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Technical Memorandum 33-301

Volume IV

*Tracking and Data System Support for Surveyor
Mission VI*

N. A. Renzetti

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**JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA**

December 1, 1969

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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 fourth 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 VI*, 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 sixth *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 VI

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.

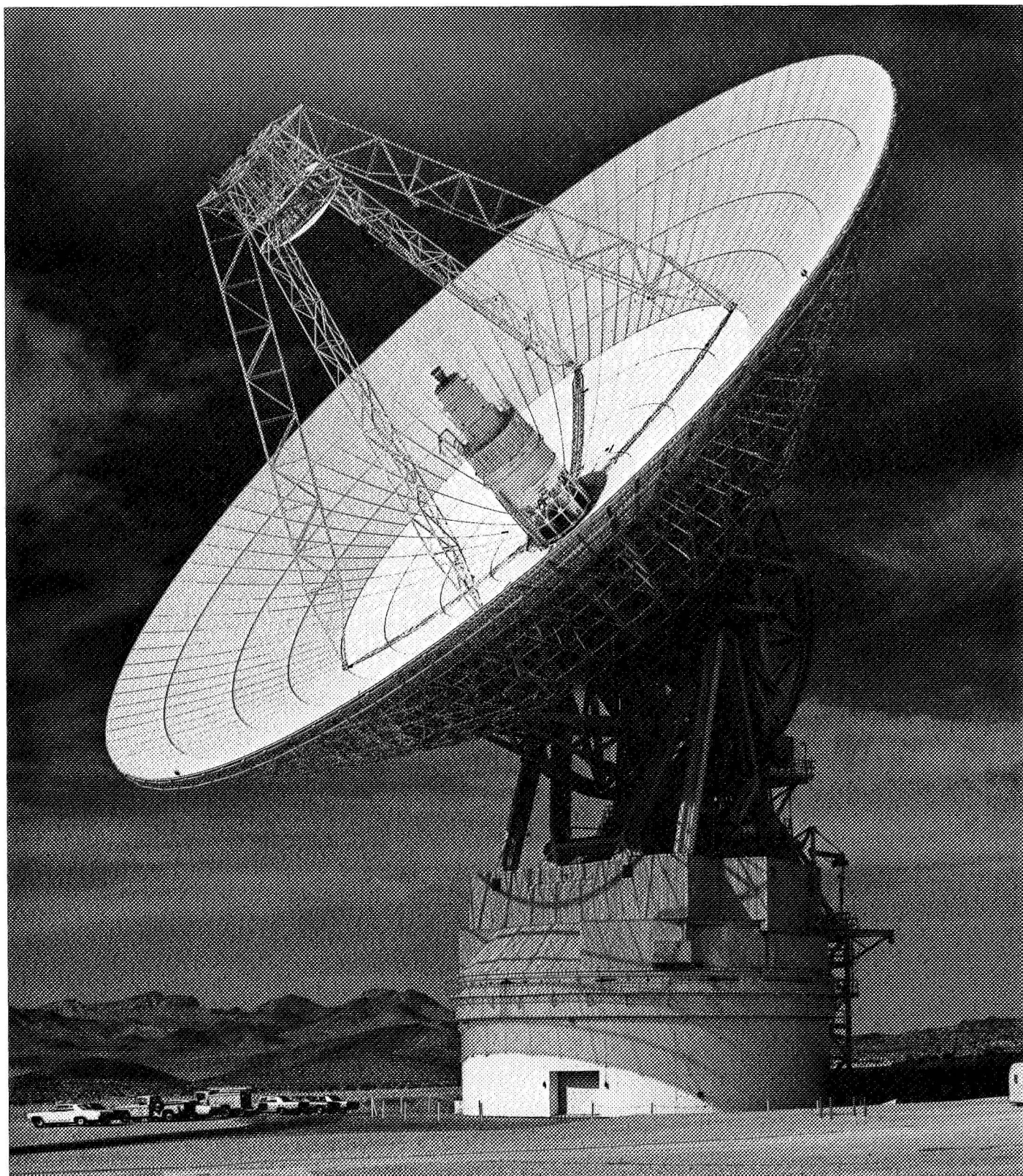


Fig. 1. Goldstone, Calif., Mars station (DSS 14) 210-ft antenna

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 Network (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 semi-major axis are 0.98 and 384,000 km, respectively. The

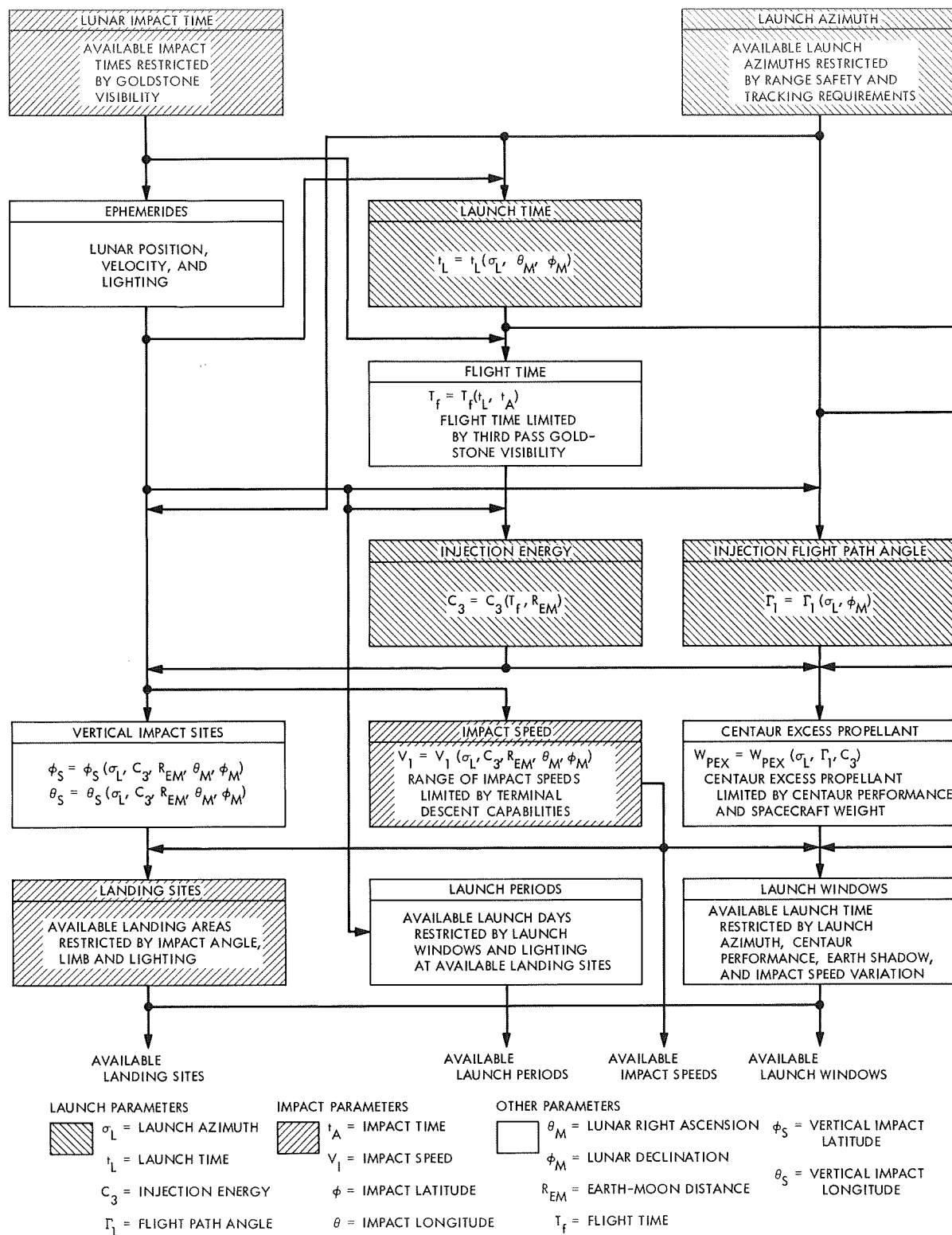


Fig. 2. Functional relationships between launch parameters, impact parameters, mission design constraints, and Surveyor trajectory design

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.

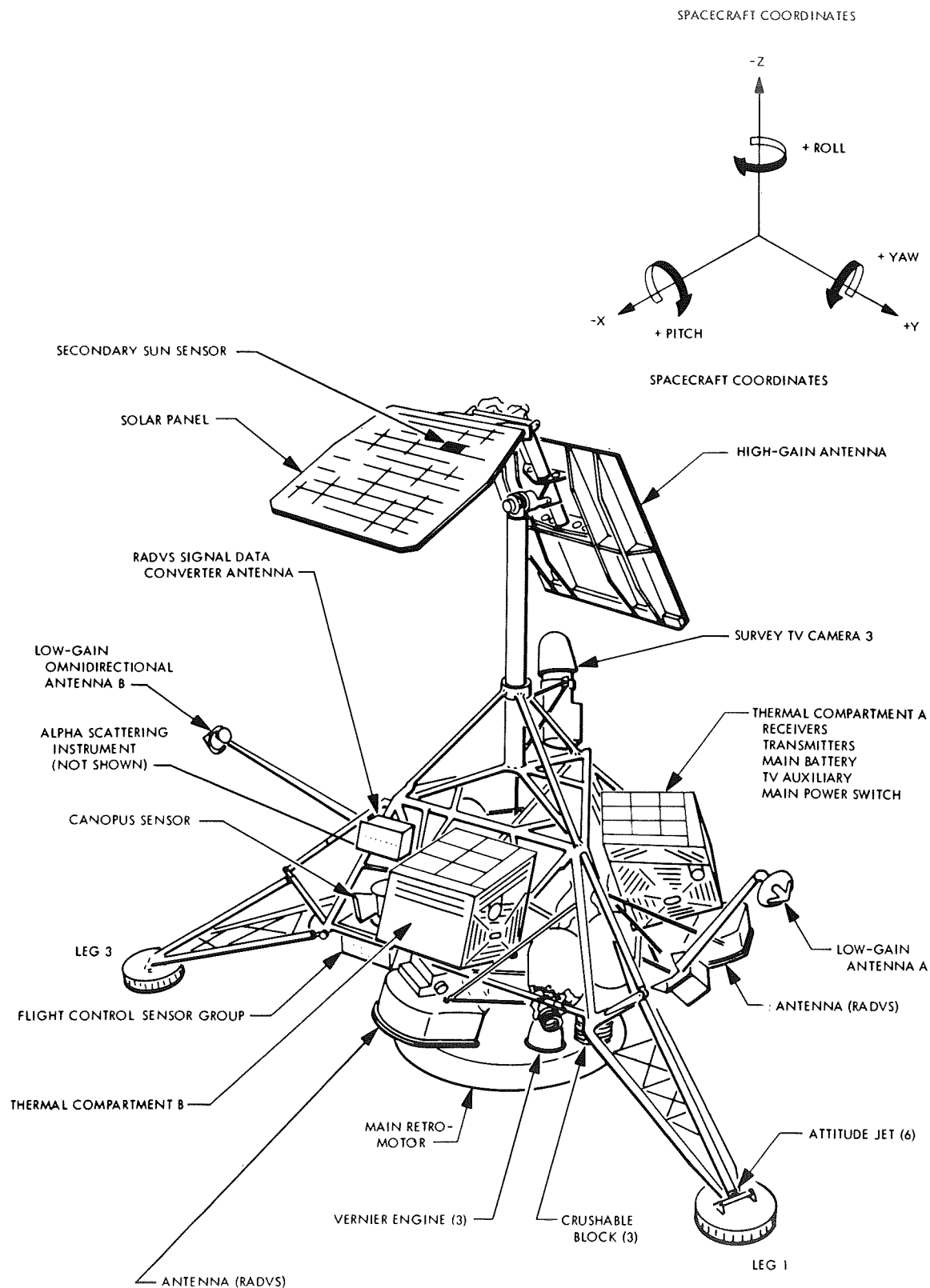


Fig. 3. Surveyors V, VI, and VII spacecraft configuration

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 gimballed 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

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 for AC-10 to overcome a deployment control problem that had been suspected on vehicle development flights of AC-6 and AC-8. 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 gimballed 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

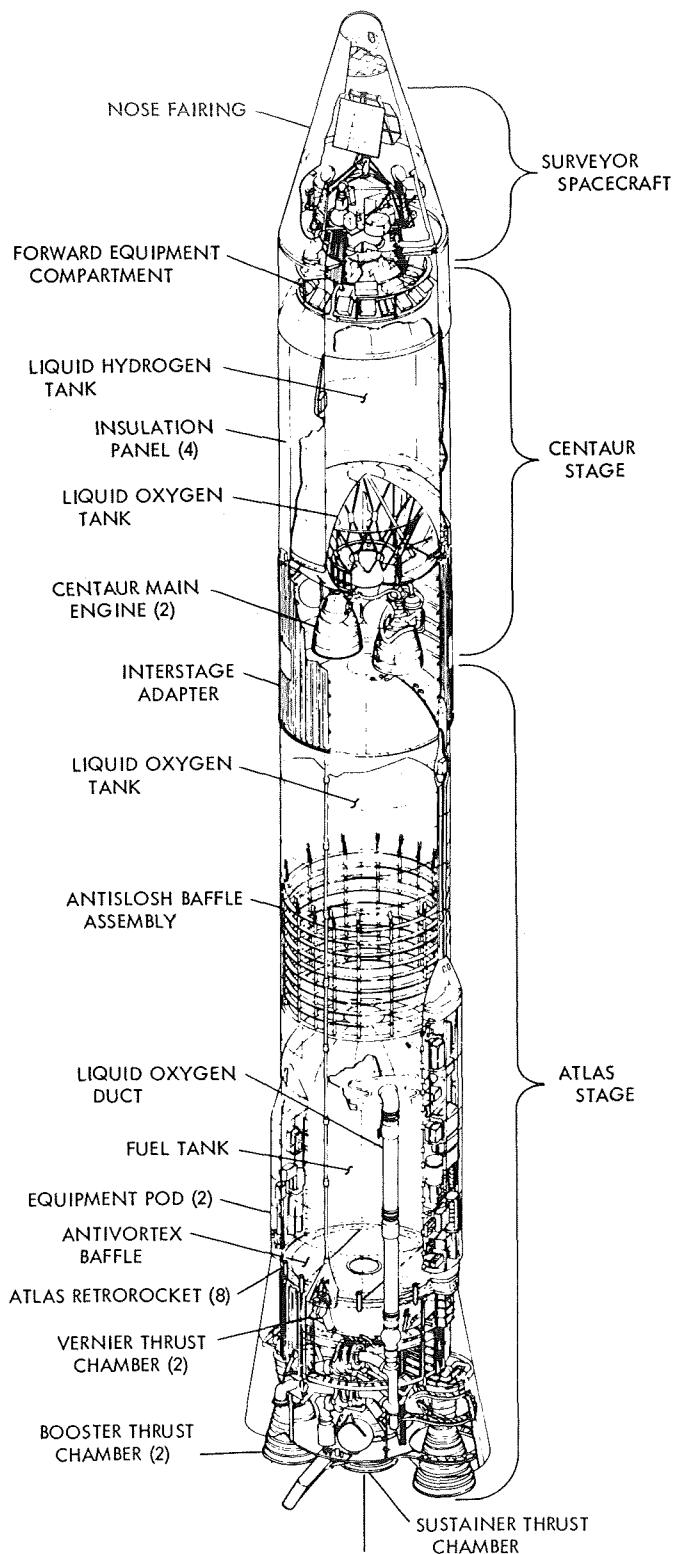


Fig. 4. Atlas/Centaur Surveyor space vehicle configuration

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 VI Mission Synopsis

A. General

Atlas/Centaur (AC-14) *Surveyor VI* spacecraft was the sixth in the series of operational vehicles designed for lunar soft-landing missions. Three previous *Surveyor* missions used direct-ascent (one-burn) *Atlas/Centaur* launch vehicles (AC-10, AC-7, and AC-11), and two used a parking-orbit-ascent (two-burn) launch vehicle (AC-12, AC-13). Launch vehicle AC-14 used the parking-orbit-ascent launch mode, and was the second to use an improved *Atlas* booster.

The launch vehicle for *Surveyor VI* employed a two-burn powered ascent from launch to injection of the *Centaur/Surveyor* into the required lunar transfer orbit. Following the second burn there was a brief coast period (for damping engine shutdown transients) before spacecraft separation. The *Centaur* was then programmed through a retromaneuver to increase the *Centaur/Surveyor* rate of separation. After separation the *Surveyor* spacecraft acquired, and maintained, communication and control throughout the mission by means of the world wide network of the JPL DSN stations and the SFOF at Pasadena, Calif. The spacecraft flight sequence consisted of an attitude-stabilized coast phase, a midcourse trajectory correction (some 15 h after launch), a second attitude-stabilized coast phase, and a terminal descent phase for a soft-landing on the moon. Touchdown on the moon occurred after approximately 66 h of flight. The midcourse correction and terminal descent were commanded and controlled from earth by the Deep Space Station at Goldstone, Calif.

The *Surveyor VI* spacecraft contained the same alpha scattering experiment as was used on *Surveyor V*. This scientific instrument was designed to perform compositional (elemental) analysis of lunar surface material by bombarding a small portion of the surface adjacent to the spacecraft with 6-MeV alpha particles, using 25–100 mCi of CM^{242} as an alpha source. Backscattered alpha particles, as well as protons generated within the sample by the incident alpha particles, are detected by solid-state, barrier-type detectors. The instrument was capable of detecting backscattered alpha particles from all elements except hydrogen and helium; and protons from lithium, boron, nitrogen, fluorine, sodium, magnesium, aluminum, silicon, phosphorus, and sulfur. Detection threshold of individual elements is expected to be about 1 wt %. Major alpha scattering experiment components consisted of the sensor device, an instrument digital electronics unit, an instrument auxiliary unit, and a deployment mechanism for lowering the sensor to the lunar surface after touchdown.

The *Surveyor VI* spacecraft was successfully launched from launch complex 36B, Cape Kennedy, Fla., at 07:39:01.075 GMT, November 7, 1967 (11:39:01.075 PST, November 6, 1967), after a 17-min extension of the scheduled 10-min hold at $T - 5$ min to obtain better spacecraft coverage by the tracking stations. The *Atlas/Centaur* launch vehicle launched and injected the spacecraft into its lunar orbit with a launch azimuth of 82.995 deg.

The transit phase of the mission was satisfactory, all subsystems worked as expected, and no spacecraft anomalies were experienced. A minor problem was encountered, consisting of loss of lock during star verification. This was because of an unexpected null depth in the omniantenna B uplink, rather than an anomalous spacecraft condition. Although loss of data was anticipated during the star mapping sequence, loss of two-way lock was considered only a remote possibility. However, two-way lock was lost, and spacecraft roll was intentionally stopped prior to Canopus coming into the star sensor field of view to reacquire and interrogate the spacecraft, reassuring that all subsystems were operating.

At 01:01:05.480 GMT on November 10, a successful soft landing was made at 0.47 deg N and 1.48 deg W in the moon's Sinus Medii approximately 10.5 km from the original target point determined from *Lunar Orbiter* photographs. The spacecraft landed with a velocity of approximately 12 ft/s. Scheduled lunar operations were successfully conducted, including: television surveys, antenna and solar panel positioner (A/SPP) movements,

alpha scattering soil analysis, and telecommunications experiments. Also, a highly successful, historic first, liftoff and translation experiment was performed.

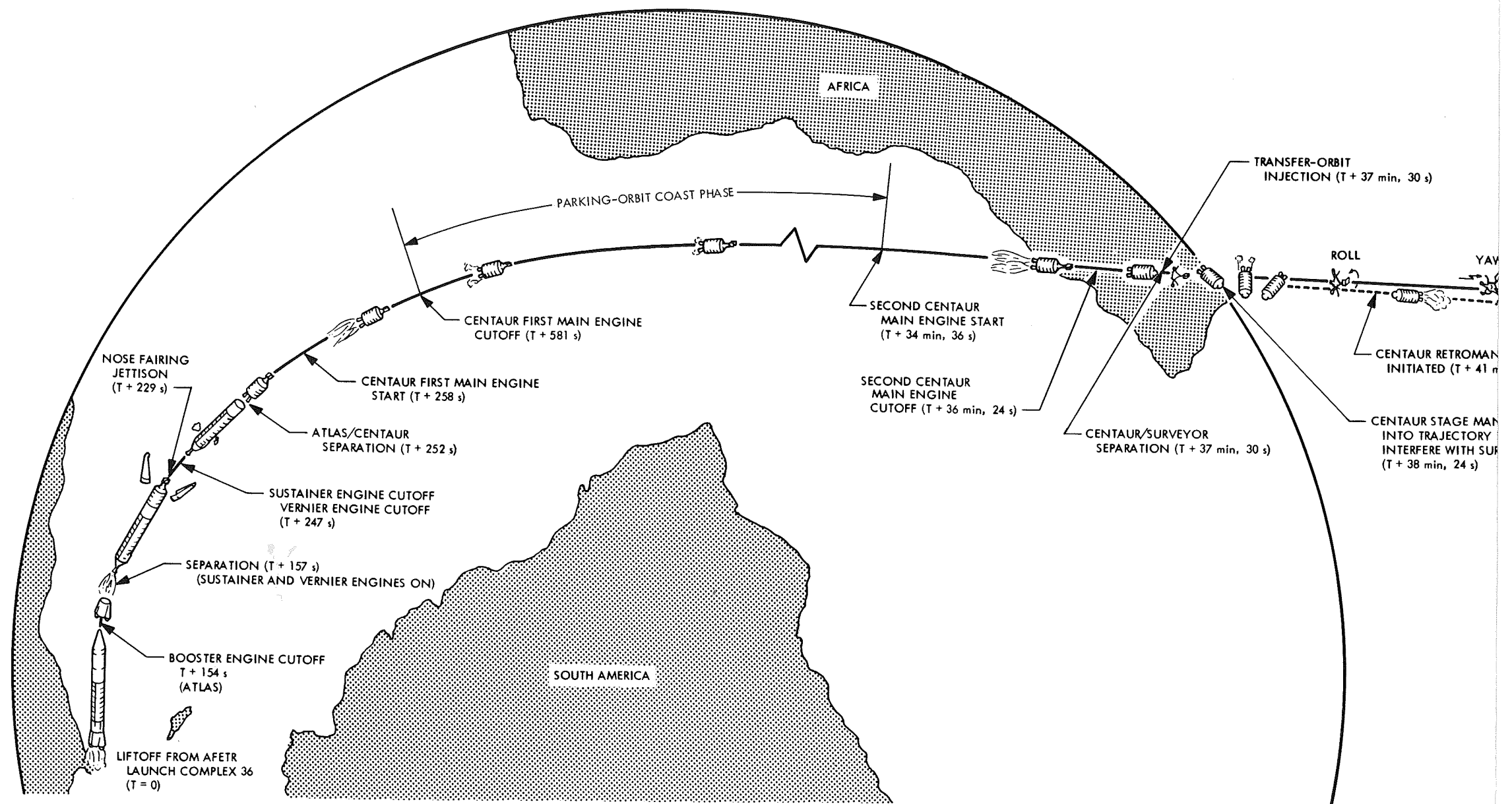
The prime functions of telemetry recover and command generation were accomplished at the Deep Space Stations. The Deep Space Stations used in a prime capacity were DSS 11, DSS 42, DSS 51, and DSS 61; DSS 14 was committed as a backup to DSS 11 during each transit pass, and as prime during terminal descent for the recovery of touchdown strain-gage data.

B. Mission Summary

The *Surveyor VI* spacecraft was launched by the *Atlas/Centaur* launch vehicle from launch complex 36B at Cape Kennedy after a smooth countdown to $T - 5$ min, at which time the built-in, 10-min hold was extended some 17 min to obtain better spacecraft coverage by tracking stations. Liftoff occurred at 07:39:01.075 GMT on November 7, with a launch azimuth of 82.995 deg. The *Atlas/Centaur* launch vehicle performance was excellent throughout the flight period; all marks occurring very close to predicted times.

The transit phase through touchdown of the *Surveyor VI* was from November 7, 1967 through November 10, 1967, with the spacecraft responding, as commanded, to 359 commands prior to touchdown. Lunar day 1 operations commenced after touchdown and continued through November 26, 1967 at approximately 01:34 PST. All *Surveyor VI* lunar day 1 operations were ended at that time, after obtaining 30,064 good television pictures.

A time-ordered, detailed, mission profile of the transit phase is tabulated in Table 2. Unless specified otherwise, the times listed are from telemetry data received in the performance analysis area at the SFOF; they include transit time from spacecraft to ground, SFOF processing delay, and commutation delay. A summary description of the important mission events is detailed in Fig. 5. Injection of the spacecraft occurred at 08:03:19.099 GMT on November 7, 1967 with a trajectory that would have provided, with no midcourse correction, a total miss of 125 km (78 mi) from the targeted landing site within Sinus Medii (Central Bay) at 0.42 deg N and 1.33 deg W. Normal preprogrammed spacecraft events occurred successfully; i.e., high power, landing legs extended, omnidirectional antenna extended, electrical disconnect from *Centaur*, automatic solar panel stepping, A/SPP roll axis stepping, and automatic sun acquisition, and in the proper order.



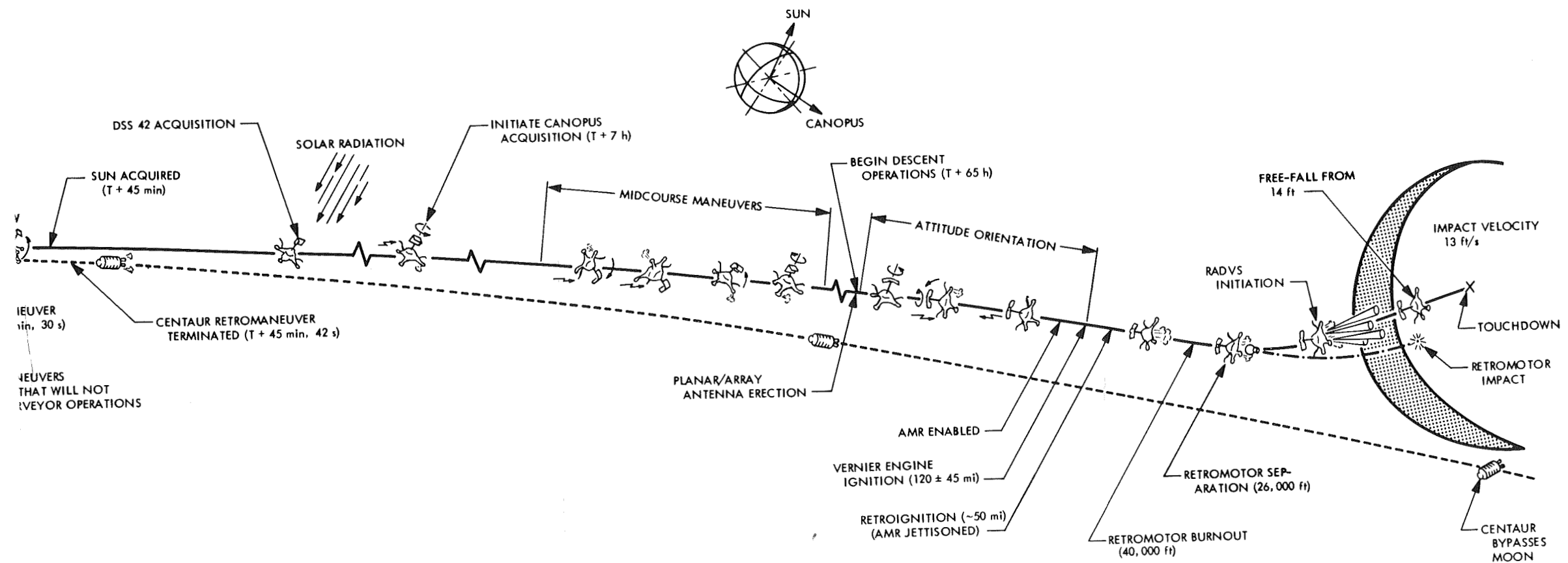


Fig. 5. Surveyor VI Mission flight profile

Table 2. Mission profile

Time		Command sequence		Event
After launch	GMT	Major	Minor	
Launch to separation				
0	07:39:01.075, Nov 7, 1967			Launch
24 ^m 48 ^s	08:03:49			Extend Landing Gears commanded by <i>Centaur</i>
24 ^m 59 ^s	08:04:00			Extend Omnantennas commanded by <i>Centaur</i>
25 ^m 19 ^s	08:04:20			Transmitter High Voltage On commanded by <i>Centaur</i>
25 ^m 24 ^s	08:04:25			Spacecraft/ <i>Centaur</i> electrical disconnect
25 ^m 29 ^s	08:04:30			Separation
31 ^m 09 ^s	08:10:10			Solar panel locked in transit position
34 ^m	08:13			Initial DSIF acquisition completed (two-way lock)
35 ^m 03 ^s	08:14:04			Sun acquisition cell illuminated (after 264-deg roll)
35 ^m 09 ^s	08:14:10			Roll axis locked in transit position
35 ^m 23 ^s	08:14:24			Sun lockon achieved (primary sun sensor cell illuminated after 10-deg yaw)
DSIF acquisition through star acquisition				
40 ^m 32 ^s	08:19:33	0040	0552	Turn spacecraft high power transmitter off
43 ^m 39 ^s	08:22:40	0040	0050	Turn accelerometer amplifiers and solar panel deployment logic off
44 ^m 19 ^s	08:23:20	0040	0454	Rocking solar panel back and forth to seat locking pin
45 ^m 27 ^s	08:24:28	0040	0455	Rocking roll axis back and forth to seat locking pin
46 ^m 23 ^s	08:25:24	0040	0051	Mode 1 interrogation
46 ^m 31 ^s	08:25:32	0040	0052	Initial/100-bits/s selection (change from 550-bits/s low modulation index)
51 ^m 26 ^s	08:30:27	0040	0055	Mode 4 interrogation
54 ^m 17 ^s	08:33:18	0040	0251	Mode 2 interrogation
57 ^m 43 ^s	08:36:44	0040	1356	Mode 6 interrogation
59 ^m 34 ^s	08:38:35	0040	1354	Return to mode 5 for coast phase monitoring
04 ^h 35 ^m 38 ^s	12:14:39	0040	0250	Mode 4 interrogation
04 ^h 41 ^m 29 ^s	12:20:30	0040	0251	Mode 2 interrogation
04 ^h 46 ^m 01 ^s	12:25:02	0040	0252	Mode 1 interrogation
04 ^h 49 ^m 11 ^s	12:28:12	0040	0550	Return to mode 5 for coast phase monitoring
05 ^h 33 ^m 29 ^s	15:30:00	0046	0250	Start of pre-star verification engineering interrogation
07 ^h 51 ^m 00 ^s	15:30:01	0046	0250	Mode 4 interrogation
07 ^h 57 ^m 06 ^s	15:36:07	0046	0251	Mode 2 interrogation
08 ^h 00 ^m 23 ^s	15:39:24	0046	0252	Mode 1 interrogation
08 ^h 03 ^m 35 ^s	15:42:36	0041	0652	Turn transmitter filament on
08 ^h 05 ^m 19 ^s	15:44:20	0041	0653	Turn transmitter high voltage on
08 ^h 05 ^m 57 ^s	15:44:58	0041	0253	Selection of 4400 bits/s
08 ^h 06 ^m 51 ^s	15:45:52	0041	0654	Cruise mode, manual delay mode, and positive angle maneuver commanded
08 ^h 07 ^m 30 ^s	15:46:31	0041	1051	Select omniantenna A

Table 2 (contd)

Time		Command sequence		Event
After launch	GMT	Major	Minor	
DSIF acquisition through star acquisition (contd)				
08 ^h 11 ^m 21 ^s	15:50:22	0041	1251	Start roll
08 ^h 17 ^m 39 ^s	15:56:40	0041	1052	Select omniantenna B
08 ^h 19 ^m 43 ^s	15:58:44			Sun mode commanded to stop roll maneuver
08 ^h 25 ^m 38 ^s	16:04:39		1050	Transponder off
08 ^h 27 ^m 51 ^s	16:06:52			Mode 4 interrogation
08 ^h 33 ^m 11 ^s	16:12:12			Mode 1 select
08 ^h 34 ^m 00 ^s	16:13:01		0654	Cruise mode, manual delay mode, and positive angle maneuver commanded
08 ^h 35 ^m 21 ^s	16:14:22	0041	1251	Roll maneuver restarted
08 ^h 46 ^m 27 ^s	16:25:28	0041	0655	Star acquisition mode commanded to permit automatic star lockon to occur
08 ^h 50 ^m 11 ^s	16:29:12	0041	0054	Cruise mode on
08 ^h 51 ^m 04 ^s	16:30:05	0041	0550	Mode 5 selected
08 ^h 53 ^m 06 ^s	16:32:07	0041	1053	Transponder B turned on
08 ^h 57 ^m 15 ^s	16:36:16	0041	0150	Bit rate reduction from 4400 to 1100 bits/s
08 ^h 58 ^m 15 ^s	16:37:16	0041	0552	Turn transmitter high power off
Coast phase I				
09 ^h 04 ^m 04 ^s	16:43:05	0041	0354	Initiate gyro drift check 1, three-axis
09 ^h 13 ^m 57 ^s	16:52:58		0306	Solar panel switch commanded on
09 ^h 18 ^m 41 ^s	16:57:42		0307	Optimum charge regulator bypass commanded on
10 ^h 25 ^m 10 ^s	18:04:11	0041	0054	Terminate gyro drift check
10 ^h 39 ^m 21 ^s	18:18:22		0354	Initiate gyro drift check 2, three-axis
10 ^h 40 ^m 31 ^s	18:19:32		0306	Solar panel switch commanded on
10 ^h 41 ^m 45 ^s	18:20:46		0306	Solar panel switch commanded on
11 ^h 43 ^m 31 ^s	19:22:32		0054	Terminate gyro drift check
11 ^h 45 ^m 24 ^s	19:24:25		0354	Initiate gyro drift check 3, three-axis
12 ^h 44 ^m 31 ^s	20:23:32		0306	Solar panel switch commanded on
12 ^h 59 ^m 57 ^s	20:38:58		0054	Terminate gyro drift check
13 ^h 05 ^m 51 ^s	20:44:52		0354	Initiate gyro drift check 4, three-axis
14 ^h 21 ^m 28 ^s	22:00:29		0306	Solar panel switch commanded on
14 ^h 24 ^m 02 ^s	22:03:03		0054	Terminate gyro drift check
14 ^h 37 ^m 17 ^s	22:16:18		0250	Mode 4 interrogation
14 ^h 40 ^m 54 ^s	22:19:55		9B4	Bit rate reduction from 1100 to 137.5 bits/s to obtain alpha scattering temperatures
14 ^h 44 ^m 31 ^s	22:23:32		9D2	Bit rate increased from 137.5 to 1100 bits/s
14 ^h 46 ^m 33 ^s	22:25:34	0046	0251	Mode 2 interrogation
14 ^h 50 ^m 00 ^s	22:29:01	0046	0252	Mode 1 interrogation
14 ^h 53 ^m 02 ^s	22:32:03	0046	0550	Return to mode 5
15 ^h 09 ^m 03 ^s	22:48:04		0306	Solar panel switch commanded on

Table 2 (contd)

Time		Command sequence		Event
After launch	GMT	Major	Minor	
Coast phase I (contd)				
16 ^h 33 ^m 00 ^s	00:12:01	0042	0250	Initiate premidcourse interrogation
16 ^h 33 ^m 14 ^s	00:12:15	0042	0250	Mode 4 interrogation
16 ^h 35 ^m 25 ^s	00:14:26	0042	0251	Mode 2 interrogation
16 ^h 37 ^m 24 ^s	00:16:25	0042	0252	Mode 1 interrogation
16 ^h 39 ^m 36 ^s	00:18:37	0042	0550	Return to mode 5
Midcourse correction				
16 ^h 45 ^m 42 ^s	00:24:43	0042	0350	Initiate gyro speed check
16 ^h 47 ^m 39 ^s	00:26:40	0042	0351	Select next gyro three times
16 ^h 52 ^m 34 ^s	00:31:35	0042	0352	Gyro speed signal processing off and return to mode 5
17 ^h 57 ^m 51 ^s	01:36:52	0043	0250	Initiate midcourse correction interrogation
17 ^h 57 ^m 57 ^s	01:36:58	0043	0250	Mode 4 interrogation
18 ^h 00 ^m 20 ^s	01:39:21	0043	0251	Mode 2 interrogation
18 ^h 03 ^m 48 ^s	01:42:49	0043	0252	Mode 1 interrogation
18 ^h 10 ^m 26 ^s	01:49:27	0043	0652	Turn transmitter filament on
18 ^h 12 ^m 18 ^s	01:51:19	0043	0653	Turn transmitter high power on
18 ^h 13 ^m 03 ^s	01:52:04	0043	0253	Increase bit rate from 550 to 4400 bits/s
18 ^h 17 ^m 47 ^s	01:56:48	0403	1150	Command desired roll maneuver magnitude and direction (+91.9 deg)
18 ^h 23 ^m 59 ^s	02:03:00	0403	1251	Start of roll near zero crossing of Canopus error signal
18 ^h 28 ^m 03 ^s	02:07:04	0403	1155	Command desired yaw maneuver magnitude and direction (+127.3 deg)
18 ^h 30 ^m 07 ^s	02:09:08	0403	1253	Start of yaw near zero crossing of primary sun sensor yaw error signal
18 ^h 35 ^m 13 ^s	02:14:14	0403	0751	Propulsion strain gage powered, inertial mode and reset group IV outputs commanded
18 ^h 36 ^m 56 ^s	02:15:57	0403	0750	Turn OFF cyclic loads, AMR ^a , vernier line heaters
18 ^h 36 ^m 58 ^s	02:15:59	0740	0750	Pressurize vernier system (helium) unlock vernier engine 1
18 ^h 38 ^m 16 ^s	02:17:17	0043	0752	Thrust phase power on
18 ^h 38 ^m 41 ^s	02:17:42	0043	0753	Command desired thrust duration (10.25 s)
18 ^h 41 ^m 01 ^s	02:20:02	0043	0754	Execute midcourse thrust
18 ^h 41 ^m 14 ^s	02:20:15	0043	0754	Command terminate thrust
18 ^h 41 ^m 41 ^s	02:20:42	0043	0754	Turn thrust phase power off
18 ^h 41 ^m 10 ^s	02:20:11	0043	0754	Turn propulsion strain gage power off
18 ^h 43 ^m 11 ^s	02:22:12	0043	0550	Operations to obtain coast mode data
18 ^h 44 ^m 19 ^s	02:23:20	0043	0755	Cyclic loads turned on vernier line, AMR heaters
18 ^h 45 ^m 52 ^s	02:24:53	0043	1252	Command reverse yaw maneuver magnitude and direction (-127.3 deg)
18 ^h 47 ^m 05 ^s	02:26:06	0043	1253	Execute yaw (sun reacquired at 02:31:44)
18 ^h 52 ^m 43 ^s	02:31:44		0357	Command sun mode on

^aAMR = Altitude marking radar.

^aAMR = Altitude marking radar.

Table 2 (contd)

Time		Command sequence		Event
After launch	GMT	Major	Minor	
Midcourse correction (contd)				
18 ^h 53 ^m 08 ^s	02:32:09	0043	1250	Command reverse roll maneuver magnitude and direction (—91.9 deg)
18 ^h 53 ^m 56 ^s	02:32:57	0043	1251	Execute roll (Canopus reacquired at approximately 02:35:33)
18 ^h 58 ^m 38 ^s	02:37:39		0054	Cruise mode commanded
18 ^h 59 ^m 16 ^s	02:38:17	0043	0157	Mode 2 interrogation
19 ^h 03 ^m 06 ^s	02:42:07	0043	0055	Mode 4 interrogation
19 ^h 05 ^m 01 ^s	02:44:02	0043	0550	Return to mode 5
19 ^h 07 ^m 07 ^s	02:46:08	0043	0150	Bit rate reduction 4400 to 1100 bits/s
19 ^h 07 ^m 07 ^s	02:46:08	0043	0552	Turn transmitter high power off
Coast phase II				
19 ^h 33 ^m 27 ^s	03:12:28			Touchdown strain gage power and data channel commanded on for special test
19 ^h 49 ^m 19 ^s	03:28:20			Touchdown strain gage power and data channel commanded off
20 ^h 43 ^m 40 ^s	04:22:41		0250	Mode 4 interrogation
20 ^h 49 ^m 49 ^s	04:28:50		0251	Mode 2 interrogation
20 ^h 54 ^m 38 ^s	04:33:39		0252	Mode 1 interrogation
20 ^h 57 ^m 12 ^s	04:36:13		0550	Return to mode 5
20 ^h 58 ^m 42 ^s	04:37:43		0354	Initiate gyro drift check 5, three-axis
22 ^h 03 ^m 50 ^s	05:42:51		0054	Terminate gyro drift check
24 ^h 53 ^m 25 ^s	08:32:26			Initiate gyro drift check 6, roll only
28 ^h 46 ^m 23 ^s	12:25:24		0250	Mode 4 interrogation
28 ^h 50 ^m 15 ^s	12:29:16		0251	Mode 2 interrogation
28 ^h 52 ^m 59 ^s	12:32:00		0252	Mode 1 interrogation
28 ^h 57 ^m 27 ^s	12:36:28		0550	Return to mode 5
29 ^h 07 ^m 28 ^s	12:46:29		0054	Terminate gyro drift check
32 ^h 39 ^m 38 ^s	16:18:39		0354	Initiate gyro drift check 7, three-axis
33 ^h 35 ^m 54 ^s	17:14:55		0250	Mode 4 interrogation
33 ^h 44 ^m 32 ^s	17:23:33		0251	Mode 2 interrogation
33 ^h 48 ^m 46 ^s	17:27:47		0252	Mode 1 interrogation
33 ^h 53 ^m 13 ^s	17:32:14		0550	Return to mode 5
34 ^h 14 ^m 40 ^s	17:53:41		0054	Terminate gyro drift check
35 ^h 20 ^m 38 ^s	18:59:39			Initiate gyro drift check 8, roll only
37 ^h 37 ^m 38 ^s	21:16:39		0250	Mode 4 interrogation
37 ^h 40 ^m 55 ^s	21:19:56		0251	Mode 2 interrogation
37 ^h 45 ^m 48 ^s	21:24:49		0550	Return to mode 5
37 ^h 58 ^m 08 ^s	21:37:09		11E1	Mode 1 interrogation
38 ^h 02 ^m 59 ^s	21:42:00		11A5	Return to mode 5
38 ^h 03 ^m 27 ^s	21:42:28		0054	Terminate gyro drift check
39 ^h 06 ^m 00 ^s	22:45:01		0354	Initiate gyro drift check 9, three-axis

Table 2 (contd)

Time		Command sequence		Event
After launch	GMT	Major	Minor	
Coast phase II (contd)				
40 ^h 32 ^m 17 ^s	00:11:18		0054	Terminate gyro drift check
41 ^h 32 ^m 24 ^s	01:11:25	0046	0354	Initiate gyro drift check 10, three-axis
42 ^h 11 ^m 32 ^s	01:50:33	0046	0250	Mode 4 interrogation
42 ^h 14 ^m 02 ^s	01:53:03	0046	0251	Mode 2 interrogation
42 ^h 15 ^m 47 ^s	01:54:48	0046	0252	Mode 1 interrogation
42 ^h 18 ^m 31 ^s	01:57:32	0046	0550	Return to mode 5
42 ^h 46 ^m 35 ^s	02:25:36	0046	0054	Terminate gyro drift check
43 ^h 50 ^m 51 ^s	03:29:52	0046	0354	Initiate gyro drift check 11, three-axis
45 ^h 09 ^m 08 ^s	04:48:09	0046	0054	Terminate gyro drift check
46 ^h 34 ^m 59 ^s	06:14:00	0046	0250	Mode 4 interrogation
46 ^h 40 ^m 51 ^s	06:19:52	0046	0251	Mode 2 interrogation
46 ^h 44 ^m 05 ^s	06:23:06	0046	0252	Mode 1 interrogation
46 ^h 46 ^m 01 ^s	06:25:02	0046	0550	Return to mode 5
46 ^h 46 ^m 56 ^s	06:25:57	0046	0354	Initiate gyro drift check 12, three-axis
47 ^h 59 ^m 31 ^s	07:38:32	0046	0054	Terminate gyro drift check
49 ^h 25 ^m 07 ^s	09:04:08	0046	0354	Initiate gyro drift check 13, three-axis
51 ^h 03 ^m 27 ^s	10:42:28	0046	0054	Terminate gyro drift check
51 ^h 07 ^m 45 ^s	10:46:46	0046	0250	Mode 4 interrogation
51 ^h 11 ^m 35 ^s	10:50:36	0046	0251	Mode 2 interrogation
51 ^h 14 ^m 24 ^s	10:53:25	0046	0252	Mode 1 interrogation
51 ^h 18 ^m 46 ^s	10:57:47	0046	0550	Return to mode 5
51 ^h 22 ^m 21 ^s	11:01:22		0357	Initiate gyro drift check 14, roll only
51 ^h 24 ^m 55 ^s	11:03:56		3054	Compartment A thermal control commanded on
54 ^h 13 ^m 55 ^s	13:52:56		0250	Mode 4 interrogation
54 ^h 17 ^m 54 ^s	13:56:55		0251	Mode 2 interrogation
54 ^h 21 ^m 00 ^s	14:00:01		0252	Mode 1 interrogation
54 ^h 23 ^m 32 ^s	14:02:33		0550	Return to mode 5
55 ^h 14 ^m 16 ^s	14:53:17		1350	Vernier fuel tank 2 and oxidizer tanks 2 and 3 thermal control commanded on
55 ^h 47 ^m 54 ^s	15:26:55		0054	Terminate gyro drift check
58 ^h 19 ^m 15 ^s	17:58:16	0046	0250	Mode 4 interrogation
58 ^h 22 ^m 51 ^s	18:01:52	0046	0251	Mode 2 interrogation
58 ^h 25 ^m 59 ^s	18:05:00	0046	0252	Mode 1 interrogation
58 ^h 28 ^m 06 ^s	18:07:07	0046	0550	Return to mode 5
58 ^h 29 ^m 42 ^s	18:08:43		7B3	Bit rate reduction 1100 to 550 bits/s
60 ^h 16 ^m 37 ^s	19:55:38	0046	1757	Survey TV electronics thermal control on
60 ^h 46 ^m 06 ^s	20:25:07		3056	Compartment C thermal control on
60 ^h 58 ^m 13 ^s	20:37:14	0046	0250	Mode 4 interrogation
61 ^h 04 ^m 09 ^s	20:43:10	0046	0550	Return to mode 5

Table 2 (contd)

Time		Command sequence		Event
After launch	GMT	Major	Minor	
Coast phase II (contd)				
61 ^h 56 ^m 38 ^s	21:35:39	0046	0250	Mode 4 interrogation
62 ^h 11 ^m 08 ^s	21:50:09	0046	0251	Mode 2 interrogation
62 ^h 14 ^m 03 ^s	21:53:04	0046	0252	Mode 1 interrogation
62 ^h 19 ^m 27 ^s	21:58:28	0046	0550	Return to mode 5
62 ^h 48 ^m 26 ^s	22:27:27			Alpha scattering heater power on
65 ^h 00 ^m 24 ^s	22:39:25	0046	0250	Mode 4 interrogation
63 ^h 03 ^m 09 ^s	22:42:10	0046	0251	Mode 2 interrogation
63 ^h 07 ^m 03 ^s	22:46:04	0046	0252	Mode 1 interrogation
63 ^h 09 ^m 51 ^s	22:48:52	0046	0550	Return to mode 5
63 ^h 12 ^m 22 ^s	22:51:23	0046	0350	Initiate gyro speed check
63 ^h 13 ^m 31 ^s	22:52:32	0046	0351	Select next gyro three times
63 ^h 15 ^m 39 ^s	22:54:40	0046	0352	Return to mode 5
63 ^h 17 ^m 42 ^s	22:56:43	0046	1050, 1053	Narrowband voltage-controlled crystal oscillator
63 ^h 34 ^m 13 ^s	23:13:14		3054	Compartment A heater off
Terminal descent				
64 ^h 13 ^m 10 ^s	23:52:11	0044	1355	Mode 6 interrogation
64 ^h 15 ^m 59 ^s	23:55:00	0044	0250	Mode 4 interrogation
64 ^h 26 ^m 51 ^s	00:05:52	0044	0652	Turn transmitter filament on
64 ^h 28 ^m 31 ^s	00:07:32	0044	0653	Transmitter high power
64 ^h 29 ^m 18 ^s	00:08:19	0044	0255	Bit rate increase 550 to 1100 bits/s
64 ^h 30 ^m 03 ^s	00:09:04	0044	2057	Presumming amplifier off
64 ^h 30 ^m 20 ^s	00:09:21	0044	0251	Mode 2 interrogation
64 ^h 32 ^m 35 ^s	00:11:36	0044	0550	Return to mode 5
64 ^h 35 ^m 33 ^s	00:14:34	0044	1755	Propulsion strain gage power turned on
64 ^h 36 ^m 00 ^s	00:15:01	0044	1756	Touchdown strain gage power and SCOs turned on
64 ^h 36 ^m 41 ^s	00:15:42	0044	1757	Survey camera vidicon temperature control on
64 ^h 37 ^m 58 ^s	00:16:59	0044	1050	Transponder power turned off and one-way lock achieved
64 ^h 39 ^m 37 ^s	00:18:38	0044	1154	Cruise mode commanded
64 ^h 39 ^m 38 ^s	00:18:39	0044	1154	Roll maneuver magnitude and direction commanded (+81.7 deg)
64 ^h 46 ^m 19 ^s	00:25:20	0044	1251	Execute sun and roll at Canopus error signal null
64 ^h 49 ^m 29 ^s	00:28:30	0044	1155	Yaw magnitude and direction command (+111.7 deg)
64 ^h 50 ^m 37 ^s	00:29:38	0044	1253	Execute yaw at primary sun sensor yaw error null (retromotor thrust direction aligned properly)
64 ^h 54 ^m 57 ^s	00:33:58	0044	1157	Roll maneuver magnitude and direction commanded (+120.5 deg)
64 ^h 55 ^m 55 ^s	00:34:56	0044	1257	Roll executed
65 ^h 01 ^m 01 ^s	00:40:02	0044	2152	Presumming amplifier on commanded (to get touchdown strain gage data)

Table 2 (contd)

Time		Command sequence		Event
After launch	GMT	Major	Minor	
Terminal descent (contd)				
65 ^h 01 ^m 59 ^s	00:41:00	0044	1751, 1656	Vernier thrust level (200 lb) for retromaneuver phase and delay between AMR mark and vernier ignition (5.875 s) commanded
65 ^h 09 ^m 57 ^s	00:48:58	0044	1355	Command on mode 6 data
65 ^h 11 ^m 29 ^s	00:50:30		1652	Command reset group IV outputs repeated twice
65 ^h 13 ^m 03 ^s	00:52:04	0044	1657	Retromaneuver sequence mode on commanded
65 ^h 13 ^m 26 ^s	00:52:27	0044	1752	Vernier lines and tanks, alpha scattering, TV, and AMR thermal control commanded off
65 ^h 14 ^m 16 ^s	00:53:17	0044	1753	AMR on
65 ^h 15 ^m 16 ^s	00:54:17	0044	1754	Thrust phase power on
65 ^h 17 ^m 16 ^s	00:56:17	0044	2051	AMR enabled
65 ^h 18 ^m 55 ^s	00:57:56	0044	2051	Backup AMR mark commanded
65 ^h 18 ^m 56 ^s .083	00:57:57.083 ^b			AMR mark
65 ^h 19 ^m 01 ^s .983	00:58:02.983 ^b			Vernier ignition
65 ^h 19 ^m 03 ^s .083	00:58:04.083 ^b			Retroignition
				Radar altimeter and doppler velocity sensor on
				Reliable-operate doppler velocity sensor
65 ^h 19 ^m 58 ^s .892	00:58:59.892 ^b			Reliable-operate radar altimeter
65 ^h 22 ^m 04 ^s .480	01:01:05.480 ^b			Touchdown

^bBased on reduced data obtained directly from the 96-kHz microwave link data (1.21 s must be subtracted to account for RF propagation).

^bBased on reduced data obtained directly from the 96-kHz microwave link data (1.21 s must be subtracted to account for RF propagation).

Initial DSN acquisition, one-way lock, was accomplished by DSS 51 at approximately 08:10 GMT and two-way lock was established at approximately 08:13 GMT. Spacecraft operations were initiated at 08:19:32 by commanding off the transmitter high power. Star verification and acquisition sequence was initiated at 15:50:21 GMT by commanding a sun and roll maneuver. After approximately 143 deg of roll, the spacecraft signal was lost at DSS 11. This was because of deeper than expected null within the predicted null region of the spacecraft's omnidirectional antenna B pattern. The maneuver was temporarily terminated. After the spacecraft was assessed, and determined to be satisfactory, the star map sequence was resumed at 16:14:22 GMT. After some 658 deg of total roll, automatic Canopus lockon was obtained and verified at 16:28:20 GMT. During the star map sequence, two star intensity signals (Deneb and Canopus), in addition to earth, were observed and identified. Two closely spaced (3 deg), unidentified and nonrepeatable signals were observed during the star map sequence.

Spacecraft preparation for midcourse maneuver was started at 12:01 GMT on November 8, with an engineering interrogation. The spacecraft was configured in high power at 01:51:19 GMT and 4400 bits/s at 01:52:05 GMT. A premidcourse correction maneuver consisting of 91.9 deg of positive roll was successfully executed at 02:02:59 GMT, followed by a successful positive yaw of 127.3 deg. The vernier engine was pressurized (offset of 179 psia noted, as anticipated), and vernier engine 1 was unlocked at 02:15:58 GMT on November 8. Thrust phase power was commanded on at 02:17:16 GMT, and the roll actuator null was verified. Midcourse velocity-correction duration was loaded and verified at 02:17:42 GMT. At 02:20:02.1 GMT, the midcourse velocity correction was initiated with a resulting engine burn of 10.25 s, for a change in spacecraft velocity of 10.06 m/s. (See Table 3 for tabulation of midcourse parameters.) Spacecraft telemetry and doppler shift indicated that the midcourse velocity correction was as commanded. Following midcourse thrust, the reverse midcourse maneuvers were commanded. Sun and star acquisitions were obtained at

02:31:44 and 02:35:33 GMT, respectively. The midcourse was designed to adjust the spacecraft trajectory to obtain a desired landing site at 0.417 deg N and 1.133 deg W, rather than the prelaunch targeted landing site of 0.42 deg N and 1.33 deg W.

Following the postmidcourse maneuvers, the spacecraft was configured for coast phase II, and the spacecraft

bit rate was returned to 1100 bits/s and low power operation. Coast phase II was without abnormalities as all temperatures remained within operational, or transit survival limits. Spacecraft performance was excellent. At 03:09:00 GMT on November 8, while in coast phase II, a special inflight test was performed with DSS 14 to verify theoretical performance of the spacecraft telecommunication system, configured for the simultaneous transmission of engineering and touchdown strain-gage data.

Table 3. Summary of midcourse maneuver parameters

Parameter	Maneuver		Maneuver duration, s		Maneuver/thrust command quantity	
			Computed by the midcourse and terminal guidance system	As commanded after interpolation		
	Polarity	Axis			Octal	Binary
First premidcourse maneuver	Positive	Sun and roll	183.6108	183.8	1614	0111001100
Second premidcourse maneuver	Positive	Yaw	254.6174	254.6	2335	1001111101
Midcourse thrust	—	—	10.2810	10.25	0307	0001100111
First postmidcourse maneuver	Negative	Yaw	254.6174	254.6	2335	1001111101
Second postmidcourse maneuver	Negative	Sun and roll	183.6108	183.8	1614	0111001100

Table 4. Summary of terminal maneuver parameters

Parameter	Maneuver		Maneuver duration, s				Maneuver/retro delay command quantity	
			As computed by midcourse and terminal guidance system	As commanded after interpolation	As verified by telemetry	Thrust bias setting		
	Polarity	Axis					Octal	Binary
First terminal maneuver	Positive	Roll	163.24430	163.4	164	—	1431	0110011001
Second terminal maneuver	Positive	Yaw	223.34755	223.4	—	—	2117	1000101111
Third terminal maneuver	Positive	Roll	241.09585	241.0	241	—	2233	1001011011
Thrust bias/retromaneuver delay	—	—	5.8970065	5.875	—	H1	0326	0001110110

The data showed good correlation of the theoretical and actual performance.

During the transit phase, there were 14 gyro drift checks performed. This large number of checks were required to validate and refine the large drift rate of the yaw gyro (1.4 deg/h). The final gyro drift rates in terminal maneuver calculations were: (1) roll, 0.65 deg/h; (2) pitch, 0.00; and (3) yaw, +1.40 deg/h.

Terminal descent operations were initiated during the DSS 11 pass at 05:51 GMT on November 10, by performing the preterminal maneuver engineering interrogation. The spacecraft was commanded, and successfully executed three terminal maneuvers. The terminal maneuver directions and magnitudes initiated were: (1) plus roll of 81.7 deg, (2) positive yaw of 111.7 deg, and (3) positive roll of 120.5 deg. The times of initiation were 25:19, 29:38, and 34:55 GMT, respectively (Table 4). In order to obtain touchdown strain-gage data, the phase-modulated presuming amplifiers were commanded on at 40:02 GMT. The DSS-received carrier-power, at DSS 14, was -114.1 dBmW, well within the turnon criteria for a minimum-received carrier-power signal (-128.0 dBmW at DSS 14). A retromaneuver sequence-delay quantity of 5.875 s was loaded, and verified, at 41:41 GMT. Altitude marking radar (AMR) power on was commanded, and verified at 53:16 GMT, followed by thrust phase power on at 54:16 GMT. The AMR was enabled at 56:16 GMT, and the emergency AMR signal was commanded at 57:56 GMT. The AMR *mark* was obtained at 57:57.083 GMT. The automatic portion of the terminal descent sequence was implemented at that time by the spacecraft.

Touchdown occurred at 01:01:05.480 GMT on November 10, 1967 within Sinus Medii, at 0.437 deg N and 1.373 deg W, only 7.2 km (4.5 mi) from the inflight aiming point. This miss is determined by final posttouchdown orbit determination. Continuous telemetry and touchdown strain gage data were obtained throughout the touchdown period, indicating a successful landing and satisfactory spacecraft conditions.

The postlanding power shutdown sequence start was indicated at 01:01:37 GMT with the turn off of thrust phase power, and completion was indicated at 01:02:04 GMT with the turn off of flight control power. The spacecraft, evaluated by performing an engineering interrogation and by stepping the A/SPP, was in perfect condition. At 01:30 GMT, the spacecraft was configured for 200-line television operation, and the space science

analysis and command group received the first 200-line television picture at 01:51 GMT.

III. Surveyor VI TDS Mission Requirements

A. General

This section delineates the detailed TDS requirements and support capabilities for tracking and telemetry coverage during the *Surveyor VI* Mission.

Requirements for tracking and data acquisition are categorized in accordance with their importance to the successful accomplishment of the mission and are grouped into the following three classes:

- (1) Class I requirements reflect minimum essential needs to ensure accomplishment of the primary flight objectives. These are mandatory requirements that, if not met, may result in the decision not to launch.
- (2) Class II requirements define the needs to accomplish all stated flight objectives.
- (3) Class III requirements define the ultimate desired support. Such support should enable the achievement of flight objectives early in the program.

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

1. Launch. The requirements placed on the TDS for the *Surveyor VI* Mission launch phase were as follows:

- (1) The *Atlas/Centaur* boost vehicle will be used in a parking orbit mode of operation.
- (2) Launch shall take place from launch complex 36B of the Cape Kennedy facilities of 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 second hold, at $T - 5$ min, is to be established, as required, at launch.

2. Preinjection. The requirements during the preinjection phase were as follows:

- (1) The 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 1.9×10^4 lb/s³.
- (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/s³.
- (4) Throughout the period from main engine start 2 until the end of significant aerodynamic heating effects, the 3- σ integrated value of ρV^3 shall not exceed 10,300 lb-min/s³, and the instantaneous 3- σ value shall not exceed 4250 lb/s³.
- (5) Parking orbit coast time is restricted to vary between the limits of 116 s and 25 min.

3. Postinjection. The postinjection phase requirements stated that the *Centaur* retromaneuver shall be such that the *Surveyor/Centaur* separation distance, at 5 h after injection, will be at least 336 km.

4. Telecommunications. The specified requirements for telecommunications were as follows:

- (1) No trajectory shall have an hour angle, or declination rate in excess of 0.85 deg/s and acceleration in either hour angle or declination in excess of 5.0 deg/s² when station tracking is required.
- (2) For the downlink initial acquisition phase following injection, there shall be 20 min of visibility that is not in violation of (1). The spacecraft slant range shall have 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. The spacecraft slant range shall have at least 99% confidence in 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 in order to prevent the degradation of DSIF receiver sensitivity by solar noise. This constraint guarantees that signal-to-noise ratios will not be degraded by more than 1 dB.

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

5. Thermal control. The thermal control requirements were as follows:

- (1) The spacecraft is limited to a maximum duration of 42 min in the earth's shadow immediately after launch.
- (2) The spacecraft is limited to a maximum duration of 30 min in the earth's shadow during any phase after initial sun acquisition.
- (3) The spacecraft is limited to a maximum duration of 30 min at a random attitude to the sun during any phase between initial sun acquisition and lunar touchdown.
- (4) The spacecraft is limited to a maximum duration of 30 min in the lunar penumbra shadow during any phase prior to touchdown.
- (5) Initial spacecraft acquisition and the establishment of a command link must take place no later than 1 h after High-Power-On command in order to permit switching the transmitter from high to low power to satisfy thermal constraints.

6. Midcourse maneuver. The requirements for the midcourse maneuver were as follows:

- (1) The spacecraft shall be capable of performing midcourse maneuvers of up to 50 m/s in magnitude. The midcourse maneuver time is approximately 15–20 h after launch.
- (2) The landing accuracy goal shall be less than, or equal to, 30 km.

7. Lunar arrival. The requirements at lunar arrival were as follows:

- (1) Flight times from injection to lunar impact shall be in the 66-h class.
- (2) Transit trajectories are to be designed so that lunar arrival takes place not earlier than 2 h after DSS 11 moonrise and not later than 3 h before DSS 11 moonset.¹ Furthermore, DSS 11 postlanding visibility shall be maximized.

¹These constraints apply only to targeting. The visibility constraints that are used at midcourse are: earliest arrival, 80 min after DSS 11 rise; latest arrival, 3 h before DSS 11 set.

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

8. Terminal descent. The requirements at terminal descent were as follows:

- (1) The incidence angle at unbraked impact shall not be greater than 45 deg from the vertical.
- (2) The range of allowable unbraked impact speed is from 2623 to 2635 m/s.
- (3) The spacecraft roll orientation constraints are given in Fig. 6. The RADVS (see Table 2) and stability constraints shown graphically encompass all possible launch dates. The actual constraint regions for each launch date are presented in the accompanying tables. The stability constraint regions apply only if a midcourse maneuver greater than zero but less than approximately 10 m/s is executed.

9. Alpha scattering experiment. An alpha scattering device was carried on *Surveyor VI*. The device, shown in Fig. 7, consisted of an instrumented package to be placed on the lunar surface. The package contained a source 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 these energy data, scientists hoped to gain some insight into the atomic structure of the lunar soil.

B. Air Force Eastern Test Range

The AFETR coverage capability was based on the use of Cape Kennedy facilities, five additional land stations, and three instrumentation ships. The proper positioning of the three ships should result in coverage of the near-earth class I tracking and telemetry requirements over reasonable-size launch windows. A review of the available launch windows is presented in the chart of Fig. 8. Because of AFETR commitments it is sometimes necessary to refine these windows. The AFETR performs *Surveyor mission supporting functions for TDS during countdown, launch, and the near-earth phase of the flight.*

During the near-earth phase of the mission, the major launch vehicle and spacecraft events that have a strong impact on the success of the remaining phases of the mission, take place automatically. Because of this, it is important during the countdown that any failure in the

TDS support to this phase be carefully evaluated to determine a launch, or a hold condition.

1. Near-earth tracking and telemetry requirements.

This subsection provides information useful in real-time decision making during the countdown in the event of loss of any planned TDS support for the near-earth phase; i.e., from launch to DSN initial acquisition.

Tables 5 and 6 list the class I tracking and telemetry coverage requirements, the basis for levying these requirements, their ratings of relative importance, and the required supporting stations. All of the tracking and telemetry stations listed are not necessarily required for each launch azimuth on each launch date. The mission director will be advised during the countdown as to the stations required for the predicted launch azimuth. Three rating categories were selected. These are referred to as: (1) critical, (2) highly desirable, and (3) desirable, in descending order of importance. Requirements were placed in one of these categories according to their role of support during the near-earth phase for near-real-time mission evaluation, and the receipt and recording of data for postflight analysis. It should also be noted that the AFETR real-time computer system (RTCS) is critical for the near-real-time mission evaluations. Thus, at least one of the two RTCS 3600 computers must be operational at launch.

Figure 9 gives a comprehensive picture of the *Surveyor* near-earth class I tracking and data acquisition requirements for the *Surveyor VI* Mission. Figure 10 shows the projected AFETR uprange coverage for the *Surveyor VI* Mission, while Fig. 11 reveals the earth tracks for the entire TDS on launch day.

2. The AFETR coverage capabilities. The AFETR coverage capabilities and potential limitations are based on the configuration of land, sea and air stations, as well as the assumption that three ships will support the mission. However, there was a good possibility that a fourth ship, the *Rose Knot*, would support the *Surveyor VI* Mission to provide launch vehicle telemetry coverage. Table 7 lists the AFETR stations that were committed to support the mission.

Figure 10 shows the coverage capability of the AFETR (and the MSFN Bermuda station) for the phase from launch to parking orbit insertion. It is clear from Fig. 10 that the AFETR should provide adequate coverage of this phase to meet requirements.

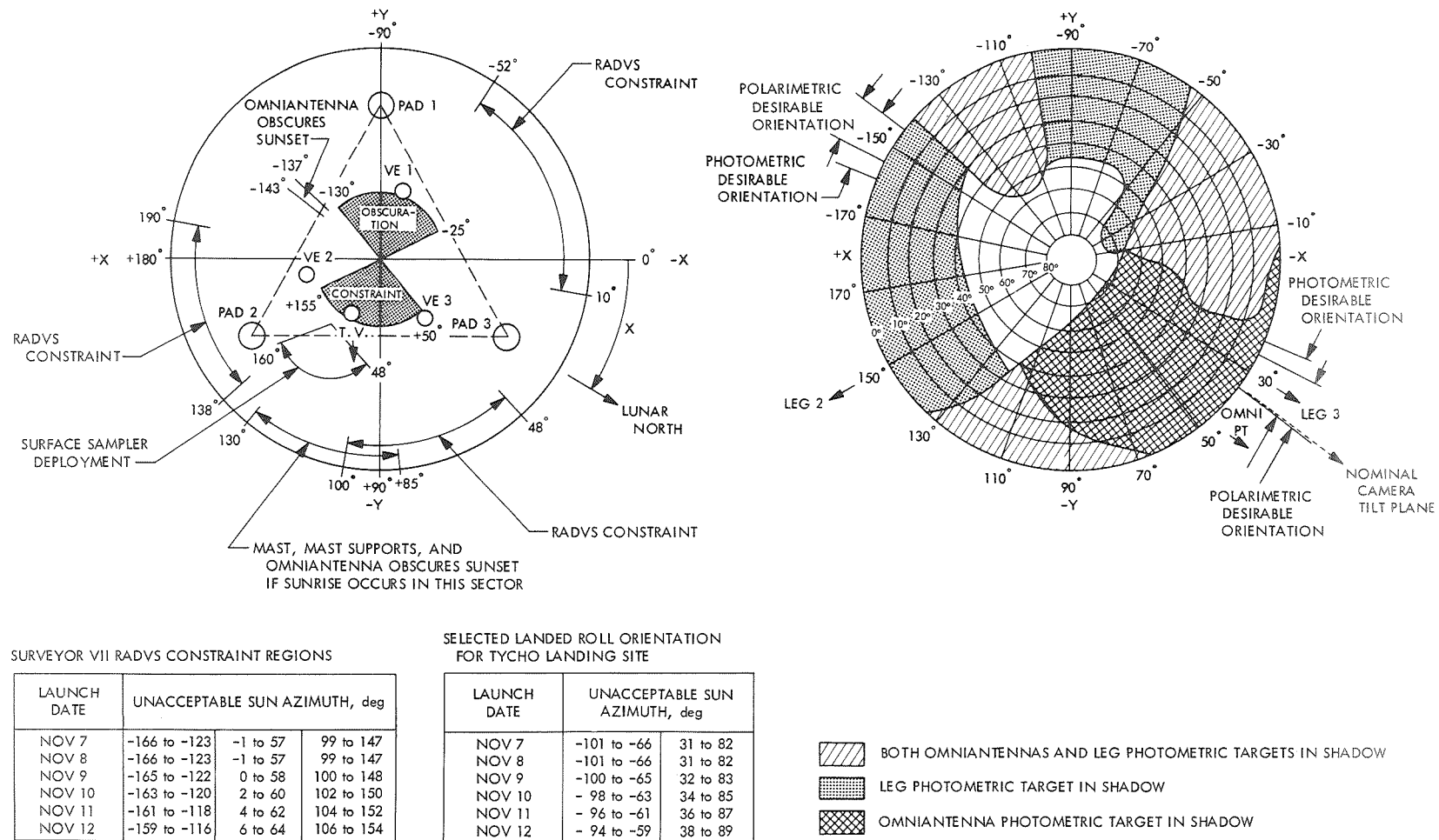


Fig. 6. Surveyor VI roll angle constraints, sun azimuth at landing

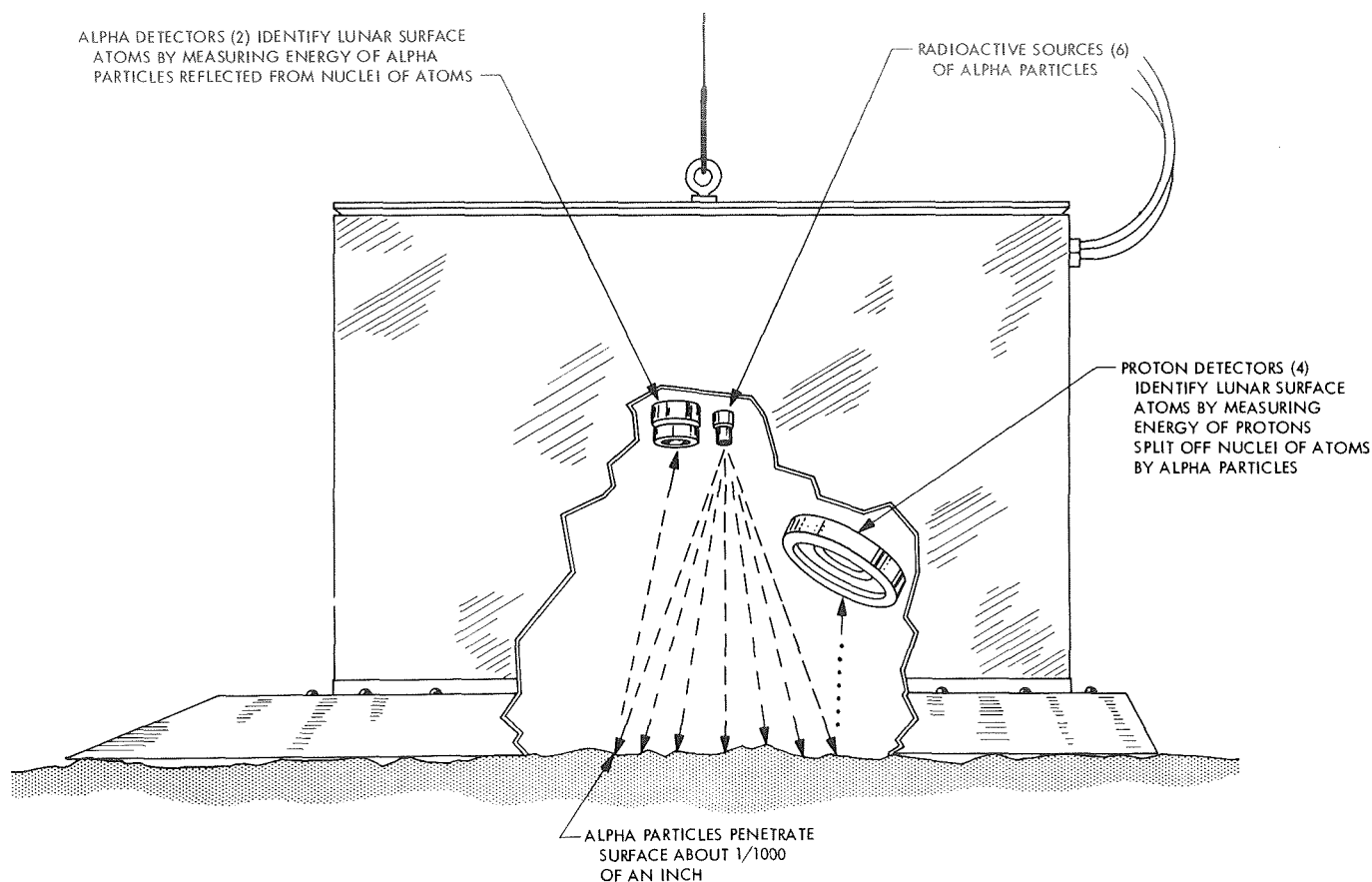


Fig. 7. Surveyor alpha scattering experiment

a. Telemetry data coverage. It is anticipated that the three ships planned for the *Surveyor VI* Mission will fill all possible coverage gaps except during the parking orbit, over reasonable size launch azimuth corridors. The AFETR may partially or completely fill the gaps in parking orbit telemetry coverage with aircraft.

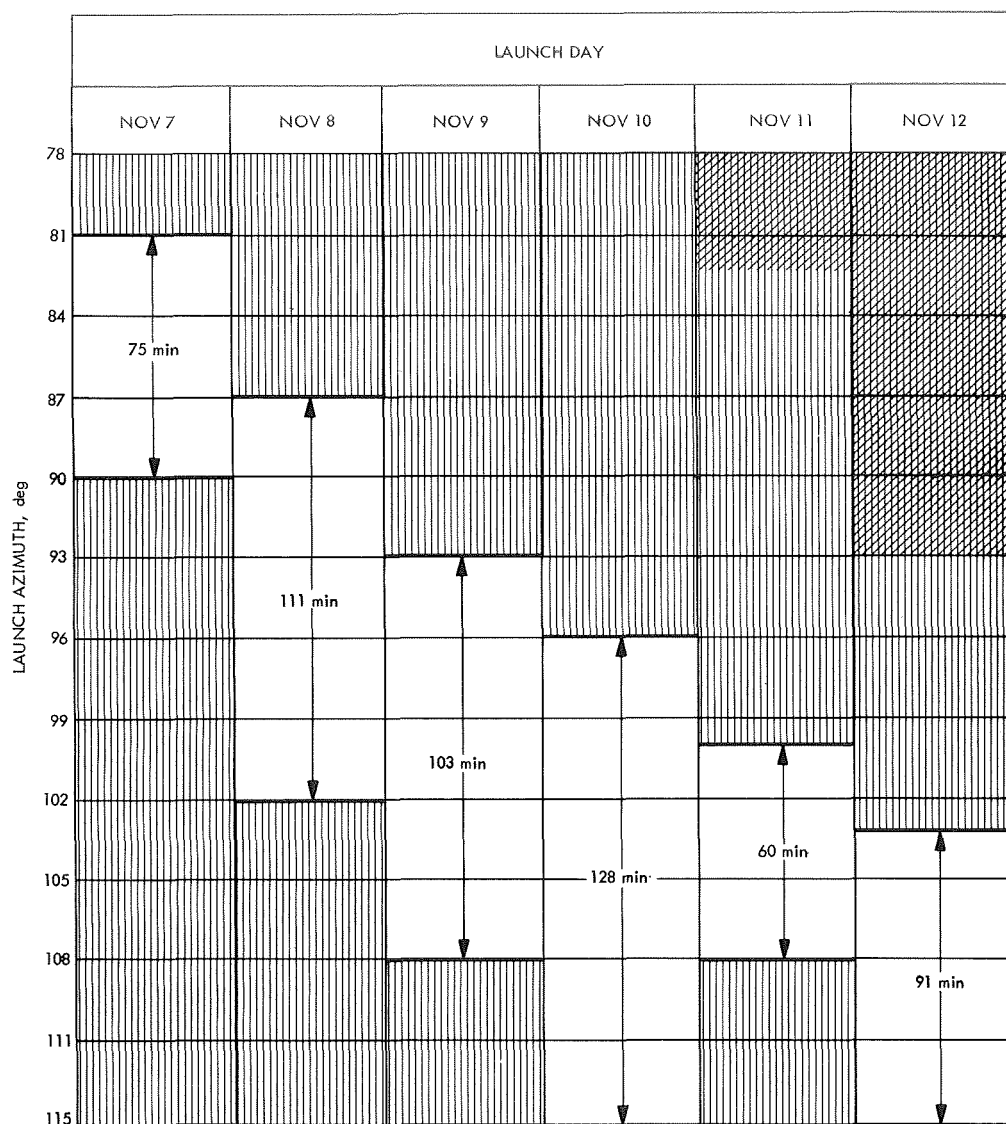
b. Telemetry real-time retransmission. Real-time retransmission capability will be provided by the same land and ship stations providing the receive and record support. Since aircraft do not have the capability to retransmit telemetry data in real-time, there may be some gaps during the parking orbit coast phase in order to optimize the coverage of the second burn and separation phases of the flight.

Further: approval was given for the priority of the real-time retransmission of selected launch vehicle data over spacecraft data for the interval of flight from main engine cutoff 1 through main engine cutoff 2. This permitted the real-time evaluation of the launch vehicle performance prior to and during the *Centaur* second burn.

c. Tracking data coverage. Figure 10 shows that the AFETR could provide adequate coverage of the parking orbit requirement.

The only support that the AFETR could provide, of the transfer orbit coverage requirement for the first day of the launch period, was with the RIS *Twin Falls*. There was no other ship on the AFETR with C-band radar capability. Furthermore, figures indicated that there were no AFETR land stations that could provide the coverage of this requirement. Thus, the positioning and resultant coverage capability of the *Twin Falls* was critical in the final launch window design for November 7. On subsequent days of the November launch period, the combination of the *Twin Falls* and the Ascension radars provided the coverage of the transfer orbit tracking.

The AFETR station at Pretoria, South Africa, could provide adequate coverage of the requirement for post-retromaneuver tracking data for most of the planned launch azimuth corridors. (The MSFN Carnarvon radar would also be able to satisfy this requirement on all days for all azimuths.)



