battery to discharge until the battery voltage decreased below the solar panel switch trip level. Interrogation of modes 2 and 1 was normal, and transmitter B filament power was turned on at $T + 6{:}02{:}16$. At $T + 6{:}05{:}28$, the solar panel switch was commanded back on. Transmitter B high voltage and switching to omniantenna B were commanded at $T + 6{:}06{:}27$ and 6:07:30, respectively. Switching to omniantenna B resulted in a decrease in signal level of approximately 20 dB, verifying that the earth–spacecraft vector was still in a deep null of omniantenna B.

The spacecraft roll sequence for obtaining the star map and for locking on to Canopus was initiated at $T + 6{:}13{:}01$. During the star map revolution, star intensity signals from 10 stars (Zeta Ophiuchi; Antares and Tau Scorpii; Alnitak, Alnilam, and Mintaka; Bellatrix; El Nath; Capella; and Polaris) in addition to Canopus, as well as a strong signal from the earth, were identified, with Canopus being observed after 179 deg of roll. It was also noted that a Canopus lock signal did appear when Canopus was in the field of view of the Canopus sensor. The Star Acquisition Mode On command for achieving automatic lockon was sent at $T + 6{:}28{:}35$, and Canopus was automatically acquired at $T + 6{:}30{:}51$. Cruise mode on was commanded at $T + 6{:}33{:}09$, the bit rate was reduced from 4400 to 1100 bits/s at $T + 6{:}35{:}38$, and the transmitter high power was commanded off at $T + 6{:}36{:}40$. With Canopus now acquired, a check of the received signal strength at DSS 61 indicated that it was almost exactly nominal.

The spacecraft continued to coast, with its attitude being controlled to keep the primary sun sensor and Canopus sensor locked on to the sun and to Canopus. Coast mode data were transmitted continuously at 1100 bits/s via transmitter B operating in the transponder mode until $T + 9{:}25{:}03$ when a special mode 4 interrogation was initiated to obtain alpha scattering sensor head and electronics temperatures (which are only available in mode 4). During this interval, the solar panel switch tripped five more times (at $T + 6{:}46{:}04$, 7:39:28, 7:58:26, 8:26:52, and 9:16:29) and had to be recommanded on. The spacecraft was commanded to switch back to its transmission of coast mode data at $T + 9{:}29{:}37$. It was necessary to reduce the spacecraft data rate initially from 1100 to 137.5 bits/s (at $T + 12{:}21{:}07$) and then to 17.2 bits/s ($T + 12{:}55{:}59$) to permit DSS 72 (which was the only station having visibility of the spacecraft) to obtain satisfactory data. The data rate was increased back to 1100 bits/s at $T + 13{:}52{:}58$ when DSS 11 acquired the spacecraft.

In the period from the return to coast mode data until midcourse, the solar panel switch tripped six more times, requiring the switch to be commanded back on at $T + 9{:}47{:}03$, $T + 10{:}36{:}27$, $T + 10{:}56{:}42$, $T + 11{:}37{:}23$, $T + 12{:}10{:}37$, and $T + 13{:}41{:}52$. Coast mode data were transmitted at all times during this interval except for engineering interrogations of modes 4, 2, and 1 (at $T + 13{:}50{:}44$, $T + 15{:}44{:}42$, and $T + 17{:}02{:}38$—the latter two being the premidcourse interrogations) and the premidcourse gyro speed check (at $T + 15{:}58{:}12$). Two three-axis gyro drift checks (at $T + 7{:}48{:}50$ to $T + 10{:}19{:}24$ and $T + 10{:}37{:}26$ to $T + 12{:}19{:}00$) and one roll-only drift check (at $T + 13{:}46{:}55$ to $T + 15{:}43{:}30$) were also made during this phase. Spacecraft performance throughout this period was flawless, the earth track traced by *Surveyor V*, on its flight to the moon, is shown in Fig. 26.

E. Midcourse Maneuver to Terminal Descent

The spacecraft encountered a helium regulator problem after the first midcourse maneuver and additional maneuvers were performed in an attempt to overcome this problem. Since the first midcourse maneuver was performed at 01:45 GMT on September 9, Goldstone had viewed *Surveyor V* for about 4¾ hours premidcourse. The first four midcourse maneuvers were performed over Goldstone between 01:45 and 04:19 GMT on September 9. The fifth midcourse was performed at 08:24 GMT September 9 over Canberra. The final midcourse was performed at 23:31 GMT September 9 over Goldstone.

For the predicted touchdown time of 00:45.3 on September 11, the pre- and postlanding Goldstone visibility was approximately 3¼ and 4¾ h, respectively.

Figures 27–31 show the trajectory path on a stereographic projection of DSSs 72, 51, 11, 42, and 61, respectively.

During the course of the problem with the helium regulator some consideration was given to placing the spacecraft into an earth orbit through firing the retrorocket. Consequently, some analysis was done and trajectories for three possible earth orbits were generated. Two types of orbits were considered, a polar orbit and an in-plane circular orbit. The injection conditions for these orbits were found by mapping a trajectory forward to a specified maneuver time and printing out the geocentric block to obtain the inertial cartesian and the

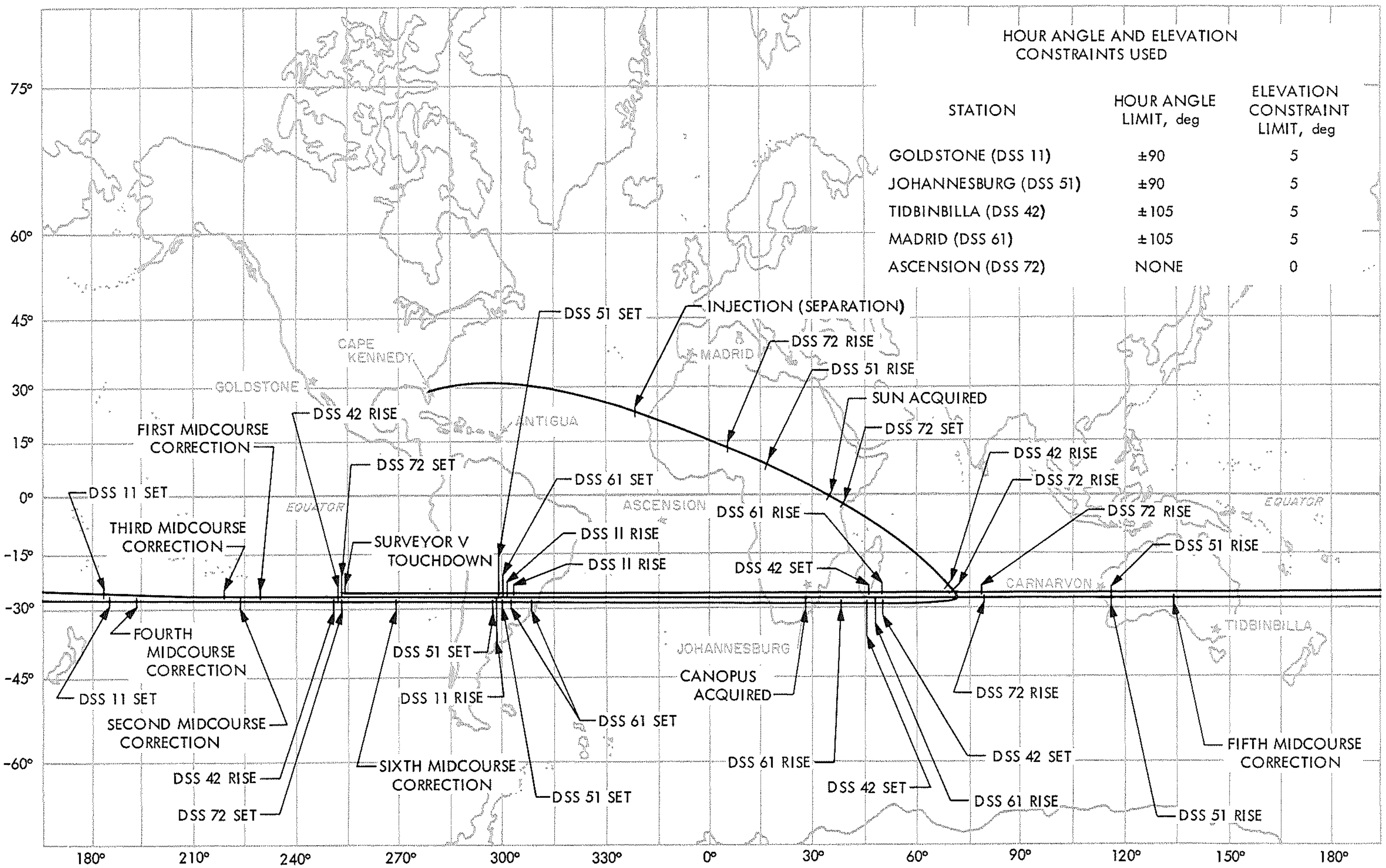


Fig. 26. *Surveyor V actual earth track*

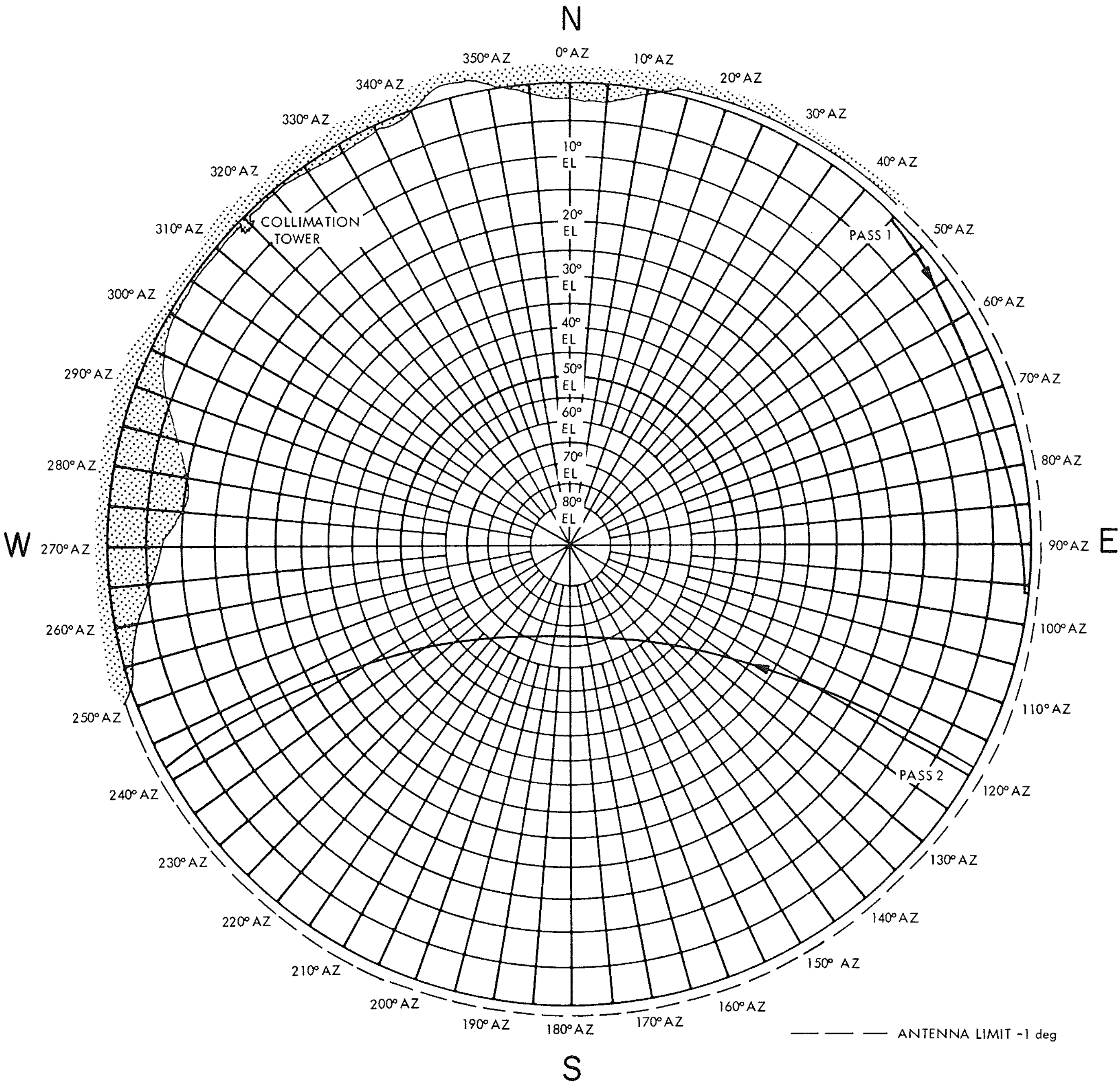


Fig. 27. Stereographic projection for DSS 72

earth-fixed spherical conditions. The earth-fixed spherical conditions were then altered by changing the azimuth to zero degrees for the polar orbit and the path angle to zero degrees for the in-plane circular orbit. These injection conditions were then input into a trajectory program to obtain the inertial cartesian components of the new earth-fixed spherical conditions. The velocity vector of the original trajectory was subtracted from the altered trajectories velocity vector to obtain the direction in which the retrorocket would be fired. This velocity vector was unitized and then multiplied by the magnitude of the rocket's velocity change capability. The rocket velocity vector was then added to the original velocity vector to obtain the injection conditions of the new orbits. For retrorocket firings at 09:00 GMT on September 9, an in-plane orbit and a near-polar orbit were generated.

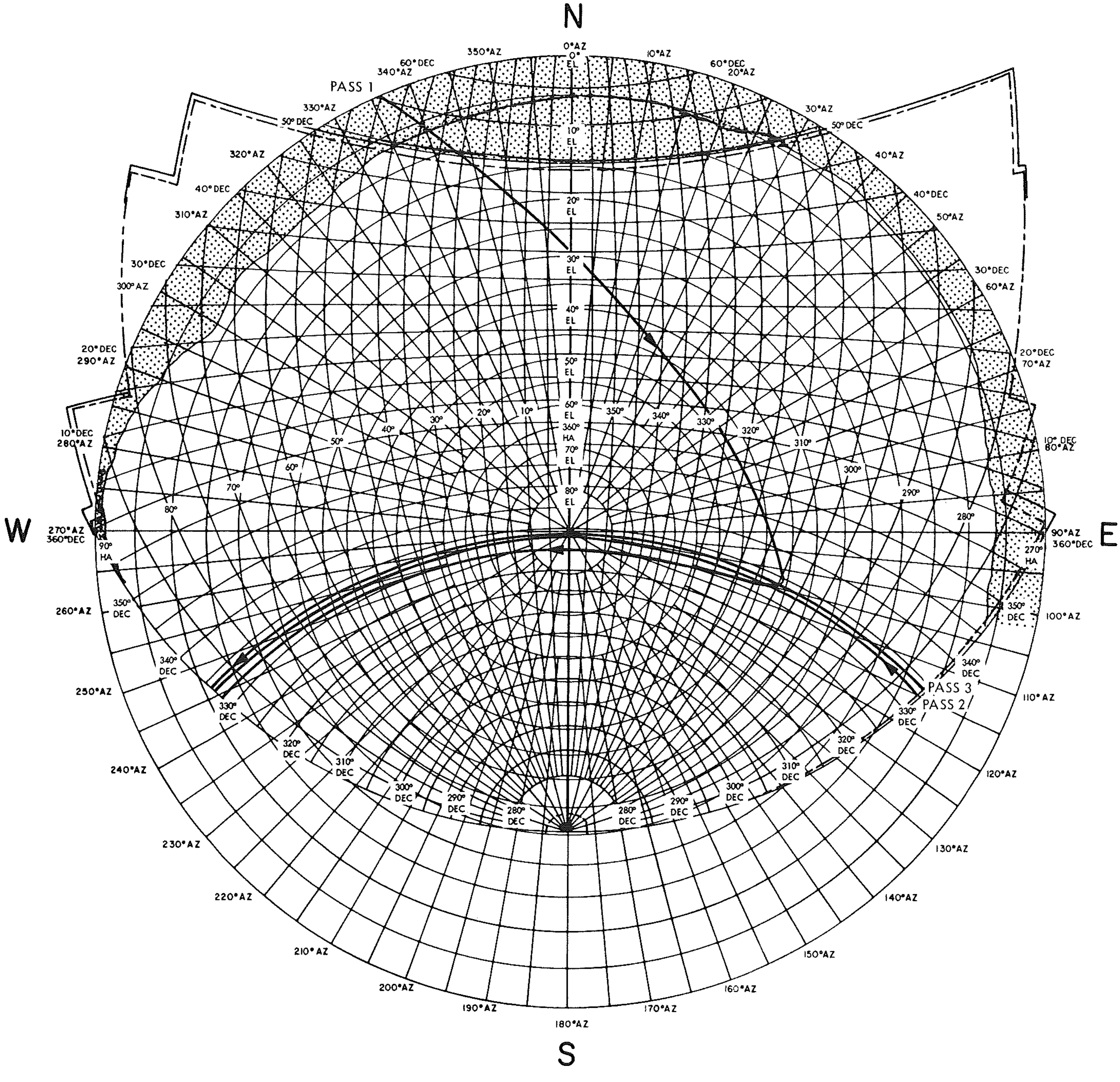


Fig. 28. Stereographic projection for DSS 51

A polar orbit was also generated for a retrorocket firing at 05:25 GMT on September 10.

The required maneuvers for these orbits were found by inputting the retrorocket velocity vector and the original sun, probe, and Canopus vectors into the midcourse program. The necessary maneuvers were obtained from the command program.

All premidcourse operations were performed normally. With the spacecraft being commanded from DSS 11, the maneuver sequence for applying the desired midcourse thrust in the proper direction was initiated. The first maneuver (a roll of +71.9 deg) was commanded at $T + 17{:}25{:}56$. Initiation of this maneuver was delayed (as in the case of the *Surveyor IV* Mission) until the roll axis limit cycle was at a null (i.e., until the Canopus error

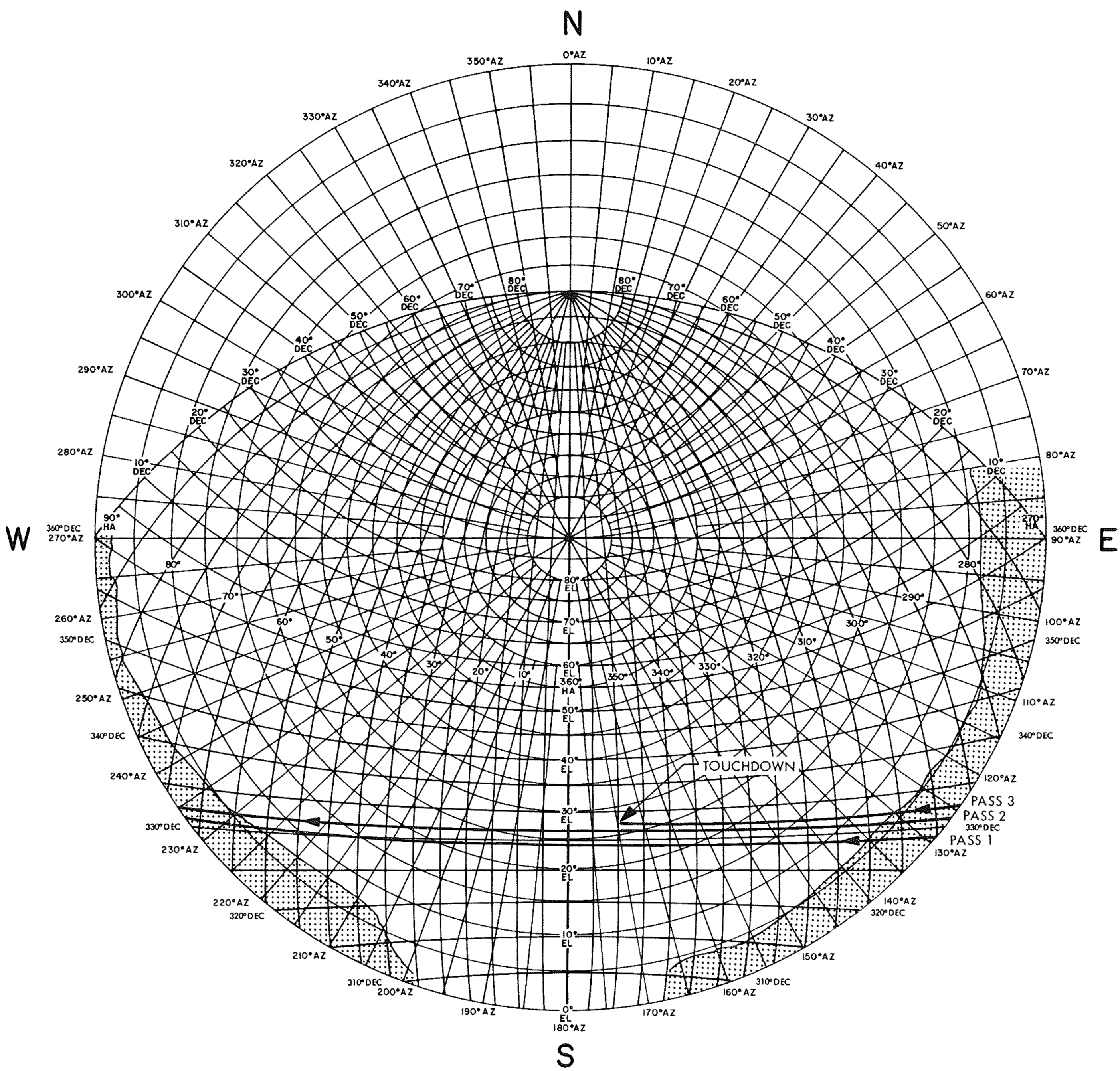


Fig. 29. Stereographic projection for DSS 11

signal was passing through a null). The second maneuver (a yaw of -35.7 deg) was also delayed in an attempt to null the yaw axis limit cycle, the maneuver was commanded at $T + 17{:}41{:}03$. With the vehicle thrusting direction now positioned properly, the vernier engine system was pressurized at $T + 17{:}45{:}26$, and flight control thrust phase power was commanded on 50 s later. The midcourse velocity correction was applied by commanding the ignition of the vernier engines at $T + 17{:}48{:}01$ so that the necessary controlled thrust was applied to achieve a constant acceleration of 0.1 g for 14.25 s (a correction of 14.0 m/s in the negative noncritical direction). Analog recorder, 7044 bulk and teleprinter, and 1219 teleprinter data and near-real-time

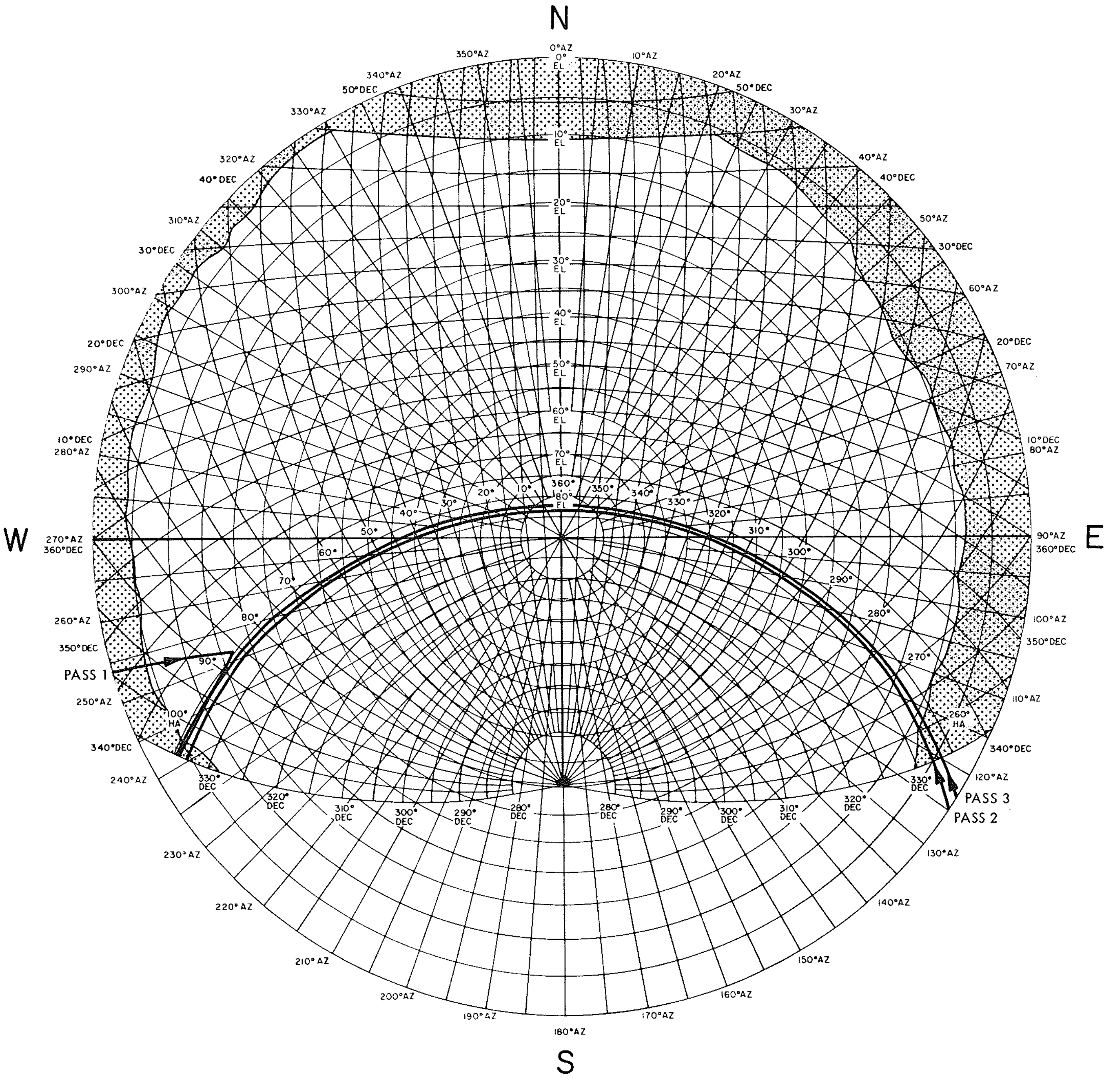


Fig. 30 Stereographic projection for DSS 42

CALCOMP plots confirmed the proper execution times and direction for the attitude maneuver, as well as the duration of the thrusting period.

As the postmidcourse sequence was initiated by commanding a transfer from mode 5 to mode 1 to obtain thermal data, a suspected leak was reported in the helium pressurization system. Consequently, the spacecraft was commanded back to mode 1 at $T + 17{:}52{:}48$ to observe all of the system pressures. It was determined that the leak rate of helium was approximately 10 psi/min, that the leak was probably due to the regulator valve not reseating properly, and that this leak rate could not be tolerated if a normal terminal descent were to be

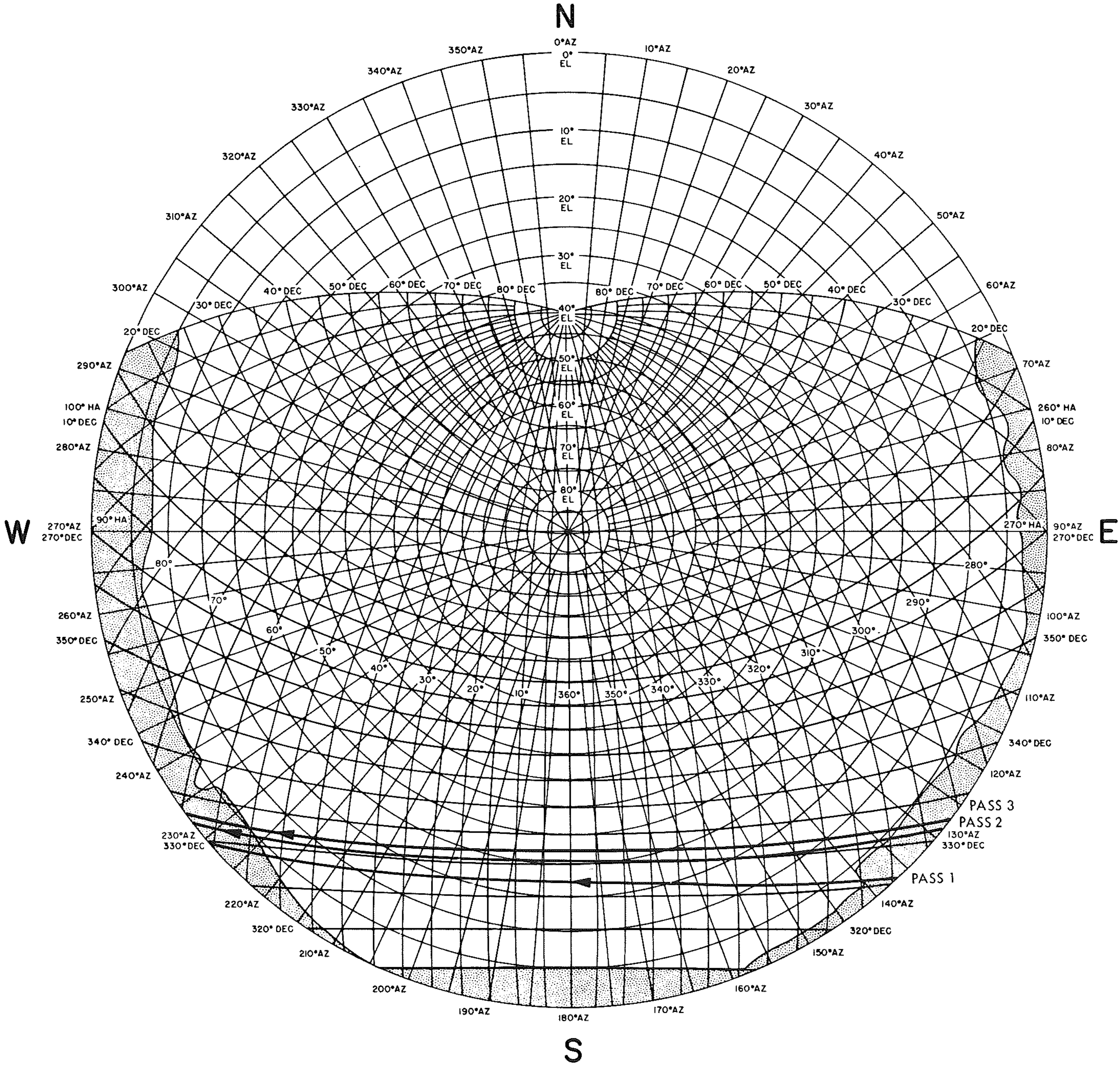


Fig. 31. Stereographic projection for DSS 61

achieved. It was determined that the pressure leak would have to be stopped before the pressure dropped below 2500–3000 psi so that a normal terminal descent could be executed. Consequently, it was decided to fire the engines again in an attempt to reseat the regulator valve properly by getting it to open and then close.

To fire the engines as quickly as possible (i.e., to attempt to stop the leakage with a minimum loss), it was decided to have the engines thrust along the sun line. Consequently, the reverse yaw maneuver performed during the premidcourse maneuver (a yaw of +35.7 deg) was executed at T + 17:56:50, resulting in relock to the sun at T + 17:58:01. At T + 18:15:01 the vernier engines were ignited for 10.05 s, but the leak continued.

It was then decided to fire the engines again with a longer burn duration than before to ensure that the regulator valve would open again. A decision was also made to thrust in the anti-sun line direction, and a minus 180.1-deg yaw was performed at T + 18:27:33 to point the spacecraft in the desired direction. At T + 18:42:49, the vernier engines were commanded to fire for 23.05 s. Again, the results were negative, and the leak continued.

Pending further analysis, the spacecraft was maneuvered to reacquire the sun (by performing a negative 180.1-deg yaw) at T + 18:48:21; relock to the sun was achieved at the end of the maneuver 6 min later. The bit rate was reduced to 1100 bits/s at T + 18:57:55, and low transmitter power operation was resumed at T + 18:58:05.

At T + 20:02:59, a roll of −71.9 deg was executed to reacquire Canopus since the flight path analysis and command (FPAC) computations for the next firing attitude maneuvers were being made assuming that the spacecraft orientation was the normal transit attitude. A decision was reached to execute several engine firings in rapid succession (in a direction to put the spacecraft back on target) in an attempt to shock the regulator valve into seating properly.

The maneuvers computed by FPAC were executed (a roll of +68.5 deg at T + 20:08:53 and a yaw of +106.7 deg 3 min, 39 s later), and the engines were fired in a sequence of 12 s on, 1 s off, 0.5 s on, 1 s off, 0.5 s on, and then off. The sequence was initiated at T + 20:21:47, and was controlled from the ground by tape. Again, the results were negative. Although the leak appeared to stop for approximately 5 min following the firings, it resumed again following this temporary stoppage. At the conclusion of these firings, the spacecraft was returned to its normal transit attitude by performing a yaw of −106.7 deg at T + 21:01:10 and a roll of −68.5 deg 5 min, 58 s later. Sun and Canopus lock were regained.

At T + 21:29:43, an interrogation of modes 2 and 4 was initiated to obtain thermal data. At T + 21:47:01, the spacecraft resumed transmission of coast mode data.

At this point, Mission Control concentrated on assessing two possible courses of action: (1) firing the retro-engine to place the spacecraft in an earth orbit from which TV pictures of the earth could be taken and the alpha scattering experiment conducted, or (2) redesigning the terminal descent to attempt to achieve a soft landing.

In preparation for the possible decision to place the spacecraft in an earth orbit, the SPAC was directed to turn on heaters required to raise the temperatures of the TV and the alpha scattering instrument to their proper operating range. Heater control power was turned on for compartment C and the TV electronics at T + 21:49:47 and 21:53:44, respectively. In an attempt to conserve power, the AMR heater control power was turned off at T + 21:57:44, with the prediction that this heater would have to be turned back on within 4 h if the AMR were to survive and be available for a terminal descent.

With the helium pressure continuing to drop, it was decided to fire the engines to lighten the spacecraft (to improve its chances for a soft landing by reducing burnout velocity) while there was still helium pressure available to do so. Suitable maneuvers for firing the engines in the positive noncritical direction were computed by FPAC and accomplished by SPAC (a roll of +64.5 deg at T + 23:57:29 and a yaw of +143.3 deg). At T + 24:27:03, the engines were fired for 33.05 s. The helium pressure at the completion of the burn was 1235 psi, and the leak continued. Reverse maneuvers to re-establish spacecraft lock on sun and star were then executed (a yaw of −143.3 deg at T + 24:36:50 and a roll of −64.5 deg at T + 24:43:34). To permit maximum visibility of all spacecraft pressure data, the spacecraft maneuvers were executed with the spacecraft transmitting mode 1 data, and the spacecraft remained in this mode following the maneuvers.

The sixth and final midcourse maneuver was executed at 23:30:58 GMT on September 9. The purpose of this maneuver was to correct a trajectory error caused by the previous maneuvers and to further reduce propellant weight. At this time the helium leak had stopped; however, the pressure was below the minimum operating level specified for a normal terminal descent. Table 20 summarizes the events at midcourse.

Table 20. Summary of midcourse events

Time from launch	Event	Remarks
17:48:01	First midcourse maneuver	All programmed events nominal. At $T + 17{:}52{:}48$, mode 1 data indicated 10-psi/min leak in helium pressurization system. Probable cause: regulator valve not seating properly
18:15:01	Second midcourse maneuver	Second through fourth midcourse maneuvers executed in unsuccessful attempt to reseat regulator valve
18:42:49	Third midcourse maneuver	
20:21:47	Fourth midcourse maneuver	
24:27:03	Fifth midcourse maneuver	Executed to reduce weight of spacecraft to increase probability of successful soft landing by reducing propellant residuals
39:33:57	Sixth midcourse maneuver	Executed to correct trajectory error caused by previous maneuvers. Helium leak stopped but pressure below specified level for normal terminal descent

F. Terminal Descent to Touchdown

The terminal-descent operations were initiated at $T + 63{:}45{:}42$ with the performance of the last engineering interrogation. In accordance with an agreement with FPAC, initiation of the first terminal descent maneuver (a roll of +73.9 deg) was delayed until a Canopus error null was observed at $T + 64{:}15{:}14$ (32 min, 37 s prior to predicted retroignition). Similarly, initiation of the second maneuver (a yaw of +119.5 deg) was delayed until $T + 64{:}19{:}20$ when the sun sensor yaw error was crossing its null position. These first two maneuvers (which aligned the retroengine thrust axis in the desired direction) were completed at $T + 64{:}23{:}19$. Since the spacecraft roll orientation that resulted from these first two maneuvers was satisfactory from a RADVS and telecommunication standpoint, there was no need to execute a third attitude maneuver.

The two attitude maneuvers, as well as other preretroignition spacecraft operations [e.g., loading the proper altitude *mark*-to-vernier-ignition delay quantity (12.325 s), establishing retroignition sequence mode to ensure that the desired automatic flight control sequences would occur in response to the altitude radar *mark*, establishing the proper vernier engine thrust level (15-lb total) for the retromotor burn phase, turning on flight control thrust phase power, etc.], were executed on schedule and without any difficulty. In addition, the AMR was turned on at $T + 64{:}42{:}59$ (4 min, 56 s before retroignition or 4 min, 40 s prior to predicted AMR *mark* time) and enabled at $T + 64{:}46{:}00$.

The automatic-descent sequence for vernier ignition, retroignition, and RADVS ON was initiated by the AMR *mark*, the generation of which was confirmed on the ground from computer data system modern data at 00:44:40 GMT ($T + 64{:}47{:}39$). Vernier ignition, retroignition, and RADVS turnon occurred at the proper times.

The preliminary real-time assessment of the actual descent timing with engines turned off automatically by the 13-ft *mark* and a soft landing was verified by the retention of the communications link and continued nominal spacecraft performance, and later by the touchdown strain-gage data. The helium tank pressure and oxidizer tank pressure were only 575 psia at touchdown, with evidence that vernier engine 1 apparently had gone into pressure saturation during the acquisition of the terminal-descent segment.

The touchdown strain-gage data indicated that touchdown occurred at approximately 00:46:44, with leg 1 touching the surface first, followed by the touchdown on legs 2 and 3 at practically the same time. The peak loads experienced by legs 1, 2, and 3 were approximately 1340, 1640, and 1660 lb, respectively. These levels are indicative of a landing velocity of approximately 12 ft/s on a surface with a 7-psi bearing pressure and with a slope of approximately 15 deg. (A preliminary determination of the actual spacecraft attitude on the lunar surface was obtained following sun and earth acquisition by the A/SPP. It was estimated that the attitude of the spacecraft was 19.9 deg, with leg 1 uphill and legs 2 and 3 downhill and at approximately the same level.)

It was noted that although this sequence initiated the doppler steering phase approximately 4 s earlier than normal, it did not begin this phase while the retroengine was still burning (reflecting the results of tests at the AFETR that indicated it would not be feasible to attempt to initiate the doppler steering phase prior to the retroengine burnout due to saturation of the acceleration loop). Three other points of interest regarding this sequence are:

(1) The sequence was based on the normal automatic initiation of the vernier engine ignition, retroengine ignition, and RADVS turnon by the AMR, trigger generated at a slant range of 60 mi from the surface.

(2) The command delay time between the generation of AMR *mark* and vernier engine ignition was increased to adjust the retroengine ignition altitude (and range) to the desired lower values.

(3) The time that the Emergency-AMR-*Mark* command was sent to the spacecraft was significantly delayed from its usual time to ensure that the probability of sending it too soon was negligible.

G. Touchdown to End of Mission

Following touchdown and a positive verification that all spacecraft vernier engines had been turned off, the initial postlanding power shutdown and spacecraft assessment sequence was initiated.

Thrust phase power, RADVS power, and flight control power were commanded to permit an assessment of the landing leg positions. This check clearly indicated that there was no need to command the locking of the landing gear since all leg deflections were less than 0.7 deg.

Following completion of the engineering assessment of the spacecraft, 18 (200-line) TV pictures of excellent quality were taken; the first picture was obtained approximately 1 h, 14 min after touchdown. After these pictures were obtained, the alpha scattering experiment was turned on. The spacecraft condition was assessed and found to be normal.

The A/SPP earth-search sequence was initiated at 02:58:15 GMT on September 11. The earth search was terminated at 03:55:30, and the A/SPP sun acquisition sequence was initiated. This sequence was successfully completed; the sun was acquired at 04:10:23. With the sun direction established, the A/SPP earth search was resumed, and the earth was acquired at 05:29. The spacecraft was then prepared for obtaining high-resolution TV pictures, and the first 600-line picture was obtained at approximately 4 h, 51 min after touchdown (05:40 GMT).

Figure 32 gives a very comprehensive picture of station tracking periods including commands sent, TV pictures received, length of track, and total hours of alpha scattering data received.

H. Summary of Deep Space Station Operations

The following pages comprise a summary of Deep Space Station operations for the *Surveyor V* Mission. Table 21 is included in the description of the less self-explanatory columns of Table 22 which follows.

1. Tracking, ground mode and total time. These columns list the duration (in hours, minutes, and seconds) of each tracking ground mode. The ground mode indications, numerals 0–5, are defined in Table 21. At the end of each station entry is the total tracking time in all modes.

Table 21. 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

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

3. TV pictures received: commanded, noncommanded. Unless otherwise indicated, these figures represent 600-line TV pictures received by a station while the spacecraft was under its command. Noncommanded pictures are those received by a station while the spacecraft was commanded by another station.

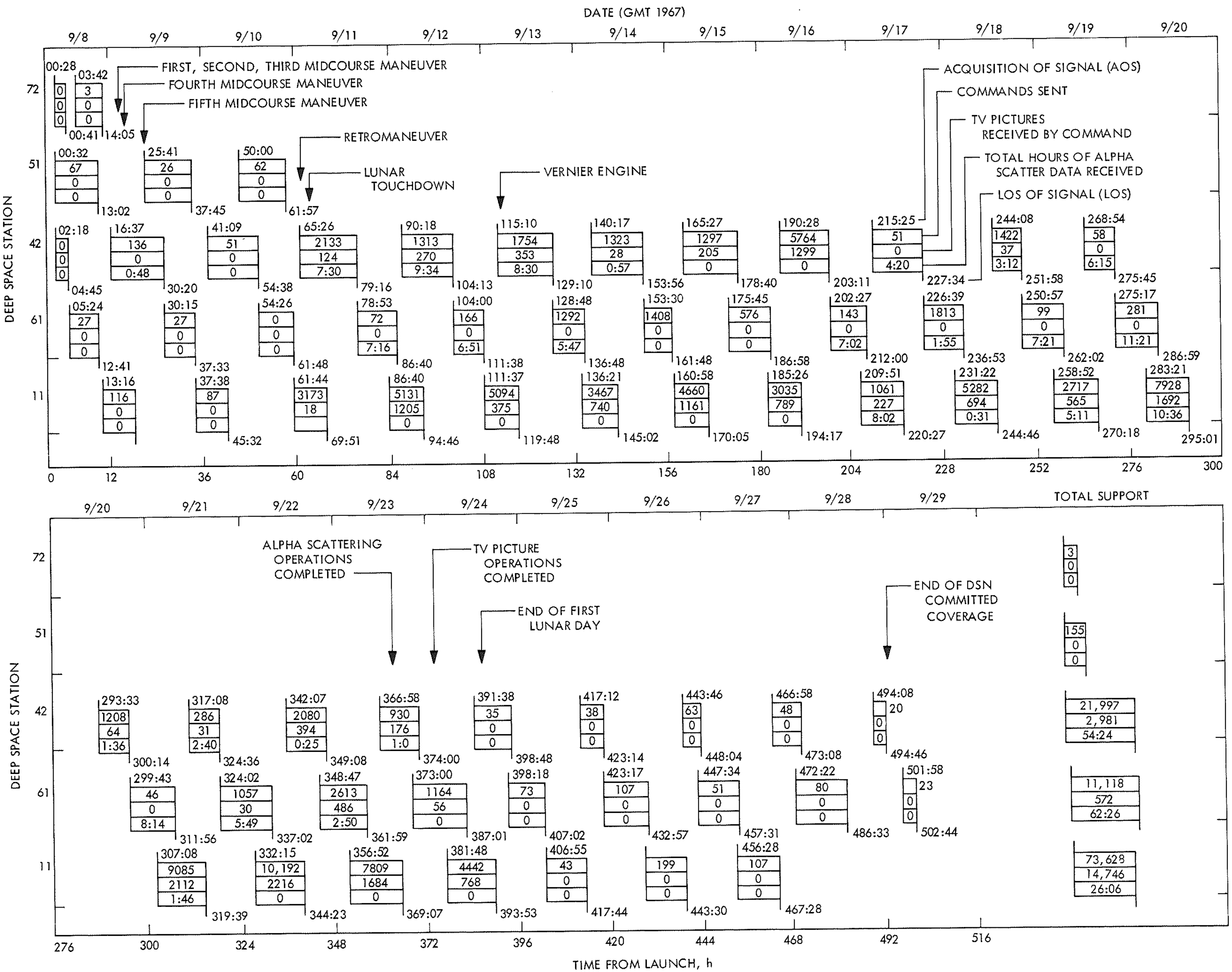


Fig. 32. Station tracking periods—first lunar day

Table 22. Summary of Deep Space Station operations for the *Surveyor V* Mission

DSS	Time from acquisition to end of track, GMT		Tracking		Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received		Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time			Commanded	Noncommanded	
					Launch				
71	251	07:57:01 08:01:40	1 Total	00:04:39 ——— 00:04:39	71.0 156.0	0	0	0	Liftoff: 07:57:01.2 GMT Launch azimuth: 079.517 deg
72	251	08:20:00 08:33:00	1 3 Total	00:08:53 00:04:07 00:13:00	128.0 148.0	0	0	0	Sanborn multimarker failure. Function being performed on two-channel recorder
					Pass 1—launch pass				
51	251	08:24:25 20:54:38	1 2 3 Total	00:04:18 09:01:06 03:23:13 12:28:37	95.0 147.0	67	0	0	Tape speed too fast because pinch roller too tight. Adjusted during countdown Leaking pipe in hydromechanical building. Pipe replaced during countdown Pen 7 broken on Sanborn recorder Computer (910) would not load program; switched to 920. The 910 was out at 04:20; operational at 06:00 First two-way lock on a sidelobe after initial high power off Spacecraft transferred to DSS 42 at 10:30, DSS 61 at 13:30, and DSS 72 at 20:30
42	251	09:10:11 12:37:32	2 3 Total	02:00:00 02:27:21 04:27:21	119.8 137.3	0	0	0	At 04:20, high-speed motor on antenna had broken shaft. Motor repaired at 06:01 From acquisition at 09:10:11 to 09:25, PCM data from CDC to recorders lost due to patch error in CDC Galvanometer lamp lost intensity during track. Lamp replaced at 11:26:40 No angle channels on recorder after galvanometer lamp change. During postcalibrations they reappeared, possibly after opening and closing patch panel Spacecraft transferred to DSS 51 at 11:30
72	251	11:34:19 21:57:00	2 3 Total	01:00:02 09:22:39 10:22:41	122.0 163.0	3	0	0	Marker pens on Sanborn recorder failed in azimuth and elevation error channels on receivers 1 and 2. With one replacement on station, replaced pen in receiver 1 elevation error channel Dropped lock at 11:46 to check if on sideband. Tried to get a better signal level

[a]Ground mode; refer to Table 21.