MAXIMUM WINDOWS ^a												
TIME	NOV 7		NOV 8		NOV 9		NOV 10		NOV 11		NOV 12	
	OPEN	CLOSE	OPEN	CLOSE	OPEN	CLOSE	OPEN	CLOSE	OPEN	CLOSE	OPEN	CLOSE
GMT	06:55	10:53	06:56	11:03	06:56	11:12	06:56	11:20	07:24	11:28	08:16	11:37
EST	01:55	05:53	01:56	06:03	01:56	06:12	01:56	06:20	02:24	06:28	03:16	06:37
PST	22:55	02:53	22:56	03:03	22:56	03:12	22:56	03:20	23:24	03:28	00:16	03:37
AZ	78	115	78	115	78	115	78	115	82	115	90	115

MAXIMUM COAST TIME CONSTRAINT
 ESTIMATE OF TDS NEAR-EARTH COVERAGE CONSTRAINT

^a ONE DAY EARLIER IF PST EXCEEDS GMT TIME
 ROUNDED TO NEAREST MINUTE WITHIN CONSTRAINT
 AZ = AZIMUTH, deg

Fig. 8. Surveyor launch window constraints for the November 1967 launch period

Table 5. Near-earth class I tracking coverage requirements

Source	Class I tracking coverage requirements	Basis for requirements	Requirements rating	Required tracking stations ^a
Launch vehicle (C-band)	From launch to main engine cutoff (MECO) 1	Provides a reasonable level of confidence for being able to track vehicle during parking orbit Required by range safety until orbit velocity is acquired	Critical	Cape Kennedy Antigua
	Continuous 60 s from MECO 1 to MECO 1 + 136 s	Allows calculation of parking orbit so that: An early evaluation of the powered flight can be made Inflight acquisition information can be provided to downrange TDS stations beginning with the ships and Ascension DSN acquisition information can be generated based on the actual parking orbit and a theoretical second burn (constitutes first set of inflight predicts)	Critical	Antigua Bermuda
	Any 60 s of continuous tracking from MECO 2 + 5 s to retroignition	Input data for calculation of actual transfer orbit so that: An early evaluation of the transfer trajectory can be made using lunar mapping technique Inflight acquisition data can be provided to the DSN Acquisition information can be supplied to the MSFN station at Carnarvon, Australia	Critical	Twin Falls Ascension
	Any 60 s of continuous tracking subsequent to power changeover switch	Establishes post-retrotrajectory of Centaur to determine any possible interference with the spacecraft star sensor	Highly desirable	Carnarvon Pretoria
^a All of these stations are not necessarily required for each launch azimuth on each launch date.				

Table 6. Near-earth class I telemetry coverage requirements

Source	Class I telemetry coverage requirements	Basis for requirements	Requirements rating	Required telemetry stations ^a
Launch vehicle (VHF); spacecraft (S-band)	From launch to Atlas/Centaur separation	Provides Atlas performance data during its lifetime Establishes SECO ^b event time which is a good indicator of what can be expected for Centaur burn duration Receipt of spacecraft telemetry via Centaur link and spacecraft S-band link	Critical for receive and record Highly desirable to retransmit in real-time	Cape Kennedy
	From Centaur MES ^c 1 to MECO ^d 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	Critical for receive and record Highly desirable to retransmit in real-time	Cape Kennedy Antigua
^a All of these stations are not necessarily required for each launch azimuth on each launch date. The mission director will be advised during the countdown which stations are required for the predicted launch azimuth. ^b Sustainer engine cutoff. ^c Main engine start. ^d Main engine cutoff.				

Table 6 (contd)

Source	Class I telemetry coverage requirements	Basis for requirements	Requirements rating	Required telemetry stations ^a
Launch vehicle (VHF); spacecraft (S-band) (contd)	From MECO 1 to MECO 1 + 76 s	<i>Centaur</i> propellants are settled by thrusting two of the 50-lb vernier engines during this period Receipt of spacecraft telemetry via <i>Centaur</i> link and spacecraft S-band link	Critical for receive and record Highly desirable to retransmit in real-time	Antigua Bermuda
	From MECO 1 + 76 s to MES 2 — 40 s	<i>Centaur</i> propellants are retained at tank outlets during this period by thrusting two of the 3-lb engines Receipt of spacecraft telemetry via <i>Centaur</i> link and spacecraft S-band link	Highly desirable to receive, record, and retransmit in real-time	Antigua Bermuda Telemetry ships Ascension
	From MES 2 — 40 s to MES 2	The following critical <i>Centaur</i> events take place: (1) Further propellant settling applied by firing two of the 50-lb vernier engines (2) Boost pumps are started (3) Chilldown Receipt of spacecraft telemetry via <i>Centaur</i> link and spacecraft S-band link	Critical for receive and record Highly desirable to retransmit in real-time	Telemetry ships Ascension
	From MES 2 to MECO 2	Provides <i>Centaur</i> performance data during its second burn Establishes MES 2 and MECO 2 event times Receipt of spacecraft telemetry via <i>Centaur</i> link and spacecraft S-band link	Critical for receive and record Highly desirable to retransmit in real-time	Telemetry ships Ascension
	From MECO 2 to <i>Centaur</i> /spacecraft separation	The following major spacecraft events occur: Release of spacecraft landing gear Unlock of spacecraft omnidirectional antennas Switch spacecraft transponder transmitter to high power <i>Centaur</i> /spacecraft separation	Critical for receive and record Highly desirable to retransmit spacecraft channel in real-time	Ascension Telemetry ships Pretoria
Spacecraft (S-band)	From spacecraft high power on to DSN initial acquisition	Provides spacecraft status information	Critical for receive and record Highly desirable to retransmit in real-time	Ascension Carnarvon Telemetry ships

^aAll of these stations are not necessarily required for each launch azimuth on each launch date. The mission director will be advised during the countdown which stations are required for the predicted launch azimuth.

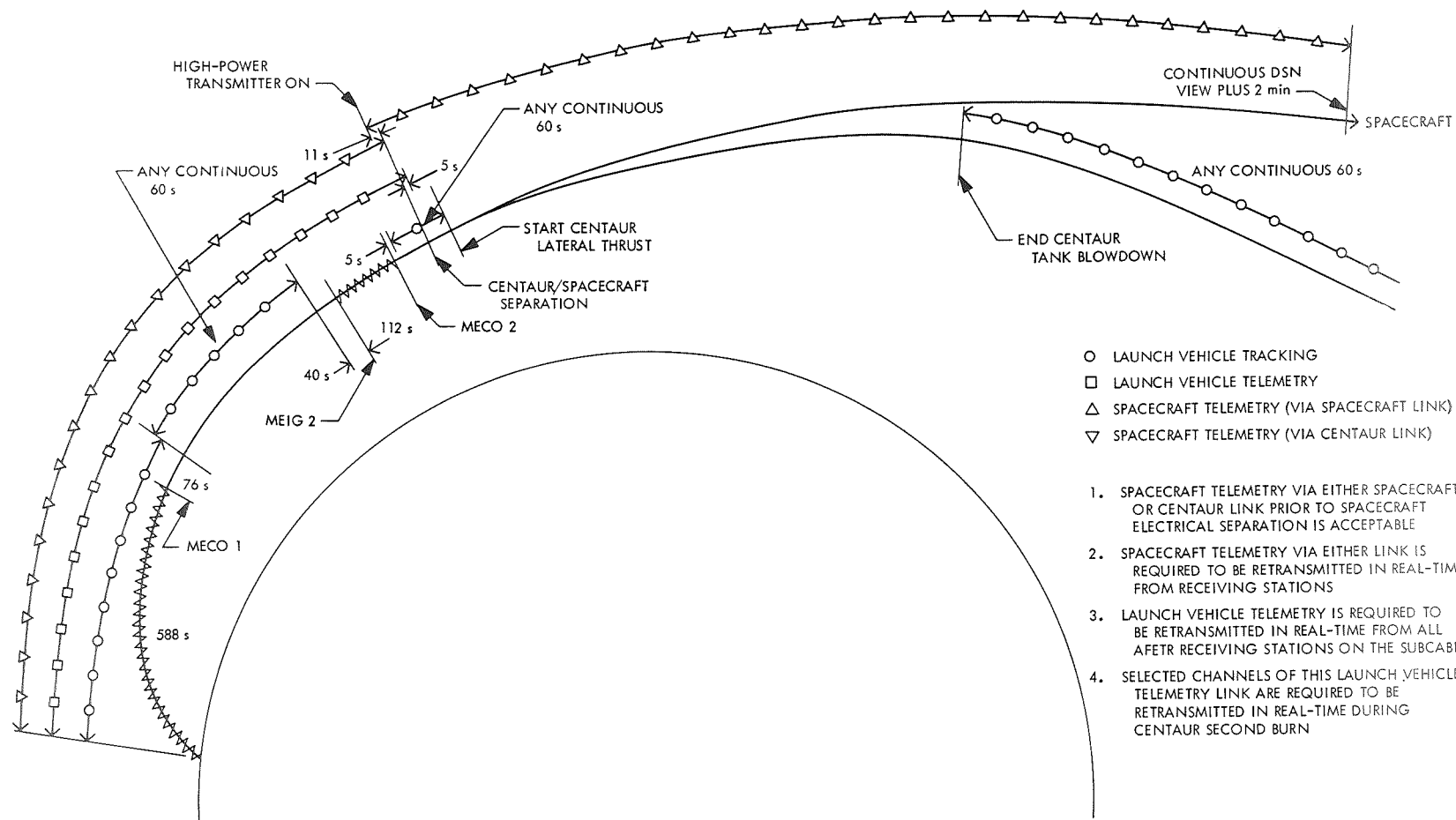


Fig. 9. Near-earth class I tracking and data acquisition requirements for Surveyor VI

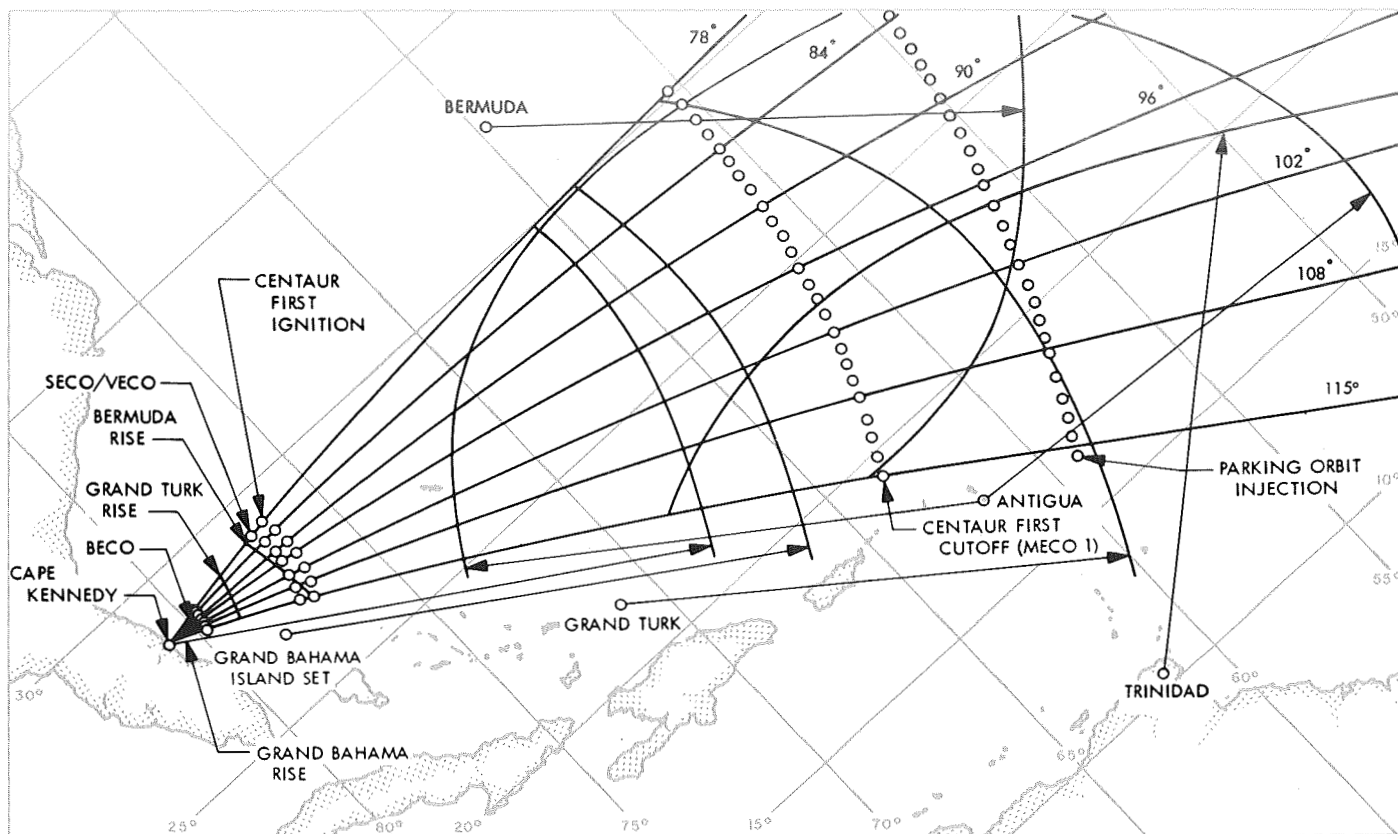


Fig. 10. Uprange coverage for Surveyor VI

C. Manned Space Flight Network

Tracking and telemetry requirements placed on the MSFN, managed by the GSFC, were as indicated in the paragraphs that follow.

It was anticipated that the MSFN stations at Bermuda, Grand Canary, Tananarive, and Carnarvon; GSFC computers, and portions of NASCOM, would contribute the following support:

- (1) C-band radar beacon tracking and recording of the *Centaur* beacon.
- (2) Telemetry receiving and recording of the *Centaur* beacon 232.4 MHz and the *Centaur* link 225.7 MHz.
- (3) Flight *mark* event confirmation in real-time.
- (4) Real-time computing during launch or orbital phases.
- (5) Ground communications: voice, teletype and high-speed data circuits.
- (6) Backup range safety support.

The acquisition aids at Bermuda, Grand Canary, Tananarive, and Carnarvon are required to provide RF inputs to the telemetry receivers and steering inputs to station radar antennas. At Grand Canary, the unified S-band system was being used as an additional means of acquisition.

Acquisition aids were to track the *Atlas* and *Centaur* vehicles. The Bermuda acquisition aid link assignments for each antenna are as follows:

Antenna	Acquisition aids 1 and 2	Acquisition aid 3
Primary	Link 225.7 MHz	Link 229.9 MHz
Secondary	Link 229.9 MHz	Link 232.4 MHz

Grand Canary, Tananarive and Carnarvon configured acquisition aids for the 225.7-MHz link only. The acquisition aid antennas tracked in the cross-correlation mode at a 300 kHz bandwidth.



Table 7. The AFETR station facilities

Station	Tracking capability (radar type)	Telemetry capability
AFETR stations		
Cape Kennedy area: Patrick AFB Cape Kennedy KSC	C-band: 0.18 (FPQ-6) 1.16 (FPS-16) 19.18 (TPQ-18)	VHF, S-band KSC
Grand Bahama	C-band: 3.16 (FPS-16) 3.18 (TPQ-18)	VHF, S-band
Grand Turk	C-band: 7.18 (TPQ-18)	VHF
Antigua	C-band: 91.18 (FPQ-6)	VHF, S-band
Ascension	C-band: 12.16 (FPS-16) 12.18 (TPQ-18)	VHF, S-band
Pretoria	C-band: 13.16 (MPS-25)	VHF, S-band ^a
AFETR ships		
Sword Knot (10 knot cruising speed)	—	VHF, S-band
Coastal Crusader (10- knot cruising speed)	—	VHF, S-band
Twin Falls (15-knot cruising speed)	C-band: (FPS-16)	VHF, S-band
^a 3-ft antenna only.		

1. Tracking C-band. The C-band radars at Bermuda, Grand Canary, Tananarive and Carnarvon were required to beacon track the *Centaur* vehicle. 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 GMT of acquisition of signal (AOS) and loss of signal (LOS) to the MSFN network controller.

a. Bermuda requirements. The Bermuda requirements were as follows:

- (1) Beacon tracking and magnetic tape recordings of the *Centaur* from AOS to LOS.
- (2) Real-time transmission of high-speed data and low-speed data to GSFC and RTCS at AFETR.
- (3) Backup range safety support.
- (4) Voice circuit for handover between Bermuda and AFETR.

(5) Verbal confirmation in real-time of the GMT of AOS and LOS to MSFN network controller.

(6) Magnetic tape recordings, strip chart recordings and postlaunch instrumentation message (PLIM) data sheets.

b. Grand Canary, Tananarive, and Carnarvon requirements. The Grand Canary, Tananarive, and Carnarvon requirements were as follows:

- (1) Beacon tracking and magnetic tape recordings of the *Centaur* from AOS to LOS.
- (2) Real-time transmission of low-speed data from Grand Canary and Carnarvon to GSFC for reformatting and retransmission to RTCS and AFETR.
- (3) Tananarive was to transmit low-speed data in the standard 38-character radar data format to RTCS and AFETR.
- (4) Voice circuit for radar handover between Grand Canary and AFETR, Tananarive and AFETR, and Carnarvon and AFETR.
- (5) Verbal confirmation in real-time of the GMT of AOS and LOS to the MSFN network controller.
- (6) Grand Canary unified S-band system to assist MPS-26 radar in acquisition.
- (7) Magnetic tape recordings, strip chart recordings and PLIM data sheets.

2. Telemetry (VHF). The MSFN stations at Bermuda, Grand Canary, Tananarive, and Carnarvon, as well as portions of the NASCOM networks 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-MHz and 232.4-MHz links.

Mark event readouts were required from all stations, except Carnarvon, in real-time, or in as near-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 GMT of AOS, *mark* events (except at Carnarvon) and LOS to the MSFN controller. Real-time transmission of telemetry data was required from Grand Canary.

a. *Bermuda requirements.* The Bermuda requirements were as follows:

- (1) Receive, decommutate and record the *Centaur* 225.7-MHz link from AOS to LOS.
- (2) Receive and record the *Atlas* 229.9-MHz link and the 232.4-MHz link for range safety purposes.
- (3) Display range safety parameters on the *Atlas* and *Centaur* links.
- (4) Provide real-time readout of *mark* events 4-11.
- (5) Teletype confirmation of *mark* events.
- (6) Make magnetic tape recordings, strip chart recordings, and PLIM data sheets.

b. *Grand Canary Island and Tananarive requirements.* The Grand Canary and Tananarive requirements were as follows:

- (1) Receive, decommutate, and record the *Centaur* 225.7-MHz link from AOS to LOS.
- (2) Provide real-time readout of *mark* events 25 and 26.
- (3) Teletype confirmation of *mark* events.
- (4) Transmit, via voice/data circuits, in real- and near-real-time, specified telemetry data to building AE at AFETR.
- (5) Make magnetic tape recordings, strip chart recordings, and PLIM data sheets.

c. *Carnarvon requirements.* The Carnarvon requirements were as follows:

- (1) Receive and record the *Centaur* 225.7-MHz link from AOS to LOS.
- (2) Make magnetic tape recordings, strip chart recordings, and PLIM data sheets.

3. *Telemetry S-band.* There was a requirement for Carnarvon reception of S-band spacecraft telemetry data and retransmission to DSS 42.

4. *Computer.* The requirements levied on GSFC with respect to computer support were as follows:

- (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 participating MSFN stations, except Bermuda.

Bermuda-powered flight data were to be used for this mission.

- (3) Receive launch trajectory data from Bermuda and AFETR, via the launch trajectory data system.
- (4) Generate radar simulation tapes for Grand Canary, Tananarive and Carnarvon.
- (5) 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 controllers.
- (6) Use the refined orbital parameters to drive displays at the GSFC operations control center.
- (7) Generate and transmit real-time acquisition messages to participating MSFN stations, based on postinjection tracking data.
- (8) Reformat Grand Canary and Carnarvon radar data to the standard 38-character radar data format for transmission to RTCS and AFETR.
- (9) 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 reformat on magnetic tape the low-speed teletype 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.
- (10) Reformat on magnetic tape the Bermuda high-speed raw data, including a list of the contents and formats for shipment to the RCA data processing requirements group at Patrick Air Force Base.

5. *Events reporting.* Bermuda, Grand Canary, Tananarive and Carnarvon will confirm AOS, LOS, and occurrence of the *mark* events listed in Table 8. *Mark* events shall be confirmed as follows:

- (1) Verbally confirm each *mark* event in real-time to the MSFN network controller as each event occurs.
- (2) Verbally confirm the GMT time of occurrence of each event to the network controller as soon as possible.
- (3) Confirm each *mark* event (include GMT time of occurrence).

Tananarive will configure for *mark* events 12, 22, and 23 post-pass, shown on track-1 (Sanborn recorder configuration for Tananarive). Time of the *mark* events will be reported as in items (2) and (3) in the preceding paragraph.

Table 8. Mark events

Station	Mark ^a	Event	Time, min/s	Link, MHz/channel kHz/pulse	Description
—	1	Liftoff <i>Atlas</i> BECO ^b	0 T + 02:34	229.9/0.96/ continuous	2-in. motion B-1 pump speed measurement goes out of band on low- frequency side
—	2	<i>Atlas</i> booster engine	T + 02:38	229.9/40/ commanded	All booster section measurements to open
—	3	<i>Centaur</i> insulation panel jettison	T + 03:19	229.2/70/ 3 and 18 12 and 27	Segment levels change from 11 to 74 %. Each seg- ment represents two panel sections
—	4	<i>Centaur</i> nose fairing jettison	T + 03:49	225.7/3.9/7	Segment levels change from 50 to 67 % at jettison
Bermuda	5	<i>Atlas</i> SECO ^c VECO ^d	T + 04:08	229.9/0.73/ continuous	Sustainer pump speed measure- ment goes out of band on low- frequency side
Bermuda	6	<i>Atlas</i> / <i>Centaur</i> separation	T + 04:10	225.7/30/1	Segment should in- crease from 0 to 100 % at separa- tion
Bermuda	7	<i>Centaur</i> MEIG ^e 1	T + 04:20	225.7/0.96/ continuous	C-2 chamber pres- sure goes from 0 to 75 % of band
Bermuda	8	<i>Centaur</i> MECO ^f 1	T + 09:43	225.7/0.96/ continuous	C-2 chamber pres- sure goes from 75 to 0 %
Bermuda	9	100-lb thrusters on	T + 09:43	225.7/7.35/ 6, 25	Segments go slowly from 0 to 50 % of band
Bermuda	10	100-lb thrusters off	T + 10:59	225.7/7.35/ 6, 25	Segments go slowly from 50 to 0 % of band
Bermuda	11	6-lb thrusters on	T + 10:59	225.7/7.35/ 7, 28	Segments go slowly from 0 to 50 % of band
Bermuda Grand Canary Tananarive	12	100-lb thrusters on	Firing times are variable	225.7/7.35/ 6, 25	Segments go slowly from 0 to 50 % of band

^aReal-time reporting of marks 9–12 may be delayed in order to expedite readout of mark times for marks 13, 14 and 15. Vehicle may not be in view at all sites for all mark events noted, this is dependent on vehicle flight azimuth.

^bBooster engine cutoff.

^cSustainer engine cutoff.

^dVernier engine cutoff.

^eMain engine ignition.

^fMain engine cutoff.

Table 8 (contd)

Station	Mark	Event	Time, min/s	Link, MHz/channel kHz/pulse	Description
Grand Canary Tanarive	13	Centaur MEIG 2	Mark 12 + 00:40	225.7/0.96/ continuous	Same as mark 7
Grand Canary Tanarive	14	Centaur MEIG 2	Mark 12 + 00:40	225.7/0.96/ continuous	C-1 chamber pres- sure goes from 0 to 75 %
Tanarive	15	Centaur MECO 2	Mark 12 + 02:33	225.7/0.96/ continuous	Same as mark 8
Tanarive	16	Surveyor landing gear extend command sent	Mark 12 + 02:54	225.7/3.0/7	Segment goes from 0 to 100 % for one segment; signal is integrated
Tanarive	17	Surveyor omniantenna extend command sent	Mark 12 + 03:03	225.7/3.0/ 11	Command goes to approximately 100 %
	18	Surveyor high power on	Mark 12 + 13:25	229.0 MHz	Receiver AGC shows increased signal
Tanarive	19	Centaur/spacecraft electrical disc	Mark 12 + 03:31	225.7/3.0/ 22	Measurement goes to 98 %
Tanarive	20	Centaur/spacecraft separation	Mark 12 + 03:36	225.7/14.5/ 22/52.5/ continuous	At release of pay- load signal goes to 100 %
Tanarive	21	Begin Centaur turnaround	Mark 12 + 03:41	225.7/70/ 5, 6	Both gradually in- crease from 60 to 80 %
Tanarive	22	Start Centaur lateral thrust	Mark 12 + 04:21	225.7/7.35/ 6, 25	Segments go slowly from 0 to 50 % of band
Tanarive	23	End Centaur lateral thrust	Mark 12 + 04:41	225.7/7.35/ 6, 25	Segments go slowly from 50 to 0 % of band
Tanarive	24	Start blowdown	Mark 12 + 07:36	225.7/70/ 12, 13, 18, 22	Pump inlet pressure increase from 0 to approximately 20 %
Tanarive Carnarvon	25	End blowdown	Mark 12 + 11:46	225.7/70/ 12, 13, 18, 22	Pump inlet pressure decreased to 0 %
Tanarive Carnarvon	26	Power changeover	Mark 12 + 13:26	225.7/0.4/ continuous	400-Hz frequency from 50 % to open

D. Deep Space Network

The DSN was required to support the *Surveyor VI* Mission with the DSIF, the GCF, and the DSN facilities in the SFOF.

The DSN requirements included S-band tracking and two- and three-way doppler coverage. The DSN responsibilities were to obtain continuous spacecraft telemetry coverage from the first acquisition by DSS 42 to the end of the mission. Three DSIF stations described in subsequent paragraphs were required for this coverage. The

full Goldstone duplicate standard 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 by Tables 9 and 10. With the requirements outlined by the foregoing tables it was possible to specify the tracking coverage required to meet the orbit determination accuracy requirements. Before presenting the tracking coverage requirements, however, the ground rules upon which the tracking coverage analysis was based will be delineated.

Table 9. Deep Space Network tracking data accuracy requirements

Effective noise at 1 sample/min						
Data accuracy	Correlation width T_L , 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	$T_L < 1$	0.01	0.05	0.05	0.005	5.0×10^{-11}
	$1 \leq T_L < 10$	0.01	0.05	0.05		
	$T_L \geq 10$	0.1	0.2	20.0		
B, desired, not guaranteed	$T_L < 1$	0.005	0.01	0.005	0.001	3.0×10^{-12}
	$1 \leq T_L < 10$	0.005	0.01	0.005		
	$T_L \geq 10$	0.005	0.06	0.005		
C, ultimate Surveyor block I	$T_L < 1$	0.001	0.005	0.001	0.00001	3.0×10^{-13}
	$1 \leq T_L < 10$	0.001	0.005	0.001		
	$T_L \geq 10$	0.001	0.014	0.001		

Table 10. 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)

ments would not have to be satisfied to ensure 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 DSN station supplying data would supply data of good quality. In order to ensure these good-quality data assignment of additional DSN stations was desired to provide redundancy in the tracking pattern.

In summary, the DSN was required to provide continuous telemetry coverage during transit and the postlanding phase from touchdown through lunar day 1, continuing through the first 6 h of lunar night 1. A summary of tracking requirements placed on the DSN is presented in Table 10.

The prime DSN coverage was to be provided by DSS 11, DSS 42, DSS 51, and DSS 61. Figure 12 depicts the coverage of these stations from launch through the first 20 h after launch. Additional DSN support was provided by DSS 14 and DSS 71. The 210-ft antenna at DSS 14 provided backup support for DSS 11 during the midcourse maneuver and terminal descent phases. Prelaunch checkout and launch phase support of the spacecraft was to be provided by DSS 71; also, DSS 71 was the key interface in relaying spacecraft telemetry data from AFETR to SFOF.

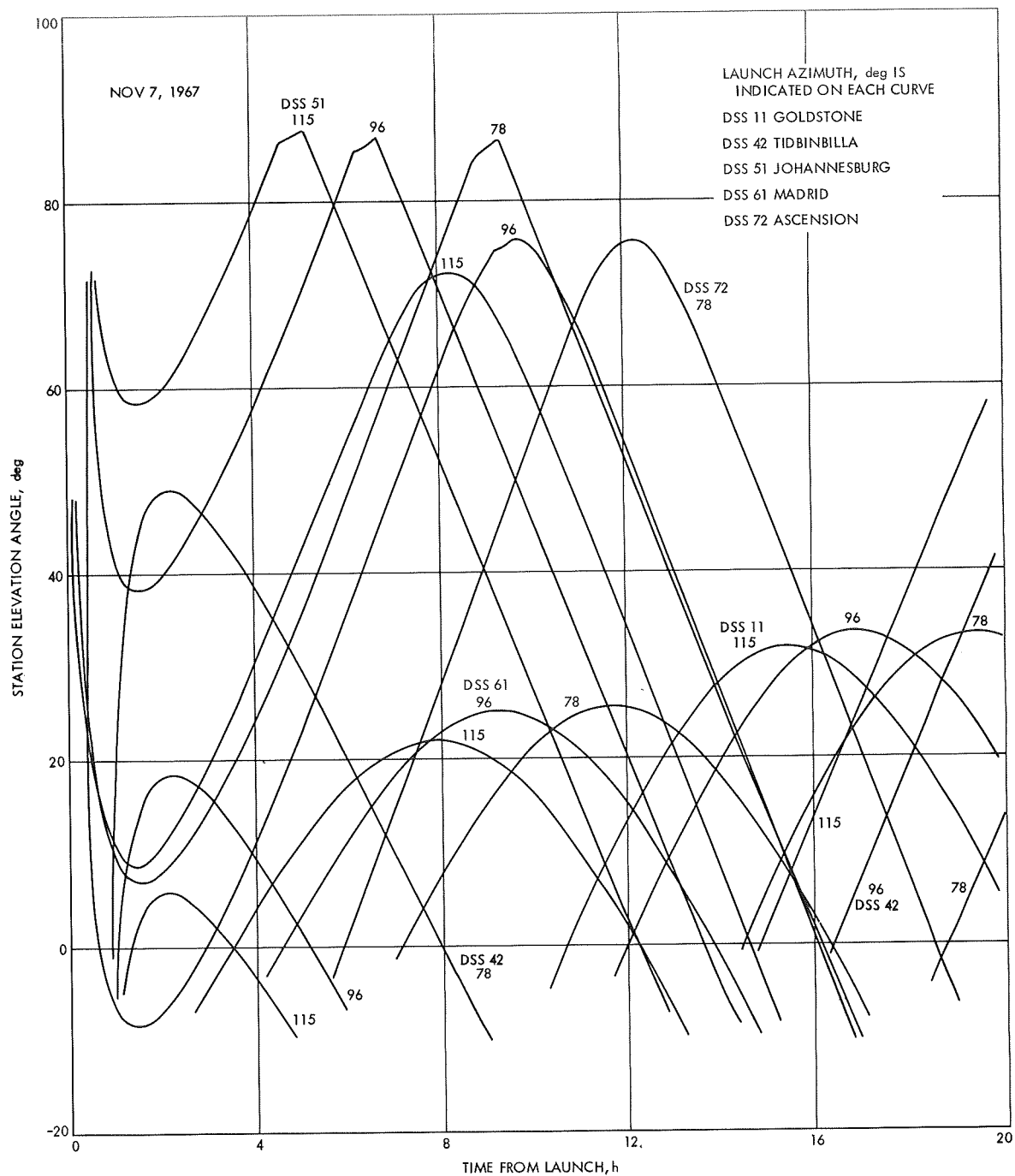


Fig. 12. Station elevation angle vs time from launch (0-20 h)

The initial DSN acquisition station was to be DSS 51 or DSS 42, depending on launch day and launch azimuth. Figure 13 shows DSS 51 and DSS 42 as having the only view periods that permitted commanding the spacecraft transmitter to switch from high to low power before reaching the thermal limit. (This task could be accomplished by DSS 72 only over a small launch corridor on November 7.) This key function is vital to the mission, and constraints to the launch window may have resulted during the first few days of the periods, if DSS 51 was not able to support this phase of the mission.

Coverage by DSS 51, or DSS 72, was required to eliminate a gap between the initial DSS 42 set and the DSS 61 rise. Figure 13 shows that this gap occurred on the azimuth used on November 7, 1967. The last day of the period for which there was an overlap on all azimuths was November 12, 1967.

The anticipated configuration of the DSN did not impose any launch constraints.

1. Deep Space Instrumentation Facility. A bar chart of Deep Space Stations view periods for the November 7, 1967 launch opportunity is presented in Fig. 14.

a. Initial acquisition station. The following minimum capabilities are required from the initial acquisition station:

- (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.

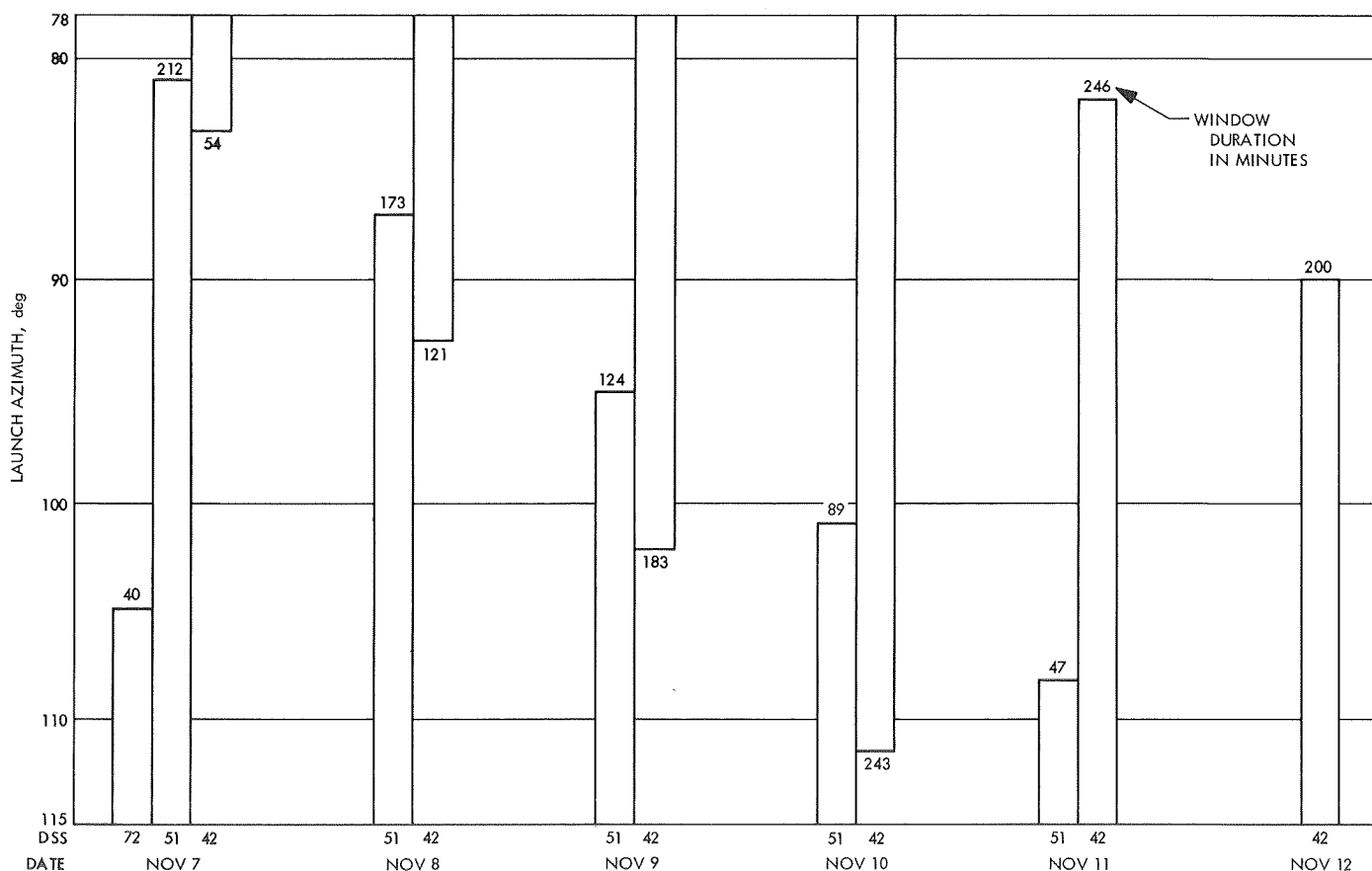


Fig. 13. Approximate launch azimuths for which specific DSN stations qualify as the initial acquisition site

b. *Coverage by DSS 72.* Support by DSS 72 will not be available for the *Surveyor VI* Mission due to the *Apollo* commitment of the station. The three-station orbit determination solution will be provided by DSSs 42, 51 and 61.

c. *Coverage by DSS 71.* Support by DSS 71 was committed for the RF compatibility tests between spacecraft SC-6, located on the launch pad, and DSS 71. These tests were successfully completed on September 28 and 29, 1967, including verification that there is no transmitter over-deviation during video operations. At time of launch, DSS 71 receives and records telemetry data from $T - 5$ min to loss of signal. In addition, DSS 71 will use its

command data console (CDC) and telemetry and command processor computer to process AFETR telemetry data for transmission to JPL via NASCOM high-speed data lines.

d. *Coverage by DSS 14.* The DSN has committed DSS 14, the 210-ft Mars station antenna, to support the midcourse and terminal descent phases of the *Surveyor VI* Mission. This will include telemetry reception and recording, and a backup transmitter if required for commanding. The station was to be available to the end of the touchdown pass. Baseband telemetry was to be transmitted to SFOF in real-time.

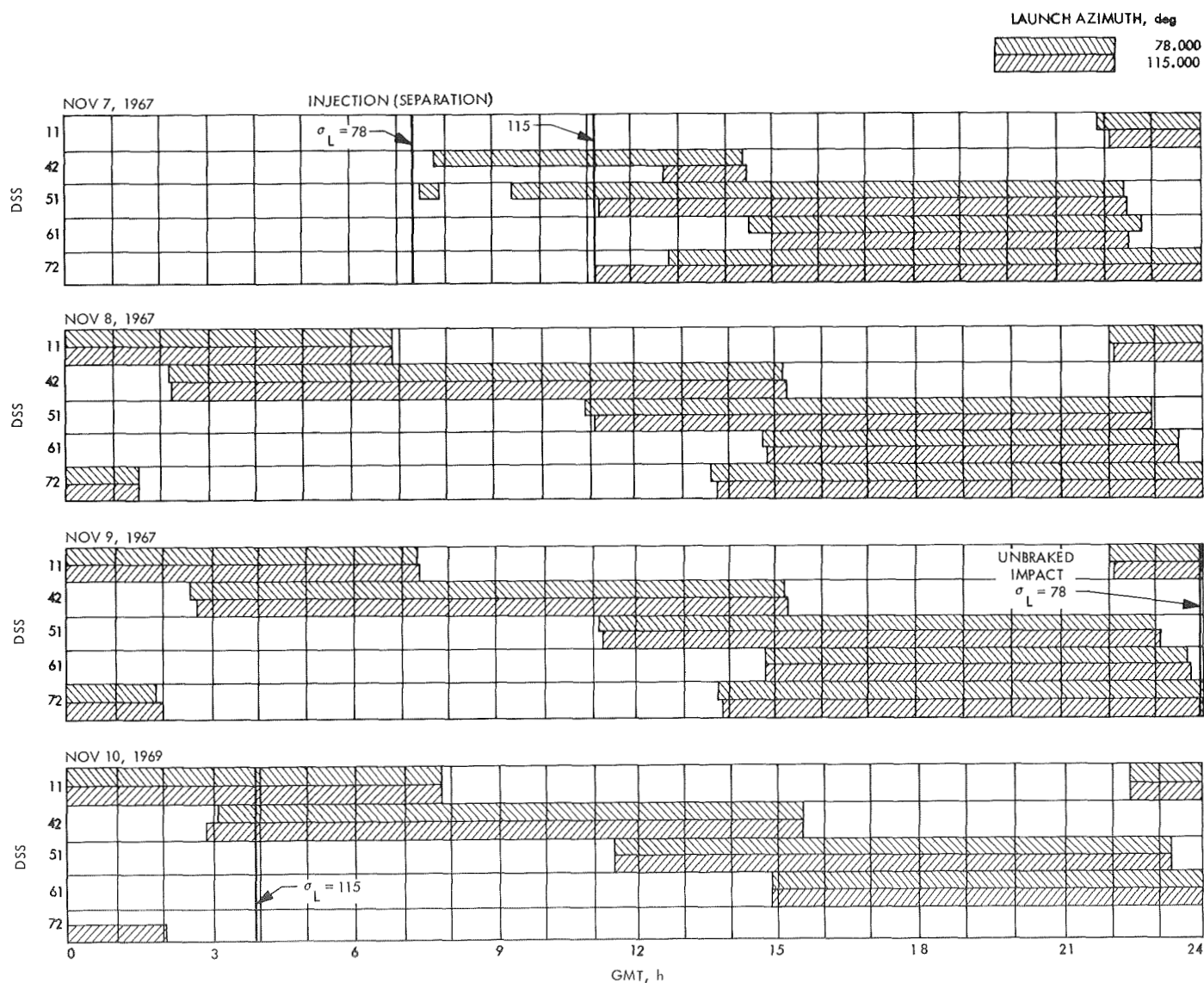


Fig. 14. Bar charts of station view periods

e. *Criteria for DSIF acquisition.* The criteria for DSIF acquisition of a spacecraft are as follows:

- (1) The DSIF will employ the acquisition aid antenna and either the parametric amplifier or the second maser to the receiver. This configuration will be used to determine the tracking margin.
- (2) The tracking phase lock loop phase error due to the doppler rate will not exceed 30 deg.
- (3) A signal level of -140 dBmW or higher must be available.
- (4) For an 85-ft antenna, the angular rate of the DSIF-spacecraft vector must not exceed 0.25 deg/s during acquisition.
- (5) The antenna angular rates during auto track must not exceed 0.85 deg/s for 85-ft antenna.
- (6) Auto track on the S-band cassegrain monopulse antenna cannot be obtained until the elevation angle of the spacecraft is more than 10 deg above the local horizon.
- (7) From the 10 deg elevation point, 20 min will be allowed for the DSIF to acquire the spacecraft and obtain auto track on the S-band cassegrain monopulse antenna.
- (8) Acquisition will be considered complete when:
 - (a) The uplink is acquired.
 - (b) The two-way downlink is acquired.
 - (c) Good angle and doppler data are obtained.
 - (d) Good telemetry data are confirmed.
 - (e) It is confirmed that the spacecraft and the station receivers are not locked on sidebands, the station antenna is not on a side lobe, and the station is ready for commanding.

Figure 15 shows the acquisition study by DSN stations for November 7, 1967.

f. *Additional requirements.* Participating stations are required to have the following minimum capabilities:

- (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.

In addition to the five requirements listed, DSS 11 is required to provide capability for acquisition, recording, and processing of *Surveyor* spacecraft video data.

At the start of each Deep Space Station respective views, the following minimum communication capabilities will exist for each committed station:

- (1) One voice line.
- (2) Two duplex teletype lines.

In addition to the two requirements listed, DSS 11 must provide communication capability consisting of one high-speed data line (1100 bits/s or 96 kHz).

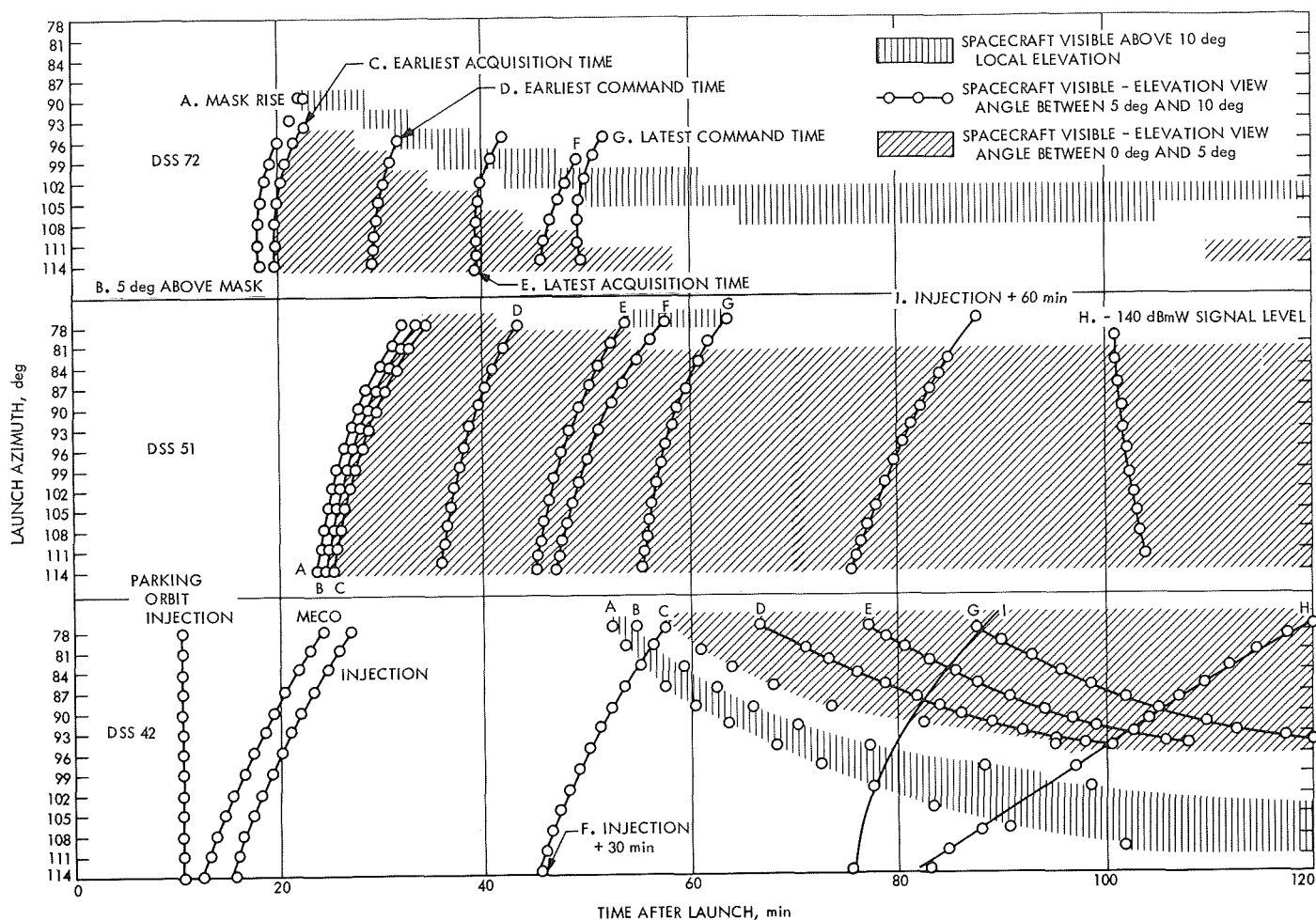
2. *Ground communications facility/NASCOM.* The DSN GCF is that portion of NASCOM that supported the *Surveyor VI* Mission by providing communication paths between the various DSN tracking stations throughout the world and SFOF. This communication system comprised the landlines, undersea cables, and radio circuits that carried teletype, voice, and high-speed data in real-time support of the *Surveyor VI* Mission. Figure 27 illustrates the configuration of the GCF in support of *Surveyor VI* and the type of data carried over these circuits.

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

The minimum number of DSN/GCF and SFOF intra-communications system (ICS) circuits, and minimum equipment required to be operational are shown in the subsequent paragraphs.

a. *Space Flight Operations Facility/ICS operational circuits.* The SFOF/ICS operational circuits consisted of the following:

- (1) Operational voice communication system less inter-communication capabilities.



- Line A — Time of spacecraft rise over local station mask
- Line B — Time that spacecraft is 5 deg above local mask. Telemetry is expected by that time
- Line C — Time that spacecraft is 10 deg above local mask. Acquisition sequence is started at this time
- Line D — Earliest possible time that the station would be ready for commanding
- Line E — Latest acquisition time. This time allows 20 min from the 10-deg point for the station to acquire the spacecraft. If the spacecraft is not acquired by this time, the acquisition is considered nonstandard
- Line F — Injection or separation plus 30 min. The spacecraft has been on high power for 30 min at this time
- Line G — Latest command time: the latest time at which the station would be ready for commanding for a normal acquisition
- Line H — Limit of normal S-band acquisition aid. This line indicates the time at which the nominal spacecraft signal level falls below -140 dBmW. Below this level the station cannot autotrack on the S-band acquisition aid. This prevents the normal DSIF procedure from operating
- Line I — Injection or separation plus 60 min. The spacecraft has been on high power for 60 min at this time

Fig. 15. Acquisition study, Surveyor VI launch data, November 7, 1967

- (2) Television communication system display of teletype data and line status capability.
- (3) Capability of transmission of incoming telemetry data, both high-speed and teletype, to the appropriate processing and display devices.

b. Deep Space Network/GCF operational circuits. The DSN/GCF operational circuits consisted of the following:

- (1) AFETR/SFOF circuits including:
 - (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 the SFOF.
- (2) Initial DSIF acquisition station/SFOF circuits including:
 - (a) One voice line.
 - (b) Two duplex teletype lines.
- (3) All other committed Deep Space Stations circuits including:
 - (a) One voice line.
 - (b) Two duplex teletype lines.
 - (c) One high-speed data line, 1100 bits/s or 96 kHz (DSS 11 only).
 - (d) The communications processor will be used in the implementation of the teletype portion of these criteria for the *Surveyor VI* Mission. In the event of a communications processor failure, the manual teletype switching system will be needed to provide adequate backup capability in support of the mission.

The *Surveyor* Project plan called for all phases of the mission to be supported by the communications processor, with the capability of switching to manual teletype lines if required.

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

a. Data processing. There have been no significant hardware changes to the basic data processing system *Surveyor* configuration. The 7044 V and 7040 W computers have been removed and the Univac 1219 computers are being installed in room 320 as discussed previously. It is planned to use the 7044 computer model 2-B system for *Surveyor VI*. This system is being used for extended lunar operations and premission testing.

b. Telemetry processing system. A slight modification was made to stations 1 and 2 of the telemetry processing system to provide pulse code modulated (PCM) data to the 1219 computer area at *Surveyor* request. No other changes were required.

c. Input/output system. No change is required to the input/output system to support *Surveyor VI*.

d. Monitor support system. No change is required to the monitor support system for the *Surveyor VI*.

e. Power system. Generator 3 has remained down due to regulator difficulty. However, installation for 1219 computers requires a 400-Hz power unit to be installed on the third floor, building 230.

f. The following minimum capabilities are 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 communication system 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 and display devices.

IV. *Surveyor VI* TDS Flight Preparation

The TDS organization had the responsibility to properly prepare for the *Surveyor VI* Mission. Such flight preparation was accomplished by unique TDS configuration and testing which is treated in the following subsections.

A. Configuration

The configuration of individual agencies that comprise the TDS, in preparation for the *Surveyor VI* Mission, is given in subsequent paragraphs.

1. Air Force Eastern Test Range. The AFETR configured its facilities in such a manner as to give maximum coverage for the near-earth phase of the *Surveyor VI* Mission. The various facilities and their preparations to meet the requirements placed on AFETR are discussed here. The AFETR stations and facilities prelaunch configuration committed to support *Surveyor VI* are depicted in Table 11. Figure 16 gives an overall map showing the planned coverages for November 7, 1967. Figures 17 and 18 show the view periods for all ships and stations during the first hour of the near-earth phase.

Table 11. The AFETR prelaunch configuration

Station	Radar	VHF telemetry	S-band telemetry
Merritt Island	X	X	X
Cape Kennedy	X	—	—
Patrick AFB	X	—	—
Grand Bahama Island	X	X	X
Grand Turk	X	X	X ^a
Antigua	X	X	X
Twin Falls	X	X	X
Coastal Crusader	—	X	X
Sword Knot	—	X	X
Ascension	X	X	X
Pretoria	X	X	X

^aEngineering test basis.

a. Tracking (C-band). The AFETR was to provide adequate coverage of the powered flight and parking orbit with the up-range stations. Range instrumentation ship, *Twin Falls*, was positioned to provide transfer orbit coverage (Fig. 18). Ascension and Pretoria were to cover the pre-, and post-retromaneuver tracking requirement.

b. Telemetry (VHF). The planned VHF telemetry configuration, along with the radar and S-band configuration, for the *Surveyor VI* Mission is shown in Table 11.

c. Telemetry (S-band). The *Twin Falls*, *Coastal Crusader* and *Sword Knot*, as well as Ascension and Pretoria, were

configured to satisfy the S-band telemetry requirements. Since Pretoria would be using a 3-ft antenna, no coverage estimates were made. The *Sword Knot* was to be positioned to provide prime coverage during the same interval when Pretoria would have a view. The planned S-band configuration, along with the radar and VHF telemetry configuration, for the *Surveyor VI* Mission are shown in Table 11.

Three and possibly four range instrumentation ships were to support the *Surveyor VI* Mission. The ships and their planned locations are presented in Table 12 for each day of the November launch period. The *Rose Knot*, if available, was to be used to receive and record launch vehicle data. The *Coastal Crusader*, *Twin Falls*, and the *Sword Knot* were to be used in this capacity in addition to receiving and recording spacecraft data (S-band). Also, the *Twin Falls* was to track the C-band beacon aboard the *Centaur* in order to provide tracking data taken during the transfer orbit; i.e., between main engine cutoff 2 and retroignition.

Table 12. Ship positions planned for the *Surveyor VI* Mission

Launch date, 1967	Range instrumentation ship	Positions	
		Latitude, deg	Longitude, deg
Nov 7	<i>Rose Knot</i>	10.5 N	32.0 W
	<i>Coastal Crusader</i>	6.5 N	11.5 W
	<i>Twin Falls</i>	2.0 N	1.0 W
	<i>Sword Knot</i>	8.5 S	40.0 E
Nov 8	<i>Rose Knot</i>	7.5 N	32.0 W
	<i>Coastal Crusader</i>	4.5 N	9.5 W
	<i>Twin Falls</i>	1.0 S	1.5 E
	<i>Sword Knot</i>	11.5 S	41.0 E
Nov 9	<i>Rose Knot</i>	4.0 N	32.0 W
	<i>Coastal Crusader</i>	1.5 N	10.5 W
	<i>Twin Falls</i>	5.0 S	3.0 E
	<i>Sword Knot</i>	15.0 S	41.0 E
Nov 10	<i>Rose Knot</i>	3.0 N	31.0 W
	<i>Coastal Crusader</i>	2.0 N	12.5 W
	<i>Twin Falls</i>	9.0 S	4.0 E
	<i>Sword Knot</i>	7.5 S	39.0 E
Nov 11	<i>Rose Knot</i>	3.0 N	34.5 W
	<i>Coastal Crusader</i>	2.5 N	16.0 W
	<i>Twin Falls</i>	12.0 S	6.5 E
	<i>Sword Knot</i>	19.0 S	42.0 E
Nov 12	<i>Rose Knot</i>	2.5 N	37.5 W
	<i>Coastal Crusader</i>	2.0 N	19.0 W
	<i>Twin Falls</i>	16.0 S	7.0 E
	<i>Sword Knot</i>	20.25 S	43.75 E

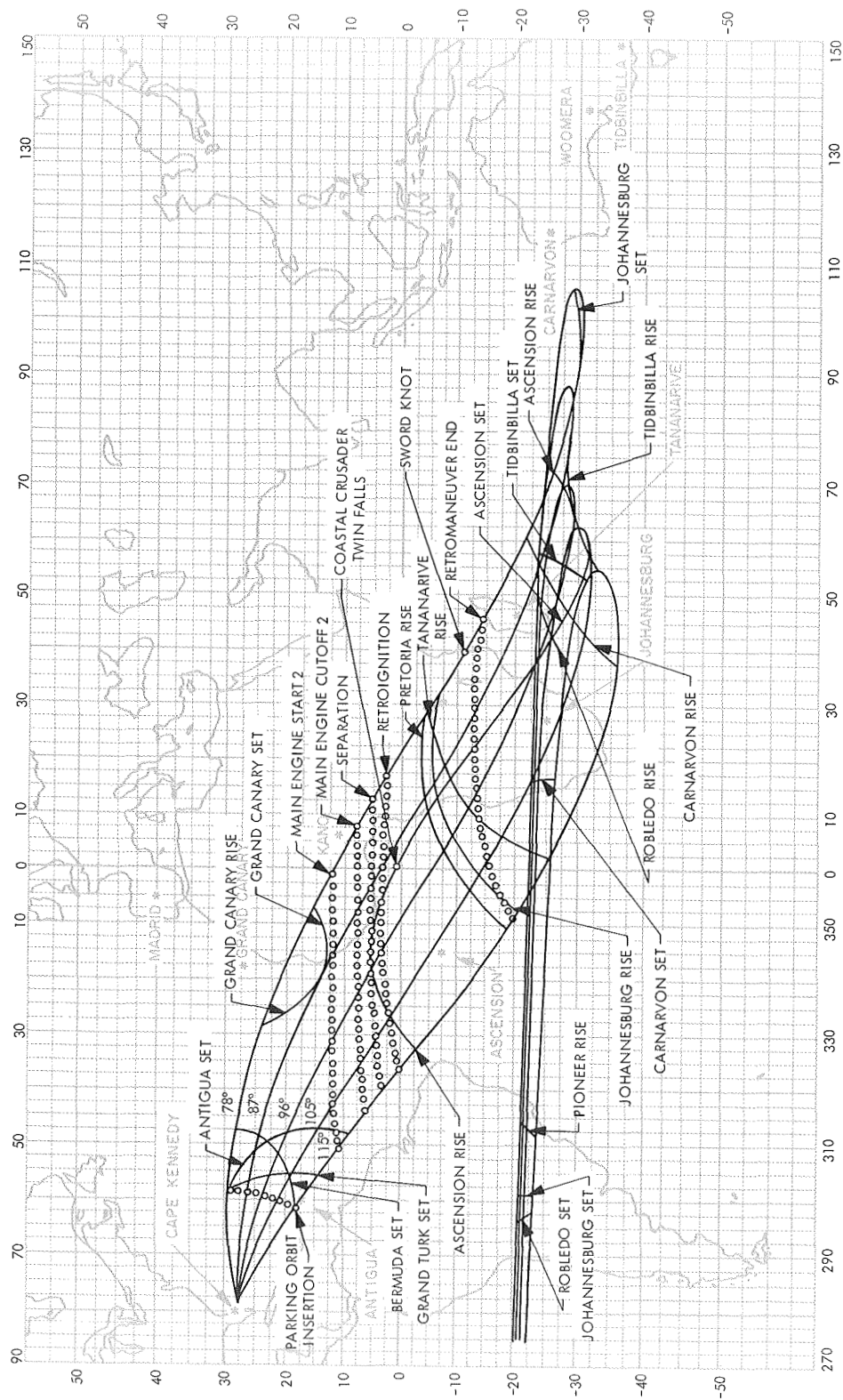


Fig. 16. Earth tracks and TDS station coverage for November 7, 1967

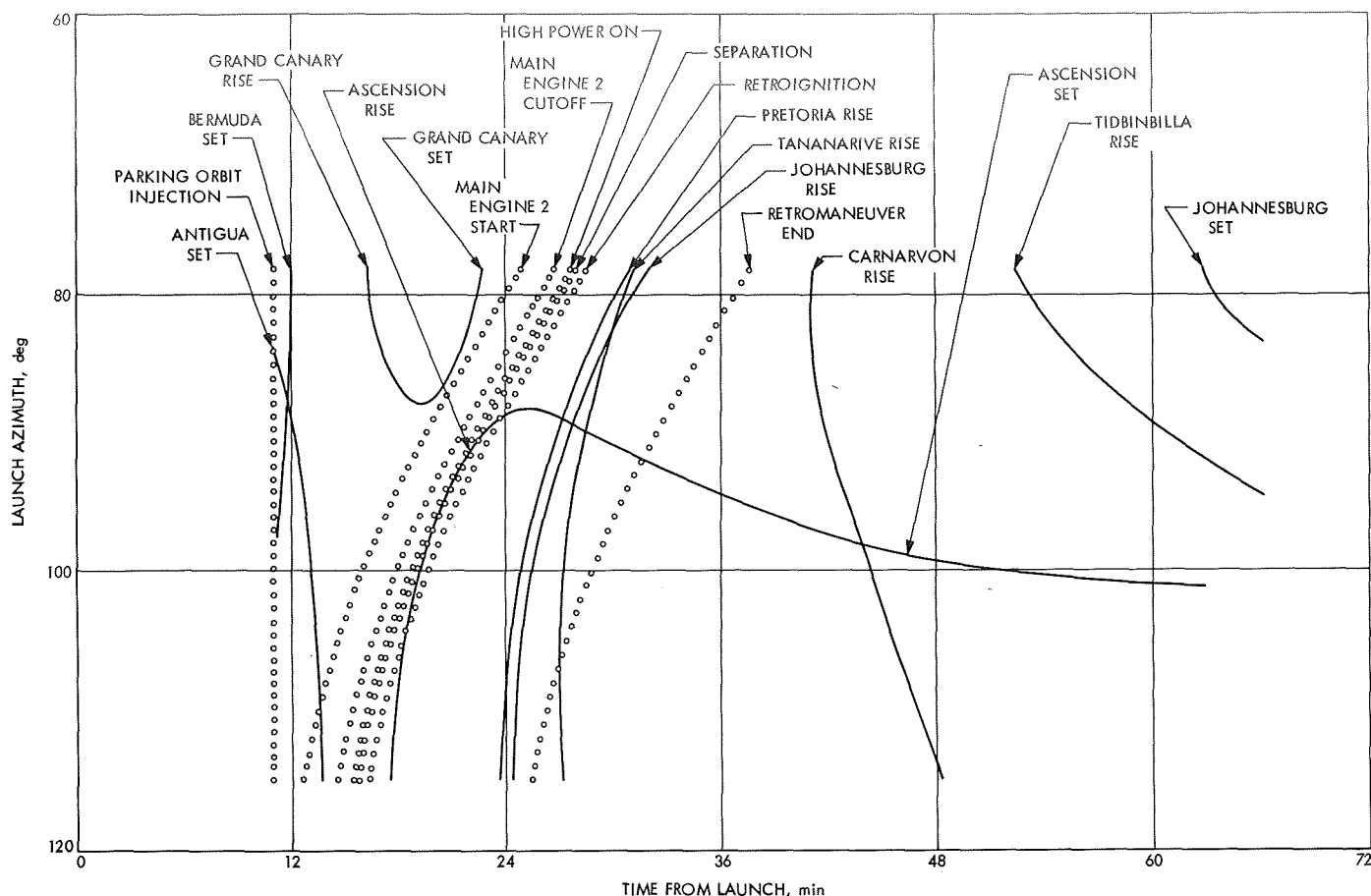


Fig. 17. View period graph for first hour, November 7, 1967

The view period graphs for the supporting land station during the first 60 min may be seen in Fig. 18 for convenience in examining the total support capabilities of the TDS.

d. Computed data. In addition to relaying the data to JPL, the RTCS was to use the data to compute orbital elements and injection conditions (parking orbit, transfer orbit and post-retromaneuver) which would be transmitted to JPL in the following formats: (1) standard JPL orbital message, (2) interrange vector, and (3) standard orbital parameter message.

All DSN and MSFN acquisition information, based on the parking orbit plus theoretical second burn and actual pre-retromaneuver orbital computations, were to be prepared and forwarded by the RTCS. In addition, AFETR was to transmit interrange vector messages directly to DSS 72, if this would not conflict with *Apollo* support.

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 JPL pre- and post-retromaneuver recursive accumulative orbits. An I-matrix and a lunar mapping message based on each solution would be included.

Figure 19 shows the planned configuration for the flow of metric data into and out of the RTCS.

e. Real-time retransmission of telemetry data. The planned spacecraft telemetry data flow from the supporting AFETR stations to building AO and DSS 71 is shown in Figs. 20-22. The AFETR stations: KSC, Grand Bahama, Antigua, Ascension, and Pretoria were expected to acquire and transmit spacecraft telemetry. The Rixon 1, 2 and 3 lines in Fig. 21 represent PCM telemetry data transmitted via direct high frequency (HF) radio links from RIS and Ascension to Cape Kennedy. Pretoria data were to be relayed through Ascension and then by radio frequency (RF) link directly to Cape Kennedy.

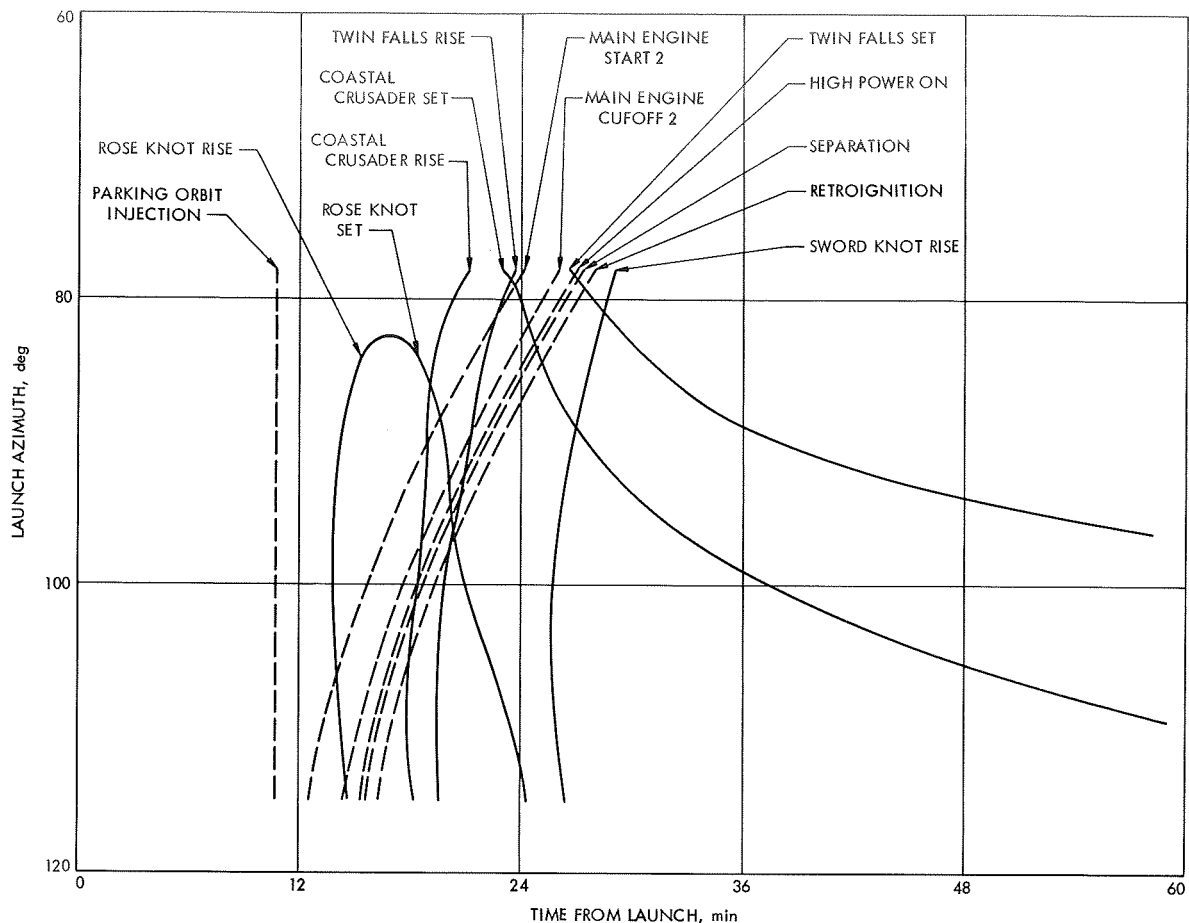


Fig. 18. Range instrumentation ship view periods for first hour after launch, November 7, 1967

The data were to be routed to KSC as shown in Figs. 20 and 21. There, after analysis by using the time division multiplex, the AFETR telemetry coordinator would select the best source for transmission to building AO and DSS 71 via modems (modulator-demodulator). As shown in Fig. 22, there are two modem lines between KSC and the X-Y building to provide redundancy.

The modem lines are bridged at the X-Y building to provide two modem lines each to building AO and DSS 71. DSS 71 routes the data through a CDC and 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.

Real-time transmission of launch vehicle data (VHF) was to be accomplished using the subcable, down through Antigua, as in prior missions.

When more than one station viewed the high-power-on event, one station was to be configured to retransmit

that spacecraft event in real-time. For the other viewing station, it was a class I requirement to retransmit launch vehicle performance data during the interval (-40 s) from main engine start 2, through main engine cutoff 2.

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 they were to be routed, as a back-up 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 back-up to their modem lines from X-Y building.

2. Manned Space Flight Network. The MSFN, managed by GSFC, was configured to support the *Surveyor VI* Mission by providing tracking, VHF telemetry, and computer support. Table 13 indicates the GSFC/MSFN station and equipment configuration used for supporting the *Surveyor VI* Mission.

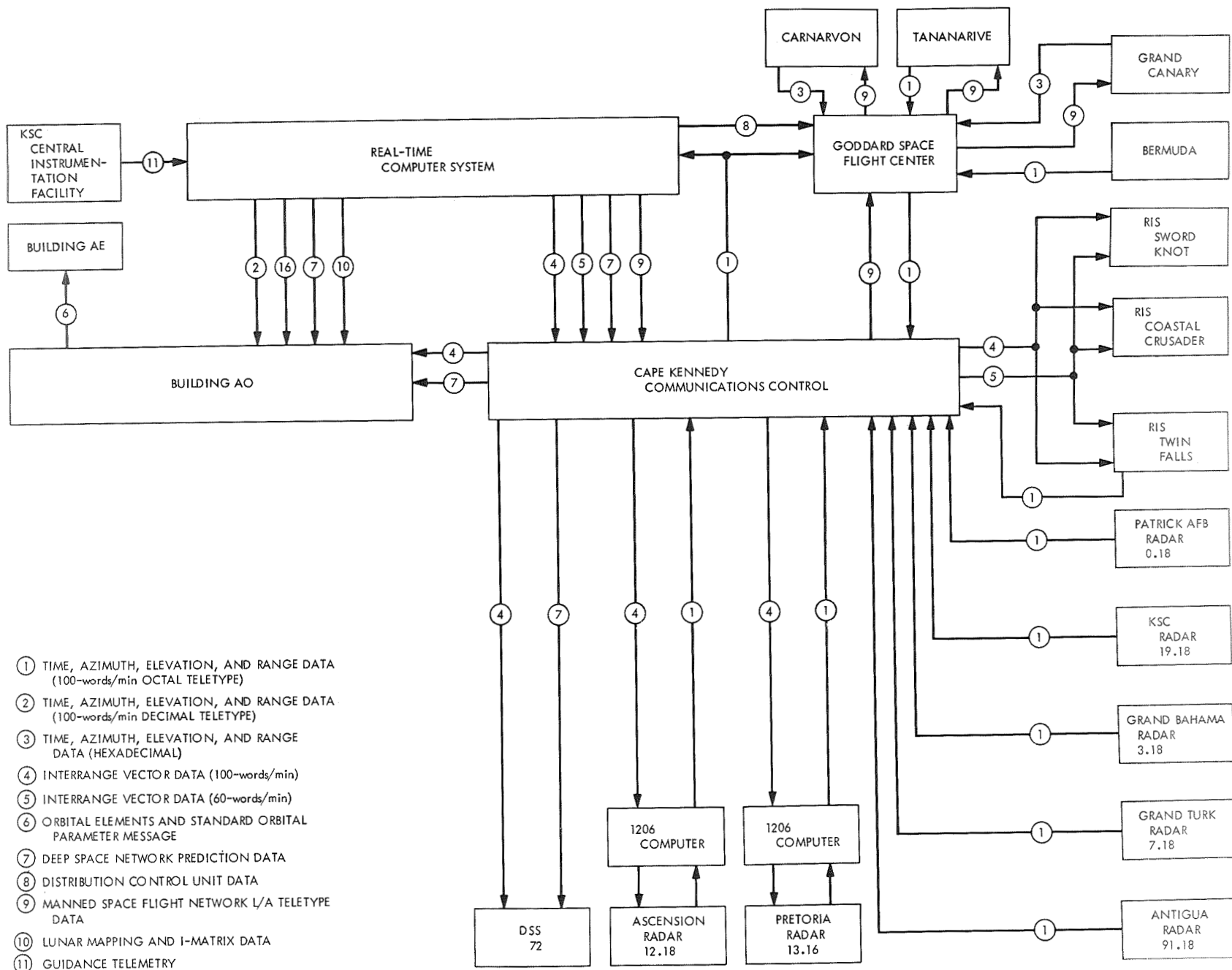


Fig. 19. Metric data flow for Surveyor VI

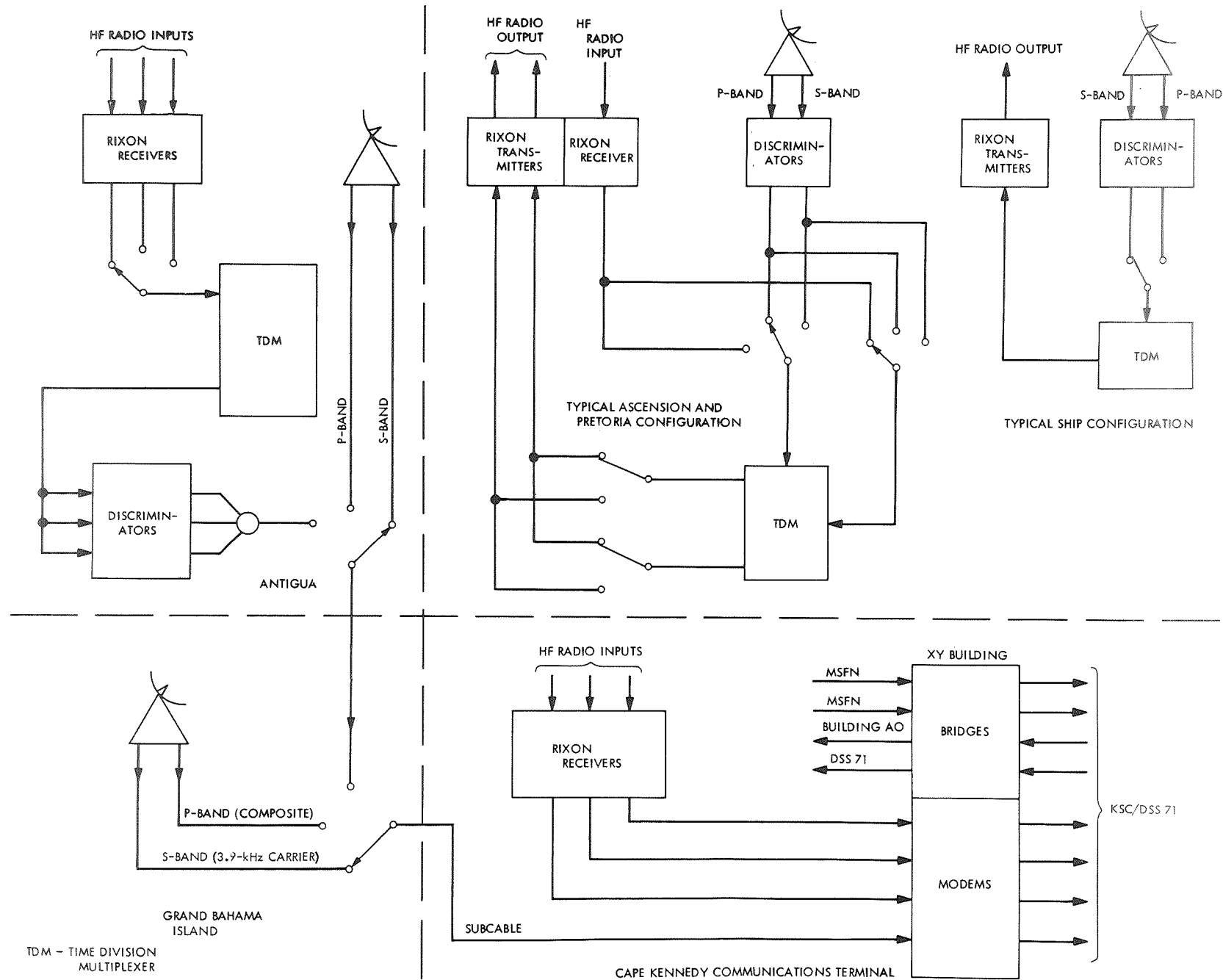


Fig. 20. Downrange telemetry data flow

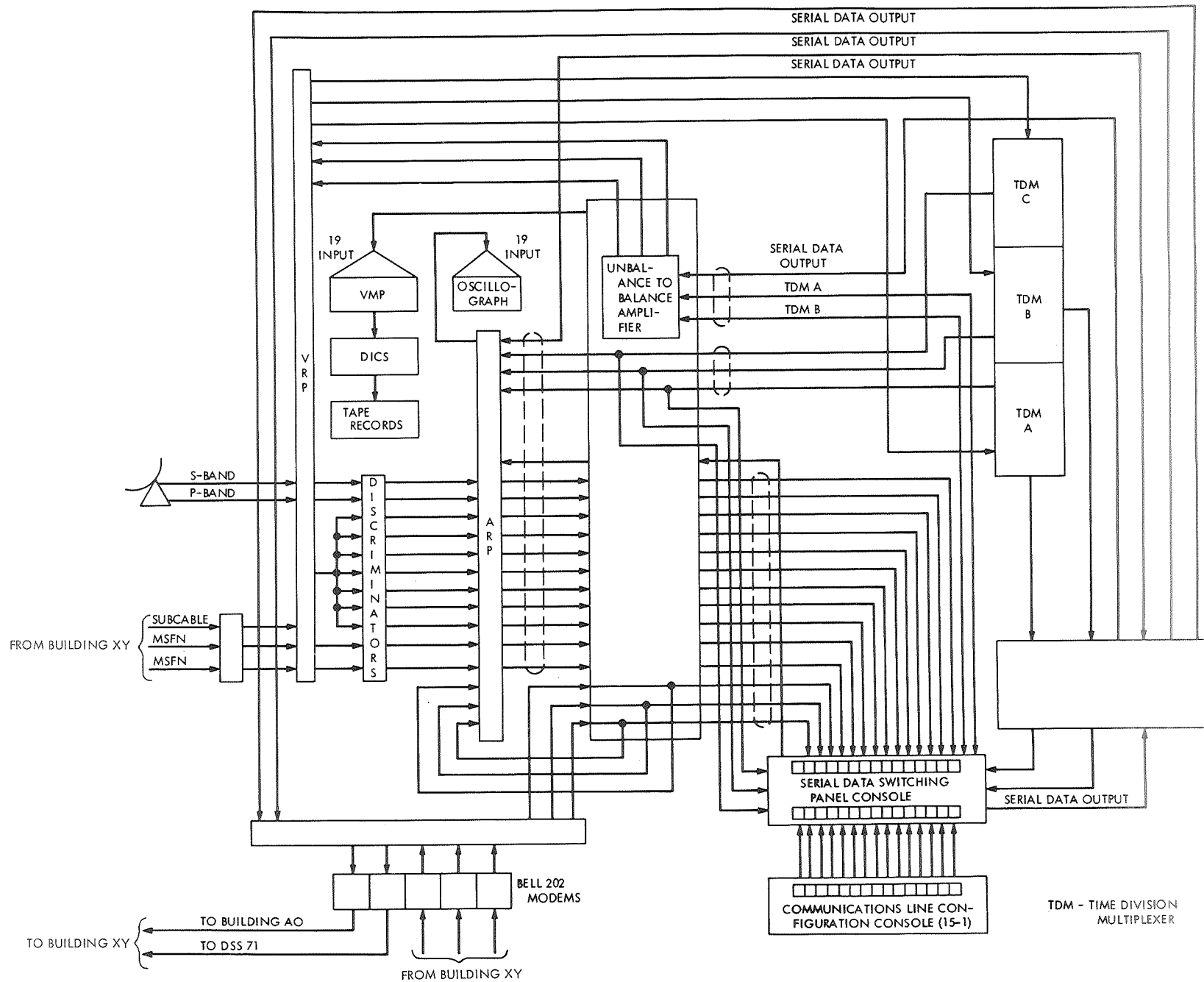


Fig. 21. AFETR serial data routing and switching system

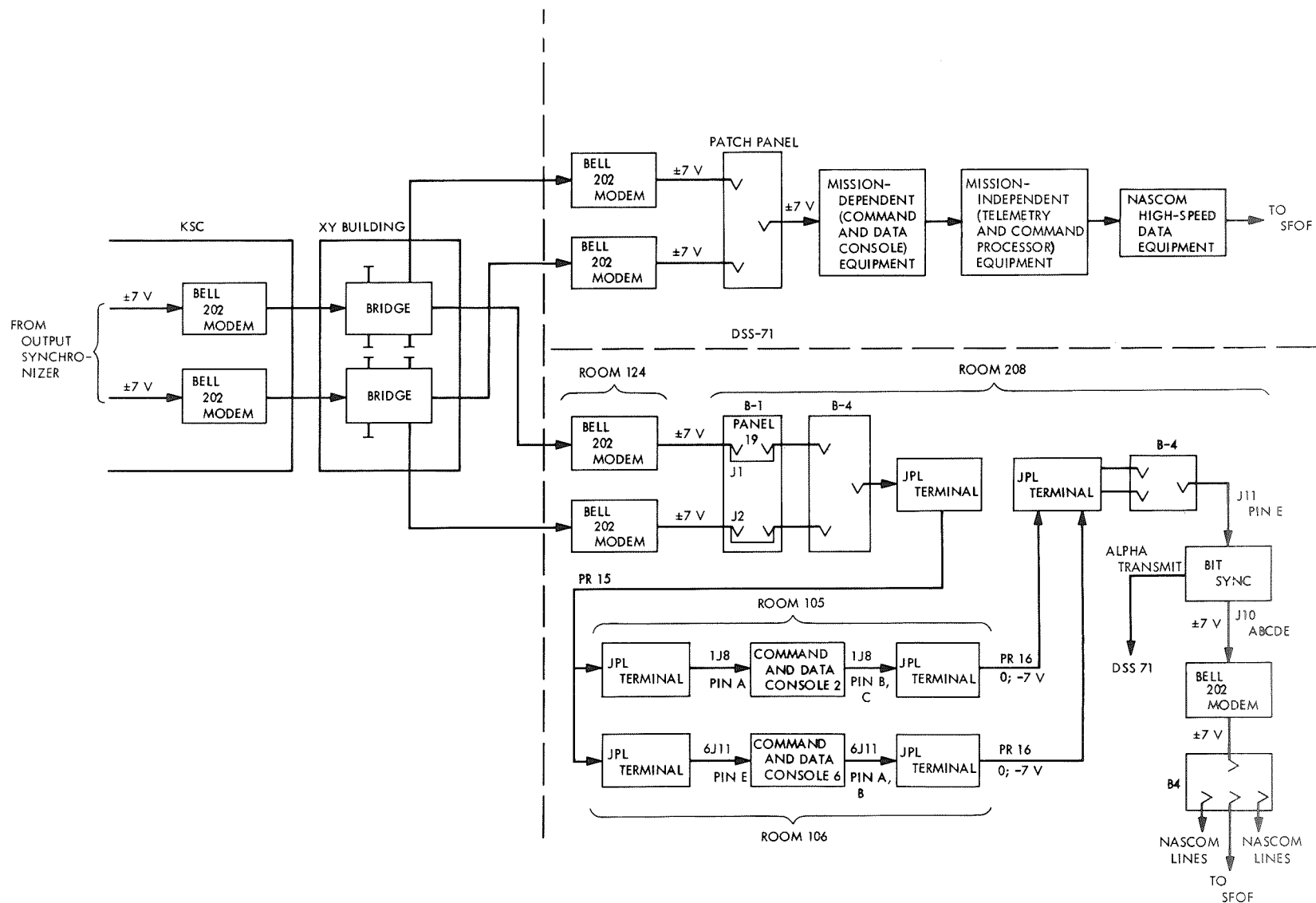


Fig. 22. Telemetry data distribution building AO-DSS 71

Table 13. Goddard Space Flight Center/MSFN Surveyor VI configuration

Station	Acquisition aid	Telemetry	C-band radar	Unified S-band	SCAMA ^a	Teletype	Radar high-speed data	Radar low-speed data	Real-time readouts	Real-time transmission
Bermuda	X	X	X		X	X	X	X	X	X ^b
Grand Canary	X	X	X	X	X	X	X	X	X	
Tananarive	X	X	X		X	X	X	X	X	
Carnarvon	X	X	X	X	X	X	X	X	X	
GSFC					X	X	X			
GSFC/AFETR Interface					X	X	X			

^aSignaling, conferencing, and monitoring arrangements. ^bTelemetry data.

Bermuda, Grand Canary, Tananarive and Carnarvon were to receive, decommutate and record the *Centaur* telemetry 225.7-MHz link and confirm flight mark events. Bermuda was to also receive and record the *Atlas* 229.9-MHz telemetry link and the 232.4-MHz telemetry link for range safety purposes.

a. *Tracking (C-band)*. The MSFN stations shown in Table 13 were to provide C-band radar, VHF telemetry support, and real-time transmission of telemetry data, for *Surveyor VI*.

Bermuda. During the powered flight phase of the mission, the Bermuda FPQ-6 radar was to beacon track the *Centaur* vehicle in conjunction with the AFETR radars. The mode of operations for the FPS-16 radar would depend on the flight azimuth. Two phasing slots were provided, both radars were to actively beacon track the *Centaur* vehicle. If only one phasing slot was provided, the FPS-16 radar was to passively angle track, using the auxiliary track mode of operation, as backup to the FPQ-6. Specific phasing information was to be provided when available. The FPQ-6/FPS-16 high-speed (2400 bits/s), real-time data was to be transmitted to GSFC and the RTCS at AFETR. The FPQ-6/FPS-16 was also to transmit real-time, low-speed radar data to GSFC and the RTCS at AFETR.

Grand Canary. The MPS-26 radar was to beacon track the *Centaur* vehicle from AOS to LOS or as otherwise instructed by the radar controller. If mechanical range limits are exceeded, an attempt would be made to reacquire track by recycling range. The radar was to transmit real-time, low-speed radar data to GSFC for reformatting and retransmission to the RTCS at AFETR.

The unified S-band system was to be called up as an additional means of acquisition.

Tananarive. Tananarive's FPS-16-M radar was to beacon track the *Centaur* vehicle from AOS to LOS, or as otherwise instructed by the radar controller. The radar was to transmit real-time, low-speed radar data to the RTCS at AFETR.

Carnarvon. The FPQ-6 radar was to beacon track the *Centaur* vehicle from AOS to LOS, or as otherwise instructed by the radar controller. The radar was to transmit real-time, low-speed data to GSFC for reformatting and retransmission to the RTCS at AFETR.

b. *Telemetry (S-band)*. The MSFN participated in S-band acquisition, on a noninterference basis, for unified S-band site training.

Carnarvon was to receive 550-bit, bilevel, nonreturn-to-zero telemetry data via the S-band and was to transfer these data via NASCOM data modem facilities to DSS 42.

c. *Unified S-band instrumentation support*. The SFOF required that it receive real-time *Surveyor VI* spacecraft telemetry continuously from launch until touchdown. On past missions some real-time data requirements have been met during the near-earth phase of the flight, from launch to Deep Space Network acquisition by AFETR. Carnarvon was to provide coverage for the Australian continent until acquisition by DSS-42, Tidbinbilla.

Carnarvon was to receive 550-bit, bilevel, nonreturn-to-zero telemetry data via the S-band link and will transfer this data via NASCOM data modem facilities to DSS 42. Applicable engineering instructions were provided by

the manned flight engineering division to alter the unified S-band configuration to meet this requirement.

All Carnarvon unified S-band data associated with this mission were to be collected and disposed of in accordance with *Surveyor* real-time telemetry transmission from Carnarvon. Figure 23 gives the *Surveyor* unified S-band configuration.

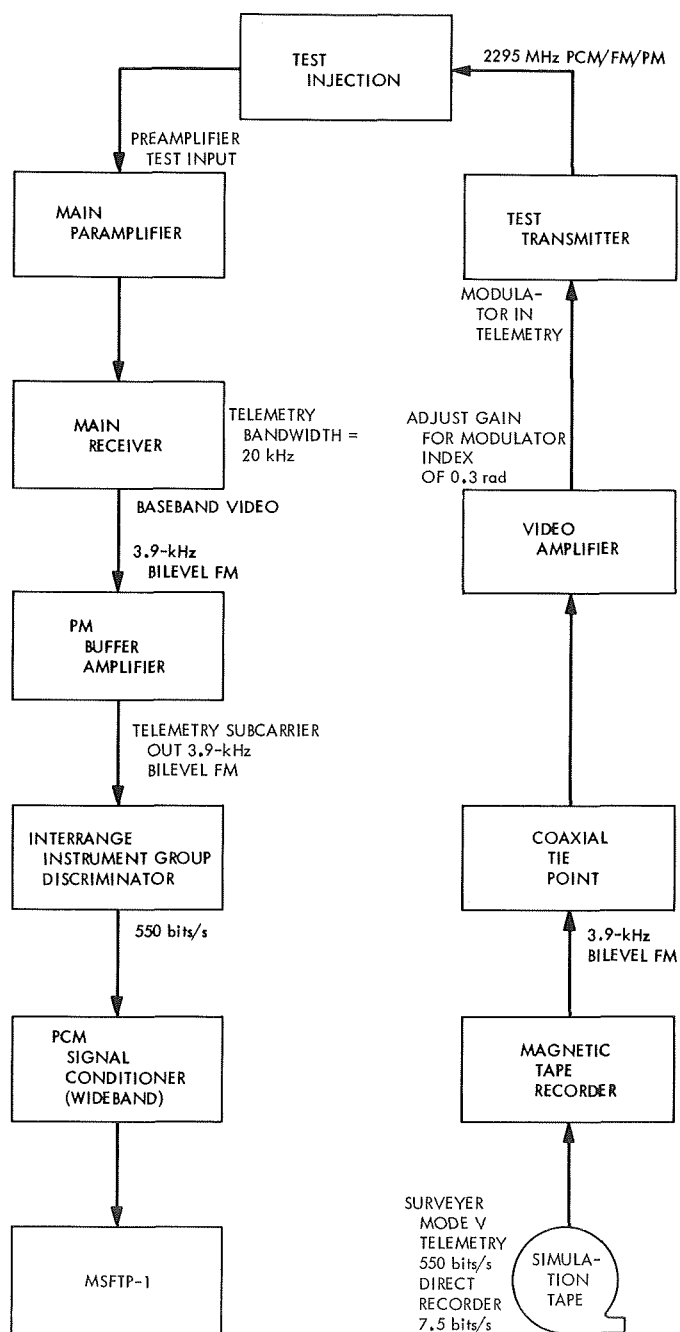


Fig. 23. *Surveyor* unified S-band simulation configuration

d. *Telemetry (VHF)*. Bermuda, Grand Canary, Tananarive, and Carnarvon were to receive, decommutate and record the *Centaur* 225.7-MHz telemetry link and confirm flight mark events. Bermuda would also receive and record the *Atlas* 229.9-MHz telemetry link and the 232.4-MHz link for range safety purposes.

e. *Computed data*. During the powered flight phase, GSFC computers receive launch trajectory data from Bermuda and AFETR via the launch trajectory data system. The trajectory is computed and the resulting parameters are used to drive displays at the GSFC operations control center. Upon termination of the *Centaur* first burn, the data operations branch passed orbital injection parameters to the MSFN.

The GSFC computers receive low-speed data from AFETR radars. The real-time acquisition messages generated were to be transmitted to the participating MSFN stations, based on the actual first burn and anticipated second burn data. The Deep Space Station acquisition messages, based on postinjection tracking data, were to be generated and transmitted—time permitting.

The low-speed teletype data from Grand Canary 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.

f. *Communications*. The MSFN communications were to consist of the following:

- (1) Existing NASCOM facilities were to provide the required voice, teletype, and data circuits to participating stations. The communications network configuration is shown in Fig. 19.
- (2) NASA communications operating procedures were to be used as a basis for message preparation, transmission, and distribution.
- (3) Voice conferencing was to be accomplished at the GSFC switching, conferencing, and monitoring arrangement facility under the direction of the NASA network controller at the MSFN operations center.
- (4) All mission traffic originating from, or going to, MSFN stations was to have GCEN as an information addressee. Any traffic received on-station that did not have GCEN as information addressee was to be retransmitted by that station to GCEN. In addition, each message will include in the first line of the text: mission traffic identification, NCG test number, and mission identification (example: Radar PLIM, NCG XXX, AC-14).

- (5) Reformatting of Grand Canary and Carnarvon radar data by GSFC data operations branch will be required. Circuits required for reformatting this data and forwarding to RTCS and Cape Kennedy will be provided.
- (6) Commencing at $T - 180$ min, hangar AE will be included as information addressee on all mission traffic messages.
- (7) GSFC/AFETR interface personnel will make patches necessary to complete Cape Kennedy circuits shown in Fig. 24.

3. Deep Space Network. The major elements of the DSN configured to support the *Surveyor VI* Mission were, the DSIF, the GCF, and the SFOF.

a. Deep Space Instrumentation Facility. The DSIF configuration for tracking and data acquisition stations (Deep Space Stations) are so located around the earth, so the antennas of one of three selected stations situated 120 deg apart in longitude, may continuously observe a spacecraft during its mission. The following stations were committed, as indicated, to support the TDS for the two remaining *Surveyor* missions:

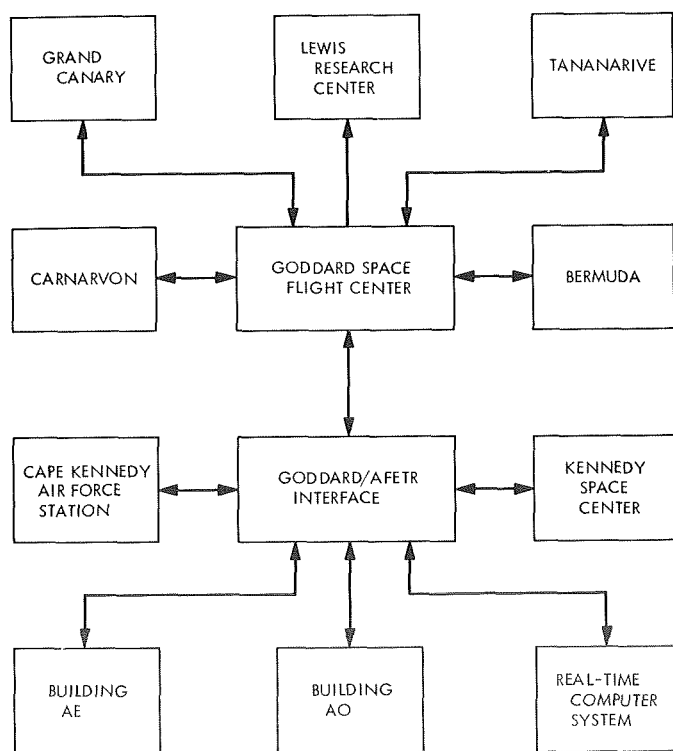


Fig. 24. Ground communications configuration

- (1) DSS 11.
- (2) DSS 42.
- (3) DSS 61.
- (4) DSS 71 (Prelaunch support to ensure compatibility of the *Surveyor* spacecraft and the DSN and record the spacecraft telemetry from launch to loss of signal at horizon).
- (5) DSS 51 (Cislunar tracking only).
- (6) DSS 14:
 - (a) Command backup to DSS 11 during the entire mission.
 - (b) Prime telemetry during midcourse and terminal descent phases.
 - (c) Telemetry backup to DSS 11 during other portions of the mission.

Figure 25 gives the DSIF earth track. The DSIF view periods, for the first 20 h, are shown in Fig. 26.

For the *Surveyor VI* Mission, there were no major changes in *Surveyor* Project requirements upon the DSN or DSIF. The *Surveyor VI* spacecraft carried a survey TV camera and an alpha scattering instrument, and operations were similar to those conducted for *Surveyor V*. One exception was that the *Surveyor VI* TV system did not produce over-deviation of the spacecraft transmitter as was the case with *Surveyors IV* and *V*. Therefore the ground receiver frequency offsets used for these missions were not used for *Surveyor VI*.

Other changes in total DSIF support provided to the *Surveyor* Project include those discussed in the subsequent paragraphs.

Extended support for Surveyor V. Extensive tracking support was provided during the second lunar day for *Surveyor V*. This activity helped verify that the prime *Surveyor* stations are properly configured and operationally capable of supporting *Surveyor*. Tracking coverage continued into the second lunar night with brief interrogations to determine spacecraft status. These interrogations were scheduled with decreasing frequency until approximately 200 h after sunset, at which time operations were terminated for the lunar night. Preliminary planning then began for conducting third lunar day operations of *Surveyor V*, on a basis of noninterference with the *Surveyor VI* Mission. This required simultaneous operation of two spacecraft on the lunar surface.

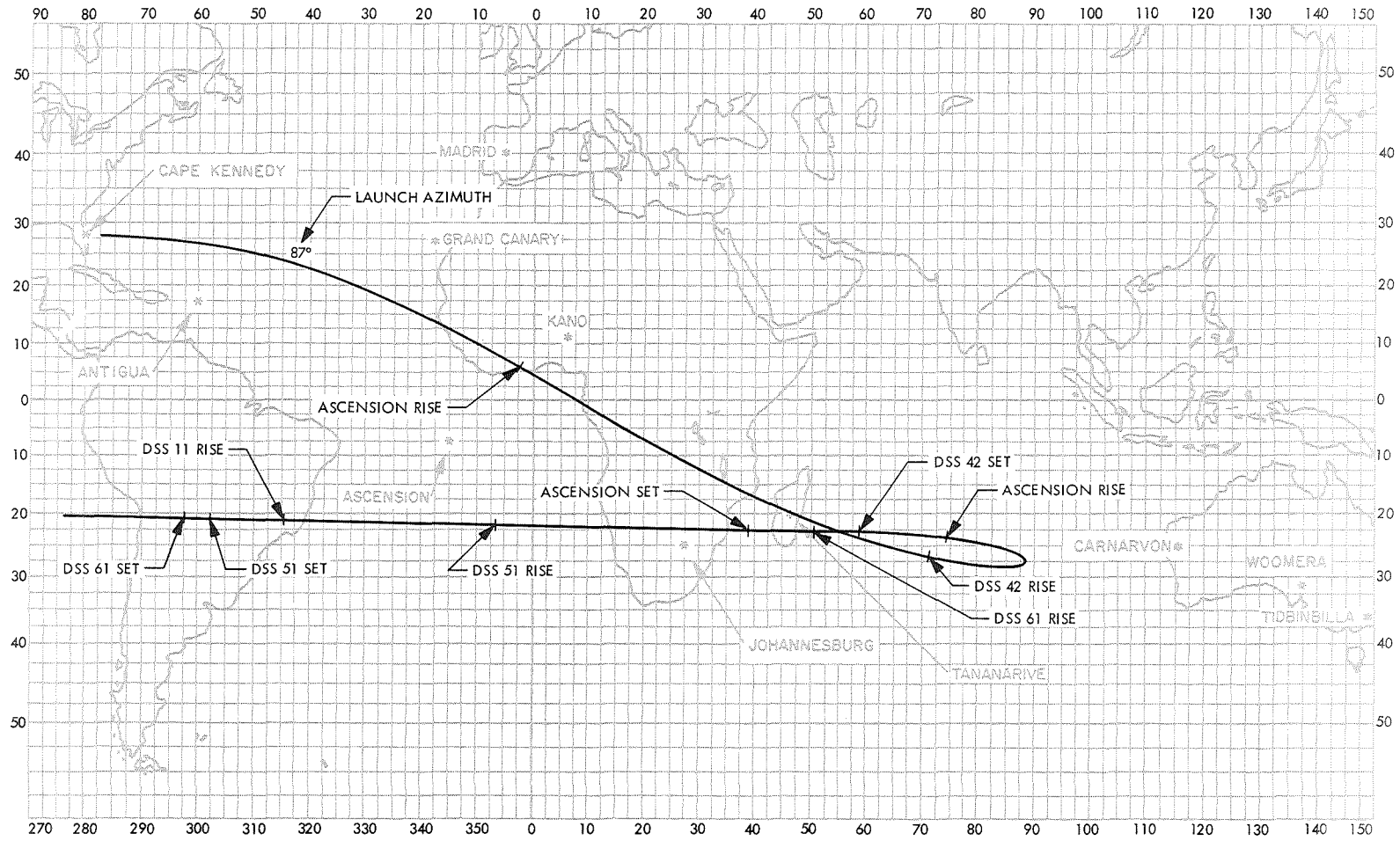


Fig. 25. Earth track

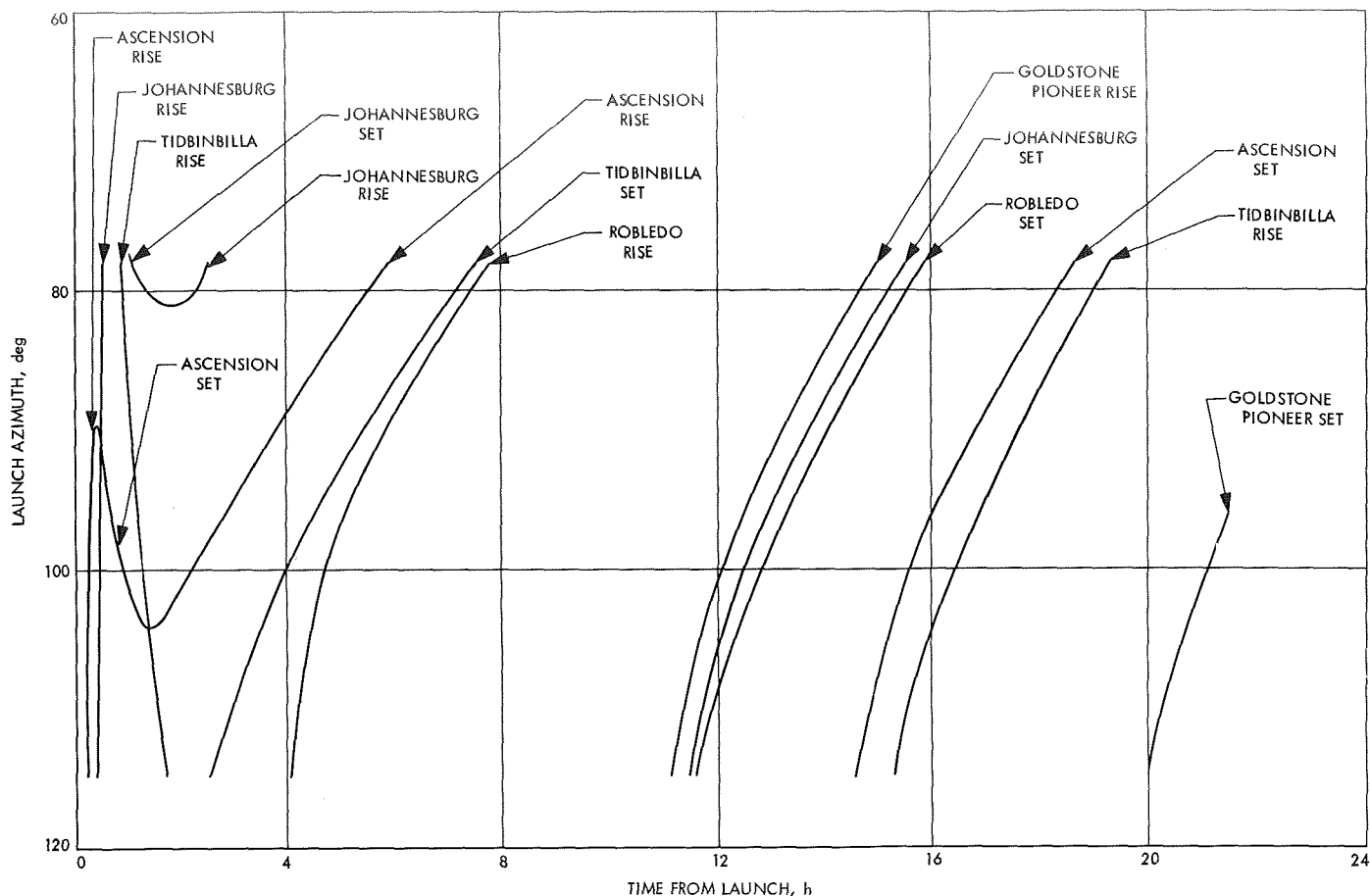


Fig. 26. View period graph for first 20 h for November 7, 1967

Reduced prelaunch testing. Due to the continuing high level of *Surveyor V* activity, project requirements for the *Surveyor VI* Mission prelaunch testing decreased. There was no special alpha scattering testing since alpha scattering operations were conducted with all stations during the second lunar day of *Surveyor V*. The major project tests were: one flight training test (conducted in two phases), a video certification test (lunar operations test), and a single operational readiness test at $T - 48$ h. Furthermore, the DSN conducted no special system readiness verification tests for this mission, since data flow paths had been verified by extended lunar operations. However, regular DSIF configuration verification tests were performed.

Coverage by DSS 72. Coverage by DSS 72 was not available for the *Surveyor VI* Mission because of commitment of the station to the *Apollo*. The three-station orbit determination solution was provided by DSSs 42, 51, and 61.

Coverage by DSS 71. The RF compatibility tests between spacecraft SC-6, located on the launch pad and DSN were supported by DSS 71. These tests were successfully completed on September 28 and 29, including verification that there is no transmitter over-deviation during video operations. At time of launch, DSS 71 receives and records telemetry data from $T - 5$ min to LOS. In addition, DSS 71 uses its CDC and telemetry and command processor computer to process AFETR telemetry data for transmission to JPL via NASCOM high-speed data lines.

Coverage by DSS 14. The DSIF committed DSS 14, the 210-ft Mars station antenna, to support the midcourse and terminal descent phases of the *Surveyor VI* Mission. This will include telemetry reception and recording, and a backup transmitter, if required, for commanding. DSS 14 will be available to the end of the touchdown pass. Baseband telemetry will be transmitted to SFOF in real-time upon request by the space flight operations director.

DSS 51 WILL SUPPORT SURVEYOR VI DURING LAUNCH
AND CISLUNAR PHASES ONLY
DSS 14 WILL PARTICIPATE IN THE MIDCOURSE AND
TERMINAL PHASES ONLY

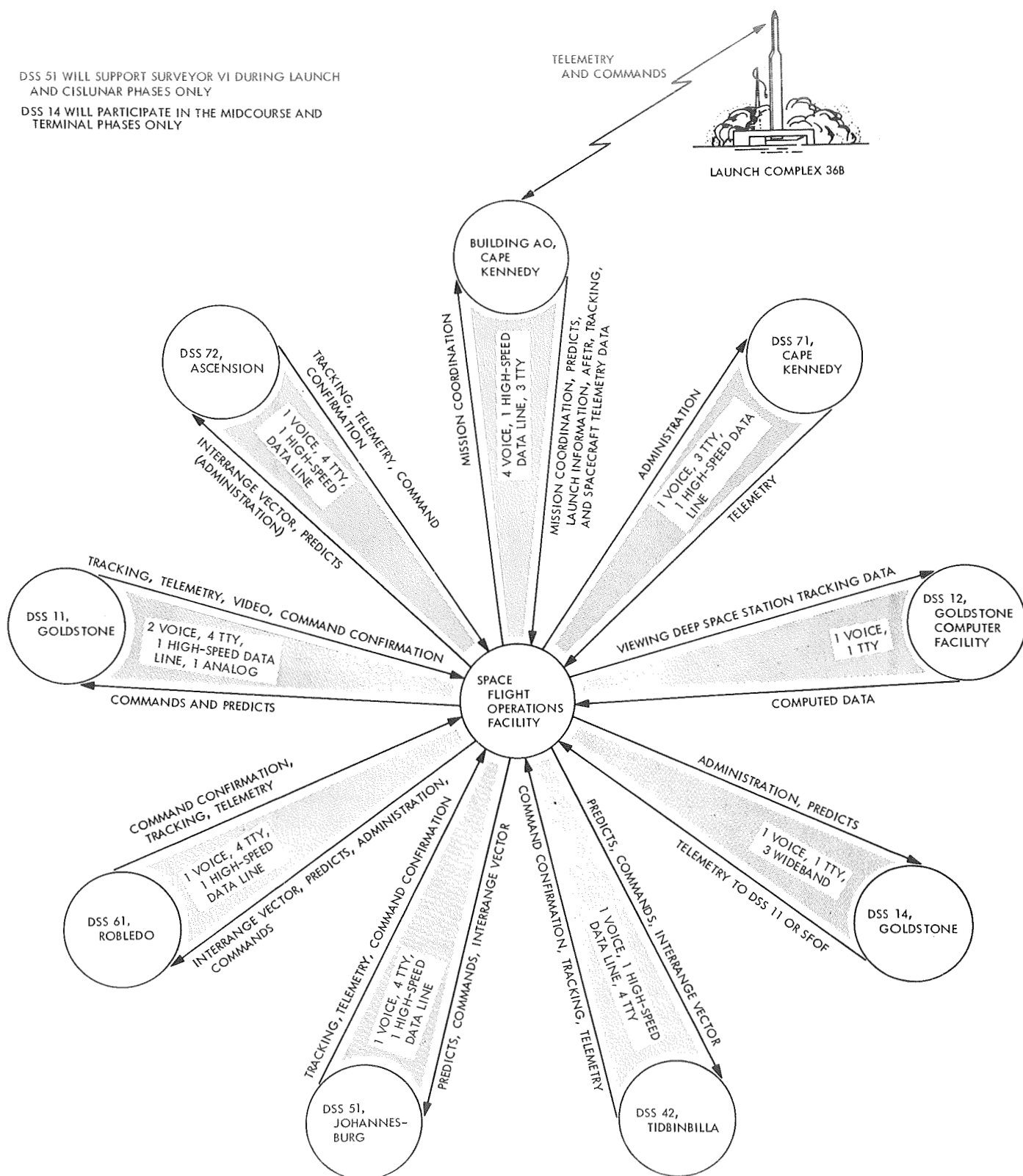


Fig. 27. Deep Space Network/GCF configuration diagram, Surveyor VI

b. *The DSN communications system.* The GCF circuit configuration for *Surveyor VI* is shown in Fig. 27. The changes in the GCF since the *Surveyor V* Mission are all minor in scope as follows:

- (1) One temporary JPL/GSFC voice interconnect was added October 27–November 13, 1967 to comply with the *Surveyor* support instrumentation requirements document that specifies voice data circuits.
- (2) The teletype circuits remain the same as for the *Surveyor V* Mission (Fig. 28).
- (3) The changes in the high-speed data system since the *Surveyor V* Mission consist of rerouting the 96-kHz line to Goldstone during midcourse and touchdown. The 96-kHz line will carry DSS 14 high-speed telemetry data direct to the SFOF telemetry processing station rather than through the DSS 11 CDC (Fig. 29). The Carnarvon data, via the DSS 42 CDC, and the high-speed data line will be available as in previous *Surveyor* missions (Fig. 30).
- (4) The JPL/Goldstone microwave systems have not been changed since the previous *Surveyor* missions. However, the maintenance coverage scheduled during the midcourse and touchdown/terminal phases was increased for the *Surveyor VI* Mission.
- (5) The communications processor, from a communications standpoint, is good and is well capable of supporting the *Surveyor VI* Mission. The documentation by the *Surveyor* Project, DSIF and SFOF communications group has improved since the *Surveyor V* Mission. Figure 31 depicts a sample of detailed DSN GSF communications processor teletype circuit configurations.

The SFOF DSN/ICS is also in excellent condition to support the *Surveyor VI* Mission; however, the following minor modifications were made:

- (1) The public information office for the voice of *Surveyor* was relocated, and modifications were made to the configuration of the operational voice communication system, TV, and special circuits.
- (2) A new spacecraft performance analysis and command telemetry video digital display system provides a visual alpha numeric display derived from the digital output of the Univac 1219 computer. This visual information is available on the *Surveyor* area monitors (Fig. 32).

c. *Space Flight Operations Facility.* The SFOF served as the control and processing center for the DSN during the *Surveyor VI* Mission. Specifically, this included communications control, command transmissions, data processing, data analysis, data display, and facility support, as required by the 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 configured and supported this mission follows. Figure 33 provides the SFOF functional block diagram for the *Surveyor VI* Mission.

Data processing system. There have been no significant hardware changes to the basic *Surveyor* data processing system configuration. The 7044 V and 7040 W computers have been removed and the Univac 1219 computers installed in room 320. Figure 34 depicts the SFOF/1219 computer interface. It was planned to use the 7044 model 2-B system for *Surveyor VI*. This system is used for the extended lunar operations and premission testing.

During the premission period of *Surveyor VI*, performance of data systems operations was more than adequate. There were no manning or personnel problems encountered by any unit of operation.

The X and Y string computer systems provided primary support for the premission period. Some premission testing was run on the W string computer system to check out backup capabilities.

The *Surveyor VI* Mission used the 7044 R, computer model 2 software system for the operational readiness test. This system was a vast improvement over the previous 7044 R, computer model 2 systems used by the *Surveyor* Project.

Preparation for the mission in the input/output (I/O) and telemetry processing/simulation data conversion center areas began approximately three weeks prior to mission ORT. Preventive maintenance tests were accomplished on all equipment committed to the *Surveyor* Project. Data processing maintenance ensured that an ample quantity of operational supplies was available at SFOF stores.

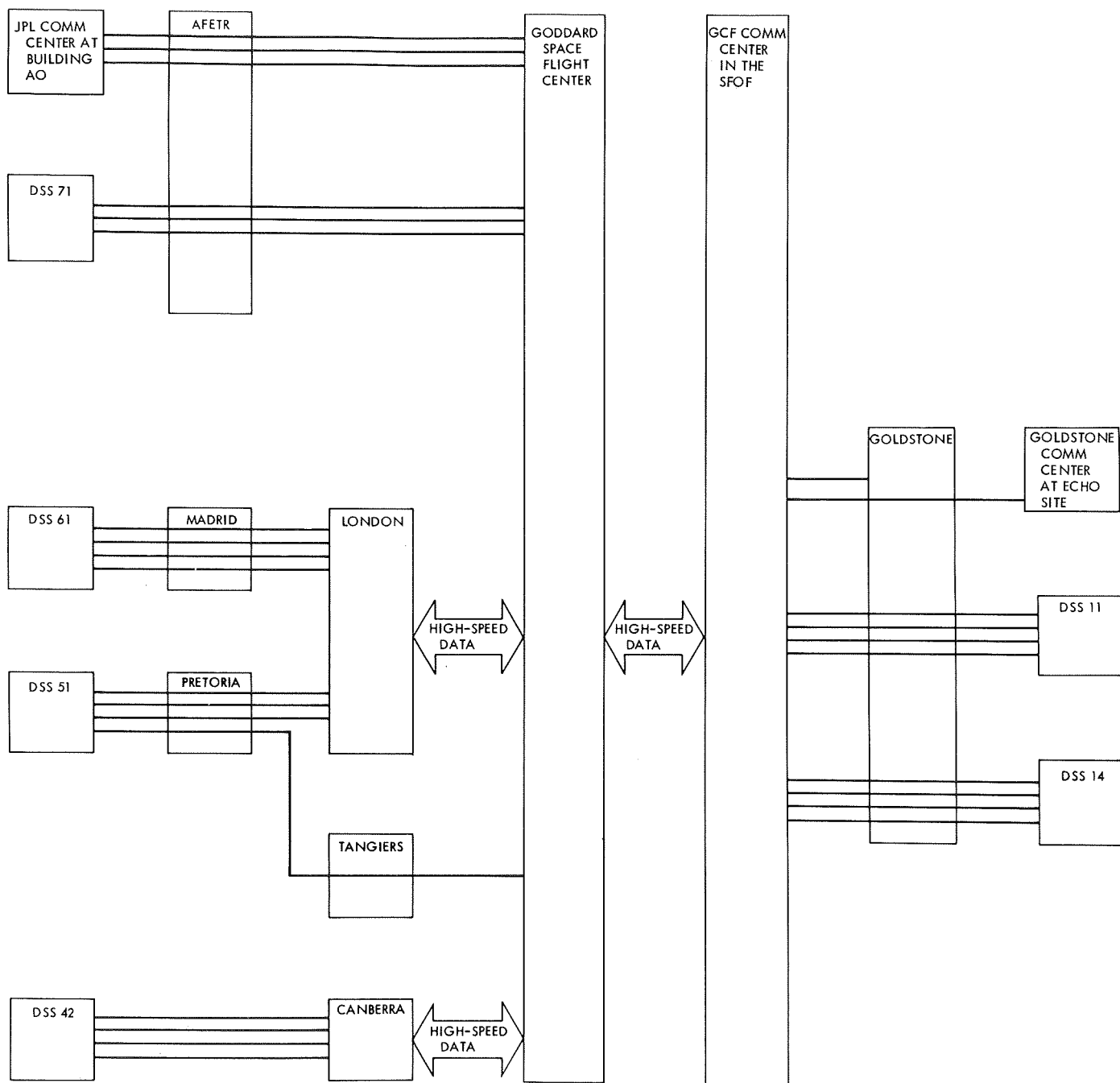
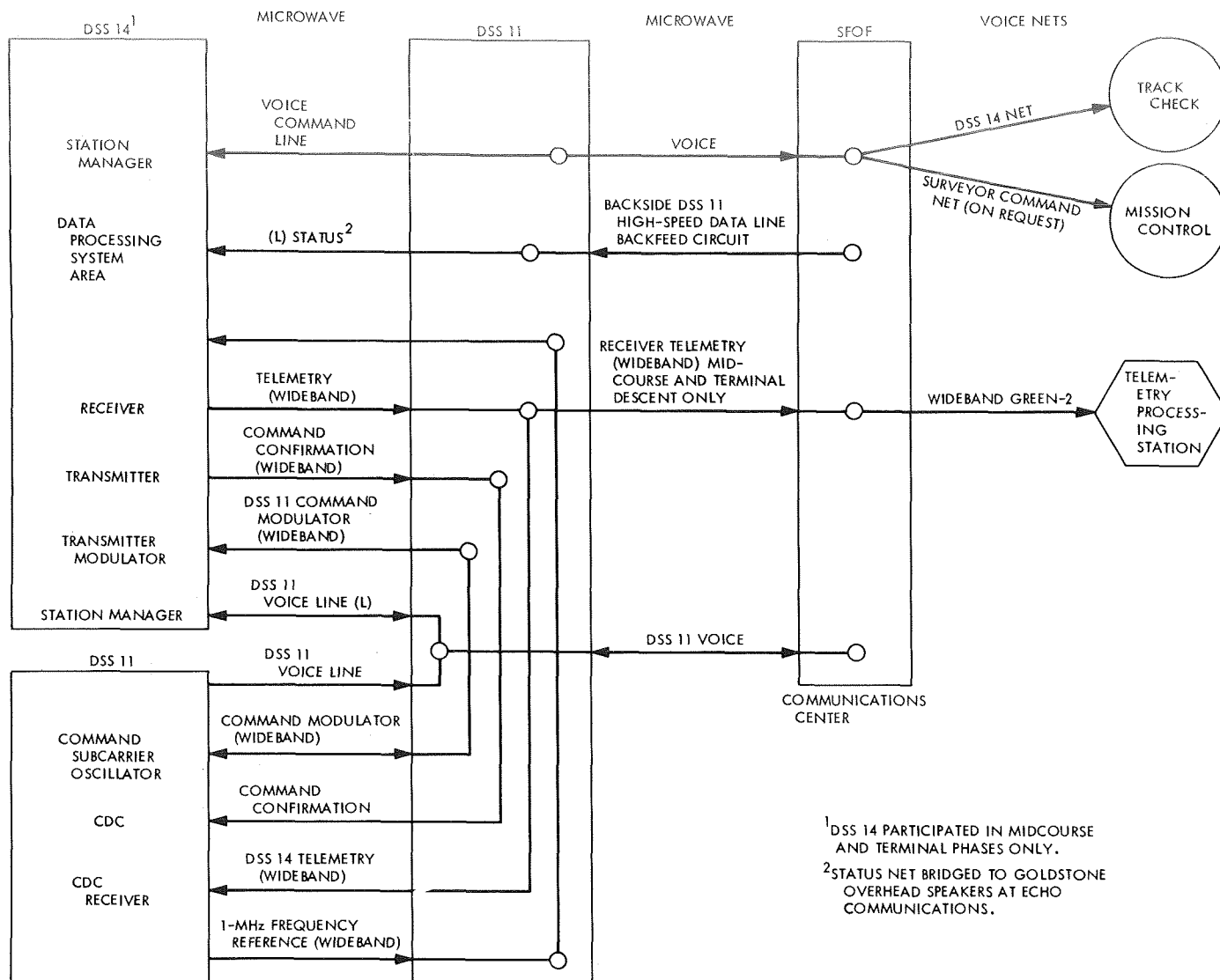


Fig. 28. NASCOM/GCF teletype routing for Surveyor VI



Circuit type/ mode	SFOF display designation	Direction of data (DSS-JPL)	Special circuit uses and remarks ^a
Voice	DSS 14 net	↔	Station voice line. DSIF control traffic
Voice	DSS 11 net	↔	DSS 11 voice line extended on (L) basis to allow DSS 14 to monitor voice commands to DSS 11
Video	None	DSS 14 to DSS 11	Wideband microwave channel used for DSS 14 command confirmation to DSS 11 CDC
Video	None	DSS 14 to DSS 11	Wideband microwave channel used for DSS 14 receiver. Spacecraft telemetry data to DSS 11 CDC receiver
Video	None	DSS 11 to DSS 14	Wideband microwave channel used for DSS 11 command modulation to DSS 14 transmitter
Wideband (96 kHz)	96 kHz	DSS 14 to DSS 11 and SFOF	Wideband microwave channel used for DSS 14 CDC receiver telemetry routed to Echo Communications, then split to DSS 11 CDC and SFOF telemetry processing station

^aStandard configuration for midcourse and touchdown will be DSS 14 receiver telemetry to SFOF telemetry processing station via 96-kHz line.

Fig. 29. Space Flight Operations Facility/DSS 14 initial circuit configuration diagram

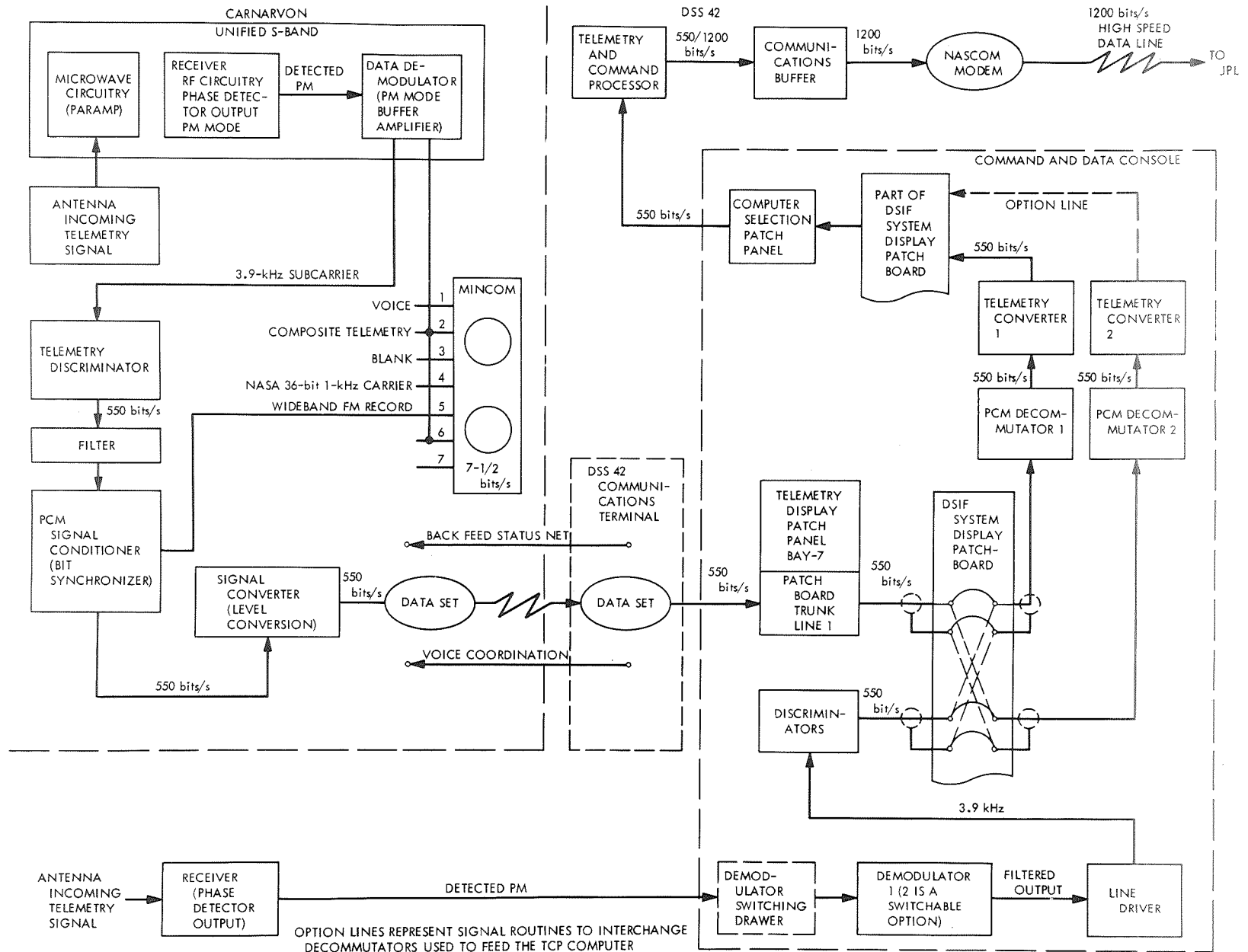


Fig. 30. Carnarvon/DSS 42 Surveyor VI spacecraft telemetry, circuit configuration

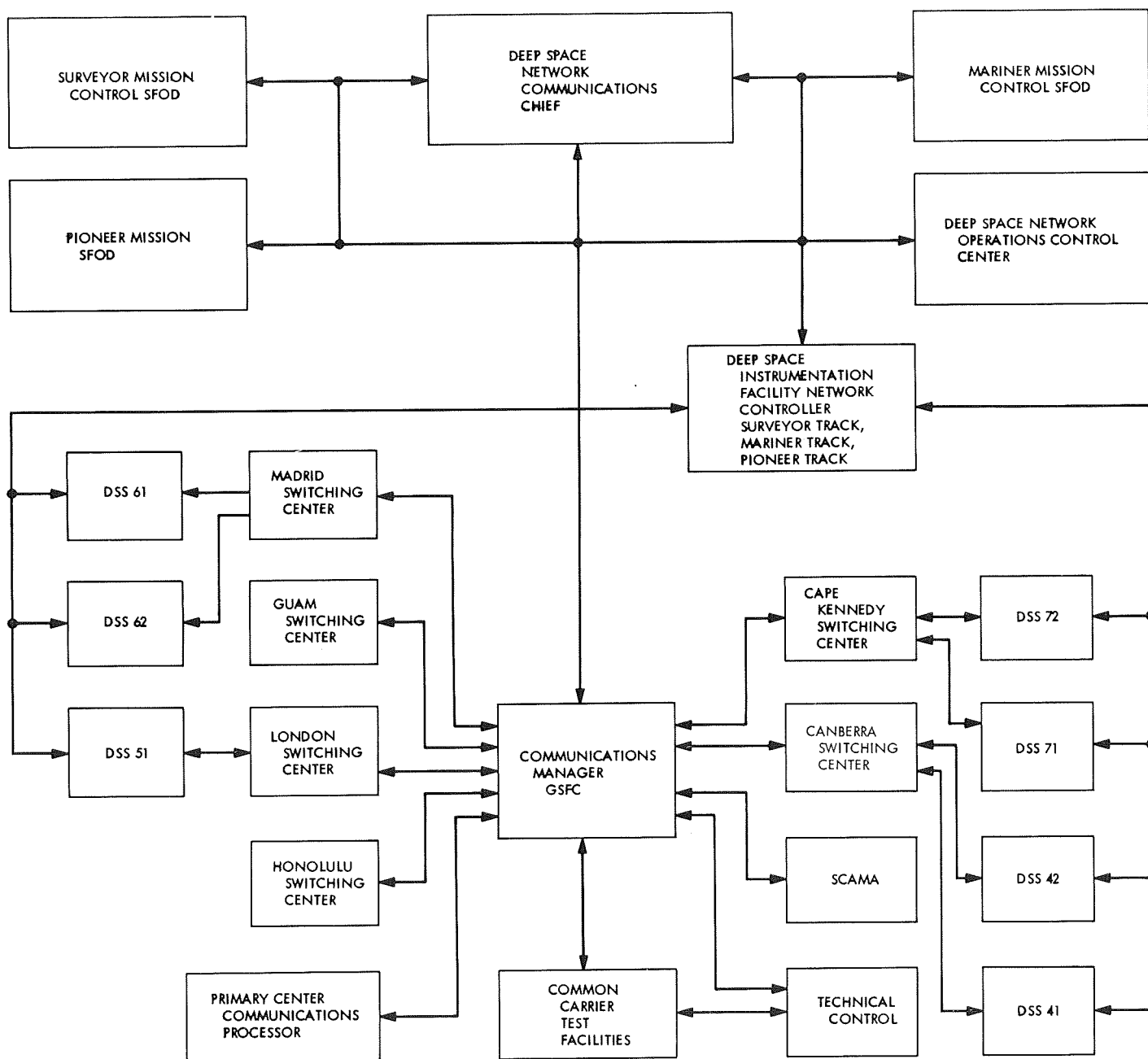


Fig. 31. Deep Space Network/GCF/communications processor/teletype circuit configuration

Problem areas. The following problem areas were encountered during the premission period:

- (1) At 14:00 (GMT), November 4, 1967, a failure occurred in the multiply-divide function of the 7094 Y computer central processing unit. This problem was discovered during the scheduled preventive maintenance period. The defective circuit card was replaced to correct the problem, returning the computer string to operational use at 18:40, November 4.
- (2) At 04:00, November 5, 1967, a drum parity error was encountered on the IBM 7320 drum of the 7044 Y computer. Diagnostic programs were run to determine the failure and none was found. The loss of the 7044 Y computer made it necessary to switch to the W string computer system to continue the testing. Support for *Surveyor* during this period was interrupted for 19 min.
- (3) At 06:42, November 5, 1967, the B-122 Burroughs card reader in area 6 started misreading cards. Maintenance found a dirty read lamp. Cleaning of the read lamp corrected this problem and the reader was placed back in operation at 06:55, November 5. Total loss of time was 13 min.
- (4) At 20:10, November 5, 1967, a carriage feed roller failed on the 7040 Y computer, 1403 printer 1. The roller was replaced and the printer was returned to operational status by 20:40, November 5. During this 30-min period, the 7040 Y computer output printing capability was reduced, causing only minor inconvenience.
- (5) At 03:00, November 6, 1967, the PDP-7 computer 1 could not gain access to the IBM 729 tape decks. Maintenance personnel found memory buffer bits 5 and 6 true at all times. The problem was corrected by placing pulse amplifier B201E and flip-flop BC620C. Operations were restored to normal at 06:00, November 6.
- (6) At 08:15, November 6, 1967, the data chief assigned at the data processing control center could not switch the I/O tasker console in area 6 from the W or Y computer strings. Maintenance personnel found that the computer selector switches on the I/O console were stuck in the on position. The selector switches were repaired and operation was restored to normal at 08:38, November 6.

- (7) At 03:35, November 7, 1967, the milgo plotter in area 6, encountered a plotter arm problem. There was a loss of the +20-V reference voltage to the plotter arm. The +20-V reference logic can, 4113C, was restored in the dc amplifier assembly. Normal operation was restored at 03:45, November 7.

Data systems section. Data systems operation performed real-time operation of computer systems, key-punch, expeditor/library functions, and nonreal-time computer operations for tracking data processing. Data processing support in the simulated data conversion center, telemetry processing system, and I/O user areas.

Operational control of these areas was provided at the data processing control area.

Communications section. In performing the tasks to support the *Surveyor VI* Mission, the communications section made use of two separately administered communications systems: the DSN GCF, and the SFOF ICS.

The GCF provided full-period, leased, four-wire voice circuits; full-period, full-duplex, leased teletype links; full-period, leased, high-speed data circuits for the purpose of transmitting spacecraft telemetry requiring a higher bit rate than that of teletype; full-period, leased, wideband data circuits between the SFOF and the Goldstone Deep Space Stations.

For teletype switching, the *Surveyor VI* Mission used the JPL communications processor. The communications processor is the switching center for DSSs 11, 12, 13, and 14 at Goldstone and HAC, and performs switching functions for data processing and operational functions within the SFOF. The communications processor capabilities include switching, real-time monitoring, quick-access message logging, 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 NASCOM system, and is the single access point for all DSN overseas and Cape Kennedy traffic.

The ICS provided a system for receiving, switching, and distributing all voice, teletype, and high-speed data and closed circuit television to all users in the SFOF.

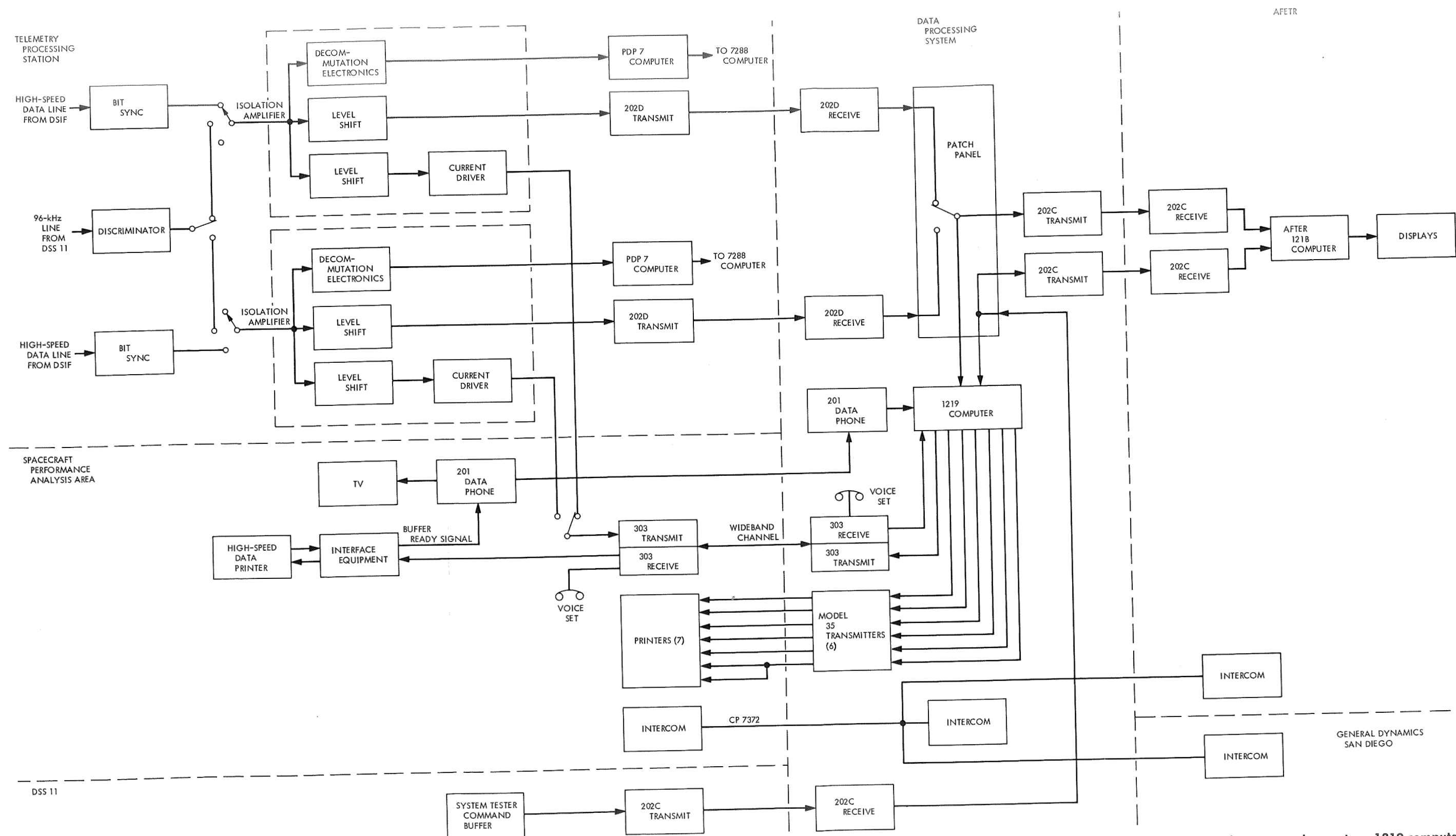
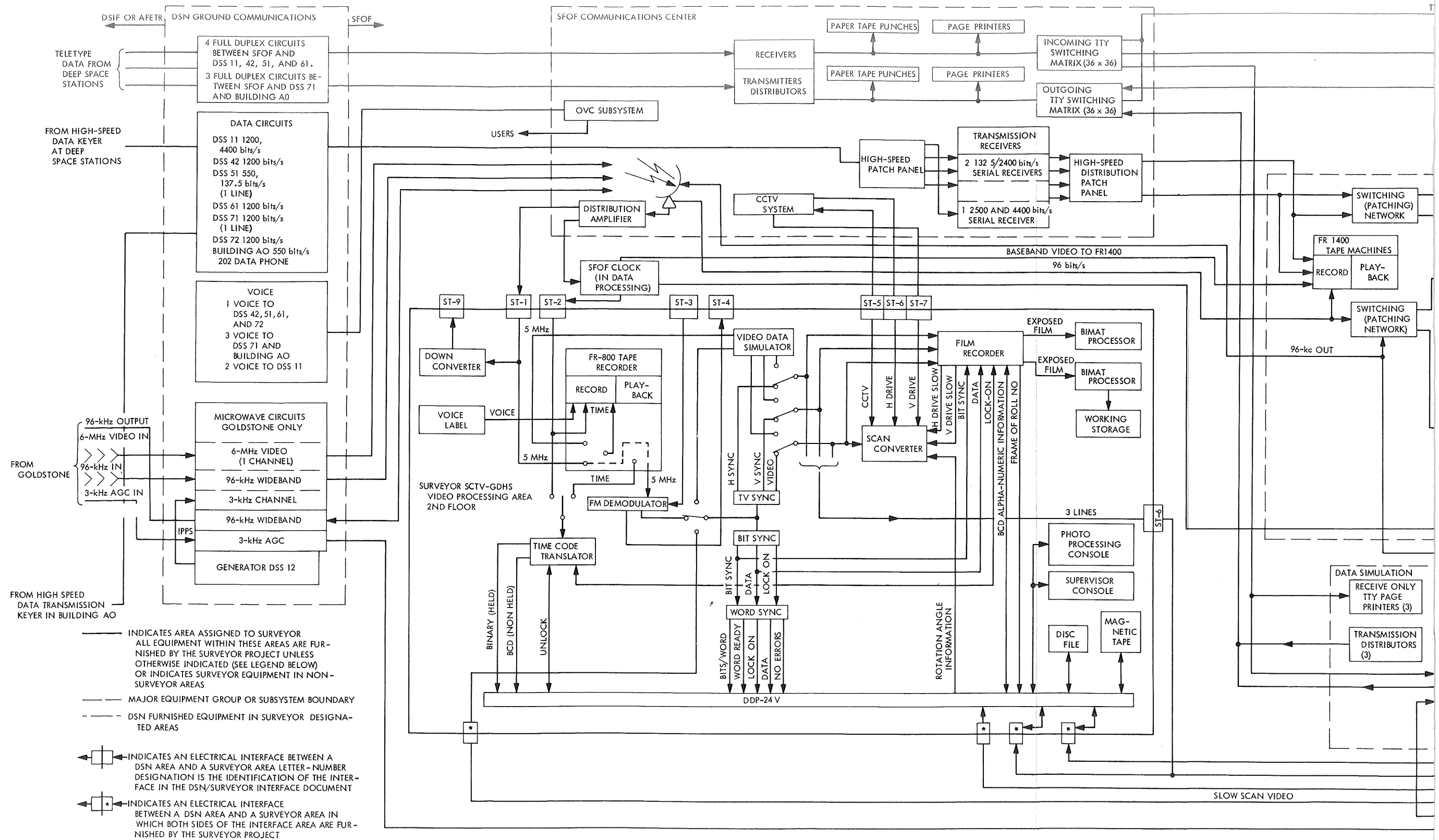


Fig. 32. Surveyor VI/SFOF data processing system, 1219 computer real-time telemetry processing system diagram



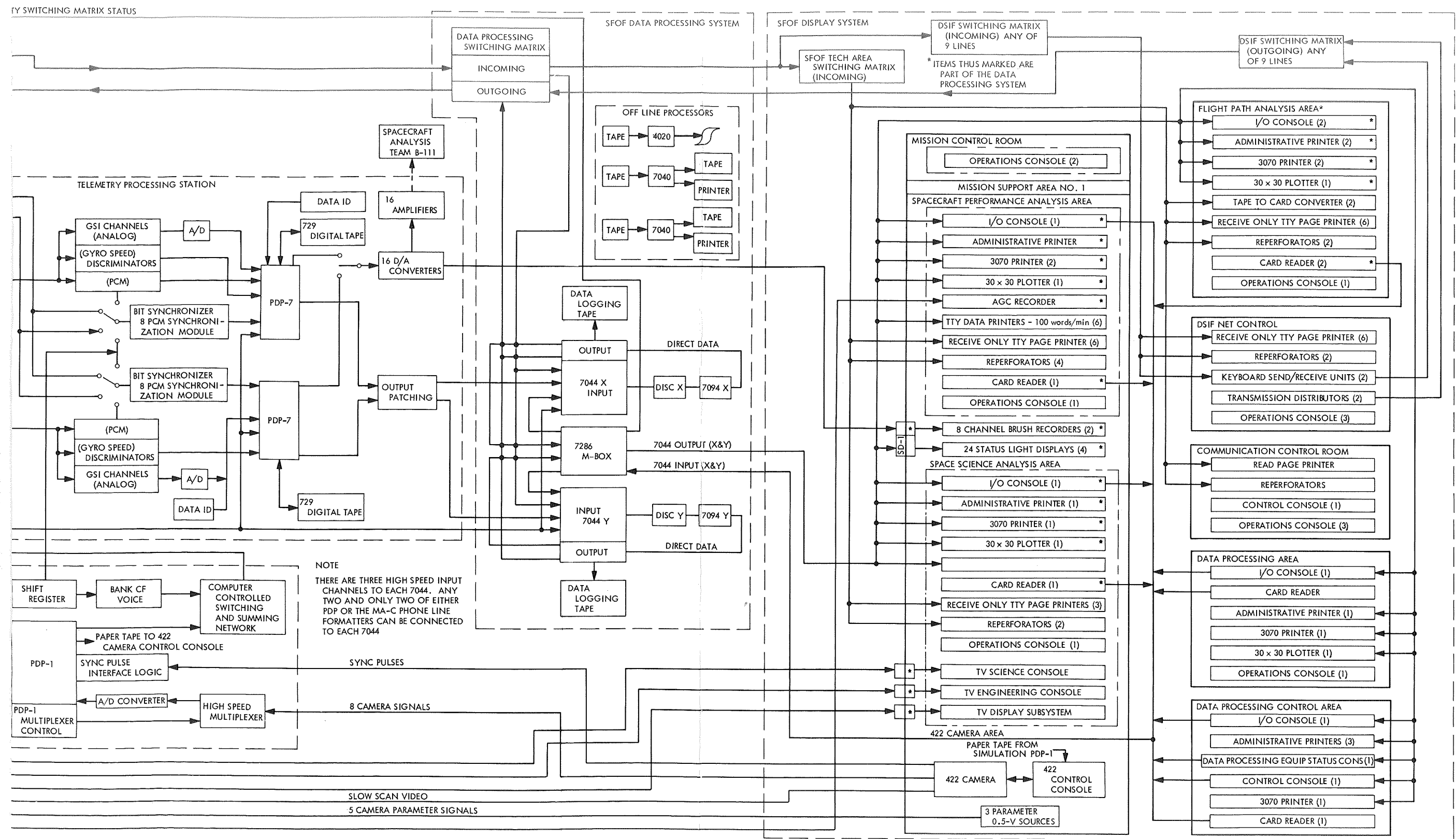


Fig. 33. Space Flight Operations Facility functional block diagram

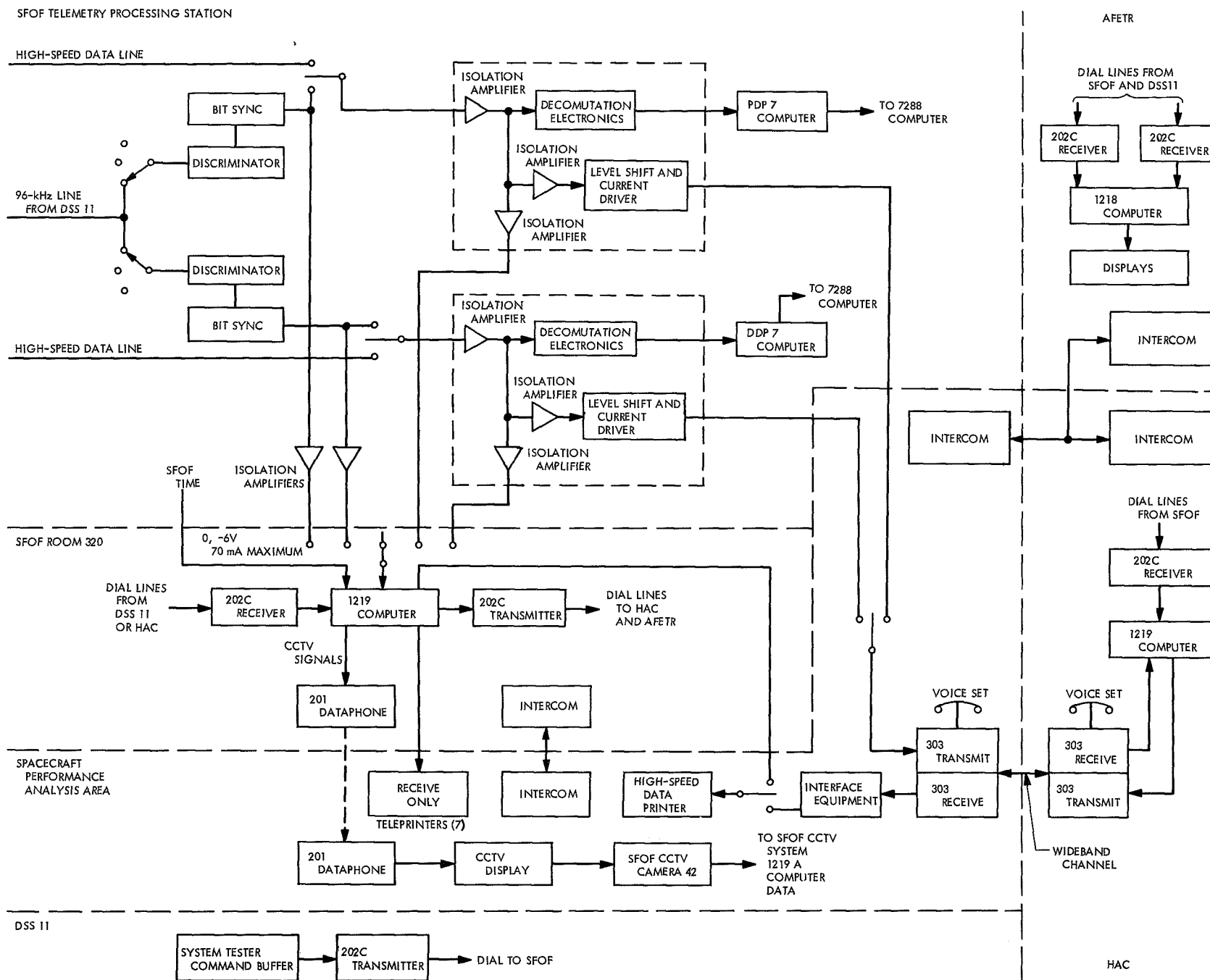


Fig. 34. Space Flight Operations Facility/1219 computer interface, Surveyor VI

Space Flight Operations Facility operations and support. Operations prepared and operated the display system, DSN monitoring system, and filled the support chief position. Support consisted of the following:

- (1) Internal access control.
- (2) Discrepancy reporting system.
- (3) Equipment failure reporting system.
- (4) Maintenance and operation of all electro/mechanical equipment and building facilities.
- (5) Scheduling of DSN resources and logistic services.
- (6) Reproduction services.

B. Tests

The *Surveyor VI* Mission required testing support to assure mission success. The various classes of tests, and the actual testing performed, are discussed in the subsequent paragraphs.

The facility internal tests (class A) were scheduled and conducted by each station manager and involve only the individual station. (There was Deep Space Station or SFOF participation.) The class A tests used the standard sequence of events and were employed as a countdown exercise. The two test phases were: those that prepare the station for class B tests, and those that were designed to train personnel for class C tests. Both test phases developed the ability of the personnel to use proper procedures and hardware within a time constraints. The prime stations continually perform significant sequences in the class A tests for practice, station countdown, and training of personnel.

The space flight operations/DSN functional compatibility tests (class B) ensured that the ground-based facilities are compatible with, and capable of processing, spacecraft command, telemetry, and video data. Class B tests were not performed in real-time and did not require adherence to operational procedures. Table 14 provides a summary of tests conducted prior to the *Surveyor VI* Mission.

The operational tests (class C) ensured that all elements of the space flight operations/DSN, including the technical and operational personnel, were capable of totally supporting the mission in accordance with the *Surveyor* space flight operations plan. The class C tests:

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

Table 14. Summary of tests conducted prior to the *Surveyor VI* Mission

Test	October	November
	2 9 16 23 30	6 13 20 27
Class B — communications processor/ 7044R, model 2 computer	Δ	
Flight training		Δ
Operational readiness		Δ

- (2) Included standard operational procedures and emphasized nonstandard operational procedures.
- (3) Required handling, processing, and interpretation of the full range of mission data under conditions of normal and degraded communications.
- (4) Generally established the operational readiness of the space flight operations /DSN for the *Surveyor* mission.

1. Air Force Eastern Test Range. The first two ORTs, conducted October 23 and 27, were not conclusive enough to assure that the telemetry retransmission system was ready to support the launch, and it was necessary to reschedule the telemetry portion of the test for October 30. Adequate data paths were not provided throughout the 8-h test duration.

Telemetry from alternate data paths was not available to the range user. The AFETR reported that alternate data paths had been established and checked out; however, they believed the switch panel at KSC did not allow data from these circuits to be sent to the range user. An action item was assigned to the range to investigate the capabilities of the switch panel for providing data from alternate paths to the range user. The AFETR also reported that data transmission problems would be eased if the NASCOM communication satellite circuits from Ascension could be released for their use. The AFETR participated in all tests, while the MSFN supported the tests on October 27 and November 5. The DSN participated in the final ORT on November 5.

a. Operational readiness tests. Two TDS tests were scheduled prior to the full project ORT. The ORTs are summarized in the subsequent paragraphs.

Operational readiness test 1. On October 23 ORT 1 was conducted without the support of the *Coastal Crusader*. Subcable support was not available either

because of a higher priority test. The following stations participated in the test:

- (1) Antigua.
- (2) RIS *Sword Knot*.
- (3) Ascension.
- (4) Pretoria.
- (5) RIS *Twin Falls*.

Although the total test time exceeded 6 h, no usable telemetry data were received from the real-time transmission system. The AFETR radars at Antigua, Ascension, Pretoria and the *Twin Falls* transmitted simulated metric data to the RTCS during this test. All data flow was good except for the *Twin Falls* data. A data tape was played from the *Twin Falls*, which was located at Antigua. The data, which contained many hits, were barely usable for orbital computations. The RTCS input and output of data appeared good.

Operational readiness test 2. On October 27 all MSFN and AFETR stations and ships scheduled to support the launch participated in ORT 2. Good telemetry checkouts with Grand Bahama, Antigua, Pretoria, Ascension and the *Coastal Crusader* were conducted in the minus count. The *Coastal Crusader* was reconfigured for vehicle data transmission. A hold of 30 min was called in an unsuccessful attempt to conduct a good telemetry checkout with the *Twin Falls* and the *Sword Knot*.

During the plus count, only Grand Bahama and Antigua provided usable data. The *Twin Falls* was held over after the test in an attempt to establish a good data circuit. This was unsuccessful, and the ship was finally released at approximately 20:00 GMT (total time in test 8 h). The *Sword Knot* was released because of the confidence built up from their demonstrated past performance.

The AFETR, MSFN and DSN metric data from ORT 2 were processed at the RTCS, although the acquisition messages for Grand Canary and Tananarive were sent late—the MSFN simulated tapes, and the data flow from the MSFN sites, proved satisfactory. The quality of the data played from the *Twin Falls* simulation tape was much improved. The RTCS performance was good with the exception of garbled DSS 51 predicts.

Reschedule of telemetry ORT—October 30. The intent of this test was to obtain a good checkout with each of the downrange stations and ships and then release them. Antigua and Grand Bahama were not scheduled to participate.

Good data were received from the *Coastal Crusader*. Ascension data were less than 20% usable; Pretoria approximately 15%; and the *Sword Knot* completely unusable. In each case, this was attributed to poor RF propagation and the stations were subsequently released. A repetitive error was noted in the *Twin Falls* data. This was cleared immediately after notifying the KSC telemetry coordinator.

Project ORT—November 5. All DSN, MSFN and AFETR stations and ships scheduled to support the near-earth phase of the *Surveyor VI* Mission participated in this test.

Good telemetry data were received from the *Twin Falls* throughout the minus and plus counts. Satisfactory checks with Ascension, Pretoria, and the *Sword Knot* had not been accomplished by $T - 90$ min. Checkout of the *Sword Knot* was completed by $T - 47$ min; however, no usable data were provided by Pretoria. Although previously planned, the NASCOM HF circuit from Ascension to Cape Kennedy was not used during this test. With vehicle data from the *Coastal Crusader* being relayed through Ascension, adequate data paths for spacecraft data were not available.

Metric support from Antigua and Ascension was not scheduled because of the flight azimuth. All metric tracking and computed data were delivered satisfactorily, with the exception of the DSS 51 predicts which were again garbled. This was cleared prior to launch.

2. Deep Space Network. The DSN supported the *Surveyor* Project test plan including various operational compatibility and integration tests. The tests conducted in preparation for the *Surveyor VI* flight are discussed in subsequent paragraphs.

a. Spacecraft SC-6/DSS 71 compatibility test. The primary objective of this test was to demonstrate the ability of a typical DSIF station, represented by DSS 71, to acquire command configuration with the spacecraft. This involved measuring those spacecraft and ground RF systems parameters that related to the command link. Such parameters include transmitter and receiver frequencies, receiver thresholds, and receiver acquisition and tracking ranges.

A secondary objective of this test was to obtain measurements of spacecraft SC-6 modulation parameters to verify that they are within the specified limits.

For this test, the spacecraft was encapsulated in the shroud, mounted on the launch vehicle on launch complex 36, and the entire assemblage was enclosed by the service tower. The directional RF link between the service tower and DSS 71 was used. Figure 35 shows the DSS 71 test configuration.

The variable attenuators between the antenna and the transmitter and receiver were for performing threshold tests of the spacecraft and ground receivers. The printer was used to print out an apparent biased doppler frequency during the narrowband, voltage controlled auxiliary oscillator frequency drift test. The spectrum analyzer provided a means of observing the spectral content of the wideband, voltage-controlled auxiliary oscillator during the wideband frequency modulation test. The wave analyzer and rms voltmeter (part of the wave analyzer) were used during the search for spurious signals and the carrier suppression and subcarrier sideband power tests. The magnetic recorder recorded all

test sequences. Transmitter frequency slewing was accomplished by use of the data input subsystem with particular program techniques. This programming allowed the frequency to be slewed at a prescribed rate and causes the computer to stop the slewing ramp when downlink, loss-of-lock occurs. During the automatic frequency control portion of the test, the computer was stopped manually when the system test equipment assembly telemetry engineer reported the occurrence of the desired spacecraft response.

The CDC at DSS 71 was used to command the spacecraft during all test periods, except power turn on. Command modulation was applied for all uplink tests except automatic phase control and automatic frequency control acquisition frequencies test.

C. Test Results

The data presented in this subsection describes the spacecraft SC-6 compatibility test conducted by DSS 71

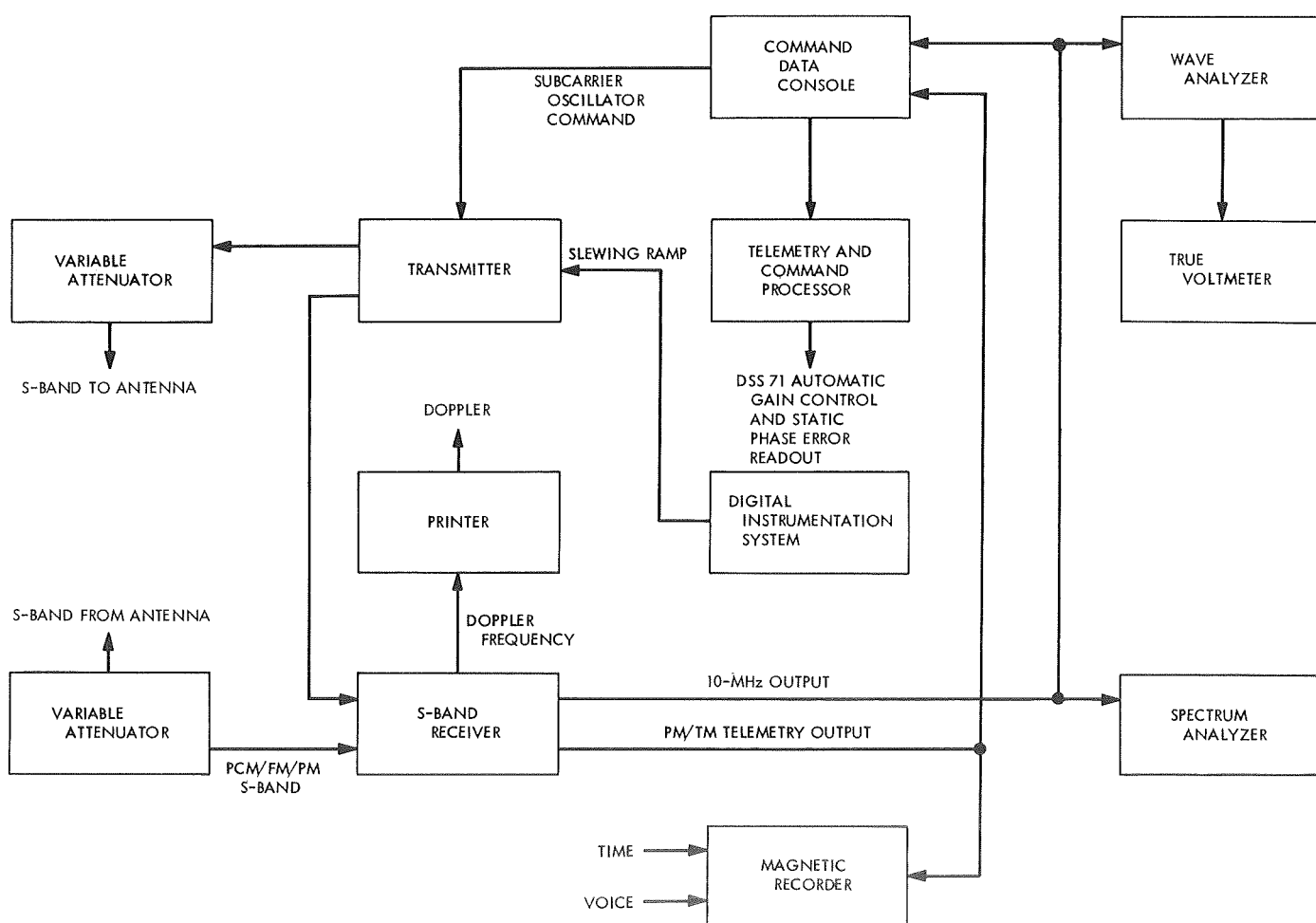


Fig. 35. Test configuration for DSS 71

on September 28-29, 1967. The spacecraft calibration data, corresponding to telemetered data numbers, was obtained from the telemetry calibration handbook for spacecraft SC-6. If allowance is made for measurement accuracy, the spacecraft and ground systems performed within specified limits in the cases where specifications are clearly defined.