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT		Tracking		Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received		Significant events, equipment failures and anomalies
	Day of year	*Time*	Ground mode	Total time			Com-manded	Noncom-manded	
Pass 1 (contd)									
72 (contd)									At 20:36, station permitted to tune transmitter down since it was approaching saturation Spacecraft transferred to DSS 11 at 21:30
61	251	13:15:49 20:33:11	2 3 Total	01:52:34 05:09:40 07:02:14	116.4 151.0	27	0	0	Spacecraft transferred to DSS 51 at 15:30
11	251 252	21:08:08 04:46:00	2 3 Total	06:59:42 00:37:50 07:37:32	116.6 156.9	116	0	0	First midcourse maneuver accomplished at 01:45:02 Tracking data handling processor sent 1-s sample instead of 10-s sample to SFOF. Operator corrected problem Telemetry data indicated helium pressure leakage shortly after midcourse correction Second, third, and fourth (with three vernier engine firings) midcourse maneuvers accomplished in attempt to reseat helium pressure regulator FR-800 playback noisy between 200-line TV video frames Fuse in power supply failed to blow and caused computer failure Spacecraft transferred to DSS 42 at 04:30
14	251 252	21:32:55 04:41:17	3 Total	*07:08:22* ——— 07:08:22	*109.0* 129.5	*0*	0	0	*Provided backup telemetry recording for DSS 11*
Pass 2									
42	252	00:29:00 14:12:13	1 2 3 Total	01:07:46 06:22:14 06:13:13 13:43:13	117.9 140.1	136	0	0	Faulty spacecraft automatic gain control and static phase error on station manager's console in mode 4. No similar display in mode 1 After transfer, station was not two-way from 04:30 to 05:39 due to operator error and nonavailability of automatic gain control and static phase error displays on station manager's console. Accomplished fifth midcourse maneuver Spacecraft transfer to DSS 51 occurred at 12:00
51	252	09:33:21 21:37:20	2 3 Total	06:05:04 05:58:55 12:03:59	138.0 153.0	26	0	0	No static phase error recorded during precalibrations due to operator error Poor response at FR-1400B due to worn heads Tracking data handling punch 1 failed at 08:40. Punch assembly changed

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT		Tracking		Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received		Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode	Total time			Commanded	Noncommanded	
Pass 2 (contd)									
51 (contd)									910 hardware problem. At 13:10, the 920 computer brought on line with *Surveyor* on-site computer program with marked improvement in high-speed data At 21:25, the power supply to the digital clocks was inadvertently kicked off Spacecraft transferred to DSS 61 at 16:50 and DSS 11 at 21:35
61	252	14:07:13 21:25:02	2 3 Total	03:30:02 03:47:47 07:17:49	135.0 139.0	27	0	0	Spacecraft transferred to DSS 51 at 20:20
11	252 253	21:30:25 05:24:00	2 3 Total	05:25:02 02:28:33 07:53:35	122.0 152.6	87	0	0	At 23:30, when spacecraft was at 4400 bits/s and FEP-4 was entered into telemetry and command processor, a command confirmation problem was noted. Believed to be *Surveyor* on-site computer program problem Tracking and data handling preamble generator not outputting on JPL circuit. Patch was corrected Accomplished vernier engine thrusting and sixth midcourse maneuver Spacecraft transferred to DSS 42 at 03:00
14	252 253	21:31:00 05:13:57	3 Total	07:42:57 07:42:57	125.0 134.0	0	0	0	Backup for DSS 11 telemetry
Pass 3									
42	253	01:01:20 14:30:00	2 3 Total	09:00:00 04:28:40 13:28:40	140.9 141.7	51	0	0	No command link verification from 07:42:56 to 08:15:59 due to failure of command SCO At 12:30, the telemetry and command processor was changed from B to A configuration for check of station manager's console telemetry local display Receivers dropped lock during station transfer to DSS 51 at 11:57:50 Spacecraft transferred to DSS 51 at 12:00
51	253	09:52:37 21:49:38	2 3 Total	09:40:02 02:16:04 11:56:06	140.6 142.1	62	0	0	Unable to load program on 910 computer; 920 used for this pass FR-1400B recorder stopped from 10:07 until 10:08 to clean heads Spacecraft transferred to DSS 11 at 21:40

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT		Tracking		Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received		Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode	Total time			Com-manded	Noncom-manded	
Pass 3 (contd)									
61	253	14:18:20 21:40:06	3 Total	07:21:46 07:21:46	141.0 142.8	0	0	0	
14	253 254	21:35:07 05:34:00	1 3 Total	03:34:00 04:24:53 07:58:53	115.3 144.0	0	0	0	Telemetry backup recording for DSS 11
11	253 254	21:36:33 05:43:56	1 2 3 Total	00:04:48 07:15:04 00:47:31 08:07:23	121.5 144.7	3,173	18[b]	13	Fifty-channel distribution on amplifier failed. Problem believed to be power supply. Bypassed distribution amplifier to temporarily correct problem Transmitter turned on 4 s late in transfer from DSS 51. Downlink acquired 20 s later Tracking data handling processor doppler drops most significant digit intermittently Helium pressure stabilized at 836 psi Accomplished terminal maneuver using an overriding command tape Touchdown at 00:46:45, at 1.50 deg N, 23.19 deg E Spacecraft transfer to DSS 42 at 05:00
Pass 4									
42	254	01:18:00 15:08:45	1 2 3 Total	03:49:48 09:50:00 00:10:57 13:50:45	113.6 167.0	2,133	124	18	Transmitter off for station transfer to DSS 61 at 14:50:02 instead of 15:00. Unscheduled one-way transfer to DSS 61
61	254	14:45:00 22:23:27	1 2 3 Total	00:04:05 07:35:32 00:03:00 07:42:37	118.0 155.0	72	0	0	Station performed standard one-way, and two-way acquisition Lost on-site alpha scattering accumulation record 22 due to switching transient break point 3. Cause unknown Station noted RF interference on spectrum analyzer when *Lunar Orbiter* spacecraft traveling-wave tube amplifier on. Checks were run to determine effects on data. No apparent ill effects noted Necessary at end of pass for station to replay tracking data handling, command confirmation, and on-site alpha scattering data Spacecraft transfer to DSS 11 at 22:32:27
11	254	22:32:16	1	00:04:48	94.1	5,131	1205	0	Tracking data handling doppler most significant digit read zero. Replaced card A26

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT		Tracking		Ground-received signal level, —dBmW (max, min)	Total commands sent	TV pictures received		Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode	Total time			Commanded	Noncommanded	
Pass 4 (contd)									
11 (contd)	255	06:38:46	2 3 Total	07:47:43 00:13:46 08:06:17	129.1				Fifty-channel timing distribution amplifier bypassed Spacecraft transfer to DSS 42 at 06:25
Pass 5									
42	255	02:10:00 16:05:00	3 4 Total	04:20:00 09:35:00 13:55:00	95.5 118.9	1,313	270	912	Change in signal-to-noise ratio of wideband TV receiver 1 due to *Lunar Orbiter*, which was commanded to high power at 04:13:58 and to low power at 04:56:37, when interference stopped Repeated again when *Lunar Orbiter* again in view at 08:39 Telemetry and command processor B failed due to power unit fuse +25 V Spacecraft transferred to DSS 61 at 16:00
61	255	15:53:43 23:31:10	1 2 Total	00:06:17 07:31:10 07:37:27	118.7 119.1	166	0	0	FR-800 frequency converter was down from 13:30 until 23:30 due to a loose solder connection in transformer. This loose connection also caused failures in power transistors and zener diodes in the same circuit Station transmitter off at 23:31:10
11	255 256	23:29:31 07:40:00	1 2 3 Total	07:35:39 00:33:14 00:01:36 08:10:29	96.6 148.1	5,094	375	0	Fifty-channel timing distribution amplifier intermittent. System operational at rise In two-way at 23:33:17, low on horizon CDC command generator elapsed time meter malfunctioned. Replaced meter Static firing of spacecraft vernier engines at 05:38:05 Spacecraft transfer to DSS 42 at 07:10
14	256	03:45:00 06:24:00	3 Total	02:39:00 02:39:00	92.0 138.5	0	0	0	Monitored static firing of spacecraft vernier engines
Pass 6									
42	256	03:02:00 17:02:00	1 2 3 4 Total	04:10:00 05:28:00 00:06:00 04:16:00 14:00:00	99.0 145.1	1,754	353	111	During data transfer test, incorrect commands were being printed in the CDC, due to loose patchboard Alpha scattering accumulation, started at 10:26, appeared to be lost as tape was writing continuous errors. Program loop was broken by switching tape deck from address BM3 address 2. Cleaned tape heads and able to recall accumulation Spacecraft transfer to DSS 61 at 16:55

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT: Day of year	Time from acquisition to end of track, GMT: Time	Tracking: Ground mode	Tracking: Total time	Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received: Commanded	TV pictures received: Noncommanded	Significant events, equipment failures and anomalies
					Pass 6 (contd)				
61	256 257	16:40:13 00:40:58	2 3 Total	07:25:41 00:35:04 08:00:45	118.7 144.8	1,292	0	0	Spacecraft transfer to DSS 11 at 00:25
11	257	00:13:00 08:54:00	1 2 Total	08:10:37 00:30:23 08:41:00	96.9 136.6	3,467	740	0	Fifty-channel distribution amplifier intermittent Tearing of trailing edge of video is occurring 40% of the time on the on-site recorder Spacecraft transfer to DSS 42 at 07:35
					Pass 7				
42	257	04:09:00 17:48:00	0 1 3 4 Total	05:49:00 03:26:00 00:17:00 04:07:00 13:39:00	111.5 136.9	1,323	281	359	A large number of TV frames processed by CDC from start of pass until 06:15 had loss of horizontal sync on bottom of picture. Problem corrected by readjusting sync lever on video processor Commands 0232 at 11:19 and 0506 at 11:19:09 not on command confirmation due to replaying tape at that time Spacecraft transferred to DSS 61 at 17:30
61	257 258	17:22:00 01:40:00	0 2 3 Total	06:12:14 01:20:16 00:45:30 08:18:00	111.3 136.0	1,408	0	23	FR-800 recorder has high noise level during playback. Faulty cable harness suspected Spacecraft shut down for majority of pass to cool down Spacecraft transfer to DSS 11 at 01:00
11	258	00:50:05 09:57:00	1 4 Total	00:46:53 08:20:02 09:06:55	116.5 135.0	4,660	1161	205	Replaced FR-1400B record head which failed Replaced defective tracking data handling preamble generator Spacecraft transfer to DSS 42 at 09:20
					Pass 8				
42	258	05:19:00 18:32:00	0 1 3 4 Total	01:43:00 04:01:00 00:16:00 07:13:00 13:13:00	112.7 141.3	1,297	205	581	During data transfer test: (1) Telemetry and command processor B computer would not output telemetry. *Surveyor* on-site computer program loaded on A computer. Replaced B telemetry and command processor CK 53. Operational at 13:32 (2) Telemetry and command processor A had intermittent fault on high-speed data line. Fault traced to bent pins on computer patch board

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT: Day of year	Time from acquisition to end of track, GMT: Time	Tracking: Ground mode	Tracking: Total time	Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received: Commanded	TV pictures received: Noncommanded	Significant events, equipment failures and anomalies
				Pass 8 (contd)					
42 (contd)									(3) FR-800 frequency response out of specification at top end. Also removed take-up motor for demagnetization Spacecraft transfer to DSS 61 at 18:15
61	258 259	17:53:38 02:50:23	0 3 Total	07:40:46 01:15:59 08:56:45	113.7 155.0	576	0	116	FR-800 still intermittent on playback Spacecraft transfer to DSS 11 at 01:30
11	259	11:18:54 11:09:00	1 2 3 Total	06:53:50 01:01:06 01:53:58 09:48:54	116.4 140.0	3,035	789	407	FR-800 female guide failed to close several times during recorder on commands Spacecraft transfer to DSS 42 at 09:15
				Pass 9					
42	259	06:20:00 19:03:00	1 2 3 4 Total	02:55:00 02:51:00 00:32:00 06:22:00 12:40:00	116.1 118.8	5,764	1,299	432	CDC faults: (1) Punch 2 unreliable, mechanical misalignment (2) Command generator zero contact bouncing (3) Command rack Franklin printer ribbon broke. No printer record from 09:50 to 10:22. Replaced by spare unit (4) Film recorder not switched on for 93 frames of survey. Commanded from DSS 42 at 12:30 due to operator error in reconfiguring for 600-line TV Telemetry and command processor A typewriter intermittently unserviceable; machine checked out and operating *Surveyor* on-site computer program on processor B problem caused by repeat entry while output was present on W string buffer Spacecraft transfer to DSS 61 at 18:30
61	259 260	18:19:31 03:52:51	1 2 3 Total	00:05:14 07:24:33 02:03:18 09:33:05	118.8 121.5	143	0	0	Lost several accumulations on on-site alpha scattering program; cause unknown Computer B had to reinitialize. Computer A could not call out on-site alpha scattering accumulations for teletype. Lost one accumulation During precalibrations found bad transmitter harmonic filter; replaced it ARC detector interlock tripped; reset Reel 2B of FR-900 threaded on machine wrong; operator error Spacecraft transfer to DSS 11 at 02:00

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT		Tracking		Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received		Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode	Total time			Commanded	Noncommanded	
Pass 9 (contd)									
11	260	01:43:50 12:19:25	1 2 Total	00:35:35 10:00:00 10:35:35	105.5 150.1	1,061	227	0	FR-1400A had excessive dropouts FR-800 reproduce unacceptable; believe record good Spacecraft transfer to DSS 42 at 12:00
Pass 10									
42	260	07:17:00 19:26:00	2 3 Total	06:40:00 05:29:00 12:09:00	121.4 136.0	51	0	0	Telemetry and command processor A typewriter input/output not functioning. Computer swap was at 12:53, putting on-site alpha scattering data in telemetry and command processor B and *Surveyor* on-site computer program on the faulty telemetry and command processor A. Telemetry and command processor A did not operate with *Surveyor* on-site computer program and was shut down for maintenance. Telemetry and command processor A fault cleared at approximately 19:00. *Surveyor* on-site computer program loaded and checked out with SFOF. Oscillator module CX15 in typewriter coupler replaced Intermittent GMT fault on telemetry and command processor B with on-site alpha scattering program loaded. Tens and unit hours incorrect Spacecraft transferred to DSS 61 at 18:40
61	260 261	18:31:10 04:45:40	1 2 3 Total	06:30:34 03:25:29 00:18:27 10:14:30	114.7 163.0	1,813	0	213	Power failed on *Surveyor* on-site computer program computer. Reset, reinitialized and system now operational. Down time from 18:50 to 18:56 Spacecraft transfer to DSS 11 at 02:30
11	261	02:14:47 12:38:00	1 2 3 4 Total	03:07:36 01:13:30 00:14:13 05:45:17 10:20:36	100.9 148.1	5,282	694	0	TV-11 on-site film recorder has ac power oscillations. Dynamic focus deflection driver going into oscillation Received considerable hits on 6-MHz line during video sequence, starting at 03:00 Spacecraft transfer to DSS 42 at 12:00
Pass 11									
42	261	12:00:00 19:50:17	0 2 3 4 Total	00:08:00 03:19:00 00:40:17 03:43:00 07:50:17	117.8 145.0	1,422	37	0	Telemetry and command processor A typewriter output garbling, as per passes 009 and 010. Program reloaded and operational Spacecraft transferred to DSS 61 at 19:10

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT		Tracking		Ground-received signal level, —dBmW (max, min)	Total commands sent	TV pictures received		Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode	Total time			Commanded	Noncommanded	
Pass 11 (contd)									
61	261 262	18:49:55 05:54:00	1 2 3 Total	02:51:36 07:35:36 00:36:53 11:04:05	117.3 159.0	99	0	309	Did not finish telemetry and video precalibrations due to procedural problem in CDC Unable to pullout alpha scattering accumulation 16 from magnetic tape. Attribute to program and human engineering at the telemetry and command processor. Accomplished best-lock frequency measurement FR-800 playback noisy, per pass 007 Spacecraft transferred to DSS 11 at 03:00
11	262	02:44:50 14:10:00	2 3 4 Total	05:33:51 01:10:17 04:40:51 11:24:59	117.9 144.4	2,717	565	0	TV-11 film recorder green at 01:27 Tracking data handling processor, doppler frequency counter, malfunctioning in the most significant digit At 12:10, lost on-site alpha scattering program in telemetry and command processor A Spacecraft transferred to DSS 42 at 13:15
Pass 12									
42	262	12:46:00 19:37:00	2 3 Total	06:15:00 00:36:00 06:51:00	121.6 124.8	58	0	0	Spacecraft transferred to DSS 61 at 19:30
61	262 263	19:09:55 06:52:00	1 2 3 Total	02:58:15 08:00:02 00:43:48 11:42:05	117.1 157.0	281	0	495	Lost alpha scattering accumulation 20; operator error FR-800 playback noisy during countdown Spacecraft transferred to DSS 11 at 03:30
11	263	03:13:34 14:53:00	1 2 3 4 Total	00:03:58 02:54:19 00:30:16 08:09:13 11:37:46	116.4 136.6	7,928	1,692		Preamble generator intermittent Receiver 2 10 MHz to station down-converter intermittent from 04:20 to 04:27. Only FR-900 recorder affected. FR-800 recorded video during this Spacecraft transferred to DSS 42 at 14:40
Pass 13									
42	263	13:27:20 20:06:00	1 2 3	00:16:00 01:11:30 01:12:40	095.2 128.3	1,200	64	0	FR-1400B stretching tape. Shutdown at 16:01. Transducer voltage readjusted. Operational at 16:07 Transmitter trip due to ac overload; trip reset and transmitter operable

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT: Day of year	Time from acquisition to end of track, GMT: Time	Tracking: Ground mode	Tracking: Total time	Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received: Commanded	TV pictures received: Noncommanded	Significant events, equipment failures and anomalies
Pass 13 (contd)									
42 (contd)			4 Total	03:58:30 06:38:40					CDC command printer sticking when printing figure 5 Due to operator error, command 1100 was sent four times instead of command 0404 four times Spacecraft transferred to DSS 61 at 19:50
61	263 264	19:35:19 07:48:00	1 2 3 Total	04:28:23 07:39:30 00:04:48 12:12:41	119.6 120.5	46	0	667	FR-900 noisy Accomplished best-lock frequency measurement from 20:19:35 to 20:35:07 Spacecraft transferred to DSS 11 at 03:45
11	264	03:35:42 15:31:40	1 2 3 4 Total	00:07:35 01:44:18 00:22:03 09:40:18 11:54:14	116.6 148.4	9,085	2,112	0	At 07:50, camera reel tension spring broke; old spring temporarily repaired; camera back in service Tracking data handling VCO counter printout occasionally in error, jumping as much as 20 counts At 09:20, loose pinch roller on FR-900 recorder; adjusted and operational at 09:30 Spacecraft transferred to DSS 42 at 15:20
Pass 14									
42	264	13:00:00 20:28:00	1 2 3 4 Total	00:39:00 04:04:00 01:59:00 00:46:00 07:28:00	113.8 153.0	286	31	133	Spacecraft transferred to DSS 61 at 20:10
61	264 265	19:54:00 08:54:00	1 2 3 Total	05:58:22 06:45:38 00:16:00 13:00:00	110.5 161.0	1,057	30	784	Antenna clutch sticking on declination axis, north side; cleaned and adjusted; system operational Bypassing 10-MHz signal amplifier between down converter and FR-900 recorder. FR-900 green for video *Surveyor* on-site computer program version 6 in computer A would not accept instructions from typewriter. Program reloaded and ran successfully. Down time 3 min Illegal command 3232 sent at 22:32:38 instead of command 0232. Correct command transmitted at 22:33:17 Spacecraft transferred to DSS 11 at 04:15

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT		Tracking		Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received		Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode	Total time			Commanded	Noncommanded	
Pass 14 (contd)									
11	265	04:07:47 16:15:00	1 2 3 4 Total	02:07:18 00:34:14 00:21:13 08:48:23 11:51:08	115.2 144.0	10,192	2,216	20	Tracking data handling preamble generator out. Will be sending preambles manually Spacecraft transferred to DSS 42 at 16:00
Pass 15									
42	265	13:59:00 21:00:00	1 2 3 4 Total	01:49:00 01:26:00 00:28:00 03:18:00 07:01:00	115.5 122.7	2,080	394	392	FR-800 down converter local oscillator frequency equals 14.1 MHz in lieu 14.3 MHz to improve performance Incomplete headers generated on average alarm teletype circuit, telemetry and command processor Retightened loose supply reel on FR-800. TV sequence rerun Best-lock frequency measurement from 16:56 to 17:09 Spacecraft transferred to DSS 61 at 20:50
61	265 266	20:38:11 09:51:00	1 2 3 Total	08:55:23 03:39:17 00:32:57 13:07:37	113.2 123.2	2,613	486	720	Lost 4 or 5 pictures from beginning of second shadow progression due to down converter being patched to wrong receiver from 22:53 to 22:57 Spacecraft transferred to DSS 11 at 05:00
11	266	04:44:44 16:59:00	1 2 3 4 Total	00:46:16 00:25:00 00:08:00 10:53:00 12:12:16	115.4 146.0	7,809	1,684	42	Tracking data handling preamble generator still down TV-11 down converter inoperative; using backup Spacecraft transferred to DSS 42 at 16:20
Pass 16									
42	266	14:55:00 21:52:00	1 2 3 4 Total	01:05:00 01:48:00 00:27:00 03:37:00 06:57:00	124.0	930	176	129	Spacecraft transferred to DSS 61 at 21:45
61	266 267	21:00:30 10:53:00	1 2 3 Total	05:42:36 07:26:16 00:43:38 13:52:30	112.2 118.4	1,164	56	663	Spacecraft transferred to DSS 11 at 05:50

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT		Tracking		Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received		Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode	Total time			Commanded	Noncommanded	
Pass 16 (contd)									
11	267	05:40:37 17:45:20	0 2 3 4 Total	01:09:19 01:23:04 00:14:41 09:15:30 12:02:34	114.8 148.0	4,442	768	0	TV-11 10-MHz/4-MHz down converter still down Preamble generator still down Lunar sunset (sunlight off solar panel) at 11:30 (Sep 24, 1967) Spacecraft transferred to DSS 42 at 17:40
Pass 17									
42	267	15:30:00 22:40:00	1 2 3 4 Total	00:03:00 00:22:00 01:09:00 00:21:00 01:55:00	137.0 139.5	35	0	0	Spacecraft in standby mode from 20:25:00 to 22:11:18
61	267 268	21:34:00 07:18:02	0 2 Total	07:59:04 01:07:40 09:06:44	138.6 141.4	73	0	0	At 17:50, low output of guidance loop power supply during precalibrations. Replaced power supply. No down time
11	268	06:49:45 17:36:23	0 1 4 Total	09:07:47 00:24:21 01:14:30 10:46:38	139.7 141.9	43	0	0	Preamble generator still down. Maser 2 contaminated, down at 20:00 Spacecraft transferred to DSS 42 at 17:12
Pass 18									
42	268	17:04:12 23:06:00	0 1 4 Total	04:45:29 00:13:46 01:02:33 06:01:48	141.1 141.2	38	0	0	Datex timing has intermittent fault on last digit on all readouts Spacecraft transferred to DSS 61 at 23:00
61	268 269	23:00:00 08:49:37	0 1 4 Total	04:48:35 00:29:23 03:51:27 09:09:25	138.8 141.7	107	0	0	During precalibrations, tracking data handling punches had continuous feed causing the punch magnets to burn out. Intermittently bad contact in the record switch on KP-144 control panel cleared at approximately 08:00 Spacecraft transferred to DSS 11 at 07:40
11	269	07:40:00 19:20:02	0 4 Total	07:56:03 03:43:59 11:40:02	140.0 141.5	199	0	0	Preamble generator still down Maser 2 still down Spacecraft transferred to DSS 42 at 19:20

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT: Day of year	Time	Tracking: Ground mode	Total time	Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received: Commanded	Noncommanded	Significant events, equipment failures and anomalies
Pass 19									
42	269	18:38:40 23:56:00	0 1 4 Total	03:02:03 01:22:39 00:32:00 04:56:52	141.0 142.3	63	0	0	Telemetry and command processor A interrupt 5 permanently true Spacecraft transferred to DSS 61 at 23:50
61	269 270	23:26:25 09:23:00	0 1 2 4 Total	07:34:13 00:42:59 00:18:56 00:36:53 09:13:01	139.2 139.8	51	0	0	Spacecraft transferred to DSS 11 at 08:20
11	270	08:20:00 19:20:02	0 1 2 4 Total	08:56:45 00:08:30 01:16:50 00:37:22 10:59:27	138.8 141.6	107	0	0	Maser 2 still inoperative (operational again at 15:00) Spacecraft transferred to DSS 42 at 19:20
Pass 20									
42	270 271	18:50:21 01:00:02	0 1 4 Total	04:52:40 00:22:26 00:47:22 06:02:28	140.6 141.6	48	0	0	Telemetry and command processor A interrupt 5 permanently true (same as pass 19) due to failure of module SK 55 Spacecraft transferred to DSS 61 at 01:00
61	271	00:12:10 14:26:10	0 1 4 Total	11:18:42 00:47:50 02:07:28 14:14:00	136.2 158.0	80	0	0	
Pass 21									
42	271	21:45:00 22:38:00	0 4 Total	00:19:20 00:33:40 00:53:00	140.1 141.4	20	0	0	
61	272	05:50:00 06:36:01	0 4 Total	00:12:54 00:33:07 00:46:01	123.8 123.8	23	0	0	Stopped CEC recorder to release paper Spacecraft shut down for first lunar night at 06:36:01

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT		Tracking		Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received		Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode	Total time			Commanded	Noncommanded	
Pass 2-1—second lunar day									
42	288	08:02:30 17:14:00	0 2 3 4 Total	00:05:04 06:21:13 00:03:58 02:41:15 09:11:30	118.3 150.0	1,594	0	0	During precalibrations, telemetry and command processor B Y-buffer fault. No problem with on-site alpha scattering program No reconstructed PCM recorded for first 2 min of telemetry due to patching error in CDC Maser 1 cooling down Spacecraft transferred to DSS 61 at 17:10
61	288 289	16:56:30 03:49:00	0 2 3 4 Total	00:02:20 09:44:38 00:58:18 00:07:14 10:52:30	114.8 163.4	929	0	20	Spacecraft transferred to DSS 11 at 03:05
11	289	02:50:00 12:01:00	2 3 4 Total	06:00:30 00:30:58 02:25:51 08:56:19	113.6 145.6	694	80	0	No legible video recorded. Cable lid from CDC to received loads down when connected to CDC discriminator and this causes a slower turn around from 600-line TV to PCM mode Spacecraft transferred to DSS 42 at 11:45
Pass 2-2									
42	289	10:47:17 18:22:00	1 2 3 Total	00:08:04 06:21:10 01:04:08 07:33:22	113.7 123.5	181	0	0	Telemetry and command processor B no high-speed data capability. Maser unstable, appears to be warming up. FR-1400 reels 1A and 1B both sent in data packing due to calibrations on 1A Spacecraft transferred to DSS 61 at 18:15
61	289 290	17:20:21 02:30:00	2 3 Total	07:14:02 01:55:37 09:09:39	120.2 124.9	166	0	0	Spacecraft transferred to DSS 61 at 01:30
11	290	01:24:00 11:40:02	0 1 2 3 4 Total	03:08:45 00:10:19 03:22:02 00:05:00 03:04:04 09:50:10	117.2 144.8	1,856	159[c]	0	Pre-pass had no TV countdown per instructions from Space Flight Operations Director Spacecraft transferred to DSS 42 at 11:40
Pass 2-3									
42	290	11:11:20	0	03:53:00	127.0	51	2	0	Maser 1 now cool on ground; awaiting installation in cone

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT		Tracking		Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received		Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode	Total time			Commanded	Noncommanded	
Pass 2-3 (contd)									
42 (contd)		16:40:00	1 4 Total	00:10:52 01:07:00 05:10:52	141.7				Although 200-line TV pictures were received they were a test sequence only (two frames). No magnetic or 35-mm film. Recorders used on advice from mission control View period gap between DSSs 42 and 61
61	290 291	18:53:47 04:56:00	0 1 2 3 4 Total	01:59:28 01:39:05 04:44:03 00:10:58 01:28:39 10:02:13	120.2 141.0	754	4	0	Spacecraft transferred to DSS 11 at 04:45
11	291	04:15:00 13:39:00	0 1 2 3 4 Total	01:33:58 00:15:37 00:09:10 00:16:34 07:08:36 09:23:55	117.3 122.7	1,433	0	0	PC 145 counter bad. No 1- and 10- s tracking data handling sample rates available. No spare on hand Lunar eclipse 07:58–12:59
Pass 2-4									
Honeysuckle Creek, Australia	291	11:05:00 14:31:30	1 Total	03:26:30 03:26:30	119.5 122.0	0	0	0	Tracking in place of DSS 42 prior to *Mariner* Venus 67 encounter
61	291 292	18:06:29 06:33:00	1 2 Total	00:34:21 11:50:39 12:25:00	117.2 143.4	1,106	5	0	Loss of interim monitoring program doppler differences for first 7 h of track. Operator failed to enter all doppler parameters *Mariner* Venus 67 encounter period
Pass 2-5									
61	292 293	18:36:53 07:31:54	0 1 2 Total	01:29:13 00:18:43 11:07:05 12:55:01	115.9 138.9	2,485	6	0	*Mariner* Venus 67 occultation, 17:40–17:55 Interim monitoring program doppler readings extremely high. Unable to monitor in real-time doppler deviation as computed by digital instrumentation system. No data lost Accomplished best-lock frequency measurement *Mariner* Venus 67 encounter period

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT		Tracking		Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received		Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode	Total time			Commanded	Noncommanded	
Pass 2-6									
61	293 294	19:05:00 00:43:00	0 1 2 Total	00:05:01 01:03:14 02:28:26 03:36:41	114.8 117.3	193	4	0	*Mariner* Venus 67 playback period At 22:07:28, interface command 0314 failed to go out. Command confirmation indicated interlock command 3617 only. Retransmitted command 0314 at 22:08:35
11	294	04:08:16 11:30:00	1 2 4 Total	01:50:59 03:30:30 01:54:10 07:15:39	99.2 120.0	947	117	0	Maser 2 down due to a stuck valve at the cross heads Identification clock in video data system of TV-11 had burned out potentiometer Conducted best-lock frequency measurement
14	294	04:08 07:05	1 3 Total	01:12:43 01:17:28 02:30:11	111	0	0	0	Conducted special telemetry test to determine why PCM data received at DSS 14 during terminal descent was unusable by SFOF The 700-Hz tracking bandwidth may be problem, getting intermodulation between tracking bandwidth and spacecraft
Pass 2-7									
42	294	12:19:30 20:00:02	0 2 4 Total	02:04:11 00:53:32 01:07:25 04:05:08	117.8 138.0	392	0	0	Spacecraft transferred to DSS 61 at 20:00
61	294 295	19:33:00 07:34:00	0 2 4 Total	02:28:31 07:06:29 01:54:02 11:29:02	113.9 134.0	1,119	212	0	Station schedule extended to 08:00 to command video due to transmitter problem at DSS 11 Spacecraft transferred to DSS 11 at 07:30
11	295	04:51:35 15:11:00	1 2 3 4 Total	00:40:34 05:49:09 01:08:25 01:14:58 08:53:06	114.0 122.6	63	0	213	Maser 2 still down Transmitter drive bad from 04:00 to 08:45. Problem apparently was a bad cable. Spare cable installed Spacecraft transferred to DSS 42 at 14:50
Pass 2-8									
42	295	13:08:00 21:01:00	1 2 3 4 Total	00:11:12 04:54:48 01:52:58 00:52:24 07:51:22	118.0 123.1	72	0	0	At 16:08:52, transmitter failure due to body flow trip. Suspected cause was air in the line. Maintenance was performed on system earlier in the day Transmitter back on at 16:19:20 Spacecraft transferred to DSS 61 at 20:50

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT: Day of year	Time from acquisition to end of track, GMT: Time	Tracking: Ground mode	Tracking: Total time	Ground-received signal level, —dBmW (max, min)	Total commands sent	TV pictures received: Commanded	TV pictures received: Noncommanded	Significant events, equipment failures and anomalies
Pass 2-8 (contd)									
61	295 296	20:15:20 05:39:35	1 2 3 Total	00:05:30 08:29:03 00:49:42 09:24:15	115.2 137.0	239	0	0	Accomplished best-lock frequency measurement Spacecraft transferred to DSS 11 at 05:25
11	296	05:13:00 15:18:00	1 2 3 4 Total	00:05:16 07:38:16 00:14:50 01:58:54 09:57:16	116.6 121.0	2,009	459	0	Maser 2 still being pumped down Maser 1 failed at approximately 14:46. Signal level dropped to —159.0 dBmW. Station released at 15:18 after bringing DSS 42 up early Spacecraft transferred to DSS 42 at 15:15
Pass 2-9									
42	296	15:01:10 21:52:00	1 2 3 Total	00:47:42 05:36:58 00:25:50 06:50:30	118.5 121.8	48	0	0	Station brought up 1½ h early due to maser failure at DSS 11 Spacecraft transferred to DSS 61 at 21:40
61	296 297	20:59:16 05:41:24	0 1 2 3 4 Total	03:55:44 00:05:00 01:36:43 00:39:44 02:24:57 08:42:08	114.9 139.7	1,087	0	0	Conducted best-lock frequency measurement Lunar sunset (sunlight off the solar panel) occurred at 23:38
11	297	07:00:00 14:23:00	0 1 2 Total	05:49:52 00:31:01 01:02:07 07:23:00	129.0 131.4	40	0	0	Maser 2 operational at 07:00 Conducted best-lock frequency measurement
Pass 2-10									
42	297	18:00:16 22:30:30	0 1 Total	00:02:37 00:43:19 00:45:56	127.5 131.2	42	0	0	FR-1400B motor drive amplifier unusable; motor speed referenced to 60-Hz line Spacecraft interrogations performed at 18:00 and 22:00
61	297 298	22:07:10 09:47:00	0 1 2 3	00:42:15 00:04:36 00:20:41 00:20:44	128.7 131.3	52	0	0	Accomplished best-lock frequency measurement

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT		Tracking		Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received		Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode	Total time			Commanded	Noncommanded	
Pass 2-10 (contd)									
61 (contd)			4 Total	00:11:33 01:39:49					
11	298	11:30:00 12:43:00	0 1 2 Total	00:55:05 00:03:53 00:14:02 01:13:00	130.0	21	0	0	
Pass 2-11									
42	298	16:15:13 20:26:33	1 2 Total	00:07:14 00:15:25 00:22:39	129.5 131.2	34	0	0	Spacecraft interrogations at 16:15 and 20:15
61	299	00:01:00 12:48:45	0 2 Total	00:51:59 01:18:20 02:10:19	127.7 129.2	38	0	0	
Pass 2-12									
42	300	00:23:00 01:05:00	2 Total	00:42:00 00:42:00	129.2 129.3	14	0	0	Antenna immobile from 23:45 to 00:14 due to a circuit breaker trip which supplied 60-Hz power to antenna clutches and brakes
11	300	15:06:38 16:08:04	0 1 2 Total	00:16:12 00:02:33 00:35:12 00:53:57	127.0 129.3	17	0	0	Station had difficulty locking receiver when narrow band voltage controlled crystal oscillator turned off during shutdown procedure. Narrowband oscillator turned back on, receiver relocked. Spacecraft shut down Doppler resolver switch left in times two position
Pass 2-13									
42	300 301	23:54:00 00:38:17	0 1 2 Total	00:14:25 00:03:56 00:25:44 00:44:05	127.8 129.0	11	0	0	Both digital instrumentation system computers are out of service for modification to period register No interim antenna pointing subsystem or interim monitoring program
11	301	14:53:20 16:01:51	0 1 2 Total	00:16:37 00:03:02 00:44:12 01:03:51	130.0 139.5	17	0	0	

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT		Tracking		Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received		Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode	Total time			Commanded	Noncommanded	
					Pass 2-14				
61	302	13:28:10 14:47:45	0 4 Total	00:33:20 00:46:15 01:19:35	136.7 144.5	36	0	0	Doppler resolver out of calibration; using times two mode
					Pass 2-15				
11	303	16:08:37 17:56:26	1 2 Total	00:27:05 01:20:44 01:47:49	130 (approx)	44	0	0	Maser 1 down (contaminated) PC-141 master clock intermittent causing 2-s jump in time SFOF unable to process high-speed data. Data appeared normal leaving DSS 11 Loss of teletype, telemetry, and command confirmation due to communications technician working on new teletype patch panel at DSS 11 Digital instrumentation system interim monitoring program malfunctioned twice at 17:14:00 due to bad doppler magnetic tape
					Pass 2-16				
61	304	11:56:19 13:09:13	0 4 Total	00:12:12 01:00:42 01:12:54	120.4	10	0	0	Maser 2 down for maintenance Doppler resolver inoperative, using times two mode
					Pass 2-17				
61	305	11:51:26 12:19:44	0 4 Total	00:09:53 00:18:25 00:28:18	113.2	22	0	0	Maser 2 down for maintenance Tracking data handling doppler resolver down, using times two doppler mode Second lunar day/night operations concluded
					Pass 3-1—third lunar day				
51	314	11:30:00 18:56:00	0 1 Total	03:05:00 02:03:00 05:08:00		187	0	0	Received *Surveyor VI* noncommand video 11:30–14:26 on receiver 1, pass 4 *Surveyor V* revival attempt unsuccessful
42	314	13:55:00 14:21:00	0 Total	00:26:00 00:26:00		6	0	0	During *Surveyor VI* tracking, pass 4, unable to reacquire *Surveyor V* on receiver 2
61	314	18:50:00 19:06:00	1 Total	00:16:00 00:16:00		0	0	0	During *Surveyor VI* tracking, pass 4, unable to reacquire *Surveyor V* on receiver 2

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT		Tracking		Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received		Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode	Total time			Commanded	Noncommanded	
				Pass 3-2					
51	315	13:30:00 18:34:00 18:45:00 20:00:00	0 1 Total	04:37:41 01:41:19 06:19:00		430	0	0	*Surveyor VI*, pass 5 on receiver 1 from 13:30 to 14:14:11 and 18:45 to 19:06 *Surveyor V* revival unsuccessful
42	315	13:48:14 13:56:00	0 Total	00:07:46 00:07:46		13	0	0	During *Surveyor VI* tracking, pass 5, unsuccessful revival of *Surveyor V* on receiver 2
61	315	20:04:01 20:09:20	0 Total	00:05:19 00:05:19		0	0	0	During *Surveyor VI* tracking pass 5, unable to reacquire *Surveyor V* on receiver 2
				Pass 3-3					
61	316	20:01:46 21:59:40	0 Total	01:57:54 01:57:54		263	0	0	During *Surveyor VI* tracking, pass 6, unsuccessful *Surveyor V* revival attempt
				Pass 3-4					
61	317	20:09:35 22:07:00	0 Total	01:57:25 01:57:25		100	0	0	During *Surveyor VI* tracking, pass 7, unsuccessful *Surveyor V* contact
				Pass 3-5					
61	318	21:06:00 21:32:38 21:38:08 23:21:00	0 Total	02:09:30 02:09:30		51	0	0	During *Surveyor VI* tracking, pass 8, unsuccessful *Surveyor V* contact
				Pass 3-10					
42	323	15:12:42 15:48:00	0 Total	00:35:18 00:35:18		28	0	0	During *Surveyor VI* tracking, pass 13, unsuccessful *Surveyor V* contact

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT		Tracking		Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received		Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode	Total *time*			Com-manded	Noncom-manded	
Pass 4-1—fourth lunar day									
11	348	05:45:00 11:14:00	4 Total	05:28:50 05:28:50	126.0 160.0	242	0	0	Video received; all dark. No usable data from telemetry modes 1–6
14	348	08:05:30 10:30:00	3 Total	02:24:30 02:24:30	093.0 111.0	0	0	0	
42	348	09:05:00 14:06:00	2 3 4 Total	00:57:00 02:07:00 01:57:00 05:01:00	096.0 149.0	526	0	0	Telemetry and command processor B—on-site alpha scattering program incorrect timing, tens and units hours intermittent *Surveyor VI* unsuccessful revival attempt, pass 2-2
61	348	21:40:30 23:24:20	4 Total	01:43:50 01:43:50	113.8 148.7	1,689	0	0	Engineering commutator cycled on *Surveyor V*, but no good engineering data were obtained *Surveyor VI* successful revival attempt, pass 2-2
Pass 4-2									
11	349	01:47:02 09:07:09	1 2 4 Total	02:24:58 01:05:20 02:42:14 06:12:32	101.0 143.7	607	62[d]	0	Maser 1 down. TV-11 on-site recorder down. Operational at 18:40
42	349	09:02:00 17:04:00	1 2 3 Total	00:04:00 07:49:00 00:09:00 08:02:00	119.7 122.8	108	0	0	Telemetry and command processor B now serviceable Accomplished best-lock frequency measurements
61	349 350	17:01:00 06:21:00	0 2 Total	00:03:23 13:16:37 13:20:00	119.7 127.2	254	0	0	Computer typewriter failure. Replaced typewriter and reloaded program. Effect: loss of doppler and switch positions readout on printout and magnetic tape
Pass 4-3									
11	350								Station released from tracking this pass due to snow and ice conditions
42	350	10:00:00 17:45:00	1 2 Total	00:12:00 07:33:00 07:45:00	125.3 129.5	158	0	0	

[d]200-line TV pictures only.

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT: Day of year	Time from acquisition to end of track, GMT: Time	Tracking: Ground mode	Tracking: Total time	Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received: Commanded	TV pictures received: Noncommanded	Significant events, equipment failures and anomalies
Pass 4-3 (contd)									
61	350 351	21:30:00 02:34:00	0 Total	04:04:00 04:04:00	124.5 126.8	616	0	0	*Surveyor VI* revival unsuccessful, pass 2-4
Pass 4-4									
11	351	01:59:48 05:20:00	0 1 4 Total	01:28:45 01:48:57 00:41:15 03:58:57	123.6 125.8	132	2[d]	0	Maser 1 inoperative. Control console intercom and command network inoperative After switching from spacecraft low to high power at 03:40, the downlink was lost
42	351	13:10:00 16:07:00	0 Total	02:58:00 02:58:00		280	0	0	Unsuccessful contact with *Surveyor V* *Surveyor VI* unsuccessful revival attempt, pass 2-5
61	351 352	22:06:15 01:42:02	0 Total	03:35:47 03:35:47		221	0	0	No contact with *Surveyor V* *Surveyor VI* revival attempt unsuccessful, pass 2-5
Pass 4-5									
61	352	19:00:57 21:43:42	0 Total	02:42:45 02:42:45		221	0	0	No contact with *Surveyor V* *Surveyor VI* attempt unsuccessful, pass 2-6
Pass 5-1—fifth lunar day									
61	016	00:19:00 01:45:00	0 Total	01:26:00 01:26:00		108	0	0	During *Surveyor VII*, pass 9, tracking period, unsuccessful attempt was made to revive *Surveyors V* or *VI*, pass 3-1
11	016	04:44:00 05:44:00	0 Total	01:00:00 01:00:00		112	0	0	During *Surveyor VII*, pass 9, tracking period, unsuccessful attempt to revive *Surveyor I* (lunar day 20), *Surveyor III* (lunar day 9), *Surveyor V* or *VI*, pass 3-1
Pass 6-1—sixth lunar day									
61	043	18:50:00 19:15:00	0 1 Total	00:10:00 00:12:00 00:22:00		4	0	0	Revival attempt for *Surveyors V* and *VI* (pass 4-1) or *Surveyor VII* (pass 2-1) Receiver in lock at 19:00:56 on *Surveyor VII*

[d]200-line TV pictures only.

Table 22 (contd)

DSS	Time from acquisition to end of track, GMT		Tracking		Ground-received signal level, −dBmW (max, min)	Total commands sent	TV pictures received		Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode	Total time			Commanded	Noncommanded	
Pass 6-1 (contd)									
61 (contd)									Unsuccessfully searched from 19:03 to 19:15 on receiver 2 for any other carrier
Pass 6-2									
11	044	07:10:00 08:35:00	0	01:25:00		111	0	0	With *Surveyor VII* in standby mode, pass 2-2, unsuccessful attempt to revive *Surveyor V*
			Total	01:25:00					

Lunar day	Total			
	Commands sent	Commanded TV pictures	Noncommanded TV pictures	Alpha scattering data, h:min
1	104,906	18,052[e]	7744	93:30
2	17,816	1,048[f]	233	24:35
3	1,078	0	0	0
4	5,054	64[g]	0	0
5	220	0	0	0
6	115	0	0	0
Grand totals[h]	129,189	19,164[i]	7977	118:05

[e]Includes 18 (200-line) TV pictures.
[f]Includes 5 (200-line) TV pictures.
[g]200-line TV pictures only.
[h]Total commanded and noncommanded TV pictures 27,141.
[i]Includes 87 (200-line) TV pictures.

I. Station Tracking Summary

1. Deep Space Station 11 (Goldstone). During the mission, *Surveyor V* was tracked by DSS 11 with DSS 14 as backup. A total of 3426 commands were transmitted during the first three view periods. No major anomalies occurred in the ground equipment.

Major mission events occurring at DSS 11 were midcourse maneuvers during the first and second phase passes and terminal descent during the third pass. The midcourse maneuver during pass 2 was an unscheduled event. It was required as a result of a helium leak in the spacecraft which occurred during the first midcourse maneuver.

Initial lunar operations following touchdown showed the posttouchdown spacecraft status to be good and excellent TV pictures were being received.

a. First pass. Surveyor V was acquired by DSS 11 for the first time at 21:10:00 GMT on September 8. The signal level was −151 dBmW. Decommutator lock was achieved at 21:15:53 with a bit rate of 17.2 bits/s and a signal level of −138.4 dBmW. The low bit rate was used so that DSS 72 could receive telemetry with its smaller antenna during a gap between the time of spacecraft set at DSS 51 and rise at DSS 11.

Midcourse maneuver was the significant event scheduled for this pass. It was successfully completed at 01:45:17 GMT. Immediately following the first post-midcourse maneuver, it was discovered that there was a helium gas leak in the vernier propulsion system of the spacecraft. Five additional thrusting maneuvers were commanded in an attempt to stop the leak. The leak continued, however, and at the end of the track it appeared that a successful soft landing would not be possible.

The track was terminated at 04:40:00. No problems occurred with the CDC equipment during countdown or track. One hundred and sixty-six commands were transmitted during the first pass.

One operational problem occurred at approximately 01:10. The level of the detected signal from DSS 11 dropped to about 5 mV and remained low for about 5 min. It was necessary to increase the gain in the demodulator from 20 to 40 dB during this time to maintain decommutator lock. The cause of this decrease in signal level was not determined.

b. Second pass. Initial decommutator lock for the second view period at DSS 11 occurred at 12:33:58. Track was terminated at 05:18:00. During this pass, 87 commands were transmitted. Included in the second pass was commanding for another midcourse maneuver. This was done to correct a trajectory error caused by the unscheduled additional thrusting of the first pass and also to lighten the spacecraft by using vernier fuel. The helium leak had stopped but the pressure was below the specified minimum operating level for a normal terminal-descent procedure. In spite of this, the maneuver was successfully completed and a successful soft landing seemed likely.

One problem occurred during countdown for this pass. The TV generator intermittently gave no video output in the 600-line mode. Card 2 was reseated and this appeared to solve the problem. No further CDC problems occurred during countdown or track.

c. Third pass. Third pass acquisition occurred at 21:36:00 and initial decommutator lock was at 21:39:50 GMT. The third pass is always exciting at DSS 11 because of terminal descent. This was particularly true with *Surveyor V* because of the low helium pressure and corresponding nonstandard terminal sequence. The spacecraft, ground equipment, and personnel functioned perfectly through the nonstandard terminal sequence, the successful touchdown, and initial lunar operations.

A total of 3173 commands was sent to the spacecraft from DSS 11 and 31 TV pictures were received during this pass. Of these pictures, 18 were 200-line commanded from DSS 11 and 13 were 600-line commanded from DSS 42. Picture quality was excellent; even the 200-line pictures showed good detail. End of track was at approximately 05:44 GMT with the station configured for television.

Two problems occurred during the CDC countdown. First, the FM calibrator output decreased to zero when the plus deviation switch was depressed. This problem was solved by reseating a card in the unit. The second problem was a recurrence of the TV generator problem reported during the pass 2 countdown. A trouble/failure report was written and a further investigation made. (During a later pass, a faulty circuit was discovered and replaced clearing the problem.) No other CDC problems were encountered during this pass. Table 23 gives a summary of station activities.

Table 23. Summary of DSS 11 activities

Pass	Date (Sep 1967)	Time (GMT), h:min	No. of Commands[a]	Problems
1	8 9	21:10 04:40	166	Low signal level received at demodulator from DSS 11
2	9 10	21:33 05:18	87	Generator failed intermittently. Card 2 reseated
3	10	21:36	3173	Recurrence of TV generator failure, begin troubleshooting
	11	05:44		Loose card in FM calibrator reseated

[a]TV pictures commanded: 18. Thirty-one 200-line and thirteen 600-line pictures were received.

2. *Deep Space Station 42 (Canberra).* During the transit phase, this station had three tracking periods. The station was in two-way lock with the spacecraft for 1 h during the first pass; 7 h, 30 min during the second pass; and 9 h during the third pass. During this phase 186 commands were transmitted to the spacecraft. The spacecraft responded normally to all commands, including a 33-s vernier engine firing.

a. First pass. The spacecraft was acquired at DSS 42 at 09:11 GMT in low power at 1100 bits/s with spacecraft control transferred from DSS 42 at 10:30 GMT. There was no command activity and control was transferred back to DSS 51 at 11:30 GMT. While the spacecraft was in three-way lock, the signal level gradually decreased; at 12:08 it was at −140.2 dBmW with a telemetry bit error rate of 0.009. At 12:19 omniantenna A was selected and the signal level increased to −126.8 dBmW. Tracking ended at 12:37. No commands were transmitted from DSS 42 during this pass.

b. Second pass. The spacecraft was acquired at 00:35 GMT with a signal level of −137.8 dBmW. DSS 42 monitored the midcourse thrusting while in three-way lock.

The maneuver looked very nominal until the helium leak problem occurred at about 02:00 GMT.