1. Spurious signals. The downlink spectrum was searched for spurious signals under the following conditions:

- (1) Two-way phase lock, high-power mode.
- (2) One-way phase lock, high-power mode, transponder on.
- (3) One-way phase lock, high-power mode, transponder off.

All tests were performed for both transmitters A and B. Only signals within 30 dB of the carrier were reported. Test results are listed in Table 15 for transmitter A and Table 16 for transmitter B.

The only signals noted in the spectrum were carrier or telemetry components. Variations in the observed frequencies were caused by carrier frequency drift while in the high-power mode and not in two-way lock.

During initial testing of spacecraft transmitter A, the 3.9-kHz telemetry components did not appear to be present at normal power levels. At the conclusion of the compatibility test, the spacecraft was reconfigured to the conditions required for the spurious signal test and the test rerun. At this time, telemetry components appeared to be at the expected levels. No explanation to the original anomaly is known.

2. Carrier suppression and sideband power. The specified values of carrier suppression and P_s/P_t (total first-order sideband power relative to the unmodulated carrier) were arrived at and the results indicated that the spacecraft modulation parameters were within the specified limits if the measurement uncertainty was taken into account. The results are tabulated in Table 17.

Table 15. Results of spurious signal test for transmitter A

Test step	DSS 71 receiver frequency, MHz	Δ Frequency, kHz	Received signal level, dBmW	Relative power, dB	Remarks
002.006	2294.997920	0	-74	0	Carrier
	2295.001568	+3.648	-98	-24	Telemetry
	2294.994368	-3.552	-98	-24	Telemetry
002.017 ^a					
002.021 ^a					

^aDuring initial test of transmitter A, the 3.9-kHz telemetry sidebands were not present within 40 dB of carrier. At the conclusion of the compatibility test, the spacecraft was configured to the parameters required for test step 002.006 and data appeared nominal.

Table 16. Results of spurious signal test for transmitter B

Test step	DSS 71 receiver frequency, MHz	Δ Frequency, kHz	Received signal level, dBmW	Relative power, dB	Remarks
002.006	2295.005888	0	-74	0	Carrier
	2295.009632	+3.744	-100	-26	Telemetry
	2295.001760	-4.128	-100	-26	Telemetry
002.017	2294.985248	0	-74	0	Carrier
	2294.988704	+3.456	-99	-25	Telemetry
	2294.981120	-4.128	-102	-28	Telemetry
002.021	2294.981120	0	-74	0	Carrier
	2294.984768	+3.648	-100	-26	Telemetry
	2294.977472	-3.648	-100	-26	Telemetry

Table 17. Carrier suppression and subcarrier sideband power test results

Test step	Subcarrier oscillator center frequency, kHz	Measured sideband frequency, kHz ^a		Carrier suppression, dB		P _c /P _i , dB		Transmitter
		Lower	Upper	Measured ^a	Specification	Measured ^a	Specification	
002.029	3.9 signal processing auxiliary low power	3.691	3.690	-0.2	+0.04 -0.2 -0.04	-13.75	+0.8 -13.6 -0.9	A
		3.691	3.691	0.0	+0.04 -0.2 -0.04	-13.1	+0.8 -13.6 -0.9	B
002.039	0.560	0.555	0.553	-5.3	+1.17 -5.36 -1.42	-1.85	+0.29 -2.18 -0.44	A
		0.555	0.554	-5.75	+1.17 -5.36 -1.42	-1.5	+0.29 -2.18 -0.44	B
002.051	7.35 0.96 multiplex 1.30 1.70	6.955 0.916 1.256 1.656	6.954 0.915 1.255 1.656	-4.7	+0.95 -4.84 -1.07	-8.0 -11.25 -11.25 -11.25	+1.17 -7.39 -1.34 +1.50 -11.11 -1.69	A
		6.956 0.916 1.256 1.656	6.955 0.915 1.255 1.656	-4.5	+0.95 -4.84 -1.07	-8.12 -11.12 -11.12 -11.12	+1.17 -7.39 -1.34 +1.50 -11.11 -1.69	B
002.072	33	31.584	31.776	-7.0	+1.56 -6.83 -1.96	+1.0 -2.0 -1.0	+0.16 -1.87 -0.33	A
		31.584	31.776	-6.25	+1.56 -6.83 -1.96	+1.0 -3.0 -1.0	+0.16 -1.87 -0.33	B
002.081	3.9 signal processing auxiliary high power	3.606	3.605	-0.2	+0.04 -0.2 -0.04	-13.9	+0.8 -13.6 -0.9	A
		3.607	3.605	0.0	+0.04 -0.2 -0.04	-13.5	+0.8 -13.6 -0.9	B

^aAll measurements ±0.5 dB unless otherwise indicated.

3. *Receiver threshold.* The DSS 71 receiver threshold was measured utilizing various telemetry modes for both spacecraft transmitters. These results are tabulated in Table 18. The measured threshold values were approximately 1-4 dB below theoretical values. No degradation

due to telemetry modes was noted. The theoretical threshold equals:

$$P_c = -198.6 + 10 \log 13269 + \log 12$$

where

13269 = system noise temperature, °K

12 = receiver loop bandwidth, Hz

$P_c = -146.6$ dBmW

4. Subcarrier oscillator frequencies and telemetry error rates. Pulse code modulator bit error rates were measured in two modes for each transmitter. All bit error rates appeared normal for the signal-to-noise ratios measured as indicated by Table 19.

Voltage levels corresponding to the points illustrated in Fig. 36 were measured. These are tabulated in Table 20. From these data, it was determined that all measurements were within subcarrier oscillator (SCO) center frequency tolerances, with the exception of the 3.9-kHz SCO on spacecraft transmitter B which indicates approximately 44 Hz of static offset.

5. Narrowband voltage-controlled auxiliary oscillator drift. Frequency change and transmitter temperature were measured for a 40-min period following high power turnon. The test results indicate a maximum rate of change in transmitter A of 2.7 Hz/s. The temperature change on transmitter A was 60°F. The maximum rate of change in transmitter B was 4.4 Hz/s. The temperature change of transmitter B was 35°F as indicated in Figs. 37 and 38.

6. Wideband frequency modulator telemetry. The spacecraft was commanded to the wideband voltage-controlled auxiliary oscillator mode and spacecraft transmitter frequency measured. For transmitter A, the frequency was 2294.934656 MHz. For transmitter B, the frequency was 2295.019328 MHz. No spurious signals were observed for either transmitter. Twenty minutes of high power operation caused frequency shifts of 3.1 kHz for transmitter A and 4.8 kHz for transmitter B.

Table 18. Deep Space Instrumentation Facility receiver threshold test results

Test step	Telemetry mode, kHz	Strong signal		Threshold		Spacecraft transmitter
		Attenuator, dB	Pulse code/automatic gain control, dBmW	Attenuator, dB	Pulse code/automatic gain control, dBmW	
002.034	3.9 SPA low power	27	-91	83	-147	A
		26	-91	86	-151	B
002.046	0.560 low power	27	-96	79	-148	A
		26	-98	77	-149	B
002.057	7.35 plus strain gages low power	27	-96	80	-149	A
		26	-96	79	-149	B
002.075	33 low power	27	-96	79	-148	A
		26	-99	77	-150	B
002.087	3.9 SPA high power	27	-74	— ^a	— ^a	A
		26	-74	— ^a	— ^a	B

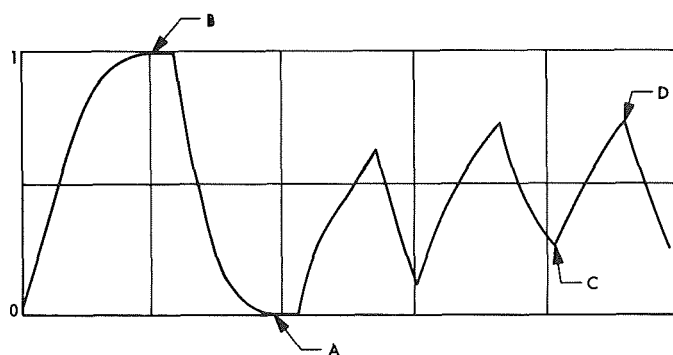
^aUnable to measure threshold values due to excessive RF leakage in the DSS-71 receiver. Levels correlate down to -140 dBmW but threshold could not be achieved.

Table 19. Parity error rate measurements

Test step	Transmitter	Mode, kHz	Discriminator bandpass signal-to-noise ratio		Parity error rate		
			Calculated, dB	Measured, dB	Bits	Errors	Rate
005.007	A	7.35 kHz plus strain gages	12	11.8	100,024	6	6×10^{-5}
	B		12	11.4	100,165	91	9.1×10^{-4}
005.043	A	0.560 kHz	12	12.0	10,005	0	0
	B		12	12.2	10,002	0	0

Table 20. Discriminator output voltages for PCM data

Mode, kHz, subcarrier oscillator	Voltages at test points, V				Space- craft trans- mitter
	A	B	C	D	
7.35 plus strain gages	-2.6	+2.5	-0.6	+0.9	A
	-2.5	+2.4	-0.9	+1.1	B
3.9 SPA	-2.8	+2.5	-0.95	+0.8	A
	-3.0	+2.2	-1.4	+0.6	B
0.560	-2.6	+2.5	-1.0	+1.0	A
	-2.7	+2.5	-1.1	+0.9	B
33	-2.6	+2.5	-0.6	+0.9	A
	-2.6	+2.6	-0.6	+0.9	B



- A = DISCRIMINATOR OUTPUT VOLTAGE CORRESPONDING TO BINARY 0 WHEN TWO OR MORE 0s IN A ROW ARE TRANSMITTED
- B = DISCRIMINATOR OUTPUT VOLTAGE CORRESPONDING TO BINARY 1 WHEN TWO OR MORE 1s IN A ROW ARE TRANSMITTED
- C = DISCRIMINATOR OUTPUT VOLTAGE CORRESPONDING TO BINARY 0 WHEN ALTERNATE 1s AND 0s ARE TRANSMITTED
- D = DISCRIMINATOR OUTPUT VOLTAGE CORRESPONDING TO BINARY 1 WHEN ALTERNATE 1s AND 0s ARE TRANSMITTED

Fig. 36. Pulse code modulator waveform test points

The spacecraft was then commanded through the following modes and the PCM discriminators and decommutators were locked in each mode:

- (1) 33-kHz SCO at 4400 bits/s.
- (2) 7.35-kHz SCO at 1100 bits/s.
- (3) 3.9-kHz SCO at 550 bits/s.

When testing spacecraft transmitter B, the 3.9-kHz SCO was commanded ON before the 7.35-kHz SCO was commanded OFF. At this time, the 3.9-kHz discriminator signal-to-noise ratio was observed to be very low. The CDC decommutator would not stay in lock due to excessive errors. The 7.35-kHz SCO was commanded OFF and the condition did not change. When the demodulator

input switch on the CDC demodulator was switched from wideband FM to narrowband FM position, the 3.9-kHz discriminator indicated a strong signal and the decommutator locked up with no problem. At the conclusion of the compatibility test, the spacecraft was returned to the configuration required and the 3.9-kHz SCO was checked. All indications were normal and the previous problem could not be duplicated. No explanation of this is known.

7. Six hundred-line TV frequencies. Spacecraft frequencies corresponding to TV sync, porch, PCM one and PCM zero were measured. Before the measurement, the DSIF receiver was adjusted so that the 10-MHz output to the CDC was exactly 10 MHz. This was done with the spacecraft transmitter on wideband voltage-controlled auxiliary oscillator, high power RF mode and survey TV camera power off. Both transmitter outputs were identical and the measured frequencies referenced to the 10-MHz output are shown below.

Parameter	Frequency, MHz
Sync tip	-1.24
Porch	-0.72
PCM one	0.68
PCM zero	1.22

The transfer curve of the CDC FM demodulator used to obtain the TV frequencies is shown in Fig. 39.

8. Spacecraft receiver phase-lock threshold. The results of this test and the tests for automatic frequency control threshold are tabulated in Table 21. Both receivers met or exceeded the threshold specification at best-lock frequencies. No specification is known for threshold at ± 70 kHz. Receiver A degraded 13.7 dB at 70 kHz and receiver B degraded 9 dB at 70 kHz. This amount of degradation has been observed on prior spacecraft. The test was conducted with command modulation applied.

9. Spacecraft receiver automatic frequency control threshold. The threshold of both receivers at ± 50 kHz was comparable to thresholds measured on previous spacecraft. No specification for this is known.

10. Spacecraft receiver phase-lock tracking range. The results of the automatic phase control and automatic frequency control thresholds, acquisition frequencies, and tracking range tests are listed in Table 22 and shown

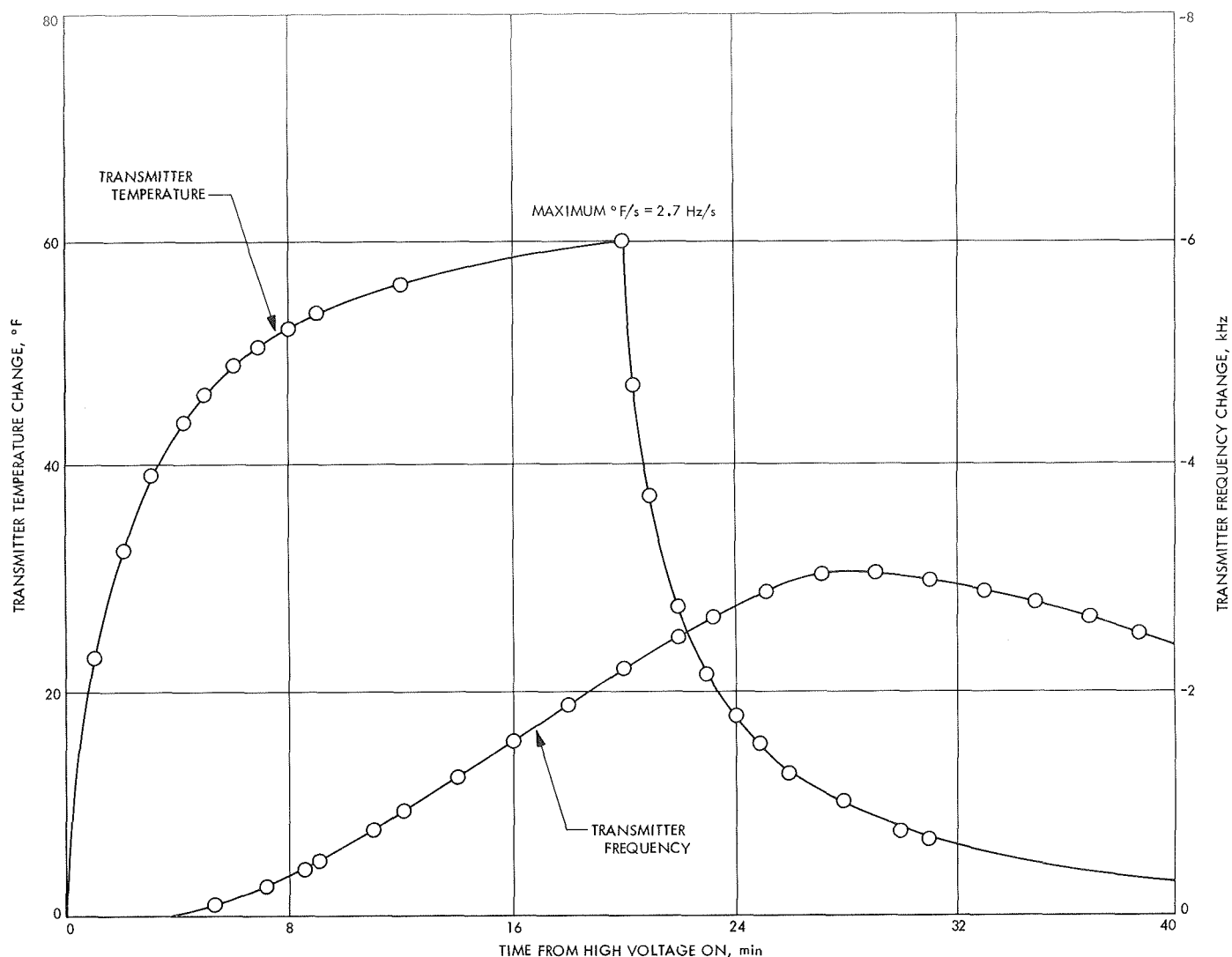


Fig. 37. Transmitter A, narrowband voltage-controlled oscillator drift rate

on Figs. 40 and 41. Receiver A tracking range exceeded ± 19 kHz at 3 dB above threshold. Receiver B tracking range exceeded ± 27 kHz at 3 dB above threshold. At strong signal, both receivers exceeded ± 70 kHz.

11. Spacecraft receiver phase-lock acquisition frequencies. The results of these tests are given in Table 23 and shown on Fig. 40 and 41. Results of this test indicate the following best-lock frequencies:

Receiver	Frequency, MHz	Temperature, °F
A	2113.311264	84.92
B	2113.320240	82.27

12. Automatic frequency control tracking range. The tracking range at both strong and weak signal levels was greater than ± 50 kHz for both receivers.

13. Automatic frequency control acquisition frequencies. The results of this test are tabulated in Table 24 and shown in Figs. 40 and 41. The acquisition frequencies indicate the following automatic frequency control center frequencies.

Receiver	Frequency, MHz	Temperature, °F
A	2113.315440	83.15
B	2113.317648	81.38

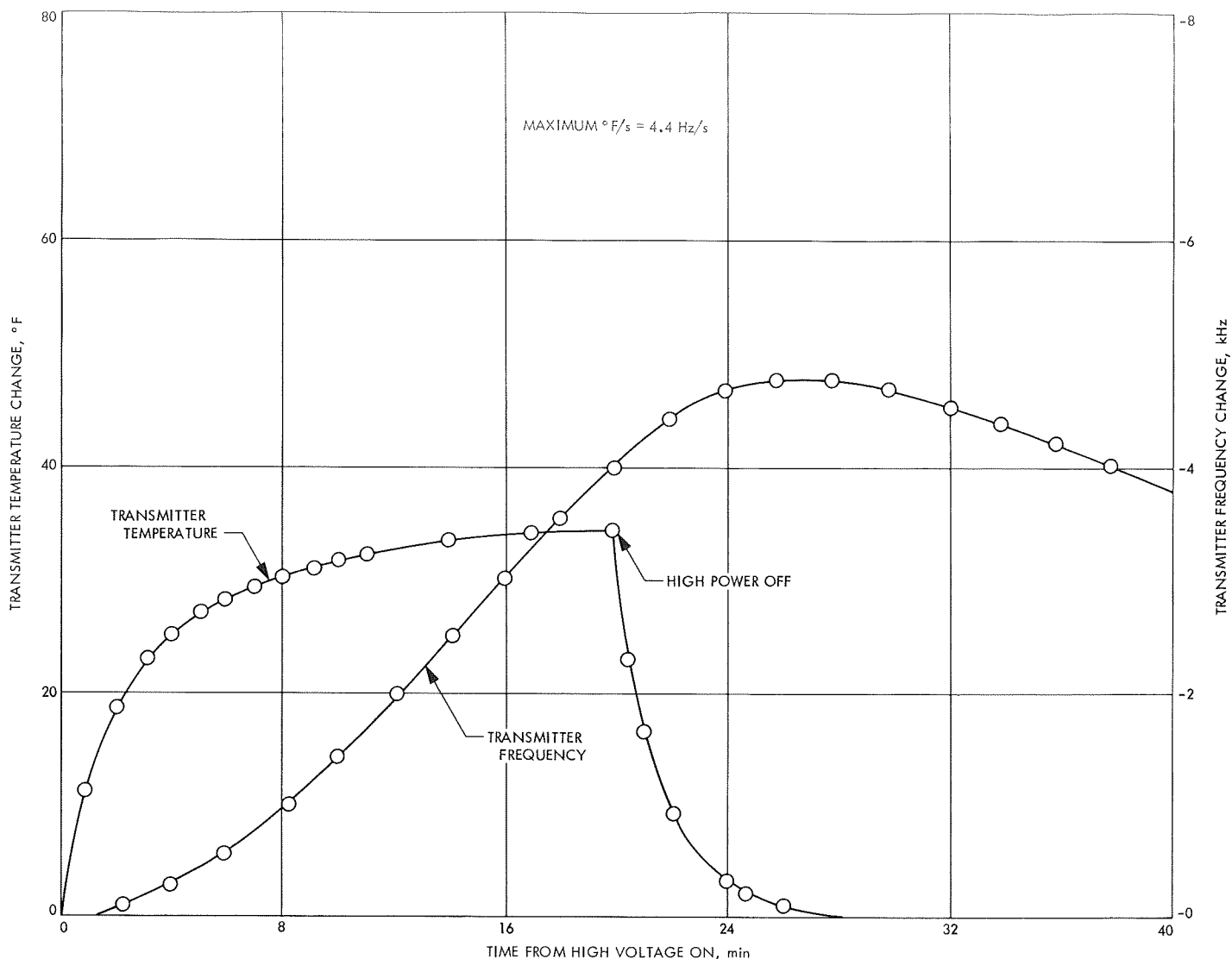


Fig. 38. Transmitter B, narrowband voltage-controlled oscillator drift rate

D. Conclusions

1. *Spacecraft SC-6/DSS 71 compatibility test.* The spacecraft and DSS 71 systems met, or exceeded, test requirements except the 3.9-kHz SCO on the spacecraft transmitter B indicates a static offset of approximately 44 Hz. The antenna at the service tower was boresighted on DSS 71 during this test. This provided a more stable RF link than has been observed on previous tests and resulted in a shorter test time.

2. *Class B test for 7044R computer program, model 2.* The 7044 computer real-time program was updated to the model 2 version between *Surveyors V* and *VI* Missions. This necessitated a test, which was conducted on October 13, to qualify the new version. "Canned" telemetry and tracking data were used along with selected test

cases for the spacecraft performance analysis and command computer programs. Command confirmation network data were generated at DSS 61 and routed through the system. An unsuccessful attempt was made to prepare a command tape message for transmission to DSS 61.

During the test, the AGCM, CPPM, PLAS, and SCPS programs were run with no problems; however, the CVTS program failed to operate in the "prepare to transmit" mode. This made it impossible to transmit the message generated by SCPS to DSS 61. The failure would not repeat at a later date, and the cause has not been determined.

Numerous minor errors occurred in the telemetry displays, but most were corrected prior to launch. As a

Table 21. Spacecraft receiver threshold test results

Test step	Receiver	Mode ^a	Strong signal			Threshold			Remarks
			Attenuator, dB	Receiver, dB	Automatic gain control, dBmW	Attenuator, dB	Receiver, dBmW ^b	Specification, dBmW ^c	
003.007	A	APC	22.5	125	-101.7	56.5	-135.7	-128.5	Best-lock frequency
	B		22.5	143	-98.1	50.5	-126.1	+2.3 -1.8	
003.010	A	APC	22.5	123	-101.4	44.5	-123.4	None	+70 kHz from best lock
	B		22.5	143	-98.1	40.5	-116.1		
003.013	A	APC	22.5	123	-101.4	42.5	-121.4	None	-70 kHz from best lock
	B		22.5	144	-98.4	42.5	-118.4		
003.037	A	AFC	22.5	123	-101.4	43.5	-122.4	None	-50 kHz from center frequency
	B		22.5	145	-98.7	40.5	-116.7		
003.043	A	AFC	22.5	124	-101.5	43.5	-122.5	None	+50 kHz from center frequency
	B		22.5	147	-99.2	40.5	-117.2		

^aAPC = automatic phase control; AFC = automatic frequency control.

^bTotal power.

^cCarrier power.

result of this test, the 7044R computer program, model 2, was certified for the *Surveyor VI* Mission.

3. *Class C series, flight training tests.* The objective of this test was to maintain and improve the efficiency of the personnel within the SFOF and selected portions of the DSN. Particular emphasis was placed on the critical portions of the mission that occur during the transit phase. The test was conducted in two segments covering the following parts of the transit sequence of events:

- (1) Midcourse: first run, $M - 2$ h, 45 min, to $M + 20$ min, second run, $M - 50$ min, to $M + 20$ min.
- (2) Terminal: R (retromaneuver) - 2 h 45 min, to TD (touchdown) + 36 min.

Both midcourse and terminal segments of the test were accomplished on the same day (November 5). In each segment, spacecraft and/or space flight operations system anomalies were simulated by the test conductor and simulation team.

The midcourse segment of the test was divided into two phases. In the first phase when the telemetry was switched from mode 5 to mode 4, DSS 11 reported that

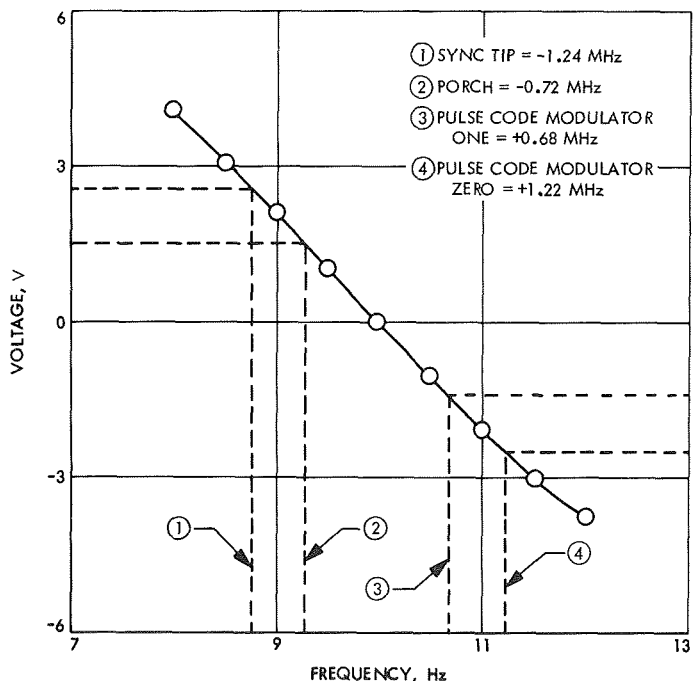


Fig. 39. Demodulator frequency response

they were not able to achieve decommutator lock. Subsequent investigation by station personnel determined that the Barker word was missing from the sync pattern

Table 22. Spacecraft receiver phase-lock tracking range^a

Test	Near threshold			Strong signal		
	Test step	Receiver A	Receiver B	Test step	Receiver A	Receiver B
Conditions						
Spacecraft receiver temperatures, °F		84.92	82.27		84.04	82.27
DSS 71 transmitter attenuator, dB		53.5	47.5		22.5	22.5
Spacecraft receiver input power, dBmW		-132.4	-123.1		-101.5	-98.1
Results						
Lower frequency limit, MHz	003.018	2113.296960	2113.294560	003.024	2113.238496	2113.249632
Upper frequency limit, MHz	003.020	2113.335168	2113.349760	003.026	2113.379136	2113.390560
^a Best-lock frequencies as determined from no signal static phase error at beginning of test with receiver A at 2113.3118140 and receiver B at 2113.317936.						

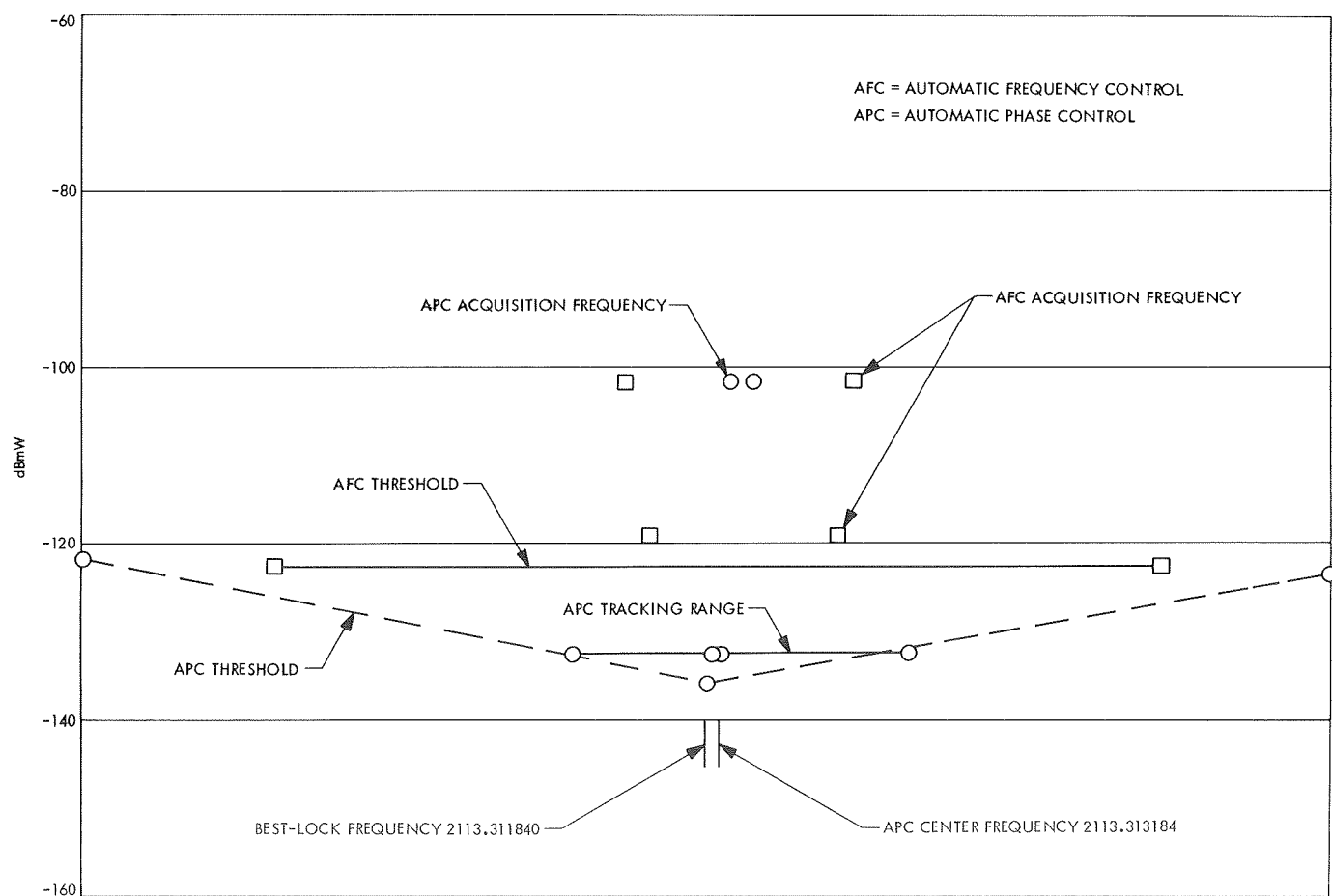


Fig. 40. Spacecraft SC-6 receiver A automatic frequency control and automatic phase control acquisition and tracking frequencies

in data frames from the engineering commutators. With this knowledge available, it was possible to program the decommutator to recognize the Barker complement and to maintain lock. No further anomalies were encountered until the flight control programmer was loaded with the quantity for the first premidcourse maneuver. At this time, the maneuver started without being commanded. Various other anomalies occurred and were compounded by frequent data outages. As a result, the spacecraft performance analysis and command group could not configure the spacecraft for a midcourse burn within the time constraints imposed by the flight-path-analysis area. An alternate midcourse maneuver was recommended. Upon investigation, it was determined that the simulation did not fully support the planned flight control anomaly and was misleading to the spacecraft performance analysis and command group.

The second midcourse phase was delayed for approximately 20 min because of an equipment failure in the

communications processor area. Ten minutes after the test started, the I/O console in the spacecraft performance analysis area failed and the engineering computer program operation group was forced to move to the flight-path-analysis area. After several relatively minor flight control anomalies, the midcourse thrusting was accomplished 1 min late. It was apparent from this test that data handling operations are severely handicapped if the engineering computer program operations group cannot operate in the spacecraft performance analysis area.

In the terminal segment of the test, the flight control programmer register would not accept the maneuver quantity for the first maneuver and the maneuver was accomplished using the manual delay mode. The other maneuvers were performed normally in the automatic mode. Operations proceeded normally until just prior to AMR Power On when the spacecraft signal level dropped approximately 20 dB. The spacecraft performance analysis and command group recommended the use of the

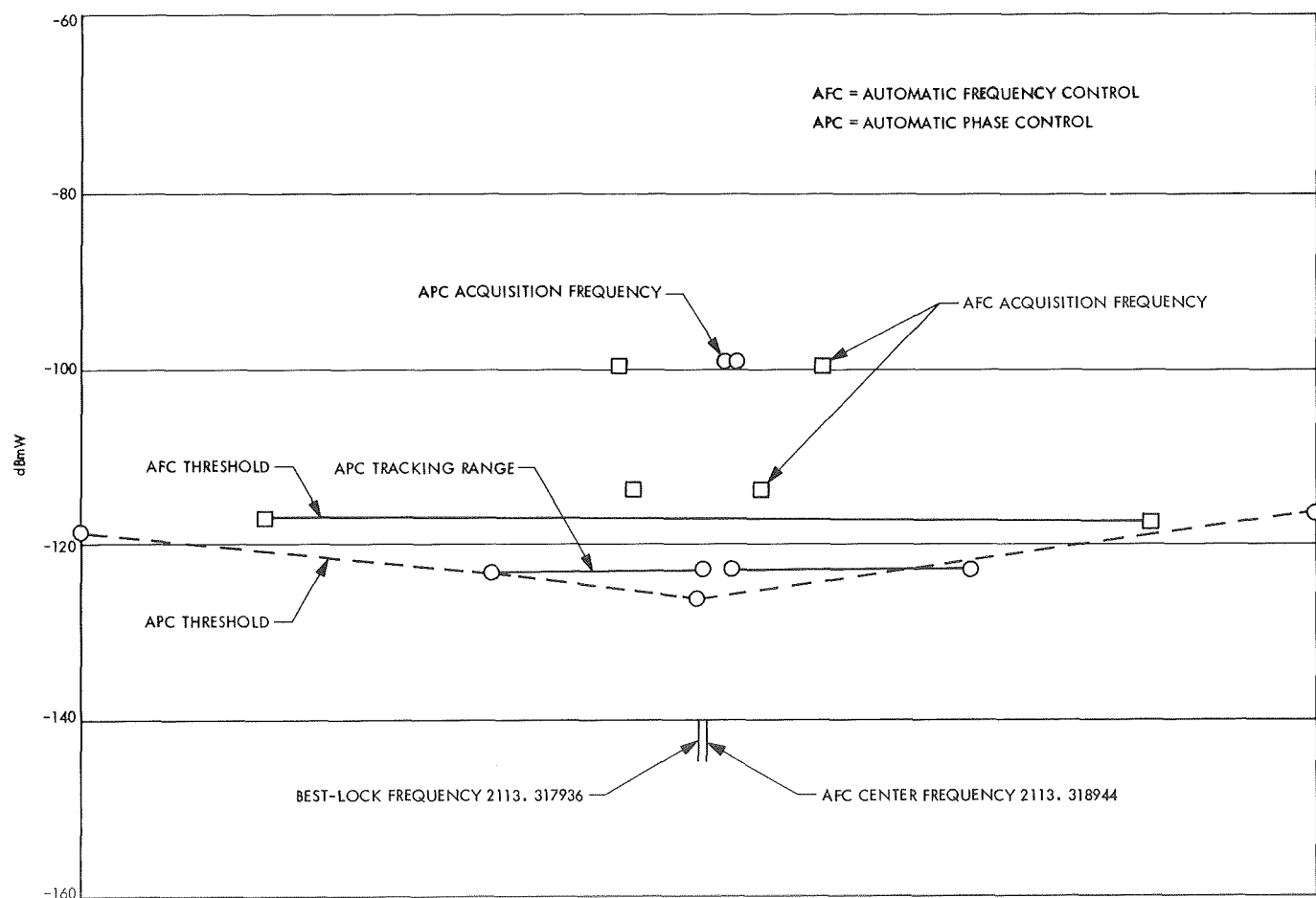


Fig. 41. Spacecraft SC-6 receiver B automatic frequency control and automatic phase control acquisition and tracking frequencies

Table 23. Spacecraft receiver phase-lock acquisition frequencies test^a

Test	Near threshold			Strong signal		
	Test step	Receiver A	Receiver B	Test step	Receiver A	Receiver B
Conditions						
Spacecraft receiver temperature, °F		84.92	82.27		82.27	82.27
DSS 71 transmitter attenuator, dB		53.5	47.5		22.5	22.5
Spacecraft receiver input power, dBmW		-132.7	-123.1		-101.5	-98.1
Results						
Lower acquisition frequency, MHz	003.019	2113.312416	2113.321728	003.025	2113.316832	2113.322304
Spacecraft receiver automatic gain control, dBmW		-132.7	-123.1		-101.5	-98.7
Spacecraft receiver static phase error, kHz		3.3	2.2		6.8	2.2
Acquisition relative to best lock, kHz		0.6	3.8		4.9	4.3
Upper acquisition frequency, MHz	003.021	2113.310112	2113.318752	003.027	2113.314528	2113.320384
Spacecraft receiver automatic gain control, dBmW		-132.7	-123.1		-101.5	-98.7
Spacecraft receiver static phase error, kHz		0.2	-1.3		4.4	0.5
Acquisition relative to best lock, kHz		-1.8	0.8		2.7	2.4

^aBest-lock frequencies as determined from no signal static phase error at beginning of test with receiver A at 2113.311840 and receiver B at 2113.317936.

data link recovery tape to switch to the other transmitter. This course of action was disapproved by mission control, and the landing was made by commanding blind. It was noted in the test critique that the loss in signal strength was intended to simulate the failure of a traveling-wave tube. However, if such a failure had occurred, the loss in signal strength would have been approximately 50 dB, rather than the 20 dB simulated.

In general, test objectives were achieved and useful experience gained.

4. Operational readiness test. The objectives of this test were to exercise the total space flight operations system in the *Surveyor VI* Mission activities preparatory to launching, and in the conduct of significant phases of the mission. Emphasis was on integrating all elements of the space flight operations system and exercising as many interfaces as possible among interacting elements.

This was a final rehearsal for the mission intended to verify the flight readiness of the systems. The test was conducted in one continuous session consisting of the following three segments:

- (1) Prelaunch through initial spacecraft operations: $T - 14$ h, to $T + 2$ h.
- (2) Midcourse: $M - 3$ h, to $M + 30$ min.
- (3) Terminal: R (retromaneuver) $- 3$ h, to TD (touch-down) $+ 30$ min.

No anomalies were inserted in the system by the test conductor. All three segments were relatively uneventful except for numerous data outages and computer breakdowns. As in the flight training test, the Univac 1219 computer proved to be a very valuable backup to the SFOF data system. In general, test objectives were met.

Table 24. Automatic frequency control mode acquisition frequency test^a

Test	Strong signal			Weak signal		
	Test step	Receiver A	Receiver B	Test step	Receiver A	Receiver B
Conditions						
Spacecraft receiver temperature, °F		83.15	82.27		83.15	81.38
DSS 71 transmitter attenuator, dB		22.5	22.5		40.5	37.5
Spacecraft receiver input power, dBmW		-101.5	-99.2		-119.0	-114.0
Results						
Lower acquisition frequency, MHz	003.038	2113.301952	2113.308288	003.051	2113.304448	2113.310496
Automatic frequency control at acquisition, kHz	003.039	-10.0	-6.7	003.052	-8.6	-4.8
Upper acquisition frequency, MHz	003.044	2113.328160	2113.332096	003.055	2113.326432	2113.324800
Automatic frequency control at acquisition, kHz	003.045	13.7	16.4	003.056	9.7	9.7

^aAutomatic frequency control center frequency (no signal automatic frequency control), with receiver A at 2113.313184, and receiver B at 2113.318944.

5. Test coordination and simulation. In order to control and execute the class A, B, and C test series in accordance with the objectives and directives stated in the test plans, a 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 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 team was divided into telemetry, tracking, science, and TV simulation groups.

The prime responsibilities of the test coordinator and his staff are: (1) to plan the telemetry and tracking data packages, including problems, starting 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 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, including problems, to produce a realistic mission simulation.

The data packages produced in support of *Surveyor VI* Mission were for the class A series tests and the operational readiness test. All these packages were delivered

on time and mailed to AFETR and the Deep Space Stations in time for the scheduled tests.

The spacecraft/DSIF compatibility test was performed at DSS 71 on September 28 and 29, 1967. The tests proved that the spacecraft is compatible with the DSIF except that the 3.9-kHz modulation index SCO has a static offset of approximately 1%.

The static offset of the 3.9-kHz modulation index SCO is outside the normal expected value. The stations will be informed and it is not expected to seriously affect the ability of the DSIF to process telemetry.

Graphic presentations of spacecraft SC-6 calibration data are given in Figs. 42, 43, and 44. The *Surveyor* Project/DSIF interface communications during test sequences are shown in Fig. 45.

V. Tracking and Data System Flight Support

A. General

The TDA support, provided by the AFETR, MSFN, and the DSN, for the *Surveyor VI* Mission are summarized here. A brief flight review and actual flight coverage is presented, from countdown through the end of the mission, placing emphasis on the significant events.

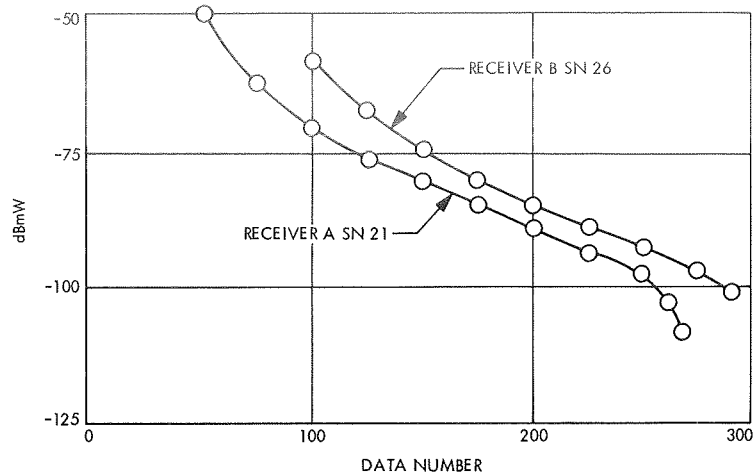


Fig. 42. Automatic gain control vs data number at 75°F

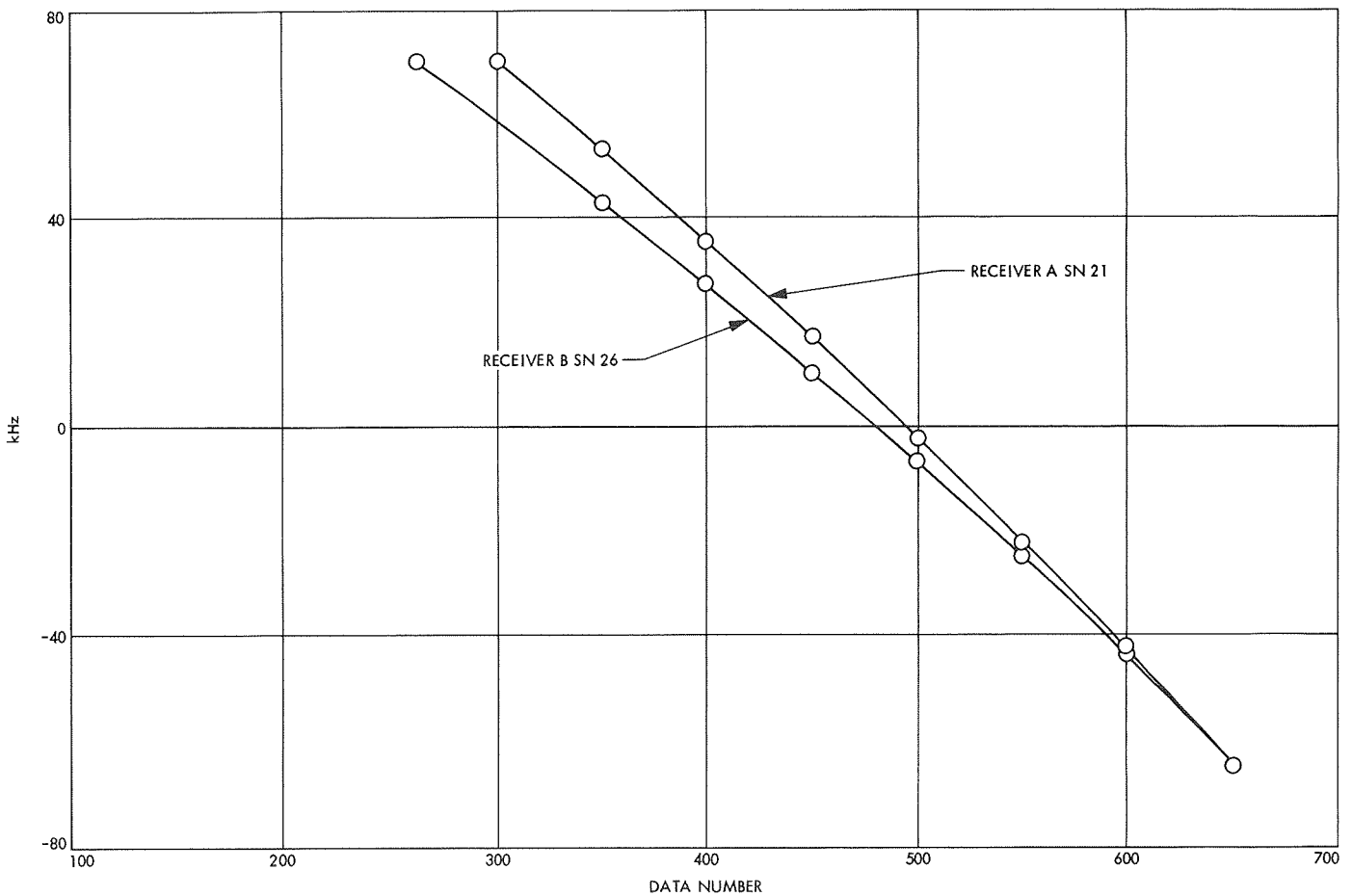


Fig. 43. Static phase error vs data number at ambient temperature

B. Countdown

The planned countdown for November 6-7, 1967 included two built-in holds; one of 60-min duration at $T - 90$ min, and a second of 10 min duration at $T - 5$

min. Liftoff was scheduled for 07:22 GMT, on November 7, with a flight azimuth of 81 deg. The launch window duration was 55 min. The actual countdown time summary is shown in Table 25.

Table 25. Surveyor VI countdown time summary

Event	Time before launch, min	Time, GMT
Start system readiness test	—	18:50 ^a
End system readiness test	—	23:48 ^a
Start vehicle countdown	335	00:37
Start 60-min built-in hold	90	04:42
Start spacecraft countdown	90 (during hold)	05:12
End built-in hold; resumed count	90	05:42
Start 10-min built-in hold	5	07:07
Hold extended; better TDS coverage	5	07:17
Resume count	5	07:34
Liftoff	0	07:39

^aNovember 6, 1967; subsequent times are November 7.

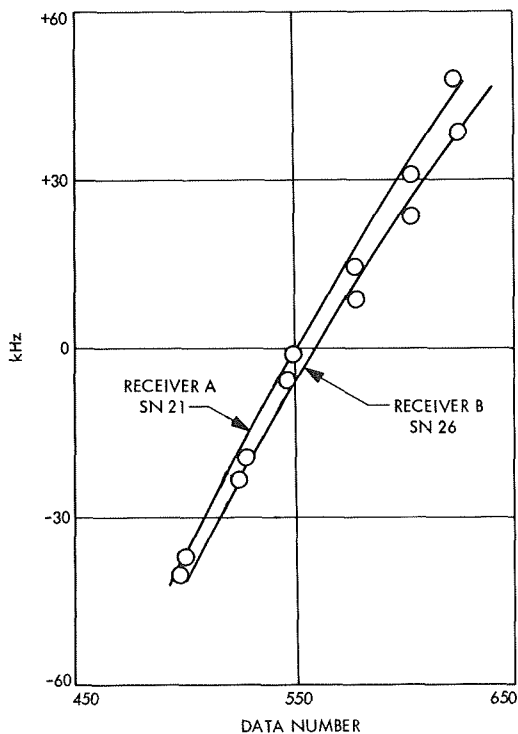


Fig. 44. Automatic frequency control vs data number at 75°F

The JPL/AFETR mission operations center was manned and operational by 18:00 on November 6. The spacecraft system readiness test (SRT) was started on schedule at 18:50. The first spacecraft frequency report

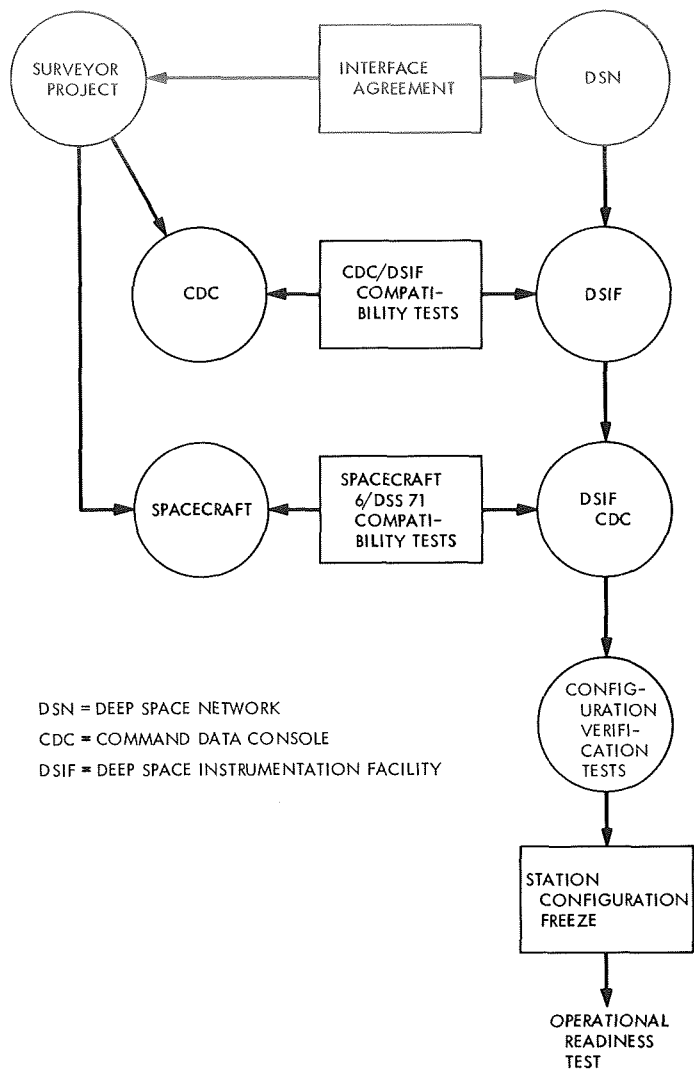


Fig. 45. Surveyor Project/DSIF interface communications

was transmitted verbally to the SFOF at 20:05, followed later by teletype confirmation. A total of six frequency reports were sent during the SRT and countdown. The SRT progressed normally and was satisfactorily completed at 23:48.

At 23:35, the supervisor of range operations reported that telemetry and beacon checks and downrange telemetry data flow checks would be delayed until completion of a higher priority launch.

The vehicle countdown was started on schedule at $T - 335$ min, at 00:37 on November 7. Some resequencing of activities was performed to minimize the delay.

The first RF propagation forecast was received from AFETR at 02:17. Six of these forecasts, each predicting the propagation conditions for $T - 0$, were provided. Table 26 lists the forecast conditions.

The telemetry checkouts were started late due to the turnaround time required from the previous launch.

In checking out the modem circuits to building AO and DSS 71, a patching problem at the CDC in building AO and a bad line between building X-Y and modem 2 at DSS 71 were discovered and corrected.

The HF circuits with RISs *Sword Knot* and *Twin Falls*, and the Ascension and Pretoria stations were established early; however, the only usable path prior to approximately $T - 90$ min was the direct HF path from the *Twin Falls*.

The HF communications with the *Sword Knot*, Ascension, and Pretoria improved by $T - 50$ min and good communications were anticipated for launch.

The HF communications with the *Twin Falls* degraded from excellent to unusable after $T - 90$ min. At $T - 30$ min their HF circuit improved and remained usable until $T - 3$ min, when the data monitor was removed.

Special coverage was established by NASCOM commencing at approximately $T - 6$ h, and special propagation forecasts were provided for all HF radio circuits effective at approximately $T - 9$ h.

The teletype circuit to DSS 51 via Ascension was activated for make-good purposes.

During the countdown, a major system failure was experienced at 03:50 GMT. This caused an outage between Cocoa Beach and Polk City, Fla., affecting all of the voice, high-speed data, and teletype circuits to DSS 71, and one voice and all of the teletype circuits to building AO. The failure was attributed to a shorted capacitor at Cocoa Beach, causing the fuses on the Polk City circuits to blow. All circuits were restored at 04:54.

Intermittent outages, due to poor HF propagation, were experienced on all of the DSS 51 circuits between 05:08 and 06:50.

Dropouts on the DSS 51 high-speed data circuit were reported at approximately 06:55. Attempts to reconfigure circuitry and equipment were ineffective until it was discovered that a Stelma converter at Riverhead, N.Y., was set on channel 8 instead of channel 2. The circuit was restored at 07:55, which was after liftoff but before DSS 51 acquisition. All other circuits were GO at liftoff.

At $T - 189$ min, the AFETR reported that there would be a configuration change between the RTCS and building AO for the transmission of DSN predicts. The DSS 51 and 42 predicts would be sent serially on the same line, rather than simultaneously on two lines as previously planned. This would have delayed the DSS 42 predicts by approximately 12 min. This was subsequently changed and two lines were made available as originally planned. This situation occurred because NORAD, requiring higher priority support, did not release a required teletype transmitter until late in the countdown.

Table 26. Surveyor VI HF propagation forecasts

Time received, GMT ^a	Merritt Island/ KSC	Mahe/ Ascension	Sword Knot/ Mahe	Twin Falls/ Ascension	Ascension/ KSC	Pretoria/ Ascension	Sword Knot/ Pretoria
02:17	Fair ^b	Fair	Fair	Fair			
03:31	↑	↑	↑	↑	Fair		
04:20	↓					Poor	
05:23	Fair	↓	↓	↓	↓	Poor	
06:07		Fair	Fair	Fair	Fair	Fair	Fair
06:42		Poor	Poor	Poor	Poor	Poor	Poor

^aNovember 7, 1967.
^bOn scale of excellent, good, fair, poor and unusable.

The MSFN reported their status as GO, with the exception of the Tananarive radar, which was considered NO-GO because of a tunnel-diode amplifier problem. It was stated that the Tananarive radar would support on a limited basis, with some degradation expected in range capability.

At $T - 142$ min, a Tananarive C-band transmitter ranging problem was reported; however, this was cleared in approximately 10 min.

The first built-in hold began at 04:42, at $T - 90$ min, with the count being resumed on schedule at 05:42.

A failure occurred in the elevation encoder system of the Grand Canary radar during the built-in hold at $T - 90$ min. The radar was returned to service 10 min later.

Countdown operations progressed normally until $T - 38$ min, when another problem was encountered with the Tananarive radar. It was reported that arcing was occurring within the transmitter. At $T - 11$ min, the MSFN reported that they would operate the transmitter at reduced power, which prevented the arcing. No further difficulties were encountered. The built-in hold at $T - 5$ min began at 07:07 and the count was resumed as planned at 07:34.

C. Liftoff to DSIF Acquisition

The *Surveyor VI* spacecraft was successfully launched from launch complex 36B at Cape Kennedy, Fla., at 07:39:01.075 GMT on day 311 (November 7, 1967), after a 17-min extension of the scheduled 10-min hold at $T - 5$ min to obtain better spacecraft coverage by the tracking stations. The *Atlas/Centaur* launch vehicle accurately launched and injected the spacecraft into its lunar orbit with a launch azimuth of 82.995 deg.

The entire transit phase of the mission was nominal with all subsystems working as expected and no spacecraft anomalies. A minor problem consisting of loss of lock during star verification was encountered. This was determined to be due to an unexpected null depth in the omniantenna B uplink signal, rather than an anomalous spacecraft condition. Although loss of data was anticipated during the star mapping sequence, loss of two-way lock was considered only a remote possibility. Two-way lock was lost, however, and spacecraft roll was intentionally stopped prior to Canopus coming into the star sensor field of view in order to reacquire and interrogate the spacecraft to provide reassurance that all subsystems

were indeed operating nominally. Provided with such reassurance, it was then discussed within spacecraft performance analysis and command group whether to proceed immediately with Canopus acquisition (since the spacecraft roll orientation had already been established) or to play it safe and go around once more to provide a more detailed map. The latter plan was agreed upon and Canopus, as expected, came into the field of view shortly after resumption of the roll.

At 01:01:05.480 GMT on November 10, a successful soft-landing was made at 0.47 deg N and 148 deg W in Sinus Medii approximately 10.5 km from the original target point as determined from *Lunar Orbiter* photographs. The spacecraft landed after a nominal terminal descent with a velocity of approximately 12 ft/s. Scheduled lunar operations, including television surveys, A/SPP positioning, alpha scattering soil analysis, and telecommunications experiments, were successfully conducted. In addition, a highly successful liftoff and translation experiment, an historic first, was performed.

Two seconds after liftoff, the launch vehicle began a 13-s programmed roll that oriented the vehicle from a pad-aligned azimuth of 45 deg to a launch azimuth of 82.995 deg. At 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 27. Times for *mark* events 22 and 23 were never made available during the mission. All *mark* times were nominal with the exception of events 10 and 13; there was some question of the validity of these *mark* times. Postflight data showed that the times received for events 10 and 13 were in error and the events were in fact nominal. The launch phase ascent trajectory profile is illustrated in Fig. 46. Deep Space Station 71 was in one-way phase lock with the spacecraft at liftoff and tracked until LOS at 07:43:44.

Separation of *Surveyor* from *Centaur* occurred at 08:04:29.995 GMT on November 7, 1967 at an approximate geocentric latitude and longitude of 6 and 4 deg, respectively. The spacecraft was in the shadow of the earth during the first 14.4 min of the ascent phase and parking orbit but left the earth shadow prior to separation and remained out of the shadow during the transit trajectory. Approximately 1 min after separation, the automatic sun acquisition was begun. The trajectory group had predicted a sun acquisition maneuver of +27 deg yaw. The actual maneuver was -264 deg roll and +22 deg yaw. No prediction was made for the roll maneuver since the *Centaur* was not roll stabilized.

Table 27. Mark events

Mark	Event	Actual, GMT	Time from launch		Nominal time from separation, s
			Actual, s	Nominal, s	
	Liftoff (2-in. motion)	07:39:01.075	0.0	0.0	
1	Atlas BECO ^a	07:41:34.5	153.42	153.5	
2	Atlas booster engine jettison	07:41:37.81	156.73	156.6	
3	Centaur insulation panel jettison	07:42:19.41	198.33	198.5	
4	Centaur nose fairing jettison	07:42:49.64	228.56	228.5	
5	Atlas SECO ^b and VECO ^c	07:43:06.63	245.55	248.2	
6	Atlas/Centaur separation	07:43:09.31	248.23	250.2	
7	Centaur MES ^d 1	07:43:19.8	258.72	259.7	
8	Centaur MECO ^e 1	07:48:42.1	581.02	579.2	
9	100-lb thrust on	07:48:44.3	583.22	579.2	
10	100-lb thrust off	07:50:09.5	668.42	655.6	
11	6-lb thrust on	07:49:58.9	657.82	655.6	
12	100-lb thrust on	08:00:57.0	1315.92	1312.92	-216.0
13	Centaur MES 2 engine C 2	08:01:45.40	1364.32	1352.92	-176.0
14	Centaur MES 2 engine C 1	08:01:35.0	1353.92	1352.92	-176.0
15	Centaur MECO 2	08:03:29.75	1468.67	1465.82	-63.1
16	Extend landing gear	08:03:49.0	1487.92	1486.92	-42.0
17	Unlock omnidirectional antenna	08:03:59.5	1498.42	1497.42	-31.5
18	Surveyor high power transmitter on	08:04:20.0	1518.92	1517.92	-11.0
19	Centaur/Surveyor electrical discount	08:04:25.1	1524.02	1523.42	-5.5
20	Spacecraft separate (injection)	08:04:30.0	1528.92	1528.92	0.0
21	Begin Centaur turn around maneuver	08:04:33.4	1532.32	1533.92	5.0
22	Start Centaur lateral thrust	—	—	1573.92	45.0
23	End Centaur lateral thrust	—	—	1593.92	65.0
24	Start Centaur tank blowdown	08:08:30.0	1768.92	1768.92	240.0
25	End Centaur tank blowdown	08:12:40.2	2019.12	2018.92	490.0
26	Power changeover switch	08:14:20.1	2119.02	2118.92	590.0

^aBECO = booster engine cutoff.^bSECO = sustainer engine cutoff.^cVECO = vernier engine cutoff.^dMES = main engine start.^eMECO = main engine cutoff.

Canopus was acquired at $T + 8$ h, 49 min with a roll maneuver of $+298$ deg. The roll maneuver predicted by the trajectory group was 273 deg.

D. Acquisition to Midcourse Maneuver

After spacecraft injection at 08:31:19.099, DSS 51 acquired one-way at 08:08:51, with two-way lock verified at 08:13:27. The initial spacecraft acquisition was flawless. The spacecraft transmitter high power was commanded off at 08:19:32 during the initial spacecraft operations.

The elevation angles were higher and view periods were longer from DSS 51 than from DSS 61, and therefore it was used as a prime two-way station during the cislunar phase. However, DSS 61 telemetry and average alarm data were preferred at the SFOF due to greater ground communications reliability.

The Carnarvon, Australia station tracked the spacecraft prior to DSS 42 rise, and provided spacecraft telemetry data to DSS 42 via the dataphone link.

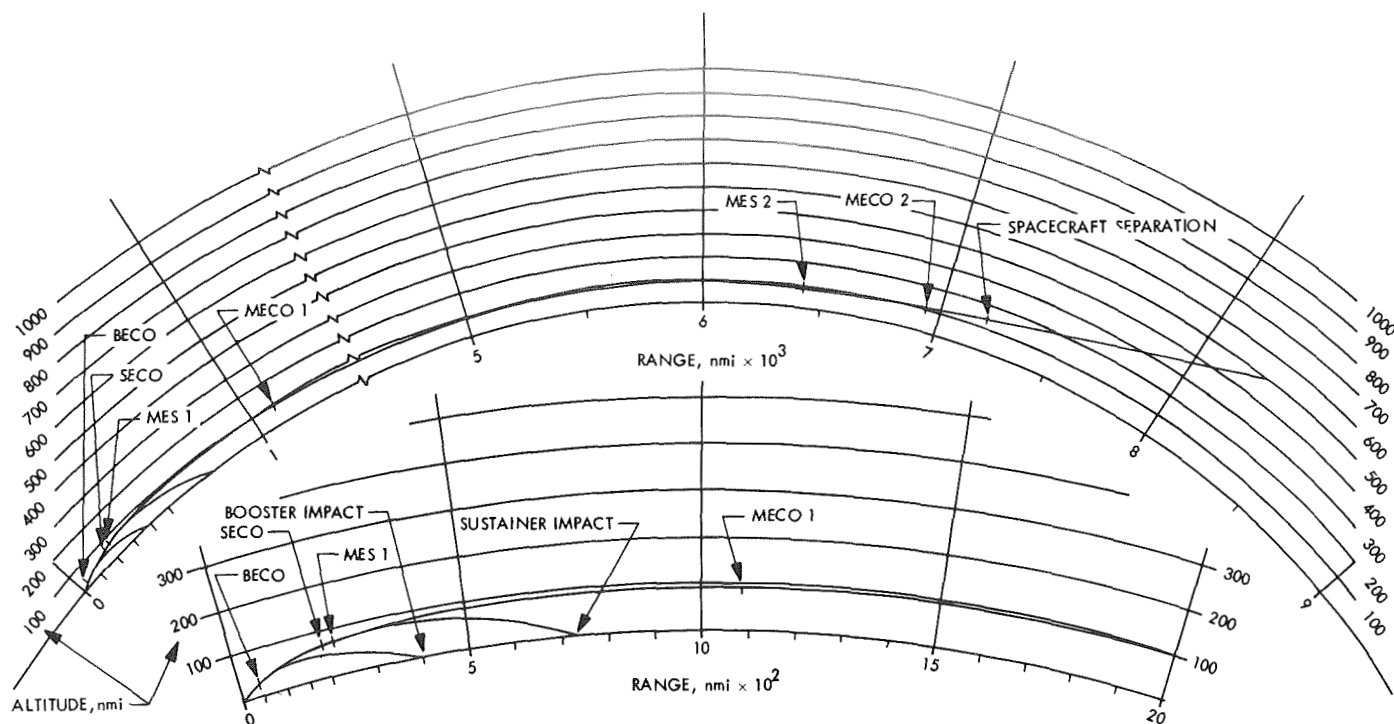


Fig. 46. Surveyor VI/AC-14 launch phase, trajectory profile

The spacecraft transfer from DSS 51 to DSS 42 was made at 10:10 on November 7; DSS 42 had a normal acquisition and an uneventful pass. Subsequent first pass transfers were made to DSS 51 at 12:10, then to DSS 61 at 14:45, initiating the star verification and acquisition sequence at 15:20:21. During the sun and roll maneuver, the spacecraft signal was lost due to a greater null within the predicted null region of the spacecraft omniantenna B pattern. The maneuver was temporarily terminated, while a spacecraft assessment was made and found to be nominal. The star acquisition sequence was reinitiated at 16:14:22, and after the roll, automatic Canopus lockon followed with verification at 16:28:20. The spacecraft was transferred back to DSS 51 at 17:30.

The personnel at DSS 61 developed a special computer program that reconstituted the available average alarm data into engineering units. The program was also used by DSSs 11 and 42, and monitored at the SFOF.

Frequent spacecraft transfers between the Deep Space Stations were employed to facilitate the determination of doppler biases at the stations and to update orbit determinations.

At approximately 22:00, just before a scheduled transfer to DSS 11 at 22:10 on November 7, DSS 51 experienced a complete loss of communications. A *power-steal*

transfer was accomplished smoothly at the scheduled time.

Prime telemetry and transmitter backup to DSS 11 was provided by DSS 14 during the cislunar passes and the spacecraft translation on pass 10.

The predicted view periods for the four committed tracking stations and the first pass over DSS 72 are shown in Table 28. This summary is a compilation of pre- and postmidcourse maneuver trajectories. The rise and set criteria are included under the event column.

Since the midcourse maneuver was performed on November 8, at 02:26, Goldstone had a premidcourse view of Surveyor VI for about 4.5 h and a postmidcourse view of about 4.5 h. For the predicted touchdown time of November 10, 1967 at 01:01:05.5, the pre- and post-landing Goldstone visibility was approximately 3 and 6.9 h, respectively.

Figures 47-51 show a stereographic projection of the trajectory paths as seen from DSSs 72, 51, 11, 42, and 61. Pre- and postmidcourse maneuver injection and terminal conditions were tabulated. It should be noted that the postmidcourse maneuver terminal conditions did not match the orbit determination conditions very closely.

Table 28. Predicted view period summary

DSS	Event								Time (GMT), h:min							
	Rise				Set											
	0-deg el	5-deg el	270-deg HA	90-deg HA	0-deg el	5-deg el	270-deg HA	90-deg HA								
51	X	X							Nov 7 08:09							
42		X												08:34		
72														12:38		
42												X		14:13		
61									X					14:31		
11									X					21:51		
51														X	22:23	
61												X			22:43	
72												X			Nov 8 01:29	
42									X						02:13	
11													X		06:51	
51										X					10:56	
61									X						14:43	
42													X		15:08	
11									X						22:01	
51															X	22:54
61													X			23:29
42									X							Nov 9 02:37
11						X			07:19							
51			X						11:08							
61		X							14:45							
42						X			15:16							
11		X							22:03							
51								X	23:03							
61						X			23:42							

This was due to use of the gas jets feature in the orbit determination program which gave a better fit of the data. The trajectory program could not simulate these jets.

The proximity of the uncorrected and the original aiming point is shown in Fig. 52. The uncorrected, unbraked impact point based upon the current best estimate is located in the central area of Sinus Medii at selenographic coordinates of -3.21 deg in latitude and 0.66 deg in longitude. The target aiming point was $+0.42$ deg in latitude and 358.67 deg in longitude. The two points are approximately 125 km (78 mi) apart on the surface of the moon.

Figure 53 is an enlarged section of the premidcourse maneuver target area discussed above. A few selected premidcourse maneuver orbit computations are shown. The last premidcourse maneuver orbit was used to determine the required midcourse correction. Also shown are the results of the AFETR orbit determination from the Cape Kennedy computer at launch plus 100 and 130 min.

Figure 54 gives the earth track traced by *Surveyor VI*. Specific events such as sun and Canopus acquisition, midcourse maneuvers, touchdown, and rise and set times for the Deep Space Stations are also shown.

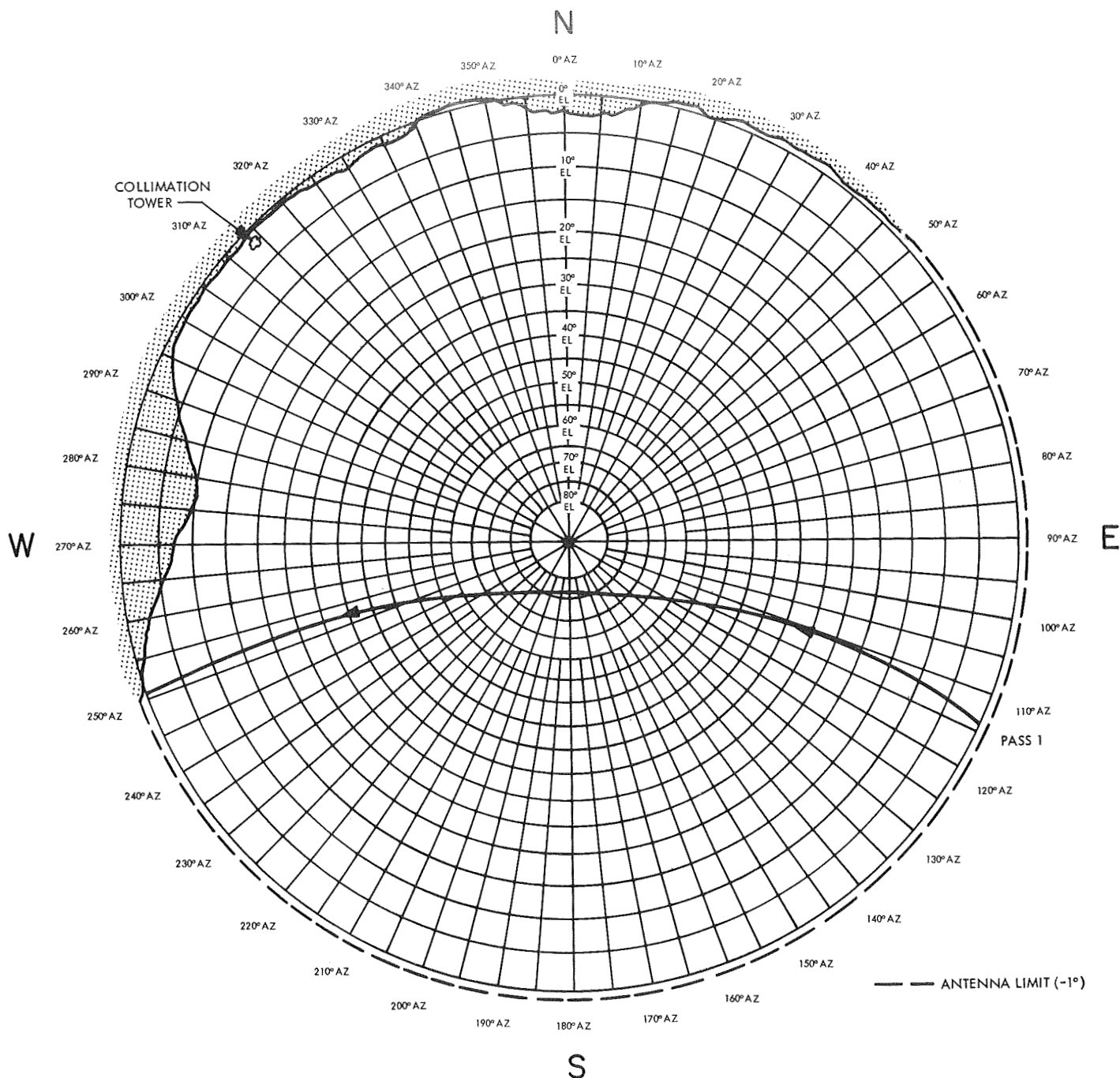


Fig. 47. Stereographic projection for DSS 72

E. Midcourse Maneuver to Terminal Descent

At 02:20:02.1 November 8, 1967, DSS 11, during pass 1, commanded the midcourse thrust with a burn of 10.28 s. Telemetry and doppler shift data indicated that the velocity correction was as expected. Reverse maneuvers were completed at 02:36 and a successful nominal midcourse maneuver was accomplished.

While tracking in three-way, postmidcourse, DSS 14 accomplished a special inflight test to verify the theoretical capability of the spacecraft telecommunications system when configured for simultaneous transmission of engineering and touchdown strain gage data. Test results showed a good correlation of the theoretical, and, later, the actual data.

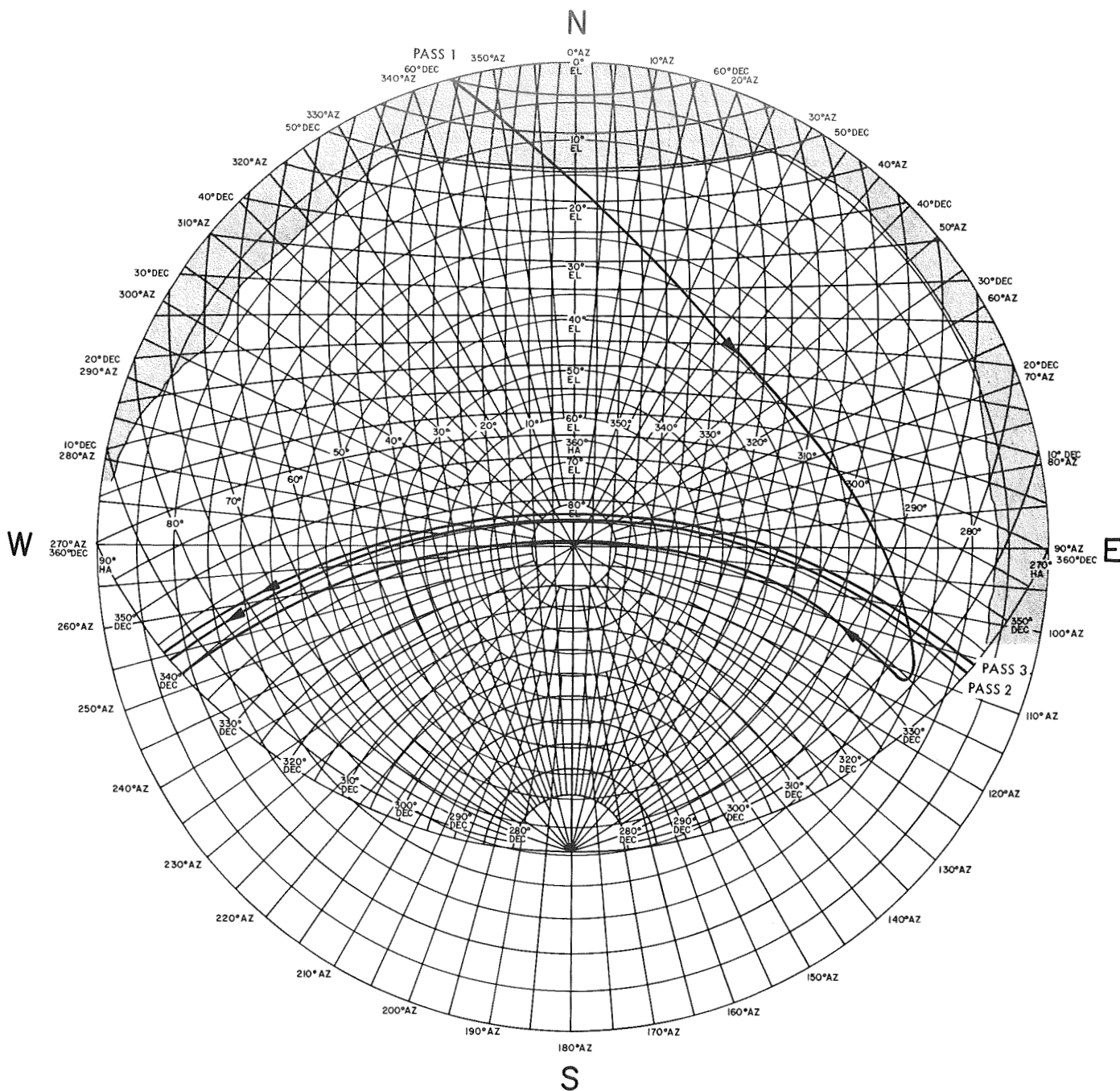


Fig. 48. Stereographic projection for DSS 51

The spacecraft was transferred to DSS 42, on pass 2, at 03:40, which again had a normal tracking pass, and to DSS 51 at 13:30. The voice communications at DSS 11 went out at 19:50 and the teletype conference circuit went out at 20:43. During this period, a severe electrical storm was occurring over the station. A nonstandard power-steal was again used with a transfer to DSS 61 which was completed at 20:43:30.

A standard spacecraft transfer to DSS 11 followed at 22:15. Operations were satisfactorily accomplished with the next transfer to DSS 42 during pass 3, at 05:40 on November 9, 1967.

At 06:35, the station transmitter tripped due to the collector flow being low. The flow was readjusted and the transmitter was again operational at 06:40.

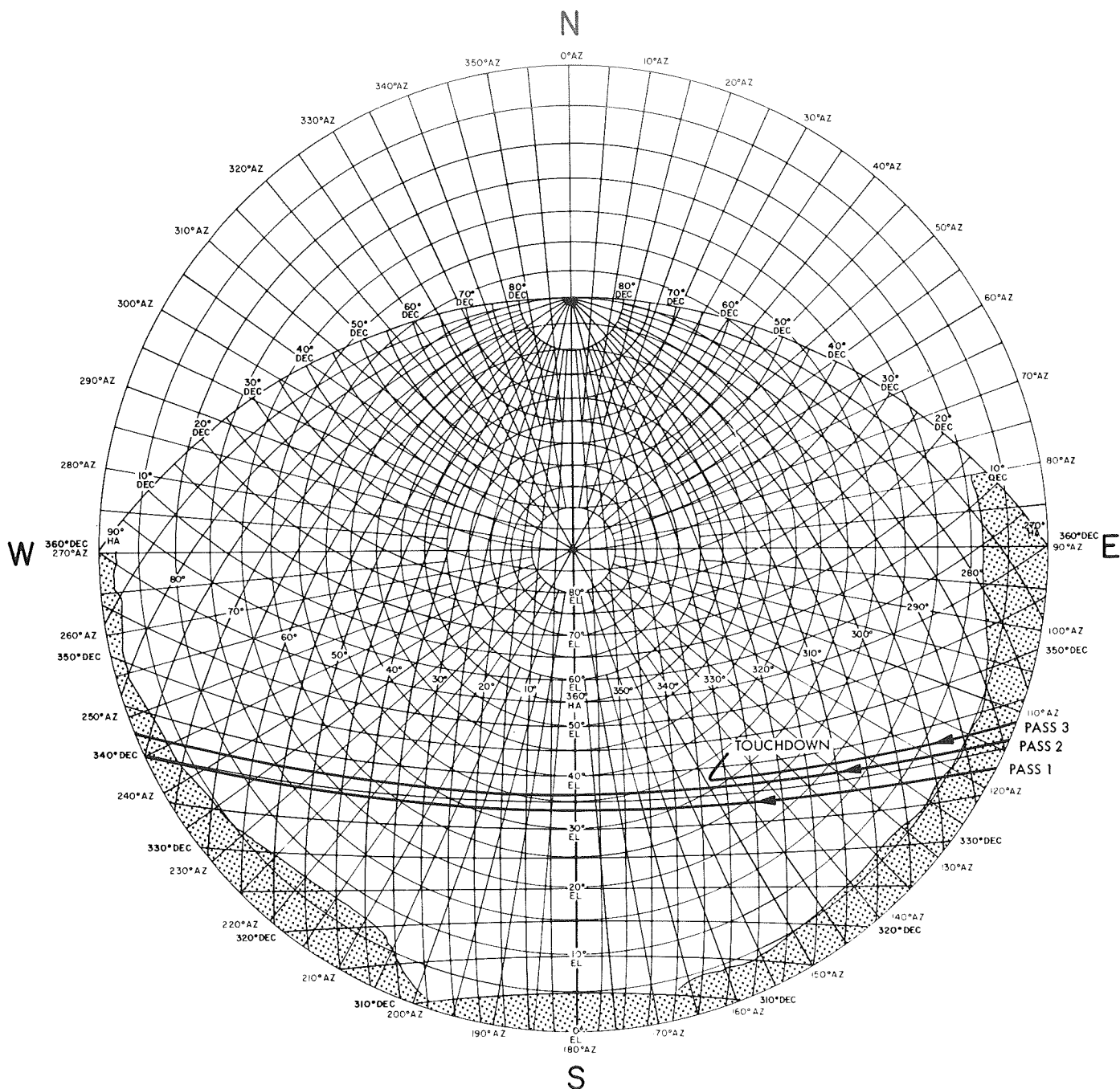


Fig. 49. Stereographic projection for DSS 11

The spacecraft transfer to DSS 51 occurred at 13:30. Pass 3 was tracked by DSS 61 in the three-way mode.

Receipt of noisy doppler data was rectified when the rubidium standard was replaced. Approximately $1\frac{1}{2}$ h of data were lost.

The transfer from DSS 51 to DSS 11 was made at 22:15. At 23:48, the transmitter voltage controlled oscillator (VCO) offset frequency of 460 binary-coded data was set in for a ground transmitter VCO frequency setting of 22.013899 MHz, which provided the capability for rapid acquisition of the uplink signal, should it be lost during the retromaneuver.

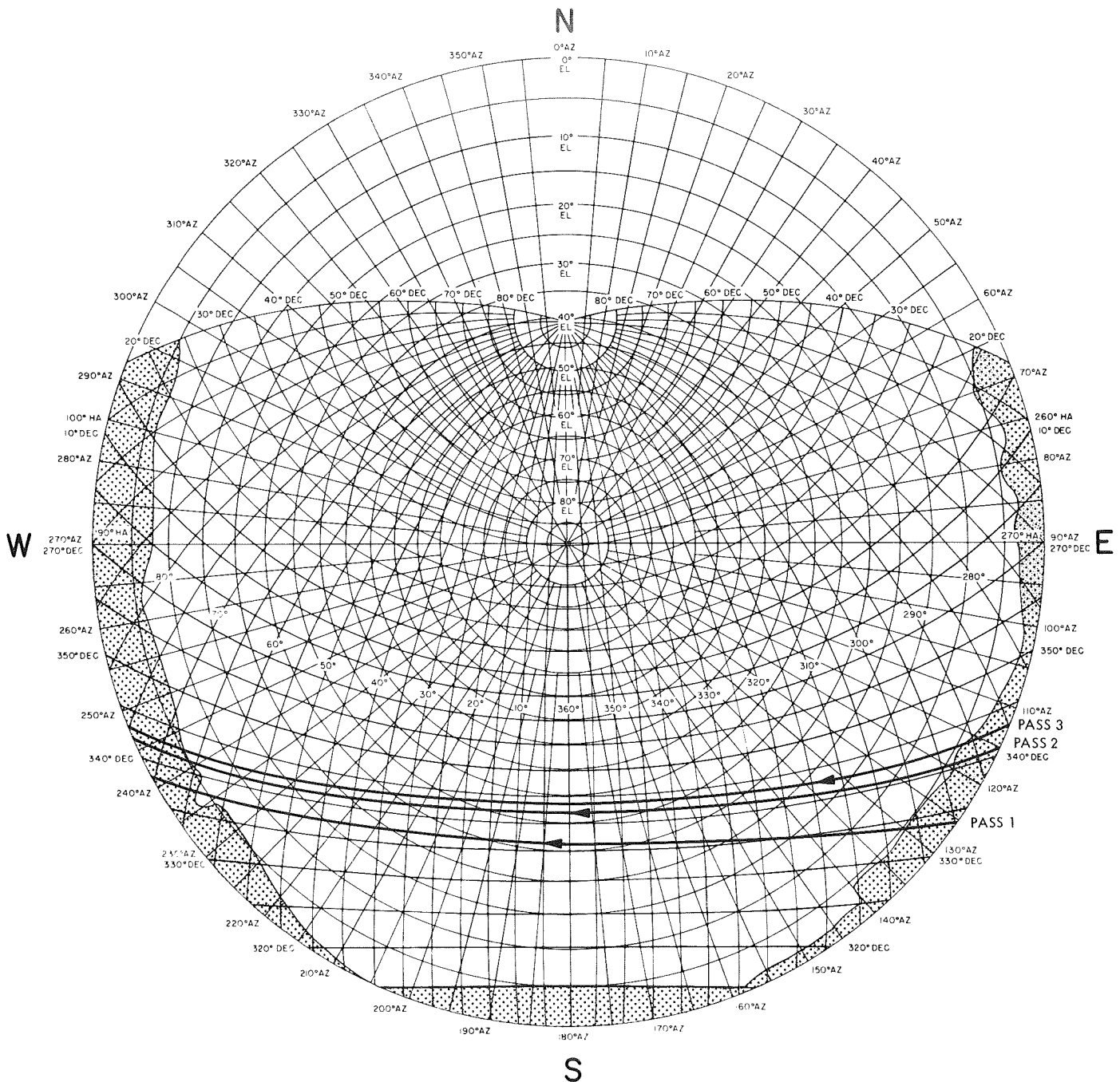


Fig. 50. Stereographic projection for DSS 61

All midcourse operations were satisfactory. With the spacecraft being controlled by DSS 11, the maneuver sequence for applying the desired midcourse thrust in the proper direction was initiated, with the first maneuver (roll $+91.9$ deg) being commanded at $T + 18$ h, 23 min, 59 s. Initiation of this maneuver was delayed until the roll axis limit cycle was at a null (i.e., the Canopus

error signal was passing through a null). The second maneuver (yaw $+127.3$ deg) was also delayed until the yaw axis limit cycle was at a null, being commanded at $T + 18$ h, 30 min, 7 s. With the vehicle thrust vector now positioned properly, the vernier engine system was pressurized at $T + 18$ h, 36 min, 58 s. The midcourse velocity correction was applied by commanding the

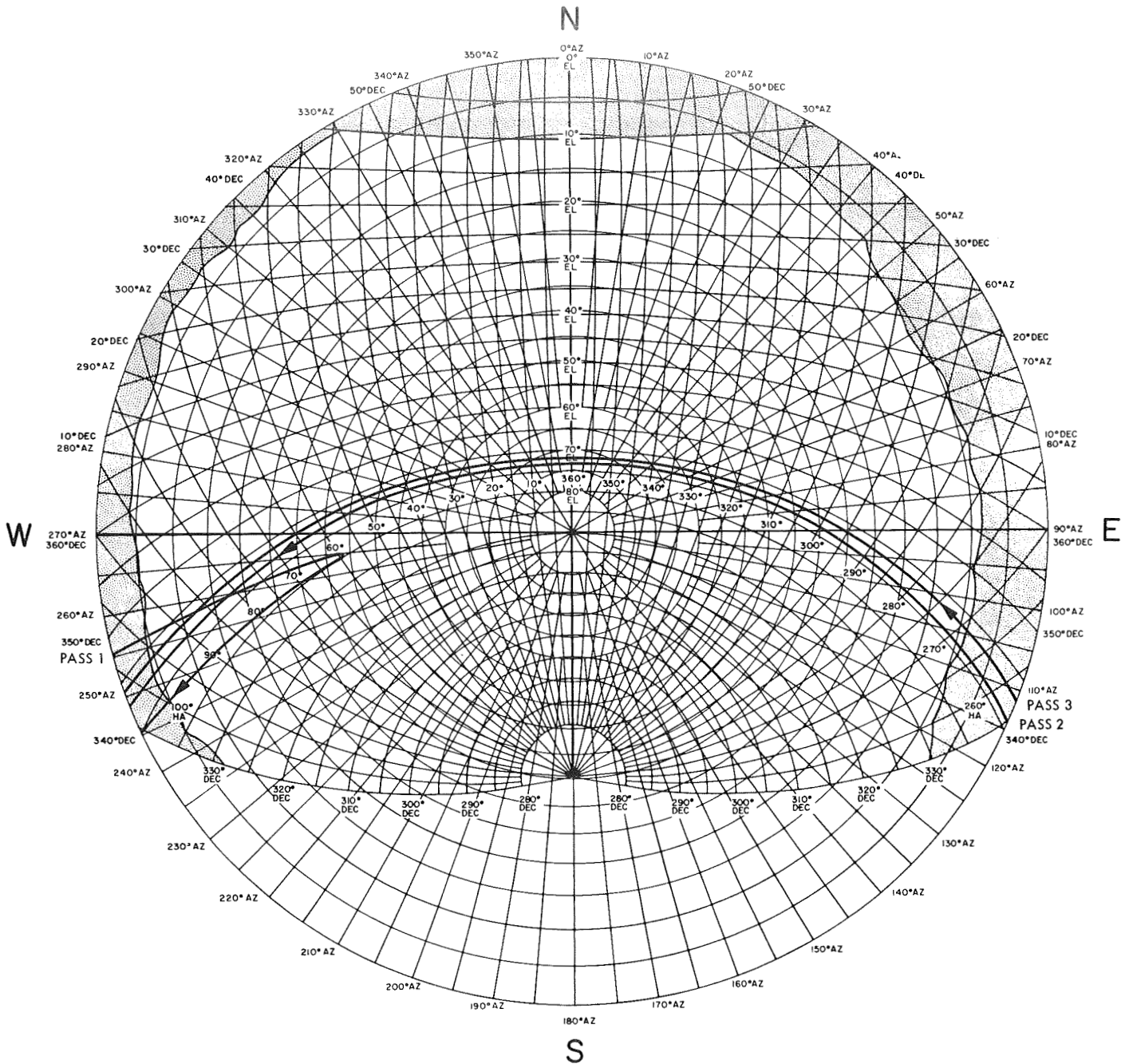


Fig. 51. Stereographic projection for DSS 42

ignition of the vernier engines at $T + 18$ h, 41 min, 1 s so that the necessary controlled thrust was applied to achieve a constant acceleration of $0.1 g$ for 10.25 s (a correction of 10.05 m/s).

Analog recorder, 7044 bulk and teleprinter, and CDS 1219 teleprinter data confirmed the proper execution times and direction for the attitude maneuvers, as well as the duration of the thrusting period.

Following the midcourse thrusting, the sun and Canopus were reacquired by performing the reverse maneuvers.

Thus, confirmation was obtained that the gyros had retained their inertial reference during the vernier engine shutdown, and the need for performing a post-midcourse star verification to ensure lockon to the proper star was eliminated.

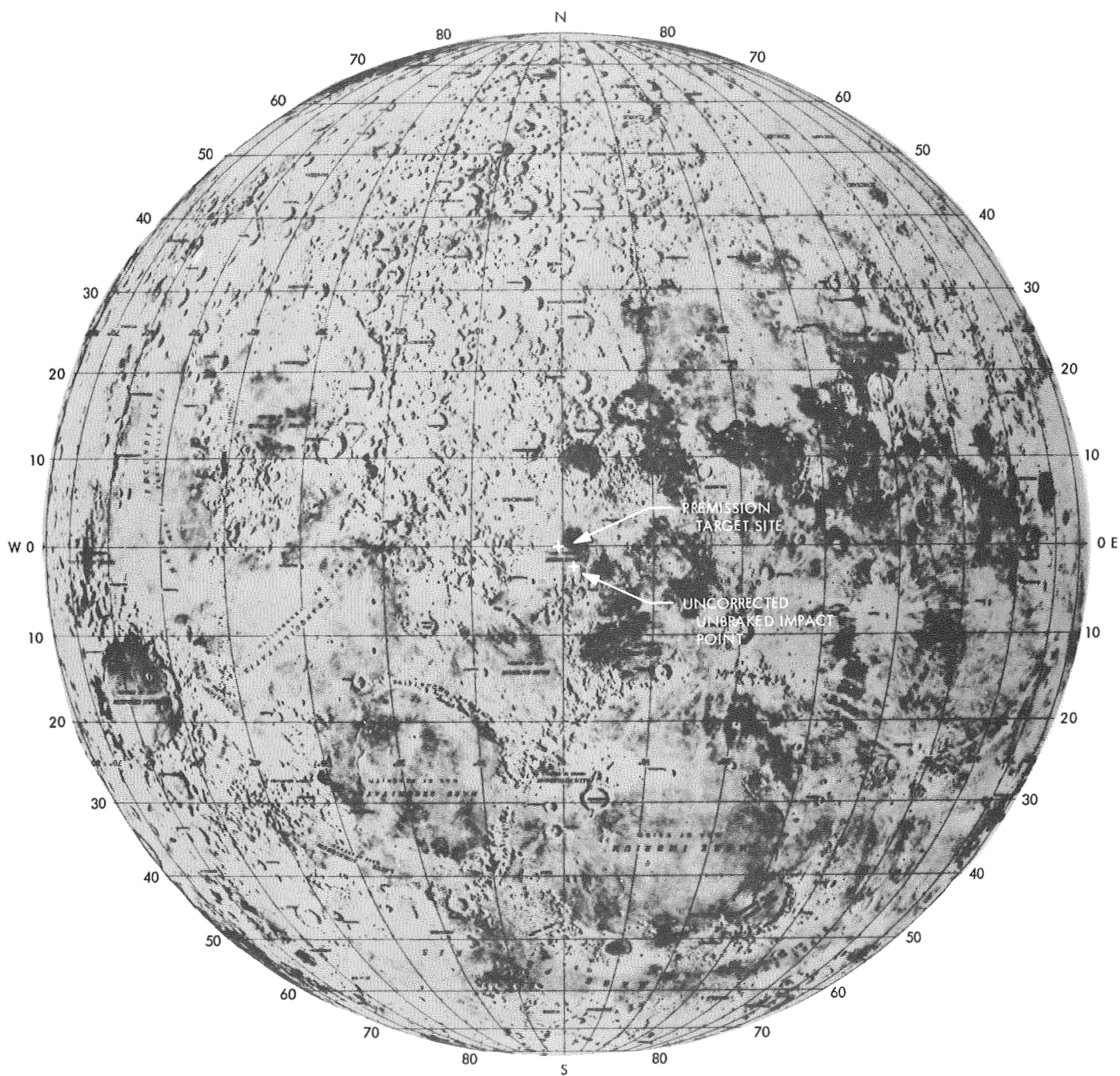


Fig. 52. Surveyor VI target and uncorrected impact points

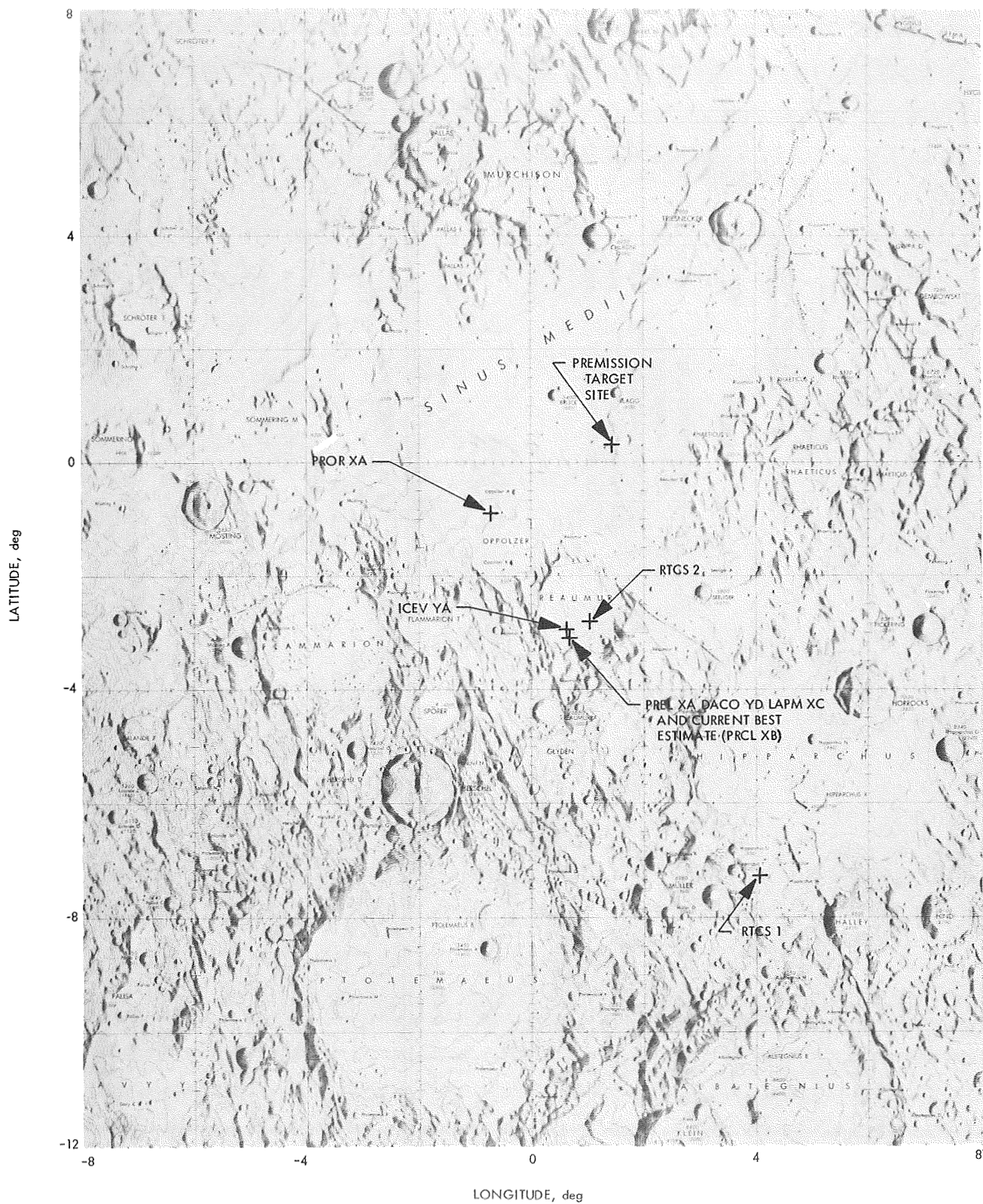


Fig. 53. Surveyor VI premidcourse unbraked impact locations

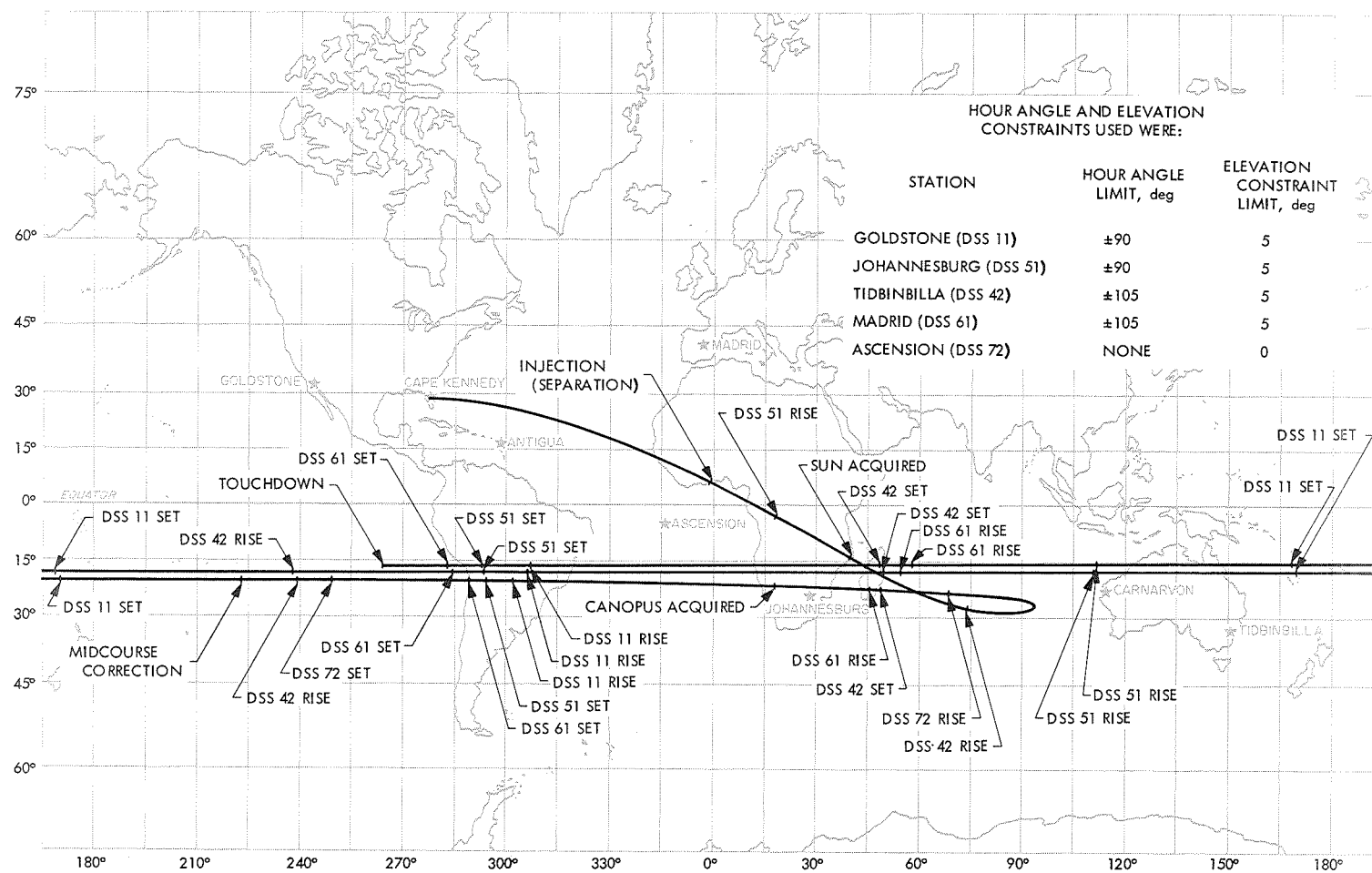


Fig. 54. Surveyor VI earth track

F. Terminal Descent to Touchdown

Terminal descent operations were initiated by DSS 11 at 00:05:51 on November 10, 1967 with a preterminal maneuver engineering interrogation. Figure 55 shows the attitude and operations of the terminal descent to the lunar surface.

In preparation for terminal descent, a combination of roll, yaw, and pitch maneuvers was executed about 35 min before retroignition, to properly align the retro-motor nozzle in the direction of the velocity vector. After the attitude orientation maneuver and other preparations commanded from earth, the actual terminal descent sequence was performed automatically by the spacecraft.

The first terminal roll was executed at 00:20:02, with a second roll starting at 02:25:18. A roll of $+81.7$ deg was accomplished. A yaw of $+111.7$ deg was started at 00:29:36, followed by a roll of $+120.5$ deg which started at 00:34:54. The terminal maneuver was completed at 00:39:08.

At 00:41:41, the receiver VCO frequency was offset by $+0.44$ V for a ground transmitter VCO frequency setting of 23.385166 MHz to compensate for doppler frequency shift. The AMR power was on at 00:53:16, and retro-maneuver thrust phase power was turned on at 00:54:16. The AMR was enabled at 00:56:16, and the emergency AMR signal was commanded on at 00:57:56.

The terminal descent was initiated at $T + 64$ h, 13 min, 10 s with the performance of the last engineering interrogation. The terminal-descent attitude maneuvers were initiated 32 min, 42 s prior to the predicted time of retroignition (or at $T + 64$ h, 46 min, 19 s). In accordance with the prior agreement, the first maneuver (a roll of $+81.7$ deg) was initiated as the Canopus error passed through its null position. Similarly, the initiation of the second maneuver (a yaw of $+111.7$ deg) was delayed until $T + 64$ h, 50 min, 37 s when the sun sensor yaw error was crossing its null position. These first two maneuvers (which aligned the retroengine thrust axis to the desired direction) were completed at $T + 64$ h, 54 min, 21 s. A third maneuver (a roll of $+120.5$ deg), which established the preferred spacecraft orientation at retroignition and at touchdown to reduce the probability of the RADVS breaking lock and to provide the desired postlanding visibility of engine 3 by the television camera, was

initiated at $T + 64$ h, 54 min, 57 s and completed 4 min, 1 s later.

The three maneuvers, as well as other pre-retroignition spacecraft operations [e.g., loading the proper altitude *mark-to-vernier* ignition delay quantity (-5.875 s), establishing the retromaneuver sequence mode to ensure that the automatic flight control sequences would occur in response to the altitude radar *mark*, establishing the proper vernier engine thrust level for the retromaneuver phase, turning on flight control thrust phase power, etc.], were executed on schedule without any difficulty. In addition, the AMR was turned on at $T + 65$ h, 14 min, 16 s and was enabled 3 min later.

The spacecraft velocity change from retroignition to touchdown caused the effective spacecraft received frequency value to increase. It was important to maintain command capability with the spacecraft; therefore, the Deep Space Station transmitter frequency was adjusted prior to retroignition to a value such that the spacecraft received frequency both before ignition and after ignition had a minimum deviation from the automatic frequency control center frequency of the receiver that had been selected to be optimized. To complicate the determination of the frequency offset value, the time when the frequency adjustment was made was at a time when the spacecraft was operating in the transponder mode. It was necessary then to determine what static phase error frequency corresponded to the desired automatic frequency control frequency. This was determined for receiver B at 22:56:43 on November 9 when transponder B was turned off to perform the narrowband voltage-controlled auxiliary oscillator check. The touchdown frequency offset summary is shown in Table 29. At 23:45:00, the DSS 11 transmitter frequency was set such that the static phase error B read 7.3 kHz. Prior to initiation of the retromaneuver sequence, it was discovered that, because of an output format change in the displayed automatic frequency control, the reading of $+10$ kHz obtained during the narrowband voltage-controlled auxiliary oscillator check was interpreted to be 1.0 kHz. A real-time evaluation showed that the automatic frequency control B would change from 0.5 to 18.5 kHz during the retromaneuver sequence ($R = 0$ at beginning of retromaneuver). Even though this condition did not satisfy the minimum deviation from the automatic frequency control center frequency criterion, it was still well within the required operating range. Therefore, no recommendation was made to retune the Deep Space Station transmitting frequency.

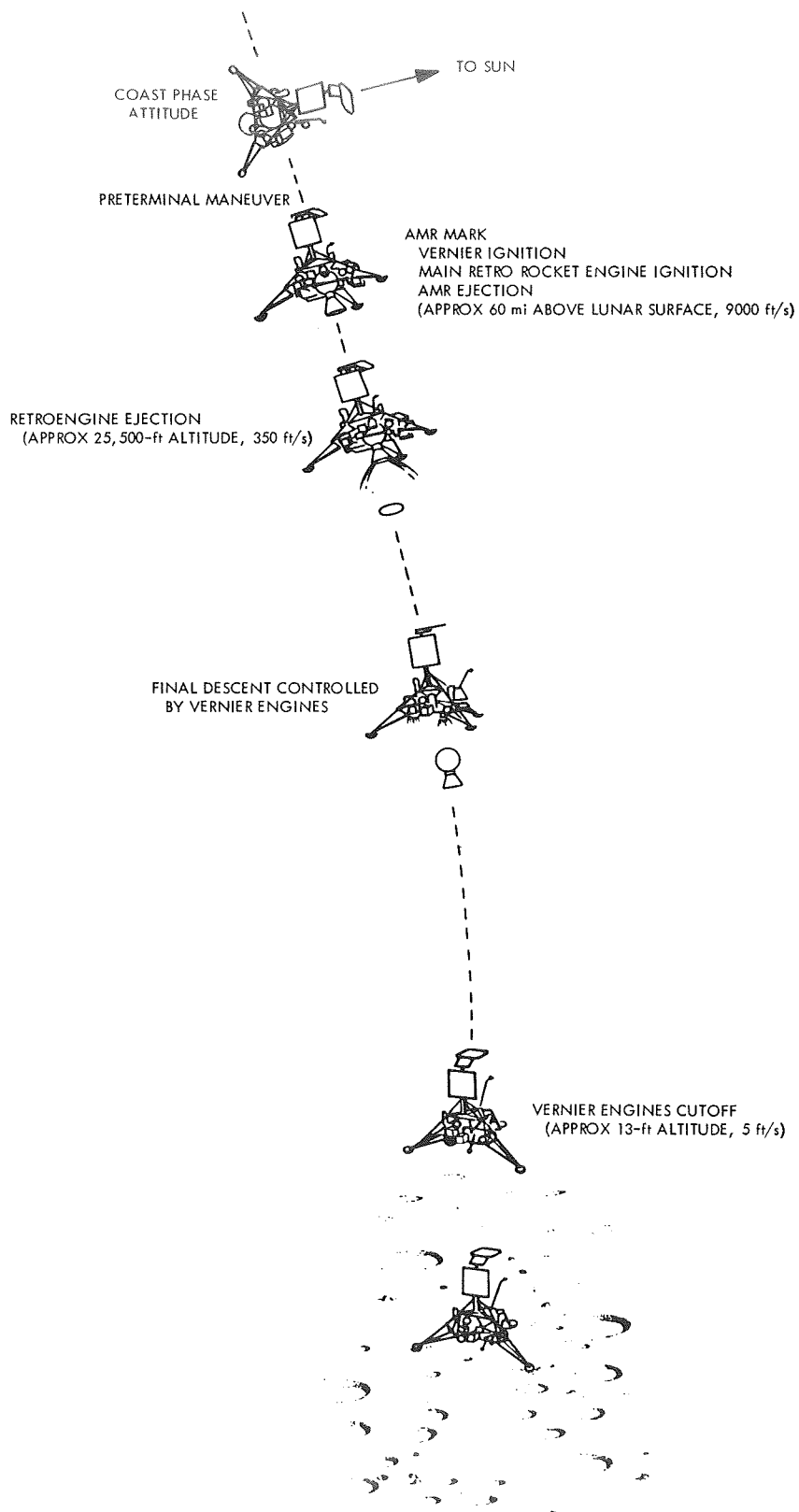


Fig. 55. Spacecraft terminal descent

Table 29. Touchdown frequency offset summary

Parameter	Value, kHz
S-band frequency change	
Retroignition minus 1 h to retro-ignition	-9.5
Retroignition to touchdown	+17.0
Desired automatic frequency control B at touchdown	+8.5
Required automatic frequency control B at retroignition	-8.5
Necessary automatic frequency control B at retroignition minus 1 h	+1.0
Static phase error (before transponder OFF)	+7.3
Automatic frequency control (after transponder OFF)	+1.0
0.0-kHz automatic frequency control corresponds to	+6.3 static phase error
Item (4) automatic frequency control corresponds to	+7.3 static phase error
Frequency offset corresponds to	Static phase error B + 7.3 kHz = 460 binary-coded decimal

At 00:40:03 on November 10, the touchdown strain gages were turned on by commanding on the phase-modulated presumming amplifier. The DSS 11 received carrier power was -122.0 dBmW prior to retroignition, which was in agreement with the predicted nominal value used for the strain-gage feasibility analysis.

Retromotor burn was initiated at approximately 00:58:04. The signal level at DSS 11 remained steady with approximately a 0.7-dB variation during the burn period. Touchdown was reported at 01:01:05.5 with DSS 11 and DSS 14 maintaining phase lock throughout the descent and touchdown phases. Good 1100-bit/s data and strain-gage data were obtained through touchdown. The minimum downlink signal level during descent was -127.5 dBmW, which agreed with nominal predictions.

The doppler change from transmitter tuning to the time when transponder B was turned off at 00:16:59 caused the static phase error B to read 6.6 kHz and the corresponding automatic frequency control B after turn-off read 9.6 kHz. At touchdown, the automatic frequency control read 18.0 kHz, which was within 0.5 kHz of the

predicted value resulting from the reevaluation of the touchdown frequency offset analysis.

Following the terminal maneuver evaluation, the touchdown strain-gage feasibility analysis was performed and a turnon criterion established. Best estimates of spacecraft worst-case performance during descent and at touchdown indicated that, with strain gage on, 1100-bit/s data could be obtained at a 3×10^{-8} bit error rate at either DSS 11 or DSS 14 with the spacecraft transmitting on omniantenna B. It was recommended that the strain gages be turned on if the received carrier power at DSS 14 was greater than -128.0 dBmW at the end of the terminal maneuver with the spacecraft transmitting data at 1100 bits/s only.

The spacecraft was commanded to high power at 00:07:32 and 1100-bit/s data selected at 00:08:20. The resulting -124.0 dBmW signal level indicated an increase of 16.4 dB over low power operation. Transponder B was turned off at 00:16:59, establishing the spacecraft configuration for the terminal sequence. Maneuver initiation times were 00:25:20 for the first roll, 00:29:38 for the yaw, and 00:34:56 for the second roll.

The automatic descent sequence was initiated by the AMR mark, the generation of which was confirmed on the ground at 57:57:08.3. Vernier engine ignition, retro-engine ignition, RADVS initial turnon and application of high power after 18 s, retromotor burnout, and retromotor separation occurred normally.

The moment disturbance produced by the retroengine firing was small (on the same order as previous spacecraft) and indicated that there certainly was no large center of gravity offset. The doppler velocity sensor acquisition and lockon (both velocity and range) were accomplished prior to retromotor burnout, and the radar altimeter achieved lockon at segment acquisition.

When the enable doppler control signal was generated (2 s after retromotor separation was initiated), the doppler control phase was initiated. Realignment of the spacecraft Z-axis to the existing velocity vector was accomplished in 3-4 s, with the gyro error signals confirming that the spacecraft was being controlled normally during this phase.

The vernier engines, under control of the RADVS, kept the spacecraft on the desired range- V_z contour, and the 1000-ft, 10-ft/s, and 14-ft marks were generated as

expected (telemetry confirmation received on the ground at $T + 65$ h, 21 min, 40 s; 65 h, 21 min, 57 s; and 65 h, 22 min, 3 s, respectively). Touchdown occurred 65 h, 22 min, 4.48 s after launch, with continuous data being received without loss of receiver lock and receiving good strain-gage data, and the spacecraft in excellent condition.

Postlanding shutdown sequences were immediately initiated with engineering assessment performed and the spacecraft prepared for television operations. Figure 56 shows the *Surveyor VI* lunar transit trajectory.

G. Touchdown to End of Mission

After a postlanding interrogation, DSS 11 received the first 200-line TV picture at 01:51:25 on November 10, 1967, 50 min, 20 s after touchdown. The sequence of events time was 1 h, 6 min. Twenty-four (200-line) TV pictures of good quality were received. The planar array antenna and the solar panel were positioned in preparation for the 600-line TV pictures.

The prime command station for lunar phase TV was DSS 11 which commanded the majority of TV pictures. (DSSs 42 and 61 also commanded and received 600-line TV pictures.)

Operations consisted of engineering interrogations, A/SPP positioning, TV pictures, alpha scattering experiment data accumulation and calibration, a magnet experiment attached to footpad 2 for investigating properties of the lunar soil, and best-lock frequency measurements.

With *Surveyor VI* placed in standby transponder mode at a frequency offset of 50 kHz, on six separate passes, attempts were made to revive *Surveyor V* on November 10 and 11 by DSSs 51, 42, and 61; on November 12-14 by DSS 61, and on November 18 by DSS 42.

A spacecraft attitude gas jet experiment was commanded by DSS 11 on November 11. A spacecraft liftoff and translation experiment was accomplished by DSS 11 November 16. The vernier engines burned for $2\frac{1}{2}$ s. The additional $\frac{1}{2}$ s of burn resulted in a flight time of 6.078 s and carried the spacecraft a distance of 10 ft instead of the planned 4 ft, in a westerly direction, clockwise from the spacecraft's plus X-axis. After the landing, a helium leak developed, precluding plans for a second hop.

Following the spacecraft translation, the alpha scattering instrument settled in an inverted position which precluded any lunar surface accumulations. However, the proton detectors of the instrument did provide cosmic radiation data.

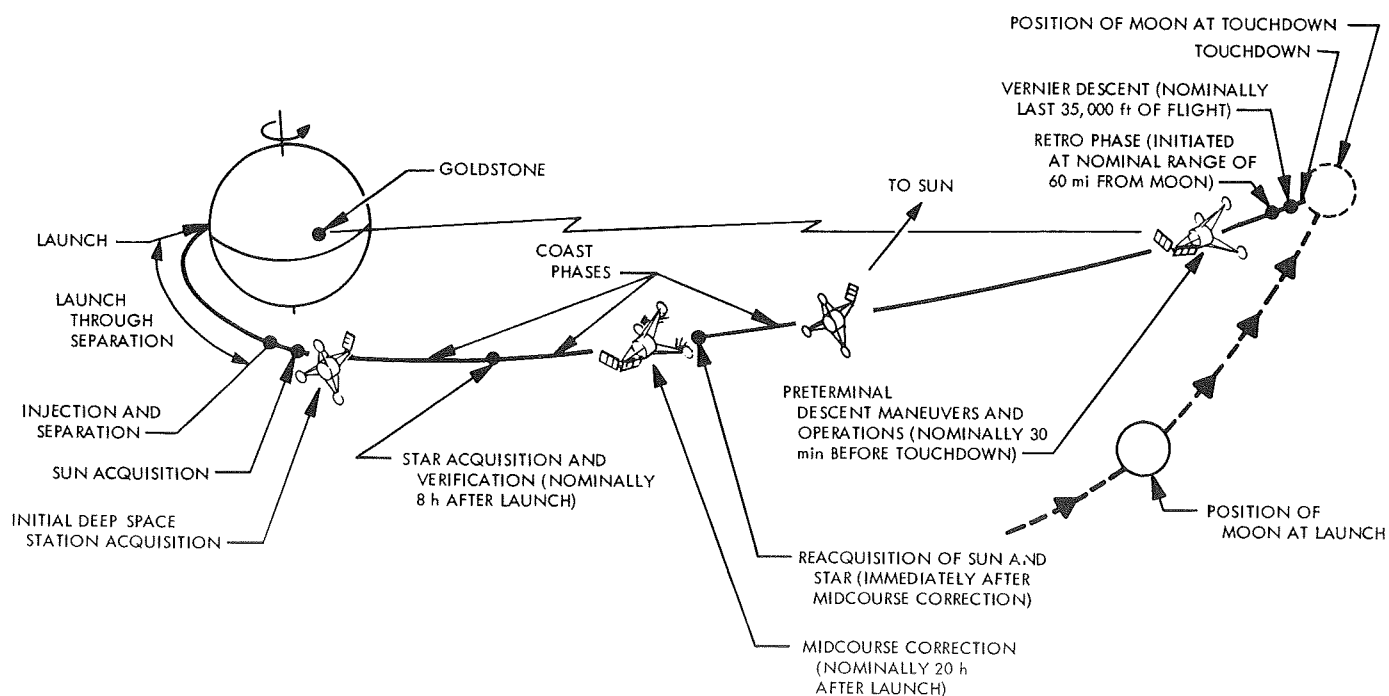


Fig. 56. Lunar transit trajectory

Significant firsts on the moon included:

- (1) Detailed view of mare ridge.
- (2) Launch from the lunar surface.
- (3) Controlled movement of a spacecraft across the lunar surface.
- (4) Discovery of post-sunset horizon, an illumination phenomenon.
- (5) Observation of solar corona out to 30 solar radii.

Toward lunar sunset, the landing legs were successfully locked at 16:08 on November 22. Thermal and power management were accomplished through the lunar day and by a night operations plan similar to the one used for *Surveyor V*. Lunar sunset (sunlight off the solar panel) occurred at 13:53 November 24, 1967.

The lunar night operations plan stabilized compartment A and B temperatures near their lower operating limits and were to extend operations as far as possible into the lunar night.

At 06:41 on November 26, 1967, the spacecraft was commanded off by DSS 61. At 07:40, the spacecraft did not respond to the engineering interrogations by DSS 61, which indicated that the temperatures were below effective operating levels.

Compartment thermal switch failures limited the post-sunset operations to 40 h, 48 min, instead of an expected minimum of 130 h.

1. Second lunar day. Unsuccessful attempts to revive *Surveyor VI* on its second lunar day were made on December 13 by DSS 11, which initiated search at 01:00, and by DSS 61. On December 14, DSSs 11 and 42 were not able to contact the spacecraft.

After a shutdown period of 18 days, 10 h, DSS 61 successfully revived *Surveyor VI* at 16:41 on December 14, 1967. The signal was unsteady and difficult to maintain lock. The spacecraft signal was lost at 19:14. Usable data received indicated a battery problem.

Earlier, at 05:45 on December 14, DSS 11 successfully revived *Surveyor V* on its fourth lunar day. Further revivals were accomplished on that day by DSSs 42 and 61. On December 16, the DSS 11 tracking period was cancelled due to heavy snow and icing conditions at Goldstone; however, at 21:30, DSS 61 was able to revive *Surveyor V*. The downlink signal was lost by DSS 11

during pass 4-4, when the spacecraft was switched from low to high power (01:59:48 on December 17).

Surveyor V operations provided 64 (200-line) TV pictures, but there was no usable telemetry in modes 1-6.

Efforts to revive either *Surveyor V* or *VI* were continued unsuccessfully through December 21, 1967 when revival attempts for that lunar day were terminated at 21:28:22.

2. Third lunar day. *Surveyor VII* soft-landed on the moon at 01:05:37.6 January 10, 1968. On January 16, 1968, with *Surveyor VII* placed in a standby transponder mode, DSS 61 unsuccessfully attempted to reacquire *Surveyor V* on its fifth lunar day, and *Surveyor VI* on its third lunar day. Also, on the same day, DSS 11 was unsuccessful in attempting to revive *Surveyor I* on its twentieth lunar day, *Surveyor III* on its ninth lunar day as well as *Surveyors V* and *VI*.

3. Fourth lunar day. This lunar day marked the sixth lunar day for *Surveyor V*, the fourth for *Surveyor VI* and the second for *Surveyor VII*.

An attempt was made by DSS 61, on February 12, 1968, to simultaneously reacquire *Surveyors V*, *VI*, or *VII*. With transmitter power ON, command modulation was on at 19:00. The first revival command was sent and a spacecraft responded; DSS 61 receiver going in lock at 19:00:56, with *Surveyor VII* responding. Attempts were made unsuccessfully to monitor the *Surveyors V* or *VI* carriers from 19:03 to 19:15, on receiver 2. On February 15, 1968, DSS 11 unsuccessfully attempted to revive *Surveyor VI* prior to tracking *Surveyor VII* on pass 2-4.

H. Summary of Deep Space Station Operations

The following pages comprise a summary of Deep Space Station operations for the *Surveyor VI* Mission. Table 30 defines the ground modes and is included in the description of the tabular columns of Table 31 which follows.

Table 30. Ground modes

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

1. *DSS No.* This number refers to the designation of the Deep Space Station participating in this mission. The stations participating were:

DSS 11 (Pioneer), Goldstone, Calif.

DSS 12 (Echo), Goldstone, Calif.

DSS 14 (Mars), Goldstone, Calif.

DSS 42, Tidbinbilla, Australia.

DSS 51, Johannesburg, South Africa.

DSS 61, Robledo, Spain.

DSS 71, Cape Kennedy, Fla.

2. *Time from acquisition to end of track, GMT, day of year, time.* Each station entry in these columns consists of two sets of numbers. The first set is the day and time, in hours, minutes, and seconds, GMT of spacecraft acquisition. The second set of numbers indicates the day and time that tracking terminated.

3. *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 30. At the end of each station entry is the total tracking time in all modes.

4. *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).

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

6. *Television pictures received, commanded, noncommanded.* Unless otherwise indicated, these figures represent 600-line television pictures received by a station while the spacecraft was under its command. Noncommanded pictures, are pictures received by a station while the spacecraft was commanded by another station.

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

1. Station Tracking Summary

Figure 57 is a profile of the mission activity of the Deep Space Stations from launch until the end of DSN committed coverage November 27, 1967. This figure contains the periods each station tracked the spacecraft plotted against mission time from liftoff, the number of commands transmitted by each station during each pass, the number of TV pictures received by command by each station during each pass, and the number of hours of alpha scattering data received by each station during each pass. Table 32 presents the total number of commands sent by each station during the mission. The total number of commanded and uncommanded TV pictures received by each station is presented in Table 33. The three prime stations committed to support alpha scattering operations received a total of 71 h, 1 min of data. The total number of hours alpha scattering data was received by each station during each pass is presented in Table 34.

The Deep Space Stations supported the *Surveyor VI* Mission with a high level of performance. Continuous tracking and telemetry coverage was provided from $T + 29$ s, November 7, 1967 until two earth days after lunar sunset which occurred November 24, 1967.

High quality angular tracking and two-way doppler data were received throughout the *Surveyor VI* Mission with the exception of minor outages, which neither adversely affected the flight or resulted in any mission objectives not being met. All requirements for tracking, telemetry, command, and data processing were met.

A number of minor equipment anomalies and procedural problems occurred, but were readily corrected by station personnel without affecting the mission.

Surveyor VI was launched with all essential elements of the DSN functioning nominally.

One-way spacecraft signals were received by DSS 71 for 4 min and 49 s after liftoff. DSS 71 also processed real-time AFETR telemetry with its CDC and telemetry and command processor.

Initial two-way acquisition was achieved by DSS 51 4 min, 11 s after spacecraft rise over the station's horizon. Less than 5 min, 39 s elapsed from the time of receipt of the first spacecraft signals until DSS 51 was prepared to command the spacecraft. The spacecraft was tracked about 14 h during the first pass, and 12 h during the second pass.

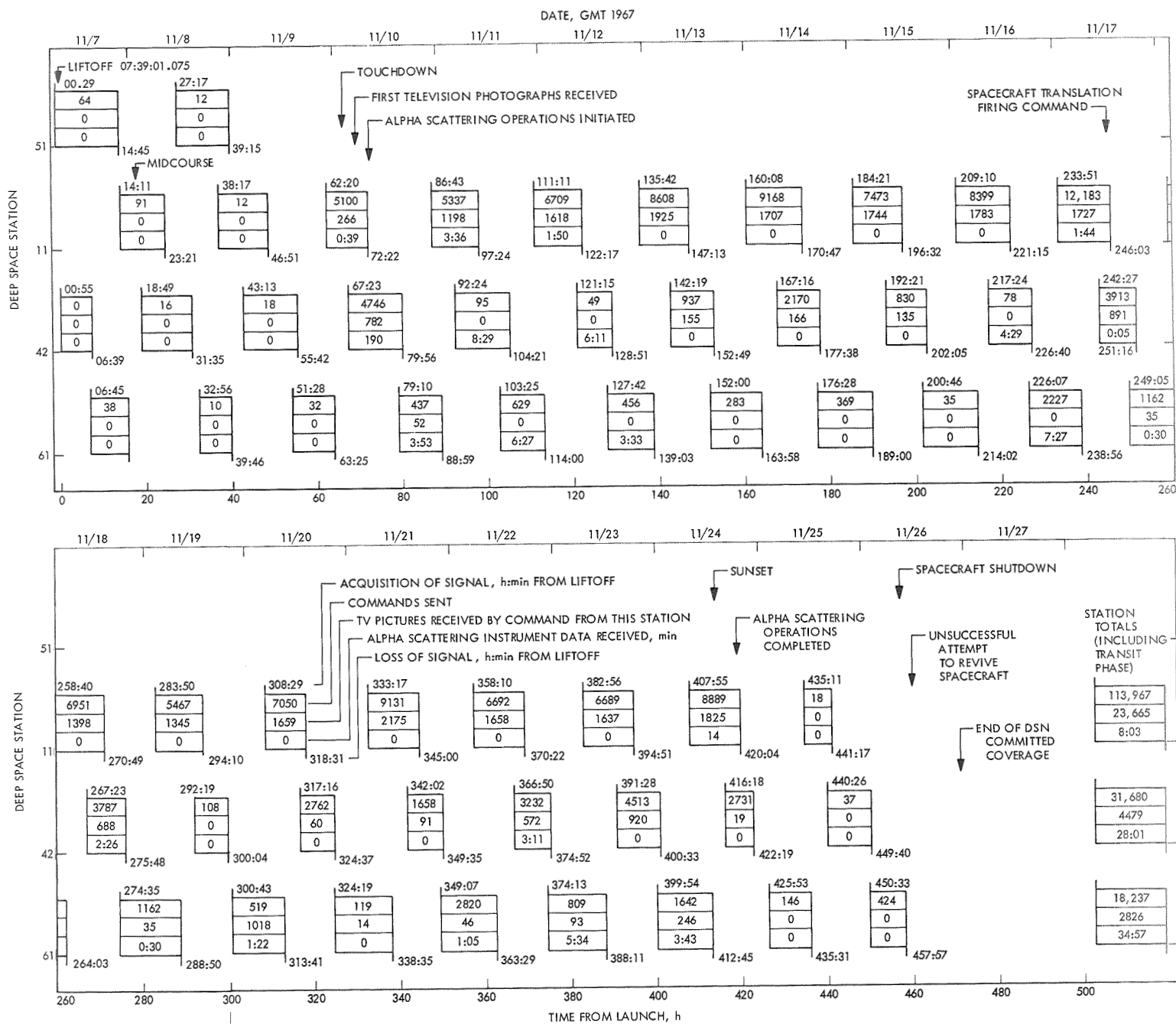


Fig. 57. Station tracking period, launch through first lunar day

Table 31. Summary of Deep Space Station operations for Surveyor VI

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			Com-manded	Noncom-manded	
Launch									
71	311	07:39:01 07:43:44	1 Total	00:04:43 00:04:43	071.0 156.0	0	0	0	Liftoff: 07:39:01.075 GMT Launch azimuth: 082.995 deg
Pass 1—launch pass									
51	311	08:08:51 22:24:00	1 2 3 Total	00:04:34 09:11:44 02:13:53 11:30:11	083.0 131.2	64	0	0	Faulty tracking data handling punch 2. Replaced loose Sanborn recorder drive belt Spacecraft transfers to DSS 42 at 10:10, to DSS 16 at 14:45, to DSS 11 at 22:10 (a power-steal transfer with complete loss of communications at DSS 51)
Carnarvon	311	08:22:00 08:50:00	1 Total	00:28:00 00:28:00	122.0	0	0	0	Provided spacecraft telemetry data to DSS 42 via data-phone link
42	311	08:34:00 14:18:03	2 3 Total	02:08:00 01:36:03 03:44:03	111.0 146.0	0	0	0	Spacecraft transfer to DSS 51 at 12:10
61	311	14:24:31 22:42:42	2 3 4 Total	02:10:06 05:32:11 00:35:44 08:18:01	119.0 158.0	38	0	0	Spacecraft transfer to DSS 51 at 17:30
11	311 312	21:52:59 07:00:00	2 3 Total	05:28:51 03:38:10 09:07:01	117.3 137.5	91	0	0	Acquired spacecraft from DSS 51 at 22:10 with a power-steal transfer Sanborn recorder had bad pens on RCV 2, DPE and TXR FWD PWR—problem was corrected Tracking data handling punch 2 malfunctioning at 10 s sample rate; awaiting spare parts Problem with command confirmation believed to be hardware problem in buffer of telemetry and command processor A Midcourse maneuver completed at 02:36 Spacecraft transfer to DSS 42 at 03:40

^aGround mode; defined in Table 30.

Table 31 (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—launch pass (contd)									
14	311	21:56:39	3	07:33:21	107.7	0	0	0	Loss of lock at 01.43 due to low film light indication. Back on spacecraft at 01:50:50. Instrumentation problem Prime telemetry recording and transmitter backup to DSS 11 Post-midcourse, station accomplished special engineering and strain gage data transmission test
	312	05:30:00	Total	07:33:21	139.0				
Pass 2									
42	312	02:28:25 15:14:00	2	09:20:02	137.0	16	0	0	Telemetry and command processor B 115 V ac power supply failed at 21:30 Spacecraft transfer to DSS 51 at 13:30
			3	03:25:33	157.0				
			Total	12:45:35					
51	312	10:56:14 22:54:00	2	07:13:20	134.9	12	0	0	Telemetry and command processor down at 17:33:37. Program reloaded. Operational at 17:37:06 Failure in Sorensen ac regulator—low output. Switched to S-band acquisition aid paramp-rack UWV 1. Switched to unregulated supply while repairs being carried out With all communications out, station reduced transmitter power to 1 kW for power-steal transfer to DSS 61; completed at 20:43:30
			3	04:44:26	135.5				
			Total	11:57:46					
61	312	14:36:51 23:25:54	2	01:33:46	137.5	10	0	0	Transmitter on at 10 kW for power-steal transfer from DSS 51 Spacecraft transfer to DSS 11 at 22:15
			3	07:15:17	134.6				
			Total	08:49:03					
11	312	21:59:49	2	08:23:12	131.5	12	0	0	Doppler portion of Interplanetary Monitoring Probe malfunctioned at 02:45:45 and 04:04:50 due to apparent bad tapes Spacecraft transfer to DSS 42 at 05:40
	313	06:30:00	3	01:07:11	137.8				
			Total	09:30:23					
14	312	22:53:15	3	06:46:45	127.0	0	0	0	Prime telemetry and transmitter backup to DSS 11
	313	06:30:39	4	00:50:00	127.9				
			Total	07:36:45					

Table 31 (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									
42	313	02:52:54 15:21:00	1 2 3 Total	00:06:09 07:46:43 04:37:14 12:30:06	137.2 160.5	18	0	0	At 14:25 telemetry and command processor B malfunctioned. Reloaded at 14:28 At 14:45, telemetry and command processor B went out again, switched to alpha telemetry and command processor at 14:58 Transmitter trip, collector flow low Surveyor on-site computer program malfunctioned on telemetry and command processor B Spacecraft transfer to DSS 51 at 13:30
51	313	11:07:15 23:04:40	2 3 Total	08:45:02 03:12:23 11:57:25	137.5 140.3	32	0	0	Spacecraft transfer to DSS 11 at 22:15
61	313	14:40:55 23:40:50	3 Total	09:00:05 09:00:05	138.2 159.0	0	0	0	Station had noisy doppler data. Replaced rubidium standard. Lost approximately 1½ h of data No spacecraft transfer
11	313 314	21:59:46 08:01:00	1 2 3 4 Total	00:14:53 05:47:14 00:55:32 02:42:41 09:40:24	96.4 156.7	5,100	266 ^b	24	Reperforator on OSAS teletype machine intermittent Tracking data handling switch panel KP 144 record switch still down. Master switch positioned to have punch 1 as prime punch on line and punch 2 as backup Teletype L garbling Teletype R line feed operating intermittently Mission support recorder FR-1400 A inoperative Touchdown at 01:01:04.18 at 0.470 deg N, 1.480 deg W (Lunar Orbiter photo evaluation) Spacecraft transfer to DSS 42 at 07:20
14	313 314	22:07:10 07:37:27	3 Total	09:30:17 09:30:17	89.0 136.0	0	0	0	Prime telemetry recording and transmitter backup to DSS 11
^b Includes 24 (200 line) TV pictures.									

Table 31 (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									
42	314	03:02:20 15:35:00	1 2 3 Total	01:38:50 07:47:00 <u>03:05:41</u> 12:31:31	112.4 140.0	4,746	782	211	Alpha telemetry and command processor high-speed data failure Unsuccessfully searched for Surveyor V on receiver, from 14:26 to 15:07:02 Spacecraft transfer to DSS 61 at 15:07
61	314 315	14:49:46 00:38:00	1 2 3 4 Total	00:24:25 06:32:28 01:13:12 <u>00:30:00</u> 08:40:05	103.0 140.0	437	52	313	OSAS program would not search for any record number after having been removed to generate a command tape Unsuccessful contact on receiver 2 with Surveyor V, from 18:50 to 19:06, pass 3-1 Spacecraft transfer to DSS 11 at 22:35
11	314 315	22:22:51 09:03:00	1 2 3 4 Total	00:59:34 03:49:52 00:25:26 <u>05:04:30</u> 10:19:22	103.6 140.0	5,337	1198	0	Station down converter noisy. ETO unknown Missed first 16 frames of 600-line TV Spacecraft transfer to DSS 42 at 08:50
Pass 5									
42	315	04:03:37 16:00:20	1 2 3 Total	00:12:24 06:27:38 <u>01:06:41</u> 07:46:43	113.0 120.0	95	0	140	OSAS telemetry and command processor alpha program hang up when addressing magnetic tape transport No high-speed data processed at SFOF from DSS 11 set at 09:00 to 10:49 due to telemetry and command processor high-speed data switches incorrectly set to 24-bit word. Reset to 22-bit word and telemetry processing station locked OK Receiver operator had difficulty tuning execute VCO smoothly during transfer due to what appears to be a faulty execute/acquire pot ASI deployed at 12:08 Unsuccessful contact on receiver 2 with Surveyor V, from 13:48:14 to 13:56, pass 3-2 Spacecraft transfer to DSS 61 at 15:30.

Table 31 (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 5 (contd)									
61	315 316	15:04:43 01:39:19	2 3 Total	07:35:00 02:59:05 10:34:05	113.4 131.0	629	0	466	Receiver out of lock about 2 min probably due to a large static phase error built up in spacecraft receiver when offsetting Surveyor VI to track Surveyor V Solved by going back to TSF Unsuccessful contact on receiver 2 with Surveyor V, from 20:04:01 to 20:08:00, pass 3-2 Spacecraft transfer to DSS 11 at 23:05
11	315 316	22:50:57 09:56:00	2 3 4 Total	01:42:20 00:00:01 08:05:06 10:27:27	112.4 121.4	6,709	1618	0	FR-900 servo will not lock in reproduce mode Spacecraft transfer to DSS 42 at 09:30
Pass 6									
42	316	08:54:20 16:30:00	2 3 Total	06:30:02 01:06:00 07:36:02	120.0 121.3	49	0	0	Telemetry and command processor OSAS program started going into a loop, permanently addressing tape unit 3 again, (carryover from pass 5). Telemetry and command processor B magnetic tape unit connected to telemetry and command A unit and vice versa to correct problem for this pass Station experiencing problem with tuning exciter VCO smoothly. Station given permission to delay acquisition scheduled for 04:55, to work on problem Spacecraft transfer to DSS 61 at 16:00
61	316 317	15:21:15 02:42:00	1 2 3 Total	00:25:03 04:59:12 03:46:28 09:10:43	112.0 119.8	456	0	506	Command 0410 transmitted in error—should have been command 0401 (23:20:42), transmitted 36 times Unable to lock up DECOM after AIS. Removed patch-panel DECOM locked up but when it went to alpha scattering mode, 70-kHz discriminator would not lock up. When it went to video, CDC could not get any video in CDC. Cause: CDC demod switch (operate—test signal) was apparently off operate position. Lost six pictures on 35-mm film but not on FR-800 video recorder SC 6 shutdown from 20:00 to 22:00 for Surveyor V revival attempt. Negative contact on Surveyor V, pass 3-3

Table 31 (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 6 (contd)									
61 (contd)									Spacecraft transfer to DSS 11 at 23:35
11	316 317	23:21:11 10:52:00	2 3 4 Total	02:37:21 00:25:47 08:17:15 11:20:23	97.4 156.0	8,608	1925	0	At 05:20:00, FR-900 recorder tape tension arm would not actuate. Tightened set screw. Operation normal at 05:38:00 FR-900 playback noisy Spacecraft transfer to DSS 42 at 10:40
Pass 7									
42	317	05:58:00 16:28:00	1 2 3 Total	03:03:00 04:30:38 01:46:49 09:20:27	112.1 114.7	937	155	677	Maser 1 withdrawn from service due to falling pressure so it can be worked on during nontracking period FR-800 recorder servo problem causing dropouts Spacecraft transfer to DSS 61 at 16:20
61	317 318	15:39:20 03:37:51	0 1 2 3 Total	02:05:33 00:06:55 05:20:42 04:19:01 11:52:11	112.1 137.0	283	0	513	Unsuccessful Surveyor V, pass 3-4, revival from 22:09:35 to 22:07:00 (Surveyor VI in standby mode) Spacecraft transfer to DSS 11 at 24:00
11	317 318	23:47:29 10:26:00	2 3 4 Total	02:24:49 00:18:46 05:49:34 08:33:09	96.1 138.5	9,168	1707	0	FR-900 playback noisy between frames. Still investigating Command confirmation repeats overline. Program problem believed to be the cause TDH not printing full line of data. Problem corrected by replacing overheated card at 07:49 From 06:14 to 06:23, FR-800 recorder having problem with takeup reel. Missed approximately seven TV frames. Problem caused by loose reel; replaced Spacecraft transfer to DSS 42 at 10:20
Pass 8									
42	318	06:55:00 17:17:52	1 2	02:25:00 04:45:22	99.9 149.0	2,170	166	436	Maser 1 still down Spacecraft transfer to DSS 61 at 16:50

Table 31 (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 8 (contd)									
42 (contd)			3 4 Total	01:15:26 00:59:00 09:24:48					
61	318 319	16:07:04 04:39:56	0 1 2 3 Total	00:21:25 00:29:58 05:10:16 04:28:07 10:29:46	113.6 120.3	369	0	836	FR-1400 A, loss of signal on track 2 of tape 1A. Same signal is recorded on track 6. Cleaned head From 21:06 to 21:32:38 and from 21:38:08 to 23:21, made unsuccessful Surveyor V revival attempt, pass 3-5 (Surveyor VI in standby) Spacecraft transfer to DSS 11 at 00:30
11	319	00:11:24 12:11:00	1 2 3 4 Total	00:44:31 04:23:50 00:26:36 06:19:04 11:54:01	102.0 157.3	7,473	1744	0	FR-900 playback noisy Spacecraft transfer to DSS 42 at 12:00
Pass 9									
42	319	08:00:06 17:44:45	2 3 4 Total	05:06:12 04:54:37 00:43:00 10:43:49	114.3 137.0	830	135	92	Maser 1 being cooled down. Estimated time down 12 h. Cannot load OSAS program into back up telemetry and command processor B. Problem cured at 07:52. Loose wire in power supply At 15:23, incorrect line feeds and carriage returns on average alarm/english language for telemetry and command processor B Spacecraft transfer to DSS 61 at 17:00
61	319 320	16:25:44 05:41:14	2 3 Total	08:00:52 05:14:38 13:15:30	93.3 114.3	35	0	1116	One video frame lost during 3-way track Spacecraft transfer to DSS 11 at 01:00
11	320	00:49:00 12:54:00	1 2 3 4 Total	00:12:30 03:17:22 00:24:28 06:59:50 10:54:10	96.7 113.8	8,399	1783	0	Magnetic tape—video playback noisy TV-11 film recorder inoperative (02:00—02:10) TV-11 transporter tension spring broken (02:55:00—03:03:00). Replaced TV-11 Schmidt trigger baseband video inoperative

Table 31 (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 9 (contd)									
11 (contd)									Antenna axial ratio experiment Spacecraft transfer to DSS 42 at 12:40
Pass 10									
42	320	09:03:00 18:19:16	1 2 3 Total	00:28:40 05:10:02 03:52:04 09:30:46	113.7 120.0	78	0	38	Maser 1 cooled down. Requires stability run to be operational Telemetry and command processor B unserviceable. Cleared at 10:30. Faulty CCT card CK 53 OSAS on telemetry and command processor B tens and unit hours erroneous on time output. Also data appears to be multiplied by factor 64 OSAS to telemetry and command processor A and SOCP to telemetry and command processor B at 15:16. Corrected Digital instrumentation system B—Interplanetary Monitoring Probe program malfunctions at 11:19 and 18:10 Spacecraft transfer to DSS 61 at 17:50
61	320 321	17:06:00 06:35:36	2 3 Total	07:50:46 05:38:50 13:29:36	116.0 119.8	2,227	0	644	Spacecraft transfer to DSS 11 at 01:40
11	321	01:30:00 13:42:00	0 1 2 3 4 Total	00:03:10 00:10:49 04:22:18 00:43:18 03:55:27 09:15:02	112.4 133.0	12,183	1727	34	Translation engine firing at 10:32 TV-11 on-site film recorder vertical sweep is intermittently jittery Spacecraft transfer to DSS 42 at 13:10
14	321	08:15:00 11:09:00	3 Total	01:54:00 01:54:00	103.0 140.0	0	0	0	Monitored translation firing at 10:32
Pass 11									
42	321	10:06:12 18:45:15	1 4 Total	03:50:06 04:48:57 08:39:03	116.3 153.5	3,913	891	537	Intermittent video on backup TV photo recorder Monitored translation engine firing Spacecraft transfer to DSS 61 at 18:00

Table 31 (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 11 (contd)									
61	321 322	17:38:01 07:42:20	1	04:56:44	98.4 121.1	6,080	1322	751	Spacecraft transfer to DSS 11 at 02:30
			2	04:09:56					
			3	04:42:58					
			Total	13:49:38					
11	322	02:19:50 14:28:00	2	02:23:39	101.1 120.3	6,951	1398	500	Four video frames lost due to loose FR-800 takeup reel Spacecraft transfer to DSS 42 at 11:50
			3	03:15:08					
			4	04:24:15					
			Total	10:03:02					
Pass 12									
42	322	11:02:00 19:27:07	2	04:22:37	119.6 125.2	3,787	688	157	Spacecraft transfer to DSS 61 at 18:50
			3	01:25:05					
			4	02:37:25					
			Total	08:25:07					
61	322 323	18:14:55 08:29:30	1	01:21:03	113.5 119.4	1,162	35	1044	Spacecraft transfer to DSS 11 at 08:00
			2	09:08:17					
			3	01:04:15					
			Total	11:33:35					
11	323	03:09:47 13:49:26	0	01:35:27	113.1 115.0	5,467	1345	0	Bit synchronizer clock varying in sync with spacecraft PCM rate causing poor film display of PCM ID Spacecraft transfer to DSS 42 at 12:30
			1	00:35:30					
			2	01:06:29					
			3	01:44:28					
			4	05:11:33					
			Total	10:13:27					
Pass 13									
42	323	11:58:00 15:12:00 15:48:00 19:43:00	0	04:58:50	113.4 115.8	108	0	0	Unsuccessful SC 5 revival, from 15:12 to 15:48, pass 3-10 Command confirmation TTY printout repetition of commands from (15:47:22.8—16:03:21.8) Spacecraft transfer to DSS 61 at 19:40
			1	00:14:57					
			2	00:22:33					
			4	00:28:39					
			Total	06:04:59					

Table 31 (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 13 (contd)									
61	323 324	19:40:00 09:20:07	0	05:40:40	113.1 125.1	519	1018	0	Spacecraft transfer to DSS 11 at 04:15 and 09:05
			1	03:58:19					
			2	00:53:09					
			3	00:07:22					
			4	02:43:23					
			Total	13:22:53					
11	324	04:08:00 14:10:00	1	00:19:43	97.~ 125.0	7,050	1659	0	No video data on FR-900 up to 10:08:00 due to signal selector switch on FR-900 in wrong position. Dubs being made from FR-800 on to FR-900 to correct this Bit synchronizer lock varying in sync with spacecraft PCM rate causing poor film display of PCM ID Horizontal sync jitter out of tolerance at 3 dB signal-to-noise ratio and below Considerable distortion of limiter output on 4-MHz record line to MSR Time code translator not updating correctly when "60 SEC." changes to "00 MIN." "01" must occur to update minutes; intermittent problem Had demodulated video overshoot on leading edge of sync. Believed to be spacecraft problem Spacecraft transfer to DSS 61 at 08:20 and to DSS 42 at 13:10
			2	00:54:28					
			3	01:58:01					
			4	06:48:17					
			Total	10:00:29					
Pass 14									
42	324	12:55:00 20:16:45	1	00:04:39	114.4 134.5	2,762	60	0	Spacecraft transfer to DSS 61 at 20:15
			2	04:56:43					
			3	00:16:45					
			4	01:01:27					
			Total	06:39:34					
61	324 325	19:58:25 10:14:14	1	04:24:46	96.7 140.7	119	14	920	Lost 35 min of prime data on tape 1A (FR-1400). Tape 1B on mission support contained same data and was included in data package. Tape was apparently stretched before being put on. It was a twice-used tape. Changed to new tape Spacecraft transfers to DSS 11 at 05:10 and 10:10
			2	01:19:28					
			3	00:26:34					
			4	02:06:01					
			Total	08:16:49					

Table 31 (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 14 (contd)									
11	325	04:56:42 16:40:00	1 2 3 4 Total	00:02:28 01:13:18 02:09:27 07:08:35 10:33:48	113.5 116.7	9,131	2175	46	Lost four or five frames of video from DSS 42 due to loss of backfeed net Spacecraft transfers to DSS 61 at 09:40, to DSS 42 at 14:00 and at 16:35
Pass 15									
42	325	13:41:00 21:14:00	1 2 3 4 Total	00:03:14 05:37:09 01:38:00 01:04:02 08:22:25	113.6 130.2	1,658	91	222	Receiver out of lock from 19:23:00 to 19:23:15 and 19:23:44 to 19:23:47. No reason found for this at station Spacecraft transfers to DSS 11 at 15:20 and to DSS 61 at 21:10
61	325 326	20:46:00 11:08:00	1 2 3 Total	03:36:38 06:28:24 05:06:58 15:12:00	96.5 152.8	2,820	46	1099	Spacecraft transfer to DSS 11 at 06:15
11	326	05:49:35 18:01:30	2 3 4 Total	01:34:27 01:35:07 06:50:40 10:00:14	112.6 120.7	6,692	1658	448	Maser 2 inoperative. Bad cross head Excess nitrogen leak in waveguide TV-11 film recorder inoperative FR-800 head 1 spring shorting to ground on head 2. Spring repositioned at 11:20. Problem corrected Spacecraft transfer to DSS 12 at 13:20 DSS 11 remained prime telemetry receiver during DSS 12 backup transmitter operation, from 13:20 to 14:45
12	326	10:00:00 15:00:00	2 3 Total	01:25:02 03:34:58 05:00:00		0	0	0	DSS 12 provided standby with transmitter antenna and associated equipment to support command activity in event of DSS 11 transmitter failure Backup transmitter operation to DSS 11 from 13:20 to 14:45 Spacecraft transfer to DSS 42 at 14:45

Table 31 (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 16									
42	326	14:29:00 22:31:00	2 3 4 Total	05:53:34 00:20:00 02:48:08 09:01:42	98.4 120.5	3,232	572	19	At 16:45, command confirmation repeated a block of 15 commands OSAS record 5 had incorrect engineering heading due to operator error Spacecraft transfer to DSS 61 at 22:25
61	326 327	21:52:30 11:50:00	2 3 Total	08:30:02 05:27:28 13:57:30	101.7 135.7	809	93	1057	Spacecraft transfers to DSS 11 at 06:55
11	327	06:35:40 18:30:00	2 3 4 Total	01:35:38 01:08:47 09:08:23 11:52:48	113.2 138.0	6,689	1637	419	Excessive oxide buildup on female guide on FR-900 video recorder Spacecraft transfer to DSS 42 at 15:30
Pass 17									
42	327 328	15:07:00 00:12:00	2 3 4 Total	04:28:29 00:31:58 03:40:48 08:41:15	114.2 115.0	4,513	920	95	CDC Sanborn recorder failure due to socket mounted transistor dislodged. Retaining clip found to be faulty CDC command printer failure Receiver dropped lock at 19:12:46. No known reason Command 05:00 not transmitted to command confirmation at 22:55:53. Telemetry and command processor B Surveyor on-site computer 6 loaded Spacecraft transfer to DSS 61 at 23:40
61	327 328	23:33:03 12:24:45	2 3 Total	08:00:02 04:51:40 12:51:42	114.0 120.0	1,642	246	1044	Spacecraft transfer to DSS 11 at 07:40
11	328	07:34:00 19:43:00	1 2 3 4 Total	00:30:25 00:51:03 00:06:00 10:31:42 11:59:10	119.5 124.3	8,889	1825	40	DIS magnetic tape ran off end of tape reel; cause unknown Lunar sunset at 13:53 Spacecraft transfer to DSS 42 at 18:45

Table 31 (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 18									
42	328	15:47:21 21:48:00	0 1 4 Total	00:12:50 02:57:39 02:49:51 06:00:20	112.6 118.5	2,731	19	105	Before end of track, spacecraft shut down for 4 h
61	329	01:32:56 11:10:00	0 2 4 Total	01:26:01 02:58:22 01:38:17 06:02:40	145.3 148.8	146	0	0	Spacecraft revival first lunar night Spacecraft transfer to DSS 11 at 11:05
11	329	10:50:29 16:56:30	2 3 Total	05:25:02 00:40:59 06:06:01	145.2 147.8	18	0	0	At 11:04, tracking and data handling punches 1 and 2 (1-min sample rates), intermittently lost data by garbling or incomplete lines Spacecraft transfer to DSS 42 at 16:30
Pass 19									
42	329 330	16:05:58 01:19:00	0 1 2 3 Total	01:03:38 00:17:30 07:54:12 00:24:02 09:39:22	145.3 148.7	37	0	0	Permission given to phase lock CDC transponder when going 2 way to help with investigations into receiver drop lock on passes 15 and 17 Receiver 1 acq. pot faulty. Telemetry and command processor B instruction diagnostic not working
61	329 330	02:12:44 09:36:09	0 2 4 Total	05:06:01 00:18:21 02:16:47 07:41:09	115.0 150.5	424	0	0	Best lock frequency test. At 06:41 spacecraft shut down. At 07:40, spacecraft could not be revived
Pass 2-1—second lunar day									
11	347	01:00:00 03:23:00	0 Total	02:23:00 02:23:00		152	0	0	At 01:49:45, Interplanetary Monitoring Probe malfunctioning. Unable to access I/O typewriter Surveyor VI revival attempt unsuccessful
61	347	15:49:00 17:48:30	0 Total	01:59:30 01:59:30		152	0	0	Surveyor VI revival attempt unsuccessful

Table 31 (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 2-2									
11	348	02:00:00 04:12:00	0 Total	02:12:00 02:12:00		160	0	0	At 02:43:50, transmitter failed. Heat exchanger interlock failure. Cause unknown. Transmitter on at 02:45:50 Spacecraft revival attempt unsuccessful Successful Surveyor V revival. Tracked Surveyor V from 05:45 to 11:14, pass 4-1
42	348	14:30:00 15:56:00	0 Total	01:26:00 01:26:00		128	0	0	Surveyor VI revival attempt unsuccessful Tracked revived Surveyor V, from 09:05 to 14:06, pass 4-1
61	348 349	16:00:00 19:42:00 23:47:40 01:27:20	0 4 Total	02:48:00 02:33:00 05:21:00	140 151	609	0	0	Revived Surveyor VI at 16:41. Signal was unsteady, difficult to maintain lock. Lost signal at 19:14 Tracked revived Surveyor V, from 21:40 to 23:24:20, pass 4-1
Pass 2-3									
11	350								Tracking cancelled due to snow and icing conditions at Goldstone
Pass 2-4									
61	350	17:58:00 21:30:00	0 Total	03:32:00 03:32:00		418	0	0	Surveyor VI revival unsuccessful Tracked revived Surveyor V, from 21:30 to 02:34, pass 4-2
Pass 2-5									
11	351	05:20:00 11:08:00	0 Total	05:17:20 05:17:20		299	0	0	Transmitter off at 08:37:50 due to heat exchanger interlock. Transmitter on at 09:08:30 Unsuccessful Surveyor VI revival Tracked revived Surveyor V, from 01:59:48, until the switch from Surveyor V low to high power at 03:40, pass 4-4, when the downlink was lost
42	351	10:58:00 13:01:00	0	03:38:00		293	0	0	Surveyor VI revival unsuccessful Surveyor V revival unsuccessful from 13:10 to 16:07, pass 4-4

Table 31 (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 2-5 (contd)									
42 (confd)		16:21:00 17:56:00	Total	_____					
61	351 352	17:58:00 21:18:50 01:44:02 03:36:02	0 Total	05:12:50 _____		909	0	0	No contact with Surveyor VI Negative contact with Surveyor V from 22:06:15 to 00:14:22, pass 4-4
Pass 2-6									
61	352 353	21:43:42 01:33:30	0 Total	03:49:48 _____		444	0	0	Lost 4 digits in units of declination readout. No data lost. Declination does not cover this number during this pass No contact with Surveyor VI Negative contact with Surveyor V from 19:00:57 to 21:43:42, pass 4-5
Pass 2-7									
42	353	15:10:40 20:47:53	0 Total	05:37:13 _____		1,006	0	0	No contact with Surveyor VI
Pass 2-8									
42	354	15:48:00 20:42:02	0 Total	04:54:02 _____		482	0	0	No contact with Surveyor VI
Pass 2-9									
42	355	16:31:49 21:28:22	0 Total	04:56:33 _____		745	0	0	No contact with Surveyor VI
Pass 3-1—third lunar day									
61	016	00:19:00 01:45:00	0 Total	01:26:00 _____		108	0	0	During Surveyor VII, pass 9 tracking period, unsuccessful attempt to revive Surveyors VI or V, pass 5-1

Table 31 (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 3-1 (contd)									
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 (lunar day 5), or Surveyor VI
Pass 4-1—fourth lunar day									
61	043	18:50:00 19:15:00	0 Total	00:25:00 00:25:00		4	0	0	Revival attempt for Surveyor V, pass 6-1, Surveyors VI or VII, pass 2-1 Receiver in lock at 19:00:56 on Surveyor VII Searched from 19:03 to 19:15 on receiver 2 for any other carrier Unsuccessful attempt to reacquire Surveyors V or VI
Pass 4-4									
11	046	03:58:00 05:10:35	0 Total	01:12:35 01:12:35		38	0	0	Revival attempt unsuccessful prior to Surveyor VII tracking; pass 2-4
Mission totals									
Lunar day		Commands sent	TV pictures received		Alpha scattering data received, h, min	Proton data, h, min			
			By command	Noncommanded					
1		163,960	29,952 ^b		30:42	13:06			
2		5,797	0		0	0			
3		220	0		0	0			
4		42	0		0	0			
Grand totals		170,019	29,952		15,567	Total ASI data = 43 h, 48 min			
^b Includes 24 (200-line) TV pictures.									

Table 32. Commands transmitted by
Deep Space Stations

Pass	Date (Nov 1967)	Event	DSS commands transmitted				
			71	51	11	42	61
Launch	7	Midcourse maneuver	0				
1	7			64	91	0	38
2	8			12	12	16	10
3	9						
4	10	Terminal maneuvers			5,100	18	32
5	11				5,337	4,746	437
6	12						
7	13				6,709	95	629
8	14	Spacecraft translation			8,608	49	456
9	15				9,168	937	283
10	16				7,473	2,170	369
11	17				8,399	830	35
12	18						
13	19				12,183	78	2,227
14	20						
15	21					3,913	6,080
16	22					6,951	1,162
17	23					5,467	
18	24					7,050	519
19	25					9,131	119
20	26					6,692	2,820
DSS totals			0	76	113,967	31,680	18,237
Grand total			163,960				

Table 33. Television pictures received

DSS	Commanded	Uncommanded
71	0	0
51	0	0
42	4,749	2,459
61	2,826	10,309
11	14,746	1,511
14	0	0
Totals	22,321	14,279
Grand total	36,600	

Table 34. Alpha scattering data received by
Deep Space Stations

Pass	Date (Nov 1967)	ASI data received by DSS, h:min		
		11	42	61
3	10	00:39		
4	10		03:10	03:53
4	11	03:36		
5	11		08:29	06:27
5	12	01:50		
6	12		06:11	03:33
10	16		04:29	07:27
11	17	01:44	00:05	01:23
12	18		02:26	00:30
13	19			01:22
15	21			01:05
16	22		03:11	
17	23			05:34
18	24	00:14		03:43
Totals		08:03	28:01	34:57
Grand total		71:01		

From the time of initial two-way acquisition by DSS 51 until approximately 40 min before spacecraft main retro-ignition, Deep Space Stations tracked *Surveyor VI* in the two-way mode and, with minor exceptions, received high quality doppler data.