The next 4 h were devoted to monitoring the midcourse thrust attempts by DSS 11 to close the helium valve. Control was transferred from DSS 11 to DSS 42 at 04:30 GMT.

From DSS 42, the spacecraft was commanded through a negative yaw and a negative roll to reacquire the sun and Canopus. Cruise mode was commanded at 05:08 with normal lockons. Engineering interrogations were performed at 05:27 and 06:06 GMT along with various heater control commands.

At 07:50 the spacecraft was commanded to high power, 4400 bits/s in mode 1 in preparation for another midcourse maneuver. The spacecraft was commanded through positive roll and yaw, and the vernier engines fired for 33 s. Thrusting was nominal, and at 08:30 the spacecraft was maneuvered back to the prethrusting attitude. At 08:44 GMT the sun and Canopus were reacquired with cruise mode commanded on.

The spacecraft was commanded back into low power at 1100 bits/s and a three-axis gyro drift check initiated at 09:08 GMT. The bit rate was lowered to 550 bits/s at 09:23 GMT.

A gyro drift check was performed which terminated at 09:57 GMT and an engineering interrogation was performed ending in mode 4 in high power in preparation for turning on the alpha scattering instrument. The alpha scattering sequence was successfully completed at 11:28 GMT and the alpha scattering instrument was commanded off. The spacecraft was commanded to low power at 550 bits/s and an engineering interrogation performed before spacecraft control was transferred to DSS 51 at 12:00 GMT. Tracking was ended at 14:11 GMT.

The total number of commands transmitted to and accepted by the spacecraft during this pass was 136.

c. Third pass. The decommutator was in lock at 01:03 GMT with mode 5, 500-bit/s data. A gyro drift check conducted from DSS 11 was in progress. Spacecraft control was transferred to DSS 42 at 03:00 GMT. The decision to try for a soft landing had been made. The gyro drift check started by DSS 11 was terminated from DSS 42 at 04:33 GMT. Engineering interrogations were performed at 03:16, 04:43, 06:06, 07:09, 08:16, 09:18, 10:17, and 11:38 GMT.

It should be noted that at 08:16, the spacecraft did not respond when command 0232 was transmitted from the command generator. It was discovered that the command SCO 1 had failed. Command SCO 2 was selected and a normal command link was restored. At DSS 42, the command SCO output to the recorders is also patched to a 2.3-kHz CDC discriminator whose output is patched to a channel of the station recorder. A check of this showed that the SCO had suddenly stopped at 07:42:56 GMT.

At 09:25 the bit rate was changed to 137.5 bits/s (on the 3.9-kHz SCO) to get a more accurate reading of the alpha scattering temperatures. The bit rate was returned to 550 bits/s after readings were obtained.

Fifty commands were transmitted to and accepted by the spacecraft (this does not count the command attempted when the SCO was off, as this was not transmitted to the spacecraft).

Spacecraft control was transferred to DSS 51 at 12:00. Tracking ended at 14:30 GMT. Table 24 gives a summary of station activities. There were no CDC equipment problems, but two operational problems occurred during the first pass.

Table 24. Summary of DSS 42 activities

Pass	Date (Sep 1967)	Time (GMT), h:min	No. of commands	Problems
1	8	09:11 12:37	0	No non-return to zero data from decommutator at FR-1400—missing patch
2	9	00:35 12:00	136	Intermittent trace on channel 4—stylus-heater pigtail open. Circuit replaced Decommutator channel 4 gave false readings "4-bit" data, Q14 shorted Decommutator channel 4 gave false readings "2-bit" data, R42 open
3	10	01:03 14:30	50	Command SCO 1—no output

*3. **Deep Space Station 51 (Johannesburg).*** During the launch and transit phase, DSS 51 tracked *Surveyor V* for three passes from initial acquisition at 27 min after launch to approximately 3 h before retroignition on September 10.

The primary function of DSS 51 is initial acquisition, which was accomplished very smoothly. Other important events monitored by DSS 51, but performed by other stations, included star acquisition executed by DSS 61, and alpha scattering calibration executed by DSS 42.

As DSS 51 was not provided with alpha scattering ground equipment, the data analyst and the CDC command engineer developed and fabricated the necessary interface equipment. This was satisfactorily tested as a complete system with JPL prior to the mission.

a. First pass. The spacecraft was acquired by DSS 51 with the acquisition aid antenna as it came over the horizon with receiver 2 in lock at 08:24:25 and decommutator in lock at 08:24:28. There was a slight wait for the spacecraft to appear 10 deg over the horizon. The receiver was then switched to the subcarrier modulator mode and the transmitter switched on at 08:27:45. Two-way acquisition was confirmed via telemetry at 08:29:00 GMT.

The initial commanding sequence began at 08:35:11. As the spacecraft was switched from high to low power, the Deep Space Station received signal strength decreased by 29 dB instead of the normal 20 dB. It was immediately suspected that the antenna was locked onto a sidelobe. The sequence for going from high to low power has a hold after High Voltage Off command to ensure execution of that command before commanding filament power off and transfer switch to low power. During the loss of spacecraft signal, the antenna did not track and was in fact on a sidelobe when the signal came back. The antenna was back on the mainlobe in a few minutes and the commanding sequence continued normally until spacecraft commutator mode 6 was selected.

As the thrust commutator was commanded on and mode 6 data were being received, the computer malfunctioned. This was designated an operational problem with the following cause. The CDC was operating with spacecraft commutator mode 2 data and the I/O operator had started entering the information into the digital instrumentation system for the next spacecraft mode. (The tapes were made up with an illegal character after each mode to speed up entry.) As this tape was loaded into the digital instrumentation system, the CDC locked onto mode 6 data and the I/O W-buffer typewriter started typing out long frame. This tied up the W-buffer so the digital instrumentation system could not output "illegal character" from the entry. As a result, the system was hung up in a subroutine and could not be interrupted by the Y-buffer typewriter to put in mode 6 instructions. Therefore, the *Surveyor* on-site computer program was halted and reloaded. Later analysis revealed this problem could easily be cured by breaking decommutator lock momentarily.

The second operational problem concerned the lack of patching reconstructed PCM data to the tape recorders. At 10:19 GMT, the recorder personnel reported they were not receiving reconstructed PCM data from the CDC. It was immediately obvious in the CDC because the patch cord on the telemetry data patch panel was missing. This is normally checked out during countdown. It is not known why the patch cord was removed or why the recorder personnel did not notice this shortly after acquisition. The patch cord was reinstalled and no further problems occurred.

During this pass several Deep Space Station transfers occurred:

From DSS	To DSS	Time (GMT), h:min
51	42	10:30
42	51	11:30
51	61	13:30
61	51	15:30
51	72	20:30

End of track was at 20:54:30 GMT.

Prior to transfer to DSS 61, it was necessary to switch transmitter B to omniantenna A because of a null on omniantenna B.

During the time DSS 61 was in two-way lock, an engineering interrogation was monitored and a successful automatic star acquisition accomplished.

Other significant command sequences executed during this pass included the following:

(1) Two gyro drift checks.

(2) Connecting solar panel switch on seven times.

(3) One engineering interrogation in mode 4 then back to mode 5.

(4) One bit rate reduction to 137.5 bits/s for transfer to DSS 72.

The communication processor did not work as well as desired. Data were slow getting to the SFOF and, quite often, required new headers, particularly on the command confirmation line.

Sixty-seven commands were transmitted during this pass. The telemetry bit error rate was excessive during the omniantenna B null but was negligible at other times. There were no CDC equipment problems, and the operational problems are reported above.

b. Second pass. Pass 2 is normally quiet at DSS 51 during a *Surveyor* mission, but this time it proved to be quite active. The spacecraft was acquired at 09:34:23 with decommutator lock at 09:35:38 GMT. Station transfers occurring during this pass included:

From DSS	To DSS	Time (GMT), h:min
42	51	12:00
51	61	16:50
61	51	20:20
51	11	21:35

End of track occurred with receiver out of lock at 21:37:20 GMT.

The most significant event during this pass was the alpha scattering calibration which provided an opportunity to check out the fabricated alpha scattering interface equipment while DSS 42 performed the commanding. The backfed command line was quite noisy at the beginning of the operation but gradually improved until it was usable. The first few items of optional sequence 10 were missed due to the poor voice line but the alpha scattering "batches" were correctly accumulated from item 22.0 to item 43.0. Some of the earlier items have partial results. In all, 10 records were written on magnetic tape and then dumped on the computer typewriter after optional sequence 10 was completed and the alpha scattering equipment was turned off. The computer typewriter was manned by the data analyst during the operation. The data were analyzed and the results follow:

(1) No out-of-sync messages were printed on the typewriter. This indicates the locally fabricated equipment was operating correctly.

(2) No entries were found in either the ALPHA-FALSE-PARITY or the PROTON-FALSE-PARITY. The bit error rate, therefore, was very close to zero and the equipment correctly decoded the data and clocked it into the computer.

The results of this operation have shown that DSS 51 is fully capable of supporting any alpha scattering operation.

There was a problem with the high-speed data line during the first portion of the pass. Operations at DSS 51 appeared to be satisfactory but the telemetry processing section at the SFOF could not lock onto the data. Shortly after transfer from DSS 42, after an engineering interrogation when the SFOF could not lock onto DSS 51 data, it was decided to take decommutator 2 from monitoring the tape recorder data and connect it to the modem input. This immediately showed that the digital instrumentation system was faulty as the decommutator could not lock onto the data. Permission was requested and granted to switch to the 920 computer, and this resolved the high-speed data line problems.

The 920 computer had previously been used for alpha scattering data. Assuming there might be some interference, permission was requested during a quiet period to go back to the 910 to prove this out. Investigation showed it to be a definite problem in the 910 and not interference with the on-site alpha scattering program. A switch back to the 920 was made for the remainder of the pass.

Twenty-six commands were transmitted during two-way tracking periods which consisted of engineering interrogations and gyro drift checks. The bit error rate during this pass was negligible. There were no CDC equipment or operational problems during this pass.

c. Third pass. Pass 3 began with spacecraft acquisition at 09:52:37 and decommutator lock at 09:52:53 GMT. During the transfer from DSS 42, both DSSs 42 and 51 receivers lost lock for 4 s. It was noted that DSS 42 still had phase lock on the uplink signal. The transfer was then standard.

Bit error rate during the beginning of the pass was 0.23×10^{-3} but improved to 0.02×10^{-3} about 4 h after acquisition.

Sixty-two commands were transmitted during this pass to perform the following functions:

(1) Seven engineering interrogations of commutator modes 5, 4, 2, and back to 1.

(2) Two gyro drift checks (one in roll only).

(3) Turn compartment A heater on.

(4) Turn compartment C temperature control on.

(5) Execute a 360-deg yaw maneuver (in two steps).

(6) Turn TV camera temperature control on.

(7) Turn alpha scattering heater on.

(8) Commutator change to mode 4 and back to 1.

(9) Commutator change to mode 5 for transfer to DSS 11.

During the station transfer to DSS 11 at 21:40, two-way phase lock was lost when DSS 11 turned on the transmitter 2 s late. Receiver lock was lost during the transfer and again as DSS 11 reacquired two-way lock. End of track occurred when receiver lost lock at 21:49:38 GMT.

The Goldstone command line was then monitored until the spacecraft landed safely, the engineering assessment was completed, and the first TV pictures were received. Table 25 gives a summary of station activities.

Table 25. Summary of DSS 51 activities

Pass	Date (Sep 1967)	Time (GMT), h:min	No. of commands
1	8	08:24 20:54	67
2	9	09:34 21:37	26
3	10	09:52 21:49	62

4. Deep Space Station 61 (Madrid). Three-way tracking was the general rule for DSS 61 during the *Surveyor* V Mission. Tracking and doppler were desired from DSS 51 for this mission because of the far better view angles;

however, telemetry and average alarm data were evidently preferred from DSS 61.

Commanding from DSS 61 involved a star acquisition during the first pass, engineering interrogations during the second, and three-way tracking during the third pass.

During passes 2 and 3, subsequent to the helium pressure difficulty, the average alarm data were reconstituted into engineering units by a special DSS 61 computer program. These engineering units were outputted on the average alarm circuit in place of the normal average alarm data.

Surveyor V transit passes 1 and 2 were conducted in three- and two-way from DSS 61, with a total of 49 commands transmitted to the spacecraft. Transit pass 3 was conducted entirely in three-way lock due to a look angle incompatible with good doppler data. Total tracking time was 21 h, 57 min, of which 5 h, 23 min were two-way. Telemetry data at 4400, 1100, 550, and 137.5 bits/s were successfully processed. There were no operational or equipment problems in the CDC area during the *Surveyor V* Mission.

a. First pass. Tracking began 5 h, 19 min after launch at 13:16:01 and lasted for 7 h, 17 min, ending with loss of signal at 20:33 GMT. The spacecraft was acquired in commutator mode 5 (1100 bits/s) at a signal level of −126 dBmW.

One engineering interrogation was performed, cycling the commutators through modes 4, 2, and 1, and remaining in mode 1 for star mapping and acquisition. A star map was generated with transmitter B on high power, using omniantenna B, and with a bit rate of 4400 bits/s. The decommutator lost lock several times during the mapping exercise because of spacecraft antenna nulls. Signal strength dropped to as low as −160 dBmW. After one complete revolution, star acquisition was commanded, and the spacecraft automatically locked onto Canopus at 14:28 GMT. The received signal strength stabilized to −113.2 dBmW on omniantenna B, an improvement of 20 dBmW over the pre-Canopus acquisition level. A report of received signal strength vs time in 10-s intervals was generated and transmitted to the SFOF. After star acquisition, the spacecraft was returned to mode 5 (1100 bits/s) transmitter B low power. The spacecraft solar panel switch was commanded on twice during the two-way track, once at 14:02 and again at 15:08 GMT. Twenty-seven commands were transmitted to the spacecraft. The first pass ended with the spacecraft bit rate at 137.5 bits/s, and DSS 61 in three-way lock with DSS 72.

b. Second pass. The second pass began with an acquisition time of 14:07 with received signal strength at −138 dBmW. The spacecraft was in commutator mode 1 at 550 bits/s. After acquisition, DSS 51 was in two-way lock, and DSS 61 in three-way lock. Mode 1 was retained during most of the pass because it was desired to monitor flight control data closely, specifically the helium pressure sensor.

During 3½ h of two-way tracking, 22 commands were transmitted. Periodic assessments of commutator modes 1, 2, and 5 were performed, and gyro drift checks were started and terminated. Transfer to DSS 61 from DSS 51 occurred at 16:50. Transfer to DSS 51 was at 20:20 and the pass ended at 21:25 GMT. Total tracking time was 7 h, 18 min.

c. Third pass. The entire pass was in the three-way mode. Two-way tracking was avoided because the look angle would result in poor doppler data. Acquisition was at 14:18, and the pass ended at 21:40 GMT. Received signal throughout the pass was −143 to −144 dBmW. Spacecraft bit rate was 550 bits/s. Total tracking time was 7 h, 22 min. At approximately 00:46, the terminal-descent phase was monitored on the command backfeed. Table 26 gives a summary of station activities.

Table 26. Summary of DSS 61 activities

Pass	Date (Sep 1967)	Time (GMT), h:min	No. of commands
1	8	13:16 20:33	27
2	9	14:07 21:25	22
3	10	14:18 21:40	0

5. Deep Space Station 71 (Cape Kennedy). The Cape Kennedy support for *Surveyor V* consisted of a Deep Space Station–spacecraft compatibility test, an operational readiness test, a spacecraft prelaunch countdown phase, and a postlaunch phase lasting through approximately the first 40 min of the mission.

The purpose of the Deep Space Station–spacecraft compatibility test (performed adjacent to the joint flight acceptance composite test area) was to verify the ability of the Deep Space Network to support the mission. Command, telemetry, and TV interfaces were exercised via the RF link.

The ORT consisted of processing simulated spacecraft data received: (1) prior to $T-5$ min from JPL routed via building AO, and (2) from $T-5$ to $T+40$ min from KSC. Received data in both cases were 550-bit/s PCM data, which were fed directly into the CDC decommutator. The data were then outputted in the normal manner back to the SFOF via teletype and the high-speed data line.

During the prelaunch countdown, spacecraft data were received via the RF link. At $T-5$ min, the data source was switched to 550-bit/s PCM data from KSC. The KSC data consisted of that from various AFETR tracking stations, including *Centaur* telemetry prior to liftoff. The KSC data were received until approximately 40 min after launch.

At approximately $T-5$ min the antenna was optically aligned on the spacecraft and the receiver was locked on the spacecraft transmitter during the launch until visibility was lost. This served as a backup to the KSC data source.

The only DSS 71 view period was from prelaunch through $T+42$ min. The only commitment of the CDC at DSS 71 during this period was to patch the applicable data source into the decommutator and to keep the decommutator mode select switch compatible with spacecraft modes. Due to the limited number of decommutator patchboards and telemetry overlays available, only a limited number of spacecraft signals could be monitored in real-time at the telemetry display console. Average alarm data were not available in the CDC area and entries were not under the cognizance of Hughes on-site personnel.

During the prelaunch spacecraft countdown, data quality being processed by DSS 71 was reported as being of poor quality. The station was requested to switch to the backup telemetry and command processor. This cleared the problem at the SFOF, although all available indications at the station were that the data were satisfactory prior to switching computers. An attempt to reconstruct the problem after launch failed to clarify the exact nature of problem.

6. Deep Space Station 72 (Ascension Island). Ascension Island (DSS 72) was committed to back up DSS 51 for *Surveyor V*. The launch characteristics gave two view periods separated by approximately 3 h. Initial spacecraft acquisition was at 08:20. Decommutator lock was maintained from 08:21 to 08:27 GMT. Loss of lock occurred at 08:31:55, ending the first pass.

The second pass acquisition occurred at 11:34:19. Signal level was below decommutator threshold; therefore only intermittent lock could be maintained and no useful data were obtained. At 20:18, DSS 51 commanded the spacecraft to 137.5 bits/s and decommutator lock was obtained at 20:18:40 GMT. However, the bit error rate was high. At 20:30 the spacecraft was transferred to DSS 72 from DSS 51 to cover the 18-min view gap between DSS 51 and DSS 11. Due to the high bit error rate, the spacecraft was commanded to 17.2 bits/s and remained in this configuration for the duration of the pass. At 21:30 the spacecraft was transferred to DSS 11. Tracking ended at 21:57, at which time the station was released.

No CDC anomalies occurred during the period of DSS 72 participation. Table 27 gives a summary of station activities.

Table 27. Summary of DSS 72 activities

Pass	Date (Sep 1967)	Time (GMT), h:min	No. of commands
1	8	08:20 08:31	0
2	8	11:34 21:57	3

a. First pass. The launch azimuth of 79.5 deg afforded two view periods for DSS 72. Acquisition of the spacecraft for the first pass occurred at 08:20 with a signal level of −138 dBmW at 08:21:22. Decommutator lock was obtained at 08:21:28 and maintained until 08:27:10, at which time the signal dropped below threshold. Receivers were out of lock at 08:31:55. The antenna elevation during this period was maintained at +10 deg while the spacecraft elevation remained below this value.

b. Second pass. At 11:34:19, after a lapse of approximately 3 h, the spacecraft was reacquired. Signal level was below decommutator threshold. The received signal remained below decommutator threshold until 20:18, at which time the bit rate was reduced to 137.5 bits/s by DSS 51. Intermittent decommutator lock was observed during this period, however, no valid data could be obtained because of the high bit error rate. After the bit rate change, decommutator lock was accomplished at 20:30, station transfer from DSS 51 to DSS 72 was completed. Received signal level was at that time -145 dBmW and a bit error rate of 0.24×10^{-3} was measured. At 20:43, the spacecraft was commanded to 17.2 bits/s, after which good decommutator lock was maintained with a zero bit error rate. With the bit rate change, the signal level dropped to -149 dBmW. At 21:27:23 the decommutator dropped lock and at 21:30 the spacecraft was transferred to DSS 11. At 21:57, DSS 72 was relieved of further tracking commitments. A total of three commands and modulation interrupts were transmitted during the second view period.

VI. *Surveyor V* Tracking and Data System Performance Evaluation

The *Surveyor* V Mission culminated in a successful soft landing in the Sea of Tranquility. The only serious problem was a leak from the helium tank, discussed in Sections II and V-E of this report. The performance of the AFETR, the MSFN, and the DSN is evaluated in this section.

A. Air Force Eastern Test Range

The AFETR coverage requirements are detailed in Section III-B. A summary of AFETR coverage is given in Fig. 33.

1. Tracking. The range safety impact prediction plot became erratic at approximately $T + 8$ 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 FPS-16 radar at CKAFS experienced a 13-s dropout at $T + 464$ s; however, this occurred 114 s after the end of their estimated coverage interval. Following 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 $T + 579$ to $T + 600$ s, then provided data until loss of signal at $T + 675$ s.

Redundant data from other stations were provided during both of the above dropout periods. Figure 34 shows both the estimated and actual C-band tracking coverage performed at each station.

The mode IV radars 1.1 and 1.2 did not meet range safety commitments due to signal dropouts from $T + 71$ to $T + 91$ s on the 1.1 radar, and $T + 72$ to $T + 83$ s on the 1.2 radar. The radars operated satisfactorily and the cause of the dropouts is not known at this time.

The 7.18 radar did not track due to an apparent acquisition problem with the radar target acquisition system. At $T = 0$, the radar was remotely commanded in azimuth and range to the incoming acquisition from Station 1 and all appeared normal. The expected coverage interval for this radar was from $T + 243$ to $T + 568$ s. At $T + 60$ s, the range jumped nearly 6×10^5 yards. Acquisition data from Station 3 appeared to be identical to that from Station 1.

Since radar target acquisition data were not valid, manual look angles were selected. Returns were seen long enough to get phased and separated, command on the transmitter, and confirm interrogation, but the target disappeared before the range operator could lock onto it.

Computer diagnostics were run immediately after the test but the trouble could not be isolated. Additional checks were run with the help of Cape Kennedy but the problem did not recur.

2. Telemetry. The requirements for class I VHF and S-band telemetry were satisfied. Antigua provided data beyond its estimate due to atmospheric ducting of the signal.

The VHF telemetry receive and record data met or exceeded the expected coverages. The real-time transmission of data allowed a real-time assessment of Launch Vehicle System performance. The data received by the aircraft were noisy, but not unusable. The flight azimuth flown was not one for which the aircraft had actual requirements. Figure 35 shows the VHF telemetry coverage.

Surveyor S-band telemetry was received, recorded, and retransmitted by the AFETR in real-time from the transmitter High-Power-On command until 2 min after DSN continuous view.

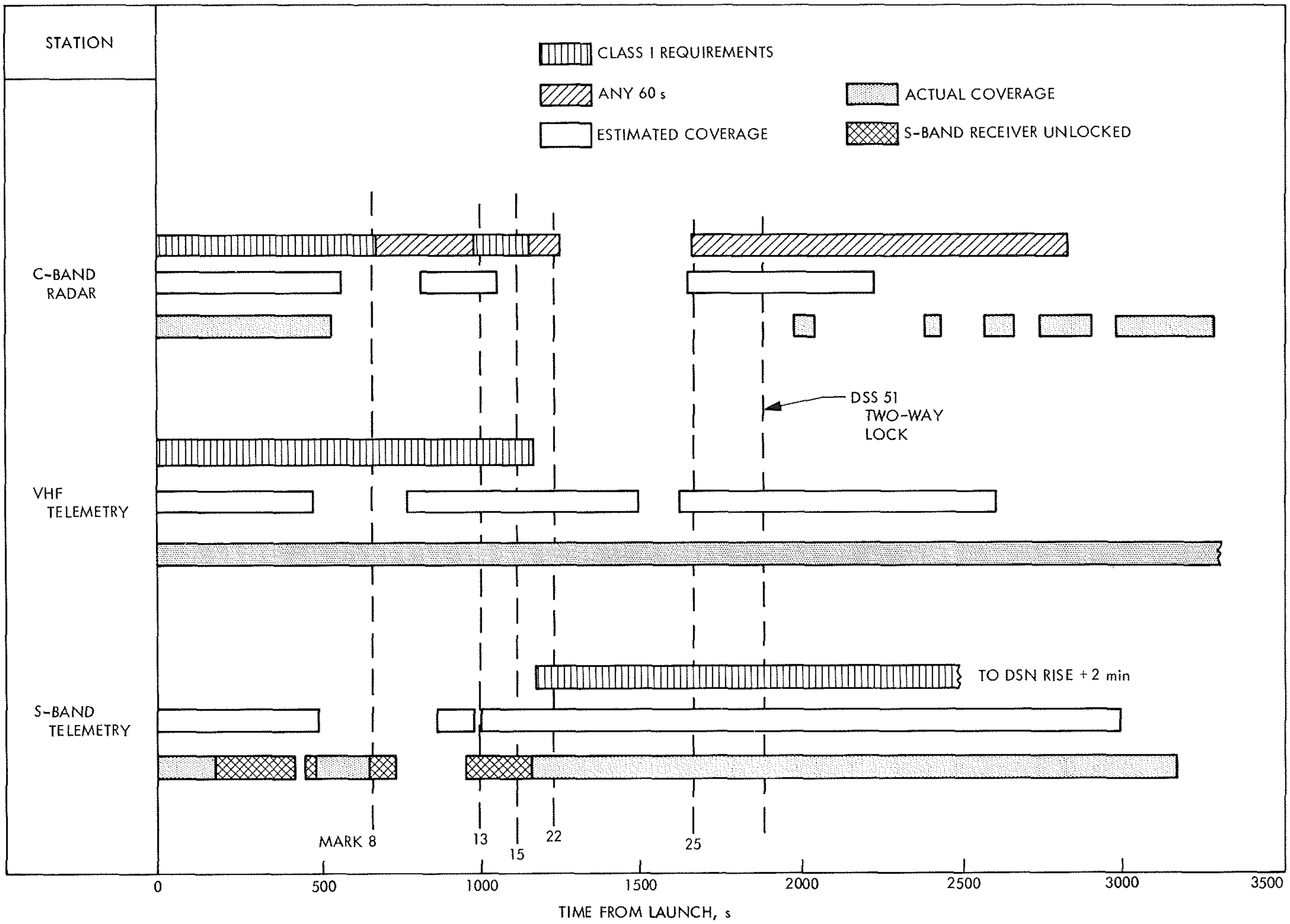


Fig. 33. Summary of AFETR telemetry coverage

The S-band telemetry resources assigned to meet this requirement are shown in Fig. 36. All primary S-band systems were used on a limited commitment basis, since the *Centaur* vehicle was not roll-attitude stabilized and the aspect angle could not be predicted.

Estimated and actual S-band coverage and receiver lock times are shown in Fig. 36. Continuous coverage was obtained from liftoff to Ascension LOS at $T + 2444$ s. Receiver lock was dropped by KSC between $T + 197$ and $T + 270$ s; however, Grand Bahama maintained lock throughout this period and provided redundant coverage.

Antigua's coverage interval was quite a bit in excess of estimated coverage, but phase lock was maintained for only 30% of their actual coverage interval. Coverage from Grand Bahama and the *Coastal Crusader* overlapped most of the Antigua view; however, during the interval from $T + 495$ to $T + 673$ s, Antigua was the only station in receiver lock.

Receiver lock was maintained continuously, by the *Coastal Crusader* and then Ascension, from $T + 673$ to $T + 2197$ s. Pretoria provided redundant coverage during this interval, with receiver lock from $T + 1377$ to $T + 1698$ s.

The requirement for class I S-band telemetry was satisfied. Early evaluation of the data indicated perhaps that good receiver lock was obtained but that the data may have been unusable. This was not the case after subsequent investigation.

Antigua received unexpected S-band data due to the ducting of the signal mentioned above. The RIS *Twin Falls* did not receive any S-band data, since it had view during the low power mode.

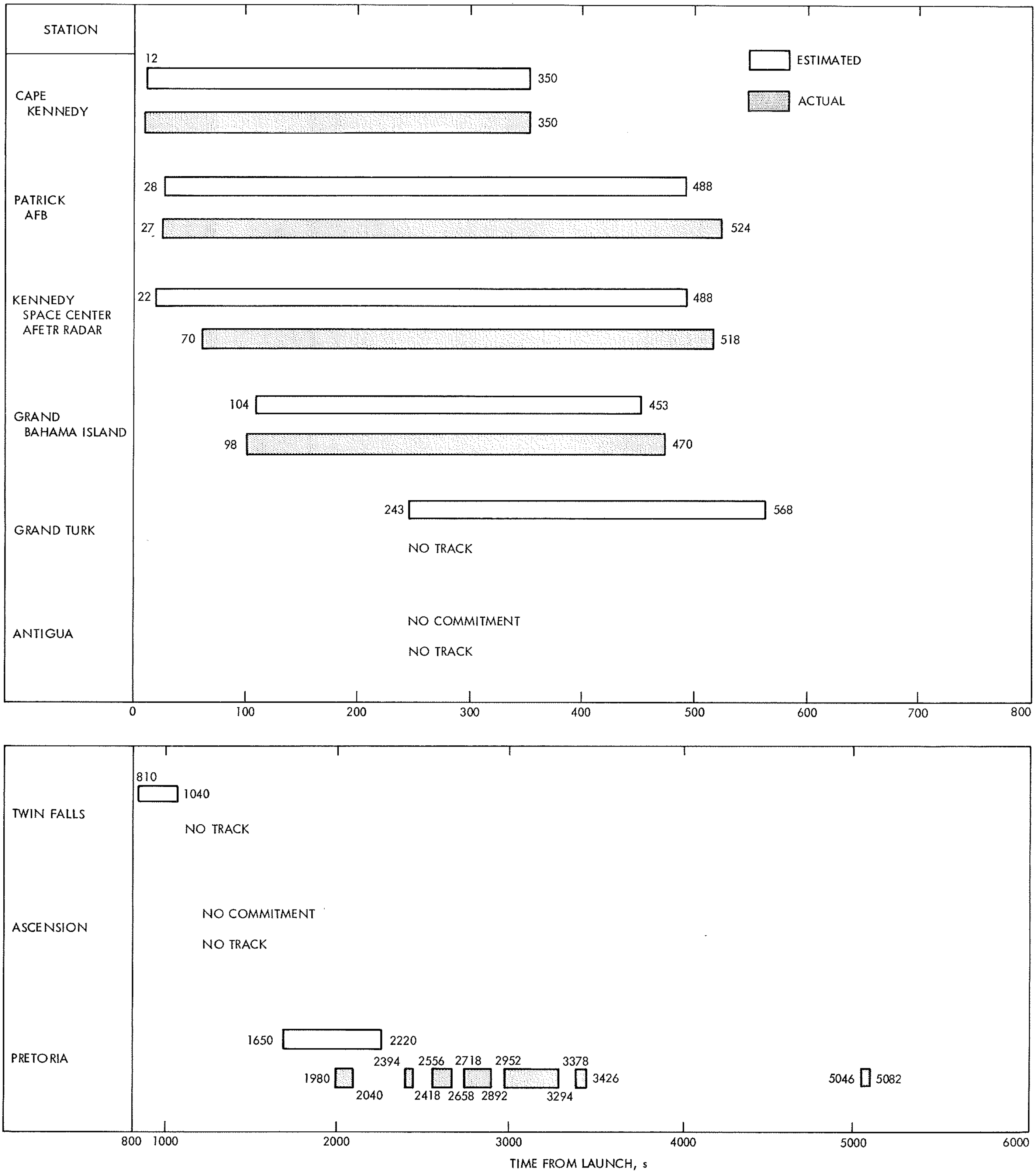


Fig. 34. Estimated and actual AFETR C-band radar coverage

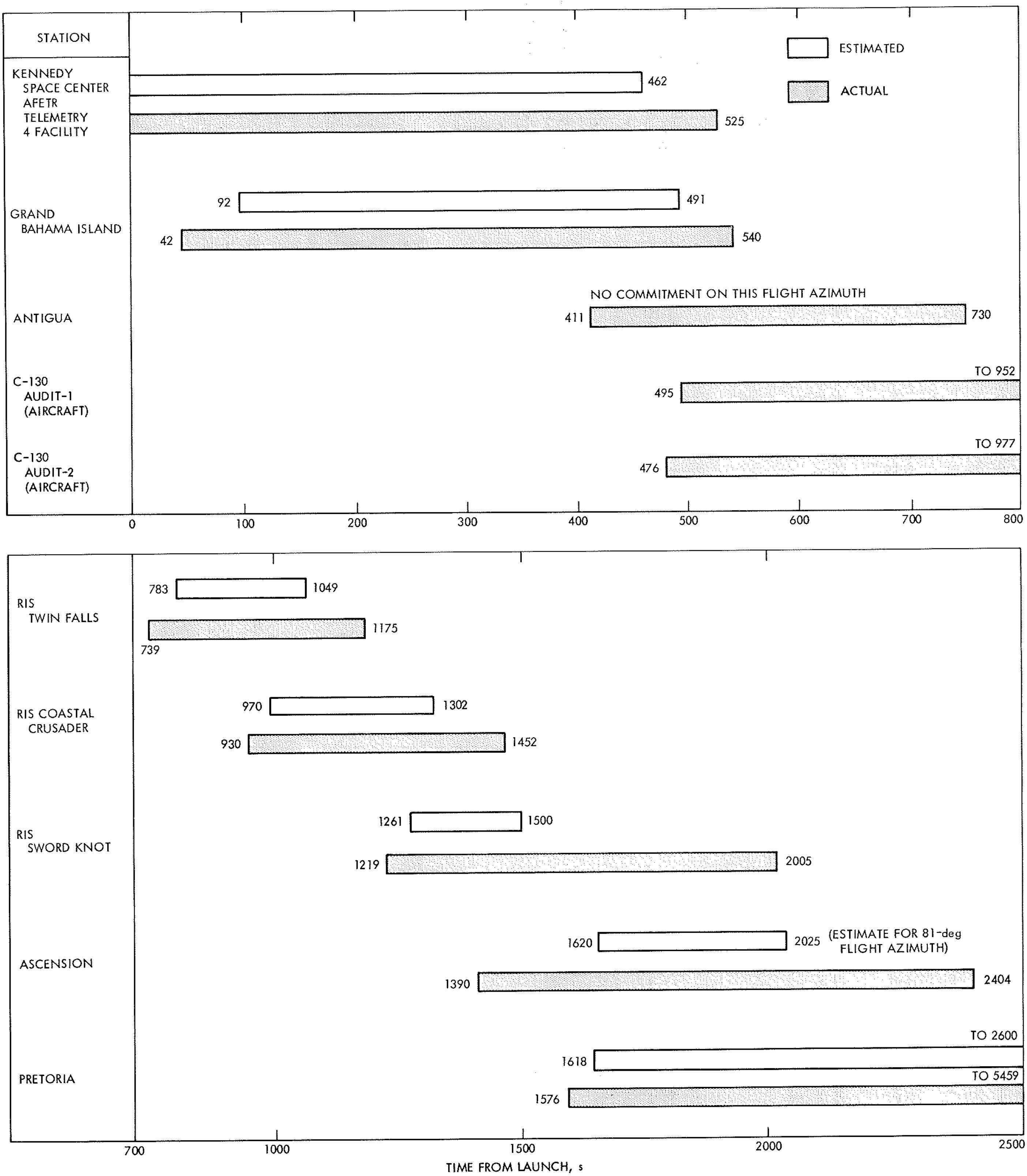


Fig. 35. Estimated and actual AFETR VHF telemetry coverage

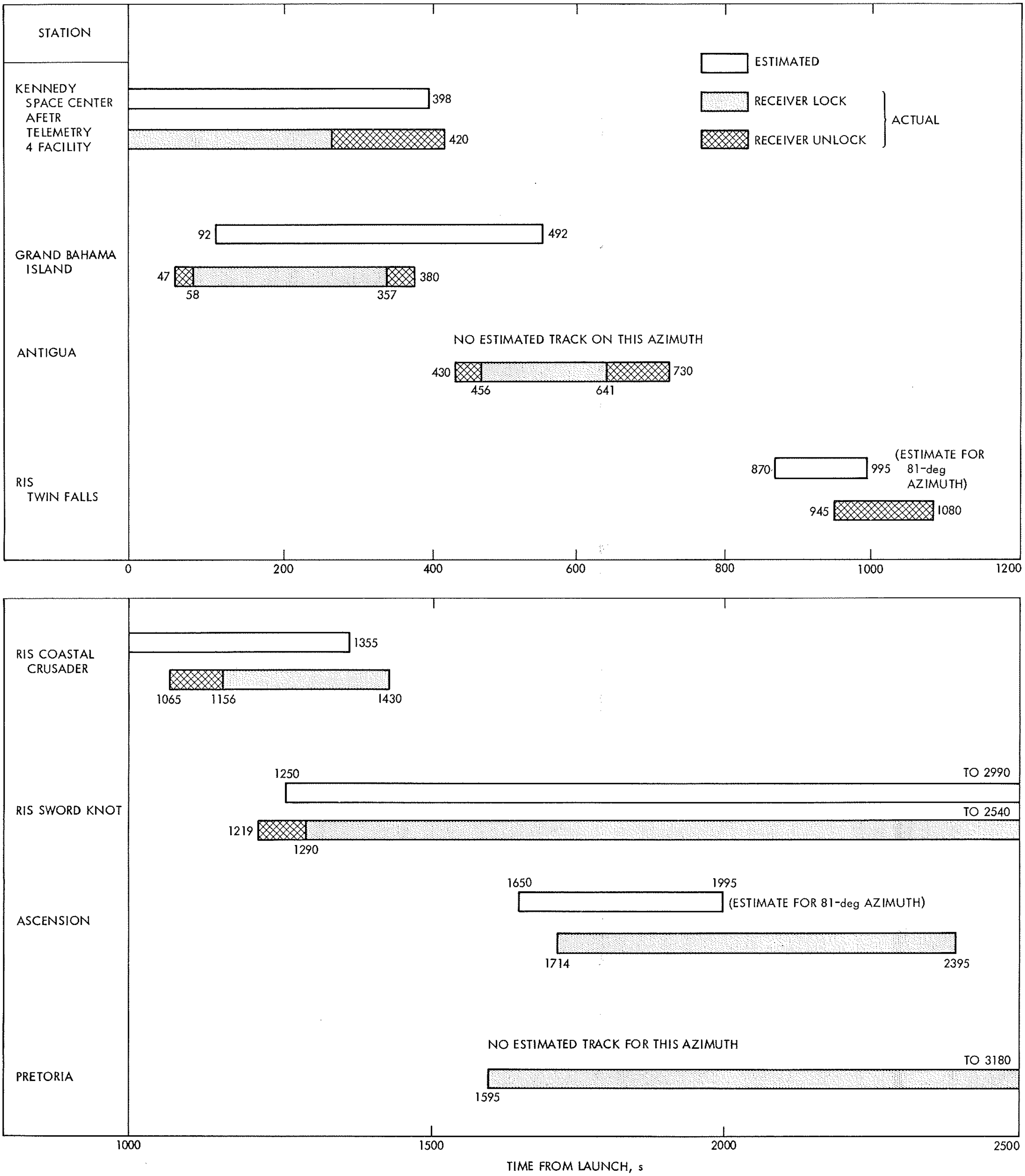


Fig. 36. Estimated and actual AFETR S-band telemetry coverage

An evaluation of the tape recordings made of S-band telemetry from the *Coastal Crusader,* the *Sword Knot,* and Pretoria indicated that the data quality was excellent-to-good, with losses of 4 to 5 data frames for each station throughout its view. The data from the *Twin Falls* was of very poor quality and essentially unusable.

3. ***Real-time computer system.*** The AFETR retransmitted *Surveyor* data (VHF or S-band) to building AO, Cape Kennedy, for display and retransmission to the SFOF. In addition, downrange stations monitor specific channels and report events via voice communication.

For the *Surveyor V* Mission, existing hardware and software facilities were utilized to meet the real-time data requirements.

All requirements were met. Very high frequency telemetry data, including 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 14, were read out and reported.

For the launch and near-earth phase of the mission, the real-time computer system provided trajectory computations based on tracking data and telemetered vehicle guidance data. The RTCS output included:

(1) An interrange vector, a standard orbital parameter message, and orbital elements.

(2) Predicts, look angles, and frequencies for acquisition use by downrange stations.

(3) An I-matrix and moon map for mapping injection conditions and estimating trajectory accuracy. Provision for early orbit evaluation prior to orbital data generated by FPAC.

A total of six orbits were computed by the RTCS, including a pre-retromaneuver orbit from Antigua data, a second pre-retromaneuver orbit from *Centaur* guidance telemetry data, a post-retromaneuver orbit using Ascension 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, which compared favorably with the SFOF final premidcourse maneuver computations.

A second DSN solution, using DSS 51 data, was computed by the RTCS. This solution was also considered fair. An interrange vector, standard orbital parameter message, orbital elements, and moon-mapping were provided from this solution.

Kennedy Space Center provided good data in real-time from the VHF link, beginning at $T - 10$. The switch to real-time Grand Bahama data from the VHF link was made at $T + 1$ h, 4 min; the quality was excellent.

In spite of expected masking (due to local terrain), Antigua provided good VHF data through the *Centaur* first burn. The switch to real-time Antigua data from the VHF link was made at $T + 9$ h, 2 min; quality was excellent. There was an overlap in coverage between Grand Bahama and Antigua, therefore, only a momentary dropout occurred when the subcable switch was made at Grand Bahama.

Real-time data from the *Twin Falls* were unusable. This occurred because the ship was configured to retransmit S-band data, rather than VHF. Since the spacecraft was still in the low power mode, the data source should have been the VHF link.

No useful data were received from the *Coastal Crusader*. Indications are that the poor performance was caused by poor HF communications. The only communication path between the ship and KSC was by HF from the ship to Antigua, where the signal was demodulated with a Rixon receiver and then transmitted on the subcable to KSC. This path had been observed during the minus count. Although not consistently good, it had been usable.

Tables 28, 29, and 30 summarize the orbital computations, initial lunar encounter predicts, and sequence of computations performed by the RTCS during the near-earth phase, respectively.

The RTCS computations on the radar metric data were as good as could be expected, considering the quality of the input data.

The HF communications path to the *Sword Knot* was excellent. However, when the switch from calibration to receiver was made, the time division multiplexer at KSC would not lock up. Parity errors were excessive, and only about 2½ min of useful real-time data were obtained.

Table 31 recapitulates real-time telemetry data retransmission.

Although AFETR had estimated no coverage from Pretoria, S-band data were provided to KSC and this source was selected for output to DSS 71 and building AO at $T + 30$ h, 55 min. The received data signal was not very good and the multiplexer could not maintain continuous lock for more than 6–8 frames.

The lack of real-time spacecraft telemetry data from the *Twin Falls, Coastal Crusader,* and *Sword Knot* placed the mission in a potentially serious position because of the loss of real-time evaluation of spacecraft performance before DSN acquisition.

The configuration as planned was hampered by a Rixon failure at Cape Kennedy, resulting in a sharing of Rixon equipment. The use of additional Rixon equipment is indicated to provide sufficient support.

A parking orbit was computed by the RTCS using Bermuda free-flight data. The solution was considered only fair, because of the low elevation angle of the data used. Interrange vector and orbital element inputs were provided from these data. The SFOF confirmed that the elements appeared to be close to nominal.

A theoretical transfer orbit was computed by the RTCS, using Bermuda data plus nominal second burn data. The solution indicated that the vehicle had slightly more energy than nominal. Interrange vector, orbital elements, and look angles for Grand Canary, Tananarive, and Carnarvon were provided from this computation. Prediction data for DSS 72 and DSS 51 were also provided.

An initial transfer orbit was computed by the RTCS, using Canary data. The data span used was during the *Centaur* turn-around maneuver, preceding post-retromaneuver blowdown. No metric data were available during the *Centaur/Surveyor* transfer-orbit coast period. The Grand Canary solution was considered only fair-to-poor, because of the low elevation angle and the slight

Table 28. *Surveyor V* RTCS orbit generation data quality

Orbit	Time from launch, s		Data source	Quality
	Epoch	Computation		
Centaur/spacecraft parking orbit	669	900	Bermuda	Fair
Predicted *Centaur*/spacecraft transfer orbit	1103	1020	Bermuda, plus nominal second burn	Fair
Centaur/spacecraft parking orbit	677	3660	Guidance telemetry	—
Transfer orbit	1150	2040	Grand Canary	Fair–Poor
Centaur post-retromaneuver orbit	3736	4800	Carnarvon	Fair
Actual spacecraft transfer orbit (1)	2600	6000	DSS 51	Fair
Actual spacecraft transfer orbit (2)	4770	7860	DSS 51	Fair

Table 29. *Surveyor V* initial lunar encounter predictions

Orbit	Orbit mapped	Data source	**B**, km	**B · T**, km	**B · R**, km	Time
1	RTCS transfer orbit	Canary	841.5	384.2	748.7	23:16:32.2[a]
2	RTCS post-retromaneuver (*Centaur*)	Carnarvon	45,902.	42,807.	−16,567.	12:39:17.9
3	RTCS first DSN spacecraft orbit based on DSS 51 data	DSS 51 (35 min)	3,580.	3,579.	74.7	23:41:13.3
4	SFOF first spacecraft orbit based on DSN data	DSS 51 (175 pts)	2,886.8	2,823.5	−496.8	23:25:02.4
5	RTCS second DSN spacecraft orbit based on DSS 51 data	DSS 51	3,512.	3,507.	174.7	23:35:01.2
6	Final SFOF solution used for midcourse maneuver	All available DSN	2,903.17	2,894.85	−219.7	23:25:13.9

[a]GMT on September 10, 1967; other times are for September 11, 1967.

Table 30. Real-time computer system computations

Estimated, min	Actual, min:s	Computation	Source
4	4	Liftoff message	
15	15:40	Parking orbit, interrange vector, and orbital elements	Bermuda
17	18:30	TTO, interrange vector, orbital elements	Bermuda
18	19:40	Grand Canary look angles	Bermuda
	20	Tananarive look angles	Bermuda
	25	Carnarvon look angles	Bermuda
30	30	DSS 72 and 51 predicts	Bermuda
48	41	Actual TO, interrange vector, standard orbital parameter message, and orbital elements	Grand Canary
53	44	Actual TO, DSS 51 and 42 predicts	Grand Canary
53	53	Actual TO, Carnarvon look angles	Grand Canary
60	61	Guidance data solution, interrange vector, standard orbital parameter message, and orbital elements	Telemetry
72	81	Post-retromaneuver interrange vector, standard orbital	Carnarvon
72 (contd)		parameter message, and orbital elements	
75	73	Pre-retromaneuver moon map	Grand Canary
80	89	Post-retromaneuver moon map	Carnarvon
90	90	Pre-retromaneuver I-matrix	Grand Canary
95	99	Post-retromaneuver I-matrix	Carnarvon
140	103	DSN solution interrange vector, standard orbital parameter message, and orbital elements	DSS 51
150	116	DSN solution moon map	DSS 51
165	121	DSN solution DSS 51 and 42 predicts	DSS 51
180	137	DSN solution I-matrix	DSS 51
	140	DSN solution 2, interrange vector, standard orbital parameter message, and orbital elements	DSS 51
	143	DSN solution 2 moon map	DSS 51
	148	DSN solution 2, DSS 51 and 42 predicts	DSS 51

Table 31. Real-time telemetry data retransmission

Station	Selection by KSC (time from launch), min:s	Telemetry link	Path to KSC	Remarks
Kennedy Space Center	− 00:10	VHF		Excellent quality. Building AO and DSS 71 receiving good data
Grand Bahama	+ 01:04	VHF	Subcable	Excellent quality. Building AO and DSS 71 in solid lock
Antigua	+ 09:02	VHF	Subcable	Excellent quality until signal began to break up near LOS at *T* + 11:04
Twin Falls	+ 11:23	S-band	HF radio	No usable data received
Coastal Crusader	+ 17:12	S-band	HF radio/ subcable relay via Antigua	No usable data received
Sword Knot	+ 22:04	S-band	HF radio via Ascension	Approximately 2½ min of usable data received near LOS, at approximately *T* + 29 min, 14 s
Pretoria	+ 30:55	S-band	HF radio via Ascension	Very little usable data received

perturbation caused by the *Centaur* lateral thrust. An interrange vector, orbital elements, standard orbital parameter message, and Carnarvon look angles were provided from this computation. Predicts for DSS 51 and DSS 42 were also provided.

Centaur guidance telemetry data were used by the RTCS to compute a parking-orbit solution. This solution appeared to be fairly close to nominal. Interrange vector, orbital elements, standard orbital parameter message, moon-mapping, and I-matrix data were provided from this solution.

Three radars were scheduled to provide post-retromaneuver metric tracking data to the real-time computer system. The Tananarive radar did not track, and the Pretoria radar tracked only intermittently; this left Carnarvon as the only radar providing usable post-retromaneuver data to the system. The RTCS used these data to compute a post-retromaneuver orbit. The solution was considered fair. An interrange vector, orbital elements, standard orbital parameter message, moon-mapping, and an I-matrix were provided from this solution.