The midcourse maneuver was successfully commanded by DSS 11 during its first pass. This phase was also supported by DSS 14 using its 210-ft antenna.

During the spacecraft's third pass over DSS 11, terminal maneuvers and descent were successfully commanded.

Surveyor VI marked the first widespread use of doppler resolver data, at all stations except DSS 51, during the inflight portion of a *Surveyor* mission. Unfortunately these data, which were to allow a significant decrease in corresponding target uncertainties, did not produce this increased accuracy as doppler data weighting was not changed.

The only major losses of good two-way doppler data occurred during the second pass over DSSs 51 and 61. When DSS 51 lost communication with the spacecraft an unscheduled transfer was made to DSS 61, which tracked in two-way until the spacecraft was transferred to DSS 11 during its second pass. The two-way data received at DSS 61 during this period (approximately 1½ h) were unusable due to excessively high noise traced to a malfunctioning DSS 61 rubidium standard. Replacement of the rubidium during the third pass resulted in an immediate improvement in three-way data levels at DSS 61.

The only other appreciable loss of two-way data occurred during Canopus acquisition over DSS 61, when an unexpected loss of lock was experienced. Reacquisition of two-way was not attempted until completion of Canopus acquisition approximately 50 min later.

During the premidcourse pass, an erroneous indication of a low hydrostatic antenna bearing clearance at DSS 14 caused a loss of 8 min of data when tracking was interrupted to investigate the cause.

The spacecraft touchdown on the lunar surface was so gentle that none of the four receivers at the Goldstone complex (two each at DSSs 11 and 14) lost two-way lock with the spacecraft.

Subsequent to the lunar landing, the DSIF provided 24-h/day tracking coverage, with DSSs 11, 42, and 61 providing mission support until final spacecraft operations 41 h after lunar sunset.

On November 17, during the tenth pass over DSS 11, with DSS 14 as a backup, DSS 11 commanded the spacecraft to perform a 6-s hopping maneuver using the flight controls to rise vertically approximately 10 ft and move laterally 8 ft. In doing so, the alpha scattering detector head ended upside down and under the spacecraft. All spacecraft systems continued to function properly after the hop—with the sole exception being the alpha scattering detector. While no longer able to perform its original function, the proton detectors of the alpha scattering instrument remained functional and continued to transmit cosmic radiation data.

Deep Space Stations 11, 42, and 61 provided postlanding spacecraft operations support by receiving and/or transmitting TV pictures, and engineering, scientific and alpha scattering experiment data.

The signal levels received at the Deep Space Stations are shown in Fig. 58 and correspond very closely to the predicted levels. The predicted levels for the pre-star acquisition track are not given as the spacecraft was not roll-stabilized during this period. Therefore, the received signal level could vary over a wide range owing to variations in spacecraft antenna patterns. During star acquisition, midcourse correction, and retromaneuver, the spacecraft was in high power mode and the received data is 16.5 dB above the low power signal level. Data bit rate changes occurred within 2 dB of the predicted thresholds. The periods during which gyro drift test were conducted are shown at the top of the figure. The random gyro drift and subsequent antenna pattern variations produced a spread in the received signal levels of ± 3 dB.

1. Deep Space Station 71. Support for *Surveyor VI* consisted of a DSS 71-spacecraft compatibility test, an ORT, a spacecraft prelaunch countdown phase, and a postlaunch phase lasting through approximately the first 40 min of the mission.

The purpose of the DSS 71-spacecraft compatibility test, performed during joint flight acceptance composite test on September 28, 1967, was to verify the ability of the DSN to support the mission. Command telemetry and television interfaces were exercised via the RF link.

The ORT, performed on November 5, 1967, consisted of processing simulated spacecraft data received prior to $T - 5$ min from JPL, routed via building AO, and from $T - 5$ through $T + 40$ min from KSC. The received data in both cases were 550-bit/s PCM which were fed directly into the CDC decommutator. The data were then output in the normal manner back to the SFOF via teletype and high-speed data line.

During the prelaunch countdown, performed on November 7, 1967, spacecraft data were received from building AO, system test equipment assembly area. At $T - 5$ min, the data source was switched to 550-bit/s PCM data from KSC. The KSC data consisted of various AFETR tracking stations, including *Centaur* telemetry link prior to liftoff. Data were received from KSC until approximately $T + 40$ min.

During the spacecraft readiness test, countdown, and launch, the DSS 71 antenna was optically aligned with the spacecraft and the receiver locked on the spacecraft during these tests until spacecraft visibility was lost. This served as a backup to the KSC data source.

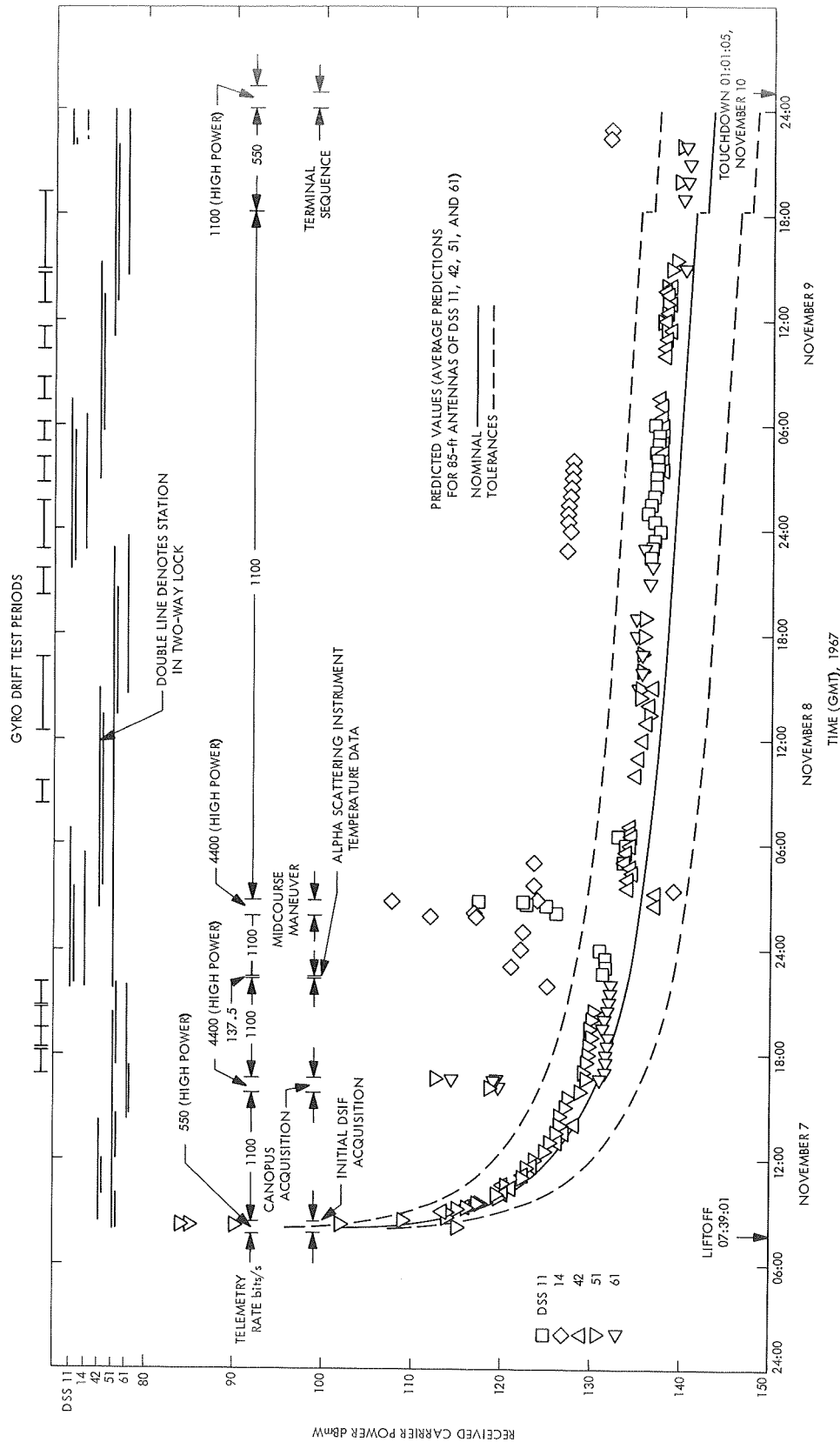


Fig. 58. Deep Space Station-received carrier power, Surveyor VI Mission

Cape Kennedy was in one-way phase lock with the spacecraft during liftoff at a received signal level of -71 dBmW. Liftoff occurred at 07:39:01.075 at a launch azimuth of 82.995 deg. The one-way frequency at the time of liftoff was 2294.989376 MHz, and was tracked until 07:43:44. The last recorded signal level before loss of lock was -156 dBmW. Downrange telemetry was processed by DSS 71 from $T - 5$ min until 08:30:30 when the station was released from its commitment.

2. Deep Space Station 11. During the first three passes of *Surveyor VI*, the Pioneer site at Goldstone tracked *Surveyor VI* for 23 h, 44 min through a perfect flight. Major activities were midcourse correction and terminal operations. For the period covered by this report (first three passes), 5203 commands were transmitted. All activity was completely normal, and no problems were encountered. A summary of the DSS 11 view periods is shown in Table 35.

Table 35. Summary of DSS 11 view periods

Pass	Date (Nov 1967)	Time (GMT), h:min	No. of commands
1	7	21:53	91
	8	03:39	
2	8	22:00	12
	9	05:40	
3	9	22:00	5100
	10	07:20	

a. Pass 1. The spacecraft was acquired at 21:53 by DSS 11; signal level stabilized to -133 dBmW with a bit rate of 1100 bits/s. Control of the spacecraft was transferred from DSS 51 to DSS 11 approximately 18 min later. With the exception of a momentary look at 137½-bit/s data through the 7.35-kHz SCO, events were standard through the midcourse correction which occurred at 02:20. The only significant postmidcourse activity was a bit error check at 1100 bits/s with touchdown strain gage data channels on. Control was transferred to DSS 42 at 03:39, and tracked three-way until 07:00. During this pass, 91 commands were transmitted. Total track time was 9 h, 7 min; however, only 5 h, 29 min of this period was in two-way lock. There were no personnel or equipment problems during the pass.

b. Pass 2. Pass 2 consisted of three gyro drift checks and one engineering interrogation. Acquisition of the spacecraft was at 22:00 with transfer at 22:17 and a signal

level of -137 dBmW. Transfer to DSS 42 was at 05:40, and track ended at 06:30. Total track time was 8 h, 30 min, with 7 h, 23 min in two-way lock. Twelve commands were transmitted. Again, there were no problems encountered during this pass.

c. Pass 3. Pass 3 began with spacecraft acquisition at 22:00 with a signal level -142 dBmW. After transfer of control from DSS 51 at 22:15, events proceeded normally through a perfect touchdown at 01:01. Operations through transfer to DSS 42 at 07:20 included posttouchdown engineering assessment, 200-line TV, planar array/solar panel positioning, 600-line TV, and alpha scattering operations in the instrument-stowed position. A total of 290 TV frames were received, 266 of which were commanded by DSS 11. Of those frames commanded by DSS 11, 24 were 200-line. The track ended at 08:00. Total track time was 9 h, 45 min; total two-way track time was 9 h, 5 min. A total of 5100 commands were transmitted during pass 3. No problems were encountered during the pass.

3. Deep Space Station 42. During the transit phase of *Surveyor VI*, DSS 42 had three tracking periods prior to touchdown. The station was in two-way lock with the spacecraft for 2 h during the first pass (launch), 9 h, 50 min for the second pass, and 7 h, 50 min during the third pass. A total of 11.5 h of three-way data were also accumulated. A total of 39 commands were transmitted to the spacecraft during the transit phase.

During all three passes, the average alarm data were reconstituted into engineering units, utilizing the special computer program provided by DSS 61 personnel. This proved to be extremely useful.

The first 21 min of CDC data during pass 1 were obtained using the Carnarvon, West Australian MSFN station via a dataphone link; the quality was excellent. There were no operational or equipment problems in the CDC area during the *Surveyor VI* transit phase.

The ground command decoder monitored the command SCO output at all times to provide reliable command enable and detected command information. Command enable pulses were monitored by a Sodeco counter to provide a reliable record of total commands transmitted for each pass. In this manner, the command generator program sequence counter could be freely reset to count repetitive commands without jeopardizing the record of total commands.

Additionally, circuitry and another Sodeco-type counter were provided to monitor the TV frames commanded. The circuitry associated with this counter used the 1103, 1104, and 1100 commands (as decoded by the ground command decoder) to turn itself on, off, and count start frame commands, respectively. The tester recorded camera pulses to indicate total pictures received.

A separate unit and two electronic counters were provided to assist monitoring the decommutator parity error rate. Parity error and bit rate signals were routed to this unit from both decommutators. The decommutator parity error signals were monitored by counters, and start and stop of count was controlled by the additional unit. Counting intervals were switched between 10, 50, 100, and 500 thousand bits as desired.

Use was made of the backup decommutator to periodically check the computer communications buffer and high-speed modem output bit streams. These data were permanently cabled to the CDC from the communications center, and frequent use of this capability was accomplished to verify acceptability of the two data streams. A summary of the DSS 42 view periods is shown in Table 36.

Table 36. Summary of DSS 42 view periods

Pass	Date (Nov 1967)	Time (GMT), h:min	No. of commands
1	8	08:21	0
	8	14:15	
2	9	02:31	17
	9	15:27	
3	10	02:59	22
	10	15:53	

a. Pass 1. The spacecraft was acquired at 08:21, 42 min after launch, with the decommutator in lock onto data supplied from Carnarvon. Spacecraft switch to 1100 bits/s was monitored on the Carnarvon data. Approximately 2 min of data were lost during the bit-rate change due to disorientation at Carnarvon caused by the spacecraft SCO change. At 08:40, DSS 42 was in solid lock. The PCM data looked solid and the switch was made from Carnarvon to DSS 42 data for the decommutator input. Two-way tracking was accomplished during the 2 h from 10:10 to 12:10. Station transfers were from and to DSS 51.

At 10:45, the report was made that possible receiver decoder selector switching could have been caused by switching the command generator between main and auxiliary command encoders. This switching occurred during a discussion of proper positioning for the command entry mode switch at standby periods. Decommulator out of lock occurred at 14:15. No commands were transmitted during this pass. Total tracking time was 5 h, 54 min.

b. Pass 2. The decommutator was in lock at 02:31 with the second postmidcourse maneuver in progress. The bit rate was 4400 bits/s, with the spacecraft transmitting in high power. Station transfer from DSS 11 to DSS 42 occurred at 03:40. Two engineering interrogations, a three-axis gyro drift, and a one-axis gyro drift check were performed in approximately 10 h of two-way tracking. Seventeen commands were transmitted to the spacecraft. The total tracking period was 12 h, 56 min.

c. Pass 3. The decommutator was in lock at 02:59. A spacecraft bit rate of 1100 bits/s was maintained throughout the pass because of the good spacecraft signal. Parity error rates of less than 2×10^{-3} were observed during the entire track period. Two engineering interrogations, two three-axis and one single-axis gyro drift checks were commanded. At retroignition minus 13 h, the compartment A heater was commanded on. The station was in two-way lock with the spacecraft for 7 h, 50 min. The total number of commands transmitted to the spacecraft was 22. The total tracking period was 12 h, 56 min.

4. Deep Space Station 51. This station was committed to *Surveyor VI* operations during the three passes of the transit phase. Initial acquisition was accomplished at $T + 30$ min in an exceptionally smooth manner and two-way lock was obtained at $T + 35$ min. Initial spacecraft operations were conducted nominally with the exception of one operator error documented in Subsection H-4-a. The station was in two-way lock with the spacecraft for 25 h, 10 min during the transit phase and 108 commands were transmitted.

Voice communications were quite poor during the latter portion of each of the three transit passes. During pass 1, a gyro drift check was terminated and the solar panel switch turned on during a complete communications outage. During pass 2, when all communications were out, the station reduced transmitter power to 1 kW, turned command modulation OFF, and a successful power-steal transfer to DSS 61 was accomplished.

Spacecraft performance appeared to be completely nominal. A successful star verification and acquisition

was performed by DSS 61 and monitored by DSS 51. There were no CDC equipment problems which could have compromised mission success. A summary of the DSS 51 view periods is presented in Table 37.

Table 37. Summary of DSS 51 view periods

Pass	Date (Nov 1967)	Time (GMT), h:min	No. of commands	CDC problems
1	7	08:09	64	No equipment problem
	7	22:24		
2	8	10:56	12	Command printer errors
	8	22:54		
3	9	11:07	32	No equipment problems
	9	23:05		

a. Pass 1. Initial spacecraft acquisition was performed by DSS 51 at 08:08 ($T + 30$ min). Automatic track on the S-band acquisition aid was achieved at 08:10:10, and automatic track on the S-band cassegrain monopulse at 08:10:41. The signal level of the S-band cassegrain monopulse maser was -83 dBmW. Decommutator lock was obtained at 08:09:00. The station obtained two-way lock at 08:13:25 ($T + 35$ min). Command modulation was turned on at 08:14:30. Telemetry at acquisition indicated that the spacecraft was attitude stabilized. Sun lockon had not yet been achieved, and the acquisition sun sensor was not illuminated. All other telemetry indications were as expected. The roll axis was still stepping. Roll axis stepping was completed at 18:14:00; the acquisition sun sensor indicated illumination at 18:14:30; and sun lockon was indicated at 18:15:15.

All CDC operations were successfully executed with the exception that during initial spacecraft operations, 550- to 1100-bit/s data were transmitted prematurely due to an operator error. During this pass, the following station transfers occurred:

DSS		Time (Nov 7, 1967)
From	To	
51	42	10:10
42	51	12:10
51	61	14:45
61	51	17:30
51	11	22:10

During this pass, 64 commands were transmitted from DSS 51. These consisted of: (1) switching to low power, (2) stepping the solar panel and roll axes in plus and minus directions to assure proper seating of the locking pins, (3) performance of two engineering interrogation cycles, and (4) performance of three, three-axis gyro drift checks.

During the first engineering interrogation, begun at 08:25, modes 1, 4, 2, and 6 were cycled through, prior to returning to mode 5 at 08:39. Following spacecraft control transfer from DSS 42, the second engineering interrogation was performed at 12:15, and consisted of cycling through modes 4, 2, and 1, returning to mode 5 at 12:28. Average alarm printouts were monitored throughout these mode changes as well as throughout the normal mode 5 monitoring sessions which occur during the noncommand activity periods. All spacecraft systems appeared to be operating normally.

During this pass, star mapping and verification and Canopus acquisition occurred as performed by DSS 61 while being monitored by DSS 51. This sequence was begun with the spacecraft and DSS 61 in two-way lock. During the roll maneuver, the uplink signal was lost as the omniantenna passed through a null; the DSS 51 receivers went out of lock at 15:55:10. The downlink was reacquired by DSS 51 at 16:05:13 after DSS 61 commanded the spacecraft transponder OFF. Star mapping/Canopus acquisition was then completed successfully with the spacecraft in one-way lock. During the above interval, when the DSS 51 receivers were out of lock, it is believed that the spacecraft receiver was locked on to a sideband of the DSS 61 uplink signal. A spacecraft signal could be heard in the receiver operator's headset, but the receiver could not lock on to it.

At the end of the pass, when all communications were out, the gyro drift check was terminated with command 0704 and the solar panel turned on with command 0306. This was in accordance with previous direction from AFETR. Transfer to DSS 11 was accomplished by reducing transmitter power to 1 kW and monitoring the spacecraft automatic gain control and static phase error to determine when DSS 11 acquired the uplink; this procedure worked well.

b. Pass 2. This pass from DSS 51 lasted from acquisition at 10:56 until LOS at 22:54. Decommutator lock occurred at 10:57. The station assumed spacecraft control from DSS 42 at 13:30, with command modulation

being turned on at 13:33. A communication outage occurred at 19:45, with command modulation being turned off at 19:50. Transmitter power was reduced to 1 kW at 19:54 in preparation for a nonstandard transfer. Power was returned to the 10-kW level at 20:12 when communications were restored. Command modulation was turned on at 20:14 and off again at 20:35. This second communication outage necessitated another reduction in transmitter power to 1 kW at 20:38 preparatory for a power-steal transfer to DSS 61, which occurred at 20:43. This successful transfer of control of the spacecraft was necessitated by a severe local electrical storm. During this period, the following station transfers occurred:

DSS		Time (Nov 8, 1967)
From	To	
42	51	13:30
51	61	20:43
61	11	22:15

During this pass, twelve commands were transmitted to the spacecraft. Between 16:18 and 17:53, a three-axis gyro drift check was performed. An engineering interrogation, involving cycling through modes 4, 2, 1, and back to 5, was performed from 17:14 to 17:32. Finally a single-axis gyro drift check was performed between 18:59 and 21:42; this was started by DSS 51 and finished by DSS 61. Other spacecraft occurrences monitored by DSS 51 during this period included a mode 1 engineering interrogation at 21:16 and a three-axis gyro drift check at 22:45. Spacecraft operation continued nominal.

c. *Pass 3.* Pass 3 for DSS 51 lasted from acquisition at 11:07 until LOS at 23:04. Decommutator lock occurred at 11:07, with two-way lock being attained at 13:30. Command modulation was turned on at 13:31 and off again at 22:09. The voice circuit went down at 18:18, the station reverting to the use of the teletype conference mode; end of track occurred at 23:04.

During this period the following station transfers occurred:

DSS		Time (Nov 9, 1967)
From	To	
42	51	13:30
51	11	22:15

During this pass, 32 commands were transmitted to the spacecraft from DSS 51. These involved the following: (1) engineering interrogations at 13:53, 17:58, 20:43, and 21:46, (2) reduction of bit rate from 1100 to 500 bits/s at 18:09, (3) turnon of survey camera electronics temperature control at 19:56, (4) turnon of vernier oxidizer tanks 2 and 3 temperature controls, and vernier fuel tank 2 temperature control at 14:53, (5) termination of a gyro drift check at 15:27, and (6) turnon of compartment C temperature control at 20:25. At the time the bit rate was lowered to 550 bits/s, the parity error rate was 1.29×10^{-8} .

Communications were degraded during the latter portions of this pass with DSS 51 voice loss occurring at 18:18. The teletype conference mode was then utilized for communicating with the SFOF. All spacecraft systems operated nominally during this pass.

5. *Deep Space Station 61.* During the transit phase of *Surveyor VI*, DSS 61 tracked the spacecraft for three passes from $T + 7$ h to 1 h, 20 min before touchdown. Although no tracking was scheduled for a few hours after launch, a full operations crew was employed for launch activities.

Three-way tracking was accomplished by DSSs 61 and 51 for most of the transit phase. Two exceptions were for star acquisition performed by DSS 61 and a spacecraft power-steal during pass 2 when DSS 51 had loss of communications. The spacecraft steal was considered successful, even though phase lock was lost, because two-way lock was reestablished promptly. A total of 48 commands were transmitted from DSS 61 during the transit phase. There were no CDC equipment or operational problems. Table 38 summarizes DSS 61 view periods.

Table 38. Summary of DSS 61 view periods

Pass	Date (Nov 1967)	Time (GMT), h:min	No. of commands
1	7	14:27	38
	7	22:40	
2	8	14:36	10
	8	23:27	
3	9	14:40	0
	9	23:35	

a. *Pass 1.* Actual tracking from DSS 61 for pass 1 of *Surveyor VI* began on November 7 at approximately

$T + 7$ h. Decommutation was in lock at 14:27, and station transfer from DSS 51 occurred at 14:45. An engineering interrogation was performed, followed by the star acquisition sequence.

Star map and acquisition were attempted in the transponder mode; however, approximately 5 min into the roll maneuver, the receivers lost lock. After no data were received for 3 min, sun mode was commanded on to stop the spacecraft roll. With still no data for 6 min, transponders were commanded off, providing a good signal. Commutator mode 4 was interrogated and mode 1 selected. Star acquisition was reinitiated with repeat of sequence 0654, and then sun and roll modes were repeated. Everything proceeded normally for an automatic Canopus acquisition. The spacecraft was reconfigured to cruise mode, mode 5 data, transponder B on, 1100 bits/s, and low power. A gyro drift check was begun at 16:43. Station transfer to DSS 51 was executed at 17:30. Tracking continued in three-way lock until the end of view, during which time DSS 11 executed an engineering interrogation and a bit rate change of 137.5 bits/s on the 7.35-kHz SCO and back to 1100 bits/s. End of track occurred at 22:40.

b. *Pass 2.* Three-way tracking was expected for the entire second pass, with DSS 51 in control. However, at 19:55, DSS 51 reduced uplink power to 1 kW. Track was advised but no spacecraft steal was attempted. Shortly afterwards teletype contact was established with DSS 51 and uplink power was increased to 10 kW. Approximately 45 min later, DSS 51 again dropped transmitter power to 1 kW, and this time it was decided to transfer to DSS 61 by stealing the spacecraft. In the process of stealing, two-way phase lock was lost and shortly regained, DSS 61 was in control by 20:43.

An engineering interrogation and gyro drift checks, commanded by DSS 51, were monitored. After transfer to DSS 61, an additional interrogation of modes 4, 2, and 5 was accomplished. A few minutes later mode 1 was interrogated, the spacecraft was then returned to mode 5. The termination of a roll drift check was executed prior to transfer to DSS 11 at 22:15. Three-way tracking continued until the decommutator was out of lock at 23:27.

c. *Pass 3.* Pass 3 began with receivers in lock at 14:40 at a signal level of -159 dBmW. The signal quickly improved to -139.5 dBmW but good decommutator lock could not be maintained. At 15:10, decommutator lock was held by allowing three errors in the sync word. Parity errors at 15:45 were 5.2×10^{-3} , with a signal level of

-138.5 dBmW. All allowed errors had been removed. At 18:08, the bit rate was reduced to 550 bits/s, thereby improving data quality.

Tracking for pass 3 was entirely three-way. Engineering interrogations and gyro drift checks commanded by DSS 51, as well as preliminary spacecraft checks prior to terminal maneuvers, commanded by DSS 11, were monitored. Decommutator out of lock occurred at 23:35. The remainder of the transit phase was monitored by the backfeed of DSS 11 command line and by the *Surveyor* signal.

VI. Tracking and Data System Performance Evaluation

A. Near-Earth Flight Phase

The near-earth flight phase is that portion of flight that is within 10,000 mi from earth. The TDS near-earth phase network is comprised of those facilities and operations that were committed by the various agencies of the AFETR, GSFC/MSFN, DSN, and NASCOM to support the launch through DSIF acquisition. Thereafter the DSN is solely responsible for spacecraft tracking and data acquisition functions.

1. *Air Force Eastern Test Range.* The AFETR was to provide coverage for tracking (metric data), *Atlas/Centaur* telemetry (VHF), and *Surveyor* spacecraft telemetry (VHF and S-band), using land stations, range instrumentation ships, and aircraft, as needed, to meet the commitments.

The TDS support for the *Surveyor* VI Mission was considered fair. Because of nominal launch vehicle and spacecraft performance, the problems experienced by elements of the TDS did not significantly impact the overall support. Class I metric data required for near-real-time computation of the actual transfer orbit, and the generation of acquisition information based on that orbit for DSS 51, was not provided. All other requirements were met and in most cases exceeded.

The AFETR configuration for the *Surveyor* VI Mission is presented in Table 39. The configuration is similar to the *Surveyor* V configuration.

a. *Tracking (metric).* The AFETR tracks the C-band beacon of the *Centaur* stage to provide metric data. These data are required during intervals of time before and after separation of the spacecraft for use in calculating the *Centaur* orbit, which can be used as a close

Table 39. Air Force Eastern Test Range configuration

Station	C-band radar	VHF telemetry	S-band telemetry
KSC (Merritt Island)	X	X	X
Cape Kennedy	X		
Patrick AFB	X		
Grand Bahama	X	X	X
Grand Turk	X		
Antigua	X	X	X
Coastal Crusader		X	X
Twin Falls	X	X	X
Ascension	X	X	X
Pretoria	X	X	X
Sword Knot		X	X

approximation of the postseparation spacecraft orbit. The *Centaur* orbit calculations are used to provide DSN acquisition information (inflight predicts).

Estimated and actual radar coverages are shown in Fig. 59. Although the RIS *Twin Falls* acquired good data during the required interval, class I requirements were not met because the data were not returned to the RTCS in time for transfer orbit computations and the generation of DSS 51 predicts. The mainland stations, Grand Bahama and Grand Turk, provided continuous coverage to $T + 614$ s. The Grand Turk radar experienced a 40-s dropout at $T + 488$ s; however, the Patrick AFB radar provided redundant coverage during this period. The RIS *Twin Falls* covered the interval from $T + 1360$ to $T + 1840$ s, and Pretoria, although experiencing intermittent track, provided continuous coverage from $T + 1877$ to $T + 5296$ s. The Antigua and Ascension radars did not have view on this flight azimuth.

b. Telemetry (VHF). To meet the class I telemetry requirements, the AFETR must continuously receive and record *Atlas* telemetry (229.9-MHz link) from before liftoff until shortly after *Atlas/Centaur* separation, plus *Centaur* telemetry (225.7-MHz link) until shortly after spacecraft separation. Thereafter, *Centaur* telemetry is to be recorded as station coverage permits, until completion of the *Centaur* retromaneuver.

Estimated and actual VHF telemetry coverage are shown in Fig. 60. All requirements were met. Continuous and substantially redundant VHF telemetry data were received beginning with the countdown and through

Antigua LOS, at $T + 755$ s, and from $T + 1184$ to $T + 3111$ s. Coverage was greater than predicted. The RIS *Coastal Crusader* retransmitted launch vehicle telemetry data in real-time. Noisy data were obtained from the initial retransmission; however, a playback provided good quality data. *Mark* event times that were received and read out by AFETR stations are shown in Table 40.

c. Telemetry (S-band). The AFETR is required to receive, record and retransmit *Surveyor* S-band (2295-MHz) telemetry in real-time from spacecraft transmitter High Power ON until DSN continuous view plus 2 min.

The S-band telemetry resources assigned to meet this requirement are shown in Table 39. All primary S-band systems were used on a limited commitment basis because the *Centaur* vehicle is not roll-attitude stabilized, and the aspect angle cannot be predicted.

Estimated and actual S-band coverage and receiver lock times are shown in Fig. 61. Coverage was provided by KSC and Grand Bahama from liftoff to $T + 377$ s. No explanation was available for the early LOS from these two stations. Unfavorable aspect angle was considered a possible cause.

Antigua's coverage was obtained with a maximum elevation of 1.8 deg. With the exception of a short drop-out in the RIS *Sword Knot* data, continuous coverage was provided from $T + 1220$ to $T + 6100$ s. As indicated in Fig. 61, however, several periods of receiver unlock occurred during this interval.

d. Surveyor real-time telemetry data. The AFETR retransmits *Surveyor* data (VHF or S-band) to DSS 71 and building AO, Cape Kennedy, for display and for retransmission to the SFOF. In addition, downrange stations monitor specific channels and report events via voice communication.

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

All requirements were met. The VHF 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. Real-time data flow, although hampered by poor RF propagation, was considered satisfactory. In addition, all *mark* events, except 22 and 23, were read out and reported.

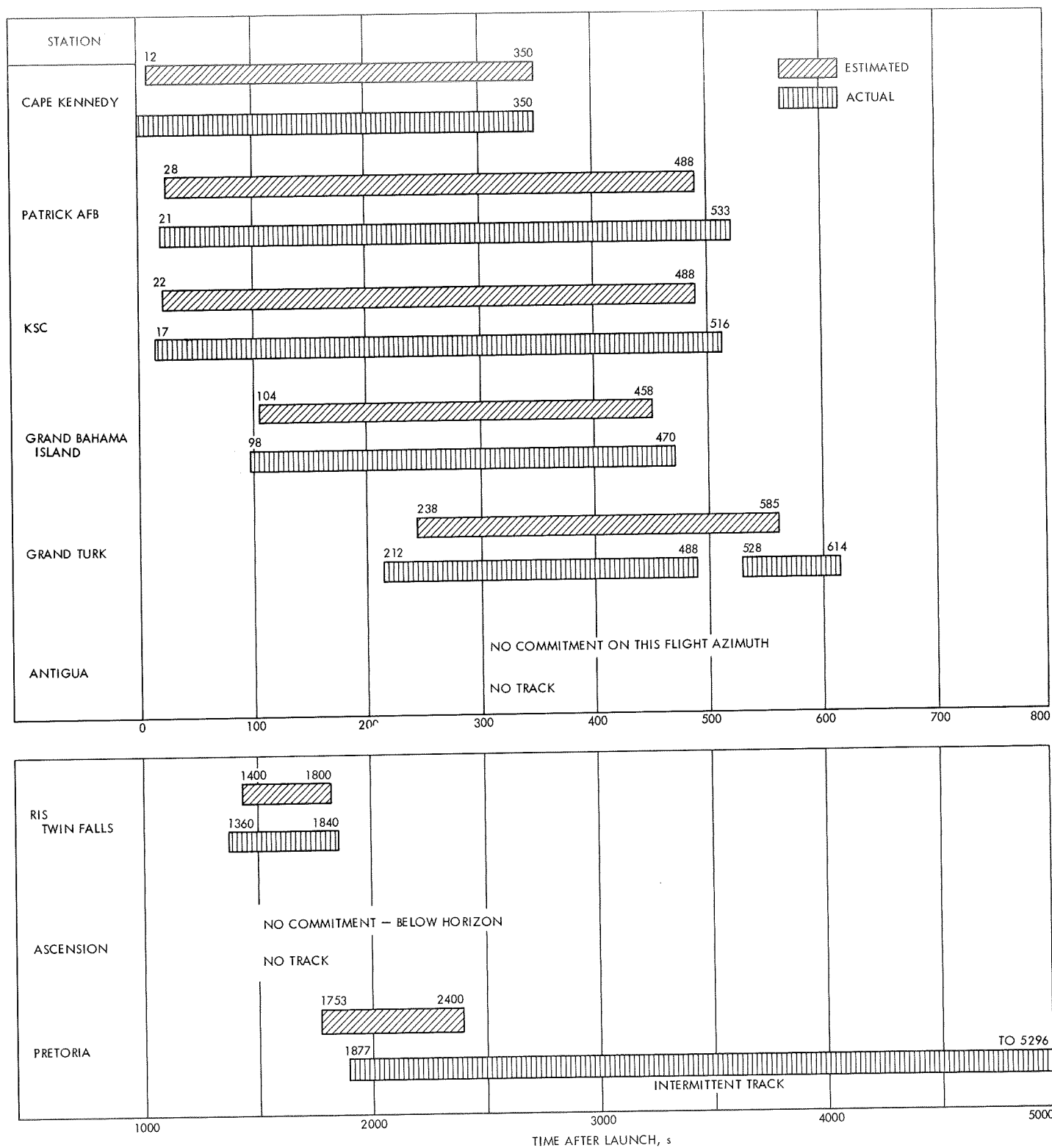


Fig. 59. Air Force Eastern Test Range radar coverage

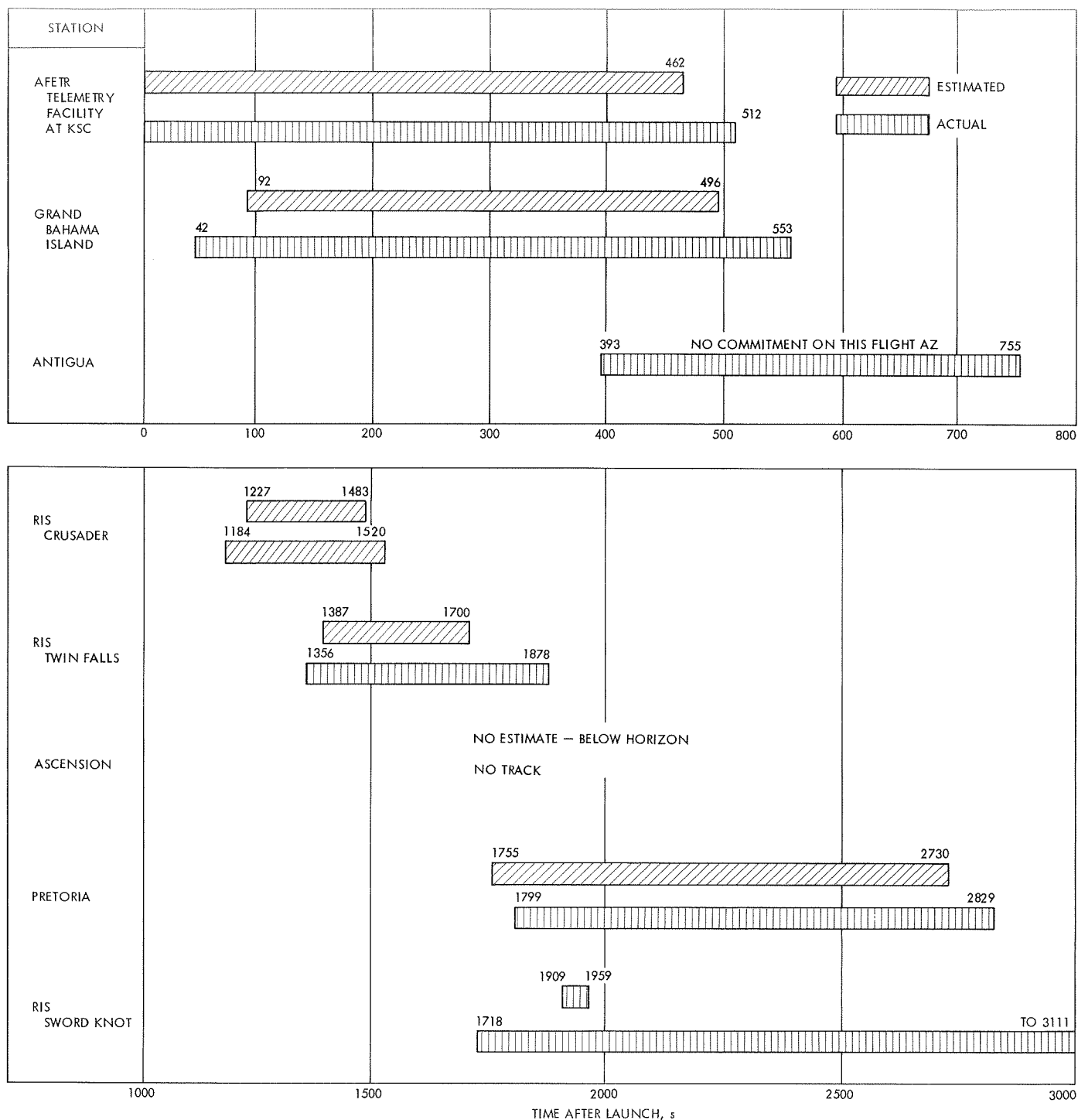


Fig. 60. Air Force Eastern Test Range VHF telemetry coverage

Table 40. Time of Surveyor VI mark events

Mark	Time, GMT	Source	Mark	Time, GMT	Source
Liftoff	07:39:01.075	Cape Kennedy	14	08:01:35.000 08:01:45.400	Coastal Crusader Twin Falls
1	07:41:34.500	Cape Kennedy	15	08:03:29.750	Coastal Crusader
2	07:41:37.810	Cape Kennedy		08:03:29.800	Twin Falls
3	07:42:19.410	Cape Kennedy	16	08:03:49.000 08:03:48.900	Coastal Crusader Twin Falls
4	07:42:49.640	Cape Kennedy	17	08:03:59.500 08:03:59.500	Coastal Crusader Twin Falls
5	07:43:06.630 07:43:06.500	Cape Kennedy Bermuda	18	08:04:20.000	Twin Falls
6	07:43:09.310 07:43:09.000	Cape Kennedy Bermuda	19	08:04:25.100	Twin Falls
7	07:43:19.800 07:43:19.800	Cape Kennedy Bermuda	20	08:04:30.000	Twin Falls
8	07:48:42.100 07:48:42.900	Antigua Bermuda	21	08:04:33.400	Twin Falls
9	07:48:44.300	Bermuda	22	Not reported	
10	07:50:09.500	Bermuda	23	Not reported	
11	07:49:58.900	Bermuda	24	08:08:30.000 08:08:30.100	Twin Falls Sword Knot
12	08:00:57.000	Canary	25	08:12:40.200 08:12:40.500	Tananarive Pretoria
13	08:01:45.400	Twin Falls	26	08:14:20.100 08:14:20.100	Tananarive Sword Knot

e. *Real-time computer system.* For the launch and near-earth phase of the mission, the RTCS provides trajectory computations based on tracking data and telemetered vehicle guidance data. The RTCS output includes:

- (1) The interrange vector, the standard orbital parameter message, and orbital elements.
- (2) Predicts, look angles, and frequencies for acquisition use by downrange stations.
- (3) I-matrix and moon map for mapping injection conditions and estimating trajectory accuracy. Provides for early orbit evaluation prior to orbital data generated by flight path analysis and command.

A total of six orbits were computed by the RTCS, including a parking orbit from Bermuda data, a second parking orbit from *Centaur* guidance telemetry data, a theoretical transfer orbit using Bermuda data plus nominal second-burn data, a post-retromaneuver orbit using

Carnarvon data and two spacecraft orbits from DSS 51 data. Because of the lack of metric data from the RIS *Twin Falls*, it was not possible to compute an actual pre-retromaneuver transfer orbit, and the only DSN predicts available were those based on the theoretical transfer orbit and the post-retromaneuver orbit.

2. Manned Space Flight Network. The MSFN, managed by GSFC, supported the *Surveyor VI* Mission by performing the following functions:

- (1) Tracking the *Centaur* beacon (C-band).
- (2) Receiving and recording *Centaur*-link telemetry.
- (3) Receiving, recording, and retransmitting S-band telemetry to DSS 42 in real-time.
- (4) Providing real-time confirmation of certain mark events.
- (5) Providing computing support through the use of the GSFC data operations branch.

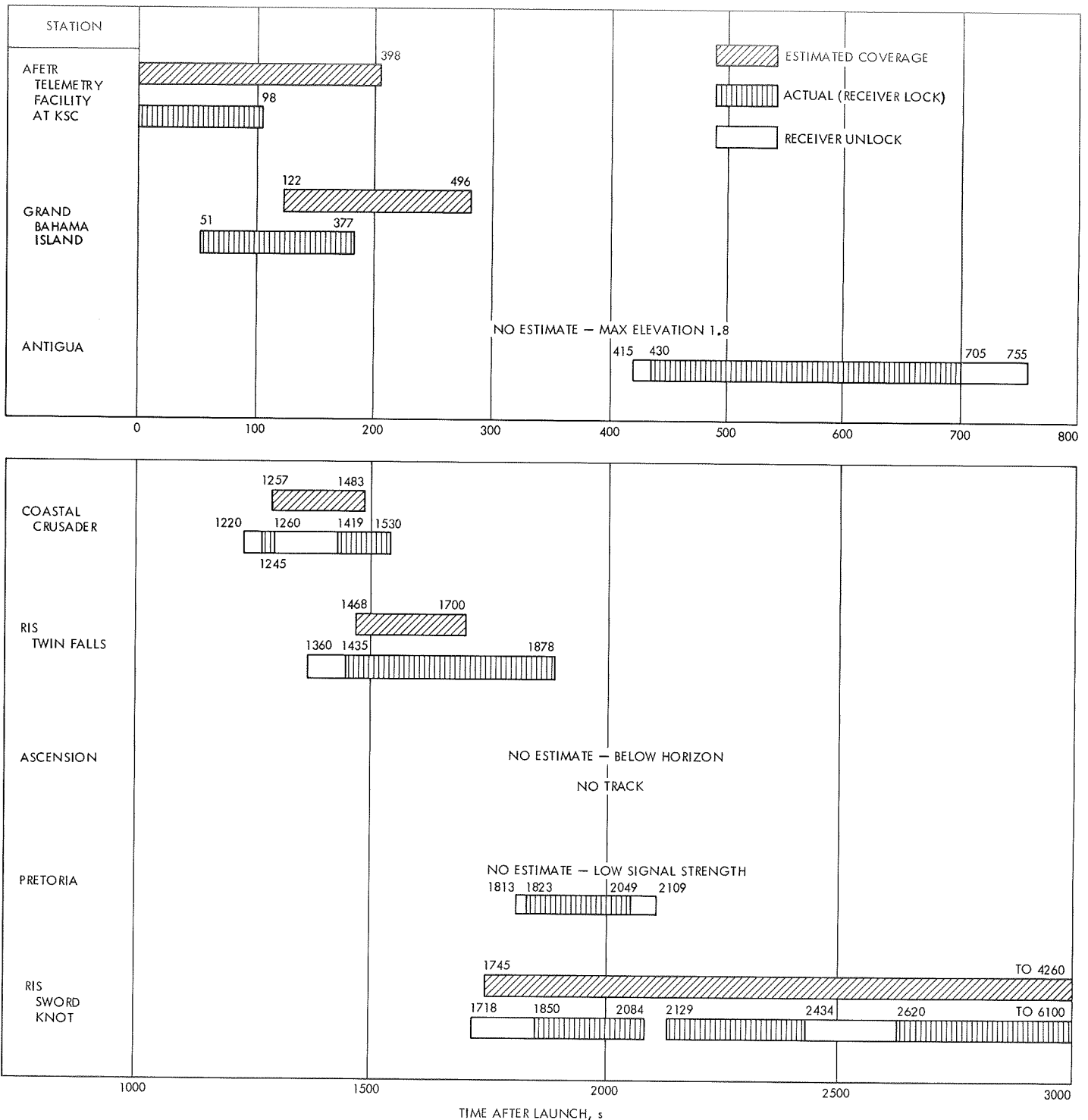


Fig. 61. Air Force Eastern Test Range S-band telemetry coverage

- (6) Providing NASCOM support to all NASA elements for simulations and launch, and extending this communications support as necessary to interface with the combined worldwide network.

The GSFC tracking and telemetry facilities and equipment used in support of *Surveyor VI* are listed in Table 41. The GSFC also supported the ORT prior to launch.

a. Acquisition aids. The MSFN stations are equipped with acquisition aids to track the vehicle and provide RF inputs to the telemetry receivers from AOS to LOS. Performance recorders are used to record automatic gain control and angle errors for postmission analysis. The acquisition aid systems performed their required functions during the *Surveyor VI* Mission.

b. Telemetry data. The MSFN stations are also equipped to decommutate, receive, and record telemetry. The telemetry requirements placed on the MSFN were:

- (1) Bermuda, Grand Canary, and Tananarive were to receive and record the *Centaur* 225.7-MHz link from AOS to LOS.
- (2) Bermuda was to receive and record the *Atlas* 229.9-MHz link from AOS to LOS.
- (3) *Centaur* mark event readouts were required from Bermuda, Grand Canary, and Tananarive in real-time or as close to real-time as possible, after the vehicle was in view of the station.
- (4) Bermuda was to display range safety parameters on the *Atlas* and *Centaur* links.
- (5) Carnarvon was to receive, record, and retransmit S-band telemetry to DSS 42 in real-time.

- (6) All stations were to provide magnetic tape recordings, strip chart recordings, and PLIM data sheets.

The telemetry systems performed all required functions. Bermuda received and recorded range safety parameters and *mark* events 5-11. Grand Canary reported *mark* event 12, attitude rates, and propellant ullages. Although no VHF coverage was predicted for Carnarvon, the station obtained 9½ min of VHF data. The predicted vs actual coverage is shown in Fig. 62.

c. Metric tracking (C-band). Bermuda provided radar beacon tracking, magnetic tape recording (at a minimum of 10 points/s), and real-time data transmission to GSFC and AFETR. The radar requirements placed on the MSFN were:

- (1) Bermuda was to provide beacon tracking of the *Centaur* from AOS to LOS and range safety support to AFETR. Bermuda was prime for range safety from 78 to 90 deg, and backup from 91 to 115 deg.
- (2) Bermuda was to provide real-time transmission of high-speed and low-speed radar data to GSFC and RTCS.
- (3) Bermuda was to provide magnetic tape recordings, strip chart recordings, and PLIM data sheets.
- (4) Grand Canary, Tananarive, and Carnarvon were to provide metric data in a backup support role.

The Bermuda FPQ-6 radar achieved 486 s of valid auto-track data. The FPS-16 radar obtained 482 s of data; however, 24 s of data were lost at $T + 524$ due to obstruction by the FPQ-6 antenna. The FPS-16 track was inhibited, due to phasing, from AOS until $T + 369$. The Grand Canary radar provided 216 s of valid data.

Table 41. Manned Space Flight Network configuration

Location	Acquisition	VHF telemetry	Radar	SCAMA ^a	Radar high-speed data	Real-time readouts
Bermuda	X	X	X	X	X	X
Grand Canary	X	X	X	X		X
Tananarive	X	X	X	X		X
Carnarvon	X	X	X	X		
GSFC				X	X	

^aSignaling, conferencing, and monitoring arrangements.

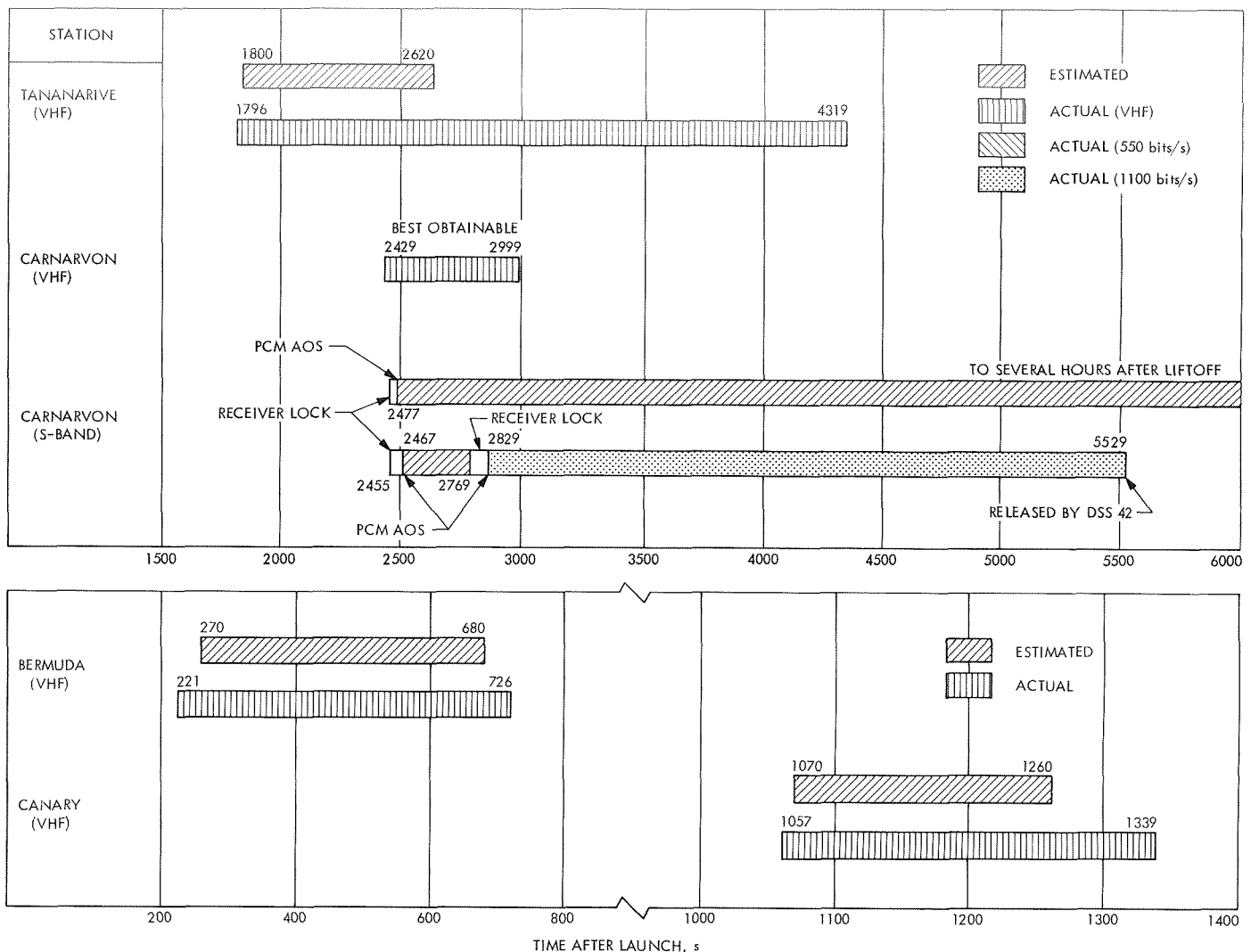


Fig. 62. Manned Space Flight Network telemetry coverage

Tananarive, which was still on an engineering test basis, did not acquire track. The reason is unknown.

Carnarvon, although experiencing several dropouts, provided data over an interval of approximately 1400 s. The reason for the dropouts is not known; however, aspect angle is suspected. The predicted vs actual coverage is shown in Fig. 63.

d. Computer support, data handling and ground communications. The GSFC data operations branch was to provide computing support for the MSFN stations during the prelaunch, launch, and orbital phases of the mission. Computer requirements were:

- (1) To provide pointing data printouts for supporting MSFN station view periods for mission planning purposes.

- (2) To generate radar simulation tapes for Grand Canary, Tananarive, and Carnarvon to be used during the ORTs.
- (3) To generate and transmit nominal pointing data to participating MSFN stations, except Bermuda. Bermuda powered flight data were to be supplied to GSFC by AFETR.
- (4) To receive launch trajectory data from Bermuda and AFETR via the launch trajectory data system.
- (5) 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 controller.
- (6) To use the refined orbital parameters to drive displays at the GSFC operations control center.

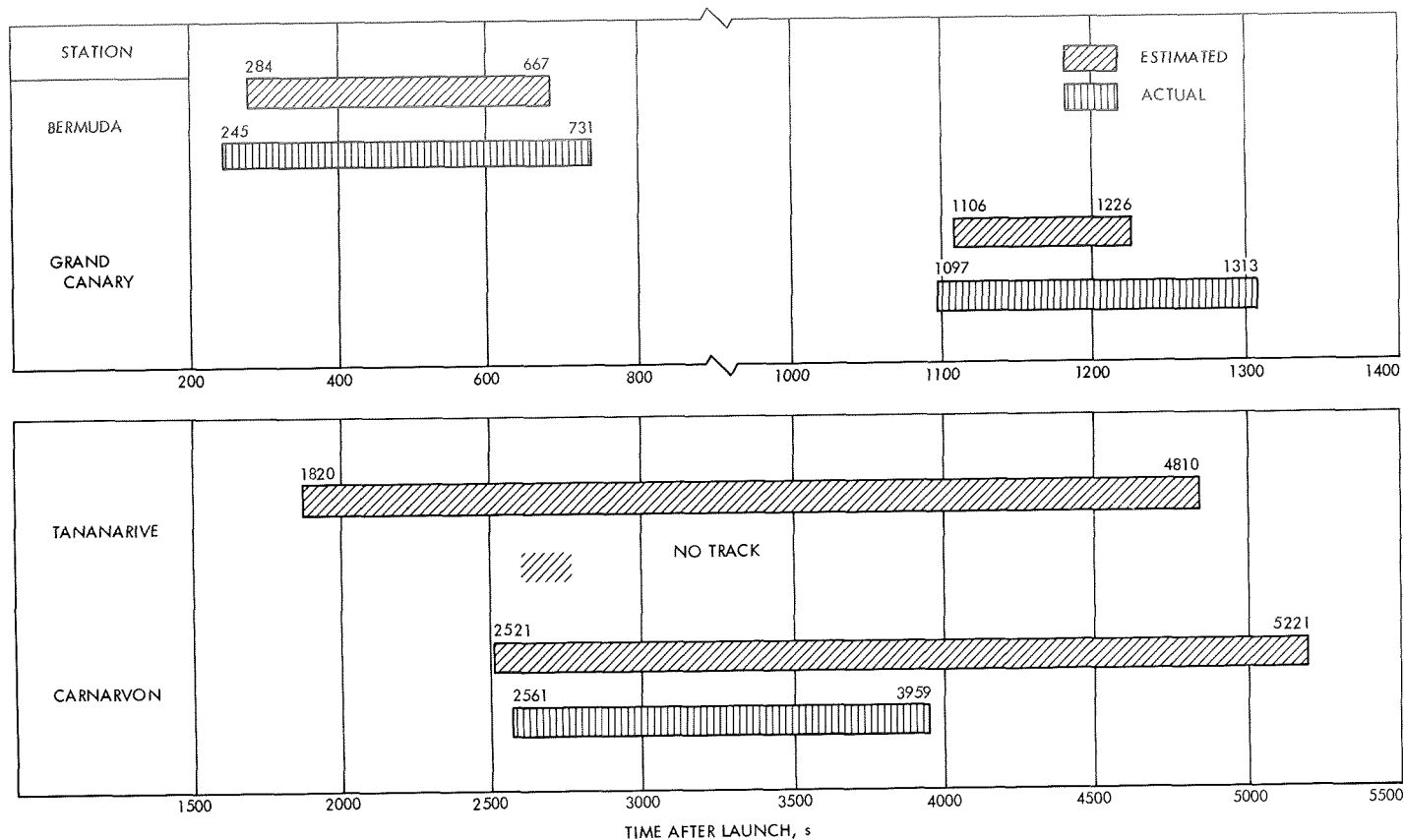


Fig. 63. Manned Space Flight Network radar coverage

- (7) To generate and transmit real-time acquisition messages to participating MSFN stations, based on inflight tracking data.
- (8) To reformat the Grand Canary and Carnarvon metric data prior to transmission to the RTCS.
- (9) 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 LeRC.
- (10) To reformat on magnetic tape the Bermuda high-speed raw radar data, including a list of the contents and formats, for shipment to the RCA data processing requirements group at Patrick AFB, Fla.

During flight, the Grand Canary rise minus 5-min acquisition message arrived on site after AOS, and the first Tananarive and Carnarvon acquisition messages were invalid. Updated messages were transmitted, but

arrived too late for Tananarive. The data operations branch provided all other required support.

e. NASCOM support. The NASCOM network provided 23 teletype, 17 voice, and 8 high-speed data circuits in support of the mission. These circuits were assigned as indicated below:

Site	Teletype	Voice	High-speed data
Building AO	3	3	1
DSS 71	3	1	1
DSS 42	4	1	1
DSS 51	4	1	1
DSS 61	4	1	1
Bermuda	2	3	1
Grand Canary	1	2	1
Tananarive	1	2	—
Carnarvon	1	2	—
Carnarvon-DSS 42	—	1	1

Special coverage was established commencing at approximately $T - 6$ h, and special propagation forecasts were provided for all HF radio circuits effective approximately $T - 9$ h.

All high-speed transmissions for London and Canberra were paralleled with low-speed input. *Minimize* was placed in effect from approximately $T - 1\frac{1}{2}$ to $T + 2$ h. The teletype circuit to DSS 51 via Ascension was activated for make-good purposes.

During the countdown, at 03:50, a major systems failure was experienced. This caused an outage between Cocoa Beach and Polk City, Fla., which affected all of the voice, high-speed data, and teletype circuits to DSS 71, and one voice and all of the teletype circuits to building AO. The failure was attributed to a shorted capacitor at Cocoa Beach, which caused the fuses on the Polk City circuits to blow. All circuits were restored at 04:54.

Intermittent outages, due to poor HF propagation, were experienced on all of the DSS 51 circuits between 05:08 and 06:50.

Dropouts on the DSS 51 high-speed data circuit were reported at approximately 06:55. Attempts to reconfigure circuitry and equipment were ineffective until it was discovered that a Stelma converter at Riverhead, N.Y. was set on channel 8 instead of channel 2. The circuit was restored at 07:55, which was after liftoff, but before DSS 51 acquisition. All circuits were GO at liftoff.

B. Deep Space Network Phase

As with *Surveyor V* Mission, the DSN provided a constant high level support for *Surveyor VI*, with the exception of that mentioned below.

From the time of two-way acquisition by DSS 51 until approximately retroignition -40 min, the DSN tracked the *Surveyor VI* spacecraft in the two-way mode, and with minor exceptions, returned extremely high quality two-way doppler data. *Surveyor VI* marked the first wide-scale use of doppler resolver data (all stations except DSS 51) during the inflight portion of a *Surveyor* mission. The result of the doppler resolver use was a reduction in the standard deviation of the doppler data (60 s) from a pre-resolver level of approximately 0.008 Hz to about 0.002 Hz, or a reduction by a factor of four. Unfortunately, this did not produce a decrease in the corresponding target uncertainties because the orbit

determination group had not changed the doppler data weighting to reflect the increased accuracy; it is hoped that a moderate improvement in target statistics can be accomplished for *Surveyor VII*.

The only major losses of good two-way doppler data occurred during the second pass over DSS 51 and DSS 61. Johannesburg (DSS 51) lost communications at 19:38:02 on November 8; and at 20:45:02 an unscheduled transfer was made to DSS 61, which stayed in two-way until the spacecraft was transferred to DSS 11 at 22:19:02. The two-way doppler data taken at DSS 61 during this time (approximately $1\frac{1}{2}$ h) was unusable due to excessively high noise; the problem was traced to the rubidium standard. When a rubidium change was made during the third pass, an immediate improvement to reasonable levels was observed in the three-way data at DSS 61. The only other appreciable loss of two-way data occurred during Canopus acquisition over DSS 61 when an unexpected loss of lock occurred, and reacquisition of two-way data was not attempted until completion of Canopus acquisition approximately 50 min later.

The DSN tracking data and alpha scattering data recovery was good throughout the mission, with very little real-time data lost. Data losses were caused, primarily, by GCF problems which occurred during the operational periods.

The DSN monitor area was able to provide backup data for most periods in the form of IBM punched cards, reperforator tapes, and page print copies by requesting retransmission of data from the Deep Space Station or communications processor when necessary. No major problems were experienced in performing scheduled DSN monitor activities.

1. Deep Space Instrumentation Facility. Prime station support was provided by DSSs 11, 42, and 61. Johannesburg, DSS 51, performed initial two-way acquisition and commanding of the spacecraft and tracked during all three of its transit phase view periods. 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. However, DSS 72 was not used to support *Surveyor VI*.

The prelaunch spacecraft-DSIF RF compatibility tests were supported by DSS 71 which was also the prime source of real-time AFETR telemetry as processed by the CDC and on-site telemetry and command processor computer and transmitted to SFOF. This data path

worked well during *Surveyor VI*, and good data were received at the SFOF at all times that good range telemetry data were received at Cape Kennedy.

Transit phase support was provided by DSS 14 using the 210-ft antenna. Project-furnished equipment was installed to permit predetection recording at DSS 14. At midcourse and touchdown the baseband telemetry output of the DSS 14 prime receiver was transmitted to SFOF using a wideband microwave line. Problems observed in *Surveyor V* regarding DSS 14 baseband data were resolved in premission testing, and good data were received from DSS 14 during all *Surveyor VI* tracking periods.

Special support for the liftoff and translation experiment was provided by DSS 14 using the touchdown configuration. Excellent strain gage data were provided to SFOF in real-time during this experiment.

Subsequent to landing, the DSIF provided 24-h/day tracking coverage. This extended until final spacecraft operations at sunset plus 41 h.

At project request, the average alarm conversion program developed at DSS 61 was implemented at all prime stations for use in the backup telemetry and command processor computers on a noninterference basis. The program is run at the option of the stations, by agreement between the station manager and *Surveyor* operations chief.

Finally, DSIF stations were commended for improvements in the quality and rapid handling of their data packages. Shipment times of two to three days are becoming common from DSS 42 and DSS 61, and the number of errors has been greatly reduced.

a. Participating stations. The following DSIF stations were assigned to support *Surveyor VI*.

(1) Prime:

DSS 11

DSS 42

DSS 51—Tracking support only during cislunar.

DSS 61

DSS 71—Prelaunch support and track to loss of signal.

(2) Recording and transmitter backup station:

DSS 14—Prime telemetry and transmitter backup to DSS 11 during midcourse, terminal, and translation maneuvers.

b. Mission profile. Launch occurred at 07:39:01 on November 6, 1967, on a launch azimuth of 82.995 deg. All tracking stations committed to support *Surveyor VI* counted down and were GO at time of launch.

c. Launch support. Solid, one-way spacecraft signals were reported by DSS 71 for a total of 4 min and 49 s after liftoff. Signal levels varied from -68 dBmW on the pad at liftoff to a -154 dBmW at loss of lock.

d. Initial acquisition. Initial two-way acquisition was performed by DSS 51. This station was in one-way receiver lock with the spacecraft at 08:08:50 and in confirmed two-way lock on the S-band cassegrain monopulse antenna in auto track at 08:13:27. At 08:14:30 DSS 51 had command modulation on and was GO for commanding.

e. Midcourse maneuver. The midcourse adjustment was performed by DSS 11 on November 8, at 02:20:00. This was the first pass by DSS 11 after launch. A successful adjustment was reported.

f. Retromaneuver and touchdown. The retrothrust maneuver, performed by DSS 11 on its third pass, started at 00:50:15 on November 10. Touchdown in the targeted area occurred at 01:01:04.18. A smooth spacecraft touchdown was achieved with no loss of tracking station decommutator lock during touchdown.

g. Spacecraft lunar translation maneuver. On November 17, at 10:32, the spacecraft successfully accomplished a hopping maneuver using the flight controls to rise vertically approximately 10 ft and move laterally approximately 8 ft. The lateral movement was in a westerly direction. In so doing, the alpha scattering detector head ended upside down and under the spacecraft. All systems functioned properly after the hop, with the sole exception of the alpha scattering detector.

h. Deep Space Station tracking period. Table 42 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. A complete summary of DSS activity from launch to the end of lunar day 1 is shown.

Table 42. Tracking times and commands sent

Pass	Station	Day	Tracking period, GMT	Total commands sent	TV pictures		Significant events
					By command	Non-command	
Launch	71	311					Liftoff: day 311 at 07:39:01.075 Launch az: 082.995 deg Flawless initial spacecraft acquisition
1	51	311	08:08:51 22:24:00	64			
	Carnarvon, Australia	311	08:22:30 08:50:00				
		311	08:34:00 14:18:03				
	61	311	14:24:31 22:42:42	38			
	11	311	21:52:59	91			
		312	07:00:00				Midcourse accomplished on day 312 at 02:35:53
	14	311	21:56:39				
		312	05:30:00				Backup telemetry recording for DSS 11, passes 1, 2 and 3
	2	312	02:28:25 15:14:00	16			
	51	312	10:56:14 22:54:00	12			
2	61	312	16:35:51 23:25:54	10			
	11	312	21:59:49	12			
		313	06:30:00				
	14	312	22:53:15				
		313	06:30:39				
	3	313	02:52:54 15:21:00	18			
	51	313	11:07:15 23:04:40	32			
	61	313	14:40:55 23:40:50				
	11	313	21:59:46	5,100	266	24	
		314	08:01:00				Touchdown on day 314 at 01:01:04.18 at 0.415 deg latitude, 358.652 deg longitude
3	14	313	22:07:10				
		314	07:37:27				
	4	314	03:02:20 15:35:00	4,746	782	211	
	61	314	14:49:46	437	52	313	
		315	00:38:00				
	11	314	22:22:51	5,337	1,198		
		315	09:03:00				
	5	315	04:03:37 16:00:20	95		140	
	61	315	15:04:43	629		466	
		316	01:39:19				Monitored Surveyor V revival on receiver 2, while DSS 51 commanded. No Surveyor V contact
4	11	315	22:50:57	6,709	1,618		
		316	09:56:00				

Table 42 (contd)

Pass	Station	Day	Tracking period, GMT	Total commands sent	TV pictures		Significant events
					By command	Non-command	
6	42	316	08:54:20 16:30:00	49			Surveyor VI shutdown from 20:00 to 22:00 for Surveyor V revival attempt Negative contact with Surveyor V
	61	316 317	15:21:15 02:42:00	456		506	
	11	316 317	23:21:11 10:52:00	8,608	1,925		
7	42	317	05:58:00 16:28:00	937	155	677	
	61	317 318	15:39:20 03:37:51	283		513	
	11	317 318	23:47:29 10:26:00	9,168	1,707		
8	42	318	06:55:00 17:17:52	2,179	436	166	
	61	318 319	16:07:04 04:39:56	369		836	
	11	319	00:11:24 12:11:00	7,473	1,744		
9	42	319	08:00:06 17:44:45	830	135	92	
	61	319 320	16:25:44 05:41:14	35		1,116	
	11	320	00:49:00 12:54:00	8,399	1,783		
10	42	320	09:03:00 18:19:16	78		38	Spacecraft translation firing on day 321 at 10:32
	61	320 321	17:46:00 06:35:36	2,227		644	
	11	321	01:30:00 13:42:00	12,183	1,727	34	
11	42	321	08:15:00 11:09:00				
	61	321 322	10:06:12 18:45:15	3,913	891	537	
	61	321 322	17:38:01 07:42:20	6,080	1,322	751	
12	11	322	02:19:50 14:28:00	5,951	1,398	500	
	42	322	11:02:00 19:27:07	3,787	688	157	
	61	322 323	18:14:55 08:29:30	1,162	35	1,044	
	11	323	03:09:47 13:49:26	5,467	1,345		

Table 42 (contd)

Pass	Station	Day	Tracking period, GMT	Total commands sent	TV pictures		Significant events
					By command	Non-command	
13	42	323	11:58:00 19:43:00	108			Attempted Surveyor V revival from 15:12 to 15:48
	61	323 324	20:22:38 09:20:07	519	1,018		
	11	324	04:08:00 14:10:00	7,050	1,659		
14	42	324	12:55:00 20:16:45	2,762	60		Lost 4 or 5 frames of video from DSS 42 due to loss of backfeed net
	61	324 325	19:58:25 10:14:14	119	14	920	
	11	325	04:56:42 16:40:00	9,131	2,175	46	
15	42	325	13:41:00 21:14:00	1,658	91	222	
	61	325 326	20:46:00 11:80:00	2,820	46	1,099	
	11	326	05:49:35 18:01:30	6,692	1,658	448	
16	42	326	14:29:00 22:31:00	3,232	572	19	
	61	326 327	21:52:30 11:08:00	809	93	1,057	
	11	327	06:35:40 18:30:00	6,689	1,637	419	
17	42	327 328	15:07:00 00:12:00	4,513	920	95	
	61	327 328	23:33:03 12:24:45	1,642	246	1,044	
	11	328	07:34:00 19:43:00	8,889	1,825	40	
18	42	328	15:47:21 21:48:00	2,731	19	105	Lunar sunset at spacecraft on day 328 at 13:53
	61	329	01:32:56 11:10:00	146			
	11	329	10:50:29 16:56:30	18			
19	42	329 330	16:05:58 01:19:00	37			Accomplished best lock frequency test at 06:37. At 06:41, spacecraft commanded off. At 07:40, could not revive spacecraft for an interrogation Stations released from Surveyor VI track. End of lunar day 1 operations
	61	330	02:12:44 09:36:09	424			
		330	09:35:00				
Totals:				164,867	31,240	14,279	

i. *Television picture data.* Table 43 tabulates the number of TV pictures received as commanded by the station and/or the number received as commanded by another Deep Space Station having mutual view of the spacecraft. Table 44 provides a comparison of commands transmitted and TV pictures received by all *Surveyor* spacecraft that achieved lunar landing.

j. *Lunar operations meeting.* A lunar operations meeting was convened by the lunar 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 track 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.

Tables 45 and 46 give a listing of *mark* and other major events readouts. Table 47 indicates the tracking and data recovery performed by the various agencies and stations. A summary, by station and pass, of the alpha scattering data monitored in the DSN monitor area is presented

Table 43. Television pictures received

DSS	Via station command	Via external command
71		
51		
Carnarvon, Australia		
42	4,749	2,459
61	2,826	10,309
11	23,665	1,511
14		
Totals	31,240	14,279
Grand total command and external command: 45,519		

Table 44. Surveyor mission command and TV comparisons

Surveyor mission	Commands transmitted	TV pictures received		
		By command	Total for first and second lunar days	By external command
I	108,312	11,240	13,097	1,857
III	63,036	6,326	10,031	3,705
V	122,722	19,054	27,011	7,957
VI	164,867	31,240	45,519	14,279

in Table 48. Table 49 provides a summary of the percentage of total usable tracking data on a Deep Space Station pass-by-pass basis.

Table 45. Mark events

Mark	Time (day 311), GMT	Event
1	07:41:34.500	Atlas booster engine cutoff
2	07:41:37.810	Atlas booster engine jettison
3	07:42:19.410	Centaur instrument panel jettison
4	07:42:49.640	Spacecraft nose fairing jettison
5	07:43:06.630	Atlas sustainer engine cutoff and booster engine cutoff
6	07:43:09.310	Atlas/Centaur separation
7	07:43:19.800	Centaur main engine start 1
8	07:48:42.100	Centaur main engine cutoff 1
9	07:48:44.300	Centaur 100-lb thrust on
10	07:50:09.500	Centaur 100-lb thrust off
11	07:49:58.900	Centaur 6-lb thrust on
12	08:00:57.000	Centaur 100-lb thrust on
13	08:01:45.400	Centaur main engine start 2 engine C2
14	08:01:35.000	Centaur main engine start 2 engine C1
15	08:03:29.750	Centaur main engine cutoff 2 injection
16	08:03:49.000	Surveyor landing gear extend signal
17	08:03:59.500	Surveyor omniantenna extend command sent
18	08:04:20.000	Surveyor high-power transmitter on
19	08:04:25.100	Centaur/Surveyor electrical disconnect
20	08:04:30.000	Centaur/Surveyor separation
21	08:04:33.400	Begin Centaur turnaround maneuver
22	08:08:30.000	Start Centaur lateral thrust
23	Not received	End Centaur lateral thrust
24	Not received	Start Centaur blowdown
25	08:12:40.200	End Centaur blowdown
26	08:14:20.100	Centaur electrical power off

Table 46. Major events

Major event	Day	Time, GMT
Liftoff	311	07:39:01:075
Midcourse	312	02:02:59
Retroignition	314	00:58:04
Touchdown	314	01:01:01
End lunar day 1 operation	330	09:37:02

Table 47. Tracking data recovery, DSN monitor area

Station	Total samples received			Total samples usable								Comments
	1 min	10 s	Total	One-way data			Two-way data		Three-way data		Total	
				1 min	10 s	1 s	1 min	10 s	1 min	10 s		
AFETR		648	648		242						242	All AFETR data 6-s sample rate
DSS 51	2,152	214	2,366	17	7		1,362	174	582		2,142	
DSS 11	11,613	518	12,131	246	330		3,157	181	863		4,777	
DSS 42	10,276	230	10,506	344	14		4,738		1974	119	7,189	
DSS 61	13,214	348	13,562	550	6		5,015		2008	751	7,730	
DSS 14	1,445	459	1,904	106	274				744	180	1,304	Pass 1; pass 2, CC3 doppler mode three-way coherent
Total	38,700	2417	41,117	1263	873	0	14,272	355	6171	450	23,384	

Table 48. Alpha scattering data monitor summary

Pass	Number of records received, DSS		
	42	61	11
1	0	0	0
2	0	0	0
3			7
4	14	19	15
5	23	16	13
6	24	11	13
7	0	0	0
8	0	0	0
9	0	0	0
10	24	25	3
11	2	10	0
12	11	2	0
13	9	0	0
14	0	0	0
15	0	8	0
16	14	17	0
17	0	11	2
18	0	0	0
19	0	0	(End lunar day 1)

Table 49. Percentage of total data usable (station vs pass)

Pass	DSS 42	DSS 61	DSS 11	DSS 14	DSS 51
1	79.40	84.50	95.14	97.32	90.43
2	98.04	96.28	95.91	97.64	91.69
3	95.35	83.64	68.36	34.02	92.49
4	34.86	61.38	40.47		
5	61.84	66.42	22.47		
6	96.06	50.75	22.21		
7	56.22	54.05	21.51		
8	53.45	48.20	39.55		
9	76.87	67.30	28.88		
10	94.49	78.53	48.80	56.10	
11	37.54	39.67	26.10		
12	56.05	57.61	23.72		
13	15.20	27.61	27.75		
14	76.96	58.45	20.20		
15	62.58	34.82	24.32		
16	56.67	61.87	16.99		
17	51.82	49.13	15.39		
18	44.11	42.59	85.37		
19	71.71	30.43	(End of tracking, lunar day 1)		

Figures 64 and 65 provide graphic presentations of AFETR and DSN tracking data coverage by station and pass, indicating the doppler configuration of the station throughout each pass. Periods indicated as having one-way doppler include the normal configuration as well as those periods in which the doppler was incoherent because of spacecraft configuration.

Figure 66 provides the usable tracking data, by percent, on a pass-by-pass basis. The seemingly low percentage of usable data after touchdown is due to unacceptable condition codes generated by normal operating procedures used during lunar operations. These operating procedures dictate that the receiver will be operated in a manual gain control configuration. This does not indicate abnormal performance by the spacecraft or the Deep Space Station.

2. Deep Space Network/Ground Communication Facility. The GCF continued to provide excellent support throughout the mission. The communications processor operations proved very reliable during critical mission phases. During lunar operations the Goddard and overseas communications processors did experience periodic outages but no serious loss of data was reported. The JPL communications processor was very reliable

during the *Surveyor VI* Mission, with the only significant outages being associated with basement flooding and reduced power capability during a series of electrical storms. It is believed that the intensive maintenance performed prior to launch contributed greatly to the high reliability of communications processor operation during *Surveyor VI*.

Problems with the Goldstone microwave links were caused by fire damage to relay antennas just prior to *Surveyor VI* launch. Voice and high speed circuits were shifted to landline backup circuits when required. The 6-MHz circuit remained reliable and was used to back up the 96-kHz line for baseband telemetry transmission to SFOF.

3. Deep Space Network/Space Flight Operations Facility. The 7044 redesign model 2B system was used for *Surveyor VI* support. The data processing system operations were reliable throughout the flight and lunar operations. Considerable 7044 sharing with *Mariner V* was done during lunar operations. No current 7044 system was available for sharing between *Surveyor VI* and *Mariner IV*, which caused some confusion in scheduling shared computer usage, but enough resources were available to meet requirements from all projects.

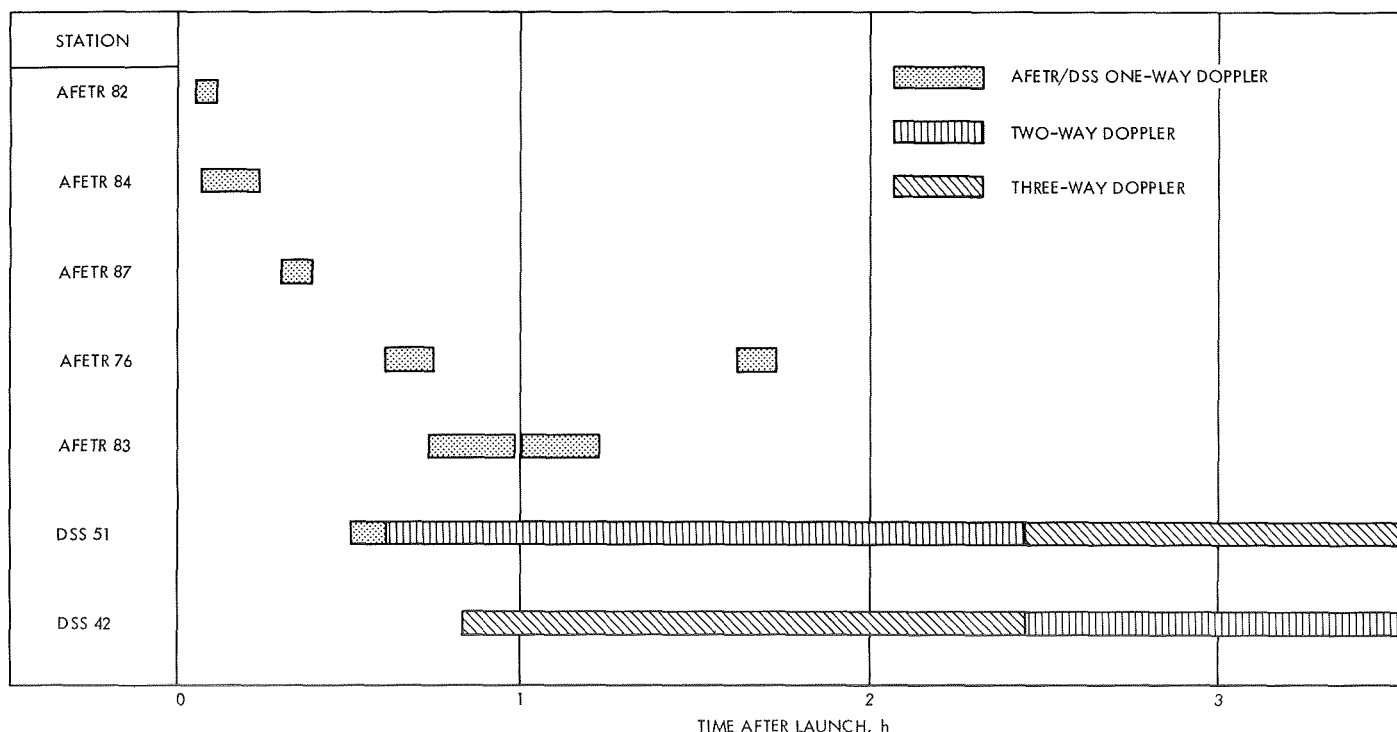


Fig. 64. Launch tracking data coverage

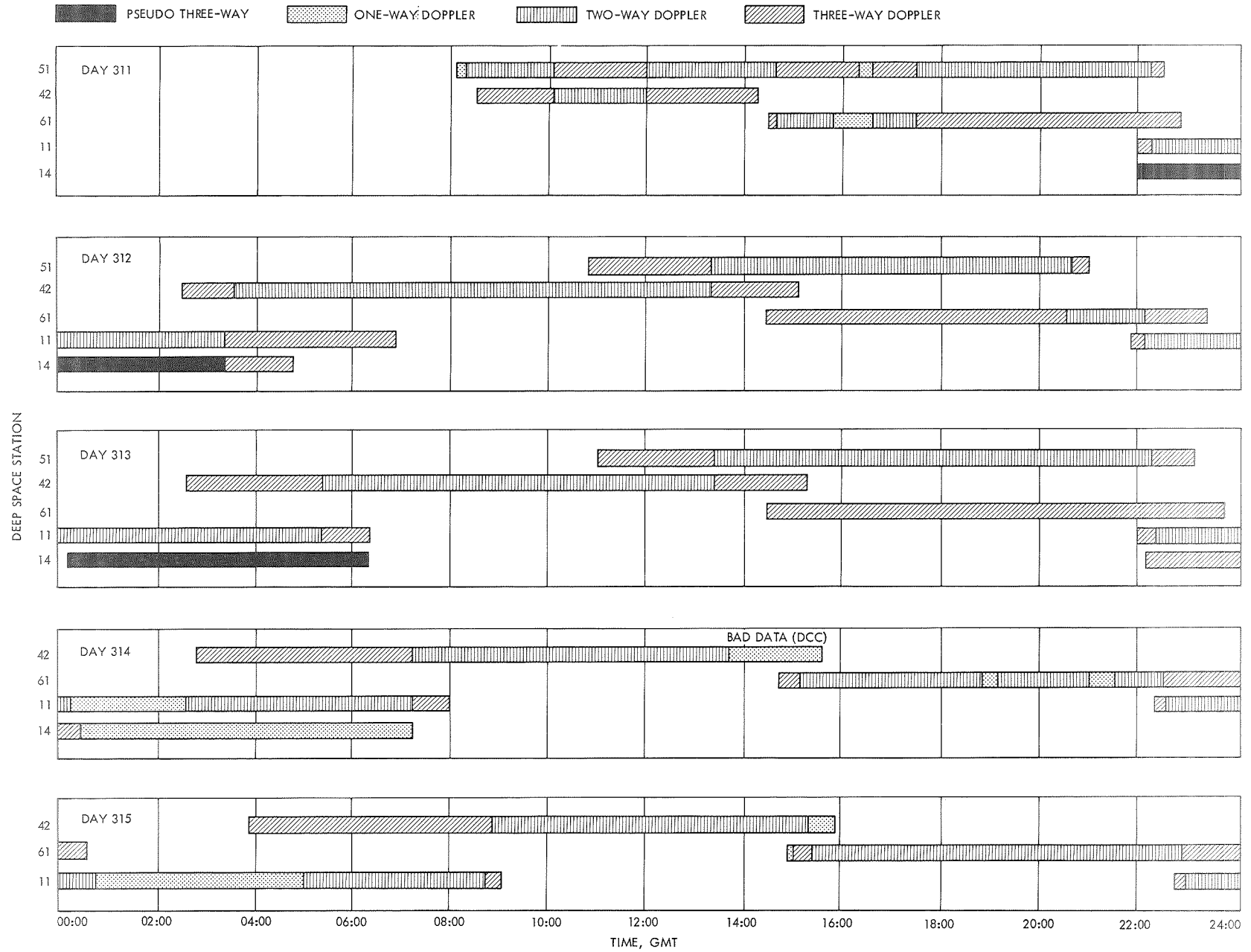


Fig. 65. Deep Space Station tracking data coverage

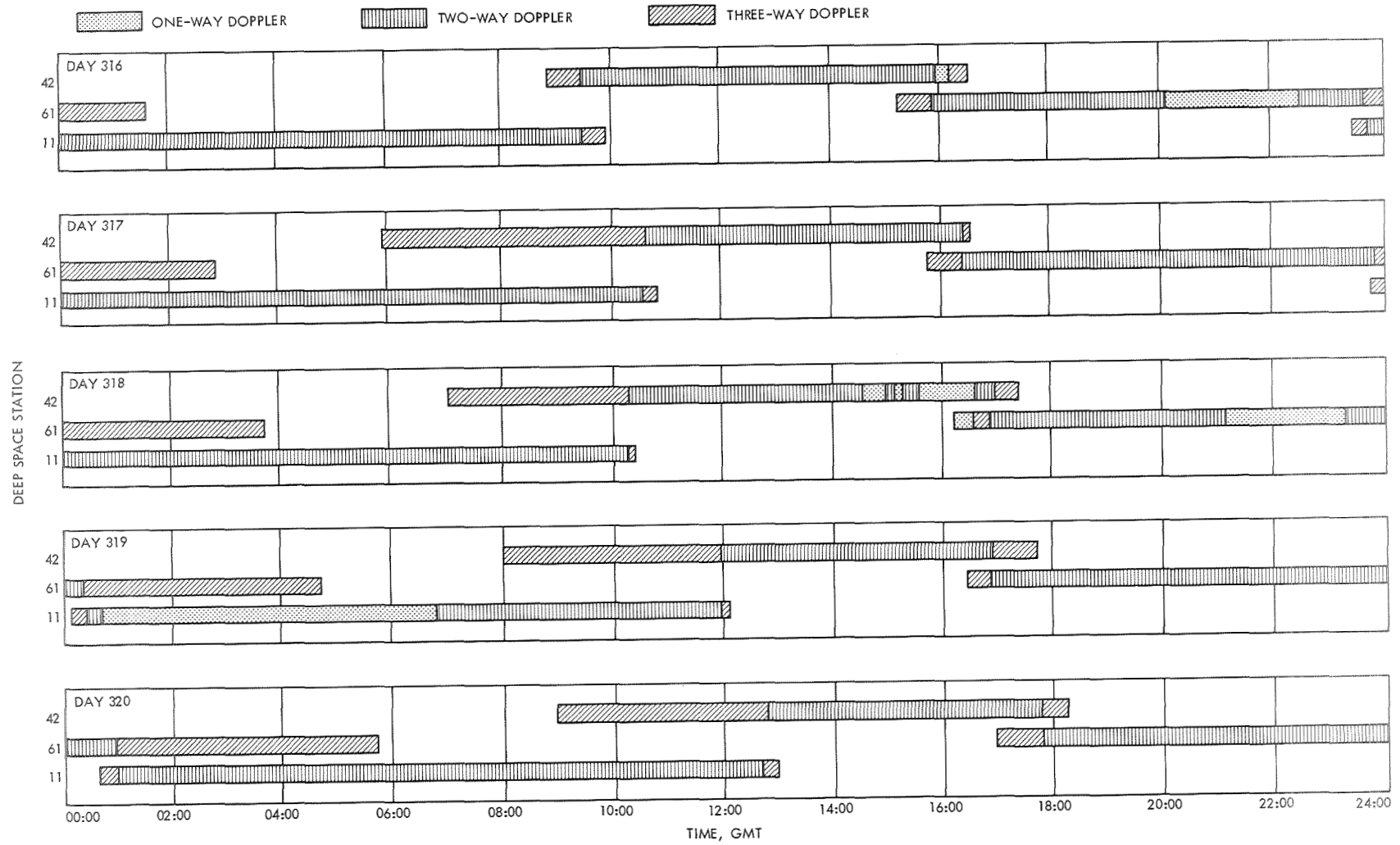


Fig. 65 (contd)

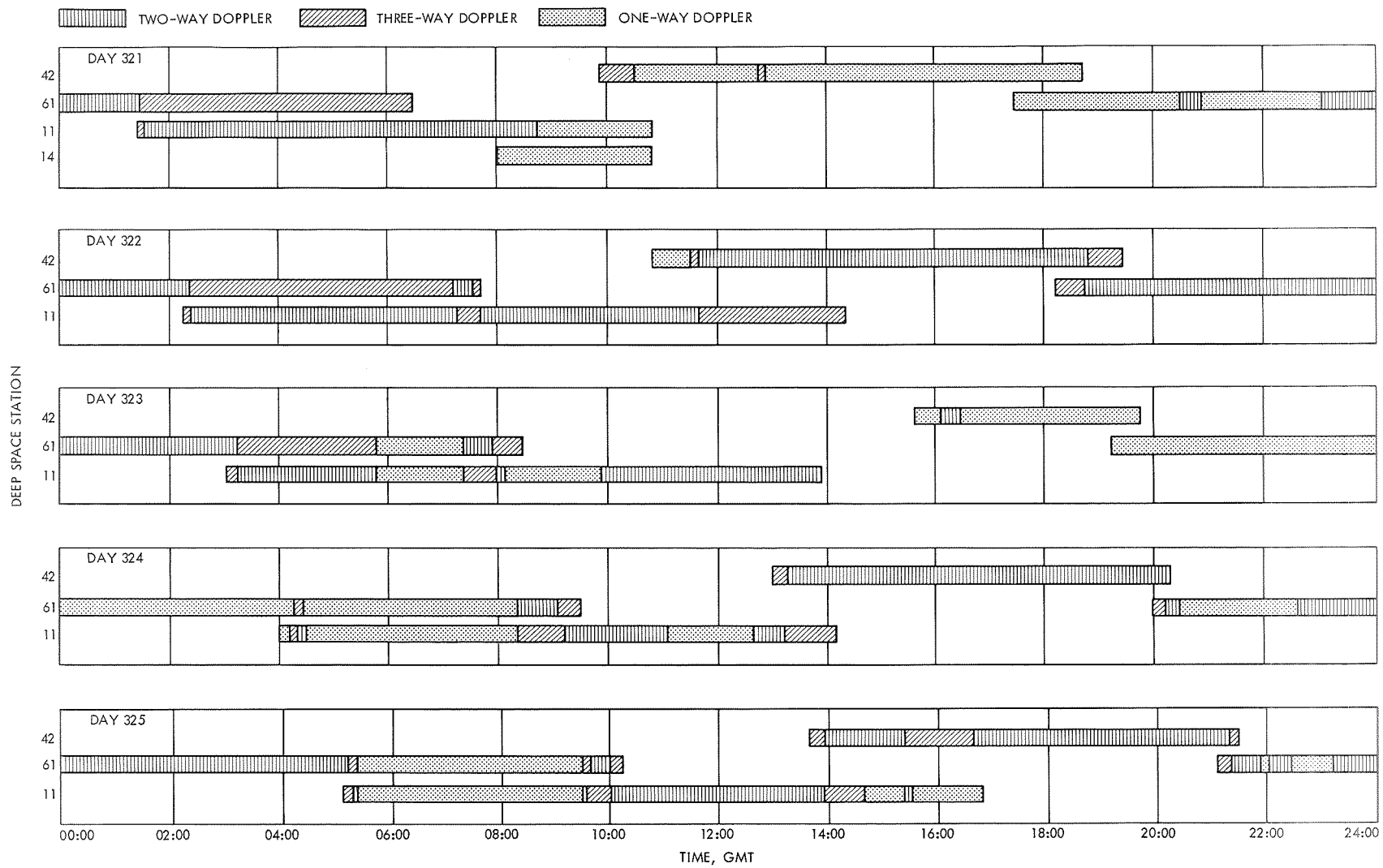


Fig. 65 (contd)

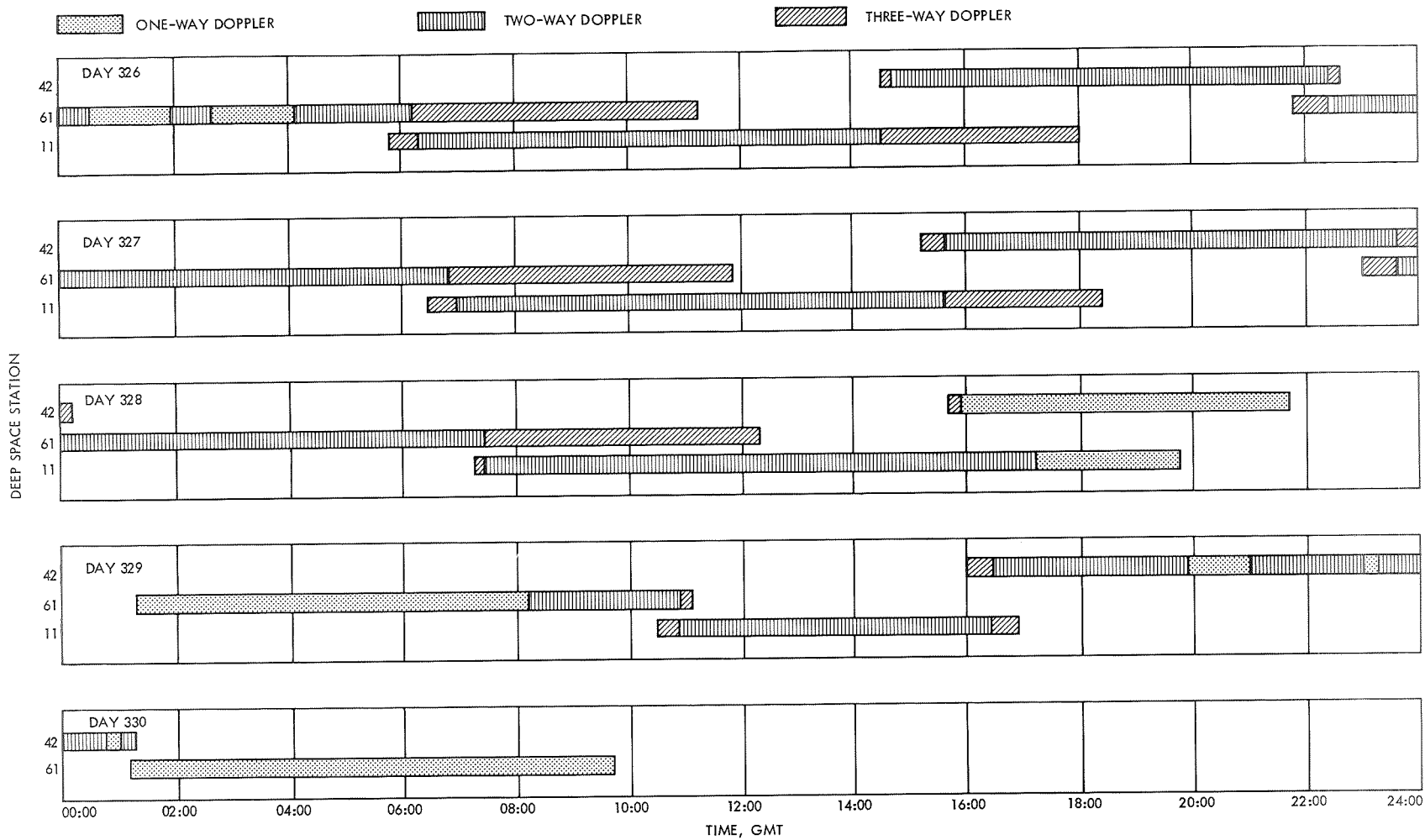


Fig. 65 (contd)

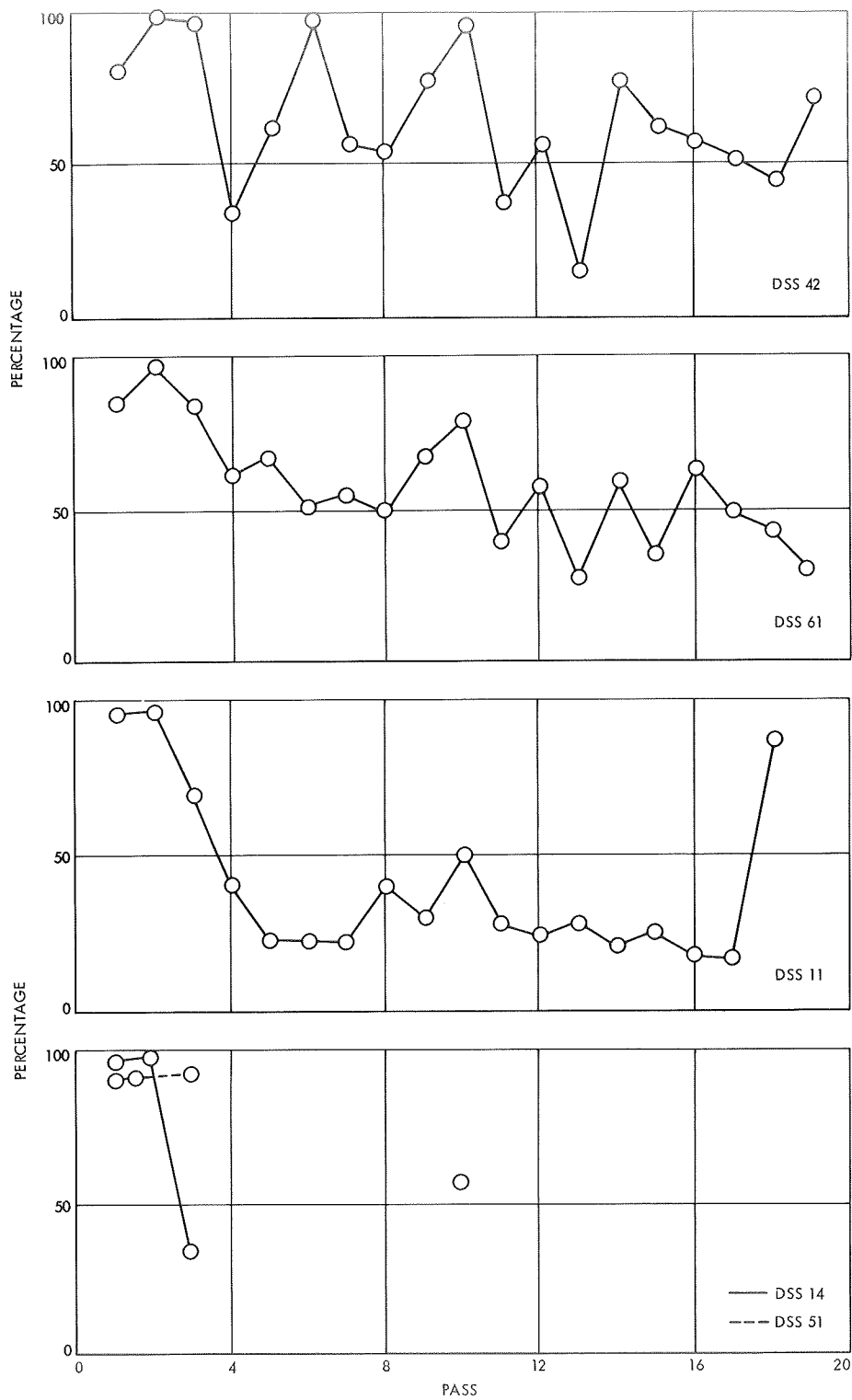


Fig. 66. Percentage of total data usable, station vs pass

It should be emphasized that a separate 7044 mission-dependent system is required for each pair of spacecraft which require sharing a 7044. This requires a high degree of coordination between projects, and the DSN operations control center scheduling office must maintain current information on 7044 share capabilities and requirements.

One operational problem occurred when sharing a 7044 with *Surveyor*. The 7044 model 2B system will output a NASCOM header every 5400 characters or 52 min, for data processing system data being printed on 100-words/min teletype machines. The *Surveyor* machines print continuously and reach the 5400 character limit in around 9 min. However, certain *Mariner* machines print only occasionally and therefore print a header only one every 52 min, which is operationally undesirable from a communications processor standpoint. This was corrected for *Surveyor VII* by reducing the 52-min limit to 15 min. This is a procedural problem only and did not cause any actual loss of data.

During lunar operations, the SFOF ran on generator power for extended periods of time during local electrical storms. Only one power outage occurred that rendered computers inoperative and resulted in a data loss for a brief period. The power outage occurred while the generators were first being put into operation.

No major area reconfigurations were made for *Surveyor VI*. Three positions were provided for project documentation personnel at the west round console. Requests for working space for project science personnel were complied with. The installation of the 1219 computer on the third floor was supported by SFOF personnel and minor changes to the 1219 telemetry processing station interface were accomplished.

During the mission period of *Surveyor VI*, performance of data systems operation was again more than adequate. No manning or personnel problems were encountered by any unit of operation during the mission period.

Surveyor VI used the 2B version of the 7044R computer software system and the X and Y string computer systems for primary support. The W string computer was used as backup during the critical phases (launch, mid-course, terminal maneuver) and released to users during noncritical portions of the mission.

The data systems operation supported *Surveyor VI* Mission activities and maintained an average I/O processing time of 15 min. The production type backlog

was contained and did not exceed 5 h. The problems that were encountered by I/O and telemetry processing station equipment caused only minor loss of data. The majority of the problems were repaired in real-time; however, in some cases the equipment was replaced with a like item.

Surveyor support areas were manned by I/O maintenance personnel during the launch and touchdown phase of the mission to ensure expeditious maintenance in the event of I/O equipment problems. This reduced equipment downtime during the most critical phases of the mission.

Prior to the *Surveyor* mission, PDP-7 computer 2 encountered memory problems. At that time, PDP-7 computer 3 was configured to general purpose station 2. During high activity portions of the mission, PDP-7 computers, 1 and 3, were used to support. No problems were encountered with the computers in this configuration. The PDP-7 computer 2 was restored to normal operation on November 18, 1967.

Problem areas were as follows:

- (1) At 14:05, November 7, 1967, the SC-3070 bulk printer in area 7 lost dc voltage to the charge grids. The printer was repaired and normal operation was restored at 15:10.
- (2) The November 7, 1967 total loss of printer time was 20 min. At 02:28, November 8, 1967, mission 1 and 2 clocks did not switch to plus time. Maintenance personnel found that both plus sign lamps were burned out. Lamps were replaced and the clock restored to normal at 03:40, November 8, 1967.
- (3) At 02:50, November 8, 1967, a D8 (residual) tape was snapped on an IBM 729 tape drive. This caused the 7044X to be interrupted on a "read tape select" while the operator was mounting another tape, and resulted in a 10-min delay of output to the project.
- (4) At 07:45, November 8, 1967, the B-12 Burroughs card reader located in area 6 started misreading cards. Maintenance personnel replaced the card reader at 08:00, November 8, 1967. Total loss of card reader time was 15 min.
- (5) At 23:00, November 8, 1967, the brush recorder in area 6 event marker pen (channel 6) would not ink paper. Maintenance personnel replaced the pen at 01:00, November 9, 1967.

- (6) At 00:59, November 9, 1967, a procedural problem caused a card read select on 7094X. This interrupted I/O processing. The problem occurred when data control bumped telemetry data processing and users in area 5 entered cards for TDPX. An internal restart was initiated to correct the problem. An interruption of 7 min of support resulted.
- (7) At 02:02, November 9, 1967, external communications to the 7044W were interrupted due to an I/O loop in the system. Support was interrupted for 12 min. The problem was caused by redundancies on the D2 recovery tape. The system was restarted from the initial program loading to correct the problem.
- (8) A floating trap problem occurred on 7094X at 07:40, November 9, 1967. This problem had no effect on *Surveyor*, other than switching from the W to the Y string computers could not be accomplished as scheduled at 18:00.
- (9) A 6-min interruption of mode II support occurred on A channel 7094X at 18:00, November 9, 1967. The problem was caused by an illegal IBM 711 card reader select. Customer engineers from IBM reset the card reader select and no further problems were encountered.
- (10) At 19:50, November 9, 1967, the Sorobam keyboard on the I/O tasker console in area 7 had three broken keys, causing the keyboard to jam. Maintenance personnel replaced the broken keys and operation was restored to normal at 20:05, November 9, 1967. Total downtime was 15 min.
- (11) At 06:20, November 10, 1967, telemetry processing general purpose station 2 could not synchronize on *Surveyor* data from DSS 11. Maintenance personnel found bad logic card 15530 DS-2 in PCM astrodata decommutator system. The logic card was replaced, which restored system to normal operation at 06:34, November 10, 1967. Total loss was 15 min.
- (12) At 07:25, November 10, 1967 general purpose station 1 could not synchronize on *Surveyor* data. A bad logic card (15530 DS-2) was found in PCM astrodata decommutator system. The logic card was replaced, and the system was restored to normal operation at 07:37, November 10, 1967. Total loss was 12 min.
- (13) At 18:40, November 10, 1967, card inputs from user area 6 were not recognized by 7044X and 7094X. The cause of the problem was undetermined. A cold start of the 7044X was directed and the card reader was replaced in the user area. The problem caused intermittent interruptions during the alpha scattering program sequence.
- (14) At 01:05, November 11, 1967, the B-122 Burroughs card reader in area 6 would not read cards correctly. Maintenance personnel replaced the card reader and operation was restored to normal at 01:18, November 11, 1967. Inconvenience to the user totaled 13 min.
- (15) At 08:20, November 11, 1967, an I/O select loop occurred on 7094X, channel A. This interrupted mode II operations for 11 min. The cause of the problem was undetermined and the 7094 was restored to solve the problem.
- (16) An intermittent 7320 drum storage failure occurred at 14:30, November 11, 1967. *Surveyor* switched operations to the 7044W. No loss of data was experienced.
- (17) At 07:20, November 12, 1967, the 200 Vdc power supply failed in the SC-4020 plotter. Backup capabilities were provided by the building 125 facility. This allowed the customer engineer to come in the next day (16:00, Monday) instead of Sunday night. Normal SFOF plot processing capability was restored at 17:45, November 13, 1967.
- (18) The 7044X user area communications were interrupted on November 15, 1967 at 11:14, due to faulty format on the IBM 7320. A 4-min loss of data was experienced while the drum was reformatted.
- (19) Intermittent problems occurred on November 15, 1967, at 15:30, when the 7044X computer went into a tight loop. Similar problems occurred between 09:29 and 09:34, November 16, 1967, causing 1- to 2-min interruptions. Reasons for these failures were undetermined. The system was downed for a period of 15 h while attempts were made to isolate the problems. The problems did not reoccur during this period. However, additional time will be scheduled in an effort to remedy the problems.
- (20) At 17:34, November 16, 1967, the SC-3070 bulk printer located in area 4 would not step paper properly. Maintenance personnel found the stepper motor bearing frozen. The bulk printer was replaced and operations were restored at 18:00, November 16, 1967.

(21) Edison power failure occurred at 08:39, November 19, 1967, affecting the X and Y computers. *Surveyor* was using the 7094Y computer string at the time of the power failure. Power was restored to the Y string; however, *Surveyor* used mode III because there was a logic card failure in the 7094Y computer. Power was restored to the X string at 09:34. There was a failure of formats on module 21 of the 7044-7094 disk. The disks were reformatted and then *Surveyor* was placed on the X string at 10:39. The power failure resulted in the project losing 2 h of mode II operation.

Figure 67 shows the SFOF computer usage of the 7044/7094 computer during the *Surveyor VI* Mission.

a. Communications/SFOF. The SFOF communications support activities are summarized in the paragraphs that follow.

Permission summary. The DSN/GCF and the ICS provided support for *Surveyor VI* Mission. Communications

personnel conducted a complete checkout of ICS equipment in the SFOF prior to the ORT and all equipment was adjusted per specifications. The ICS equipment performed very well during the premission period.

Some major problems occurred in the DSN/GCF during this period which involved the Western Union microwave system between JPL and Goldstone, the JPL communications processor, and radio propagation conditions. Communications to the stations were 92% reliable, a good to fair rating. Those stations contributing to the downgrade of reliability were DSS 51, due to propagation, DSSs 70 and 71, due to patching problems and malfunctioning equipment.

Permission problem areas. The JPL communications processor system had an extremely high volume of major faults during a 36-h period from 17:34, November 5, 1967, to 04:50, November 7, 1967. At times, the system was operational, but these were of such short duration that for all practical purposes it could be considered

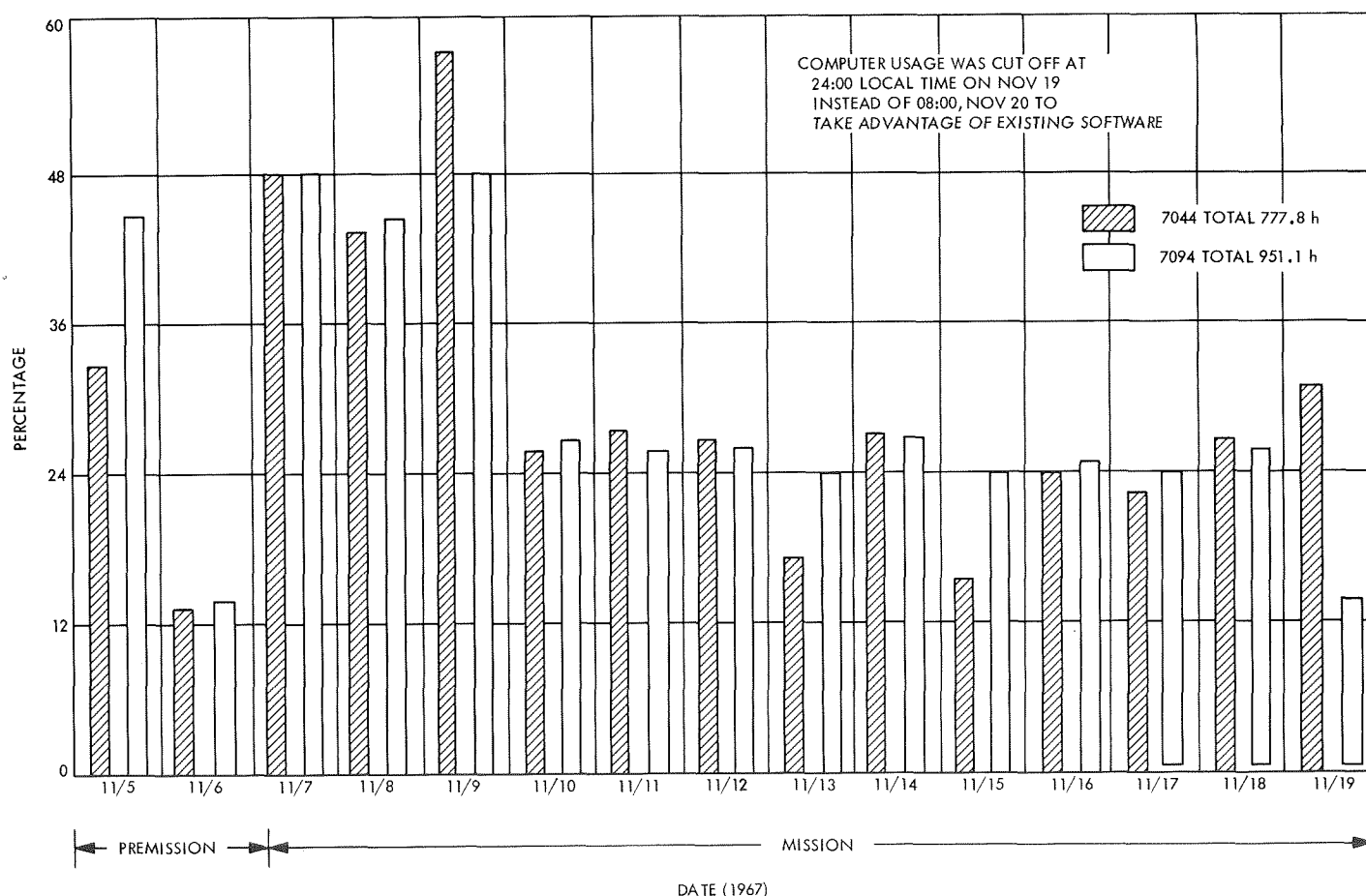


Fig. 67. *Surveyor VI* Mission 7044/7094 computer usage

nonoperational during this entire period. The Univac personnel worked continuously and had both A and B systems operational by $T - 1$ h, but in a nonstandard mode of crossed drums. The B processor, A drum, and A servos were on line and running. The A processor, B drum, and B servos were running backup. The most significant of the faults experienced by the communications processor are described as follows:

- (1) Drum packet errors that occurred at various times in the B system were traced to a bad component card in the drum control and sequence unit. The unit was replaced and released for operation at 08:13, November 6, 1967.
- (2) At 06:49, November 6, 1967, the A system experienced input sync faults. Impedance matching cards in the adapter were detected as being faulty and were replaced. The system was back in operation at 08:43, November 6, 1967.
- (3) At 04:14, November 7, 1967, a loose wire was detected inside the A system central processor unit. The wire was repaired and, after checkout, the system was back in operation at 04:50, November 7, 1967.

Other problem areas encountered during the premission period are described as follows:

- (1) A fire occurred at Sierra Peak microwave station on October 30, 1967, and the system was closely watched. Low-gain antennas were being used. Plans were made to use the 96-kHz line in place of the 6-MHz line in event of failure, but no failures occurred during the premission period. The 96-kHz line was down from 05:48, November 7, 1967, due to maladjusted amplifiers at JPL. This did not affect project data since the 6-MHz line was in use.
- (2) Poor radio conditions with DSS 51 occurred at various times during the premission period but were cleared by approximately $\frac{1}{2}$ h before liftoff. The DSS 70 lost teletype time amounted to 87 min for three teletype circuits between 03:53 and 05:20, November 7, 1967. This was due to poor patching at Cape Kennedy. The DSS 71 lost teletype time amounted to 61 min for three teletype circuits between 03:53 and 04:54, November 7, 1967, due to malfunctioning equipment at DSS 71. These outages at DSSs 51, 70, and 71 had little significance since the JPL communications processor was inoperative during this time.

Mission summary. Generally, the entire DSN/GCF and ICS performed satisfactorily, with the exception of power problems and water leakage problems late in the mission period. While the JPL communications processor experienced a minimum of failures throughout the mission period, the majority of communications processor problems were attributed to London, Canberra, and Goddard communications processor systems. An analysis of DSN/GCF premission reliability is shown in Table 50. Analysis of DSN/GCF support during the mission is shown in Table 51.

Mission problem areas. The mission problem areas were as follows:

- (1) Due to a heavy rainfall, a plugged drain, and a nonwatertight door, two separate problems occurred on November 19, 1967. First, the rainfall caused loss of SFOF power minutes before the SFOF was to have switched to generator power. The power loss caused the JPL communications processor A and B systems to fault, however, communications were restored by patching around the communications processor. After switching to generator power, the communications processor A system was restored, but as a result of the initial power failure, the backup B system was not reactivated. Within a few hours the A system faulted again, probably as a result of an instruction being lost at the instant of the initial power failure. A water leak into the sub-floor area of the communications processor resulted from excess rain water draining into the basement flooring. The cause of this drainage was determined to be a plugged drain and a large opening between the floor and an outside basement door. Communications were restored by switching around the communications processor, while the water source was stopped and the accumulated water was drained from the under floor. During this period, communications operations made the decision to power down both communications processor systems.
- (2) During the mission period, the 418 communications processor system at Goddard experienced over a dozen short-duration failures, necessitating manual and automatic recoveries as well as complete system swaps.
- (3) The 418 communications processor systems at London and Canberra also experienced a number of problems which resulted in recoveries and swaps. There were four communications processor failures in each of these switching centers.

Table 50. Deep Space Network/GCF premission phase reliability analysis

Station and mode	Total time activated, h	Total outage time, min	Number of outages	Mean outage duration, min	Reliability index, %	Outage cause by percent
11 Teletype (4)	75.1	132	16	8.3	97.1	Software, 100
11 Voice (2)	38.6	—	—	—	100	
11 High-speed data (1)	19.6	—	—	—	100	
11 Wideband (1)	19.0	104	1	104.0	90.9	Hardware, 100
11 Automatic gain control (1)	19.5	—	—	—	100	
11 Video (1)	19.6	—	—	—	100	
42 Teletype (4)	58.6	144	16	9.0	95.9	Software, 100
42 Voice (1)	15.2	—	—	—	100	
42 High-speed data (1)	15.2	—	—	—	100	
51 Teletype (4)	52.1	844	12	70.3	70.3	Inactive, 90.9; hardware, 1
51 Voice (1)	13.0	307	3	102.3	60.6	Inactive, 100
51 High-speed data (1)	13.0	144	2	72.0	81.5	Inactive, 100
61 Teletype (4)	33.1	—	—	—	100	
61 Voice (1)	8.8	—	—	—	100	
61 High-speed data (1)	8.8	—	—	—	100	
AO Teletype (3)	67.4	473	15	31.5	88.3	Software, 45.7; hardware, 54.3
AO Voice (3)	71.3	44	2	22.0	99.0	Hardware, 100
AO High-speed data (1)	21.8	107	1	107.0	91.8	Hardware, 100
71 Teletype (3)	31.2	254	4	63.5	86.4	Hardware, 66.5; inactive, 33.5
71 Voice (1)	11.7	105	2	52.5	85.0	Hardware, 100
71 High-speed data (1)	11.5	107	2	53.5	53.5	Hardware, 100

(4) The JPL communications processor B system had a fault at 20:17, November 8, 1967, due to memory lockout problems and drum packet errors. After an unsuccessful 3/2 recovery, communications were swapped to low-speed teletype at 20:22, with only a small outage. At 20:42, low-speed teletype was terminated and the A system was placed on line.

(5) During the period of time in which DSS 51 was activated for *Surveyor VI*, the teletype and voice circuits had many outages due to propagation between London and Pretoria. Most of the teletype outages were of 30- to 40-min duration, and the voice outages averaged over 60-min duration. Since DSS 51 was not a prime support station after lift-off, these problems were considered minor failures.

(6) At 03:36, November 18, 1967, a communications processor system swap was performed because communications were lost with the data processing system Y string. Communications were restored at

03:41, but the problem still remained. Subsequent investigation revealed a hung message in 7044Y computer.

(7) The communications processor indicated drum hardware errors at 15:23, November 20, 1967. The system did not fault, but a 3/2 recovery was attempted. The recovery did not take, and at 15:27 a system swap was completed. The reason for the drum errors was unknown and the system is again working satisfactorily.

b. Operations and support/SFOF. A summary of the SFOF operations and support is presented in the paragraphs that follow.

Premission summary. The SFOF maintenance and operational support of the *Surveyor VI* Mission incurred no major problems. Several minor problems involving outages were quickly resolved and had no effect on the mission.

Table 51. Deep Space Network/GCF mission phase reliability analysis

Station and mode	Total time activated, h	Total outage time, min	Number of outages	Mean outage duration, min	Reliability index, %	Outage cause by percent
11 Teletype (4)	791.3	148	20	7.4	99.7	Hardware, 21.6; software, 75.7; inactive, 2.7
11 Voice (2)	419.0	5	2	2.5	99.9	Hardware, 100
11 High-speed data (1)	210.3	—	—	—	100	
11 Wideband (1)	210.3	422	3	140.7	96.7	Hardware, 100
11 Automatic gain control (1)	210.3	6	3	2.0	99.9	Hardware, 100
11 Video (1)	210.1	115	1	115.0	99.1	Hardware, 100
42 Teletype (4)	703.1	328	48	6.8	99.2	Hardware, 24.4; software, 75.6
42 Voice (1)	181.8	4	1	4.0	99.9	Procedure, 100
42 High-speed data (1)	178.7	30	2	15.0	99.7	Hardware, 33.3; inactive, 66.7
51 Teletype (4)	269.4	1185	41	28.9	92.7	Hardware, 8.4; software, 14.5; inactive, 77.1
51 Voice (1)	67.1	452	7	64.6	88.8	Procedure, 7.7; inactive, 92.3
51 High-speed data (1)	66.9	217	4	54.3	94.6	Hardware, 3.2; procedure, 8.8; inactive, 88.0
61 Teletype (4)	764.8	686	73	9.3	98.5	Hardware, 20.8; software, 70; inactive, 9.2
61 Voice (1)	193.3	7	4	1.8	99.9	Inactive, 100
61 High-speed data (1)	193.5	16	4	4.0	99.9	Hardware, 100
AO Teletype (3)	9.1	—	—	—	100	
AO Voice (3)	7.9	—	—	—	100	
AO High-speed data (1)	2.6	—	—	—	100	
71 Teletype (3)	3.4	—	—	—	100	
71 Voice (1)	1.2	—	—	—	100	
71 High-speed data (1)	1.2	—	—	—	100	

During the premission period, reproduction services received a total of 46 programs and produced a total of 8100 copies.

The activity in the DSN scheduling office during the premission period was normal with no unusual activity experienced.

Premission problem areas. The problems occurring during the premission period, while minor in nature, involved the following major equipment outages for short periods of time.

- (1) At 02:08, November 5, 1967, generator 1 lost its automatic frequency control and was controlled manually while the load was transferred to generator 2. Investigation revealed vibration had

loosened a brush cap on the governor motor, rendering it inoperative. The brush and cap were restored and the cap sealed. Generator 1 resumed its load after an outage of approximately 68 min. Generator 2 was involved in two malfunctions, one of which required a shutdown. A fuel line cracked at 11:10, November 5, 1967 from vibration fatigue. The load was transferred to generator 1 while the line was replaced, and 2 was back on line in less than 1 h. The second problem developed at 16:20, November 5, 1967, when the fuel pressure in 2 dropped approximately 10 lb. The generator was maintained in operation until ORT completion, at which time a valve in the fuel pump was repaired. No further generator problems developed.

- (2) The elevator was out of service three times on November 5 and 6, 1967, due to an excessive oil leak. A total down time of approximately 10 h was experienced. New packing was received and installed on November 6, 1967, and no further problems were encountered.
- (3) The blueline machine was inoperative on November 5, 1967, due to a burned out lamp. The lamp was replaced on November 6, 1967. Shortly thereafter (on November 6, 1967), the Xerox 2400 Model IV broke a main drive seal which was replaced on November 7, 1967. No further problems developed.

Mission summary. The SFOF maintenance and operational support of the mission period of *Surveyor VI* was plagued with a multitude of maintenance problems. These problems were primarily a direct result of the adverse weather which began on November 18, 1967. However, the prompt corrective action provided by support functions held the effect on the mission to a minimum.

During the mission period, reproduction services received a total of 383 programs plus special work and produced a total of 125,000 copies.

Activity in the DSN scheduling office was heavier than normal. A slight delay was encountered in producing the 7-day schedule on November 9, 1967, due to backlog of *Surveyor* data being processed on the 7040 computer. No associated problems resulted from this delay.

Mission problem areas. The majority of problems occurred in the basement and on the third floor as a result of bad weather. The following specific incidents are listed due to the magnitude of their effect on the mission and on support personnel.

- (1) Due to the heavy rain and a plugged drain in the west stairwell, the communications processor area was plagued with water problems. The plugged drain caused flooding of the area on November 19, 1967. Pumping was initiated and the communications processors were shut down until enough water was removed for safe operation.
- (2) The third floor was plagued with roof leaks. Whenever possible, equipment was covered with plastic, dried out, and returned to service. A roof leak in

the reproductions area, which was not immediately repairable, resulted in shutting down the blueline machine for reasons of safety due to the high voltages involved. The Xerox 2400 Model IV was inoperative on November 9, 15, and 17, 1967, for a total of approximately 19 h. Backup from the Copy-Flo was available and utilized as required, resulting in no loss of reproduction time.

- (3) Edison power was unusually unstable during the storm period, ranging in power dips from 30 V to complete blackout. At 08:40, November 19, 1967, Edison power failed due to lightning. The generators were being brought up at the time and recovered power at 08:42, for a total power outage of 2 min. At 11:06, November 19, 1967, all four generators were on line.
- (4) Generator 2 failed at 11:45, November 19, 1967, due to a burned out governor control motor. The electrical load was lightened and generator 1 assumed the load. Generator 3 was secured and the governor removed and installed on generator 2. At 19:35, November 19, 1967, generator 2 was back on line.
- (5) The elevator was out of service on November 12 and 19, 1967, for a total of approximately 5½ h, due to minor mechanical and electrical problems.
- (6) Chiller 2A developed a bad valve on November 11, 1967. It was replaced without requiring a shutdown.
- (7) An expansion joint on hot water pump 2 cracked due to fatigue on November 10, 1967. A backup pump was installed during repair with no noticeable loss of service.
- (8) The Xerox 2400 Model IV was inoperative on November 9, 15, and 17, 1967, for a total of approximately 9 h, due to various minor problems. Immediate backup was available at all times from the Copy-Flo.

Figure 68 shows the SFOF power sources and their usage for the *Surveyor VI* Mission.

c. Performance/SFOF. The SFOF performance is summarized in the paragraphs that follow.

Premission summary. As indicated in Table 52 a number of anomalies occurred during *Surveyor VI* premission period within the SFOF. The majority of these problems

fall into distinct areas which are discussed in the following paragraphs.

Procedure. There was only one significant procedural problem that occurred during the premission period. Personnel using the teletype machine were unaware of how to use the teletype status board. This problem was corrected by instructing personnel in the use of the status board.

Hardware. As always, there are more deficiency reports written in the hardware category than in any other, but this is to be expected. It should be noted, that as in the last *Surveyor* mission, the majority of these deficiency reports were related to the data processing system area. About 40% of these reports were associated with the 3070 bulk printers. During the premission period, two 3070 printers had to be completely replaced.

There was only one deficiency report written against the support group during the premission period of this maintenance and operation report.

There were two significant problems with the communications processor. On November 5, 1967 (on the B system), selective bits were being added and deleted, causing erroneous data operations. This problem resulted in the replacement of five printed circuit cards, and an adjustment of memory. On November 6, 1967, again with the B system, there was a loss of timing pulse in the drum sequence and control unit.

This problem resulted in replacement of printed circuit board 29 C. In addition to the communications processor problems, there were other deficiency reports generated against the ICS; however, these were not significant.

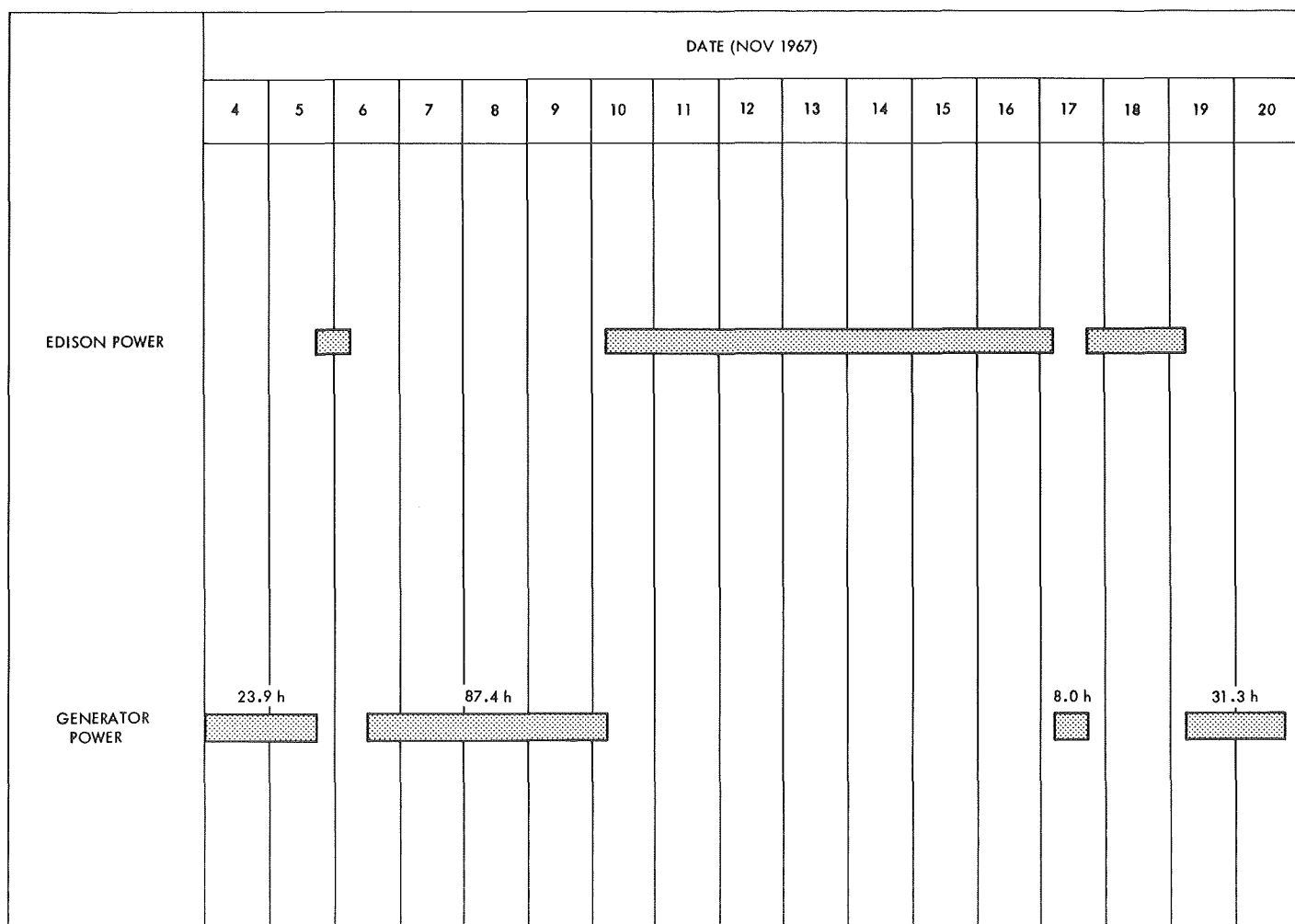


Fig. 68. Space Flight Operations Facility power mode, *Surveyor VI*

Table 52. Summary of SFOF anomalies (premission phase)

Function	Problem	NO GO condition, time, GMT, date, Nov 1967	Cause	Remedy	GO condition, time, GMT, date, Nov 1967	Effect on mission
Facility support	Generator 1 down	02:08, 5	Governor lost brush cap due to vibration	Replace and seal	03:00, 5	None. (Generator 2 absorbed load)
Facility support	Blueline machine down	03:00, 5	Burned out lamp	Replaced lamp	19:30, 6	None. (Reproduction requirements not scheduled for this period)
Data processing system	IBM 7320 drum storage parity errors on IBM 7044Y computer system	04:00, 5	Undetermined	Problem investigated by IBM customer engineering (7320 drum surface analy- sis was performed by IBM and no failure was located)	04:19, 5	A 19-min interruption in support was experienced by Surveyor. (During this period, Surveyor moved support to the W string computer system)
Data processing system	Area 5 card reader misreading cards	06:42, 5	Dirty lamps and rollers	Lamps and rollers cleaned	06:55, 5	Loss of user area card reader in user area for 11 min
Facility support	Generator 2 down	11:10, 5	Broken fuel line	Replaced line	11:59, 5	None. (Generator 1 absorbed load)
Data processing system	Delay in output tape switching on 7094Y computer	12:20, 5	Systems tape switch- ing control cards used were in im- proper order	Operators corrected control card order and restarted the 7094Y system	18:20, 5	Caused a delay in the removal of output tapes (Eight output tapes were re- moved from the 7094Y during this time; approxi- mately 2 min delay per tape)
Facility support	Generator 2 down	16:20, 5	Low fuel pressure due to stuck pump valve	Repaired stuck check valve in fuel pump	22:17, 5	None. (Generator 1 absorbed load)
SFOF communi- cations	Communications processor in a continuous drum update condition	17:34, 5	Excessive message lengths from DPS	Data processing system performed a stop-all and problem cleared	17:38, 5	Data delay of 4 min to Surveyor
SFOF communi- cations	Communication processor stopped outputting	17:55, 5	Unknown	Performed several 3/2 recoveries and one 3/1 recovery, but with no success. System swap restored operations	18:14, 5	No data loss; ORT completed prior to outage
Data processing system	Surveyor status dis- plays were not updating in area 6	18:00, 5	Surveyor software problems	Project corrected software	22:50, 5	Inconvenience to user
Facility support	Elevator down	18:30, 5	Loss of oil	Replaced oil	21:15, 5	Lost elevator for 2 h, 15 min

Table 52 (contd)

Function	Problem	NO GO condition, time, GMT, date, Nov 1967	Cause	Remedy	GO condition, time, GMT, date, Nov 1967	Effect on mission
SFOF communications	Communications processor faulted	19:46, 5	Unknown	Performed a 3/2 recovery	19:48, 5	2-min data loss
SFOF communications	Communications processor faulted	19:50, 5	Unknown	Performed a 3/1 recovery	19:55, 5	5-min data loss
Data processing system	IBM 1403 Printer 1 on IBM 7040Y computer failed	20:10, 5	Damaged carriage feed roller	IBM customer engineering replaced defective roller	20:40, 5	Reduced Surveyor 7040Y computer output processing support capabilities
SFOF communications	Both communications processor strings were experiencing numerous problems. (Decision made at 20:45 to take both strings down and turn over to Univac and programmers for repair)	21:06, 5	Many problems in both strings of communications processor: drum errors, memory errors, and output problems	(1) Projects placed on low speed hardware circuits to continue traffic. (2) B string up with 4 cards replaced to correct memory. One card replaced to correct output acknowledgment. Adjusted memory voltage	01:53, 6	No data loss, but tremendous inconvenience to the Surveyor Project. No communications processor support for 4 h and 47 min
Facility support	Elevator down	23:40, 5	Loss of oil	Tightened gland. Replaced oil	02:00, 6	Lost elevator for 3 h and 20 min
Data processing system	Could not access tape decks in PDP-7 computer 1	03:00, 6	Bad logic card in parity circuit	Replaced logic cards	06:00, 6	Found and repaired before Surveyor used
SFOF communications	Communications processor faulted	03:36, 6	Unknown—recoveries would not restore system	Communications processor A string now operational and placed on-line switching administrative traffic only at 04:30	05:40, 6 (Traffic only)	No data loss; inconvenience due to data delay
Data processing system	When the 4151 Area 6 devices were switched to Y or W string (by data processing control center), both string indications came on. Area 6 devices could be switched properly at the M box	08:15, 6	Switching device on the area 6 I/O console was stuck on W and Y string	Removed computer selector switch on I/O console and reassembled	08:38, 6	Found and repaired during data processing system checkout, reducing the probability of equipment failure during the mission
Facility support	Elevator ram needs packing	19:00, 6	Worn packing	Repacked	23:30, 6	Lost elevator for 4 h and 30 min
Facility support	Xerox 2400 Model IV down	20:10, 6	Main drive seal broken	Drive seal replaced	01:00, 7	None. (No assignments this period)
SFOF communications	Communications processor faulted	23:10, 6	Drum update problems	Performed a 3/2 recovery	23:18, 6	8-min data delay

Table 52 (contd)

Function	Problem	NO GO condition, time, GMT, date, Nov 1967	Cause	Remedy	GO condition, time, GMT, date, Nov 1967	Effect on mission
SFOF communications	Communications processor faulted	23:21, 6	Drum hardware errors	System was master cleared and up, but no data permitted to be put into the system	23:24, 6	3-min data delay; no data loss
SFOF communications	Communications processor system still appears to be very unstable	23:35, 6	Drum errors	System swapped to A string	23:45, 6	No data loss; 10-min data delay
SFOF communications	Communications processor very unstable	00:01, 7	Communications processor experiencing drum hardware errors, memory lock outs, and drum packet errors	Performed 3/2 recoveries but still reading drum packet errors	01:07, 7	Inconvenience due to data delay; no loss of data
Data processing system	Area 6 card reader not reading cards	00:05, 7	Unknown	I/O maintenance checked; card reader could not duplicate problem	00:15, 7	10-min loss of card reader usage in area 6
SFOF communications	Communications processor (B) inoperative	00:56, 7	Drum packet errors	Direct current bias buildup on A track removed	01:55, 7	No data loss; portions of A system supplemented during outage
SFOF communications	Temperature alarm on communications processor A system	01:50, 7	Unknown	System operation was not completely affected by temperature	02:13, 7	No data loss; system operative during temperature problems
Data processing system	Plotter arm oscillating on Milgo plotter, area 6	03:35, 7	No +20-V reference	Replaced +20-V reference in amplifier assembly	03:45, 7	10-min loss of plotter
SFOF communications	Teletype, voice, and high-speed data circuits down	03:53, 7	Carrier failure between Polk City and Cocoa Beach, Fla.	Carrier restored	04:54, 7	61-min data loss
SFOF communications	96-kHz line to Goldstone down	05:48, 7	Maladjusted amplifier at JPL	Adjusted level of amplifier at JPL and Goldstone	07:32, 7	Delay in operational status of line; no data loss

Software. There were no deficiency reports generated specifically against software failures. However, on November 5, 1967, the card reader in area 5 was not reading cards correctly.

The card reader was replaced twice but still did not relieve the problem. This leads to the belief that the problem might be software and not hardware.

Mission summary. As indicated in Table 53, a number of anomalies occurred during *Surveyor VI* Mission period within the DSN/SFOF. The majority of these anomalies fall into distinct problem areas which are discussed in the following paragraphs.

Procedure. There was only one significant procedural problem that occurred during the mission period.

Table 53. Summary of SFOF anomalies (mission period)

Function	Problem	NO GO condition, time, GMT, date, Nov 1967	Cause	Remedy	GO condition, time, GMT, date, Nov 1967	Effect on mission
SFOF communications	Goddard communications processor faulted	11:06, 7	Unknown	GSFC did a minor recovery	11:07, 7	1-min loss of data from DSSs 51, 42, and 61
Facility support	Edison power dip revealed on U bus recorder	11:18, 7	Edison station	Edison effected	11:18, 7	None.(No mission critical equipment on this bus)
Data processing system	S-C 3070 bulk printer in area 7 inoperative	14:50, 7	No dc voltage to charge grids	Swapped bulk printers with area 11	15:10, 7	20-min loss of bulk printer
SFOF communications	Loss of contact on the microwave system; predicts garbling to stations 11 and 14	21:25, 7	System failure Mt. Aukum-Sierra Peak	Restored system	21:26, 7	Delay in getting predicts to DSSs 11 and 14 (1 min)
SFOF communications	Communications processor interruption between JPL/GSFC	22:50, 7	Communications processor A and B lines set out to release the B system	Completed set-out	22:55, 7	5-min delay in data from DSSs 51 and 61
Facility support	Xerox 720 inoperative	00:00, 8	Paper jam and small fire	Jam cleared and machine cleaned	08:00, 8	None. (Backup support provided by reproduction services)
Data processing system	The second counter of mission 1 clock and both counters of mission 2 clock would not switch to plus time	02:28, 8	Burned out lamps	Replaced lamps	03:40, 8	Incorrect time read out
Data processing system	7044 X computer I/O processor interrupted on read select mode of 729 tape drive D8	02:50, 8	Broken magnetic tape on 729 D8	Operator replaced tape	03:00, 8	10-min delay of output to Surveyor
Data processing system	Data channel A on 7094X executed erroneous IBM 711 on-line card reader select	18:00, 9	Illegal user program select of on-line device	Card reader select reset by IBM customer engineers	18:06, 9	Interrupted mode II support for 6 min
Data processing system	I/O tasker console located in area 7 had jammed Soroban keyboard	19:50, 9	Broken typing keys	Replaced three keys	20:05, 9	Computer support unavailable from area 7 for 15 min
Facility support	Xerox 2400 inoperative.	20:05, 9	Developer spilled	Machine cleaned up and developer replaced	21:30, 9	None. (Backup by Copy-Flo)
Data processing system	Telemetry processing station 2 would not synchronize on Surveyor data from station 11	06:20, 10	Bad logic card in the astro-data decommutator	Replaced logic card 15530 DS-2	06:35, 10	Real-time loss of data for 15 min

Table 53 (contd)

Function	Problem	NO GO condition, time, GMT, date, Nov 1967	Cause	Remedy	GO condition, time, GMT, date, Nov 1967	Effect on mission
Data processing system	Telemetry processing station 1 could not synchronize on Surveyor data	07:25, 10	Bad logic card in the astro-data decom-mutator assembly	Replaced logic card 15530 DS-2	07:37, 10	12-min loss in real-time telemetry data from telemetry processing station 1
SFOF communications	JPL/GSFC communications processor interruption	14:49, 10	Unknown	3/2 recovery performed by GSFC	14:50, 10	1-min data loss from DSSs 51 and 61
Facility support	Broken expansion joint on air conditioning hot water supply pump	15:02, 10	Material fatigue	Coupling replaced	20:00, 10	None. (Backup pump installed)
SFOF communications	JPL/GSFC communications processor interruption	15:20, 10	Unknown	GSFC swapped systems	15:41, 10	21-min data loss from DSSs 42, 51, and 61
Facility support	Xerox 720 producing poor copies	17:30, 10	Preventive maintenance due	Preventive maintenance performed	01:46, 11	None. (Backup provided by reproduction services)
Data processing system	Card inputs from area 6 not accessing the 7094X from 7044X for APPS program	18:40, 10	Unknown	7044X was cold-started; the card reader in area 6 was changed	19:01, 10	Intermittent support to project; could not continue with predict transmission to JPL Space Flight Operations (due to cold start)
Data processing system	Burroughs B-122 card reader in area 6 misreading cards	07:45, 8	Read lamps out of alignment	Replaced card reader	08:00, 8	Loss of card reader for 15 min
SFOF communications	B system faulted	20:17, 8	Memory lock out fault and drum packet errors	Communications went to low-speed backup at 20:22 and swapped to A system at 20:42	20:42, 8	5-min loss of data from DSSs 11, 51, and 61
Data processing system	All Surveyor teletype data stopped	20:17, 8	Communications processor swapped systems	7044Y recovery performed	20:55, 8	Delay in teletype data of 38 min
Data processing system	Brush Instruments recorder pen problem in area 6	23:00, 8	Event marker pen not inking	Replaced pen	01:00, 9	Loss of monitors capability on channel 6
Data processing system	Program TDPX, while running on 7094X, went into a card read select mode which interrupted system I/O processing	00:59, 9	TDPX was bumped per data controller; MIED was running and an attempt to enter TDPX cards from area 5 caused the problem	Data chief initiated a 7044X internal restart	01:06, 9	Interrupted computer string X support for 7 min

Table 53 (contd)

Function	Problem	NO GO condition, time, GMT, date, Nov 1967	Cause	Remedy	GO condition, time, GMT, date, Nov 1967	Effect on mission
Data processing system	All external communication with 7044W system interrupted due to system I/O loop	02:02, 9	Redundancy encountered by system on the D2 recovery tape while trying to initiate internal automatic recovery	Restart system from initial program loading	02:14, 9	Interrupted W string support for 12 min
Data processing system	Floating trap processor failure 7094Y	07:40, 9	Faulty circuit card; problem and cause discovered by IBM during preventive maintenance	IBM customer engineering replaced bad circuit card with one removed from 7094V computer	23:15, 9	No effect; project continued operations on W string
SFOF communications	Communications processor interruption between JPL/GSFC	16:25, 9	Unknown	3/2 recovery performed by GSFC	16:28, 9	3-min loss of data from DSSs 51 and 61
Facility support	Ediphor 2 inoperative	17:00, 9	Excessive oil temperature	Cassette to be replaced	Parts ordered but not immediately available	None. (No 2 is standby)
SFOF communications	GSFC/London communications processor interruption	19:08, 10	London communications processor lost output	3/2 recovery performed	19:11, 10	10-min delay of data from station 61
Facility support	Ediphor 1 inoperative	20:15, 10	Bad cathode	Replaced cathode	20:34, 10	Inconvenience; display not critical
Data processing system	GSFC/JPL communications processor interruption	23:55, 10	Communications processor swap requested by GSFC	Swap completed	00:33, 11	38-min data loss from station 61
Data processing system	Area 6 Burroughs B-122 card reader misreading and jamming cards	01:05, 11	Read lamp out of alignment	Changed area 6 card reader with area 5	01:18, 11	13-min loss of card reader use in area 6
Data processing system	Data channel A I/O went into select loop on 7094X while executing MIED program	08:20, 11	Undetermined	7094X system terminated and restarted	08:31, 11	Interrupted mode II operations for 11 min
Data processing system	Telemetry processing stations would not lock up on mode IV high-speed data from DSS 42	09:35, 11	Unknown (DSS 42 problem)	Unknown (DSS 42 problem)	10:50, 11	No real-time data for 15 min
SFOF communications	GSFC/JPL communications processor interruption	12:40, 11	Power change at GSFC	Swap completed	12:50, 11	10-min data loss from DSS 42

Table 53 (contd)

Function	Problem	NO GO condition, time, GMT, date, Nov 1967	Cause	Remedy	GO condition, time, GMT, date, Nov 1967	Effect on mission
SFOF communications	DSS 42 teletype data stopped	12:50, 11	Bad regenerative repeater at GSFC	Changed regenerative repeater	13:00, 11	10-min data loss from DSS 42
Data processing system	Intermittent IBM 7320 drum storage failure 7044X	14:30, 11	Bad 7320 drum storage formats	Drum reformatted	22:46, 11	Switched 7044X operations to 7044W; no loss of data
SFOF communications	GSFC/JPL communications processor interruption	21:35, 11	Unknown	GSFC performed system swap	21:47, 11	10-min delay in data
Facility support	Generator 2 inoperative	22:00, 11	Burned out starter motor	Starter replaced	22:00, 14	None. (Generator was not on line)
Facility support	Blueline machine inoperative	09:13, 19	Water leak in roof	No immediate effective remedy	16:00, 19	7-h loss of blue-line machine
Facility support	Air conditioning down (building)	09:15, 19	Edison power dip	Restored system on line	09:25, 19	Lost air conditioning for 10 min
Facility support	Water leaking into communications processor through west door	09:25, 19	Plugged drain in stairwell	Installed pump to control water	19:45, 19	Communications processor inoperative
Facility support	Air conditioning down in building	09:30, 19	Momentary power dip from Edison due to lightning	Edison power restoration	09:40, 19	None. (Loss of air conditioning for 10 min; too short for effect)
Facility support	Leaking water on X string computers	09:31, 19	Roof leak	Covered machine and mopped up water	Still leaking 16:00, 20	None. (Temporary isolation from water effective; no loss of equipment)
SFOF communications	On-line communications processor faulted	10:47, 19	Water leaks causing power problems	Removed water from around communications processor areas	11:10, 19 (DSS 11) 11:35, 19 (DSS 42)	33-min loss from DSS 11. 48-min loss from DSS 42
Facility support	Water leak (Room 378)	10:53, 19	Doors leaking	Controlled by mopping	Still leaking 16:00, 19	None. (Water control measures effective)
Facility support	Lost governor control of generator 2	11:45, 19	Grounded governor control motor	Replaced with motor from generator 3	19:35, 19	E bus consumption reduced and load assumed by generator 1
Facility support	Removed generator 3 from line	18:20, 19	To remove governor motor for installation on generator 2	Governor motor on order	18:25, 19	Loss of generator 3; no effect on mission; Edison sufficient

Table 53 (contd)

Function	Problem	NO GO condition, time, GMT, date, Nov 1967	Cause	Remedy	GO condition, time, GMT, date, Nov 1967	Effect on mission
Facility support	Elevator stuck on third floor	18:50, 19	Stuck limit switch	Freed limit switch	19:15, 19	Lost elevator for 25 min. Inconvenience; stairs utilized
SFOF communications	Loss of teletype communications with DSS 61	23:55, 19	Unknown	System swap completed at London	00:13, 20	18-min delay of DSS 61 data
SFOF communications	Lost teletype communications with DSS 42	12:00, 17	Canberra communications processor faulted	Recovery performed	12:12, 17	12-min data loss from DSS 42
SFOF communications	GSFC communications processor faulted	14:08, 17	After quick recovery, TV monitors and teletype buses hung	Cleared same	14:19, 17	No data lost; inconvenience to project
SFOF communications	Lost teletype communications with DSS 42	15:53, 17	GSFC faulted	Recovery performed	15:59, 17	6-min loss of DSS 42 data
Data processing system	Sum check failures received on 7044Y from communications processor	02:04, 18	Undetermined in communications processor	Communications did a communications processor swap	04:30, 18	Numerous I/O teletype problems
SFOF communications	Communications processor not outputting to data processing system	03:36, 18	Hung message to the data processing system Y string	System swapped	03:41, 18	3-min delay to DSS 11
Data processing system	No restart blocks to communications processor from 7044 W and X	03:41, 18	Unknown	Cold started both 7044 computers	04:05, 18	Intermittent teletype printout
SFOF communications	Lost teletype communications with DSS 42	12:26, 18	Canberra communications processor faulted	Recovery performed	12:34, 18	8-min loss of DSS 42 data
SFOF communications	Loss of communications processor systems	08:40, 19	Power failure—IPL	Switched to landline backup	08:40, 19 (DSS 11) 09:14, 19 (DSS 61)	1-min loss to DSS 11, 35-min loss to DSS 61
Data processing system	Edison power failure an associated 7094Y computer problem	08:39, 19	Bad card following Edison power failure	Card replaced	20:45, 19	Surveyor went to mode III; lost 2 h on mode II on 7094Y and was moved to X string at 10:39
Facility support	Edison power failure	08:40, 19	Lightning struck Edison system	Facility placed on generator power	08:42, 19	Loss of computer strings X, Y, W, CP, blue-line printer, and air conditioning for approximately 2 min

Table 53 (contd)

Function	Problem	NO GO condition, time, GMT, date, Nov 1967	Cause	Remedy	GO condition time, GMT, date, Nov 1967	Effect on mission
SFOF communications	Scheduled communications processor swap at JPL and GSFC	23:55, 15	Sync problems with data processing system Y string	Shifted JPL and GSFC communications processors	00:13, 16	18-min data delay to DSS 11; 18-min delay to DSS 61
Facility support	Generator 2 inoperative	00:15, 16	Checking timing circuit for starter cycle	Replaced circuit contacts	04:58, 16	None. (Generator not on line)
Data processing system	X computer string went into recovery when more than two tracking data predict buffers were queued; at 09:29 and 09:34	09:29, 16	Software—unknown	Turned dump tape over to project	09:36, 16	Two short interruptions of X string support
SFOF communications	Lost teletype communication with DSS 42	13:10, 16	GSFC communications processor faulted	3/2 recovery performed by GSFC	13:15, 16	5-min data loss from DSS 42
SFOF communications	Lost teletype communication with DSS 42 and 61	17:11, 16	GSFC communications processor faulted	Recovery performed	17:13, 16	2-min data loss from DSSs 42 and 61
Data processing system	Area 4 S-C 3070 bulk printer paper would not step properly	17:34, 16	Stepper motor bearings frozen	Replaced bulk printer	18:00, 16	26-min loss of bulk printer output
Facility support	High head pressure york chillers	21:15, 16	Fouled condensers	Rodded condensers	04:25, 17	None. (One York down at a time plus carrier backup)
SFOF communications	Lost teletype communication with DSS 61	21:27, 16	GSFC communications processor faulted	Recovery performed	21:28, 16	1-min data loss from station 61
Facility support	Xerox 720 inoperative	00:45, 17	Machine smoking from paper fire	Cleaned out Xerox machine	05:18, 17	None. (Backup provided by reproduction services)
Facility support	Xerox 2400 Model IV down	09:47, 17	Electrical short	Replaced microswitch	12:00, 17	None. (Backup provided by Copy-Flo)
SFOF communications	Lost teletype communication with DSS 42	11:06, 17	Canberra communications processor faulted	Recovery performed	11:08, 17	2-min data loss from DSS 42
Data processing system	Stromberg-Carlson 4020 plotter dc power failure	07:20, 12	Faulty +200 Vdc power supply	Repaired by customer engineer	17:45, 12	Plot processing done on backup S-C 4020 system in building 125
Facility support	Elevator inoperative	09:00, 12	Park switch inoperative	Repaired door lock and parking switch	14:58, 12	Minor inconvenience; stairways utilized
Facility support	Mission display 2 inoperative	02:30, 13	Burnt out power supply	Replaced power supply	13:42, 13	None. (Switched to display 1)

Table 53 (contd)

Function	Problem	NO GO condition, time, GMT, date, Nov 1967	Cause	Remedy	GO condition, time, GMT, date, Nov 1967	Effect on mission
SFOF communications	DSS 42 teletype data stopped	15:40, 13	Unknown	System swap completed at Canberra	15:51, 13	11-min data delay
Facility support	Possible Edison power level variation	20:59, 13	Edison switching main lines	E bus put on generator power	22:57, 13	None, except no backup for W string; string brought down to protect equipment
SFOF communications	DSS 11 microwave system out	00:12, 14	Bad multiplex equipment— Shadow Mountain	Swapped to ground back- up line	00:15, 14	None; no data loss
SFOF communications	Teletype communication loss with DSS 61	16:38, 14	London communi- cations processor faulted	London made communica- tions processor recovery	14:44, 14	6-min data loss from DSS 61
SFOF communications	GSFC communications processor faulted	22:27, 14	Unknown	Recovery per- formed	22:29, 14	2-min data loss
SFOF communications	Loss of teletype commu- nication with DSS 61	00:45, 15	London communi- cations processor faulted	Recovery per- formed	00:58, 15	13-min data loss from DSS 61
Facility support	Xerox 2400 model IV down	01:50, 15	Bad collator	Repaired broken lead	07:10, 15	None. (Backup provided by Copy-Flo)
Data processing system	User area communication interrupted to 7044X	11:14, 15	Bad 7320 drum format	Drum reformatted	11:24, 15	4-min of data loss
Data processing system	7044X goes into tight loops intermittently, possible drum errors	15:30, 15	Unknown	15-h special test and complete diagnostics run with no indication of problem	16:00, 19	One 2-min inter- ruption in computer support; tests performed Nov 19 when computer not involved in support
Facility support	Water leak overhead— third floor	00:00, 20	Roof leak	Controlled by mopping	Still leaking 16:00, 20	None. (Water contained)
SFOF communications	Loss of teletype communi- cation with DSS 61	02:52, 20	Unknown	Swap completed at GSFC	03:03, 20	11-min delay of DSS 61 data
SFOF communications	Loss of teletype communi- cation with DSS 61	03:57, 20	GSFC communications processor faulted	Recovery per- formed	04:00, 20	3-min delay of DSS 61 data
SFOF communications	Loss of teletype communi- cation with DSS 42	14:16, 20	GSFC communications processor faulted	Recovery per- formed	14:18, 20	2-min data delay from DSS 42
Data processing system	No output from 7044X and Y to communi- cations processor	15:20, 20	Communications processor drum problems	CP system swapped	15:46, 20	26-min loss of teletype printouts

Table 53 (contd)

Function	Problem	NO GO condition, time, GMT, date, Nov 1967	Cause	Remedy	GO condition time, GMT, date, Nov 1967	Effect on mission
SFOF communications	Receiving drum hardware errors	15:23, 20	Unknown	Swapped systems	15:29, 20	6-min data loss from DSS 42
Facility support	Blueline inoperative	22:00, 20	Water from leak in roof of third floor	No immediate effective remedy	16:00, 21	8-h loss of blue-line machine

The problem occurred at DSS 61 on November 12, 1967. Six pictures were lost on 35mm film, however, they were not lost on the FR-800 recorder. The problem was due to the CDC demodulator (OPERATOR/TEST SIG) switch being in the TEST SIG vs the OPERATE position. The problem was corrected by returning the switch to the OPERATE position.

Hardware. On November 19, 1967, there were two major problems in the SFOF: a power failure, and flooding. The following sequence of failures will serve to illustrate the significance of these problems.

- (1) 08:40 Power failure, lightning hit Edison system.
- (2) 08:42 Generators 1 and 2 up.
- (3) 08:43 Power outage—Edison.
- (4) 09:10 Power outage—Edison.
- (5) 09:13 Reproductions had to shut down blueline due to water flooding from ceiling.
- (6) 09:15 Total Edison power outage.
- (7) 09:24 Flooding under basement east door.
- (8) 09:30 Total Edison power outage.
- (9) 09:31 Flooding over X string.
- (10) 10:42 West end of basement flooding—flooding communications processor area.
- (11) 11:06 Generators 3 and 4 up.
- (12) 11:45 Generator 2 governor motor control not functioning—all load transferred to generator 1 with Edison as backup at 12:00 (no affect on operation).
- (13) 12:08 Flooding V string area.

(14) 13:30 Flooding third floor by entrance.

(15) 13:57 Univac states communications processor can't be started because of too much water.

(16) 14:07 Water flooding third floor V string and entrance again.

The total effect of these failures and problems was that the blueline machine was inoperative and the communications processor could not be brought back up.

Software. There were the usual software failures during the mission period; however, none were significant because they had no effect on the mission.

C. Tracking Data Analysis

The *Surveyor VI* spacecraft was launched with the *Atlas/Centaur* launch vehicle from launch complex 36 of the Cape Kennedy facilities of AFETR on November 7, 1967. Liftoff occurred at 07:39:01.075 at a launch azimuth of 82.995 deg. Injection of the *Surveyor VI* spacecraft into the initial parking orbit occurred at 07:48:42.1, and injection into lunar transfer orbit occurred at 08:03:29.75. The spacecraft high power transmitter was turned on at 08:04:20.0. *Centaur* spacecraft separation was effected at 08:04:30.0, and *Centaur* retroignition was initiated at 08:08:30.0. The *Surveyor VI* spacecraft was tracked by prime *Surveyor* Deep Space Stations 51, 42, 61, 11, and by DSS 14 as the backup station, from shortly after transfer orbit injection until lunar touchdown at 01:01:06.3 on November 10, 1967. The DSIF then continued to track the spacecraft on the lunar surface until 06:41:00 on November 26, 1967, or approximately 41 h into the lunar night. Actual station tracking periods during the inflight portion of the mission, together with nominal view periods, may be seen in Table 54.

Table 54. Nominal^a view periods vs actual tracking at Deep Space Stations

Date	DSS	Nominal rise, GMT	Nominal set, GMT	Nominal view period	Acquisition by station, GMT	Loss of signal by station, GMT	Actual view period
Nov 7	51	08:10:04	22:23:46	14:13:42	08:08:55	22:24:02	14:15:07
	42	08:33:37	14:17:41	5:44:04	08:35:42	14:17:02	5:42:22
	61	14:25:41	22:46:04	8:20:23	14:26:32	22:41:02	8:14:30
	11	21:51:21	07:01:20	9:09:59	21:55:02	06:59:02	9:04:00
Nov 8	42	02:33:26	15:11:13	12:37:47	02:32:02	15:13:02	12:41:00
	51	10:56:51	22:55:04	11:58:13	10:59:02	22:54:02	11:55:00
	61	14:38:19	23:30:30	8:52:11	14:37:12	23:29:02	8:52:50
	11	21:59:11	07:31:03	9:32:52	22:02:02	06:29:02	8:27:00
Nov 9	42	02:56:23	15:19:07	12:22:44	02:55:02	15:20:02	12:25:00
	51	11:08:03	23:03:03	11:55:00	11:08:02	23:03:02	11:55:00
	61	14:38:33	23:42:35	9:04:02	14:41:32	22:56:02	8:14:30
Nov 10	11	22:00:29	07:55:54	9:55:25	22:02:02	08:01:02	9:59:00

^aBased on horizon mask for all stations except DSS 72, which is based on 0-deg elevation.