An actual transfer orbit was computed from 35 min of DSS 51 data. This solution was considered only fair by the RTCS. An interrange vector, orbital elements, standard orbital parameter message, moon-mapping, and an I-matrix were provided from this solution. Predicts for DSSs 51 and 42 were also computed.

B. Manned Space Flight Network

The MSFN, managed by GSFC, supported the *Surveyor V* Mission by performing the following functions:

(1) Tracking of the *Centaur* C-band beacon.

(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.

For the MSFN tracking and telemetry facilities and equipment used in support of *Surveyor V* (see Table 5). The MSFN also supported the ORT prior to launch.

Carnarvon achieved 910 s of valid data. An estimated 1696 s of data were lost. No cause, other than aspect angle, is known for this data loss.

Figure 37 shows the MSFN C-band radar coverage and Fig. 38 the VHF telemetry coverage.

Bermuda's FPQ-6 radar lost 78 s of data due to an equipment problem. This is believed to be failure of the signal to overcome the second AUX-track threshold.

A minor phasing problem was encountered shortly after acquisition by the Bermuda FPS-16. Although initial phasing was correct, the FPS-16 phasing operator thought he was incorrectly phased when Patrick AFB (FPQ-6) entered an interference region. The radar was rephased into an incorrect slot, the error was discovered in approximately 20–30 s and then corrected.

The Grand Canary radar acquired approximately 6-min late and provided about 2 min of data that were used to compute the pre-retromaneuver transfer orbit. Although the acquisition message was received at first view minus 30 s, operational procedures in use at the time prevented early acquisition.

The Tananarive radar was operational on an engineering basis, but had no C-band tracking capability, because of confusion in operational procedures. The radar transmitter was turned on very late, because the radar operator had misunderstood instructions and was waiting for Pretoria LOS.

Guidance data from channel 16 were transmitted in near-real-time. The quality was excellent.

The retransmission of launch vehicle VHF telemetry data from the AFETR downrange stations and ships was deleted, because of the good quality data received from the MSFN in real- and near-real-time. Table 32 tabulates the *Surveyor V* Mission *mark* events.

*1. **Computer.*** The data operations branch at GSFC provided all required support. The lateness of the acquisition message information to Grand Canary was expected because of the short time available to compute the data before Grand Canary rise.

Every effort was made to reduce the time required to generate and transmit real-time acquisition messages to Grand Canary. Solutions that were under investigation included placing a teletype machine at a location more convenient to the radar operator.

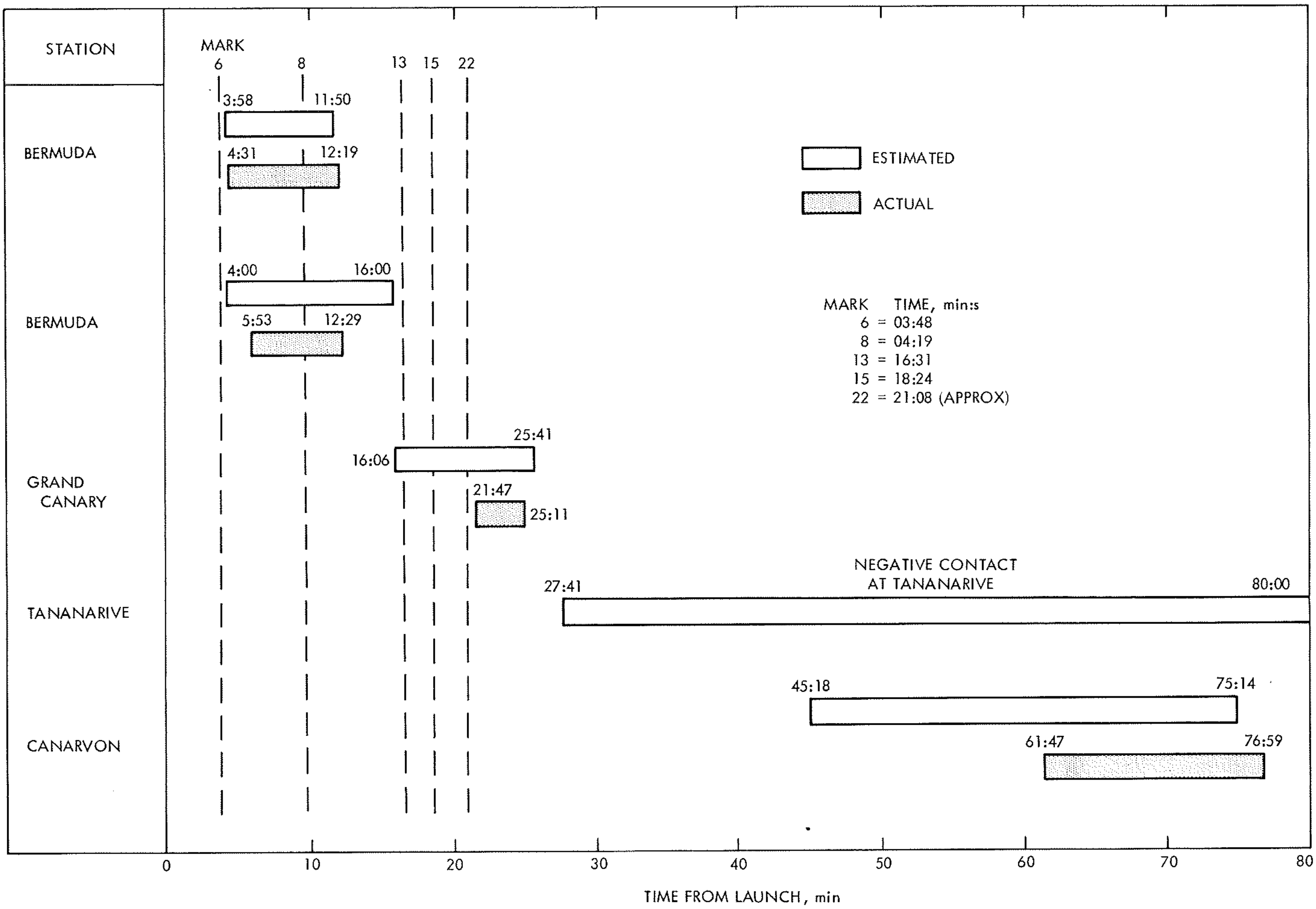


Fig. 37. Estimated and actual MSFN C-band radar coverage

The GFSC 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:

(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, except Bermuda. Bermuda powered flight data were to be supplied to GSFC by the 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 teletype 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 postinjection tracking data.

(7) To reformat on magnetic tape the high-speed radar data received from AFETR in the tape format specified (XYZ and $\dot{x}\dot{y}\dot{z}$) and to reformat on magnetic tape the low-speed teletype 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 data processing requirements group at Patrick AFB.

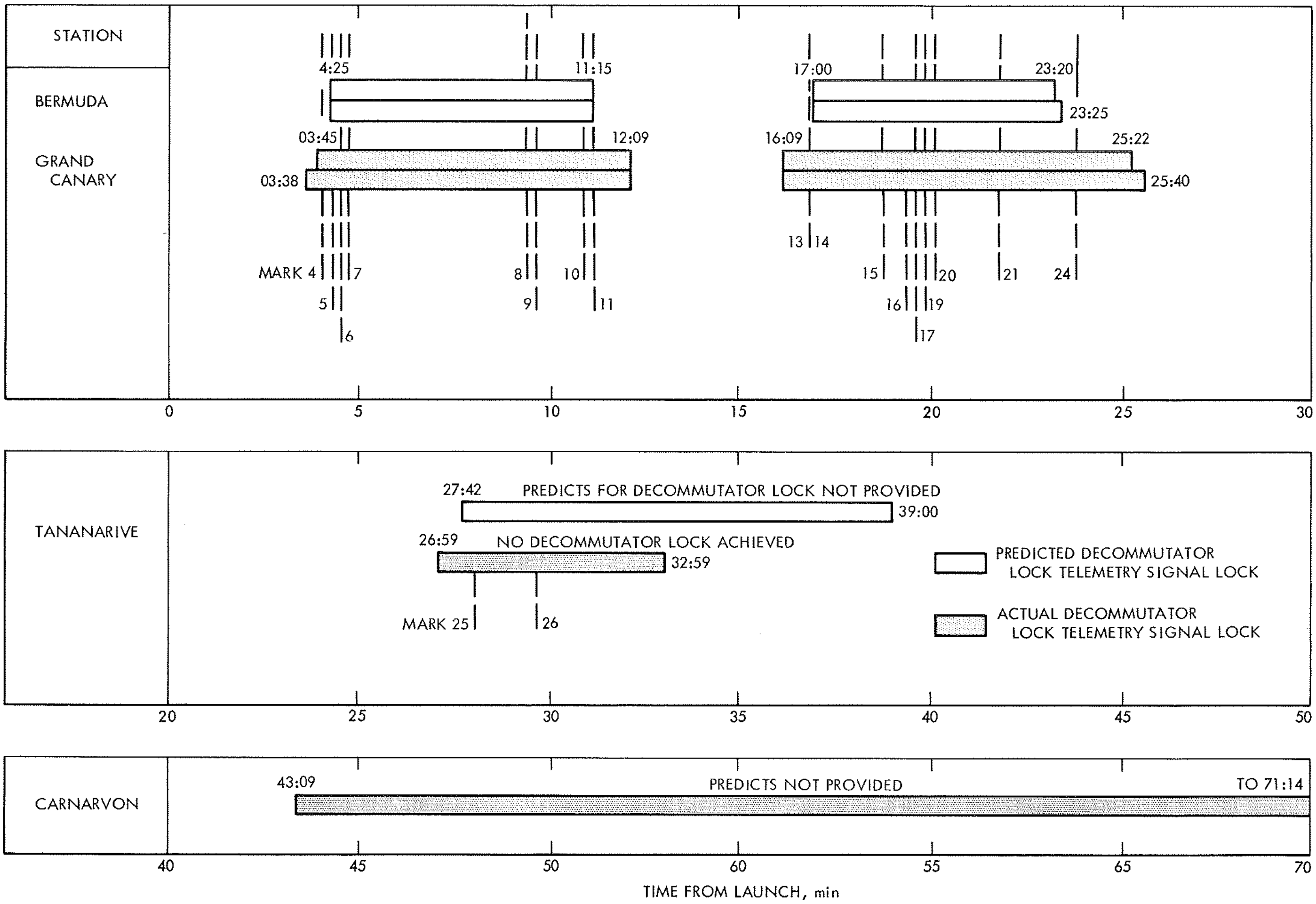


Fig. 38. Estimated and actual MSFN VHF telemetry coverage

The GSFC data operations branch provided all required support. The data operations branch generated and transmitted nominal pointing data to Grand Canary during the minus count on launch day.

Existing NASCOM and other network facility voice and teletype circuits provided ground communications to all participating stations.

2. Evaluation. Even though the near-earth phase support of the TDS was less than nominal, there are no open items in this report. There are actions to be taken by the AFETR and the MSFN to investigate their acquisition procedures, as well as to review and (where necessary) to correct their operational procedures in an attempt to avoid this type of performance in future missions.

C. Deep Space Network

The DSN provided a constantly high level of support for *Surveyor V*. After lunar landing, this included extensive alpha scattering operations, and video operations using nonstandard procedures to accommodate the overdeviated video signal on *Surveyor V*. In addition the DSN complied with a project request for expedited handling of DSSs 42 and 61 data packages for the first two passes after touchdown. These were returned to JPL less than 48 h after receipt of the data. In the week prior to launch, the DSN performed system readiness verification tests with all *Surveyor* stations to verify readiness for the ORT and mission.

During operational support, most areas of the DSN encountered problems of various sorts, but these problems caused no serious loss of data to the project. Problems involving more than one element of the DSN are summarized below.

1. Deep Space Instrumentation Facility. Prime station support was provided by DSSs 11, 42, and 61. Initial two-way acquisition and commanding of the spacecraft

Table 32. *Surveyor V mark events*

Mark event	Time (GMT)	Source
Liftoff	07:57:01.257	Cape Kennedy
1	07:59:34.65	Cape Kennedy
2	07:59:38.05	Cape Kennedy
3	08:00:19.65	Cape Kennedy
4	08:00:49.9 08:00:49.9	Cape Kennedy Bermuda
5	08:01:07.62 08:01:07.7	Cape Kennedy Bermuda
6	08:01:11.05 08:01:10.0	Cape Kennedy Bermuda
7	08:01:20.5 08:01:20.3	Cape Kennedy Bermuda
8	08:06:48.4 08:06:48.3	Antigua Bermuda
9	08:06:51.0 08:06:51.3	Antigua Bermuda
10	08:08:15.2	Bermuda
11	08:08:06.0 08:08:05.6	Antigua Bermuda
12	Not reported	—

Mark event	Time (GMT)	Source
13	08:13:32.2 08:13:32.2 08:13:32.2	*Coastal Crusader* *Twin Falls* Grand Canary
14	08:13:32.1 08:13:32.2 08:13:32.2	*Coastal Crusader* *Twin Falls* Grand Canary
15	08:15:25.2	Grand Canary
16	08:15:45.5	Grand Canary
17	08:15:55.7	Grand Canary
18	08:16:16.0	*Coastal Crusader*
19	08:16:21.0 08:16:22.2	*Coastal Crusader* Grand Canary
20	08:16:29.0 08:16:26.8	*Coastal Crusader* Grand Canary
21	08:17:29.8	Grand Canary
22	Not reported	—
23	Not reported	—
24	08:20:26.8	Grand Canary
25	08:24:37.2	Pretoria
26	08:26:16.5 08:26:17.0	Pretoria *Sword Knot*

and tracking during all three of its transit-phase view periods was performed by DSS 51. Since this station had higher elevation angles and longer view periods than DSS 61, DSS 51 was used as the prime two-way station during the transit phase of the mission. DSS 72 provided backup to the DSS 51 initial acquisition capability and provided early telemetry data.

Cape Kennedy (DSS 71) supported the prelaunch spacecraft–Deep Space Station RF compatibility tests were supported by DSS 71 and it was also intended to be the prime source of real-time AFETR telemetry as processed by the CDC and on-site telemetry and command processor and transmitted to SFOF. Shortly before launch problems occurred which caused the DSS 71 data to be unusable. The backup data path via dataphone in building AO was used, and no data were lost because of the DSS 71 computer outage.

Midcourse and terminal phase support using the 210-ft antenna at DSS 14. Project-furnished equipment was installed to permit predetection recording at DSS 14. At touchdown the baseband telemetry output of the prime receiver was transmitted to SFOF using the 96-kHz line. These data were unprocessable after touchdown strain gages were turned on. Available evidence indicated that this was a system problem, and an investigation was made. Since DSS 11 data were simultaneously being sent to the SFOF using NASCOM high-speed data modems, good PCM data were furnished at touchdown.

Subsequent to landing, the DSIF provided 24 h/day tracking coverage. This coverage was planned to extend at least 96 h into the lunar night.

a. Participating stations. The following Deep Space Stations were assigned to support the mission:

(1) Prime:
- (a) DSS 11.
- (b) DSS 42.
- (c) DSS 51: Tracking support only during cislunar phase.
- (d) DSS 61.
- (e) DSS 71: Prelaunch support and track to loss of signal.
- (f) DSS 72: Tracking from acquisition to DSS 11 first pass plus 1 h.

(2) Recording and transmitter backup station: DSS 14.

Prime telemetry and transmitter backup for DSS 11 during midcourse and retromaneuver phases were provided by DSS 14.

b. Mission profile. Table 33 gives a complete log of tracking times and commands sent. Launch occurred at 07:57:01.257 GMT on September 8, 1967 with a launch azimuth of 79.517 deg. All stations committed to support the launch of *Surveyor V* (DSSs 11, 42, 51, 61, 71, and 72) counted down and were GO for launch.

Solid one-way spacecraft signals were reported by DSS 71 for 4 min, 39 s after liftoff. Signal levels varied from a −71 dBmW on the pad to −156 dBmW at loss of lock.

Initial one-way spacecraft acquisition was performed by DSS 72. This station had visibility and tracked for 12 min (08:20 to 08:32) during the launch pass. The spacecraft did not go two-way with DSS 72 during this pass.

Initial two-way acquisition was performed by DSS 51. The station was in two-way lock with the spacecraft at 08:31 with command modulation ON. The period from receipt of the first spacecraft signal to Command Modulation ON was slightly less than 7 min.

The first midcourse was performed by DSS 11 on their first pass. A successful adjustment, as far as burn time and thrust were concerned, was accomplished. After midcourse, telemetry readout indicated that the helium pressure (used to pressurize the vernier engine fuel and oxidizer tanks) was decreasing at a rapid rate. Several vernier engine burns were made in an attempt to reseat a valve believed to be stuck in a partially open position. This attempt and subsequent vernier engine burns were unsuccessful in stopping the helium leak. See Table 33 for times of additional midcourse adjustments.

The retromaneuver, which was nonstandard due to the helium leak, was performed by DSS 11 on the third pass. The retroengine burn started at 00:44.004 with touchdown at 00:46:45 GMT. The spacecraft touchdown on the lunar surface was so gentle that none of the four receivers at Goldstone (two at DSS 11 and two at DSS 14) lost lock.

Table 33 also lists the times each DSS tracked the spacecraft during the period covered by this report. Also shown are the number of commands sent by each DSS during each pass.

Table 34 tabulates, by Deep Space Station, the number of TV pictures received commanded and the number received commanded by another Deep Space Station having mutual view of the spacecraft. A lunar operations meeting (now standard) was convened by the Space Flight Operations Director each day 3-h prior to DSS 11 rise. At this meeting the operations plan for DSSs 11, 42, and 61 was finalized. A tracking chief attended each of these meetings and prepared a teletype message for transmission to the tracking stations permitting them to better prepare for each pass.

In addition, an edited version of the Mission Summary Report prepared by the project every 24 h was configured into teletype message form and then transmitted to the *Surveyor* stations.

Table 35 gives a summary of alpha scattering data received by the various Deep Space Stations.

c. Problems. The significant DSIF equipment anomalies together with their causes and effects are given in Table 36. Because of the extremely early scheduling of the *Surveyor V* postflight critique, only those anomalies occurring prior to September 19 are included in this listing. These anomalies are grouped into four categories.

The first group is random hardware failures. These problems were cleared by repairing the equipment. These problems were minimized by redundant units and a supply of spare modules on site. A large number of random failures could be expected because the high mission loading during the last 6 mo precluded adequate station maintenance.

The second category is equipment misadjustments. The problems were cleared by making the proper adjustment. The appropriate station manager was notified for further training, providing time could be found for further training during the peak of mission activity.

The third category is operator errors. There were more operator errors during this mission than were experienced during previous missions. It appears that the many months of the constant pressure of the testing and tracking of interlocking missions was the cause. Nevertheless, the station managers were notified so that they could attempt to keep the operation handling together.

Table 33. Tracking times and commands sent

Pass	DSS	Date (Sep 1967)	Tracking period	Total commands sent	TV pictures		Events
					Commanded	Noncommanded	
	71	8	07:52:00 08:03:49	0	0	0	Liftoff: day 251, 07:57:01.257 GMT Launch azimuth: 79.517 deg
	72		08:20:00 08:33:00		0	0	
	51		08:24:25 20:54:38	67	0	0	
1	42		09:10:11 12:37:32	0	0	0	
	72		11:34:19 21:57:00	3	0	0	
	61		13:15:49 20:33:11	27	0	0	
	11	9	21:08:08 04:46:00	116	0	0	Midcourse maneuver accomplished at 01:45. Vernier engine firings accomplished in attempt to seat leaking helium pressure regulator (3 engines used)
	14	8 9	21:32:55 04:41:17	0	0	0	Backup telemetry recording for DSS 11
2	42		00:29:00 14:12:13	136	0	0	Accomplished midcourse maneuver 5 after transfer, station was not in two-way lock from 04:30 to 05:39
	51		09:33:21 21:37:20	26	0	0	
	61		14:07:13 21:25:02	27	0	0	
	11	10	21:30:25 05:24:00	87	0	0	
	14	9 10	21:31:00 05:13:57	0	0	0	
3	42		01:01:20 14:30:00	51	0	0	During transfer to DSS 51, receivers dropped lock at 11:57:50
	51		09:52:37 21:49:38	62	0	0	Unable to load program on 910 computer. Used 920 for this pass
	61		14:18:20 21:40:06	0	0	0	
	14	11	21:35:07 05:34:00	0	0	0	
	11	10 11	21:36:33 05:43:56	3173	18	13	Touchdown at 00:46:45 at 1.45 deg N, 23.25 deg E. Helium pressure stabilized at 836 psi. Accomplished maneuver 6 (terminal) with vernier engine firing 8
4	42		01:18:00 15:08:45	2133	124	18	Transponder turned off 10 min too soon before transfer to DSS 61

Table 33 (contd)

Pass	DSS	Date (Sep 1967)	Tracking period	Total commands sent	TV pictures		Events
					Commanded	Noncommanded	
4 (contd)	61	11	14:45:00 22:32:17	72	72	0	Station noted RF interference on spectrum analyzer when *Lunar Orbiter* traveling-wave tube A on —no ill effects on data
	11	12	22:32:16 06:38:46	5131	1205	0	
5	42		02:10:00 16:05:00	1313	270	912	
	61		15:53:43 23:30:59	166	0	0	
	11	13	23:29:31 07:40:00	5094	375	0	Static firing of vernier engines on Sep 13 at 05:38:05
	14		03:45:00 06:24:00	0	0	0	Provided backup recording during static firing of spacecraft
6	42		03:02:00 17:02:00	1754	353	111	Recalled alpha scattering accumulation which appeared to be lost
	61	14	16:40:13 00:40:58	1292	0	0	
	11		00:13:00 08:54:00	3467	740	0	Trailing edge of TV-1 video occurred 40% of the time on on-site film recorder
7	42		04:09:00 17:48:00	1323	281	359	Large number of TV frames processed by CDC from start of pass until 06:15 had loss of horizontal sync on bottom of picture
	61	15	17:22:00 01:40:00	1408	0	23	FR-800 recorder had high noise level during playback
	11		00:50:05 09:57:00	4660	1161	205	FR-1400 B record head failed. Telemetry and data handling preamble generator defective
8	42		05:19:31 18:32:00	1297	205	581	FR-800 frequency response out of specification at top end
	61	16	17:53:38 02:50:23	576	0	116	
	11		01:18:54 11:09:00	3035	789	407	FR-800 female guide failed to close several times during recorder on commands
9	42		06:20:00 19:03:00	5764	1299	432	CDC film recorder not switched on for 93 frames of N/A survey
	61	17	18:19:31 03:52:51	143	0	0	Lost several accumulations on on-site alpha scattering program
	11		01:43:50 12:19:25	1061	227	0	FR-800 reproduce unacceptable
10	42		07:17:00 19:26:00	51	0	0	Telemetry and command processor A typewriter I/O not functioning. Replaced oscillator module in typewriter coupler

Table 33 (contd)

Pass	DSS	Date (Sep 1967)	Tracking period	Total commands sent	TV pictures		Events
					Commanded	Noncommanded	
10 (contd)	61	17 18	18:31:10 04:45:40	1813	0	213	Power failed on *Surveyor* on-site computer down for 6 min
	11		02:14:47 12:38:00	5282	694	0	Received considerable hits on 6-MHz line during video sequence
11	42		12:00:00 19:50:00	1422	37	0	Telemetry and command processor A on-site alpha scattering program typewriter output garbling, program reloaded and okay
	61	19	18:49:55 05:54:00	99	0	309	
	11		02:44:50 14:10:00	2717	565	0	
12	42		12:46:00 19:37:00	58	0	0	
	61	20	19:09:55 06:51:00	281	0	495	
	11		03:13:34 14:53:00	7928	1692	0	
13	42		13:25:00 20:06:00	1200	64	0	
	61	21	19:35:19 07:48:00	46	0	667	
	11		03:35:42 15:31:40	9085	2112	0	
14	42		13:00:00 20:28:00	286	31	133	
	61	22	19:54:00 08:54:00	1057	30	784	
	11		04:07:47 16:15:00	10,192	226	20	
15	42		13:59:00 21:00:00	2080	394	392	
	61	23	20:38:11 09:51:00	2613	486	720	
	11		00:44:44 16:59:00	7809	1684	42	
16	42		14:55:00 21:52:00	930	176	129	
	61	24	21:00:30 10:53:00	1164	56	663	
	11		05:40:37 17:45:20	4442	768	0	Sunset day 267 at 11:00
17	42		15:30:00 22:40:00	35	0	0	
	61	25	22:10:00 06:54:00	73	0	0	

Table 33 (contd)

Pass	DSS	Date (Sep 1967)	Tracking period	Total commands sent	TV pictures		Events
					Commanded	Noncommanded	
17 (contd)	11	25	06:55:44 17:36:23	43	0	0	
18	42		17:04:12 23:06:00	38	0	0	
	61	26	23:09:15 08:49:37	107	0	0	
	11		08:20:11 19:22:00	199	0	0	
19	42		19:38:24 23:56:00	51	0	0	
	11	27	08:20:00 19:20:48	107	0	0	
20	42	28	18:50:21 01:00:02	48	0	0	
	61		00:14:00 14:25:06	80	0	0	
21	42		22:00:20 22:38:00	20	0	0	
	61	29	05:50:00 06:36:00	23	0	0	

Table 34. Received TV pictures

DSS	Station command	External command
71	0	0
72	0	0
51	0	0
42	2,981	3077
61	572	3990
11	14,746	687
14	0	0
Totals	18,652	7754
Grand total	26,416	

Table 35. Alpha scattering data received

Pass	Date (Sep 1967)	Data received, h:min		
		DSS 11	DSS 42	DSS 61
2	9		00:48	
4	11		07:30	07:16
5	12		09:34	06:51
6	13		08:30	05:47
7	14		00:57	
9	16			07:02
10	17	08:02	04:20	01:55
11	18	00:31	03:12	07:21
12	19	05:11	06:15	11:21
13	20	10:36	01:36	08:14
14	21	01:46	02:40	05:49
15	22		00:25	00:20
16	23		01:00	02:30
Totals		26:06	46:47	54:26
Grand total		127:19		

Table 36. *Surveyor V* anomalies and random failures

Item	DSS	Pass	Date (Sep 1967)	Time (GMT), h:min	Anomaly	Immediate reaction	Comments
Hardware							
1	51	Prelaunch	7	23:30	Antenna servo developed leak		Leaking pipe in hydromechanics building replaced before launch
2	51	Prelaunch	8	04:20	910 computer would not accept *Surveyor* on-site computer program	Switched to 910	Bad card; cleaned contacts. Several intermittent problems developed with the 910. On pass 3 a faulty FK-52 module was replaced which cleared the problem
3	42	Prelaunch	8	04:37	Antenna hour angle high-speed motor failure	Bad seal replaced	Antenna was GO prior to launch
4	51	Prelaunch	8		Sanborn recorder pen 7 broken.	Replaced pen	
5	72	Prelaunch	8	06:00	Sanborn recorder multimarker malfunction channel 8	Used backup brush recorder	Channel 8 function recorded on brush recorder
6	71	Prelaunch	8	07:07	Telemetry processing station receiving bad data when DSS 71 was processing data from DSS 71 receiver. This problem continued through their mission		Special tests were performed at DSS 71 prior to postcalibration. No abnormalities were found
7	42	01	8	11:26	CEC galvanometer lamp lost intensity	Replaced lamp	Refer to item 3 in equipment adjustment
8	72	Launch pass	8		Tracking data handling format intermittent; dropping low-speed data in doppler printout		Broken wire tracking data handling patch board repaired
9	42	03	10	08:00	Command subcarrier oscillator failed. Command was not transmitted	Switched to spare	After pass subcarrier oscillator would not repeat problem
10	42	03	10	11:57	Receiver dropped lock during transfer, while tuning from voltage-controlled oscillator frequency time sync to track sync frequency	Returned and reacquired	Faulty potentiometer exciter suspected, but when removed, examination indicated potentiometer was good
11	11	03	10	20:45	Tracking data handling doppler counter doubling		Suspected preamble generator. When spare generator in system, no doubling but would not work in auto mode
12	11	03	10	20:45	FTS 50 channel distribution amplifier failed	Bypassed amplifier	Problem was 120-Hz noise at output which could not be repeated enough to analyze. Amplifier is in system at present time and has been good for several days
13	11	03	10	22:40	Tracking data handling doppler dropping medium speed data, intermittent		Replaced card in frequency counter

Table 36 (contd)

Item	DSS	Pass	Date (Sep 1967)	Time (GMT), h:min	Anomaly	Immediate reaction	Comments
				Hardware (contd)			
14	51		11		Tracking data handling punch 1 failed	Replaced with punch 2	Punch 1 in repair
15	11	04	11	21:00	No 1 pulse/s to telemetry and command processor computer		Replaced card in astro data time source
16	51		11	21:25	Hardware problem with 910 computer	Switched to 920	910 outputting bad high-speed data. Under investigation
17	42	05	12	10:00	Telemetry and command processor computer failure; blown fuse	Replaced fuse	Under investigation
18	42	05	12	18:10	Telemetry and command processor B failed. Fuse blown on plus 25-V power supply	Replaced fuse	Under investigation
19	61		12	13:30–23:30	FR-800 down. Power transistor and zener diode fails when power is turned on		Loose connection on lead to power transformer was repaired. Unit operational for next pass. No data lost
20	11		12	22:32–06:38	Tracking data handling doppler most significant digit reads zero		Counter sampling card replaced
21	42	05	13	11:10	Telemetry and command processor magnetic tape unit would not read back command message during attempt to dump accumulation to tape		Ran diagnostic, cleaned deck and heads of magnetic tape. Problem cleared
22	14		14	01:55	Tracking data handling preamble generator malfunction		Switched to spare unit
23	42	08	14	04:15	FR-800 frequency response out of specification at high end		Station investigating
24	42	08	14	04:35	Telemetry and command processor B having instruction parameter problems. Could not output telemetry during data transfer	Switched to processor A	Replaced defective card
25	42	08	14	05:20	Telemetry and command processor A down; unable to output dummy frames on high-speed data		Repaired two bent pins in patch board
26	11		14	19:30	FR-1400 record head failed at countdown (AIS B recorder)		Frequency response off at high end. Head replaced, and response normal
27	61	07	14	23:00	FR-800 has high noise level on playback. Suspect faulty harness		Ampex representative states entire harness should be replaced. This would require three weeks

Table 36 (contd)

Item	DSS	Pass	Date (Sep 1967)	Time (GMT), h:min	Anomaly	Immediate reaction	Comments
				Hardware (contd)			
28	61	08	15	23:34	Arc detector faulted out transmitter. This problem occurred after replacing the harmonic filter, but has not occurred since cleaning waveguide		Burned and broken sidewall carbon absorber in harmonic filter after replacing harmonic filter, and cleaning, system normal
29	11	08	16	06:25	FR-800 female guide failed to close		Head and three broken wires replaced; adjusted female guide; problem cleared
30	11	09	17	00:30	FR-800 playback unacceptable		Replaced head driver card, realigned recorder; unit operational
31	11	09	17	00:30	Excessive dropout of data on FR-1400 B		After pass, heads cleaned; adjusted electronics; replaced reproduce pinch roller; unit operational
32	11	10	17	06:30	Dynamic focus deflection driver going into oscillations	Replaced power supply	Caused by failure of 24-V power supply
33	42	10	17	12:40	Telemetry and command processor A typewriter I/O not functioning. (This problem reported intermittent on the previous pass)	Switched to telemetry and command processor B	Oscillator module in typewriter coupler replaced, and checked out good with SFOF
34	61	10		18:50	Power failed on *Surveyor* on-site computer	Reset and operational	Problem did not repeat
				Equipment misadjustments			
1	42	*Launch*	8	09:10	PCM data from CDC to recorders lost due to patch error in CDC	Patch corrected after 30-min loss	This patch will be included on countdown check list
2	51	Prelaunch			Two tapes—track 4 (time) too low		Station informed
3	72	Launch	8	20:30	After two-way transfer to DSS 72 transmitter power reported at 8.5 kW		Readjusted klystron saturation level; power raised to 10 kW
4	11	02	9	21:00	No output on JPL teletype. Incorrect patch in tracking data handling preamble generator	Patch corrected	Operator error
5	51	03			Three tapes—track 4 (time) too low		Station informed
6	42	04			FR-1400 tape evaluation: 1 tape—time noisy through entire tape (track 4) 1 tape—no 1 MC on track 4		Station informed
7	11	01, 02 03			Did not record Deep Space Station parameters on FR-1400 recorders		Operator error

Table 36 (contd)

Item	DSS	Pass	Date (Sep 1967)	Time (GMT), h:min	Anomaly	Immediate reaction	Comments
					Equipment misadjustments (cont)		
8	42	07	16	16:15	*Surveyor* on-site computer program on telemetry and command processor B hung up; caused by RPT entry while output was present on W buffer		Program reloaded; operational
9	61	09	17	03:00	FR-900 reel 2B threaded on machine incorrectly		Operator error
					Operator errors		
1	51	Prelaunch	8	22:32	FR-1400 recorder running at 15 in./s		Pinch roller adjusted for 7½ in./s
2	51	Launch	8	10:00	Poor response on FR-1400 B recorder		Cleaned heads. Unit operational
3	42	Launch	8	19:10	No angle channels recorded on recorder after galvanometer lamp changed		Adjusted lamp intensity; data recorded
4	11	05		21:00	TV-11 on-site film recorder tearing on trailing edge of video		Adjusted photomultiplier and Schmidt trigger; ran fans. Replaced wideband amplifier in analog sweep generator. No one solution to problem was found
5	42		14		Data package contained two bad FR-800 tapes. Head dropping out throughout tape		Problem in switch block; when adjustment made, problem cleared
6	42	07	14	04:34	FR-800 recordings. One of four heads missing on 50–70% of frames		Refer to above comment
7	42	09		04:09	A large number of TV frames processed by CDC from start of pass until 06:15; had loss of horizontal sync on bottom of picture		Corrected by readjusting sync level on video processor
8	42	09		05:00	CDC punch 2 unreliable. Mechanical misalignment		
9	42	09		05:00	CDC command generated zero contact bouncing		
10	42	09		09:50	CDC command rack Franklin printer ribbon broke. No printer record from 09:50–10:22		Replaced with spare unit
					Interface compatibility		
1	61	04	11	21:00	Alpha scatter; lost accumulation record 22 due to switching transient break point three	Restarted accumulation	Cause unknown at this time

Table 36 (contd)

Item	DSS	Pass	Date (Sep 1967)	Time (GMT), h:min	Anomaly	Immediate reaction	Comments
Interface compatibility (contd)							
2	42		11	17:40	*Lunar Orbiter* interference during *Surveyor* video sequence at DSS 42		This occurred during *Lunar Orbiter*/MSFN training, (ranging with spacecraft in high power) tests conducted with DSS 61 indicated *Lunar Orbiter* carrier about 2298 MHz, interference noted only during FR-800 recordings of video operations
3	11 42	03 03			Observed excessive phase jitter on transmitter A when mirror was being stepped		Under investigation
4	61				Unable to recall alpha scattering accumulation 016 from magnetic tape	Restarted accumulation	Investigation could not find an apparent reason
5	11				Command confirmation problem in 4400-bit/s configuration *Surveyor* on-site computer program did not process all commands, same problem noted in *Surveyor IV*		Station investigating
6	11 42				Static phase error readout on station manager's console is not consistent between spacecraft modes 4 and 5		Software problem being investigated through project engineer
7	72	Launch			No system noise temperature reported through mission due to lack of nitrogen for cryogenic load		Nitrogen will be supplied for *Surveyor VI*
8	51	Launch pass			Telemetry and command processor could not gain access to I/O typewriter due to continuous long frame printouts		Reloaded program; problem cleared
9	11	Prelaunch			FR-1400 recorder—200-line TV playback noisy		New procedures for TV-11/DSS 11 record interface for 200-line TV being implemented for *Surveyor VI*
10	14		13		Telemetry processing station could not lock onto telemetry data from DSS 14 during static firing		Test is being formulated to simulate conditions and analyze the problem
11	61	09	16	14:01	Telemetry command processor B lost several accumulations from on-site alpha scattering program; cause unknown		Reloaded new tape system operational

Table 36 (contd)

Item	DSS	Pass	Date (Sep 1967)	Time (GMT), h:min	Anomaly	Immediate reaction	Comments
Interface compatibility (contd)							
12	42	10	17		Intermittent GMT fault on telemetry and command processor B with on-site alpha scattering program loaded. Tens and units hours incorrect		Reloaded program and time returned to normal

The last category is marginal interface compatibility. These were problems that appeared after hardware or software changes and were due to unforeseen difficulties. The solutions to the problems were obtained by coordination with the appropriate organizations. These specific problems were brought to the attention of the cognizant organizations for action. Several individual problems had a more direct affect on the mission and warrant further comment:

(1) The telemetry data from DSS 71 during the prelaunch phase of the mission were bad. The on-site telemetry and command processors were checked and no faults were found. These were an important data source during this phase of the mission and further DSN system tests were made to determine the cause of the problem.

(2) The telemetry data on the 96-kHz line from DSS 14 during terminal maneuver and static firing went bad when the strain-gage SCOs were turned on. This was a critical data outage and an investigation was made. Additional tests including DSS 14, telemetry processing station, and the 96-kHz line were made.

(3) The TV-11 film recorder developed a problem that exhibited itself as a marginal horizontal sync. At first it was thought that this was a result of operator error in adjusting the sync circuit. However, further investigation indicated that it was, in fact, a hardware problem. The wideband amplifier in the analog sweep generator was replaced. The amplifier was checked external to the system and was determined to be operational. However, the problem disappeared upon replacement. During the several days required to solve this problem, about 30% of the received pictures were faulty.

(4) Deep Space Station 42 had an intermittent switch block in its FR-800. This was discovered after three days of operation, and the proper adjustment was made to eliminate the problem. The condition was not uncovered by the post-pass spot tape check because of its intermittent nature. Approximately 30% of the video frames taken during the three passes affected were faulty. All video data were recorded on FR-1400.

(5) During passes 8 and 10 at DSS 42, computer problems were experienced. Alpha scattering and/or telemetry data were lost because of these outages. The extent of the data lost is under investigation. In each case hardware faults were discovered and cleared. The loss of alpha scattering data during the telemetry and command processor outage was the risk assumed by the project in using the backup computer to process this data. Normal operation was obtained by having one backup computer. No other backup is committed for the alpha scattering configuration.

(6) Interference from *Lunar Orbiter* ranging during *Surveyor* video operation was experienced by DSS 42. The interference manifested itself in the mixer of the station down converter and was recorded on the FR-800. This interference occurred only once and the DSN was notified.

(7) Several operator error problems were experienced with the on-site alpha scattering program. It is the general opinion of the Deep Space Station operators that it is a very difficult program to operate and its human engineering could be improved. No specific recommendations were made; however, a review of the operational system in light of the load on the telemetry and command processor operator is in order.

(8) The tracking data handling system exhibited many anomalies during this mission. They were principally random hardware faults and were cleared by replacing cards or making the appropriate adjustments. The DSIF was aware of the relatively low reliability level of this equipment and had a program of stock, a high level of spares, and a program of updating the marginal components.

(9) During this mission the FR-800 required a great deal of maintenance and still produced outages. During the lunar phase of the mission the DSIF had Ampex representatives at each of the sites with FR-800 recorders. This produced a high level of on-site competence and in general produced adequate FR-800 recordings. However, some problems were still experienced as noted in Table 36. It was planned to maintain this Ampex representative support at all prime sites for *Surveyors VI* and *VII*. The FR-900 magnetic tape recorders were installed at DSSs 11 and 61. These recorders proved themselves superior to the FR-800 recorders, both in reliability and performance.

(10) There were no significant maser problems.

(11) There were no doppler resolver problems.

(12) The initial acquisition of *Surveyor V* was performed by DSS 51. Initial spacecraft contact and two-way command capability was established in a nominal manner. When the spacecraft was commanded to low power, however, the ground received signal level decreased approximately 29 dB as opposed to the expected decrease of 18.5 dB. It was suspected that they were locked to a sidelobe of the ground station antenna. The station went to aided track to improve the antenna pointing. The sidelobe lock was confirmed when the 86-ft antenna was selected again and a signal level 13 dB higher than the previous value was received. The delay from the initiation of the spacecraft High-Voltage-Off command until the Low Power Transfer Switch command was transmitted caused a loss of spacecraft contact for 7 s. The ground station antenna apparently moved off the spacecraft during this period, causing the sidelobe situation to develop when low power contact was established. The delay in initiating low power operation was necessary to verify that high power operation was terminated by the High-Voltage-Off command. The earth vector during initial acquisition was changing quite rapidly, causing ground station operational problems that also contributed to the above situation.

(13) The station transfer from DSS 11 to DSS 42 on September 9 took place at 04:30:00 GMT with DSS 42 reporting two-way lock. Spacecraft telemetry was indicating a low signal in receiver B and receiver–decoder indexing was also being recorded. The postthrust maneuvers of midcourse maneuver 4 were being performed at the time, and caused a high level of activity in all operational areas. Also indicated in the telemetry was that receiver B was not phase locked. Areas in the SFOF (SPAC, trouble/failure analysis group, and DSIF control) continuously monitor the telemetry containing this information; however, the situation went uncorrected for approximately 1 h, 9 min. Perhaps a reason for not detecting this sooner was that the information was contained in a digital word that was normally displayed in octal form but, because of some situation in the computer system, was actually displayed in decimal form. The receiver operator and data analysts at DSS 42 also had data which would have given the same information, but it also went undetected there. Whatever the reasons may be for allowing the situation to continue for as long as it did, there are no excuses. Care will be taken that this or similar situations will not occur on future missions.

Figure 39 is a plot of Deep Space Station received carrier power vs time generated using the *Surveyor V* trajectory and assuming that the spacecraft was Canopus oriented and transmitting via omniantenna B. Actual measured mission values were plotted and coded by the Deep Space Station. Figure 39 also contains the signal level plots for spacecraft receivers A and B, again assuming Canopus acquisition. Measured values are indicated on each of the plots as circled values.

Both up and downlink signal level readings prior to Canopus acquisition indicated that omniantenna A was operating in a more favorable position relative to the ground tracking station than omniantenna B. At approximately 21:00:00, the ground received signal level with the spacecraft transmitting on omniantenna B had reached the nominal 1100-bit/s threshold value. At 12:19:02, omniantenna A was selected for spacecraft data transmission in order to improve the quality of the PCM data. A 17-dB increase in the signal was noted, with the resulting −125.0 dBmW received carrier power providing a 13.6-dB nominal telemetry margin for 1100-bit/s data. The spacecraft transmitted on omniantenna A for the remainder of this mission phase. After Canopus acquisition, the spacecraft attitude during this phase was determined. Deep Space Stations 72, 42, 51, and 61 tracked

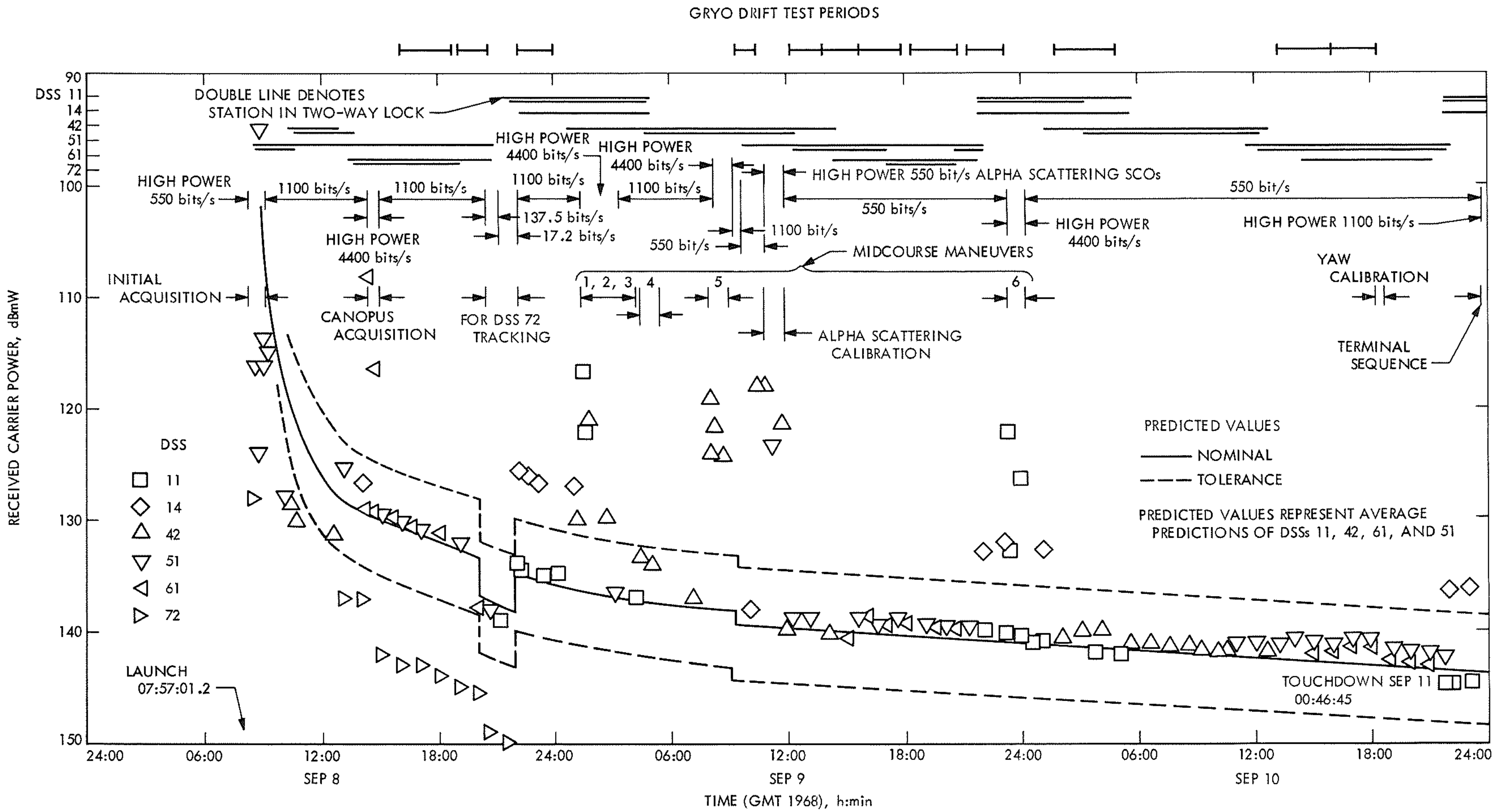


Fig. 39. Deep Space Station received carrier power

the spacecraft during this transit phase with the spacecraft transmitting data at 1100 bits/s.

d. Evaluation. The received carrier levels are shown in Fig. 39 and compare favorably with the 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 that are characteristic for each data bit rate. No level predictions were made before star acquisition because prior to this time the spacecraft was not roll stabilized and the spacecraft antenna gain could have varied significantly. This could have produced variations in the station received signal of 20 dB. This, together with the varying spacecraft look angle, made signal level prediction of limited usefulness in evaluating station performance.

The periods of high power during star acquisition, the midcourse maneuvers, and terminal descent indicated a nominal 17 dB increase over the low power signal level. It appears that the low power transmitter was 2–3 dB above its specification.

The telemetry bit rate was reduced from 1100 to 550 bits/s at launch plus 26 h. The 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.

The signal level at DSS 72 was very close to 12 dB below DSSs 51 and 61 and 10 dB below DSS 11; 10 dB between DSSs 51 and 72 was expected because of the difference in the diameter of their two antennas (85 ft vs 30 ft; apparently the extra 2 dB was the result of the different spacecraft look angle between the stations). The 4-dB decrease in received signal level on September 8, between 20:30 and 21:30, was due to the increased carrier suppression of the 137.5-bit/s modulation required when DSS 72 was two-way during this period.

Throughout the cislunar phase of the mission a 1–3 dB difference in received signal levels were observed between stations. These signal level differences were within the spacecraft antenna gain variation tolerance due to the small difference in look angle between widely separated stations.

The station view periods are shown on the bottom of the plot. The single line indicates the period of three-way tracking and the double line the periods of two-way tracking.

During the spacecraft reconfiguration after touchdown transmitter A was turned on. It was reported by DSS 11 that every time the mirror motor was stepped, phase jitter was observed on the downlink signal. This jitter was in the order of 10 deg peak-to-peak. The station's best effort was to track the signal without any loss of data.

From the time of two-way acquisition by DSS 51 until approximately 40 min before retroignition, the DSN tracked the *Surveyor V* spacecraft in the two-way mode, and with minor exceptions returned high quality two-way doppler data. The most serious loss of two-way doppler data occurred during the second pass of DSS 42. The uplink signal was dropped during the transfer from DSS 11 and the signal was not reacquired until approximately 70 min later, although the doppler data during this interval was marked good, two-way doppler. The near-real-time monitor program showed very large residuals during this period, however, since four unplanned maneuvers had been made by this time, the system data analysis group erroneously concluded that the large residuals were due to the changed trajectory and did not alert the station. During the third pass of DSS 11, approximately 2 h before retroignition, the most significant digit of the doppler data was lost for 32 min. This data was quickly recovered by hand, restoring the missing digit on punched cards. Approximately 2½ min of data were mislabeled by DSS 51 at initial two-way acquisition during the launch pass. This data was mislabeled three-way, but the orbit determination group recovered this data in near-real-time by changing the data condition code from three-way to two-way. No good doppler data were transmitted by DSS 72 during the launch pass; this problem was investigated. During the second pass of DSS 72 the antenna was initially positioned at 10-deg elevation which delayed three-way acquisition to rise plus 1 h 18 min.

*2. **Ground communications facility.*** The DSN/GCF is that portion of NASCOM that provides communications between the various DSN tracking stations through the world and the SFOF in Pasadena. This communications system comprises the land lines, undersea cables, and HF radio circuits that carried teletype, voice, and high-speed data in real-time support of the *Surveyor V* Mission. The performance of NASCOM was considered excellent, demonstrating its high degree of reliability.

Circuit restoration support by GSFC was considered excellent.

For the GCF circuits that supported the mission see Fig. 8. An evaluation of the performance of the GCF during ORTs is presented in Fig. 40. From launch through the first lunar day GCF performance was evaluated as shown in Fig. 41.

a. 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 were used during testing to transmit 202 dataphone information to the stations and during the mission to backfeed various voice nets as required. The DSS 72 data circuits were via satellite during the ORT and the mission and performed flawlessly.

b. Teletype channels. *Surveyor* V went full communications processor for teletype. The teletype channel operation was highly reliable. There were outages due to propagation on the DSS 51 channels and the DSS 72 channels that were by HF radio path. During the mission the A and D channels were via satellite and suffered no outage. The JPL communications processor faulted twice during the ORT and once during prelaunch countdown due to time list overflow. The problem was cleared by addition of errata cards. The GSFC communications processor, Canberra 418, and London 418 caused some short outages during flight. The JPL communications processor faulted again during lunar operations on September 15. This, along with a GSFC high-speed data buffer problem, caused approximately 53 min of data delay from DSSs 42 and 61.

c. Voice circuits. The NASCOM voice circuits provided for *Surveyor* V tests performed well within expectations. The *Surveyor* command network was patched at all times to the active Deep Space Station voice network. The voice of *Surveyor* was patched via GSFC to all scheduled activities plus some that came up in real-time. There were no particular problems noted except some routine voice circuits outages. The DSS 72 voice circuits were by satellite during the ORT test and mission performed exceptionally well. A commercial circuit to DSS 51 was activated as a backup voice during the mission launch phase. This circuit was used when the normal voice circuit failed. There were some short outages.

d. 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 common carrier personnel. One failure occurred on microwave during the transit phase but it was during the early part of DSS 11 pre-pass and caused no problem to the mission.

3. Intracommunications system. The 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, television communications subsystems teletype, high-speed data, and data received over the microwave channels. This system ICS performed in an exceptional manner with only minor problems noted. There was a shortage of plug-in terminals for teletype display during launch. All station C lines were combined with no particular problems. The communications status display performed satisfactorily.

a. NASCOM data sets. The NASCOM data sets were used with all stations except DSS 51 and the reliability was very high. DSS 51 used the Hallicrafter data sets and the normal circuit problems due to propagation were experienced, but no equipment problems.

b. Communications/TV ground data handling system 6-MHz video line. Extensive tests were conducted prior to the mission and no extensive problems were experienced on this interface.

c. 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 teletype/TV monitors during launch phase. All available monitors were assigned to *Surveyor* Project. The output of the scan converter was normalled to public information office at all times and no problems were encountered.

In general, considering full reliability on the communications processor system for the first time, communications support provided for this mission including NASCOM, DSN/GCF, DSN/ICS, and SFOF communications and other contractor furnished communications was considered excellent with communications imposing only minor constraints during critical phases. Most problems with respect to the microwave system and communications processors appeared just prior to prelaunch countdown or during lunar day operations. Table 37 shows the outstanding communications problems experienced for the *Surveyor* V Mission.

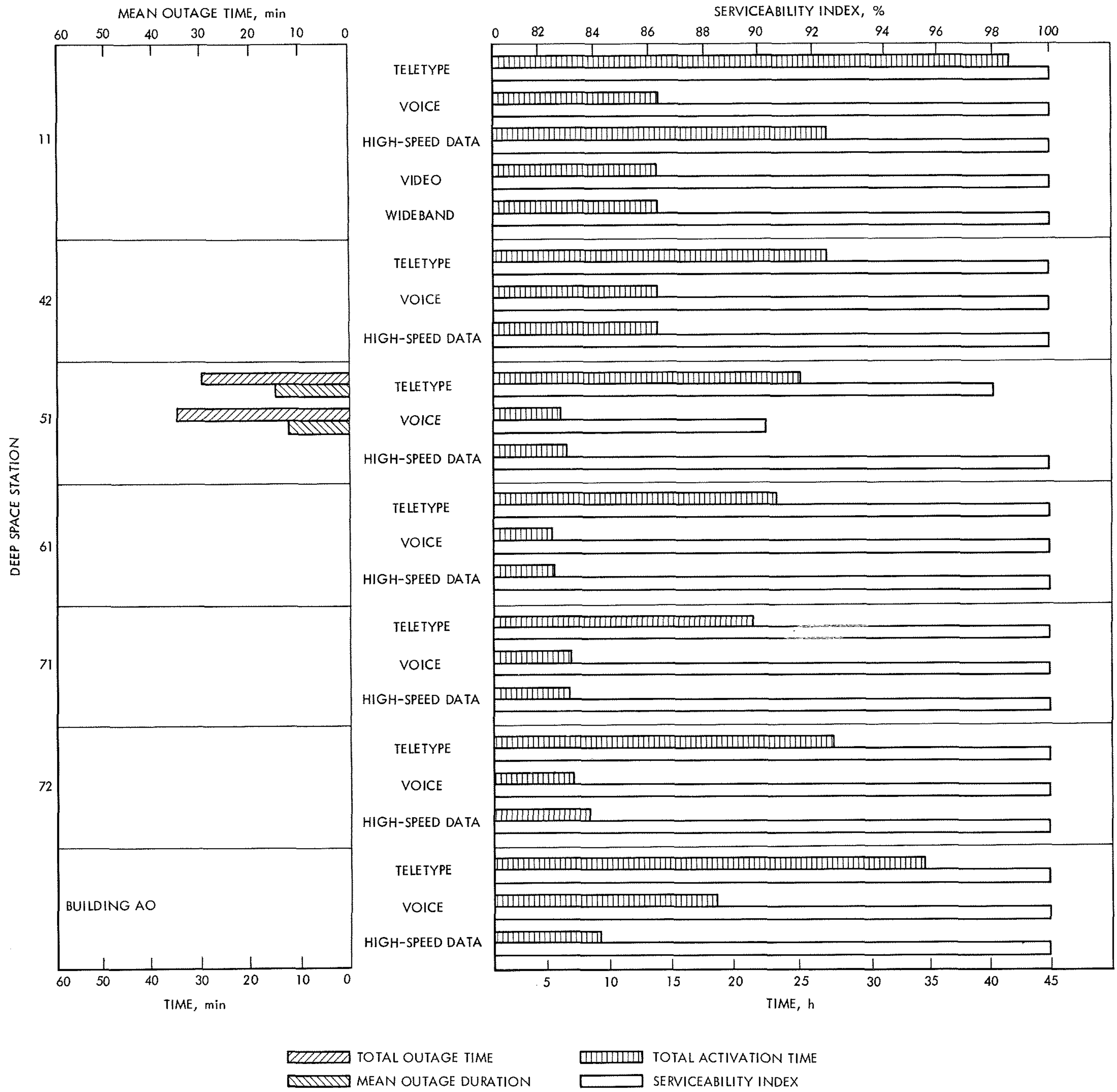


Fig. 40. Performance evaluation of GCF for first operational readiness test

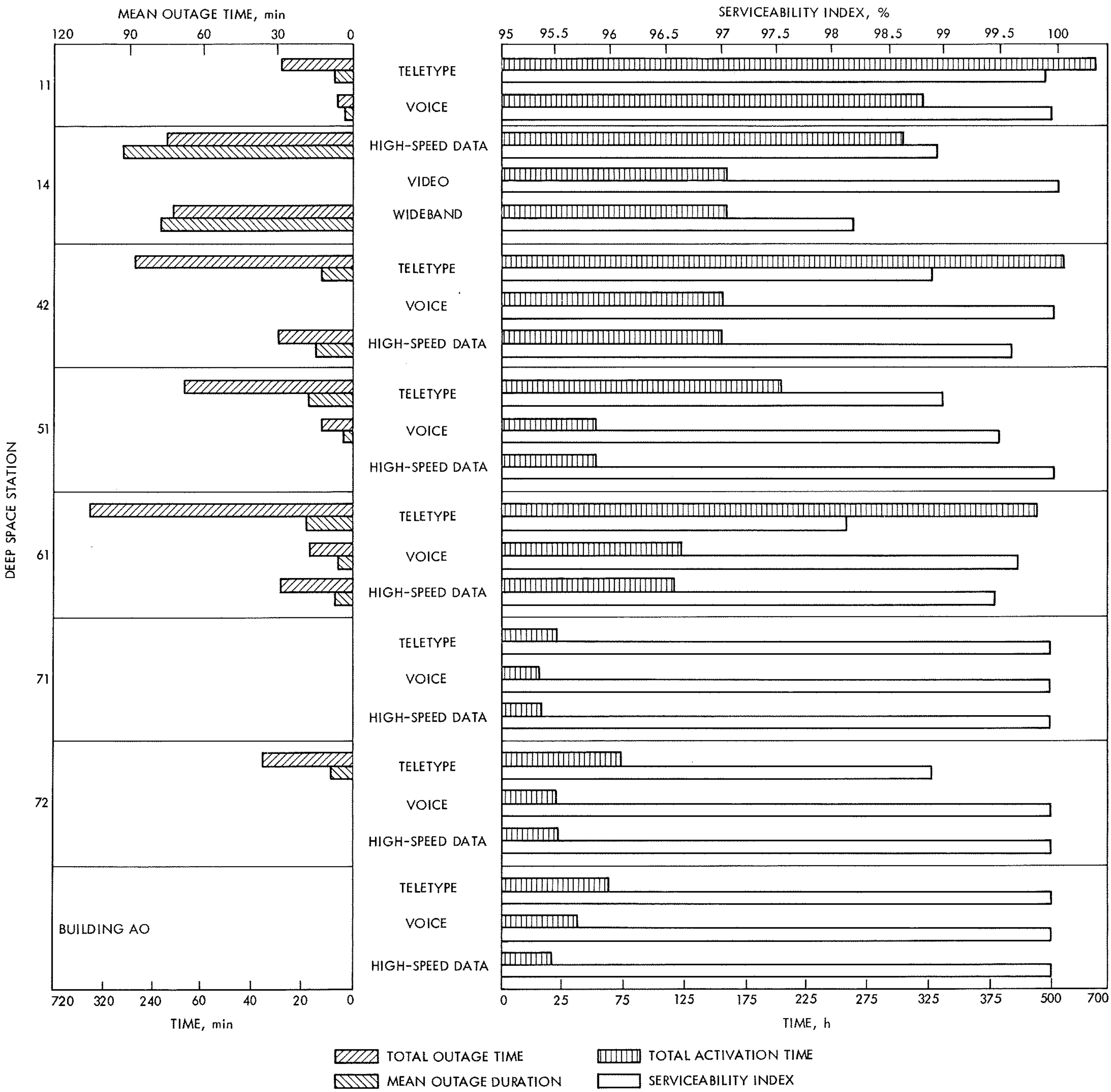


Fig. 41. Performance evaluation of GCF from launch through first lunar day

Table 37. Outstanding communications problems

Problem	Cause	Remarks
Lack of appropriate documented communication line turn up and end-to-end check-out procedure	Lack of agreement as to appropriate documents which will carry these procedures	Study documentation procedures
DSS 11 communication support problem	Split authority and responsibility and non-standard way of providing communications support to DSS 11	Some progress on this problem has been made through meeting and verbal agreement on this subject held during *Surveyor V*

4. ***Space Flight Operations Facility.*** The overall support of the *Surveyor V* Mission by the SFOF was good, despite the fact that *Surveyor* Project used the communications processor subsystem for the first time. A number of communications processor and procedural software problems were encountered. These problems, although they did not significantly affect the mission, caused a delay in supplying the user areas with incoming data. Measures are now being taken to give personnel more training in the use of the communications processor, as well as making improvements in programming. In addition, Goddard communications processor was responsible for short data losses which happened intermittently throughout the mission.

Performance of the data processing system during the premission phase was affected by numerous software problems relating to the *Surveyor* redesigned 7044 computer system. A new software program was put into effect on September 13, 1967, with the expectation that it would solve the problem, however parity errors and computer string recovery problems continued to occur.

Several power failures occurred during the mission, none of which had a significant bearing on the ability of various groups in the SFOF to support the mission.

Staffing for support of the mission was adequate and no problems were encountered in this respect.

Simulation programs were preformed through ORTs to prepare equipment and personnel for the mission.

As it has done on earlier *Surveyor* missions, the SFOF served as the control and processing center for the DSN in support of *Surveyor V* Mission. Specifically, this included communication control, command transmissions, data processing, data analysis, data display, and facility support as required by DSN commitment documents. In addition, assistance was provided in real-time to ensure complete support throughout the mission. To provide these services in an organized, efficient, and homogeneous manner, the SFOF is composed of three major sections with several systems within each section. A brief functional description of how each section supported this mission follows.

a. Data processing system. This system provided prelaunch testing and support in simulated data conversion center, telemetry processing system, and I/O user areas. Operational control of these areas was also provided at the data processing control area.

Additionally the system performed real-time operation of computer systems, keypunch, expediter/library functions and non-real-time computer operations for tracking data processing.

The performance of the data systems and data processing personnel was considered excellent during the mission phase. Some software, hardware, and procedural problems were encountered.

Problems were encountered in 7044 software and 7094 user programs. Some of the solutions to software problems are undetermined at this time. It is felt that continued and intensive coordination between project programmers and systems engineers will result in solutions to many of the software deficiencies.

Air conditioning and primary power problems occurred within the SFOF that did not affect *Surveyor* support but did cause some concern due to loss of backup equipment in the system.

Minor problems were encountered with the brush recorder. These problems fall into the following categories, operator error, noisy pen, and clogged pens. All problems were repaired in real-time without significant loss of data to the project.

During the mission phase, I/O problems were encountered. These problems were repaired in real-time or the unit was replaced. Problems that were encountered caused the project some inconvenience and a minor delay in data.

Particular problems are emphasized because of significant delay or loss of data, or they are areas that require further study.

At 08:20 on September 8, 1967, the flight chief reported to the operations controller that the Y computer string was down. The data controller advised operations controller that this was due to software (mission-dependent) problem. No report was made to data processing control center.

Surveyor experienced many recovery problems with Y string. Several times while the tracking data processor program was operating in the 7094, recovery occurred due to an illegal I/O unit request. This trouble was found to be in the user program.

Many problems with *Surveyor* on-site computer program in the 7044 system occurred causing recoveries. Investigation revealed this fault to be caused by a software error in the 7044 trap supervisor routine.

At 00:19, on September 8, 1967, the printer on the 7040Y encountered print hammer problems. The computer could not be released for repair until 10:00, September 8, 1967, because of *Surveyor* support. The 7040 was returned to operations at 11:00. *Surveyor* lost 1 h of 7040Y support due to this problem.

The W string became unavailable for use as a possible *Surveyor* back up from 19:33, on September 10, 1967, to 05:08 on September 11, 1967, when the string was "powered down" for a commercial-to-generator power switch. A subsequent disk failure, due to a faulty diode, delayed the restoration of the string to operational status. The keypunch machines in the keypunch area and in area 5 went down during the U-buss failure at 01:00 on September 11, 1967. There was no effect on support.

At 10:24 on September 11, 1967, the W string was again unavailable for backup when a third floor power failure occurred. Power was restored at 10:30. There was no effect on X or Y strings. At 15:21 on September 11, 1967, power was dropped again on the W string for power switch. Operation was restored at 15:50.

On September 11, 1967, parity errors in upper core caused 7044X to go down, the 7044X failure caused *Surveyor* to lose use of the X string. *Surveyor* switched to the Y string, bumping *Lunar Orbiter* to the V string. The switch resulted in a 1-h loss of processing time for both users. The 7044 was repaired during the scheduled manufacturer's preventive maintenance time by installing a new power supply. The system was returned to operations at 23:15 on September 12, 1967.

At 12:54 on September 17, 1967, an unusual "end of seek" problem occurred on the 1301 modules 0 and 1 on the 7094Y. This problem caused *Surveyor* to switch to the X string computers. The X string was idle at the time and *Surveyor* lost a minor amount of processing time. The disk problem and a 716 printer problem were repaired and the string returned to operation at 18:30.

Operation of *Surveyor* programs on 7094Y indicated a tape-drive file-protect problem had been encountered. When programs select a tape drive on 7094Y A-channel, they occasionally indicate a file-protect condition. This condition appears even though the tape is not file protected. This is the result of software routines and hardware logic not being compatible.

Routines are faster than the type of drive on 7094X channel A. The solution may include: (1) change of software, or (2) change in the tape-drive logic circuitry.

Many problems were encountered with the I/O equipment. There were symbol and pen problems with the Milgo plotter. For the SC-3070 bulk printer and ad printers, the problems fall into the following categories: light printing, over printing, and paper jams. The majority of the problems were repaired in real-time without loss of data. In some cases the printers were replaced with a minimum loss of data.

b. Communications. Although the GCF is not a part of the SFOF, the SFOF is the termination point of the GCF outputs. Many problems experienced by GCF have a bearing on the performance of the SFOF, and these are covered in this report when they are applicable.

The ICS provided a system for receiving, switching, and distributing all voice, teletype, and high-speed data, and closed circuit TV to all users in the SFOF.

For teletype switching, the JPL communications processor was selected for use. The communications processor is the switching center for Deep Space Stations 11, 12, 13, 14, and HAC. It also performs switching functions for data processing and operational functions internal to the SFOF. Its capabilities include switching, real-time monitoring, quick-access message logging system, and allows the use of quick-access message recall.

The JPL communications processor switching center is linked to the GSFC. The GSFC communications processor is the principal switching center for the entire NASCOM system and is the single access point for all DSN overseas and Cape Kennedy traffic.

The JPL communications processor was used for the first time by the *Surveyor* Project. This resulted in a great number of procedural interface problems.

Before the mission, the communications personnel conducted a complete plant checkout, and all equipment was adjusted per specifications with the exception of the common carrier microwave subsystem.

During the premission phase, performance of communications personnel was not acceptable. This created a problem in regard to the *Surveyor* Flight Director's concern for the status of communications. Personnel changes were made prior to launch to correct this potential problem.

In general, all systems performed within specifications with the exception of the communications link with DSS 51 at Johannesburg. The majority of these problems were due to propagation.

As stated below, the JPL communications processor had three faults during the premission phase, on September 6 and 7, 1967. These problems were turned over to programmers who prepared errata changes to the system to extend the timer list and direct inputs to the proper section for timing. Upon entry of the errata, no further major outages were attributed to this subsystem.

Considerable outages were experienced by the DSS 11 voice circuits due to propagation conditions, reducing the reliability to approximately 90%.

The microwave system presented a problem with the 96-kHz and 6-MHz data lines being out of specification. This portion of the system was turned over to common carrier personnel who properly aligned the system and returned it to operation.

There were several short circuit outages, none of which had any lasting effect on the premission phase.

The JPL communications processor continued to have problems during the mission phase due to memory lockout. The performance of the communications personnel and systems was considered excellent and, with the exception of the communications processor, overall communications subsystems performed well within expected specifications.

The JPL communications processor had three faults during the mission phase, occurring on September 15, 1967. Again, system swaps and 3/2 recoveries were made. Programming changes were made to reduce the number of outages due to memory lockout.

The Goddard communications processor faulted several times during the mission with outages being of short duration. London and Canberra 418s suffered short outages also.

There were several voice outages of short duration with DSS 51. During the launch phase a commercial phone call was established and was used to assist in maintaining voice communications with DSS 51.

The two teletype circuits to DSS 72 via RF circuits were out for 1 h, 22 min prior to launch. The satellite circuits stayed in 100%.

There was a video problem on the microwave link that passed the 6-MHz signal between Goldstone and JPL during DSS 11 pass at 03:11 on September 18, 1967. Intermittent outages and poor video quality were caused by A-beam transmitter failure and defective IF automatic switch at the Montana Mines site. Video was restored at 08:45 by deactivating the A-beam. Final system repairs were made at 03:10 on September 19, 1967.

The microwave system failed at 17:00 on September 10, 1967, between JPL and Goldstone. This outage was due to a bad demodulator at Shadow Mountain and primarily affected the voice circuits. Restoration was made at 18:33 on September 10, 1967.

The 96-kHz line to Goldstone was down at 20:30 on September 13, 1967, due to a dirty potentiometer in the common carrier terminal area at the SFOF. This caused a delay in the activation of this circuit for project use by 1 h, 34 min. Restoration time was 21:34 on September 13, 1967.

5. Tracking and data analysis. The quality of data received during the *Surveyor* V Mission was generally good. Effective tracking was achieved and a successful mission accomplished.

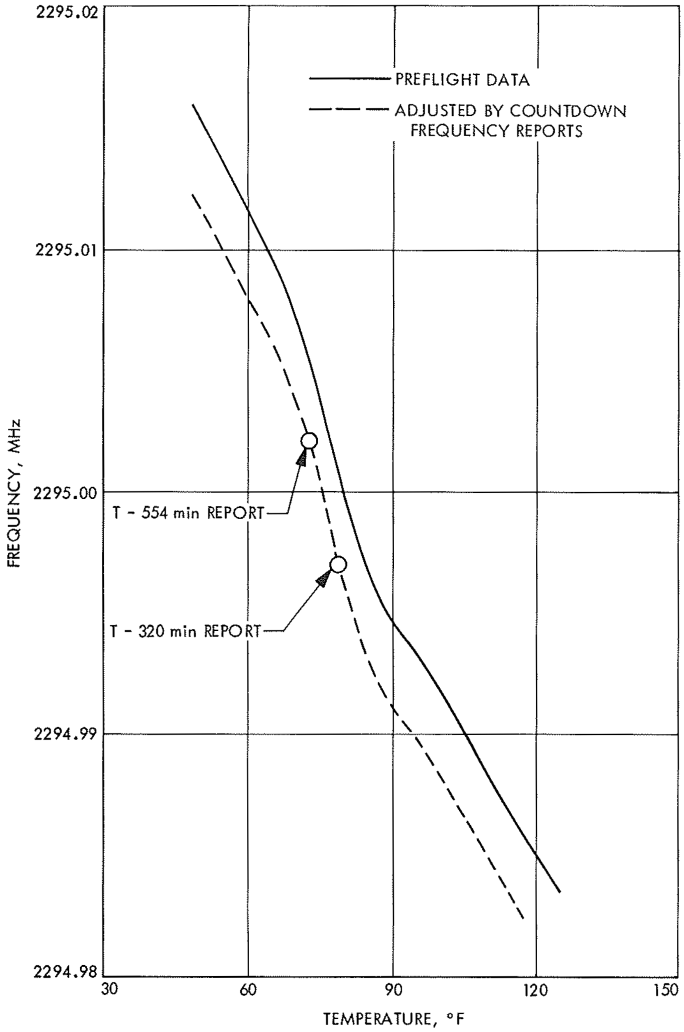


Fig. 42. Transmitter A frequency vs temperature (one way)

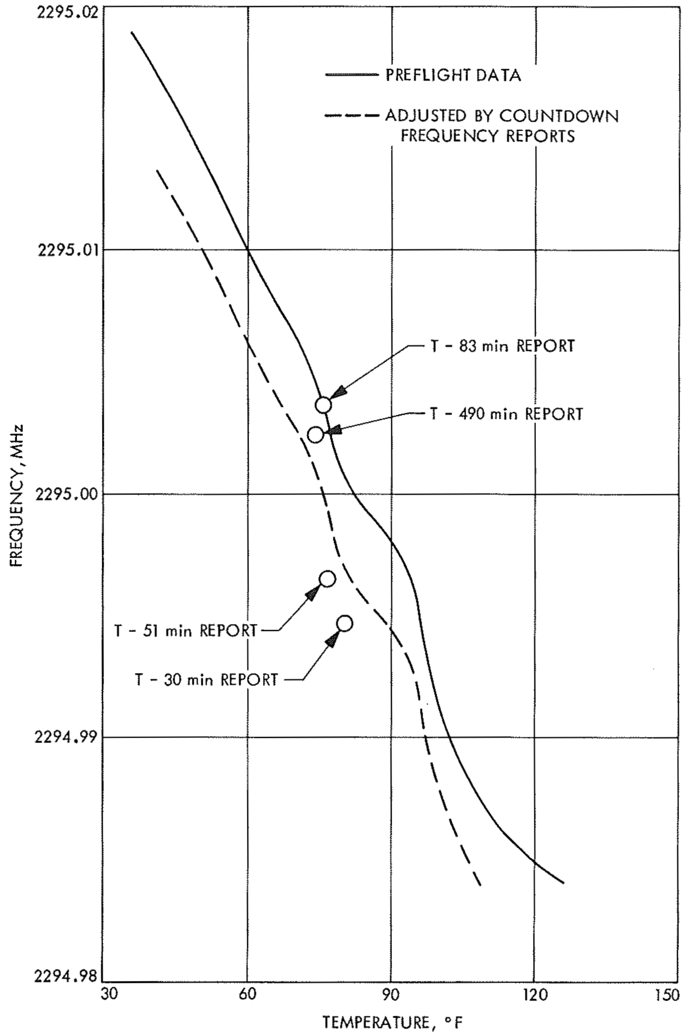


Fig. 43. Transmitter B frequency vs temperature (one way)

a. Spacecraft center frequencies. So that spacecraft predictions may be generated and supplied to the Deep Space 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 frequencies and transponder (two-way) center frequencies be accurately known. The nominal values for these frequencies at 2295.000000 MHz (at carrier level) for the transmitter center frequency and 22.013670 MHz (at station VCO level) for the transponder center frequency. These frequencies are measured months before the mission for use in the preflight prediction document, and again measured several times within the last 10 h of the countdown for use in real-time predictions. The frequencies that were used in the preflight prediction document were:

Frequency, MHz	Transmitter/ transponder	Temperature, °F
2294.997000	Transmitter A	85
2294.986900	Transmitter B	110
22.013706	Transponder A	90
22.013615	Transponder B	90

These frequencies were abstracted from preflight data supplied by HAC. During the countdown, frequency measurements were made and sent to the SFOF at T −554, −490, −320, −83, −51, and −30 min, approximately as called for in the sequence of events.

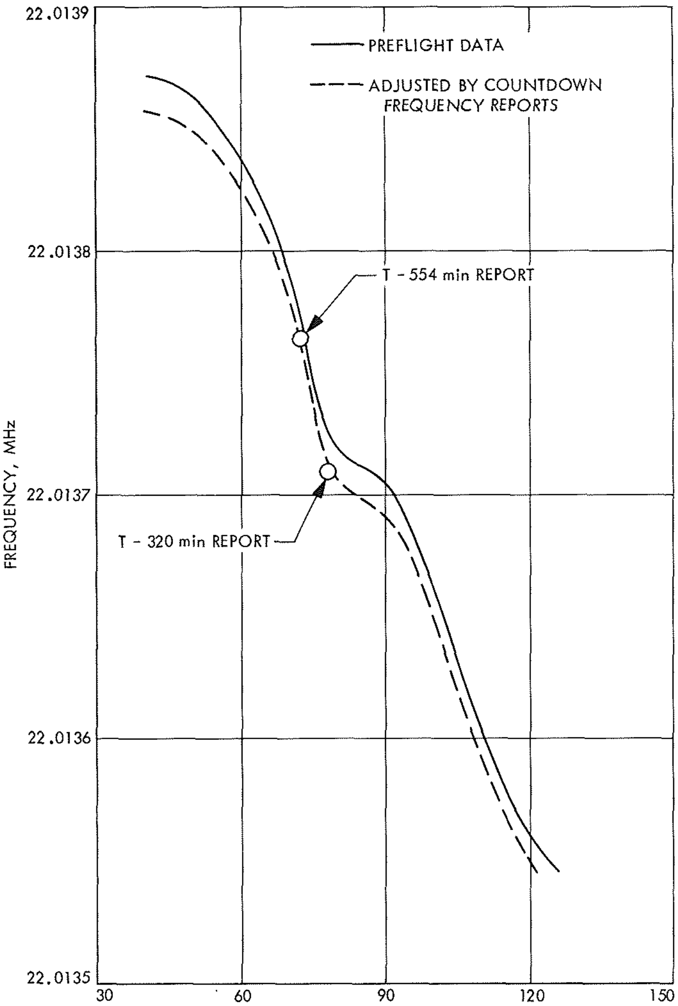


Fig 44. Transponder A frequency vs temperature (two way)

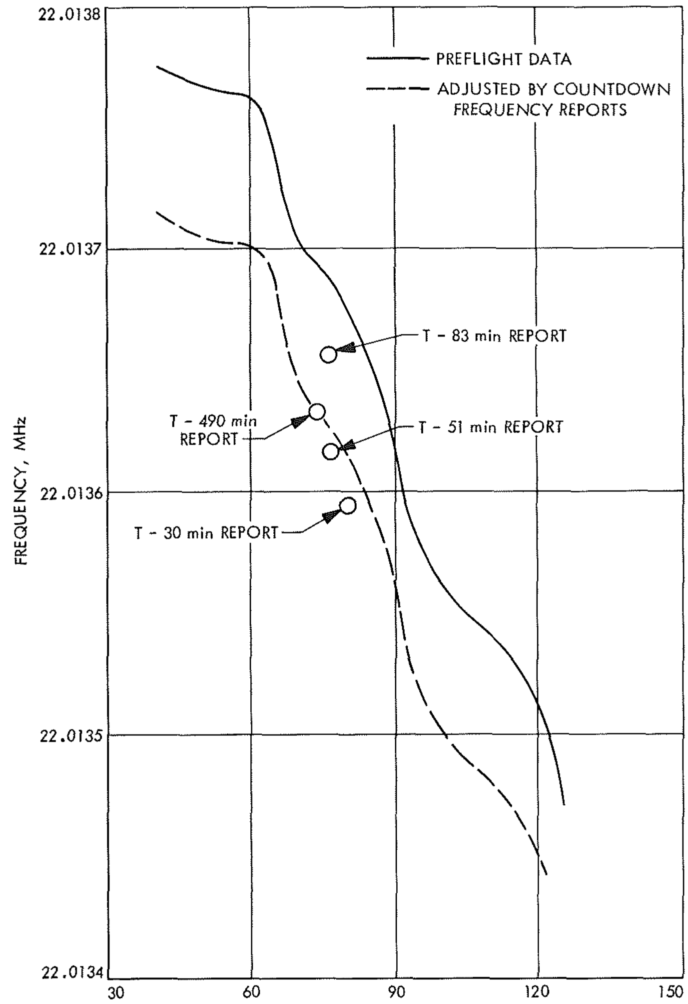


Fig. 45. Transponder B frequency vs temperature (two way)

These measurements were used to adjust the preflight frequency-vs-temperature curves by a constant frequency bias (Figs. 42–45).

During the inflight portion of the mission, temperature predictions from the SFOF were used in correlation with these frequency-vs-temperature curves to determine accurate frequency predictions for each set of predictions generated. These frequencies are shown in Table 38. The one deviation from this procedure was the prediction-data set for initial acquisition at DSSs 72 and 51, which utilized special frequencies supplied by the SFOF (2294.993699 MHz for transmitter B and 22.013587 MHz for transponder B)). Table 39 contrasts nominal vs actual tracking coverage. Close examination of Table 40 shows an average frequency over the DSS 51 first pass of 2294.992887 MHz, just 812 Hz below SPAC's special frequency. *Surveyor V* was acquired by DSS 51 in the two-way mode at a ground transmitter frequency at 22.013765 MHz, which after removing doppler indicates a transponder B frequency of 22.013614 MHz, only 27 Hz above SPAC's acquisition prediction. Tables 40–43 show transmitter B frequencies when *Surveyor V* was tracked in the one-way mode. These values can be compared to the data presented in Fig. 43.

b. Spacecraft predictions. Spacecraft predictions, which are composed of time-tagged observables such as antenna pointing angles, one-, two-, and three-way doppler, best-lock ground transmitter frequency, etc., are routinely provided to the Deep Space Stations to ensure the success of spacecraft acquisition, aided track, and station transfer of the spacecraft's signal. However, during the launch phase the provision of accurate predictions to

DSSs 72 and 51 becomes a critical matter because of the crucial need for early acquisition and commanding of the spacecraft. For first two-way acquisition at DSSs 72 and 51, there are three distinct sets of predictions available:

(1) Preflight prediction document.

(2) $T - 5$ min predictions based on actual launch azimuth.

(3) AFETR predictions based on actual postinjection tracking data.

Although both the preflight prediction data and the $T - 5$ min predicts are generated before launch, the $T - 5$ min predicts have two important advantages over the preflight predicts in that they are based on updated frequency information and are generated for the exact actual launch azimuth. For these reasons, the $T - 5$ min predicts were generated and sent to DSSs 72, 51, and 42, with the instruction that they be used instead of the previously calculated predicts. Both DSSs 72 and 51 reported receipt of the $T - 5$ min predicts by $T + 10$ min, or at least 10 min before rise, and DSS 51 subsequently acquired the spacecraft with these predicts in the two-way mode with no difficulties being encountered. Arrival time of AFETR predictions at approximately $T + 35$ min was too late to be of any value, delayed partly by the initial transmission of predicts to Grand Canary.

For the remainder of the mission, predicts were routinely supplied to all participating Deep Space Stations. However, due to the execution of six midcourse maneuvers, small inaccuracies were introduced in the doppler quantities of the otherwise accurate predicts during this interval.

A prediction program malfunction contributed a slight delay to the generation of one set of predicts. However, this problem was quickly overcome and the predicts were generated with no appreciable loss of time.

c. Initial two-way acquisition at DSS 51. Predictions indicated a *Surveyor* V rise at DSS 51 at 08:25:10 GMT on September 8, 1967 ($T + 28$ h, 9 min). Good one-way data were received by DSS 51 at 08:24:31 (39 s after rise), reported auto-track on the S-band acquisition aid antenna at 08:25:43, auto-track on the S-band Cassegrain-monopulse antenna (main beam) at 08:26:40, and good two-way data at 08:30:21. Experience with the current acquisition procedure indicates that the above sequence that occurred at DSS 51 was quite good. For instance, during the initial acquisition of *Surveyors III* and *IV* at DSSs 42 and 72, good two-way data were taken at 6 min, 55 s and 6 min, 38 s after rise, respectively.

d. Data quality. From the time of two-way acquisition by DSS 51 until approximately 40 min before retro-ignition, the DSN tracked *Surveyor* V in the two-way mode, and with minor exceptions returned high quality two-way doppler data. The most serious loss of two-way doppler data occurred during the second pass of DSS 42. For 70 min after transfer from DSS 11, DSS 42 sent bad doppler data mismarked as good data. It was supposed that the large doppler deviations reported by the near-real-time tracking data monitor were the result of the four midcourse maneuvers which the spacecraft had undergone by this time. It was for this reason that the error was not discovered sooner and the data lost. During the third pass of DSS 11 approximately 2 h before retro-ignition, the most significant digit of the doppler counter was lost for 32 min. This piece of data was quickly recovered by hand restoring the missing digit on punched cards. Approximately 2½ min of data at initial two-way acquisition during the launch pass was mislabeled by DSS 51. It was mislabeled three-way, but the orbit determination group recovered this data by changing the condition code from three-way to two-way.

Table 38. Inflight frequency predictions

Time after launch, h	Temperature, °F	Frequency, MHz
Transmitter B[a]		
2	80	2294.993699[b]
2–8	76	2294.999700
8–16	72	2295.001800
16–40	65	2295.004300
40–66	40	2295.014000
Transponder B		
2	80	22.013587[b]
2–8	76	22.013629
8–16	72	22.013638
16–40	65	22.013677
40–66	40	22.013715
Transmitter A		
Posttouchdown	70	2295.003700
Transponder A		
Posttouchdown	70	22.013784

[a]Transmitter B and transponder B were used during the entire inflight portion of *Surveyor V*.
The $T - 30$ min frequency report was corrected by SPAC and used during initial acquisition.

Table 39. Nominal view periods vs actual Deep Space Station tracking

Date (Sep 1967)	DSS	Nominal rise (GMT)	Nominal set (GMT)	Nominal[a] view period	Acquisition by station (GMT)	Loss of signal by station (GMT)	Actual view period
8	72	08:20:17	08:35:05	00:14:48	08:26:35	08:36:55	00:10:20
	51	08:25:10	20:52:37	12:27:27	08:24:41	20:54:02	12:29:21
	42	09:10:46	12:37:41	03:26:55	09:14:02	12:38:02	03:24:00
	72	10:22:58	00:10:39	13:47:41	11:40:02	21:41:02	10:01:00
	61	13:19:36	20:30:36	07:11:00	13:16:02	20:34:02	07:18:00
	11	21:11:23	04:37:12	07:26:49	21:14:02	04:47:02	07:33:00
9	42	00:20:02	14:16:31	13:56:29	00:32:02	14:13:02	13:41:80
	51	09:34:51	21:35:55	12:01:04	09:36:02	21:38:02	12:02:00
	61	14:03:44	21:26.03	07:22:19	14:11:02	21:26:02	07:15:00
	11	21:31:22	05:15:33	07:44:11	21:39:02	05:22:02	07:43:00
10	42	01:07:37	14:34:08	13:26:31	01:03:02	14:32:02	13:29:00
	51	09:52:36	21:47:47	11:55:11	09:54:02	21:51:02	11:57:00
	61	14:14:27	21:42:31	07:28:04	14:21:02	21:41:02	07:20:00
	11	21:35:28	05:36:43	08:01:15	21:47:02	05:43:56	07:56:54

[a]Based on horizon mask for all stations except DSS 72, which is based on 0-deg elevation.

Table 40. One-way doppler data from DSS 51 (September 8, 1967)

Time (GMT)	One-way doppler, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
08:24:16.0	998938.40	3559.40	2294979642.95[a]	−0.27723764E 01
08:24:26.0	995035.30	3903.10	2294984886.92[a]	−0.25972128E 01
08:24:36.0	988248.70	6786.60	2294993034.09	−0.24194748E 01[b]
08:24:46.0	989641.10	1392.40	2294993019.89	−0.22394401E 01[b]
08:24:56.0	991052.00	1410.90	2294993002.66	−0.20573869E 01[b]
08:25:06.0	992476.30	1424.30	2294992985.34	−0.18735931E 01[b]
08:25:16.0	993913.80	1437.50	2294992966.05	−0.16883365E 01[b]
08:25:26.0	995359.90	1446.10	2294992947.20	−0.15018952E 01[b]
08:25:36.0	996814.10	1454.20	2294992927.20	−0.13145471E 01[b]
08:25:46.0	998273.00	1458.90	2294992907.31	−0.11265701E 01
08:25:56.0	999736.90	1463.90	2294992885.12	−0.93824225E 00
08:26:06.0	1001202.00	1465.10	2294992862.30	−0.74984001E 00
08:26:16.0	1002665.40	1463.40	2294992839.58	−0.56164411E 00
08:26:26.0	1004136.10	1470.70	2294992805.81	−0.37393887E 00
08:26:36.0	1005581.60	1445.50	2294992791.36	−0.18700323E 00
08:26:46.0	1007031.20	1449.60	2294992764.77	−0.11182231E−02
08:26:56.0	1008470.40	1439.20	2294992738.45	0.18344688E 00
08:27:06.0	1009900.20	1429.80	2294992709.39	0.36642236E 00

[a]Bad doppler and angle data, automatically sensed. [b]Bad doppler data manual switch.

Table 40 (contd)

Time (GMT)	One-way doppler, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
08:27:16.0	1011313.90	1413.70	2294992682.31[b]	0.54755605E 00
08:27:26.0	1010047.90	1266.00	2294995318.94[b]	0.72659715E 00
08:27:36.0	995954.10	4093.80	2295010765.61[b]	0.90331692E 00
08:27:46.0	992924.90	3029.20	2295015128.17[b]	0.10774894E 01
08:27:56.0	998916.80	5991.90	2295010448.58[b]	0.12489146E 01
08:28:06.0	1007181.20	8264.40	2295003473.94[b]	0.14173972E 01

[b]Bad doppler data, manual switch.

Table 41. One-way doppler data from DSS 42 (September 9, 1967)

Time (GMT)	One-way doppler, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
04:24:32.0	1022960.41	4.73	2294995879.27[a]	0.13970619E 01
04:25:32.0	1020527.93	2432.49	2294998314.77[a]	0.13974537E 01
04:26:32.0	1021406.13	878.20	2294997439.61[a]	0.13978505E 01
04:27:32.0	1021410.91	4.78	2294997437.89[a]	0.13982524E 01
04:28:32.0	1021415.68	4.76	2294997436.25[a]	0.13986592E 01
04:29:32.0	1021420.44	4.77	2294997434.62[a]	0.13990709E 01
04:30:32.0	1021371.74	−48.70	2294997486.52[a]	0.13994877E 01
04:31:32.0	1021907.09	535.35	2294996954.41[a]	0.13999093E 01
04:32:32.0	1022358.60	451.50	2294996506.16	0.14003358E 01
04:33:32.0	1022267.40	−91.20	2294996600.66	0.14007673E 01
04:34:32.0	1022171.28	−96.12	2294996700.12	0.14012036E 01
04:35:32.0	1022076.10	−95.18	2294996798.67	0.14016447E 01
04:36:32.0	1021983.92	−92.18	2294996894.28	0.14020906E 01
04:37:32.0	1021893.72	−90.19	2294996987.91	0.14025413E 01
04:38:32.0	1021805.40	−88.33	2294997079.73	0.14029969E 01
04:39:32.0	1021720.52	−84.88	2294997168.12	0.14034571E 01
04:40:32.0	1021637.77	−82.75	2294997254.44	0.14039221E 01
04:41:32.0	1021557.28	−80.49	2294997338.55	0.14043918E 01
04:42:32.0	1021478.32	−78.96	2294997421.12	0.14048662E 01
04:43:32.0	1021401.08	−77.24	2294997502.03	0.14053453E 01
04:44:32.0	1021325.89	−75.19	2294997580.94	0.14058290E 01
04:45:32.0	1021253.15	−72.74	2294997657.39	0.14063174E 01
04:46:32.0	1021181.90	−71.25	2294997732.42	0.14068103E 01
04:47:32.0	1021112.63	−69.27	2294997805.50	0.14073079E 01
04:48:32.0	1021044.29	−68.34	2294997877.69	0.14078100E 01
04:49:32.0	1020977.51	−66.78	2294997948.34	0.14083166E 01
04:50:32.0	1020911.95	−65.56	2294998017.81	0.14088279E 01

[a]Bad doppler data, manual switch.

Table 41 (contd)

Time (GMT)	One-way doppler, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
04:51:32.0	1020848.58	−63.38	2294998085.16	0.1̄4093437E 01
04:52:32.0	1020785.17	−63.40	2294998152.52	0.1̄4098639E 01
04:53:32.0	1020723.77	−61.40	2294998217.95	0.1̄4103887E 01
04:54:32.0	1020663.31	−60.46	2294998282.44	0.1̄4109178E 01
04:55:32.0	1020602.98	−60.34	2294998346.87	0.1̄4114514E 01
04:56:32.0	1020545.28	−57.70	2294998408.70	0.1̄4119894E 01
04:57:32.0	1020486.50	−58.78	2294998471.61	0.1̄4125317E 01
04:58:32.0	1020430.02	−56.48	2294998532.30	0.1̄4130784E 01
04:59.32.0	1020374.35	−55.67	2294998592.19	0.1̄4136293E 01
05:00:32.0	1020319.20	−55.15	2294998651.58	0.1̄4141846E 01
05:02:02.0	1020238.56	−80.63	2294998738.66	0.1̄4150255E 01
05:03:32.0	1020159.88	−78.68	2294998823.86	0.1̄4158760E 01
05:04:32.0	1020108.16	−51.72	2294998879.95	0.1̄4164482E 01
05:05:32.0	1020057.41	−50.75	2294998935.11	0.1̄4170246E 01
05:06:32.0	1020008.53	−48.88	2294998988.42	0.1̄4176051E 01
05:07:32.0	1019960.38	−48.15	2294999041.06	0.1̄4181898E 01
05:08:32.0	1019912.53	−47.85	2294999093.41	0.1̄4187786E 01
05:09:32.0	1019866.41	−46.12	2294999144.08	0.1̄4193715E 01
05:10:32.0	1019820.38	−46.03	2294999194.69	0.1̄4199686E 01
05:11:32.0	1019775.79	−44.59	2294999243.87	0.1̄4205698E 01
05:12:32.0	1019731.76	−44.03	2294999292.55	0.1̄4211751E 01
05:13:32.0	1019688.32	−43.44	2294999340.64	0.1̄4217843E 01
05:14:32.0	1019645.60	−42.72	2294999388.05	0.1̄4223976E 01
05:15:32.0	1019602.74	−42.86	2294999435.64	0.1̄4230147E 01
05:16:32.0	1019561.47	−41.27	2294999481.66	0.1̄4236358E 01
05:17:32.0	1019521.72	−39.76	2294999526.22	0.1̄4242608E 01
05:18:32.0	1019481.13	−40.58	2294999571.61	0.1̄4248897E 01
05:19:32.0	1019440.53	−40.61	2294999617.06	0.1̄4255224E 01
05:20:32.0	1019402.76	−37.77	2294999659.70	0.1̄4261589E 01
05:21:32.0	1019364.59	−38.17	2294999702.77	0.1̄4267992E 01
05:22:32.0	1019327.20	−37.39	2294999745.09	0.1̄4274433E 01
05:23:32.0	1019290.78	−36.42	2294999786.47	0.1̄4280912E 01
05:24:32.0	1019252.55	−38.23	2294999829.67	0.1̄4287427E 01
05:25:32.0	1019216.88	−35.67	2294999870.37	0.1̄4293980E 01
05:26:32.0	1019182.30	−34.59	2294999910.02	0.1̄4300569E 01
05:27:32.0	1019148.93	−33.37	2294999948.44	0.1̄4307195E 01
05:28:32.0	1019114.03	−34.89	2294999988.44	0.1̄4313856E 01
05:29:32.0	1019080.09	−33.94	2295000027.52	0.1̄4320554E 01
05:30:32.0	1019046.78	−33.31	2295000065.97	0.1̄4327287E 01
05:31:32.0	1019014.03	−32.75	2295000103.91	0.1̄4334056E 01
05:32:32.0	1018982.47	−31.56	2295000140.69	0.1̄4340860E 01

Table 41 (contd)

Time (GMT)	One-way doppler, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
05:33:32.0	1018951.38	−31.09	2295000176.98	$\bar{0}$.14347699E 01
05:34:32.0	1018920.59	−30.79	2295000213.05	$\bar{0}$.14354573E 01
05:35:32.0	1018890.57	−30.02	2295000248.36	$\bar{0}$.14361481E 01
05:36:32.0	1018863.40	−27.17	2295000280.83	$\bar{0}$.14368423E 01
05:37:32.0	1020906.59	2043.19	2294998242.97[a]	$\bar{0}$.14375399E 01
05:38:32.0	1006911.47	3995.13	2295012243.55[a]	$\bar{0}$.14382409E 01
05:39:32.0	1026907.98	9996.51	2294992252.33[abc]	$\bar{0}$.14389452E 01
05:40:32.0	1021947.93	4960.05	2294997217.81[ab]	$\bar{0}$.14396528E 01
05:41:32.0	1021969.23	21.31	2294997201.95[ab]	$\bar{0}$.14403637E 01

[a]Bad doppler data, manual switch. [b]Bad angle data. [c]Automatically sensed.

Table 42. One-way doppler data from DSS 11 (September 11, 1967)

Time (GMT)	One-way doppler, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Rate rate, km/s
00:05:32.0	1017907.09	379.72	2294994928.64	0.11438938E 01[a]
00:06:32.0	1018051.84	144.75	2294994855.27	0.11532162E 01[a]
00:07:32.0	1018190.71	138.87	2294994790.16	0.11628509E 01[a]
00:08:32.0	1018332.64	141.93	2294994724.52	0.11728170E 01[a]
00:09:32.0	1018481.13	148.50	2294994654.98	0.11831334E 01[a]
00:10:32.0	1018633.21	152.08	2294994584.55	0.11937977E 01[a]
00:11:32.0	1018789.92	156.71	2294994512.36	0.12048366E 01[a]
00:12:32.0	1018959.57	169.65	2294994430.44	0.12162977E 01[a]
00:13:32.0	1019135.45	175.87	2294994345.77	0.12282098E 01[a]
00:14:32.0	1019318.21	182.76	2294994257.84	0.12406015E 01[a]
00:15:32.0	9386544.10	7225.89	2276627053.64[b]	0.12534646E 01[a]
00:16:32.0	1019706.89	6837.21	2294994070.03	0.12668413E 01[a]
00:17:32.0	1019912.21	205.31	2294993971.66	0.12808098E 01[a]
00:18:32.0	1020124.12	211.91	2294993871.56	0.12954157E 01[a]
00:19:32.0	1020343.73	219.61	2294993768.98	0.13107046E 01[a]
00:20:32.0	1020569.22	225.49	2294993665.59	0.13266539E 01[a]
00:21:32.0	1020803.56	234.34	2294993558.95	0.13433342E 01[a]
00:22:32.0	1021047.90	244.34	2294993448.94	0.13608819E 01[a]
00:23:32.0	1021299.90	252.00	2294993338.50	0.13793738E 01[a]
00:24:33.5	1021566.65	266.75	2294993224.97	0.13993881E 01[a]
00:24:43.0	1021608.54	41.89	2294993207.50	0.14025807E 01[a]
00:24:53.0	1021653.07	44.53	2294993188.94	0.14059713E 01[a]
00:25:03.0	1021697.69	44.62	2294993170.42	0.14093805E 01[a]
00:25:13.0	1021743.73	46.03	2294993150.50	0.14127917E 01[a]

[a]Bad angle data. [b]Rejected point.

Table 42 (contd)

Time (GMT)	One-way doppler, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
00:25:23.0	1021789.48	45.75	2294993131.09	0.14162351E 01[a]
00:25:33.0	1021835.41	45.93	2294993111.78	0.14197115E 01[a]
00:25:43.0	1021881.95	46.53	2294993092.11	0.14232215E 01[a]
00:25:53.0	1021927.73	45.79	2294993073.47	0.14267657E 01[a]
00:26:03.0	1021974.46	46.73	2294993054.14	0.14303447E 01[a]
00:26:13.0	1022020.85	46.39	2294993035.41	0.14339593E 01[a]
00:26:23.0	1022067.34	46.49	2294993016.84	0.14376100E 01[a]
00:26:33.0	1022116.06	48.72	2294992996.37	0.14412975E 01[a]
00:26:43.0	1022164.28	48.22	2294992976.67	0.14450224E 01[a]
00:26:53.0	1022212.13	47.84	2294992957.62	0.14487853E 01[a]
00:27:03.0	1022261.68	49.55	2294992937.19	0.14525870E 01[a]
00:27:13.0	1022310.94	49.27	2294992917.31	0.14564279E 01[a]
00:27:23.0	1022358.77	47.83	2294992899.20	0.14603089E 01[a]
00:27:33.0	1022407.74	48.97	2294992880.25	0.14642304E 01[a]
00:27:43.0	1022456.48	48.74	2294992861.84	0.14681932E 01[a]
00:27:53.0	1022506.61	50.13	2294992842.39	0.14721979E 01[a]
00:28:03.0	1022557.04	50.43	2294992822.94	0.14762451E 01[a]
00:28:13.0	1022606.83	49.79	2294992804.45	0.14803354E 01[a]
00:28:23.0	1022657.92	51.08	2294992785.02	0.14844696E 01[a]
00:28:33.0	1022709.66	51.74	2294992765.27	0.14886482E 01[a]
00:28:43.0	1022760.47	50.81	2294992746.78	0.14928718E 01[a]
00:28:53.0	1022812.80	52.33	2294992727.12	0.14971412E 01[a]
00:29:03.0	1022865.73	52.92	2294992707.25	0.15014569E 01[a]
00:29:13.0	1022917.75	52.03	2294992688.61	0.15058196E 01[a]
00:29:23.0	1022971.20	53.45	2294992668.94	0.15102300E 01[a]
00:29:33.0	1023025.87	54.68	2294992648.41	0.15146886E 01[a]
00:29:43.0	1023078.99	53.11	2294992629.77	0.15191961E 01[a]
00:29:53.0	1023132.73	53.74	2294992610.92	0.15237531E 01[a]
00:30:03.0	2024286.78	1154.05	2273991384.87[b]	0.15283336E 01[a]
00:30:13.0	1023241.56	1045.22	2294992572.12	0.15329028E 01[a]
00:30:23.0	1023296.75	55.19	2294992552.33	0.15375241E 01[a]
00:30:33.0	1023352.76	56.01	2294992532.11	0.15421989E 01[a]
00:30:43.0	1023409.98	57.22	2294992511.09	0.15469284E 01[a]
00:30:53.0	1023465.00	55.01	2294992492.70	0.15517138E 01[a]
00:31:03.0	1023522.46	57.46	2294992472.31	0.15565564E 01[a]
00:31:13.0	1023580.22	57.76	2294992452.06	0.15614574E 01[a]
00:31:23.0	1023637.02	56.80	2294992433.23	0.15664180E 01[a]
00:31:33.0	1023695.29	58.27	2294992413.42	0.15714395E 01[a]
00:31:43.0	1023753.36	58.07	2294992394.27	0.15765230E 01[a]

[a]Bad angle data. [b]Rejected point.

Table 42 (contd)

Time (GMT)	One-way doppler, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
00:31:53.0	1023812.21	58.85	2294992374.81	0.15816699E 01[a]
00:32:03.0	1023870.83	58.62	2294992356.08	0.15868813E 01[a]
00:32:13.0	1023930.58	59.75	2294992336.75	0.15921585E 01[a]
00:32:23.0	1023990.67	60.09	2294992317.56	0.15975027E 01[a]
00:32:33.0	1024053.22	62.55	2294992296.45	0.16029152E 01[a]
00:32:43.0	1024113.84	60.62	2294992277.78	0.16083972E 01[a]
00:32:53.0	1024174.87	61.03	2294992259.27	0.16139499E 01[a]
00:33:03.0	1024235.53	60.66	2294992241.66	0.16195745E 01[a]
00:33:13.0	1024297.50	61.97	2294992223.31	0.16252723E 01[a]
00:33:23.0	1024360.57	63.07	2294992204.42	0.16310445E 01[a]
00:33:33.0	1024424.09	63.52	2294992185.69	0.16368924E 01[a]
00:33:43.0	1024488.07	63.98	2294992167.05	0.16428171E 01[a]
00:33:53.0	1024552.83	64.77	2294992148.23	0.16488200E 01[a]
00:34:03.0	1024618.13	65.30	2294992129.50	0.16549022E 01[a]
00:34:13.0	1024684.39	66.26	2294992110.42	0.16610650E 01[a]
00:34:23.0	1024751.78	67.39	2294992090.83	0.16673096E 01[a]
00:34:33.0	1024817.96	66.18	2294992073.09	0.16736372E 01[a]
00:34:43.0	1024885.25	67.29	2294992054.89	0.16800492E 01[a]
00:34:53.0	1024953.59	68.34	2294992036.30	0.16865466E 01[a]
00:35:03.0	1025022.74	69.15	2294992017.53	0.16931307E 01[a]
00:35:13.0	1025092.94	70.21	2294991998.42	0.16998029E 01[a]
00:35.23.0	1025162.15	69.21	2294991980.98	0.17065642E 01[a]
00:35:33.0	1025233.04	70.89	2294991962.53	0.17134160E 01[a]
00:35:43.0	1025305.93	72.89	2294991942.80	0.17203594E 01[a]
00:35:53.0	1025377.86	71.93	2294991924.75	0.17273958E 01[a]
00:36:03.0	1025450.61	72.75	2294991906.56	0.17345262E 01[a]
00:36:13.0	1025523.99	73.38	2294991888.50	0.17417521E 01[a]
00:36:23.0	1025598.03	74.04	2294991870.50	0.17490745E 01[a]
00:36:33.0	1025672.57	74.53	2294991852.78	0.17564948E 01[a]
00:36:43.0	1025748.85	76.29	2294991834.06	0.17640141E 01[a]
00:36:53.0	1025825.13	76.28	2294991816.12	0.17716338E 01[a]
00:37:03.0	1025902.07	76.93	2294991798.28	0.17793550E 01[a]
00:37:13.0	1025978.97	76.90	2294991781.28	0.17871789E 01[a]
00:37:23.0	1026058.87	79.91	2294991762.08	0.17951068E 01[a]
00:37:33.0	1026139.07	80.19	2294991743.36	0.18031400E 01[a]
00:37:43.0	1026218.34	79.27	2294991726.41	0.18112796E 01[a]
00:37:53.0	1026299.67	81.32	2294991708.22	0.18195269E 01[a]
00:38:03.0	1026381.57	81.90	2294991690.28	0.18278831E 01[a]
00:38:13.0	1026464.04	82.47	2294991672.61	0.18363495E 01[a]

[a]Bad angle data.

Table 42 (contd)

Time (GMT)	One-way doppler, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
00:38:23.0	1026546.94	82.90	2294991655.37	0.18449273E 01[a]
00:38:33.0	1026631.99	85.04	2294991636.86	0.18536177E 01[a]
00:38:43.0	1026716.88	84.89	2294991619.36	0.18624220E 01[a]
00:38:53.0	1026802.89	86.01	2294991601.64	0.18713413E 01[a]
00:39:03.0	1026890.31	87.42	2294991583.41	0.18803770E 01[a]
00:39:13.0	1026977.98	87.67	2294991565.80	0.18895302E 01[a]
00:39:23.0	1027067.88	89.90	2294991546.87	0.18988022E 01[a]
00:39:33.0	1027158.51	90.63	2294991528.14	0.19081942E 01[a]
00:39:43.0	1027249.64	91.12	2294991509.84	0.19177075E 01[a]
00:39:53.0	1027342.42	92.78	2294991490.83	0.19273432E 01[a]
00:40:03.0	1027436.84	94.42	2294991471.11	0.19371027E 01[a]
00:40:03.0	1027436.84	94.42	2294991428.94[c]	0.19315910E 01[a]
00:40:13.0	1027531.41	94.57	2294991408.30	0.19412497E 01[a]
00:40:23.0	1027625.95	94.54	2294991387.62	0.19508975E 01[a]
00:40:33.0	1027722.38	96.42	2294991366.94	0.19607940E 01[a]
00:40:43.0	1027820.91	98.53	2294991346.22	0.19709587E 01[a]
00:40:53.0	1027919.76	98.85	2294991325.45	0.19811584E 01[a]
00:41:03.0	1028019.54	99.78	2294991304.66	0.19914758E 01[a]
00:41:13.0	1028120.40	100.86	2294991283.83	0.20019307E 01[a]
00:41:23.0	1028223.09	102.69	2294991262.98	0.20126211E 01[a]
00:41:33.0	1028327.08	103.99	2294991242.09	0.20234752E 01[a]
00:41:43.0	1028433.06	105.98	2294991221.17	0.20345866E 01[a]
00:41:53.0	1028539.99	106.93	2294991200.22	0.20458202E 01[a]
00:42:03.0	1028648.31	108.31	2294991179.23	0.20572261E 01[a]
00:42:13.0	1028758.09	109.78	2294991158.22	0.20688218E 01[a]
00:42:23.0	1028869.36	111.27	2294991137.17	0.20806072E 01[a]
00:42:33.0	1028982.09	112.74	2294991116.09	0.20925802E 01[a]
00:42:43.0	1029096.13	114.04	2294991094.97	0.21047190E 01[a]
00:42:53.0	1029211.35	115.23	2294991073.83	0.21170084E 01[a]
00:43:03.0	1029327.77	116.41	229499r052.64	0.21294482E 01[a]
00:43:13.0	1029446.24	118.47	2294991031.44	0.21421541E 01[a]
00:43.23.0	1029567.37	121.14	2294991010.20	0.21552025E 01[a]
00:43:33.0	1029690.63	123.26	2294990988.91	0.21685236E 01[a]
00:43:43.0	1029814.57	123.95	2294990967.61	0.21819297E 01[a]
00:43:53.0	1029939.96	125.38	2294990946.27	0.21955213E 01[a]
00:44:03.0	1030067.38	127.43	2294990924.91	0.22093767E 01[a]
00:44:13.0	1030196.46	129.07	2294990903.50	0.22234416E 01[a]
00:44:23.0	1030327.67	131.22	2294990882.05	0.22377792E 01[a]
00:44:33.0	1030460.61	132.94	2294990860.58	0.22523392E 01[a]

[a]Bad angle data. [c]Start of extrapolation of auxiliary oscillator frequency.

Table 42 (contd)

Time (GMT)	One-way doppler, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
00:44:43.0	1030595.40	134.79	2294990839.08	0.22671392E 01[a]
00:44:53.0	1030356.56	−238.84	2294990817.56	0.22331287E 01[a]
00:45:03.0	1027755.75	2600.81	2294990796.00	0.18905721E 01[a]
00:45:13.0	1023982.34	3773.41	2294990774.37	0.13948288E 01[a]
00:45:23.0	1018992.52	4989.82	2294990752.75	0.74019035E 00[a]
00:45:33.0	1014292.98	4699.55	2294990731.09	0.12346467E 00[a]
00:45:43.0	1013861.67	−431.30	2294990709.41	0.64288792E −01[a]
00:45:53.0	1013886.94	25.27	2294990687.67	0.64751223E −01[a]
00:46:03.0	1013926.98	40.04	2294990665.91	0.67137541E −01[a]
00:46:13.0	1013967.35	40.37	2294990644.12	0.69567484E −01[a]
00:46:23.0	1013981.73	14.38	2294990622.30	0.68592453E −01[a]
00.46:33.0	1013882.15	−99.58	2294990600.44	0.52730203E −01[a]
00:46:43.0	1013848.11	−34.04	2294990578.56	0.45427286E −01[a]
00:46:53.0	1013863.01	14.90	2294990556.62	0.44506787E −01[a]
00:47:03.0	1013887.22	24.21	2294990534.67	0.44801259E −01[a]
00:47:13.0	1013910.14	22.92	2294990512.69[d]	0.44923411E −01[a]
00:47:33.0	1013956.09	0.00	2294990072.17	−0.66171953E −02[a]
00:47:43.0	1013981.90	25.81	2294990048.08	−0.63917195E −02[a]
00:47:53.0	1014007.50	25.59	2294990024.22	−0.61662164E −02[a]
00:48:03.0	1014031.52	24.02	2294990001.91	−0.59406868E −02[a]
00:48:13.0	1014054.31	22.79	2294989980.84	−0.57151315E −02[a]
00:48:23.0	1014077.88	23.57	2294989959.02	−0.54895492E −02[a]
00:48:33.0	1014105.43	27.55	2294989933.19	−0.52639398E −02[a]
00:48:43.0	1014130.25	24.82	2294989910.09	−0.50383031E −02[a]
00:48:53.0	1014154.52	24.27	2294989887.55	−0.48126391E −02[a]
00:49:03.0	1014179.23	24.71	2294989864.58	−0.45869472E −02[a]
00:49:13.0	1014202.94	23.70	2294989842.59	−0.43612266E −02[a]
00:49:23.0	1014227.90	24.96	2294989819.36	−0.41354789E −02[a]
00:49:33.0	1014251.55	23.65	2294989797.42	−0.39097041E −02[a]
00:49:43.0	1014274.84	23.29	2294989775.87	−0.36839027E −02[a]
00:49:53.0	1014298.64	23.80	2294989753.80	−0.34580746E −02[a]
00:50:03.0	1014322.41	23.76	2294989731.78	−0.32322204E −02[a]
00:50:13.0	1014345.81	23.41	2294989710.09	−0.30063404E −02[a]
00:50:23.0	1014370.60	24.79	2294989687.03	−0.27804343E −02[a]
00:50:33.0	1014395.09	24.49	2294989664.27	−0.25545023E −02[a]
00:50:43.0	1014418.57	23.48	2294989642.52	−0.23285446E −02[a]
00:50:53.0	1014444.17	25.60	2294989618.66	−0.21025611E −02[a]
00:51:03.0	1014467.36	23.19	2294989597.17	−0.18765521E −02[a]
00:51:13.0	1014492.51	25.15	2294989573.77	−0.16505178E −02[a]

[a]Bad angle data. [d]End of extrapolation of auxiliary oscillator frequency.

Table 42 (contd)

Time (GMT)	One-way doppler, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
00:51:23.0	1014515.38	22.87	2294989552.62	−0.14244581E−02[a]
00:51:33.0	1014539.68	24.30	2294989530.06	−0.11983732E−02[a]
00:51:43.0	1014563.15	23.47	2294989508.33	−0.97226319E−03[a]
00:51:53.0	1014588.08	24.93	2294989485.11	−0.74612816E−03[a]
00:52:03.0	1014612.85	24.77	2294989462.08	−0.51996823E−03[a]
00:52:13.0	1014637.60	24.75	2294989439.06	−0.29378349E−03[a]
00:52:23.0	1014662.08	24.48	2294989416.31	−0.67574069E−04[a]
00:52:33.0	1014686.06	23.98	2294989394.06	0.15865992E−03[a]
00:52:43.0	1014710.05	24.00	2294989371.81	0.38491838E−03[a]
00:52:53.0	1014734.10	24.05	2294989349.50	0.61120119E−03[a]
00:53:03.0	1014758.69	24.59	2294989326.62	0.83750823E−03[a]
00:53:13.0	1014784.47	25.78	2294989302.58	0.10638394E−02[a]
00:53:23.0	1014809.51	25.03	2294989279.28	0.12901946E−02[a]
00:53:33.0	1014833.98	24.48	2294989256.55	0.15165737E−02[a]
00:53:43.0	1014857.91	23.93	2294989234.34	0.17429766E−02[a]
00:53:53.0	1014881.72	23.81	2294989212.25	0.19694032E−02[a]
00:54:03.0	1014905.90	24.18	2294989189.83	0.21958537E−02[a]
00:54:13.0	1014929.65	23.75	2294989167.81	0.24223281E−02[a]
00:54:23.0	1014954.69	25.04	2294989144.52	0.26488257E−02[a]
00:54:33.0	1014979.10	24.42	2294989121.83	0.28753463E−02[a]
00:54:43.0	1015003.06	23.95	2294989099.61	0.31018897E−02[a]
00:54:53.0	1015027.43	24.37	2294989076.95	0.33284556E−02[a]
00:55:03.0	1015050.99	23.57	2294989055.12	0.35550433E−02[a]
00:55:13.0	1015076.00	25.01	2294989031.87	0.37816518E−02[a]
00:55:23.0	1015100.65	24.65	2294989008.95	0.40082826E−02[a]
00:55:33.0	1015125.28	24.64	2294988986.05	0.42349358E−02[a]
00:57:32.0	1015418.32	293.03	2294988713.67	0.69338216E−02[a]
00:58:32.0	1015564.35	146.03	2294988578.08	0.82957521E−02[a]
00:59:32.0	1015708.81	144.47	2294988444.03	0.96584168E−02[a]
01:00:32.0	5053397.21	7688.39	2290950765.92[b]	0.11021785E−01[a]
01:01:32.0	1016000.22	7396.99	2294988173.50	0.12385834E−01[a]
01:02:32.0	1016145.08	144.86	2294988039.08	0.13750540E−01[a]
01:03:32.0	1016288.94	143.86	2294987905.67	0.15115878E−01[a]
01:04:32.0	1016431.06	142.12	2294987774.02	0.16481824E−01[a]
01:05:32.0	1016572.58	141.51	2294987642.97	0.17848356E−01[a]
01:06:32.0	1016711.00	138.43	2294987515.02	0.19215448E−01[a]
01:07:32.0	1016846.52	135.52	2294987389.97	0.20583073E−01[a]
01:08:32.0	1016977.77	131.25	2294987269.19	0.21951207E−01[a]
01:09:32.0	1016700.33	−277.45	2294987557.11[abc]	0.23319824 −01[a]

[a]Bad angle data. [b]Rejected point. [c]Bad doppler data, automatically sensed.

Table 43. One-way doppler velocity data from DSS 11 (September 11, 1967)

Time (GMT)	Doppler, Hz	Hypothetical doppler at lunar surface, Hz	Difference, Hz	Velocity referenced to lunar surface, ft/s
00:44:30.5	1030427.00	1013517.57	16909.43	7246.87
00:44:31.5	1030439.00	1013519.98	16919.02	7250.98
00:44:32.5	1030454.00	1013522.40	16931.60	7256.38
00:44:33.5	1030467.00	1013524.81	16942.19	7260.91
00:44:34.5	1030480.00	1013527.23	16952.77	7265.45
00:44:35.5	1030495.00	1013529.64	16965.36	7270.84
00:44:36.5	1030508.00	1013532.06	16975.94	7275.38
00:44:37.5	1030522.00	1013534.47	16987.53	7280.34
00:44:38.5	1030534.00	1013536.89	16997.11	7284.45
00:44:39.5	1030549.00	1013539.30	17009.70	7289.85
00:44:40.5	1030563.00	1013541.72	17021.28	7294.81
00:44:41.5	1030576.00	1013544.13	17031.87	7299.35
00:44:42.5	1030587.00	1013546.55	17040.45	7303.03
00:44:43.5	1030601.00	1013548.96	17052.04	7307.99
00:44:44.5	1030616.00	1013551.38	17064.62	7313.38
00:44:45.5	1030629.00	1013553.79	17075.21	7317.92
00:44:46.5	1030643.00	1013556.21	17086.79	7322.89
00:44:47.5	1030656.00	1013558.63	17097.37	7327.42
00:44:48.5	1030670.00	1013561.04	17108.96	7332.39
00:44:49.5	1030684.00	1013563.46	17120.54	7337.35
00:44:50.5	1030698.00	1013565.87	17132.13	7342.32
00:44:51.5	1030710.00	1013568.29	17141.71	7346.42
00:44:52.5	1030707.00	1013570.70	17136.30	7344.10
00:44:53.5	1030528.00	1013573.12	16954.88	7266.35
00:44:54.5	1030285.00	1013575.53	16709.47	7161.18
00:44:55.5	1030031.00	1013577.95	16453.05	7051.28
00:44:56.5	1029765.00	1013580.36	16184.64	6936.25
00:44:57.5	1029487.00	1013582.78	15904.22	6816.07
00:44:58.5	1029200.00	1013585.20	15614.80	6692.04
00:44:59.5	1028901.00	1013587.61	15313.39	6562.86
00:45:00.5	1028593.00	1013590.03	15002.97	6429.82
00:45:01.5	1028276.00	1013592.44	14683.56	6292.93
00:45:02.5	1027951.00	1013594.86	14356.14	6152.61
00:45:03.5	1027619.00	1013597.27	14021.73	6009.29
00:45:04.5	1027281.00	1013599.69	13681.31	5863.40
00:45:05.5	1026936.00	1013602.11	13333.89	5714.51
00:45:06.5	1026582.00	1013604.52	12977.48	5561.76
00:45:07.5	1026219.00	1013606.94	12612.06	5405.15
00:45:08.5	1025847.00	1013609.35	12237.65	5244.69
00:45:09.5	1025463.00	1013611.77	11851.23	5079.08

Table 43 (contd)

Time (GMT)	Doppler, Hz	Hypothetical doppler at lunar surface, Hz	Difference, Hz	Velocity referenced to lunar surface, ft/s
00:45:10.5	1025068.00	1013614.19	11453.81	4908.76
00:45:11.5	1024664.00	1013616.60	11047.40	4734.58
00:45:12.5	1024245.00	1013619.02	10625.98	4553.98
00:45:13.5	1023817.00	1013621.43	10195.57	4369.51
00:45:14.5	1023375.00	1013623.85	9751.15	4179.05
00:45:15.5	1022921.00	1013626.27	9294.73	3983.44
00:45:16.5	1022452.00	1013628.68	8823.32	3781.41
00:45:17.5	1021971.00	1013631.10	8339.90	3574.23
00:45:18.5	1021476.00	1013633.52	7842.48	3361.05
00:45:19.5	1020962.00	1013635.93	7326.07	3139.73
00:45:20.5	1020439.00	1013638.35	6800.65	2914.55
00:45:21.5	1019903.00	1013640.77	6262.23	2683.81
00:45:22.5	1019349.00	1013643.18	5705.82	2445.34
00:45:23.5	1018777.00	1013645.60	5131.40	2199.16
00:45:24.5	1018187.00	1013648.02	4538.98	1945.27
00:45:25.5	1017579.00	1013650.43	3928.57	1683.67
00:45:26.5	1016950.00	1013652.85	3297.15	1413.06
00:45:27.5	1016304.00	1013655.27	2648.73	1135.17
00:45:28.5	1015654.00	1013657.68	1996.32	855.56
00:45:29.5	1015013.00	1013660.10	1352.90	579.81
00:45:30.5	1014486.00	1013662.52	823.48	352.92
00:45:31.5	1014196.00	1013664.93	531.07	227.60
00:45:32.5	1014050.00	1013667.35	382.65	163.99
00:54:33.5	1013969.00	1013669.77	299.23	128.24
00:45:34.5	1013921.00	1013672.18	248.82	106.64
00:45:35.5	1013892.00	1013674.60	217.40	93.17
00:45:36.5	1013878.00	1013677.02	200.98	86.14
00:45:37.5	1013870.00	1013679.43	190.57	81.67
00:45:38.5	1013869.00	1013681.85	187.15	80.21
00:45:39.5	1013867.00	1013684.27	182.73	78.31
00:45:40.5	1013867.00	1013686.68	180.32	77.28
00:45:41.5	1013861.00	1013689.10	171.90	73.67
00:45:42.5	1013851.00	1013691.52	159.48	68.35
00:45:43.5	1013853.00	1013693.94	159.06	68.17
00:45:44.5	1013857.00	1013696.35	160.65	68.85
00:45:45.5	1013861.00	1013698.77	162.23	69.53
00:45:46.5	1013864.00	1013701.19	162.81	69.78
00:45:47.5	1013867.00	1013703.61	163.39	70.03
00:45:48.5	1013869.00	1013706.02	162.98	69.85
00:45:49.5	1013874.00	1013708.44	165.56	70.95

Table 43 (contd)

Time (GMT)	Doppler, Hz	Hypothetical doppler at lunar surface, Hz	Difference, Hz	Velocity referenced to lunar surface, ft/s
00:45:50.5	1013878.00	1013710.86	167.14	71.63
00:45:51.5	1013881.00	1013713.28	167.72	71.88
00:45:52.5	1013885.00	1013715.69	169.31	72.56
00:45:53.5	1013889.00	1013718.11	170.89	73.24
00:45:54.5	1013893.00	1013720.53	172.47	73.92
00:45:55.5	1013896.00	1013722.95	173.05	74.17
00:45:56.5	1013900.00	1013725.36	174.64	74.84
00:45:57.5	1013904.00	1013727.78	176.22	75.52
00:45:58.5	1013909.00	1013730.20	178.80	76.63
00:45:59.5	1013912.00	1013732.62	179.38	76.88
00:46:00.5	1013917.00	1013735.03	181.97	77.99
00:46:01.5	1013921.00	1013737.45	183.55	78.66
00:46:02.5	1013926.00	1013739.87	186.13	79.77
00:46:03.5	1013929.00	1013742.29	186.71	80.02
00:46:04.5	1013933.00	1013744.71	188.29	80.70
00:46:05.5	1013937.00	1013747.12	189.88	81.38
00:46:06.5	1013941.00	1013749.54	191.46	82.05
00:46:07.5	1013945.00	1013751.96	193.04	82.73
00:46:08.5	1013950.00	1013754.38	195.62	83.84
00:46:09.5	1013953.00	1013756.80	196.20	84.09
00:46:10.5	1013957.00	1013759.21	197.79	84.77
00:46:11.5	1013961.00	1013761.63	199.37	85.44
00:46:12.5	1013965.00	1013764.05	200.95	86.12
00:46:13:5	1013969.00	1013766.47	202.53	86.80
00:46:14.5	1013974.00	1013768.89	205.11	87.91
00:46:15.5	1013978.00	1013771.31	206.69	88.58
00:46:16.5	1013981.00	1013773.72	207.28	88.83
00:46:17.5	1013986.00	1013776.14	209.86	89.94
00:46:18.5	1013990.00	1013778.56	211.44	90.62
00:46:19.5	1013995.00	1013780.98	214.02	91.72
00:46:20.5	1013997.00	1013783.40	213.60	91.54
00:46:21.5	1014001.00	1013785.82	215.18	92.22
00:46:22.5	1014001.00	1013788.23	212.77	91.19
00:46:23.5	1013992.00	1013790.65	201.35	86.29
00:46:24.5	1013979.00	1013793.07	185.93	79.68
00:46:25.5	1013967.00	1013795.49	171.51	73.50
00:46:26.5	1013953.00	1013797.91	155.09	66.47
00:46:27.5	1013942.00	1013800.33	141.67	60.72
00:46:28.5	1013934.00	1013802.75	131.25	56.25
00:46:29.5	1013924.00	1013805.16	118.84	50.93

Table 43 (contd)

Time (GMT)	Doppler, Hz	Hypothetical doppler at lunar surface, Hz	Difference, Hz	Velocity referenced to lunar surface, ft/s
00:46:30.5	1013911.00	1013807.58	103.42	44.32
00:46:31.5	1013899.00	1013810.00	89.00	38.14
00:46:32.5	1013885.00	1013812.42	72.58	31.10
00:46:33.5	1013871.00	1013814.84	56.16	24.07
00:46:34.5	1013858.00	1013817.26	40.74	17.46
00:46:35.5	1013849.00	1013819.68	29.32	12.57
00:46:36.5	1013849.00	1013822.10	26.90	11.53
00:46:37.5	1013842.00	1013824.52	17.48	7.49
00:46:38.5	1013837.00	1013826.94	10.06	4.31
00:46:39.5	1013839.00	1013829.35	9.65	4.13
00:46:40.5	1013843.00	1013831.77	11.23	4.81
00:46:41.5	1013846.00	1013834.19	11.81	5.06
00:46:42.5	1013850.00	1013836.61	13.39	5.74
00:46:43.5	1013860.00	1013839.03	20.97	8.99
00:46:44.5	1013860.00	1013841.45	18.55	7.95
00:46:45.5	1013848.00	1013843.87	4.13	1.77
00:46:46.5	1013848.00	1013846.29	1.71	0.73
00:46:47.5	1013850.00	1013848.71	1.29	0.55
00:46:48.5	1013852.00	1013851.13	0.87	0.37
00:46:49.5	1013855.00	1013853.55	1.45	0.62
00:46:50.5	1013857.00	1013855.97	1.03	0.44
00:46:51.5	1013858.00	1013858.39	−0.39	−0.17
00:46:52.5	1013862.00	1013860.81	1.19	0.51
00:46:53.5	1013864.00	1013863.23	0.77	0.33
00:46:54.5	1013867.00	1013865.65	1.35	0.58
00:46:55.5	1013869.00	1013868.07	0.93	0.40
00:46:56.5	1013872.00	1013870.48	1.52	0.65
00:46:57.5	1013874.00	1013872.90	1.10	0.47
00:46:58.5	1013876.00	1013875.32	0.68	0.29
00:46:59.5	1013878.00	1013877.74	0.26	0.11
00:47:00.5	1013882.00	1013880.16	1.84	0.79
00:47:01.5	1013884.00	1013882.58	1.42	0.61
00:47:02.5	1013885.00	1013885.00	−0.00	−0.00
00:47:03.5	1013889.00	1013887.42	1.58	0.68
00:47:04.5	1013891.00	1013889.84	1.16	0.50
00:47:05.5	1013894.00	1013892.26	1.74	0.74
00:47:06.5	1013895.00	1013894.68	0.32	0.14

No good doppler data were transmitted by DSS 72 during the launch pass. During the second pass of DSS 72, the antenna was initially positioned at 10-deg elevation which delayed three-way acquisition to 1 h, 18 min after rise.

All two-way tracking data taken during the *Surveyor V* Mission were computer monitored in near-real-time, which resulted in the discovery of the lost digit in the doppler counter during the second pass at DSS 11.

e. Tracking performance. The DSN provided continuous angular and doppler tracking of the inflight portion of the *Surveyor V* spacecraft from initial one-way acquisition by DSS 51 at 08:24:31 on September 8, 1967 through lunar touchdown at 00:46:46 on September 11. In general, the overall quality of the tracking data taken during the *Surveyor V* Mission can be described as very good. Data types used in the orbit determination program were: (1) angular data taken during the first pass of DSSs 51 and 42, (2) two-way doppler data taken during the first pass over DSS 72, and (3) all passes of DSSs 51, 42, 11, and 61. The relative quality of the tracking data taken at each station can be obtained by comparing the standard deviation, the root-mean-square, and the first moments of the data. 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:

Orbit	Identification
Predict	PROR
Trajectory condition evaluation	ICEV
Preliminary premidcourse	PREL
Data consistency	DACO
Nominal midcourse	NOMA
Last premidcourse	LAPM
Premidcourse cleanup	PRCL
Postflight analysis	POST
*N*th postmidcourse	N POM
Final inflight	FINAL

In general, Deep Space Station operations during the *Surveyor V* 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 maneuvers, retromotor ignition backup, etc. From the time of first two-way acquisition of the spacecraft over DSS 51 until shortly before retroignition, the spacecraft was almost continuously in two-way lock, and station transfers were rapid and efficiently executed. The most serious loss of two-way doppler data occurred during the second pass of DSS 42 when the uplink signal was lost during transfer from DSS 11. For 70 min, DSS 42 tracked *Surveyor V* in the one-way mode, unaware of the loss of two-way lock. It was supposed that the large doppler deviations reported by the near-real-time tracking data monitor were the result of the four midcourse maneuvers which the spacecraft had undergone by this time. It is for this reason that the error was not discovered sooner and that the data were lost. During the third pass of DSS 11 approximately 2 h before retroignition, the most significant digit of the doppler counter was lost for 32 min. These data were quickly recovered by hand restoring the missing digit on punched cards. About 2½ min of data were mislabeled by DSS 51 at initial two-way acquisition during the launch pass. These data were mislabeled three-way, but the orbit determination group recovered the data by changing the data condition code from three-way to two-way. The resultant effect from these data losses on the mission was negligible.

f. Premidcourse phase. In general, doppler data yield 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 are available and a quick determination of the orbit necessitates the use of both doppler and angle data. During the *Surveyor V* Mission, angle data from DSSs 42 and 51 were used in the orbit determination program during the first passes of these two stations. To improve the quality of the angular data to be used in the program, it is first corrected for the antenna optical pointing error. This error is determined by having the stations 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 (for DSSs 42 and 51) used in the *Surveyor V* inflight orbit computations are given in Tables 44 and 45.

Experience gained in past missions has shown that the optical pointing error correction coefficients do not remove all systematic pointing errors. This is reasonable

Table 44. Antenna correction coefficients for DSS 51[a]

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 30 deg N and 35 deg S.

Table 45. 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]These corrections are useful for elevations greater than 15 deg, and declinations between 30 deg N and 35 deg S.

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 51 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 postflight orbit, shows a bias of +0.029 deg in hour angle and −0.012 deg in declination. These values are in reasonable agreement with the orbit determination group study of DSS 51 correction coefficients and also correlate well with past experience on the *Surveyor* Project. DSS 51 first pass angular and doppler residuals are presented in Figs. 46 and 47.

First-pass angular data from DSS 42, when fit through the final postflight orbit, show biases of +0.003 deg in hour angle and −0.040 deg in declination (Fig. 48). These biases are quite consistent with the results of a study of the present DSS 42 correction coefficients which indicated the coefficients were less satisfactory in declination than in hour angle.

Surveyor V was not acquired by DSS 72 until approximately 3 h, 43 min after the spacecraft reached an elevation of 10 deg over the horizon, which is where the antenna was initially positioned. The standard acquisition procedure is to use an initial acquisition elevation of 10 deg but as shown in the stereographic projection (Fig. 49) of the DSS 72 first pass, this procedure is clearly not desirable for this low elevation trajectory. The first pass (CC3) doppler residuals for DSSs 11, 42, 51, 61, and 72 are shown in Figs. 50–55.

The first prime station (DSS 51) to view the spacecraft continuously after injection, began taking good two-way, 10-s count doppler data at 08:30:21 on September 8, 1967. The sample rate was changed to 60 s at 08:59:51 and the spacecraft was transferred to DSS 42 at 10:34:02. This early data from DSS 51 were quite acceptable, showing a standard deviation of 0.019 Hz. The two-way doppler residuals for this initial pass over DSS 51 may be seen in the attached figures. Canberra (DSS 42) returned good 60-s count two-way doppler data from 10:34:02 to 11:24:02 on September 8. The first-pass data from DSS 42 showed a standard deviation of 0.009 Hz, a nominal figure for this period. First-pass DSS 61 two-way doppler data showed a standard deviation of 0.046 Hz. This unusually high noise was attributed to star acquisition from 14:09:00 to 14:28:27. These first-pass, two-way doppler residuals clearly show the star acquisition maneuver. *Surveyor* V was tracked in the two-way mode by DSS 72 from 20:35:02 to 21:24:02. Residuals from these data show a standard deviation of 0.009 Hz.

g. Midcourse maneuvers. Early analysis of the *Surveyor* V trajectory indicated that a midcourse maneuver during the first pass of DSS 11 would be advantageous, and therefore the first midcourse maneuver was executed during this pass. A spacecraft malfunction occurred as a result of the midcourse maneuver, and in an attempt to correct the malfunction, five more maneuvers were executed (see Sections II and V-E).

Figures 56–61 show the first through sixth midcourse maneuver two-way doppler data. Figures 62–66 show the data for the second pass of DSSs 11, 42, 51, and 61. Figures 67–72 show the third-pass residuals.

h. Postmidcourse phase. All postmidcourse orbit computations used only two-way doppler from the prime stations, DSSs 11, 42, 51, and 61. No postflight orbit determination analysis was made between the first maneuver at 01:45:03 on September 9, and the fifth maneuver at 08:24:38 of the same day.

Very good two-way doppler data were obtained from after the sixth maneuver until start of retromaneuver phase without exception. The doppler data from all stations indicated a standard deviation of less than 0.008 Hz during this period, and any biases in the data were negligible.

i. Touchdown phase. Final inflight calculations indicated a retroignition time of 00:44:54.6 on September 11, 1967, and touchdown at 00:46:46. The results of the retromotor burn as seen in the one-way doppler data at DSS 11 and the touchdown phase doppler residuals are shown in Figs. 73 and 74. To approximate the varying transmitter frequency during the retromotor burn and touchdown phases when the changing thrust vector precluded the possibility of making accurate trajectory predictions, the transmitter frequencies reduced from tracking data and predicts up to the burn were extrapolated through touchdown and used to compute range rate. (See Tables 40–43 for the values of these frequencies and corresponding range rates.) To approximate the doppler of a stationary spacecraft on the lunar surface, a least-squares quadratic curve fit was made on the data immediately after touchdown. Hopefully, this would remove the major effects of both one-way frequency drift and lunar surface–DSS 11 relative velocity. See Table 42 for the actual doppler received by DSS 11, the hypothetical doppler had the spacecraft been stationary on the lunar surface, the difference between these two doppler values, and the corresponding range rate in kilometers per second. Figure 75 is a plot of these values which is the line-of-sight velocity from DSS 11 of the *Surveyor* V touchdown, referenced to the lunar surface.

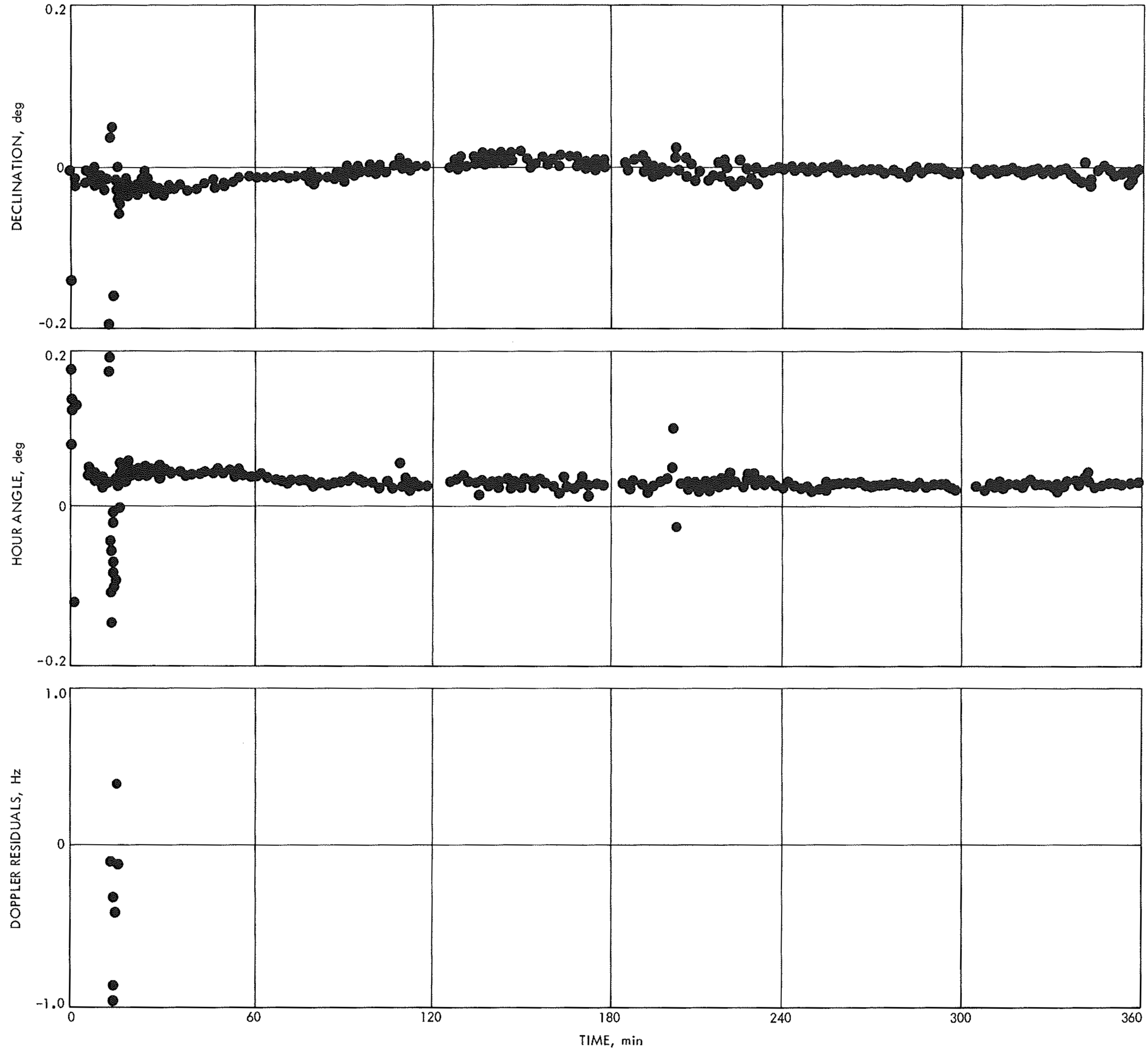


Fig. 46. First pass two-way doppler, hour angle, and declination residuals received by DSS 51 (time from 08:25:00 GMT on September 8, 1967)

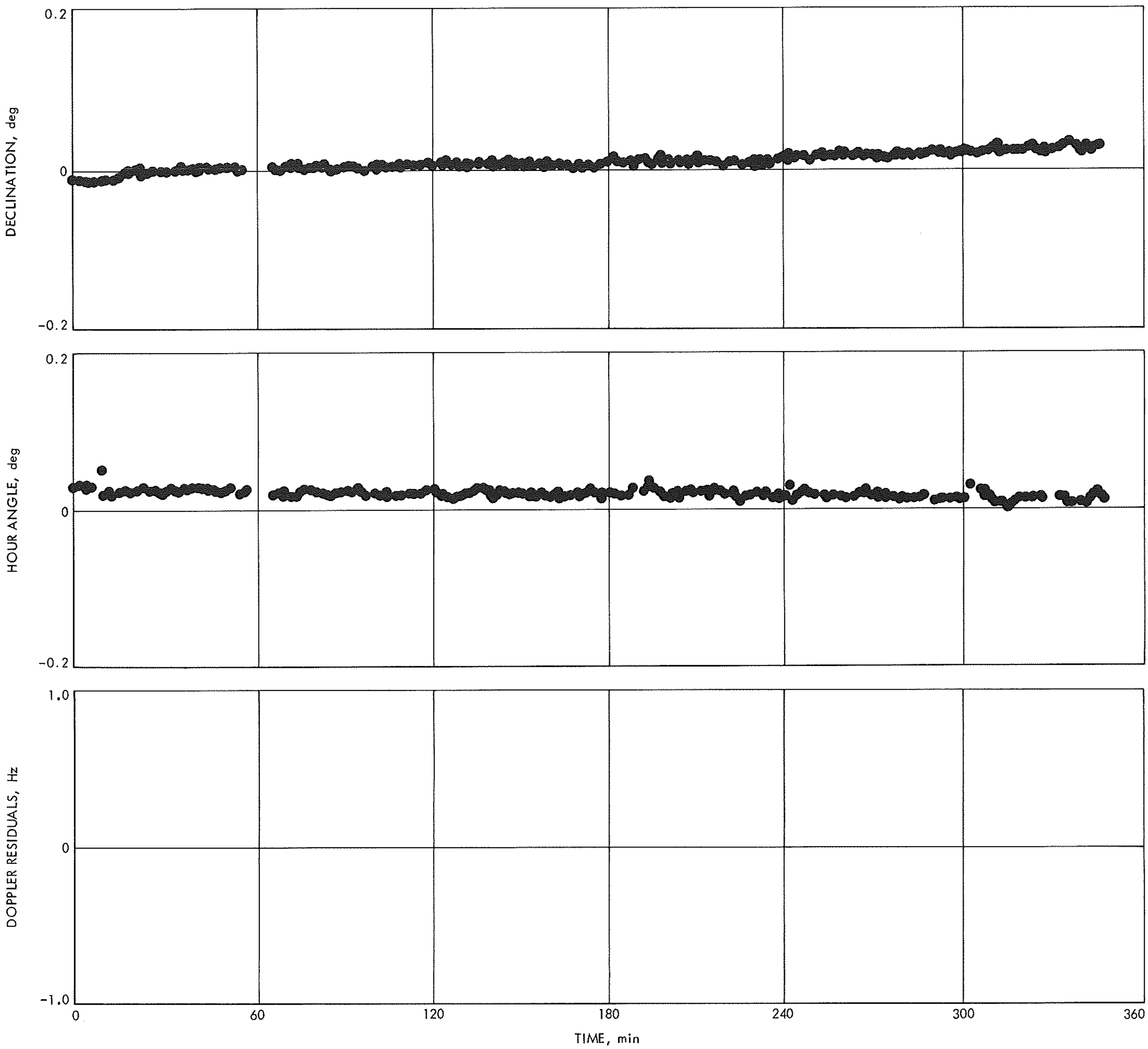


Fig. 47. First pass two-way doppler, hour angle, and declination residuals received by DSS 51 (time from 14:25:00 GMT on September 8, 1967)

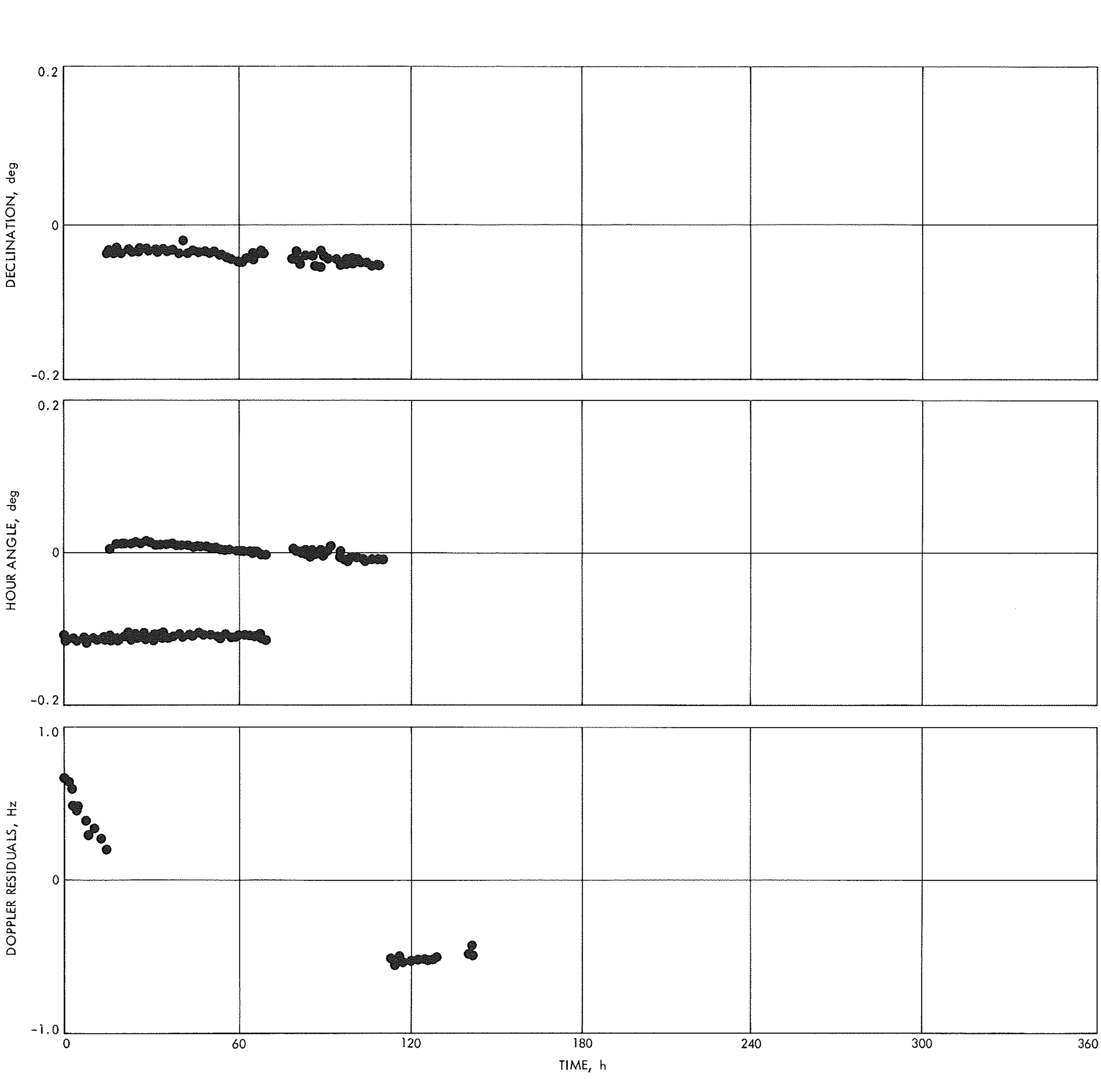


Fig. 48. First pass two-way doppler, hour angle, and declination residuals received by DSS 42 (time from 09:14:00 GMT on September 9, 1967)

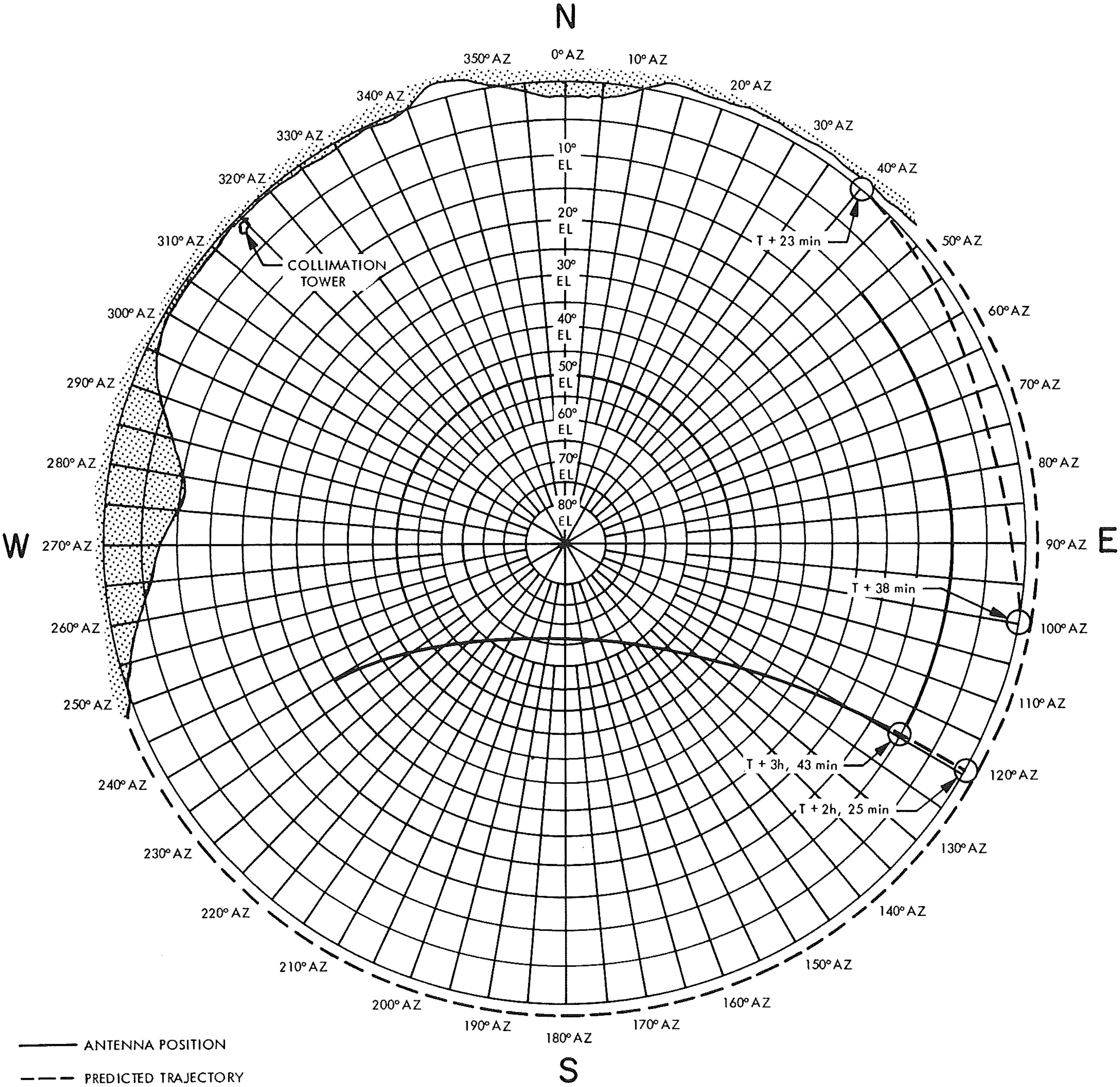


Fig. 49. Stereographic projection of DSS 72 antenna pattern, first pass

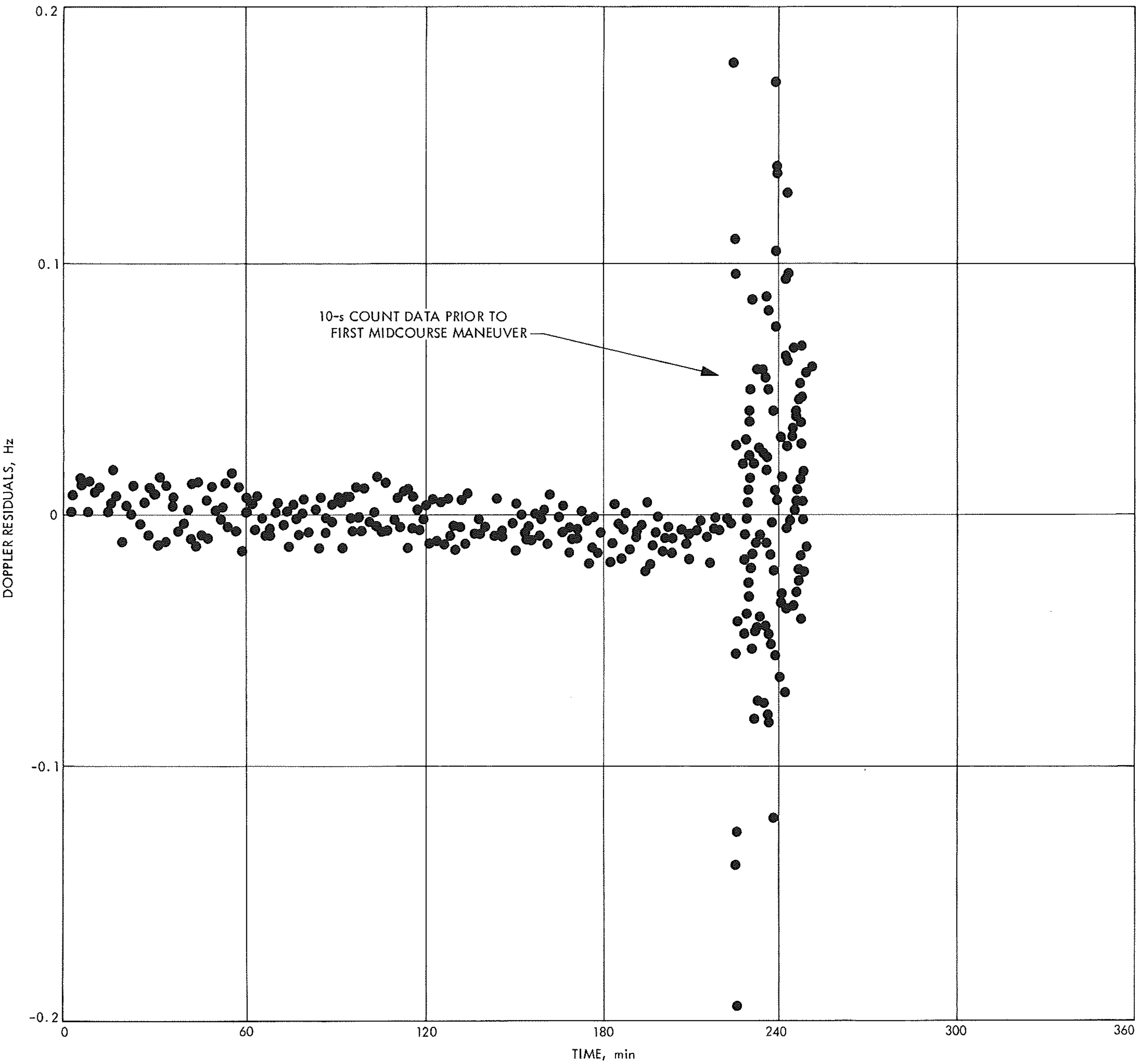


Fig. 50. First pass doppler residuals received by DSS 11 (time from 21.35:00 GMT on September 9, 1967)

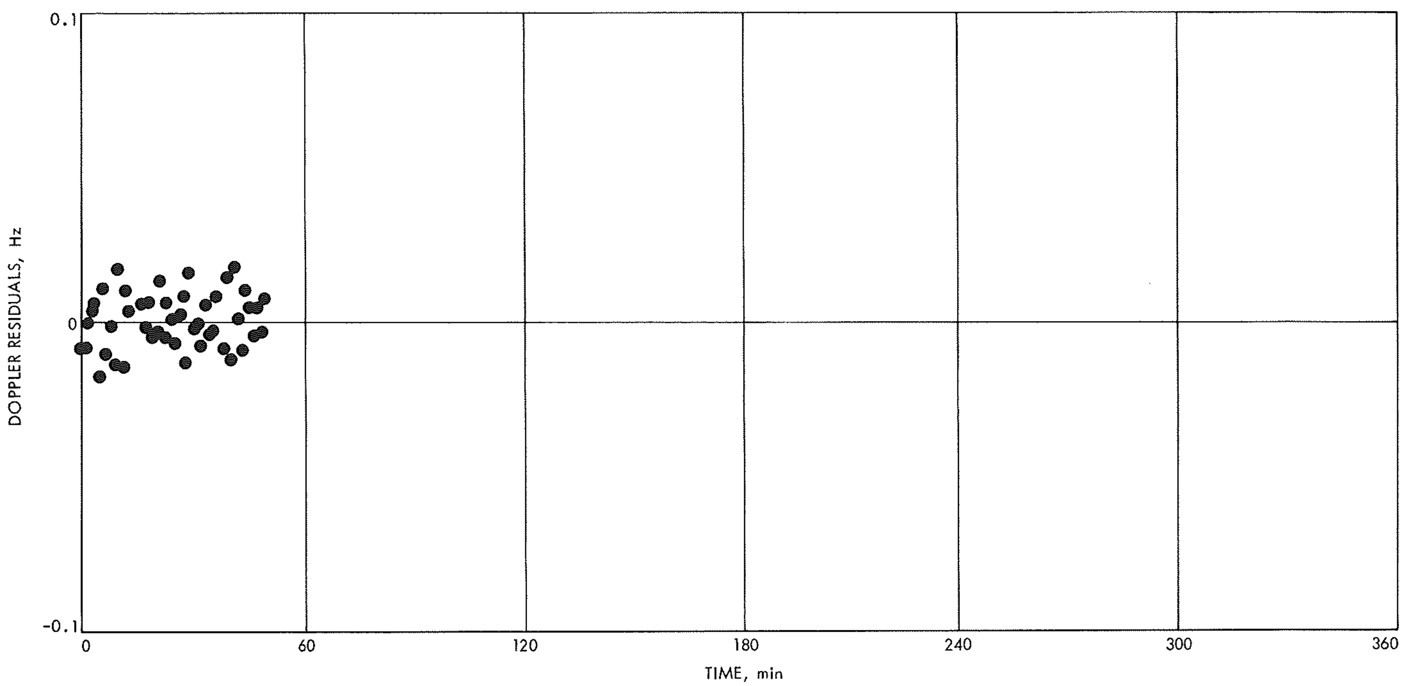


Fig. 51. First pass doppler residuals received by DSS 42 (time from 10:34:00 GMT on September 9, 1967)

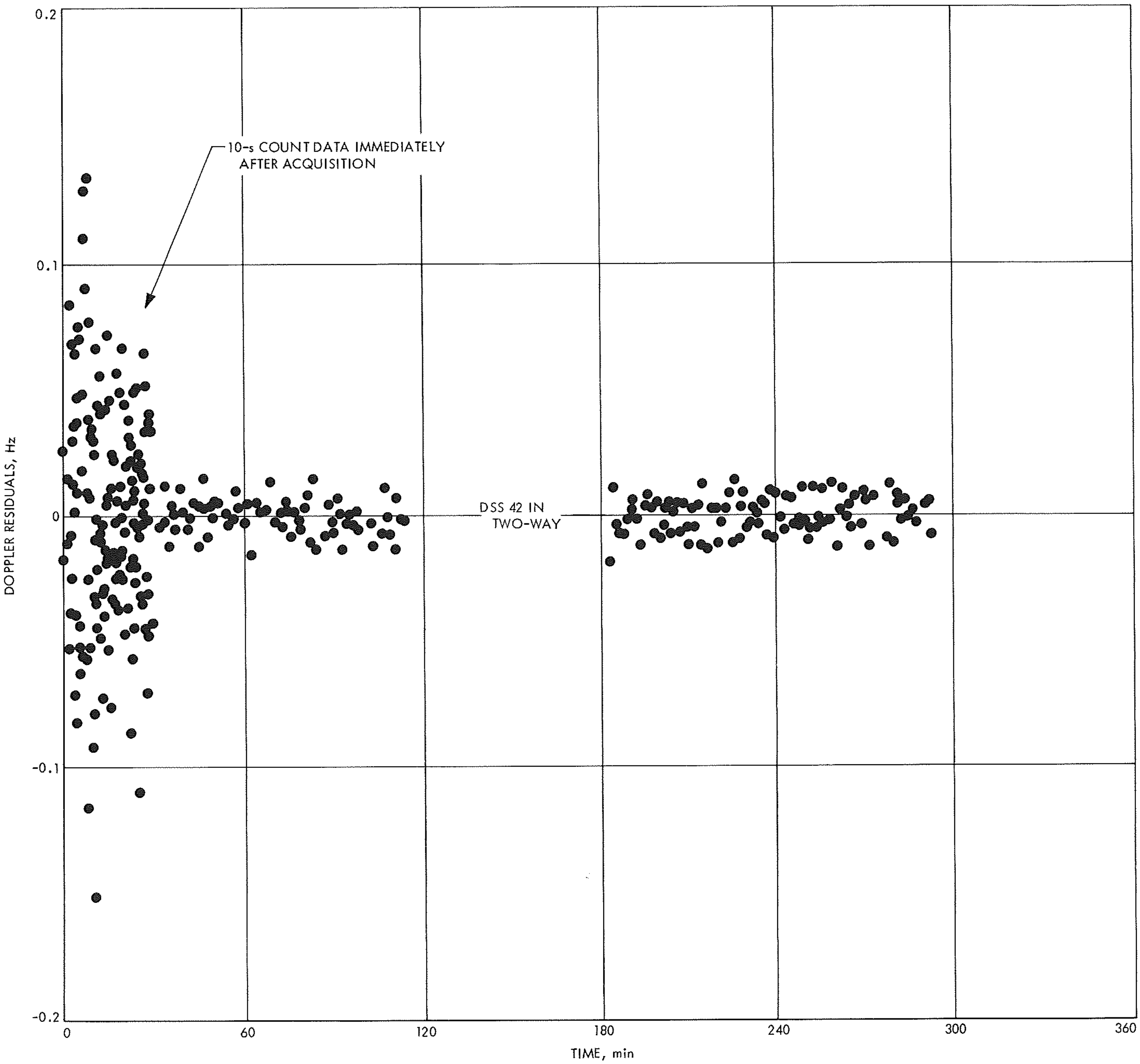


Fig. 52. First pass two-way doppler residuals received by DSS 51 (time from 08:30:00 GMT on September 9, 1967)

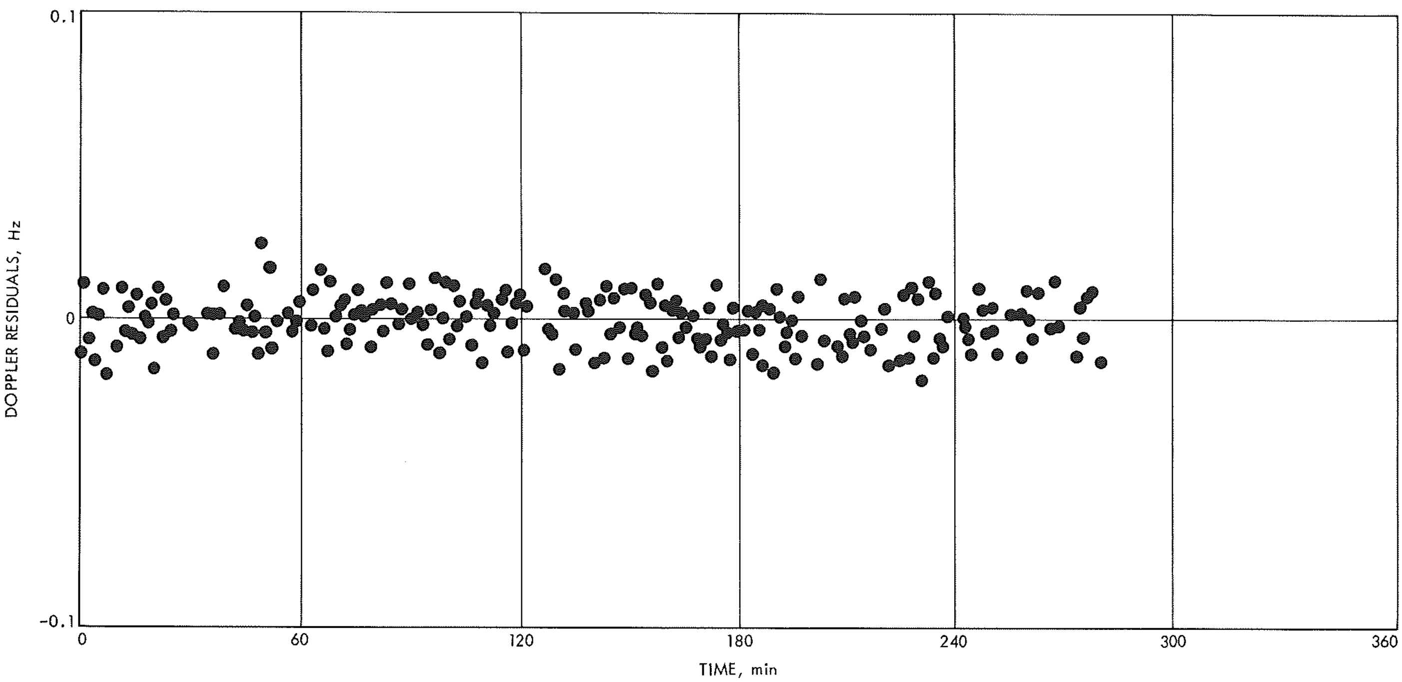


Fig. 53. First pass two-way doppler residuals received by DSS 51 (time from 15:33:00 GMT on September 9, 1967)

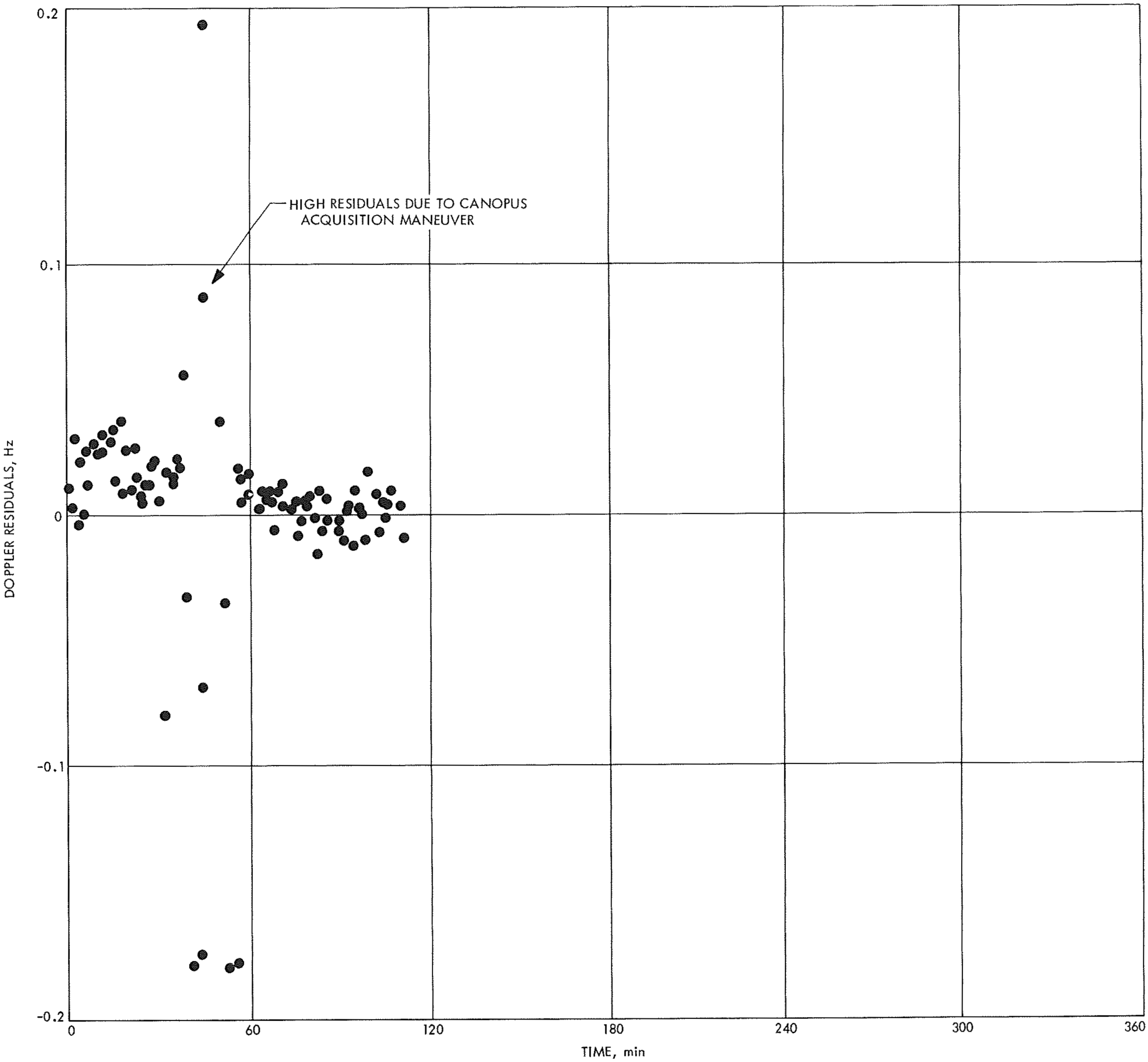


Fig. 54. First pass two-way doppler residuals received by DSS 61 (time from 13:32:00 GMT on September 9, 1967)

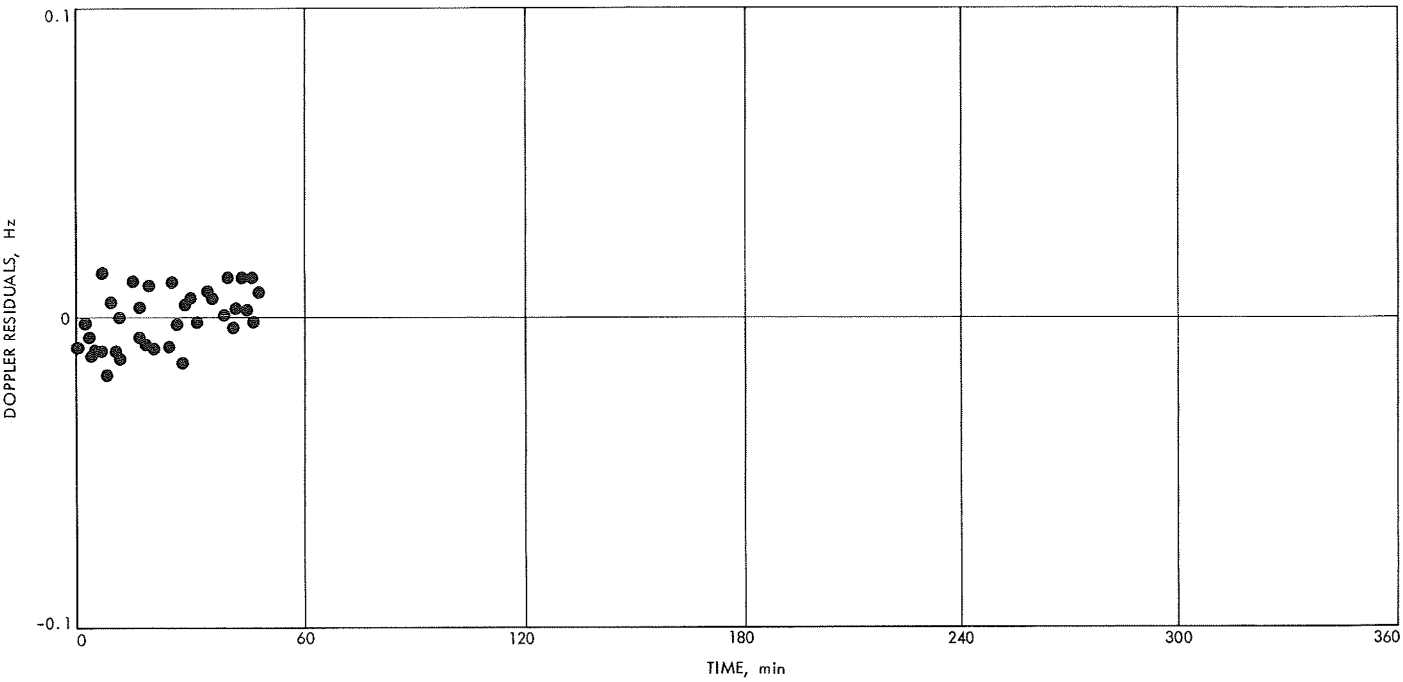


Fig. 55. First pass two-way doppler residuals received by DSS 72 (time from 20:35:00 GMT on September 9, 1967)

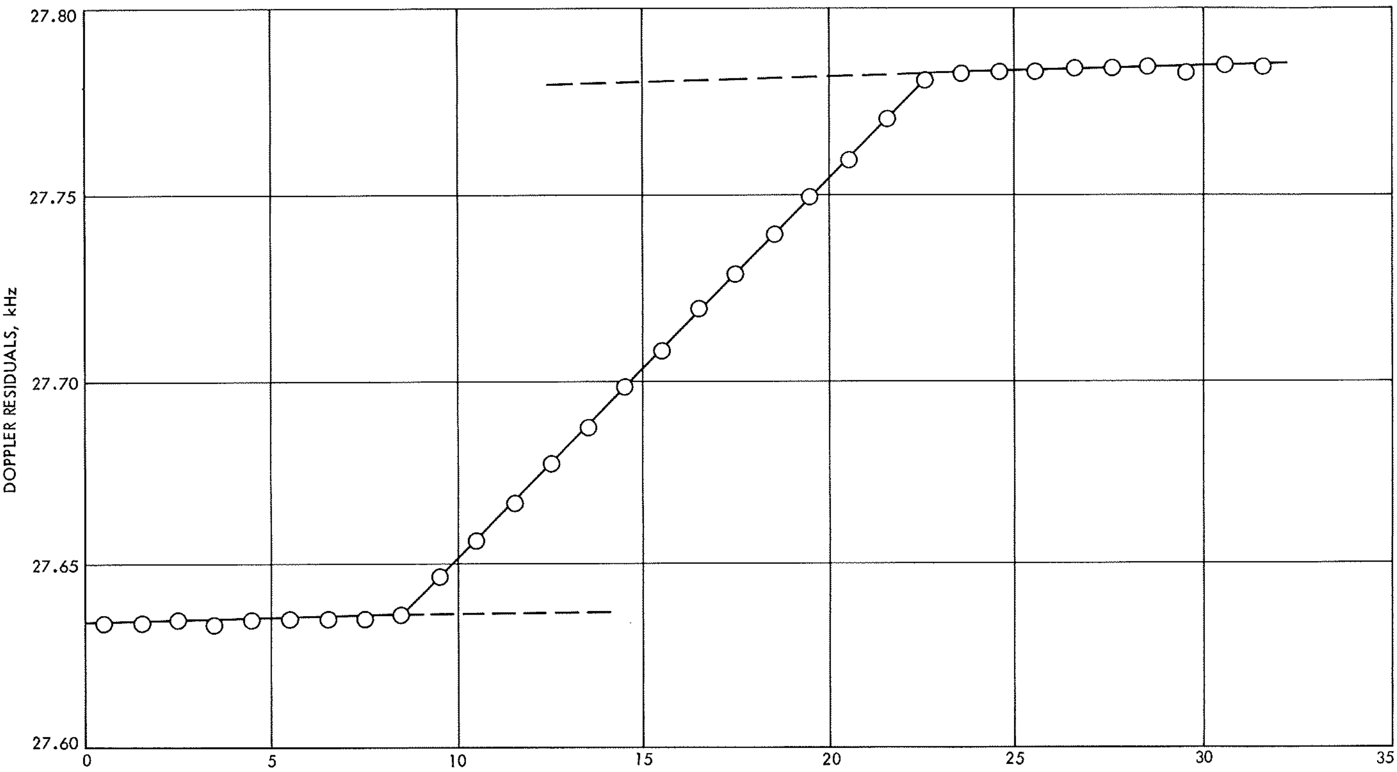


Fig. 56. First midcourse maneuver two-way doppler residuals received by DSS 11 (time from 01:44:55 GMT on September 9, 1967)

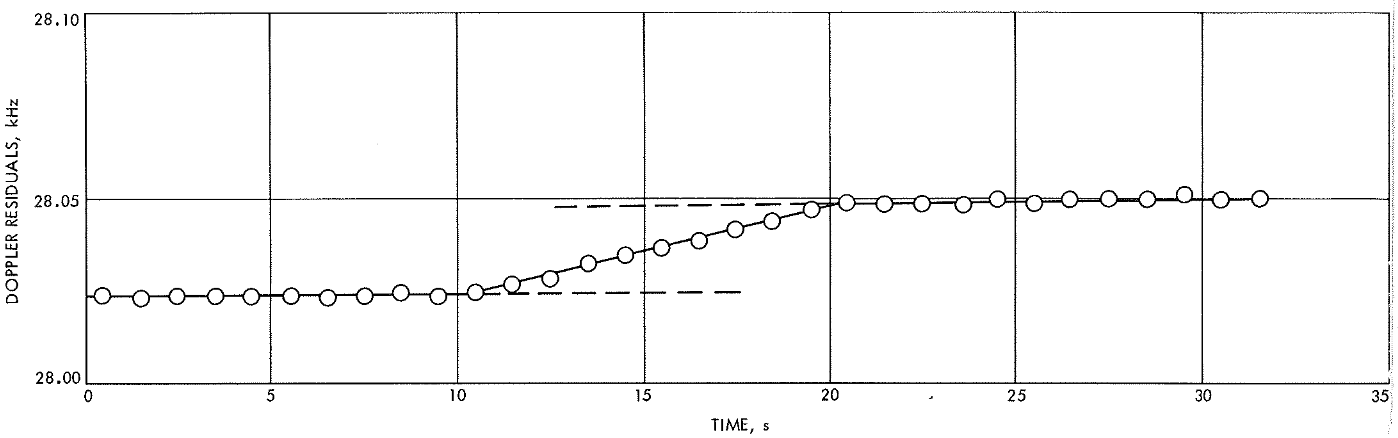


Fig. 57. Second midcourse maneuver two-way doppler residuals received by DSS 11 (time from 02:11:53 GMT on September 9, 1967)

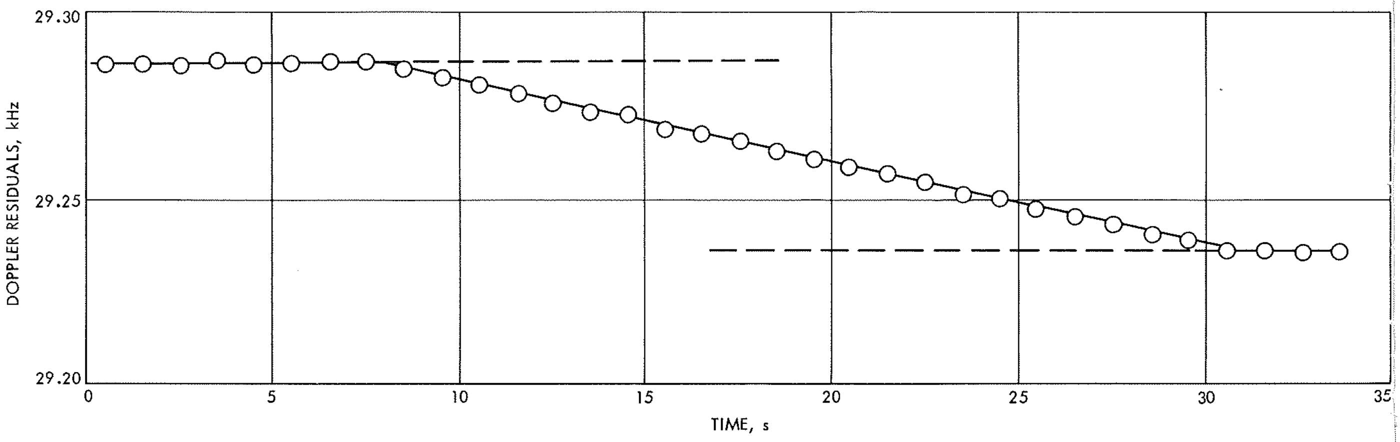


Fig. 58. Third midcourse maneuver two-way doppler residuals received by DSS 11 (time from 02:39:45 GMT on September 9, 1967)

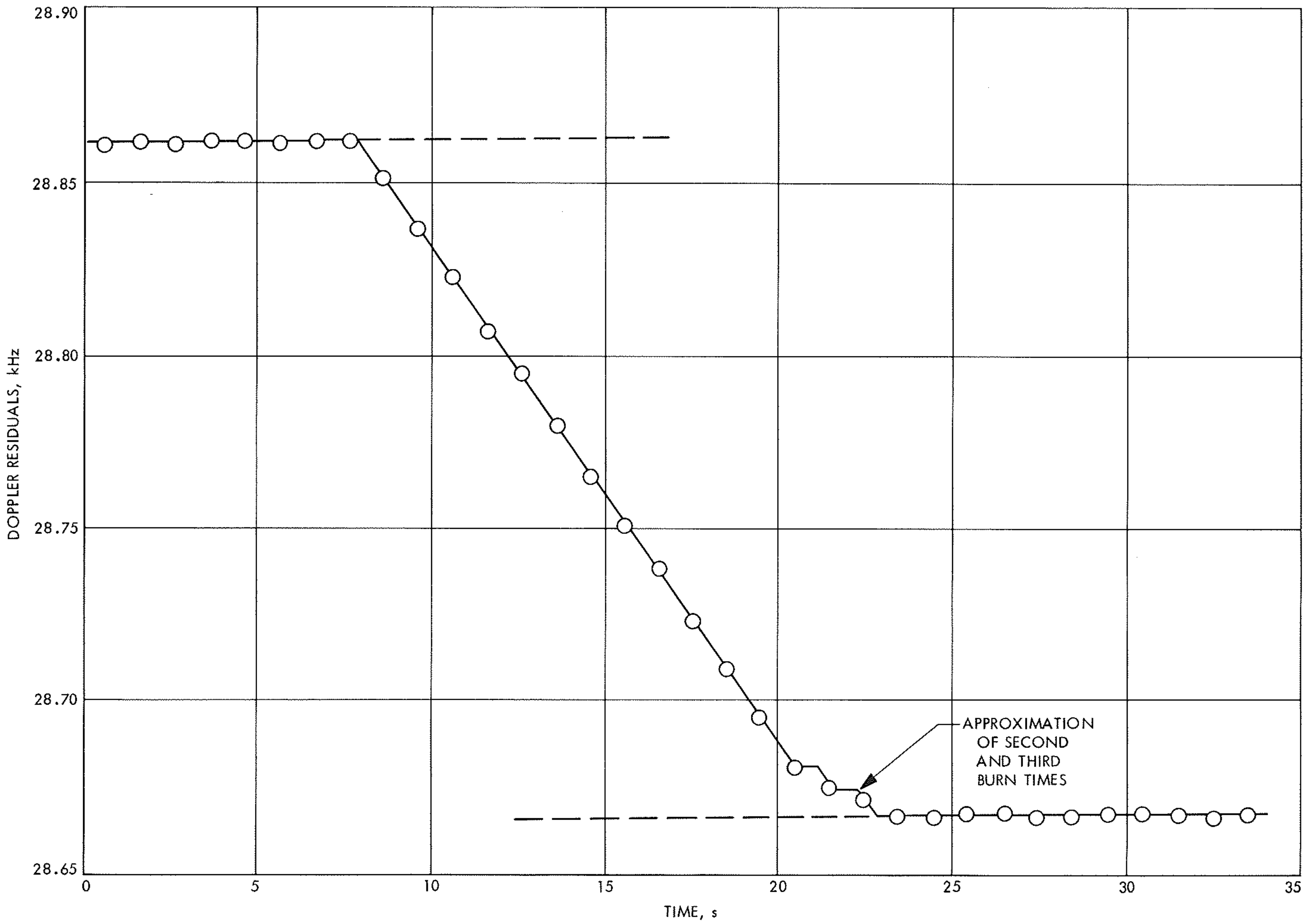


Fig. 59. Fourth midcourse maneuver two-way doppler residuals received by DSS 11 (time from 04:18:42 GMT on September 9, 1967)

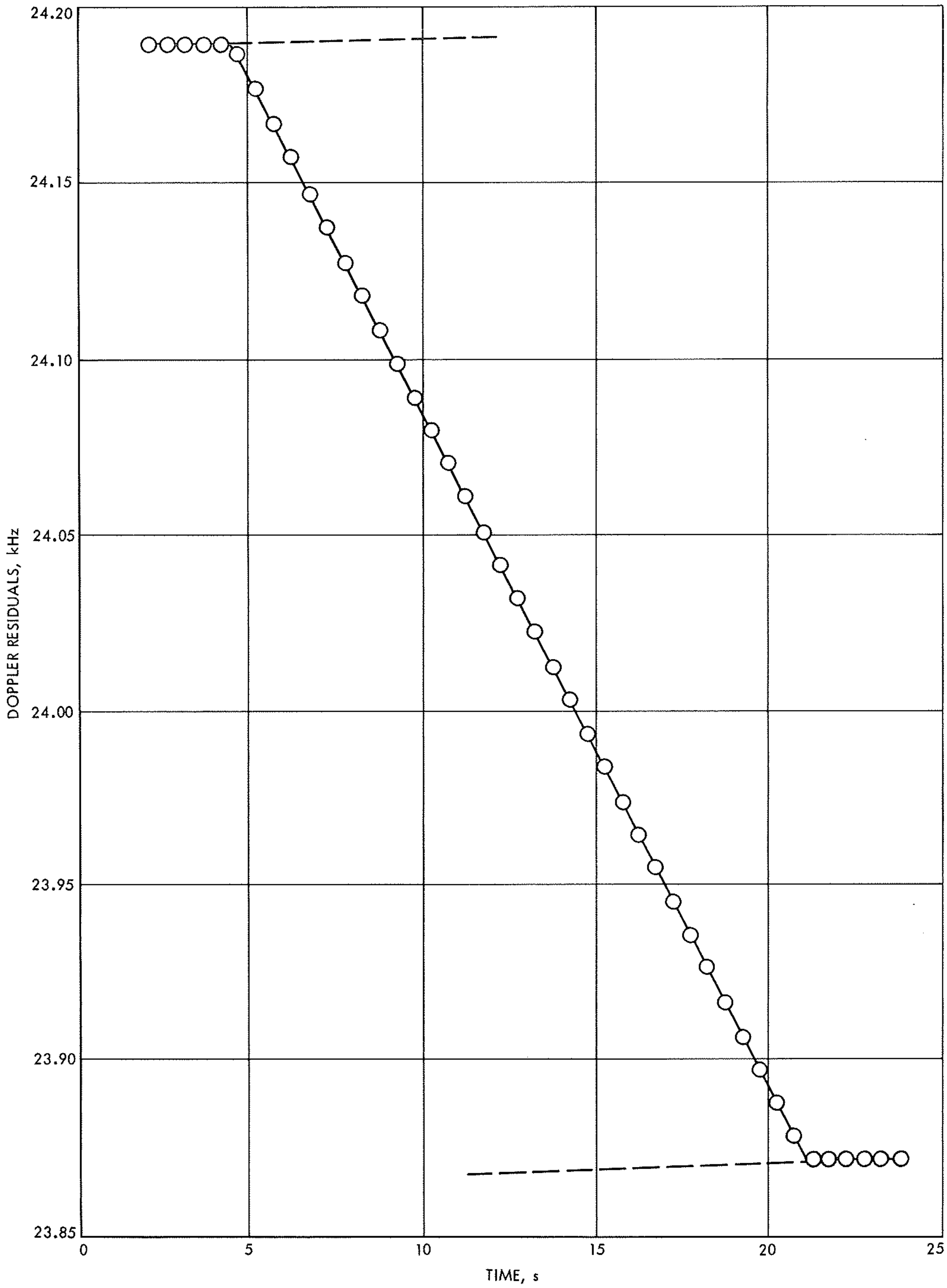


Fig. 60. Fifth midcourse maneuver two-way doppler residuals received by DSS 11 (time from 08:23:55 GMT on September 9, 1967)

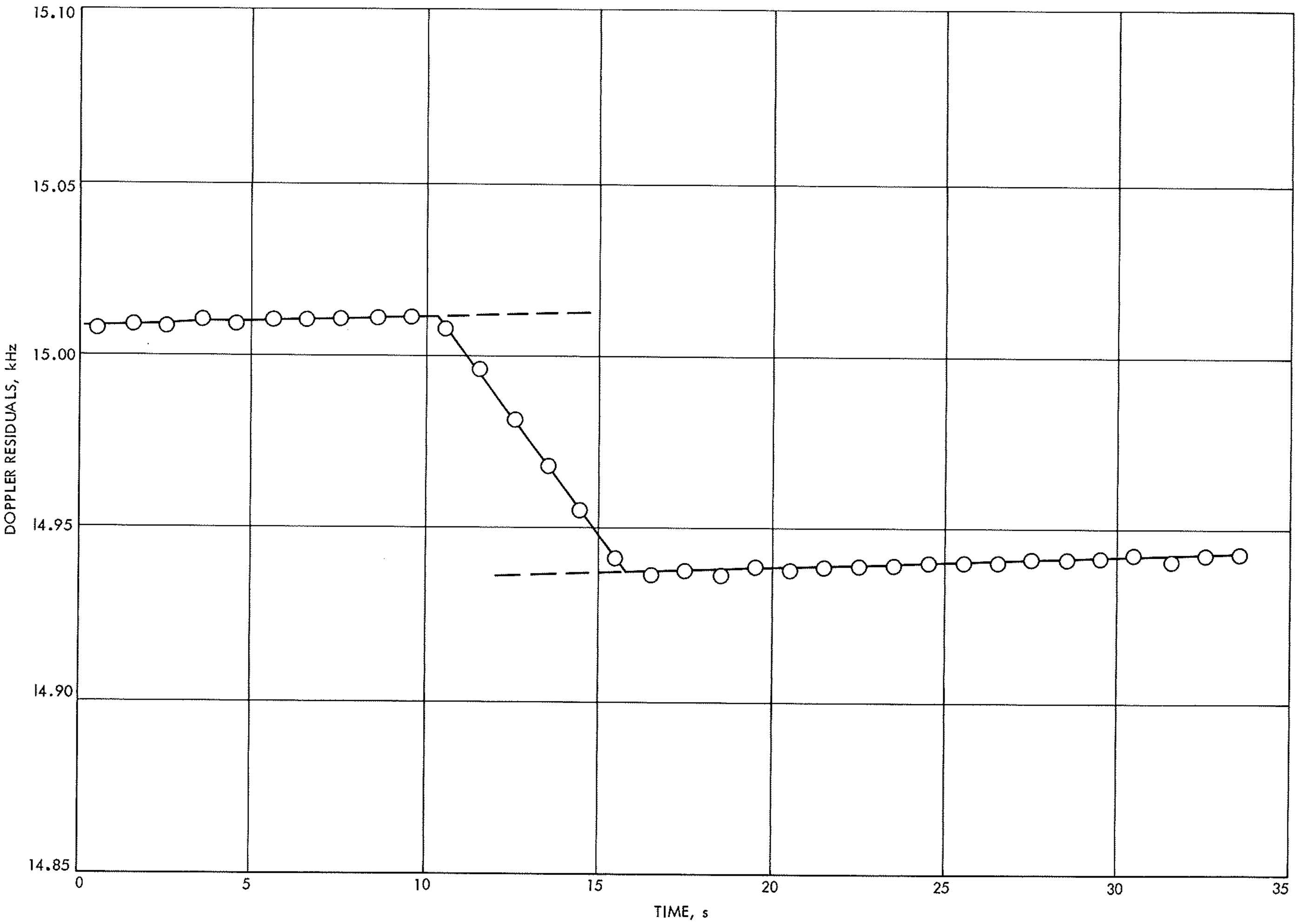


Fig. 61. Sixth midcourse maneuver two-way doppler residuals received by DSS 11 (time from 23:30:50 GMT on September 9, 1967)

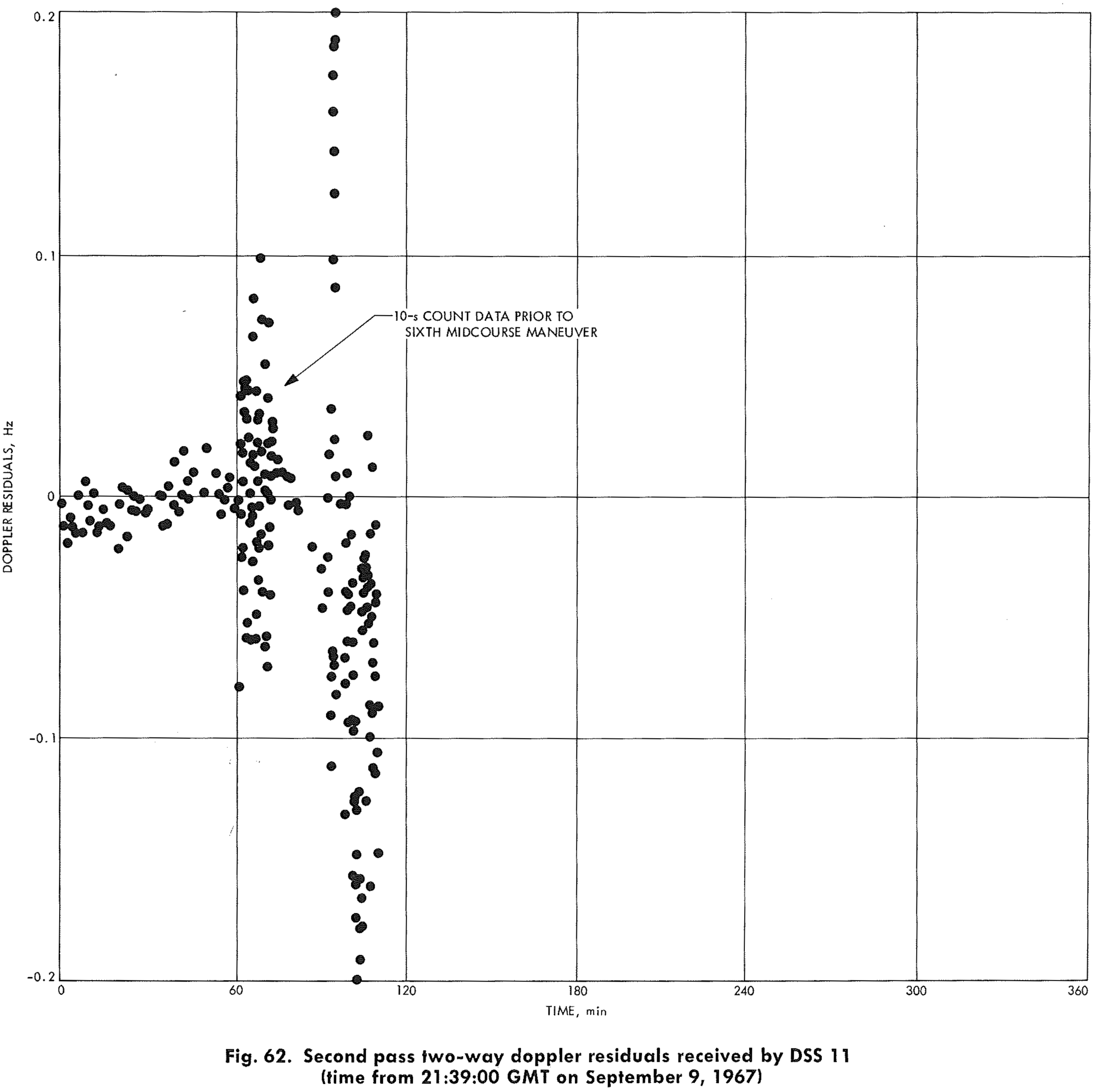


Fig. 62. Second pass two-way doppler residuals received by DSS 11 (time from 21:39:00 GMT on September 9, 1967)

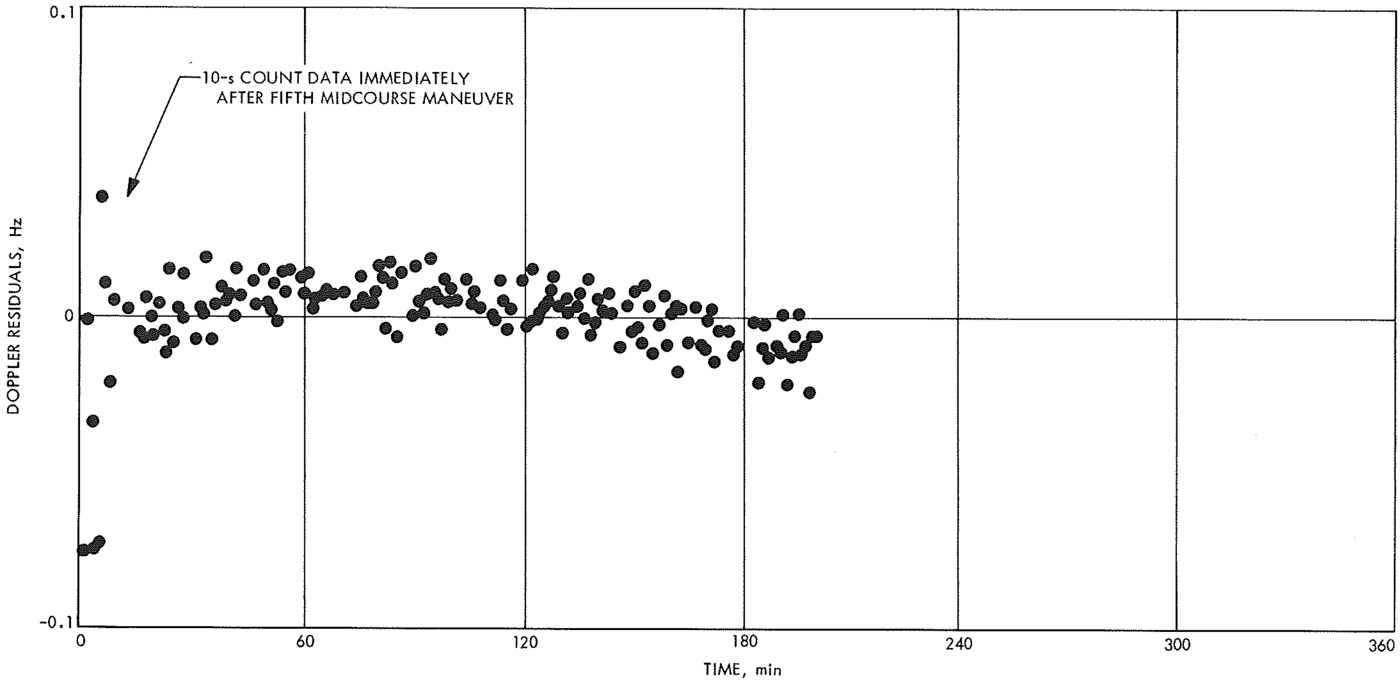


Fig. 63. Second pass two-way doppler residuals received by DSS 42 (time from 08:36:00 GMT on September 9, 1967)

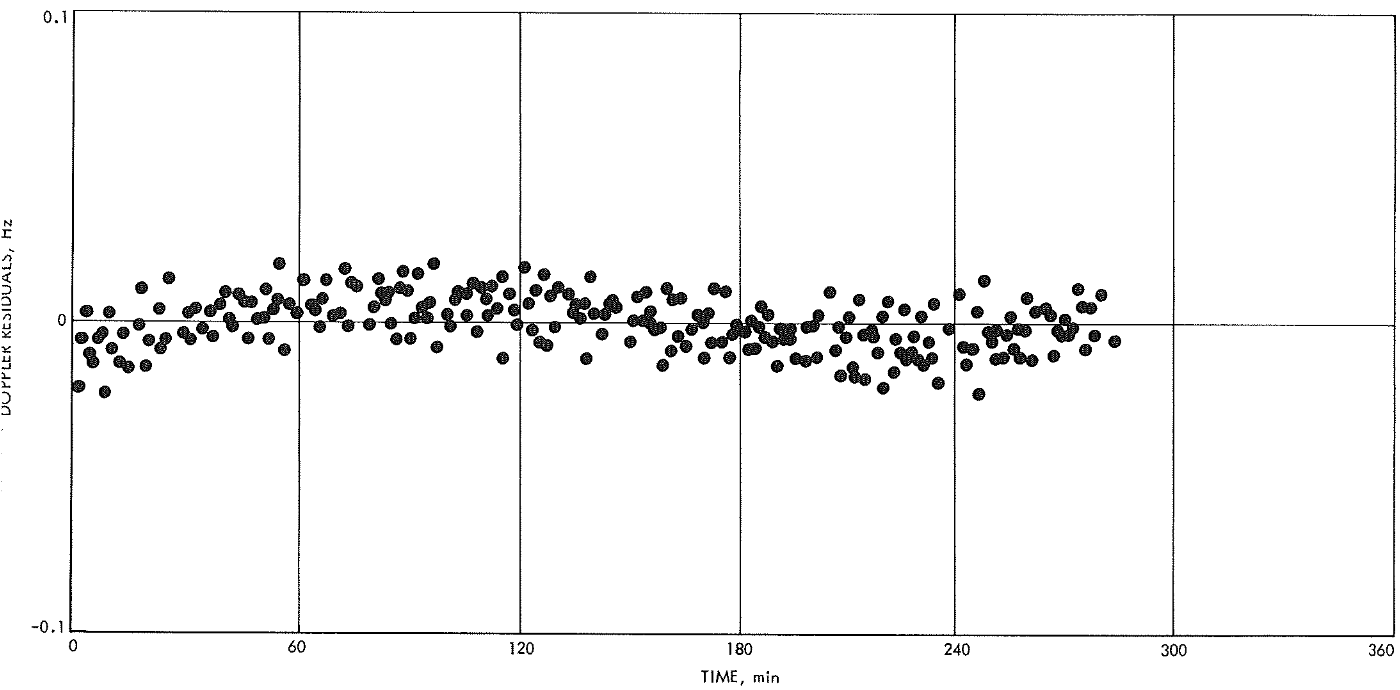


Fig. 64. Second pass two-way doppler residuals received by DSS 51 (time from 12:03:00 GMT on September 9, 1967)

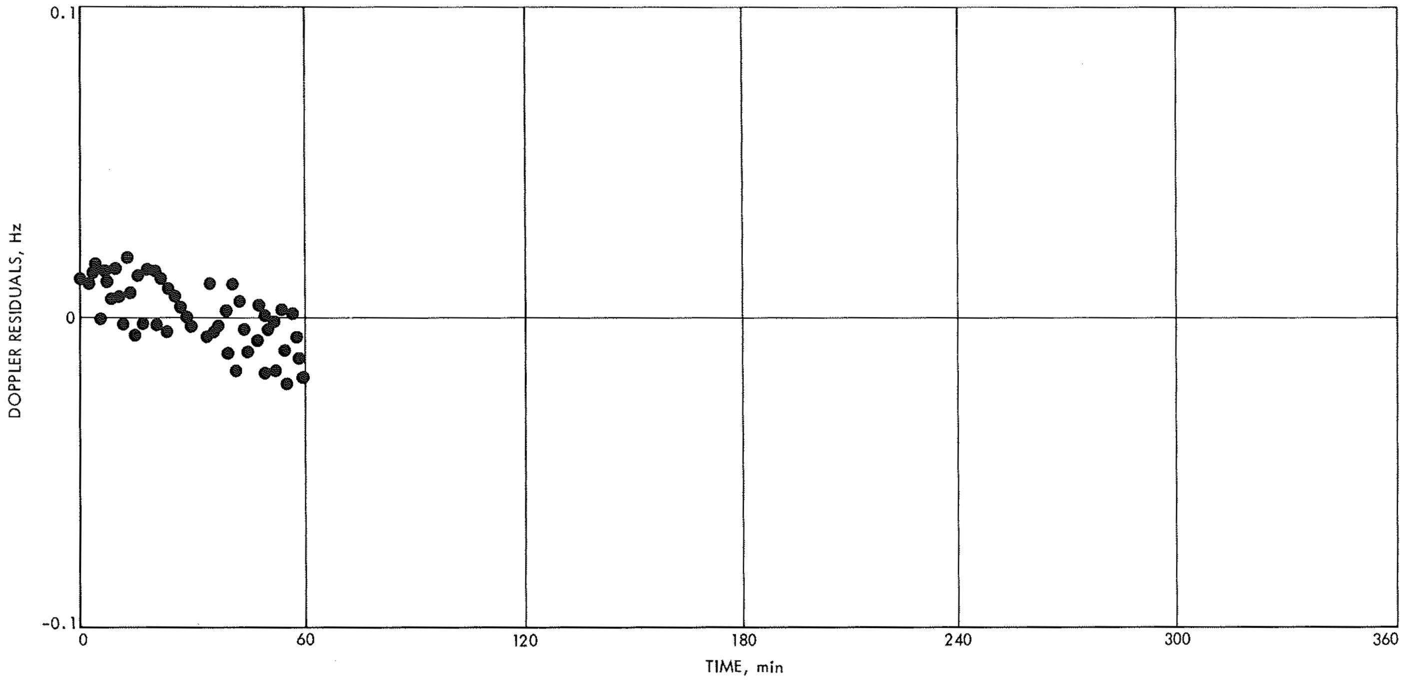


Fig. 65. Second pass two-way doppler residuals received by DSS 51 (time from 20:23:00 GMT on September 9, 1967)

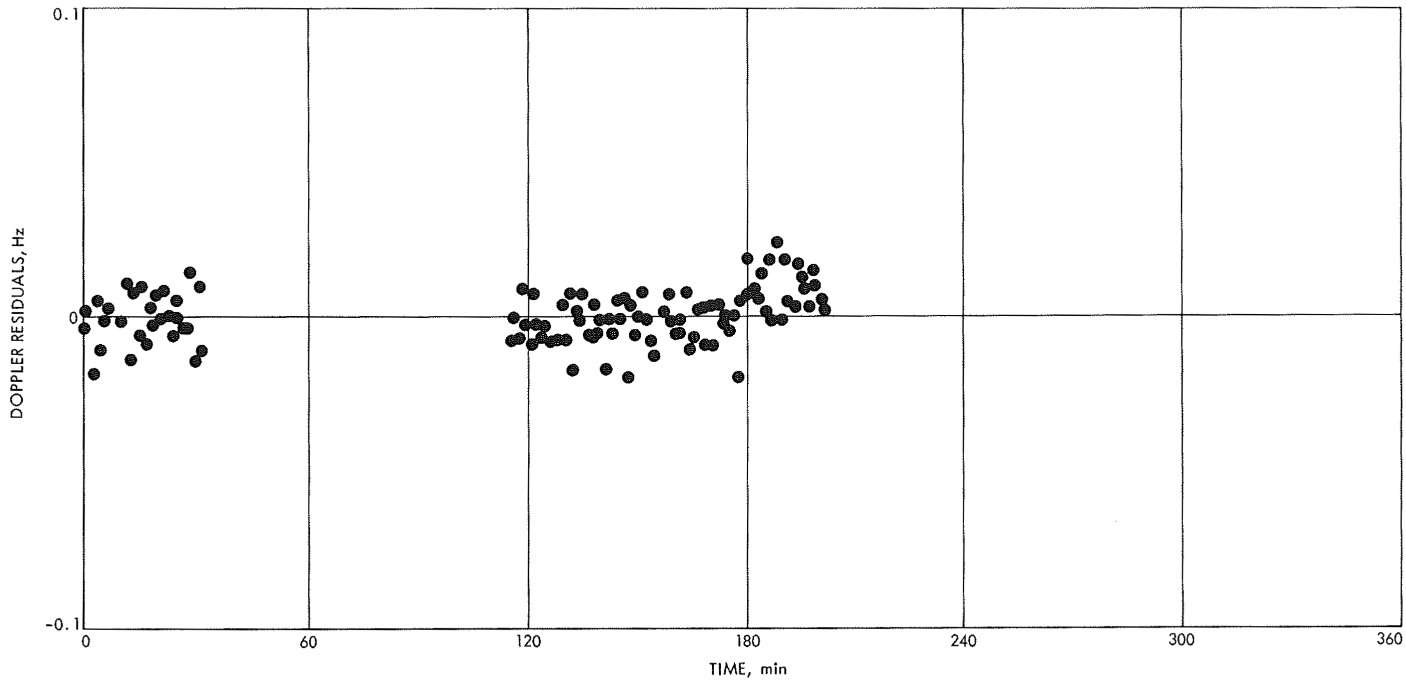


Fig. 66. Second pass two-way doppler residuals received by DSS 61 (time from 16:52:00 GMT on September 9, 1967)

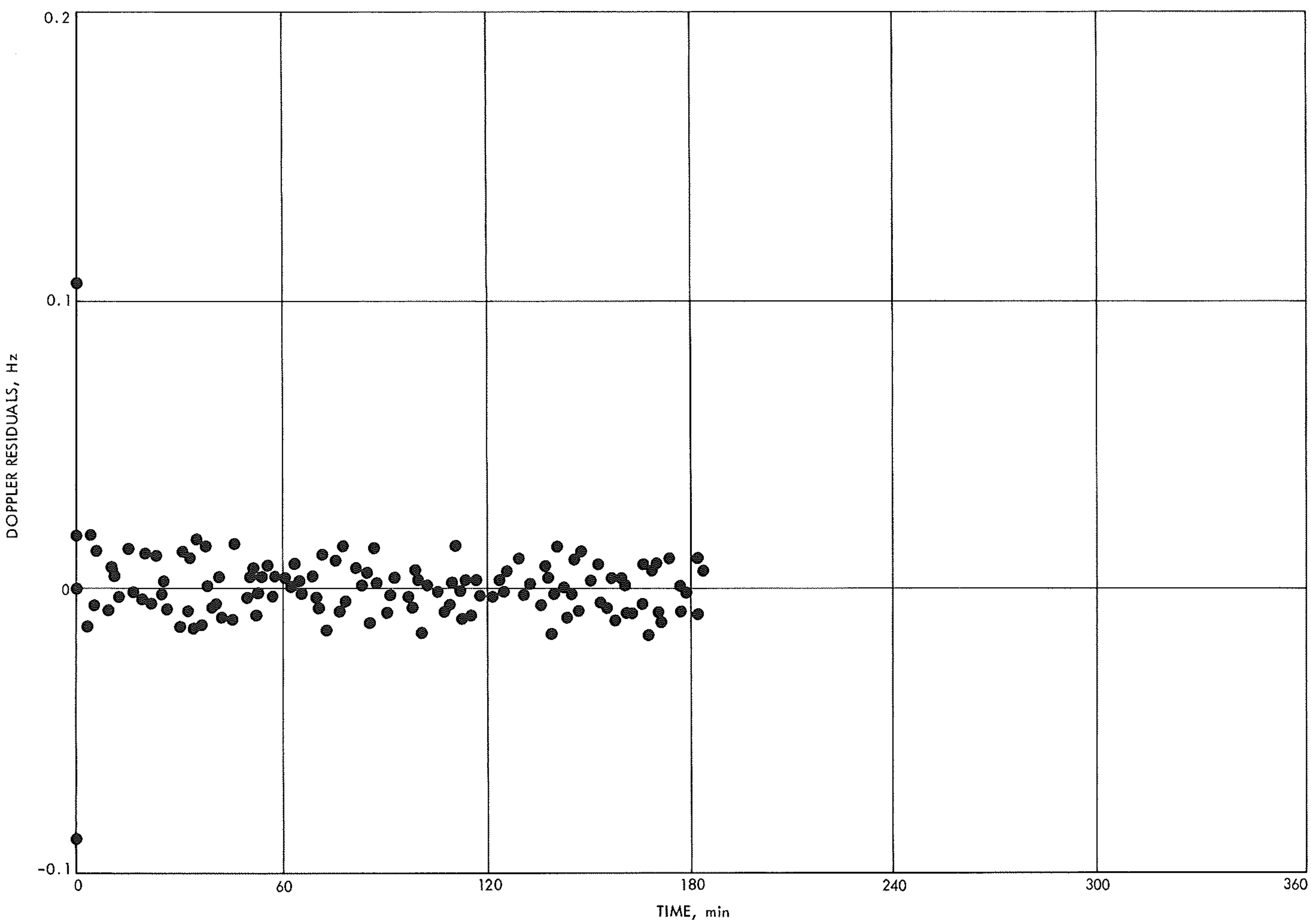


Fig. 67. Third pass two-way doppler residuals received by DSS 11 (time from 23:49:00 GMT on September 9, 1967)

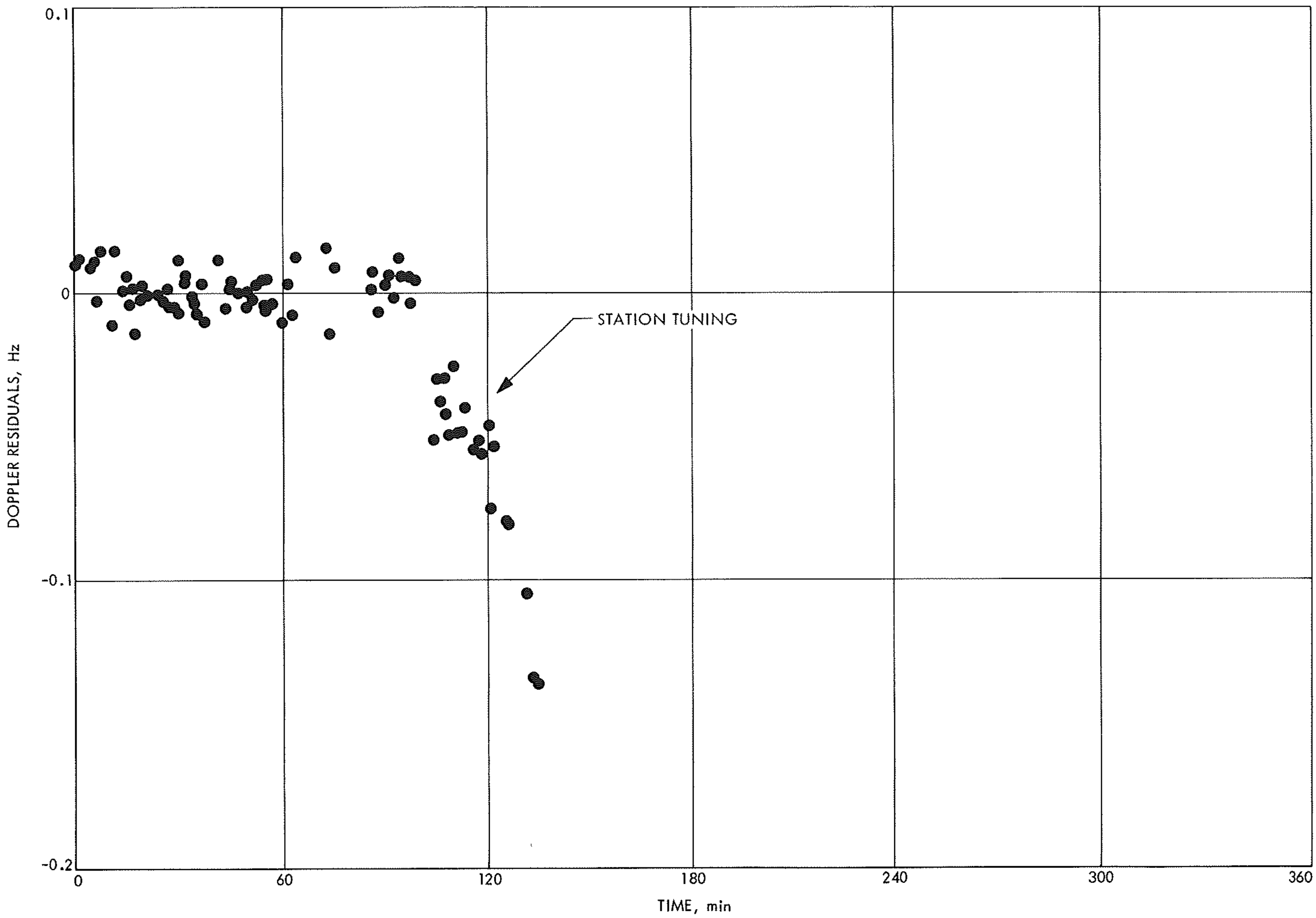


Fig. 68. Third pass two-way doppler residuals received by DSS 11 (time from 21:48:00 GMT on September 9, 1967)

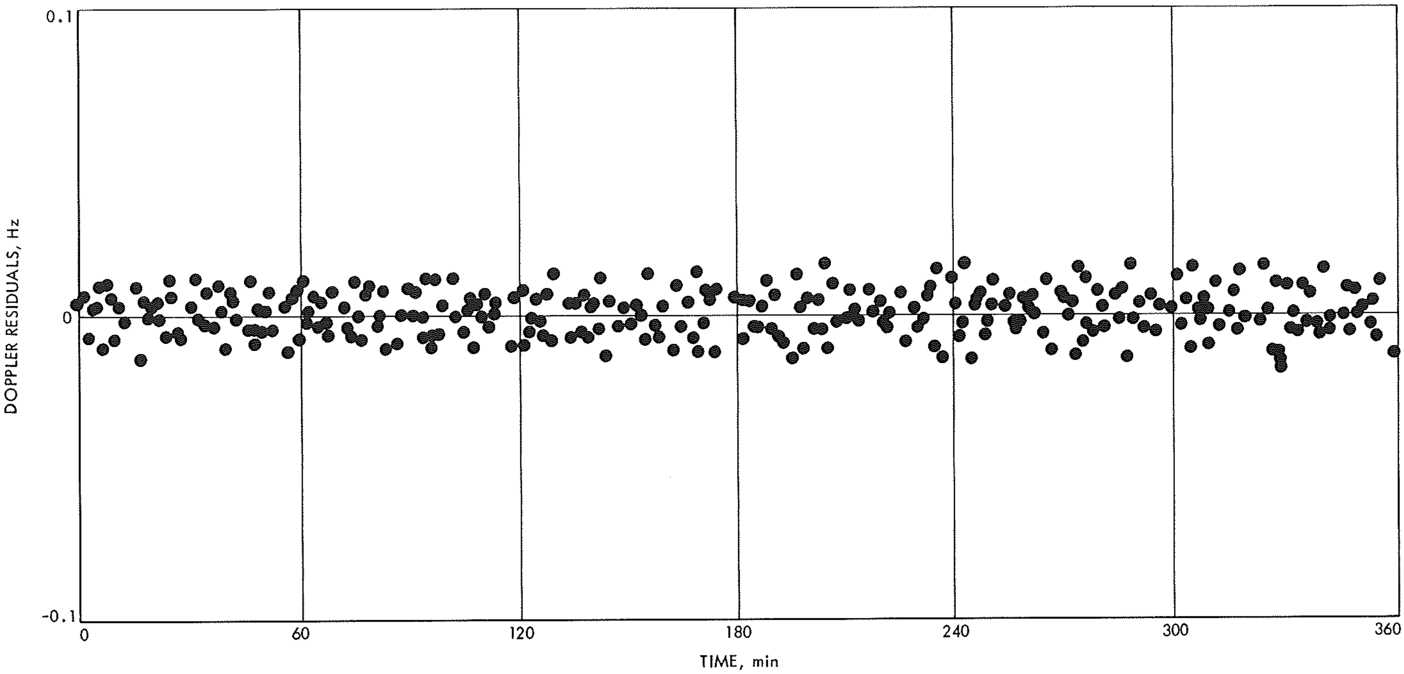


Fig. 69. Third pass two-way doppler residuals received by DSS 42 (time from 03:03:00 GMT on September 10, 1967)

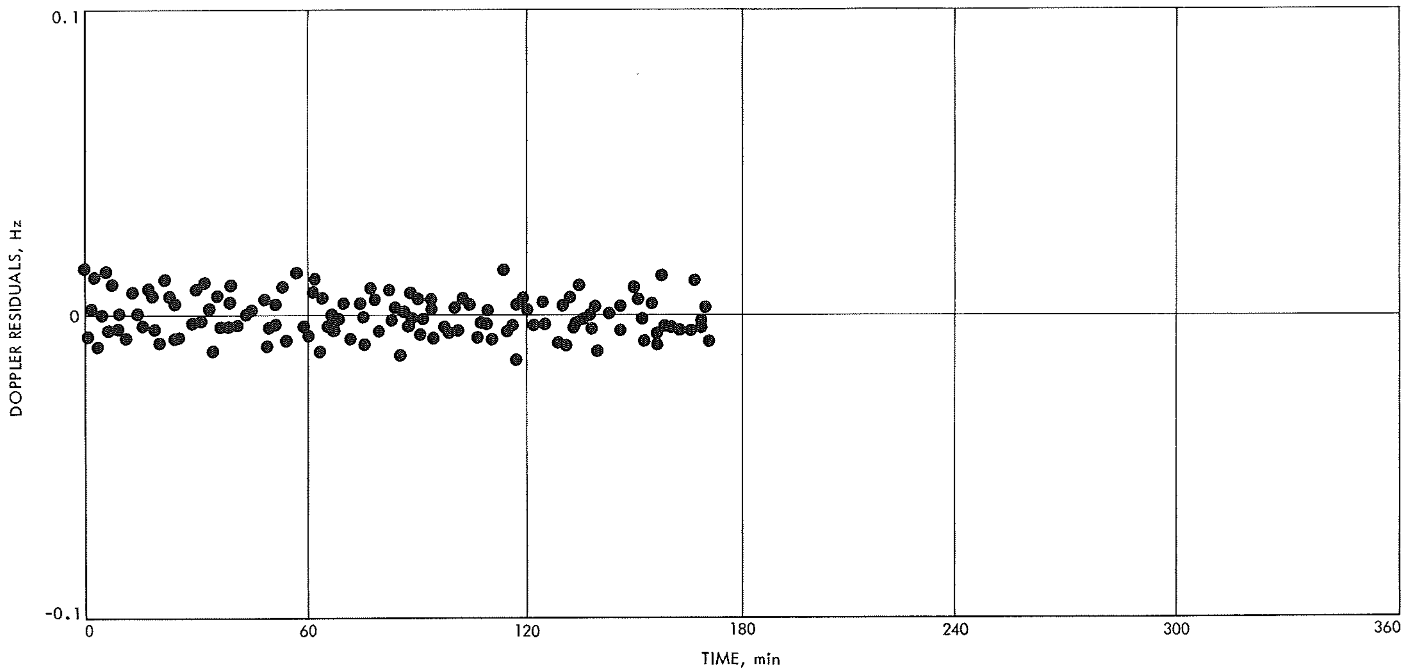


Fig. 70. Third pass two-way doppler residuals received by DSS 42 (time from 09:03:03 GMT on September 10, 1967)

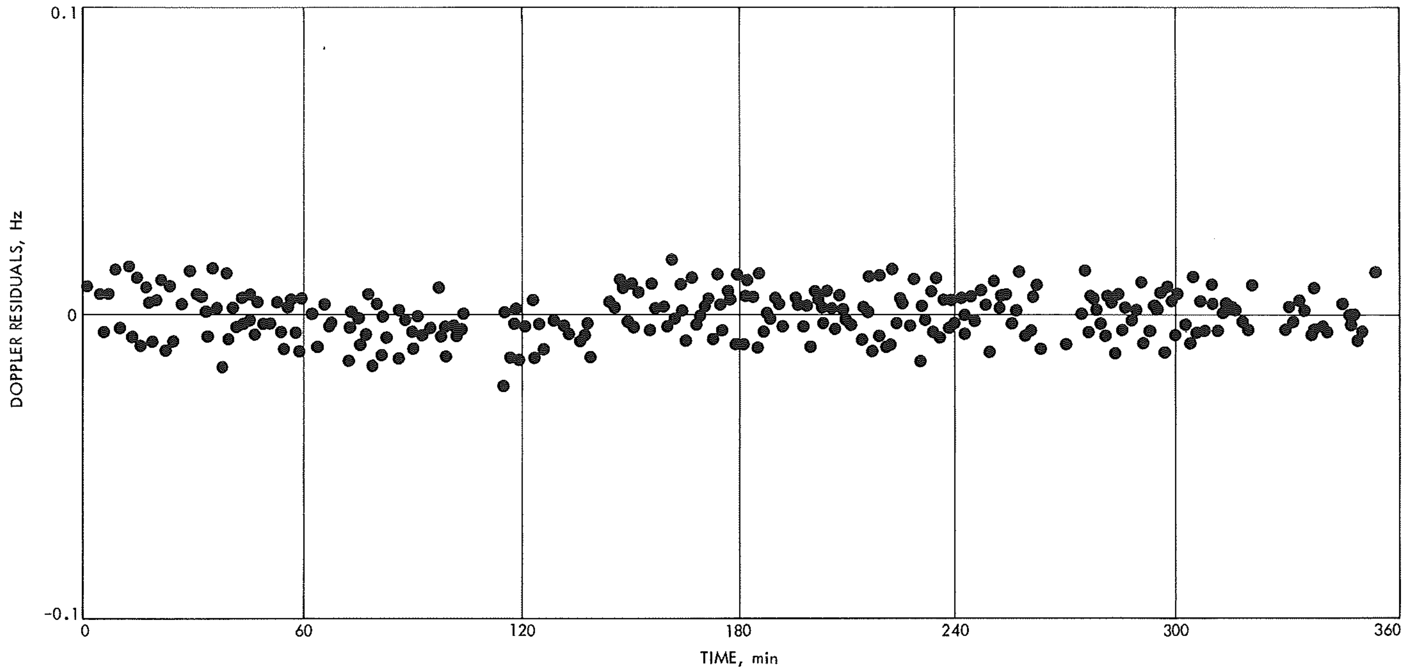


Fig. 71. Third pass two-way doppler residuals received by DSS 51 (time from 12:03:00 GMT on September 10, 1967)

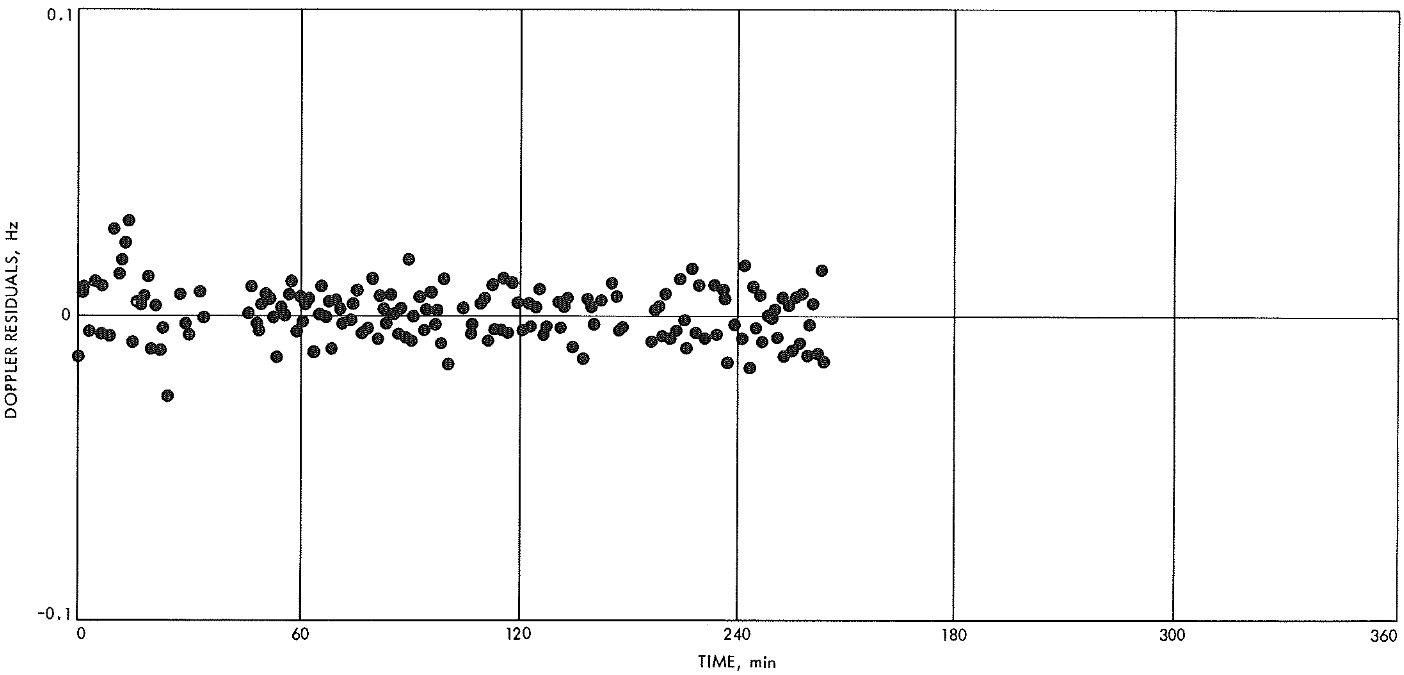


Fig. 72. Third pass two-way doppler residuals received by DSS 51 (time from 18:03:00 GMT on September 10, 1967)

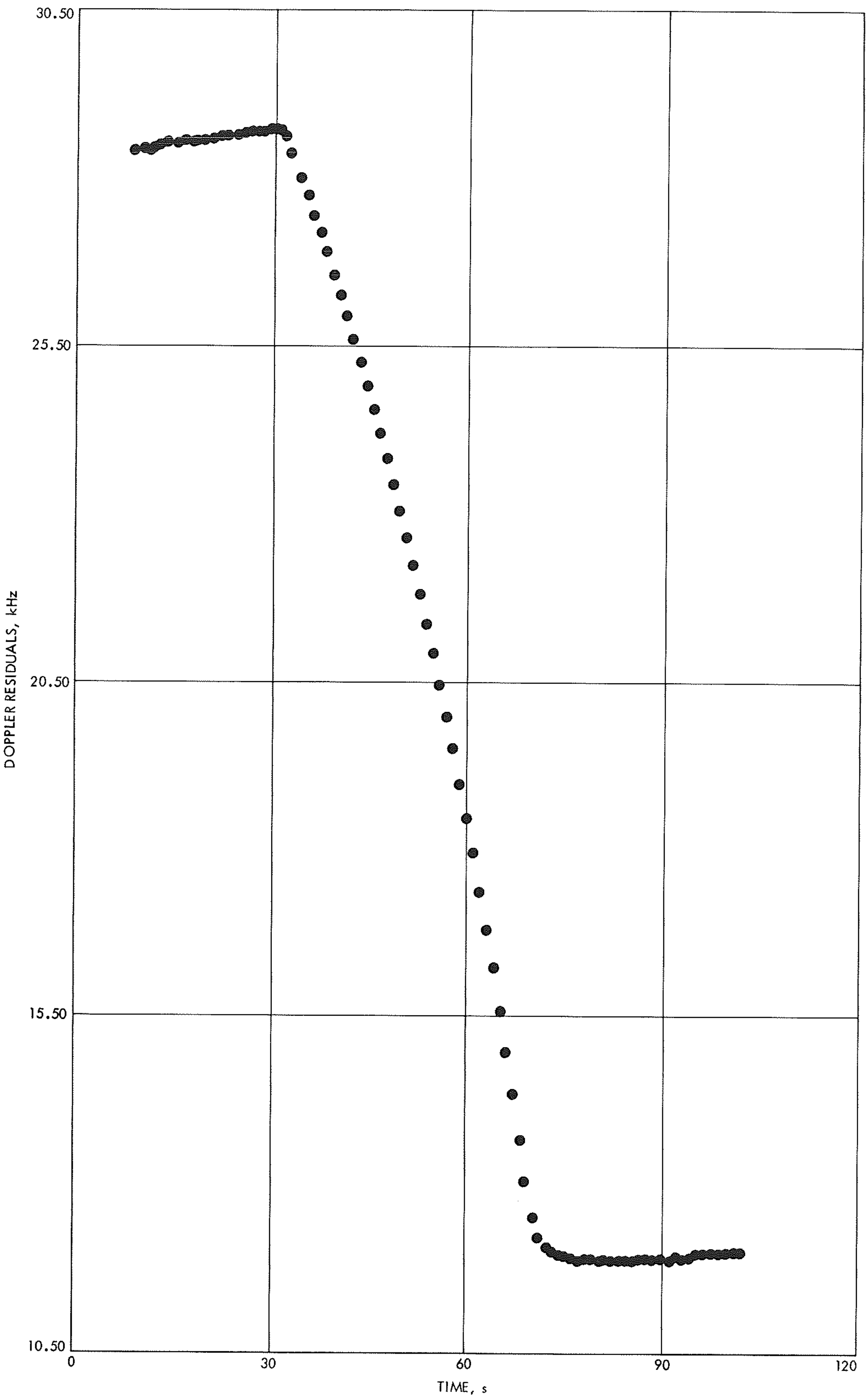


Fig. 73. Main retromaneuver phase one-way doppler residuals received by DSS 11 (time from 00:44:20 GMT on September 11, 1967)

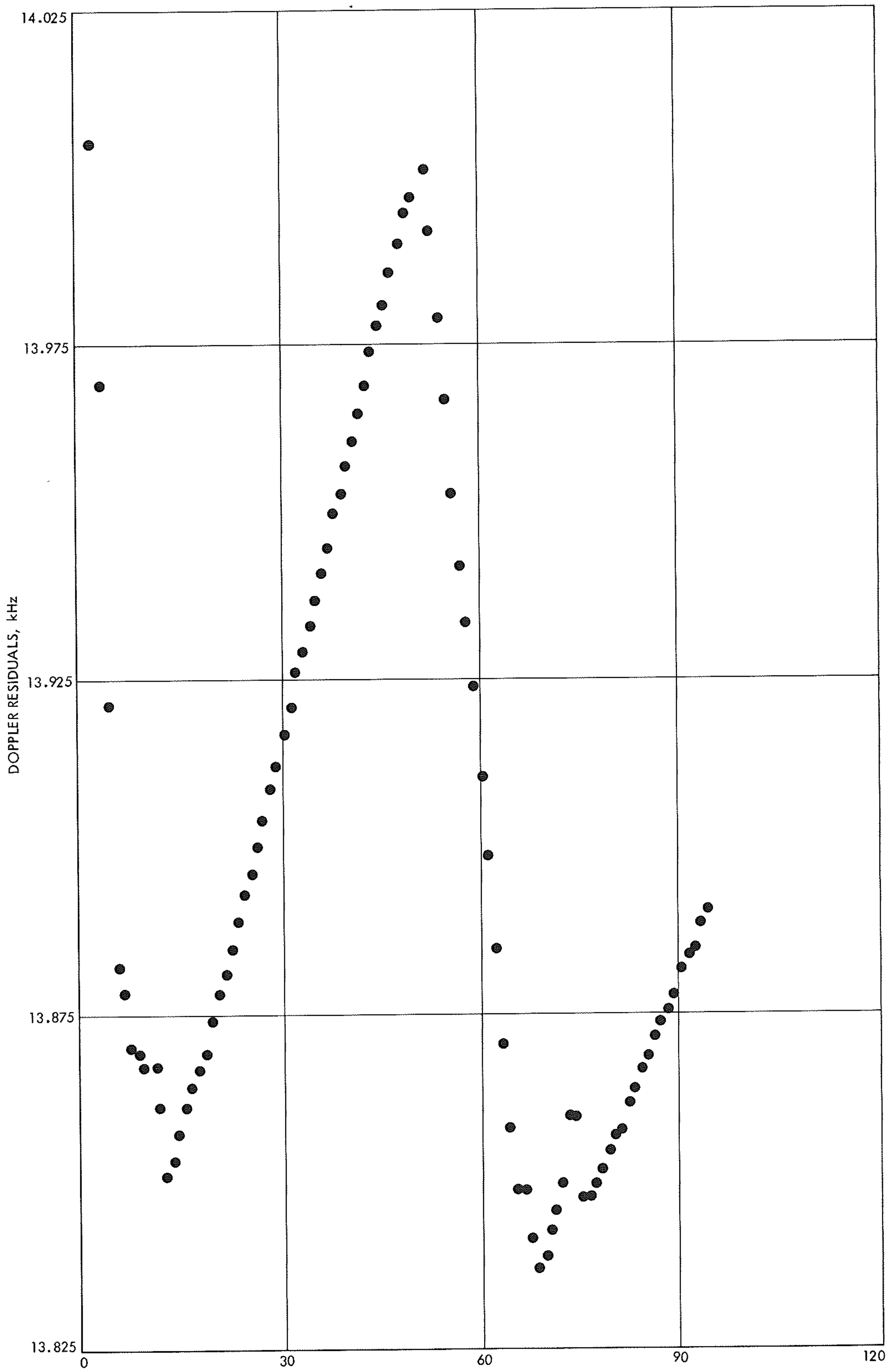


Fig. 74. Touchdown phase one-way doppler residuals received by DSS 11 (time from 00:45:30 GMT on September 11, 1967)

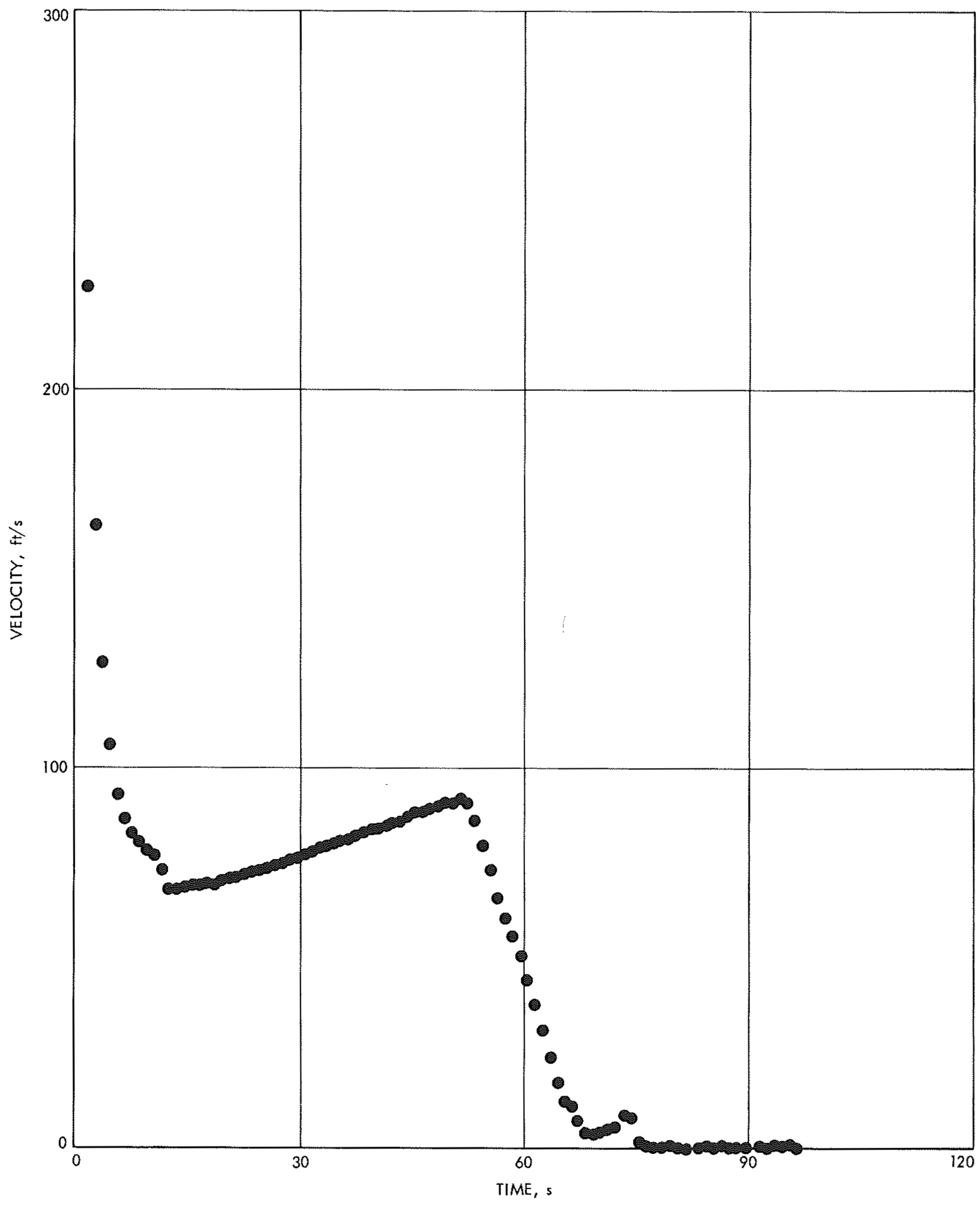


Fig. 75. Surface-referenced approach velocity of *Surveyor V* (time from 00:45:30 GMT on September 11, 1967)

Glossary

AFETR	Air Force Eastern Test Range
AFC	automatic frequency control
AGC	automatic gain control
AMR	altitude marking radar
APC	automatic phase control
AOS	acquisition of signal
ASEC	alpha scattering electronics compartment
ASI	alpha scattering instrument
ASSH	alpha scattering sensor head
A/SPP	antenna and solar panel positioner
BECO	booster engine cutoff
CDC	command data console
CKAFS	Cape Kennedy Air Force Station
DPES	direct-ascent powered flight simulator
DSIF	Deep Space Instrumentation Facility
DSN	Deep Space Network
DSS	Deep Space Station
FPAC	flight-path analysis and command (group)
FM	frequency modulation
GCF	ground communications facility
GSFC	Goddard Space Flight Center
HAC	Hughes Aircraft Co.
HPPS	Hughes post processor
ICS	intracommunications system
I/O	input/output
KSC	Kennedy Space Center
LOS	loss of signal
MECO	main engine cutoff
MEIG	main engine ignition
MES	main engine start (*Centaur*)
MSFN	Manned Space Flight Network
MTGS	midcourse and terminal guidance
NASCOM	NASA Communications Network
ODGX	orbit data generator program
ODPX	orbit determination program
ORT	operational readiness test
OSAS	on-site alpha scattering (program)
PCM	pulse code modulation
PLIM	postlaunch instrumentation message
PM	phase modulation
PRDX	JPL predicts program
RADVS	radar altimeter and doppler velocity sensor
RIS	range instrumentation ship
RTCS	real-time computer system
SCAMA	signaling, conferencing, and monitoring arrangement
SCO	subcarrier oscillator
SECO	sustainer engine cutoff
SFOF	Space Flight Operations Facility
SM/SS	soil mechanics/surface sampler
SOCP	*Surveyor* on-site computer program
SPAC	spacecraft performance analysis and command (group)
SRT	system readiness test
TDA	tracking and data acquisition
TDH	tracking data handling
TDM	time division multiplex
TDPX	tracking data processor program
TDS	Tracking and Data System
TRJX	JPL trajectory program
TTY	teletype
VCO	voltage-controlled oscillator
VCXO	voltage-controlled crystal oscillator
VECO	vernier engine cutoff
WBVCXO	wideband voltage-controlled crystal oscillator