1. *Spacecraft center frequencies.* So that spacecraft predictions may be generated and supplied to the DSN tracking stations for purposes of spacecraft acquisition, aided track, and station to station transfers of the spacecraft, it is essential that the spacecraft transmitter (one-way) center frequencies and transponder (two-way) center frequencies be accurately known. The nominal values for these frequencies are 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 ten hours of the countdown for use in real-time predictions. The frequencies which were used in the preflight prediction document were:

Frequency, MHz	Equipment, temperature, °F
2294.994040	Transmitter A, 110
2294.990221	Transmitter B, 110
22.013675	Transponder A, 90
22.013615	Transponder B, 90

These frequencies were abstracted from preflight data supplied by Hughes Aircraft Company. During the countdown, frequency measurements were made and sent to the SFOF at $T - 669$ min, $T - 565$ min, $T - 326$

min, $T - 50$ min, $T - 30$ min, and $T - 5$ min, approximately as called for in the sequence of events. These measurements were plotted against the preflight frequency vs temperature curves and can be seen in Figs. 69 through 72. In previous *Surveyor* missions, the preflight data were biased by the countdown frequency measurements for use during the actual flight. However, because of shortcomings in this method, Hughes Aircraft Company agreed to study the problem and suggested a new way of predicting the inflight frequencies. Their suggestion, which was adhered to, was to add a 60-Hz bias to the preflight transponder curves and to use the preflight transmitter curves unchanged. Subsequent inflight measurements (see Fig. 72) tend to undermine confidence in the accuracy of this approach. The frequencies actually used in the predictions during the inflight and post-touchdown portions of the *Surveyor VI* Mission are listed in Table 55. Transmitter B, one-way frequencies reduced from one-way data are listed in Tables 56 through 59; they can be compared to the data presented in Figs. 69 and 70.

2. *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 DSN tracking stations to ensure the success of spacecraft acquisition, and aided track and station handovers of the spacecraft. However, during the launch phase the provision of accurate predictions

to DSS 51 and DSS 42 becomes a critical matter because of the crucial need for early acquisition and commanding of the spacecraft. For first two-way acquisitions at DSS 51 and DSS 42, 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 predictions and the $T - 5$ min predictions are generated before launch, the $T - 5$ min predictions have two important advantages over the preflight predictions 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 predictions were generated and sent to DSS 51 and DSS 42 with the instruction that they be used instead of the preflight prediction document. Both DSS 51 and

DSS 42 reported receipt of the $T - 5$ min predictions by $T + 5$ min, or at least 25 min before rise, and DSS 51 subsequently acquired the spacecraft with these predictions in the two-way mode with no difficulties. Arrival time of AFETR predictions, at approximately $T + 20$ min (parking orbit plus nominal second burn) and at $T + 55$ min (actual transfer orbit), was late enough to destroy much of the usefulness of these predictions had they been needed. During the remainder of the mission, predictions were routinely supplied to all participating Deep Space Stations with one minor exception. Predictions for the first post-touchdown pass at DSS 14 were not generated due to a PRDX input error; however, DSS 14 was supplied with DSS 11 predictions which were used with no problems.

After touchdown, a minor, although significant, PRDX program/system interface problem was discovered that resulted in a very occasional deletion of a predict line in very long predict sets. The problem is currently under investigation by the PRDX cognizant programmer and rectification of the problem is anticipated.

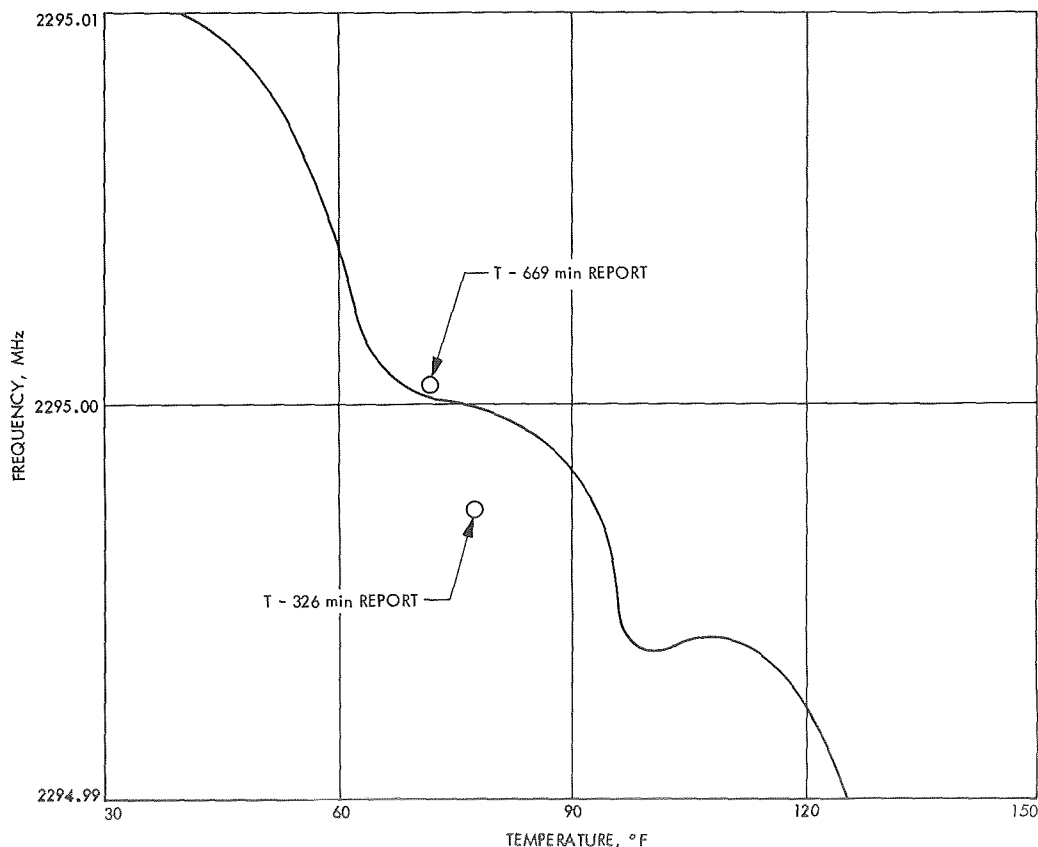


Fig. 69. Transmitter A frequency vs temperature

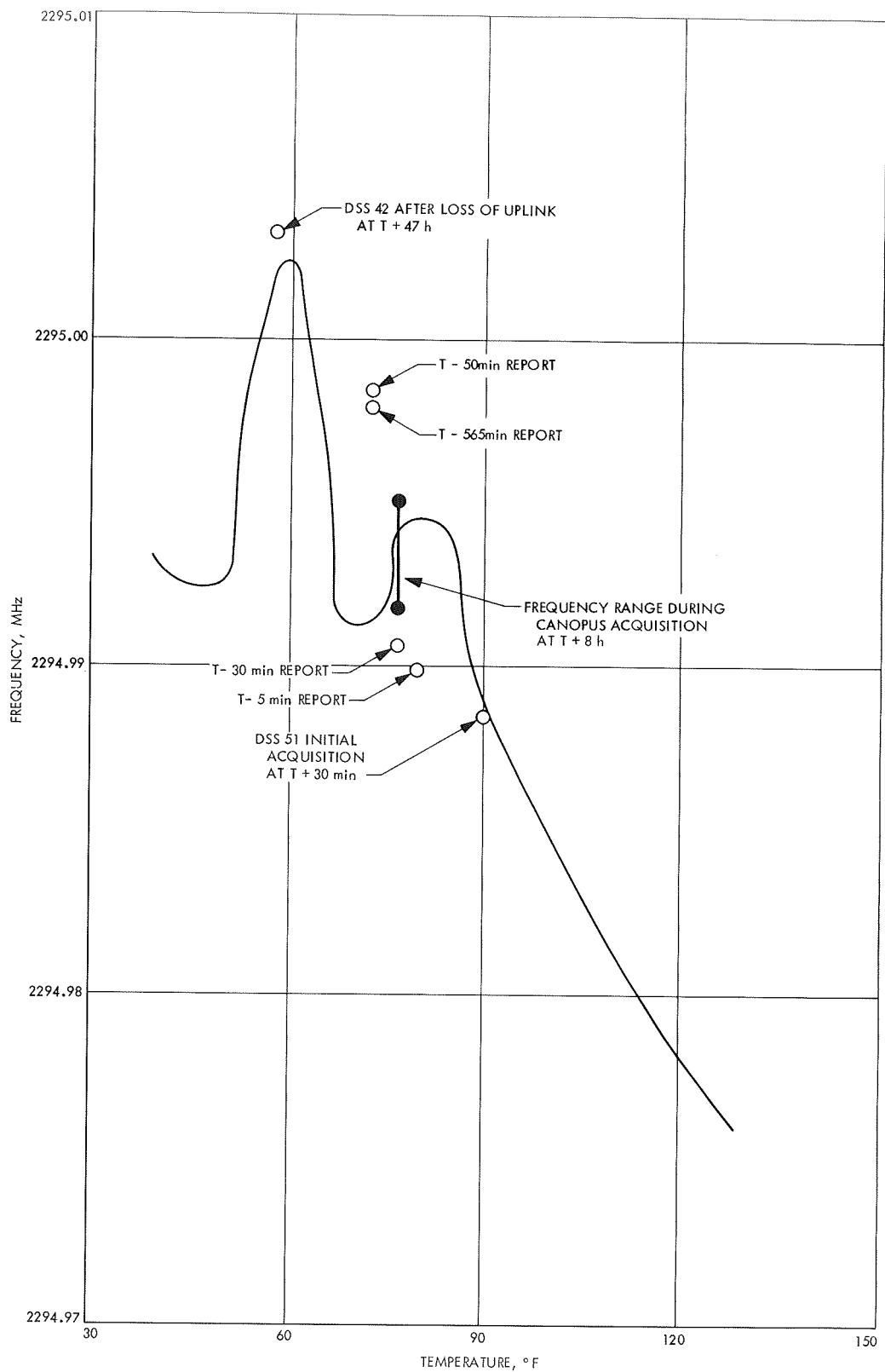


Fig. 70. Transmitter B frequency vs temperature

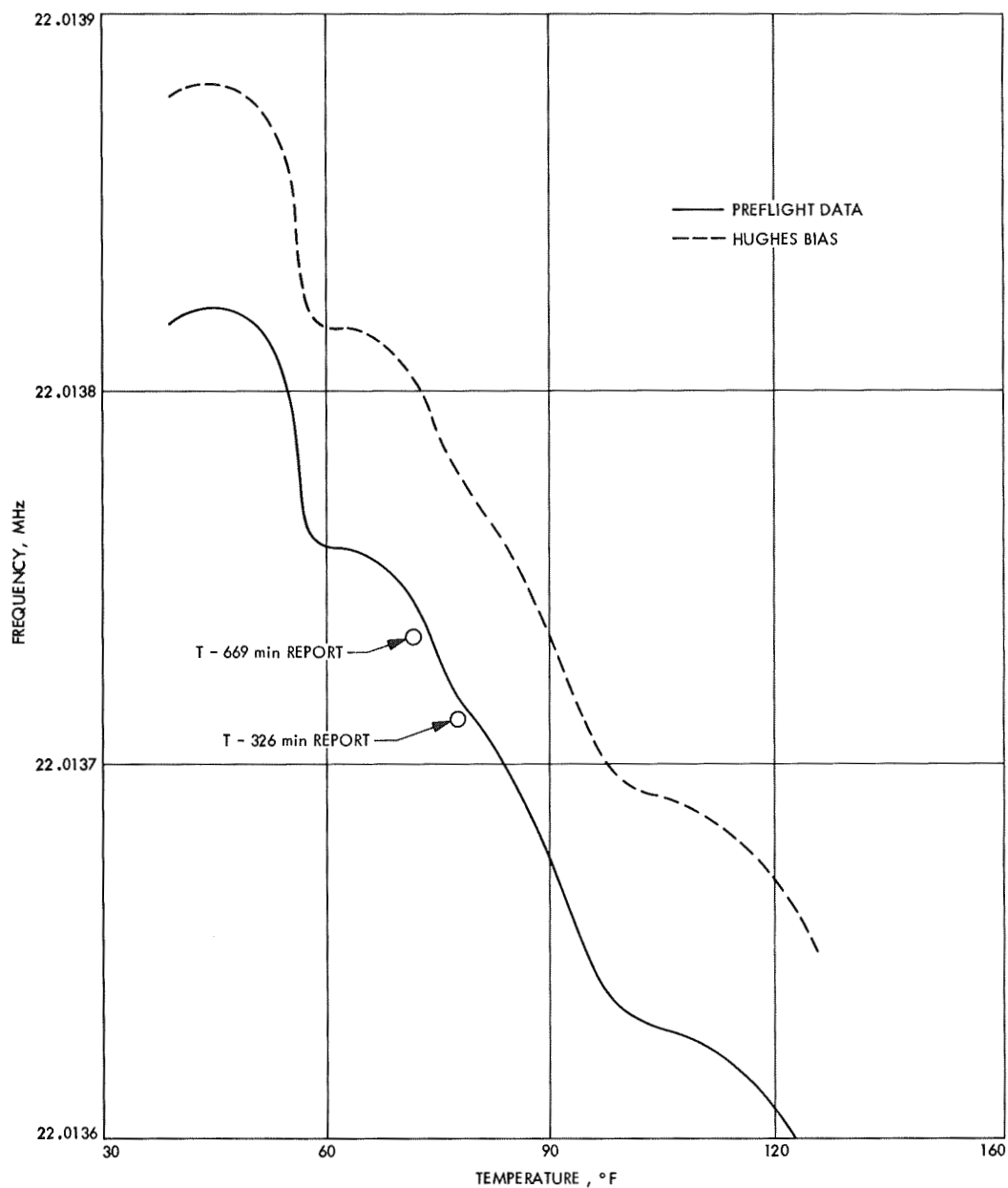


Fig. 71. Transponder A frequency vs temperature

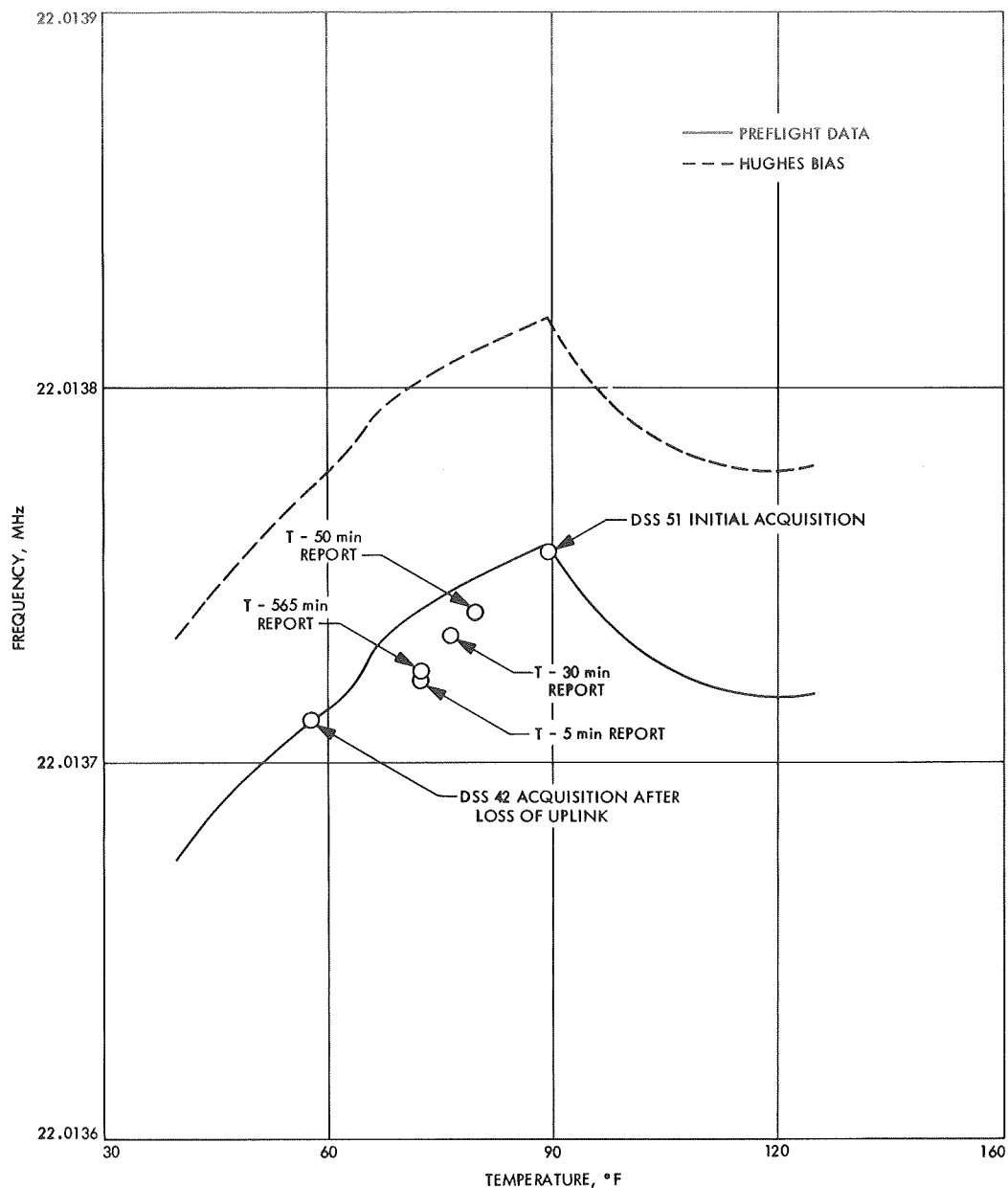


Fig. 72. Transponder B frequency vs temperature

3. *Initial two-way acquisition at DSS 51.* Predictions indicated a *Surveyor VI* rise at DSS 51 at 08:10:04 on November 7, 1967, or $T + 31:03$ min. Deep Space Station 51 received good, one-way data at 08:08:55 (rise - 01:09), reported auto-track on the S-band acquisition aid at 08:10:16 (rise + 00:12), auto-track on the S-band cassegrain monopulse at 08:10:41 (rise + 00:37), and good two-way data at 08:14:15 (rise + 04:11). This initial acquisition was entirely nominal and quite rapid; previous *Surveyor* initial acquisitions have averaged over 6 min. Part of this decrease in initial acquisition time

can be attributed to a slight modification of the acquisition procedure, wherein the station does not immediately tune to track SYNFRQ, but waits until certain early commanding of the spacecraft has been accomplished.

4. *Tracking performance.* The DSN provided continuous angular and doppler tracking of the inflight portion of the *Surveyor VI* spacecraft from initial one-way acquisition at DSS 51 at 08:14:15 on November 7, 1967 through lunar touchdown at 01:01:06.3, November 10. In general, the overall quality of the tracking

Table 55. Surveyor VI frequency predictions

Time after launch or retroignition	Temperature, °F	Frequency, MHz
Transmitter B ^a		
L-14 h	71	2294.991300
14-18 h	52	2294.998000
18-30 h	65	2294.997500
30-50 h	58	2295.000000
50 h-R	70	2294.991300
Transponder B ^a		
L-14 h	71	22.013800
14-18 h	52	22.013760
18-30 h	65	22.013790
30-50 h	58	22.013770
50 h-R	70	22.013799
Transmitter A ^b		
R-1 day	90	2294.998400
1-7 days	110	2294.994000
7-13 days	80	2294.999700
13-19 days	50	2295.008400
19-22 days	20	2295.009700
Transponder A ^b		
R-1 day	90	22.013734
1-7 days	110	22.013686
7-13 days	80	22.013773
13-19 days	50	22.013820
19-22 days	20	22.013813

^aUsed inflight.^bUsed post-touchdown.

data taken during the Surveyor VI Mission can be described as excellent. Data types used in the orbit determination program were angular data taken during the first pass of DSS 51 and DSS 42, two-way doppler data taken during the first pass over DSS 61, and all passes of DSSs 51, 42, and 11. A summary of these data, together with statistics, is given in Table 60. The relative quality of the tracking data taken at each station can be obtained by comparing the standard deviations, the root mean squares, and the first moments of the data as listed in the table. Changes in the quality of the same data as reflected in different orbits are largely attributable to the particular selection criteria of each orbit as determined by the orbit determination group. Orbit identifications are as follows:

Identification	Code
Predict orbit	PROR
Injection condition evaluation orbit	ICEV
Preliminary premidcourse orbit	PREL
Data consistency orbit	DACO
Nominal midcourse orbit	NOMA
Last premidcourse orbit	LAPM
Premidcourse cleanup orbit	PRCL
Postflight analysis orbit	POST
N th postmidcourse orbit	NPOM
Final inflight orbit	FINAL
Computer string X	X
Computer string Y	Y
Computer string W	W

In general, DSIF station operations during the Surveyor VI Mission were effectively implemented. This is best judged by the fact that the DSN was able to provide very high quality data to the orbit determination group so 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 effectively executed. The only major losses of good two-way doppler data occurred during the second passes over DSS 51 and DSS 61.

The DSS 51 lost ground communications at 19:38:02 November 8. At 20:45:02 an unscheduled transfer of the spacecraft was made to DSS 61 that stayed in two-way until the spacecraft was transferred to DSS 11 at 22:19:02. The two-way doppler data taken at DSS 61 during this time (approximately 1½ h) were unusable due to excessively high noise; the problem was traced to the rubidium and when a rubidium change was made during the third pass, an immediate improvement to reasonable levels was observed in the three-way data at DSS 61. The only other appreciable loss of two-way data occurred during Canopus acquisition over DSS 61 when an unexpected loss of two-way lock occurred and reacquisition of two-way was not attempted until completion of Canopus acquisition approximately 50 min later. The resultant effect from these data losses on the mission was negligible.

Table 56. One-way doppler data from DSS 51; initial acquisition on November 7, 1967

Time, GMT	One-way doppler frequency, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
08:08:52.5	1015286.80	0.00	2294987891.72	-0.40533759E 01
08:08:57.5	1016433.00	1146.20	2294987972.70	-0.38930682E 01
08:09:02.5	1017600.60	1167.60	2294988050.27	-0.37304153E 01
08:09:07.2	1018788.20	1187.60	2294988124.70	-0.35655567E 01
08:09:12.5	1019996.80	1208.60	2294988193.95	-0.33986322E 01
08:09:17.5	1021224.60	1227.80	2294988258.73	-0.32297812E 01
08:09:22.5	1022471.60	1247.00	2294988318.03	-0.30591434E 01
08:09:27.5	1023737.40	1265.80	2294988371.11	-0.28868584E 01
08:09:32.5	1025019.80	1282.40	2294988419.12	-0.27130658E 01
08:09:37.5	1026318.20	1298.40	2294988461.64	-0.25379051E 01
08:09:42.5	1027631.80	1313.60	2294988498.34	-0.23615160E 01
08:09:47.5	1028959.80	1328.00	2294988528.97	-0.21840380E 01
08:09:52.5	1030302.20	1342.40	2294988552.48	-0.20056108E 01
08:09:57.5	1031656.60	1354.40	2294988570.19	-0.18263739E 01
08:10:02.5	1033021.80	1365.20	2294988582.22	-0.16464670E 01
08:10:07.5	1034395.20	1373.40	2294988590.12	-0.14660296E 01
08:10:12.5	1035775.00	1379.80	2294988594.59	-0.12852013E 01
08:10:17.5	1037162.40	1387.40	2294988593.41	-0.11041217E 01
08:10:22.5	1038555.80	1393.40	2294988587.08	-0.92293049E 00
08:10:27.5	1039952.20	1396.40	2294988577.55	-0.74176717E 00
08:10:32.5	1041349.40	1397.20	2294988565.91	-0.56077134E 00
08:10:37.5	1042747.40	1398.00	2294988551.12	-0.38008262E 00
08:10:42.5	1044145.00	1397.60	2294988533.31	-0.19984060E 00
08:10:47.5	1045537.80	1392.80	2294988515.83	-0.20184864E 01
08:10:52.5	1046926.60	1388.80	2294988496.78	0.15874498E 00
08:10:57.5	1048309.00	1382.40	2294988477.50	0.33680935E 00
08:11:02.5	1049683.20	1374.20	2294988458.75	0.51386865E 00
08:11:07.5	1051049.46	1366.40	2294988439.02	0.68978327E 00
08:11:12.5	1052405.20	1355.60	2294988420.25	0.86441363E 00
08:11:17.5	1053747.20	1342.00	2294988404.19	0.10376201E 01
08:11:22.5	1055066.60	1319.40	2294988398.77	0.12092632E 01
08:11:35.0	1045427.40	9639.20	2295001263.59 ^a	0.16306146E 01
08:11:47.5	1031142.20	4285.00	2295018676.09 ^a	0.20381408E 01

^aRejected point.

Table 57. One-way doppler data from DSS 51; November 7, 1967

Time, GMT	One-way doppler frequency, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
16:15:32.0	1058446.47	136.77	2294994378.06	0.24318358E 01
16:16:32.0	1058585.95	139.48	2294994235.72	0.24314625E 01
16:17:32.0	1058724.97	139.02	2294994093.89	0.24310949E 01
16:18:32.0	1058863.55	138.58	2294993952.53	0.24307329E 01
16:19:32.0	1059005.12	141.57	2294993808.22	0.24303765E 01
16:20:32.0	1059147.32	142.20	2294993663.33	0.24300255E 01
16:21:32.0	1059292.13	144.82	2294993515.87	0.24296800E 01
16:22:32.0	1059436.72	144.58	2294993368.70 ^a	0.24293399E 01
16:23:32.0	1059580.53	143.82	2294993222.30	0.24290051E 01
16:24:32.0	1059728.43	147.90	2294993071.87	0.24286756E 01
16:25:32.0	1059879.50	151.07	2294992918.33	0.24283514E 01
16:26:32.0	1060030.53	151.03	2294992764.84	0.24280324E 01
16:27:32.0	1060185.43	154.90	2294992607.56	0.24277184E 01
16:28:32.0	1060343.37	157.93	2294992447.25	0.24274095E 01
16:29:32.0	1060503.77	160.40	2294992284.53	0.24271056E 01
16:30:32.0	1060665.63	161.87	2294992120.37	0.24268067E 01
16:31:32.0	1060829.33	163.70	2294991954.42	0.24265126E 01
16:32:32.0	1060994.85	165.52	2294991786.69	0.24262234E 01
16:33:32.0	1063578.65	2583.80	2294989200.69 ^a	0.24259390E 01
^a Rejected point.				

Table 58. One-way doppler data from DSS 61; November 7, 1967

Time, GMT	One-way doppler frequency, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
16:08:32.0	1053040.18	000.00	2294995326.67 ^a	0.22580894E 01
16:09:32.0	1053161.74	121.57	2294995198.12 ^a	0.22571785E 01
16:10:32.0	1053285.66	123.92	2294995067.30	0.22562764E 01
16:11:32.0	1053413.71	128.05	2294994932.41	0.22553830E 01
16:12:32.0	1053542.96	129.25	2294994796.37	0.22544985E 01
16:13:32.0	1053675.57	132.61	2294994657.08	0.22536227E 01
16:14:32.0	1053808.46	132.89	2294994517.53	0.22527557E 01
16:15:32.0	1053941.54	133.09	2294994377.89	0.22518972E 01
16:16:32.0	1054077.40	135.85	2294994235.52	0.22510474E 01
16:17:32.0	1054212.77	135.38	2294994093.72 ^a	0.22502062E 01
16:18:32.0	1054347.75	134.98	2294993952.37 ^a	0.22493736E 01
16:19:32.0	1054485.73	137.98	2294993808.08 ^a	0.22485494E 01
16:20:32.0	1054624.40	138.67	2294993663.16 ^a	0.22477336E 01
^a Rejected point.				

Table 59. One-way doppler data from DSS 42; November 9, 1967

Time, GMT	One-way doppler frequency, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
06:37:32.0	1021302.76	5472.97	2295003253.16 ^a	0.91809623E 00
06:38:32.0	1021279.41	-23.34	2295003284.87 ^a	0.91919226E 00
06:39:32.0	1021237.11	-42.31	2295003335.62 ^a	0.92029255E 00
06:40:32.0	1020982.98	-254.18	2295003598.25 ^a	0.92139705E 00
06:41:32.0	1017108.60	3874.33	2295007481.06 ^a	0.92250572E 00
06:42:32.0	1014651.24	2457.36	2295009946.97 ^a	0.92361856E 00
06:43:32.0	1013870.16	-781.07	2295010736.59 ^a	0.92473554E 00

^aRejected point.

Table 60. Summary of premaneuver Deep Space Station tracking data used in Surveyor VI orbit computations

Orbit identification	DSS	Data type, pass identification	Beginning data time (month/date—GMT)	End data time (month/date—GMT)	No. of points	Standard deviation	Root mean square (rms)	Mean error	Sample rate, s
PROR XA	42	HA	11/07—08:38:42	11/07—08:40:22	6	0.00550	0.0133	-0.0121	10
		DEC	11/07—08:38:42	11/07—08:40:22	9	0.0156	0.0352	-0.0316	10
	51	CC3	11/07—08:14:20	11/07—08:36:50	128	0.0710	0.0711	-0.00388	10
		HA	11/07—08:10:05	11/07—08:36:55	136	0.0138	0.0486	0.0467	10
		DEC	11/07—08:10:05	11/07—08:36:55	137	0.0130	0.0209	-0.0163	10
PROR YA	42	HA	11/07—08:38:42	11/07—08:40:22	10	0.0507	0.0527	0.0142	10
		DEC	11/07—08:38:42	11/07—08:40:22	10	0.0426	0.0654	-0.0496	10
	51	CC3	11/07—08:14:20	11/07—08:44:20	166	0.120	0.120	-0.00824	10
		HA	11/07—08:10:15	11/07—08:44:25	176	0.0771	0.0936	0.0532	10
		DEC	11/07—08:10:15	11/07—08:44:25	176	0.0510	0.0577	-0.0270	10
ICEV YA	42	HA	11/07—08:39:22	11/07—09:36:02	64	0.00537	0.0138	-0.0128	60
		DEC	11/07—08:39:22	11/07—09:36:02	64	0.00515	0.0234	-0.0229	60
	51	01 311 ^a	11/07—08:15:00	11/07—08:44:50	164	0.0844	0.0848	0.00789	10
		HA	11/07—08:14:15	11/07—08:44:55	172	0.0102	0.0511	0.0501	10
		DEC	11/07—08:14:15	11/07—08:44:55	172	0.0102	0.0200	-0.0172	10
ICEV XA	42	02 311	11/07—08:47:32	11/07—09:36:32	40	0.0316	0.0336	-0.0115	60
		HA	11/07—08:47:02	11/07—09:37:02	44	0.00416	0.0506	0.0504	60
		DEC	11/07—08:47:02	11/07—09:37:02	44	0.00236	0.0119	-0.0117	60
		HA	11/07—08:39:22	11/07—09:51:02	84	0.00387	0.0140	-0.0135	60
		DEC	11/07—08:39:22	11/07—09:51:02	85	0.00472	0.0234	-0.0229	60
	51	01 311	11/07—08:15:00	11/07—08:44:50	164	0.0920	0.0942	0.0201	10
		HA	11/07—08:14:15	11/07—08:44:55	172	0.0101	0.0505	0.0495	10
		DEC	11/07—08:14:15	11/07—08:44:55	172	0.0102	0.0206	-0.0179	10
		02 311	11/07—08:47:32	11/07—09:51:32	59	0.0240	0.0253	-0.00794	60
		HA	11/07—08:47:02	11/07—09:52:02	63	0.00426	0.0498	0.0496	60

^aPass identification; e.g., 01 311 denotes first pass, day 311. All orbits with pass identification numbers used two-way doppler (CC3) only.

Table 60 (contd)

Orbit identification	DSS	Data type, pass identification	Beginning data time (month/date—GMT)	End data time (month/date—GMT)	No. of points	Standard deviation	Root mean square (rms)	Mean error	Sample rate, s
ICEV XA (contd)	51	DEC	11/07—08:47:02	11/07—09:52:02	63	0.00247	0.0117	—0.0114	60
PREL YA	42	03 311	11/07—10:13:32	11/07—10:32:32	18	0.00148	0.00152	—0.000434	60
	51	01 311	11/07—08:15:20	11/07—08:44:50	148	0.0399	0.0399	—0.000416	10
		02 311	11/07—08:47:32	11/07—10:03:32	62	0.00763	0.00764	—0.000465	60
PREL YB	51	01 311	11/07—08:15:20	11/07—08:44:50	148	0.0400	0.0400	—0.000403	10
		02 311	11/07—08:47:32	11/07—10:03:32	62	0.00773	0.00773	0.00244	60
PREL XC	42	03 311	11/07—10:13:32	11/07—11:29:32	74	0.00154	0.00154	—0.0000198	60
	51	01 311	11/07—08:15:20	11/07—08:44:50	148	0.0399	0.0399	—0.0000330	10
		02 311	11/07—08:47:32	11/07—10:03:32	68	0.00769	0.00769	—0.000108	60
DACO XA	42	03 311	11/07—10:13:32	11/07—12:03:32	108	0.00148	0.00159	0.000556	60
	51	01 311	11/07—08:15:20	11/07—08:44:50	148	0.0400	0.0400	—0.00146	10
		02 311	11/07—08:47:32	11/07—10:03:32	68	0.00786	0.00788	0.000632	60
		04 311	11/07—12:13:32	11/07—13:19:32	63	0.00735	0.00731	—0.000411	60
DACO XB	42	03 311	11/07—10:13:32	11/07—12:03:32	108	0.00151	0.00151	0.0000904	60
	51	01 311	11/07—08:15:20	11/07—08:44:50	148	0.0399	0.0399	—0.00129	60
		02 311	11/07—08:47:32	11/07—10:03:32	68	0.00784	0.00787	0.000675	60
		04 311	11/07—12:13:32	11/07—14:13:32	112	0.00707	0.00709	—0.000562	60
DACO YB	51	01 311	11/07—08:15:20	11/07—08:44:50	148	0.0416	0.0417	—0.00252	10
		02 311	11/07—08:47:32	11/07—10:03:32	62	0.00783	0.00797	0.00144	60
		04 311	11/07—12:13:32	11/07—14:37:32	113	0.00794	0.00810	—0.00151	60
	61	05 311	11/07—14:47:32	11/07—15:17:32	27	0.00828	0.0166	0.0144	60
DACO XC	42	03 311	11/07—10:13:32	11/07—12:03:32	108	0.00399	0.00401	—0.000402	60
	51	01 311	11/07—08:15:20	11/07—08:44:50	148	0.0403	0.0403	—0.000290	10
		02 311	11/07—08:47:32	11/07—10:03:32	68	0.00788	0.00789	—0.000452	60
		04 311	11/07—12:13:32	11/07—14:37:32	136	0.00771	0.00810	—0.00247	60
DACO YC	61	05 311	11/07—14:47:32	11/07—15:33:32	35	0.00367	0.0145	0.0141	60
	42	03 311	11/07—10:13:32	11/07—12:03:32	108	0.00159	0.00165	0.000457	60
	51	01 311	11/07—08:15:20	11/07—08:44:50	148	0.0399	0.0399	—0.00126	10
		02 311	11/07—08:47:32	11/07—10:03:32	18	0.00520	0.00565	0.00220	60
DACO XE		04 311	11/07—12:13:32	11/07—14:37:32	113	0.00739	0.00739	—0.000151	60
	61	05 311	11/07—14:50:32	11/07—16:52:32	13	0.00247	0.00284	0.00139	60
	42	03 311	11/07—10:13:32	11/07—12:03:32	108	0.00214	0.00234	—0.000958	60
	51	01 311	11/07—08:15:20	11/07—08:44:50	148	0.0399	0.0399	—0.000442	10
		02 311	11/07—08:47:32	11/07—10:03:32	20	0.00503	0.00589	0.00385	60
		04 311	11/07—12:13:32	11/07—17:33:32	137	0.00731	0.00765	—0.00222	60
		06 311	11/07—17:34:32	11/07—18:39:32	51	0.00719	0.00739	0.00170	60
	61	05 311	11/07—14:51:32	11/07—17:23:32	43	0.00244	0.00607	0.00555	60

Table 60 (contd)

Orbit identification	DSS	Data type, pass identification	Beginning data time (month/date—GMT)	End data time (month/date—GMT)	No. of points	Standard deviation	Root mean square (rms)	Mean error	Sample rate, s
DACO YD	42	03 311	11/07—10:13:32	11/07—12:03:32	108	0.00244	0.00247	—0.000371	60
	51	01 311	11/07—08:15:20	11/07—08:44:50	148	0.0398	0.0398	—0.000528	10
		02 311	11/07—08:47:32	11/07—10:03:32	18	0.00527	0.00636	0.00355	60
		04 311	11/07—12:13:32	11/07—17:35:32	114	0.00746	0.00753	—0.000968	60
		06 311	11/07—17:36:32	11/07—18:44:32	60	0.00810	0.00830	0.00181	60
LAPM XA	61	05 311	11/07—14:50:32	11/07—17:23:32	41	0.00252	0.00366	0.00266	60
	11	07 311	11/07—21:13:32	11/07—22:24:32	12	0.00446	0.0257	0.0253	60
	42	03 311	11/07—10:13:32	11/07—12:03:32	108	0.00441	0.00576	—0.00370	60
	51	01 311	11/07—08:15:32	11/07—08:44:50	148	0.0404	0.0405	0.00177	10
		02 311	11/07—08:47:32	11/07—10:03:32	68	0.00782	0.00889	—0.00423	60
LAPM YA		04 311	11/07—12:13:32	11/07—17:33:32	137	0.00730	0.00731	—0.000410	60
		06 311	11/07—17:34:32	11/07—12:55:32	176	0.00817	0.00900	0.00378	60
	61	05 311	11/07—14:51:32	11/07—17:23:32	7	0.000725	0.00363	0.00356	60
	11	07 311	11/07—22:13:32	11/07—22:30:32	18	0.00372	0.00375	—0.000488	60
	42	03 311	11/07—10:13:32	11/07—12:03:32	108	0.00154	0.00154	0.0000678	60
LAPM XC	51	01 311	11/07—08:15:20	11/07—08:44:50	148	0.0402	0.0402	—0.0000059	10
		02 311	11/07—08:47:32	11/07—10:03:32	62	0.00784	0.00790	—0.000764	60
		04 311	11/07—12:13:32	11/07—17:35:32	114	0.00741	0.00741	0.000206	60
		06 311	11/07—17:36:32	11/07—21:55:32	193	0.00727	0.00727	—0.000650	60
	61	05 311	11/07—14:50:32	11/07—17:23:32	90	0.00452	0.00452	—0.0000326	60
LAPM YC	11	07 311	11/07—22:13:32	11/07—23:18:32	59	0.00459	0.00459	0.000137	60
	42	03 311	11/07—10:13:32	11/07—12:03:32	108	0.00164	0.00171	—0.000461	60
	51	01 311	11/07—08:15:20	11/07—09:41:32	149	0.0403	0.0404	—0.00233	10
		02 311	11/07—09:42:32	11/07—10:03:32	19	0.00477	0.00506	—0.00167	60
		04 311	11/07—12:13:32	11/07—17:33:32	137	0.00736	0.00736	—0.000114	60
PRCL XA		06 311	11/07—17:34:32	11/07—22:02:32	237	0.00711	0.00713	—0.000525	60
	61	05 311	11/07—16:36:32	11/07—17:23:32	43	0.00296	0.00296	—0.000148	60
	11	07 311	11/07—22:13:32	11/07—23:36:32	69	0.00356	0.00366	0.000853	60
	42	03 311	11/07—10:13:32	11/07—12:03:32	108	0.00138	0.00162	0.000850	60
	51	01 311	11/07—08:15:20	11/07—09:41:32	149	0.0401	0.0401	—0.00127	10
		02 311	11/07—09:42:32	11/07—10:03:32	17	0.00553	0.00553	—0.0000574	60
		04 311	11/07—12:13:32	11/07—17:35:32	114	0.00740	0.00747	0.000955	60
		06 311	11/07—17:36:32	11/07—21:55:32	193	0.00728	0.00731	0.000600	60
	11	07 311	11/07—22:13:32	11/08—02:01:53	207	0.00648	0.00662	0.00134	60
	42	03 311	11/07—10:13:32	11/07—12:03:32	108	0.00507	0.00709	—0.00496	60
	51	01 311	11/07—08:15:20	11/07—09:41:32	149	0.0412	0.0412	—0.00190	10
		02 311	11/07—09:42:32	11/07—10:03:32	19	0.00499	0.0121	—0.0110	60
		04 311	11/07—12:13:32	11/07—17:33:32	137	0.00742	0.00811	—0.00329	60
		06 311	11/07—17:34:32	11/07—22:02:32	237	0.00720	0.00732	0.00132	60

Table 60 (contd)

Orbit identification	DSS	Data type, pass identification	Beginning data time (month/date—GMT)	End data time (month/date—GMT)	No. of points	Standard deviation	Root mean square (rms)	Mean error	Sample rate, s
PRCL XA (contd)	61	05 311	11/07—16:36:32	11/07—17:23:32	43	0.00257	0.00533	0.00467	60
PRCL XB	11	07 311	11/07—22:13:32	11/08—02:01:53	162	0.0037	0.00349	0.000912	60
	42	03 311	11/07—10:13:32	11/07—12:03:32	108	0.00158	0.00160	0.000235	60
	51	01 311	11/07—08:15:20	11/07—09:41:32	149	0.0405	0.0405	—0.00213	10
		02 311	11/07—09:42:32	11/07—10:03:32	19	0.00512	0.00520	—0.000925	60
		04 311	11/07—12:13:32	11/07—17:33:32	137	0.00731	0.00738	0.000984	60
		06 311	11/07—17:34:32	11/07—22:02:32	215	0.00702	0.00705	0.000606	60
PRCL XC	61	05 311	11/07—16:36:32	11/07—17:23:32	43	0.00293	0.00305	0.000818	60
	11	07 311	11/07—22:13:32	11/08—02:01:53	162	0.00341	0.00342	—0.000363	60
	42	03 311	11/07—10:13:32	11/07—12:03:32	108	0.00163	0.00166	—0.000312	60
	51	01 311	11/07—08:15:20	11/07—09:41:32	149	0.0402	0.0403	—0.00268	10
		02 311	11/07—09:42:32	11/07—10:03:32	19	0.00492	0.00505	—0.00113	60
		04 311	11/07—12:13:32	11/07—17:33:32	137	0.00735	0.00737	0.000453	60
1POM XA	61	05 311	11/07—16:36:32	11/07—17:23:32	43	0.00288	0.00288	—0.0000277	60
	11	01 312	11/08—02:45:32	11/08—03:33:32	45	0.00142	0.00142	—0.0000163	60
	42	02 312	11/08—03:42:32	11/08—05:36:32	110	0.00163	0.00163	—0.0000111	60
1POM XD	11	01 312	11/08—02:45:32	11/08—03:33:32	45	0.00144	0.00145	0.0000380	60
	42	02 312	11/08—03:42:32	11/08—08:36:32	283	0.00159	0.00159	0.00000518	60
1POM XG	11	01 312	11/08—02:45:32	11/08—03:33:32	45	0.00145	0.00145	0.000114	60
	42	02 312	11/08—03:42:32	11/08—11:44:32	464	0.00163	0.00163	—0.00000105	60
2POM XB	11	01 312	11/08—02:45:32	11/08—03:33:32	45	0.00189	0.00189	—0.000	60
	42	02 312	11/08—03:42:32	11/08—13:23:32	558	0.00160	0.00160	—0.0000131	60
	51	03 312	11/08—13:33:32	11/08—14:27:32	49	0.00706	0.00706	—0.0000199	60
2POM YB	11	01 312	11/08—02:45:32	11/08—03:33:32	45	0.00160	0.00179	0.000803	60
	42	02 312	11/08—03:42:32	11/08—13:23:32	543	0.00205	0.00206	—0.000205	60
	51	03 312	11/08—13:33:32	11/08—18:10:32	269	0.00729	0.00729	0.000222	60
3POM XB	11	01 312	11/08—02:45:32	11/08—03:33:32	45	0.00152	0.00500	0.00476	60
		05 312	11/08—22:18:32	11/09—01:04:32	112	0.00652	0.00655	0.000643	60
	42	02 312	11/08—03:42:32	11/08—13:23:32	558	0.00350	0.00376	—0.00138	60
	51	03 312	11/08—13:33:32	11/08—20:38:32	388	0.00908	0.00917	0.00129	60
3POM XE	11	01 312	11/08—02:45:32	11/08—03:33:32	46	0.00193	0.00786	0.00762	60
		05 312	11/08—23:12:32	11/09—05:33:32	369	0.00412	0.00442	—0.00160	60
	42	02 312	11/08—03:42:32	11/08—13:23:32	557	0.00342	0.00403	—0.00214	60
		01 313	11/09—05:42:32	11/09—06:34:32	47	0.00188	0.00707	0.00682	60
3POM XF	51	03 312	11/08—13:33:32	11/08—20:38:32	388	0.00890	0.00934	0.00283	60
	11	01 312	11/08—02:45:32	11/08—03:33:32	46	0.00201	0.00809	0.00783	60
		05 312	11/08—23:12:32	11/09—05:33:32	369	0.00402	0.00442	—0.00183	60
	42	02 312	11/08—03:42:32	11/08—13:23:32	558	0.00339	0.00400	—0.00211	60

Table 60 (contd)

Orbit identification	DSS	Data type, pass identification	Beginning data time (month/date—GMT)	End data time (month/date—GMT)	No. of points	Standard deviation	Root mean square (rms)	Mean error	Sample rate, s
3POM XF (contd)	42	01 313	11/09—05:42:32	11/09—08:18:32	142	0.00396	0.00482	0.00274	60
	51	03 312	11/08—13:33:32	11/08—20:38:32	388	0.00896	0.00936	0.00273	60
3POM WD	11	01 312	11/08—02:46:32	11/08—03:33:32	44	0.00146	0.00149	—0.000283	60
	42	02 312	11/08—03:42:32	11/08—13:23:32	558	0.00173	0.00173	0.0000823	60
	51	03 312	11/08—13:33:32	11/08—20:38:32	388	0.00712	0.00712	—0.0000793	60
4POM XA	11	01 312	11/08—02:45:32	11/08—03:33:32	46	0.00217	0.00793	0.00763	60
		05 312	11/08—23:12:32	11/09—05:33:32	369	0.00371	0.00405	—0.00163	60
	42	02 312	11/08—03:42:32	11/08—13:23:32	558	0.00360	0.00416	—0.00209	60
		01 313	11/09—05:42:32	11/09—10:29:32	268	0.00403	0.00423	0.00127	60
4POM XD	51	03 312	11/08—13:33:32	11/08—20:38:32	388	0.00913	0.00951	0.00267	60
	11	01 312	11/08—02:24:32	11/08—23:11:32	46	0.00238	0.00915	0.00883	60
		05 312	11/08—23:12:32	11/09—05:33:32	369	0.00345	0.00373	—0.00140	60
	41	02 312	11/08—03:42:32	11/08—13:23:32	558	0.00398	0.00459	—0.00229	60
		01 313	11/09—05:42:32	11/09—13:23:32	435	0.00344	0.00371	0.00138	60
4POM WG	51	03 312	11/08—13:33:32	11/08—20:38:32	388	0.00909	0.00935	0.00223	60
		02 313	11/09—13:33:32	11/09—14:52:32	77	0.00780	0.00810	—0.00218	60
	11	01 312	11/08—02:45:32	11/08—23:11:32	46	0.00171	0.00172	0.000236	60
		05 312	11/08—23:12:32	11/09—05:33:32	361	0.00259	0.00259	0.000157	60
	42	02 312	11/08—03:42:32	11/08—13:23:32	558	0.00184	0.00184	—0.00000394	60
		01 313	11/09—05:42:32	11/09—13:23:32	437	0.00176	0.00176	0.000119	60
	51	03 312	11/08—13:33:32	11/08—20:38:32	388	0.00711	0.00711	0.0000862	60
5POM XA		02 313	11/09—13:33:32	11/09—18:37:32	268	0.00708	0.00708	—0.0000875	60
	11	01 312	11/08—02:45:32	11/08—23:11:32	46	0.00278	0.0110	0.0107	60
		05 312	11/08—23:12:32	11/09—05:33	369	0.00335	0.00387	—0.00193	60
	42	02 312	11/08—03:42:32	11/08—13:23:32	558	0.00413	0.00471	—0.00227	60
		01 313	11/09—05:42:32	11/09—13:23:32	435	0.00300	0.00348	0.00175	60
	51	03 312	11/08—13:33:32	11/08—20:38:32	388	0.00921	0.00936	0.00168	60
5POM XD		02 313	11/09—13:33:32	11/09—19:17:32	294	0.00738	0.00738	—0.000111	60
	11	01 312	11/08—02:45:32	11/08—03:33:32	46	0.00319	0.0135	0.0131	60
		05 312	11/08—23:12:32	11/09—05:33:32	369	0.00325	0.00404	0.00239	60
	42	02 312	11/08—03:42:32	11/08—13:23:32	558	0.00416	0.00469	—0.00217	60
		01 313	11/09—05:42:32	11/09—13:23:32	435	0.00295	0.00321	0.00128	60
	51	03 312	11/08—13:33:32	11/08—20:38:32	388	0.00931	0.00936	0.000978	60
		02 313	11/09—13:33:32	11/09—20:44:32	367	0.00866	0.00878	0.00145	60
5POM WD	11	01 312	11/08—02:45:32	11/08—03:33:32	46	0.00177	0.00178	0.0000796	60
		05 312	11/08—23:12:32	11/09—05:33:32	361	0.00266	0.00267	0.000234	60
	42	02 312	11/08—03:42:32	11/08—13:23:32	558	0.00184	0.00184	0.00000263	60
		01 313	11/09—05:42:32	11/09—13:23:32	437	0.00174	0.00174	0.0000229	60
	51	03 312	11/08—13:33:32	11/08—20:38:32	388	0.00711	0.00711	—0.000138	60
		02 313	11/09—13:33:32	11/09—20:44:32	370	0.00735	0.00735	—0.000160	60

Table 60 (contd)

Orbit identification	DSS	Data type, pass identification	Beginning data time (month/date—GMT)	End data time (month/date—GMT)	No. of points	Standard deviation	Root mean square (rms)	Mean error	Sample rate, s
FINAL WA	11	03 313	11/09—22:18:32	11/09—22:47:32	26	0.00646	0.00652	0.000826	60
	51	02 313	11/09—19:19:32	11/09—22:08:32	158	0.00749	0.00749	0.0000448	60
FINAL XA	11	03 313	11/09—22:18:32	11/09—22:54:32	33	0.00601	0.00604	0.000577	60
	51	02 313	11/09—19:19:32	11/09—22:08:32	158	0.00745	0.00745	—0.000117	60
FINAL WC	11	03 313	11/09—22:18:32	11/09—23:26:32	54	0.00542	0.00543	0.000339	60
	51	02 313	11/09—19:19:32	11/09—22:08:32	158	0.00747	0.00747	—0.0000958	60
FINAL XC	11	03 313	11/09—22:18:32	11/09—23:36:32	56	0.00548	0.00549	0.000434	60
	51	02 313	11/09—19:19:32	11/09—22:08:32	158	0.00748	0.00748	—0.0000433	60
FINAL WE	11	03 313	11/09—22:18:32	11/09—23:39:32	71	0.00537	0.00538	0.000339	60
	51	02 313	11/09—19:19:32	11/09—22:08:32	158	0.00749	0.00749	—0.000144	60
FINAL WF	11	03 313	11/09—22:18:32	11/09—00:15:32	98	0.00471	0.00472	0.000247	60
	51	02 313	11/09—19:19:32	11/09—22:08:32	158	0.00748	0.00748	—0.0000278	60
POST 2	11	01 312	11/08—02:45:32	11/08—23:11:32	46	0.00185	0.00201	0.000785	60
		05 312	11/08—23:12:32	11/09—05:33:32	361	0.00302	0.00302	0.000143	60
		03 313	11/09—22:18:32	11/10—00:14:32	97	0.00650	0.00674	0.00177	60
	42	02 312	11/08—03:42:32	11/08—13:23:32	558	0.00166	0.00167	0.000191	60
		01 313	11/09—05:42:32	11/09—13:23:32	437	0.00191	0.00192	0.000148	60
		03 312	11/08—13:33:32	11/08—20:35:32	387	0.00711	0.00714	0.000610	60
		02 313	11/09—13:33:20	11/09—22:08:32	457	0.00759	0.00759	—0.000236	60

a. *Angular tracking premidcourse phase.* In general, doppler data yields far greater accuracy in the determination of a spacecraft orbit than does angular data and is therefore used almost exclusively in the orbit determination process during most of the mission. The one exception is the launch phase, when little doppler data are available and a quick determination of the orbit necessitates the use of both doppler and angular data. During the *Surveyor VI* Mission, angular data from DSS 51 and DSS 42 were used in the orbit determination program during the first passes of these two stations. In order to improve the quality of the angular data to be used in the orbit determination program, it is first corrected for antenna optical pointing error. This error is determined by having the Deep Space 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 used in the *Surveyor VI* inflight orbit computations can be seen in Tables 61 and 62.

Experience gained in past missions has shown that the optical pointing error correction coefficients do not remove all systematic pointing errors. This is reasonable since the RF and optical axis of the antenna are not necessarily the same. That is, the RF axis is a function of the position of the quadripod feed, whereas the optical axis is not. Thus, if there is a quadripod reflection (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 were the most important angular data for use in the early orbits. These data, when fit through the final postflight orbit, show a bias of

Table 61. 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

^aThese corrections are useful for elevations greater than 15 deg, and declinations between N 30 and S 35 deg.

Table 62. 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

^aThese corrections are useful for elevations greater than 15 deg, and declinations between N 30 and S 35 deg.

+0.040 deg in hour angle and -0.025 deg in declination. These values are slightly higher than DSS 51 first pass angle biases averaged over previous *Surveyor* missions (+0.030 deg in hour angle and -0.020 deg in declination) but can still be regarded as being reasonably consistent with past *Surveyor*-DSS 51 experience. Johannesburg (DSS 51) residuals can be seen in Figs. 73-76. The first pass angular data of DSS 42 were also used in various inflight orbit iterations. These data, when passed through the final postflight orbit, show biases of -0.020 deg in hour angle and -0.035 deg in declination. These biases agree reasonably with past *Surveyor*-DSS 42 experience; this experience indicating that the angle correction coefficients for DSS 42 are more effective in hour angle than in declination. For instance, the averaged DSS 42 biases for *Surveyors III* and *V* are -0.005 deg in hour angle and -0.045 deg in declination. The DSS 42 angle residuals are seen in Fig. 77.

b. Doppler tracking premidcourse phase. Surveyor VI is noteworthy in regards to doppler data in that it marks the first wide-scale use of the doppler resolver at the Deep Space Stations and the corresponding use of the data produced in the orbit determination process during an actual flight. In measuring doppler frequencies, the tracking data handling system counts the number of signal zero crossings during a given time interval; this differs from the actual doppler frequency by fractions of a cycle which are alternately lost from one time interval and erroneously added to the next. This error, commonly referred to as truncation error, depends on the data sample rate (clearly, the longer the sample interval, the smaller the relative error); for 60-s count data, this truncation error produces a standard deviation of approximately 0.008 Hz in two-way doppler data. The doppler resolver effectively measures the fraction of a cycle from the start of a time interval to the first zero crossing, and correctly adds it to or subtracts it from the basic frequency measurement. The net result of the use of the doppler resolver for good two-way data is a reduction of the standard deviation by approximately a factor of four, or, to about 0.002 Hz for 60-s count data. During *Surveyor VI*, DSSs 11, 42, and 61 had doppler resolvers whereas DSS 51 did not. An immediate idea of the difference can be had by comparing the first pass DSS 51 two-way doppler (nonresolver) in Figs. 78-80 to the first pass DSS 42 two-way doppler (resolver) in Fig. 81.

Johannesburg (DSS 51), the first station to view the spacecraft after injection, began taking good two-way, 10-s count doppler data at 08:14:15 on November 7, 1967. The sample rate was changed to 60 s at 08:46:02, and the

spacecraft was transferred to DSS 42 at 10:05:02. The early data from DSS 51 were acceptable, showing a standard deviation of 0.040 Hz for 10-s count data and 0.007 Hz for 60-s count data—both being nominal figures for nonresolver data. The DSS 51 residuals are shown in Figs. 78–80. Excellent data were obtained by DSS 42 (which was in the two-way mode from 10:05:02 to 12:10:02) with a standard deviation of 0.0015 Hz. These data are presented in Fig. 81. The spacecraft was transferred to DSS 61 at 12:10:02; DSS 61 stayed in two-way until 14:45:02 when a transfer back to DSS 51 was made. The data from DSS 61 were noisy, showing a standard deviation of 0.011 Hz; this value is 6–7 times higher than nominal. The DSS 61 data, in subsequent passes, continued to deteriorate until the rubidium unit was changed, and it is probable that these excessively noisy first pass data can also be attributed to that problem. The DSS 61 two-way doppler residuals are shown in Fig. 82. The spacecraft was acquired by DSS 11 in the two-way mode at 22:10:02 and thus continued until the time of the midcourse maneuver at 02:20:00 on November 8, 1967. The doppler data from DSS 11 during this period is only fair, showing a standard deviation of 0.005 Hz; not quite as good as would be expected for resolver data. These two-way data from DSS 11 can be seen in Fig. 83.

c. Midcourse maneuver. Early analysis of the *Surveyor VI* trajectory indicated that a midcourse maneuver during the first pass over DSS 11 would be most advantageous, and therefore, the midcourse maneuver was executed during this pass. Engine ignition was programmed for 02:20:00, November 8 with a total burn time of 10.28 s. Results of the maneuver as seen in the two-way doppler data over DSS 11 are presented in Fig. 84. As can be seen in the data, the midcourse maneuver resulted in a doppler shift over DSS 11 of approximately -113.5 Hz.

d. Postmidcourse phase. All midcourse orbit computations used only two-way doppler from the prime stations, DSSs 51, 42, 61 and 11. Very good to excellent two-way doppler data were returned during this period with one significant exception. As has already been mentioned, DSS 61 took noisy two-way doppler data during the first pass; during the second pass, they tracked the spacecraft in the two-way mode for approximately $1\frac{1}{2}$ h and the noise on the data was even higher (0.013 Hz)—these data are shown in Fig. 85. It was thought that perhaps the high noise was due to a marginal rubidium unit, and when this unit was changed during the third pass of DSS 61, an immediate reduction of the noise in the three-way doppler residuals was noted. These data

can be seen in Fig. 86. The DSS 42 took excellent data during the postmidcourse phase with the two-way doppler residuals showing a standard deviation of 0.0017 Hz, this was by far the least noisy data taken by any station during *Surveyor VI*. The DSS 42 two-way doppler residuals during this period can be seen in Figs. 87–90. The DSS 11 took very good two-way doppler data during the postmidcourse phase, although it fell slightly short of optimum—DSS 11 two-way doppler residuals indicated a standard deviation during this period of 0.003 Hz, or about twice what might have been expected. The DSS 11 residuals for the postmidcourse phase are shown in Figs. 91–94. Finally, DSS 51 took uniformly good data during the postmidcourse phase. Two-way doppler residuals from DSS 51 produced a standard deviation of 0.0075 Hz—or just about as good as is possible with a nonresolver station. These residuals are displayed in Figs. 95–98.

e. Touchdown phase. Final inflight calculations by the orbit determination group indicated a retroignition time of 00:58:01.5, November 10, 1967. A soft landing occurred at 01:01:06.3, after a flight of 65 h, 22 min, and 5 s. The results of the retroengine burn as seen in the one-way doppler data at DSS 11 are presented in Fig. 99, and the touchdown phase doppler is shown in Fig. 100. To approximate the varying transmitter frequency during retroburn and touchdown phase when changing thrust vector precludes the possibility of accurate trajectory predictions, transmitter frequencies (reduced from tracking data and predicts up to the burn) were extrapolated through touchdown and used to compute range data. The values of these frequencies and corresponding range rates are presented in Table 63. 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. Table 64 shows the actual doppler received from 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 101 is a plot of these values—the line-of-sight velocity from DSS 11 of the *Surveyor VI* touchdown referenced to the lunar surface.

f. Lunar translation phase. A translation of the *Surveyor VI* spacecraft on the moon was effected on November 17, 1967, at 10:32:02. One-way doppler from this maneuver as seen by DSS 11 is presented in Fig. 102. The line-of-sight velocity from DSS 11 of the translation maneuver is shown in Fig. 103.

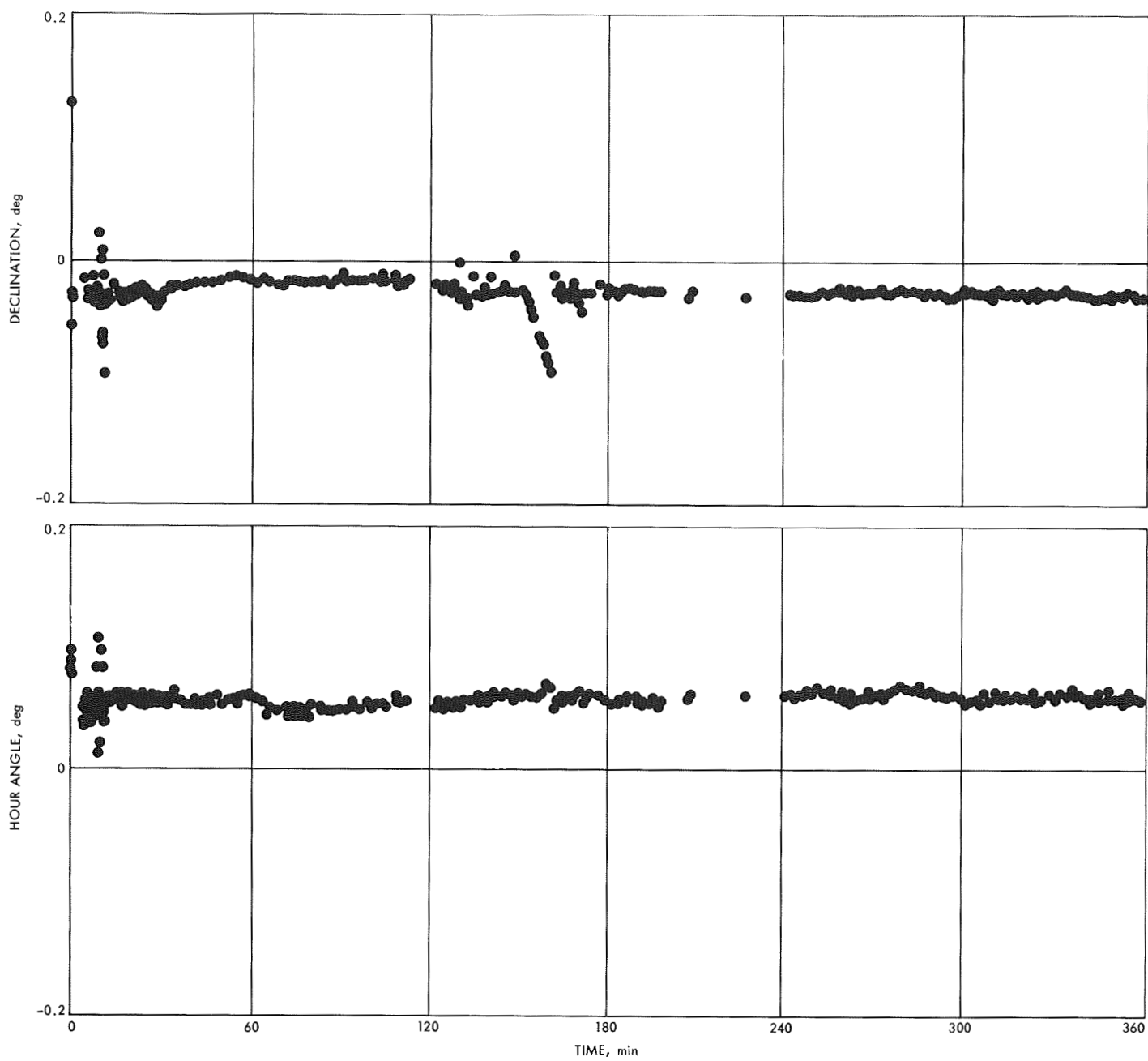


Fig. 73. Angular data, DSS 51 first pass

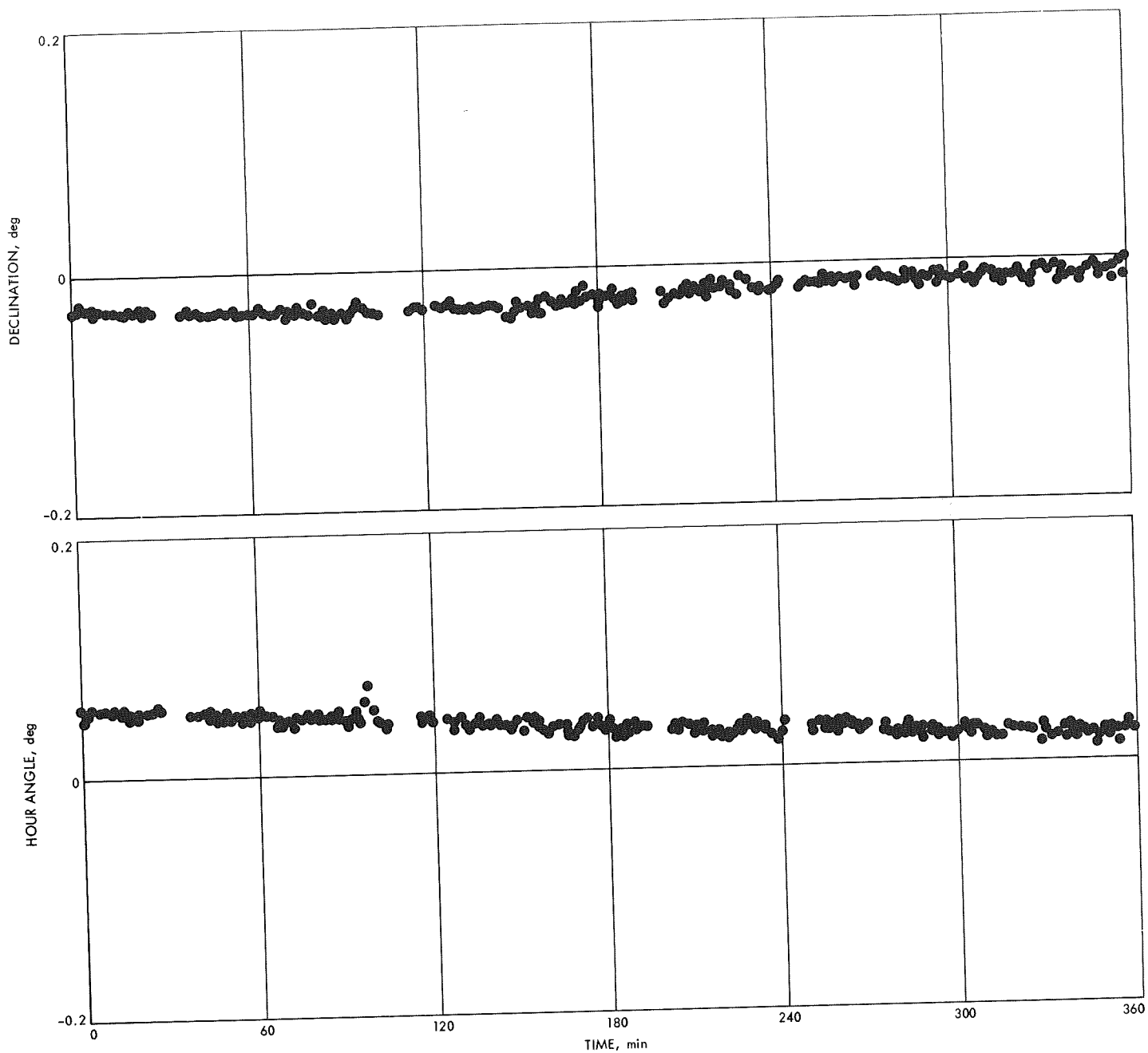


Fig. 74. First pass angular data received by DSS 51
(time from 14:10:00 GMT on November 7, 1967)

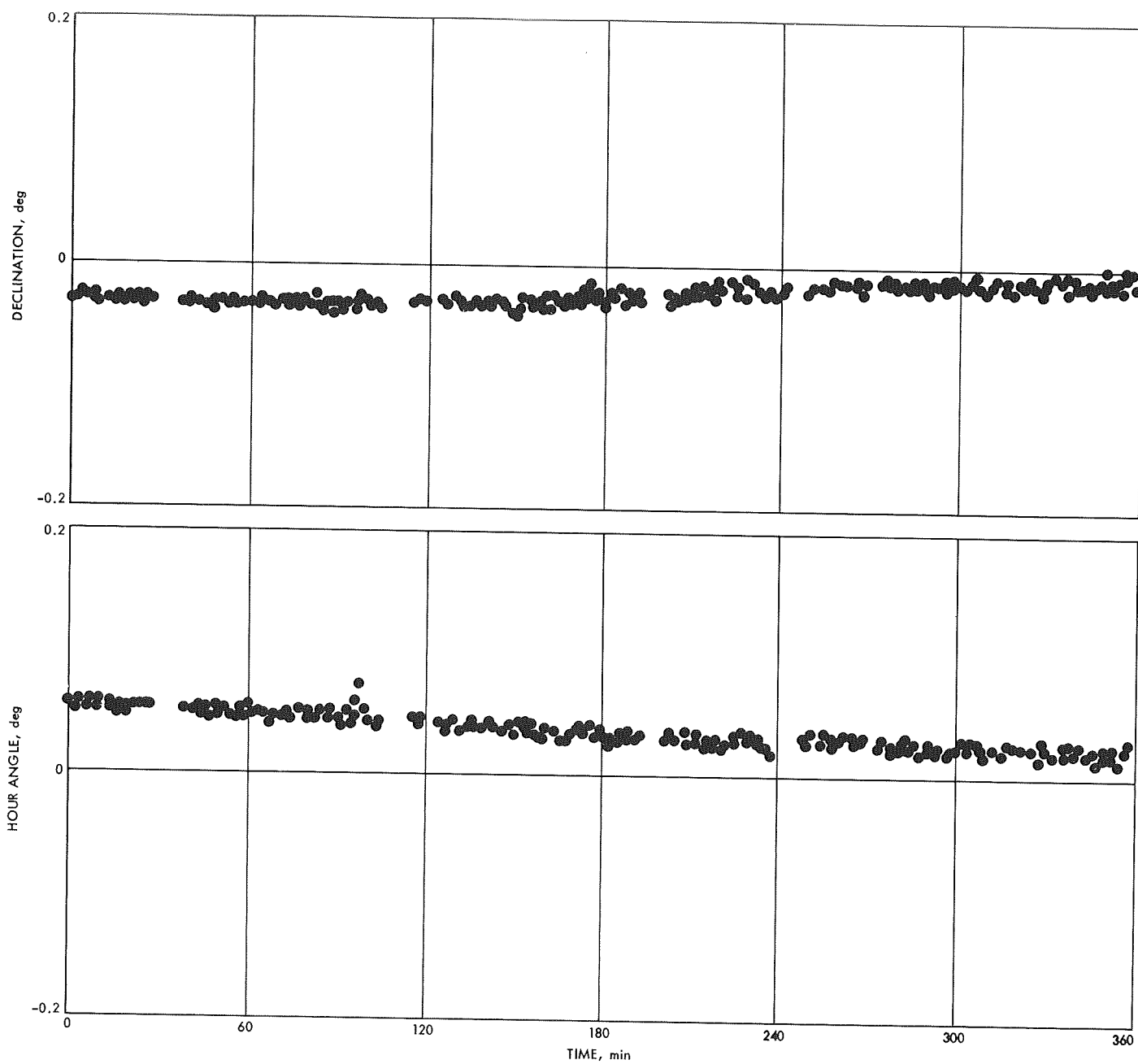


Fig. 75. First pass angular data received by DSS 51
(time from 14:10:00 GMT on November 7, 1967)

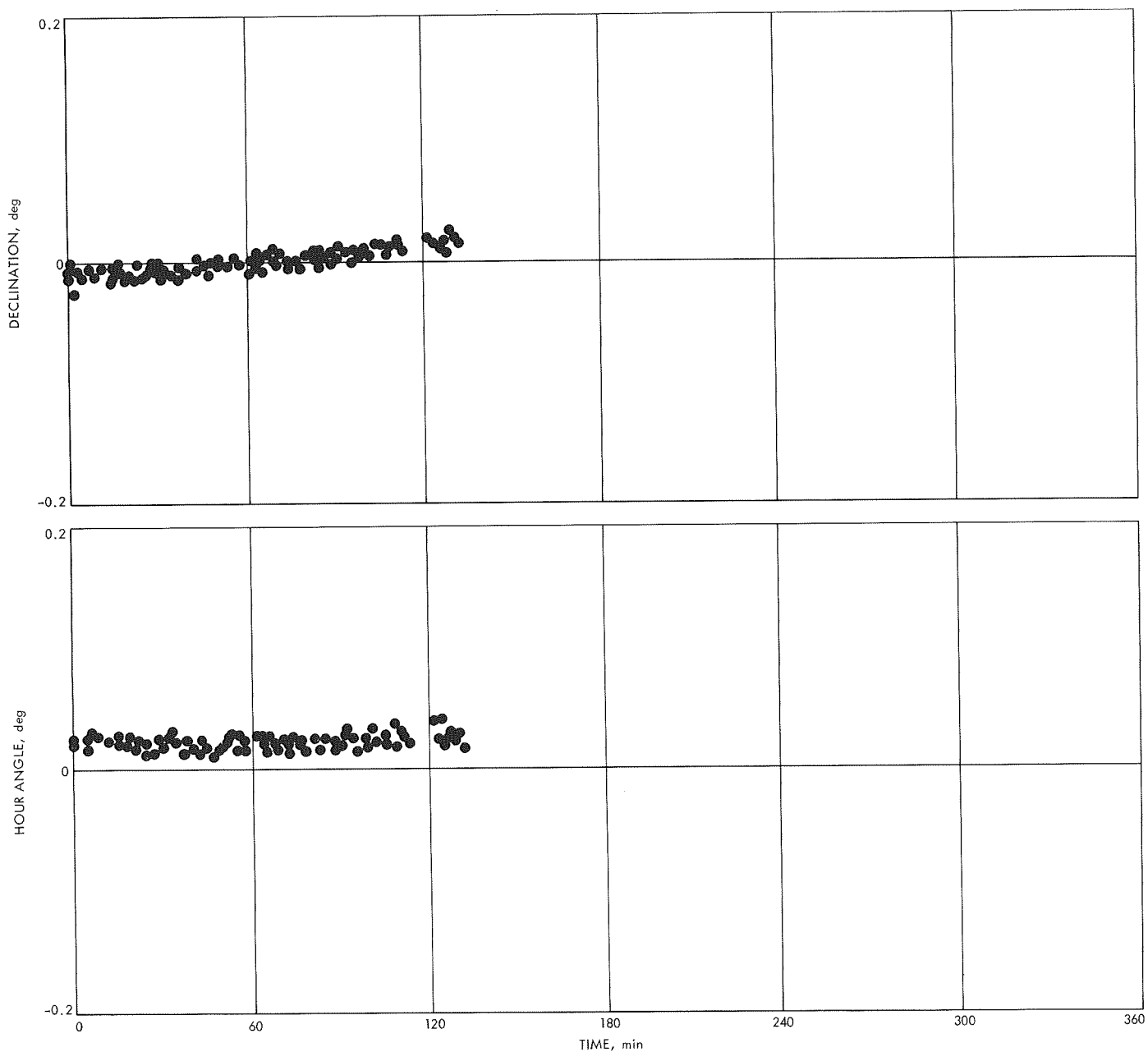


**Fig. 76. First pass angular data received by DSS 51
(time from 20:10:00 GMT on November 7, 1967)**

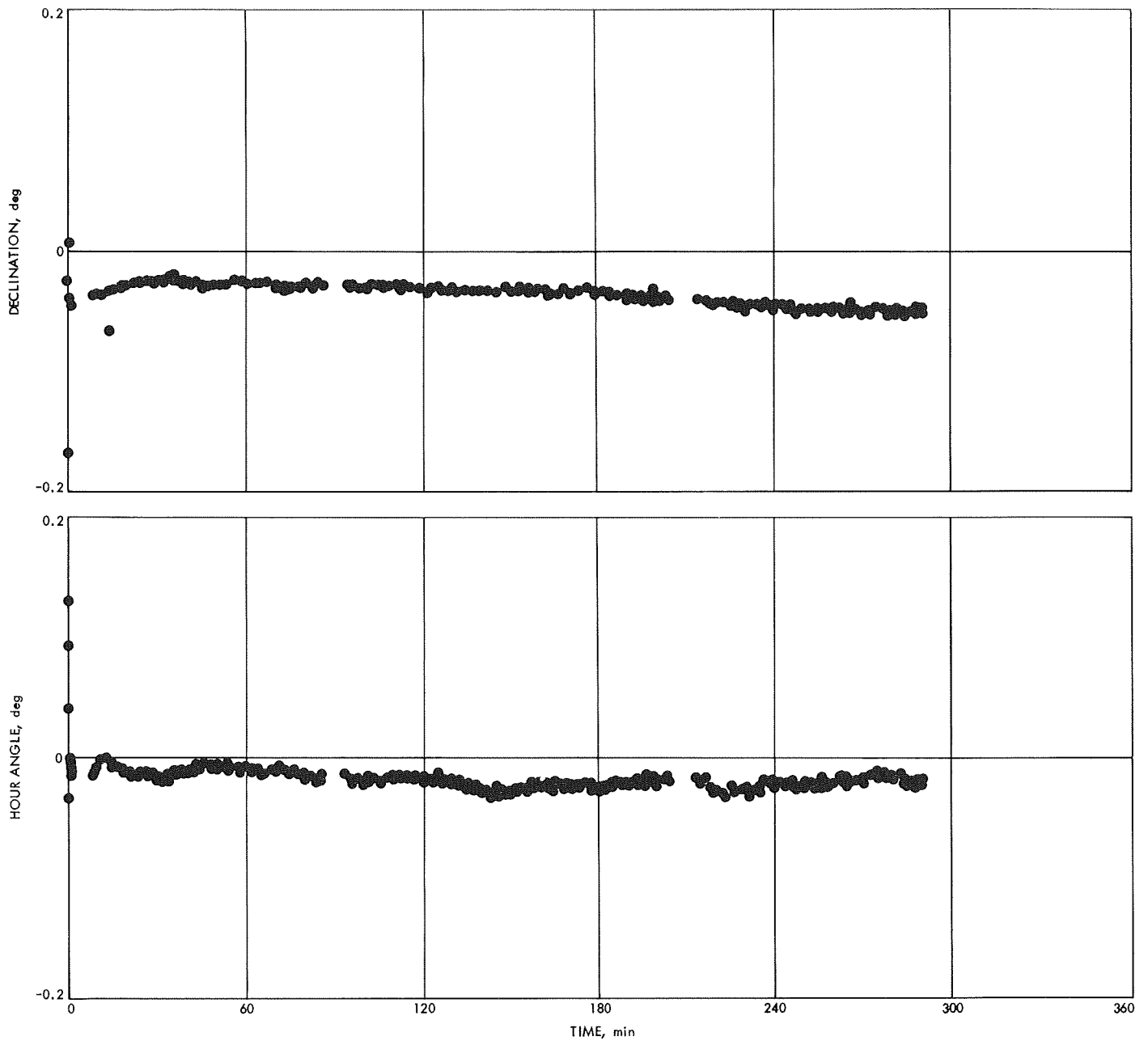


**Fig. 77. First pass angular data received by DSS 42
(time from 08:38:00 GMT on November 7, 1967)**

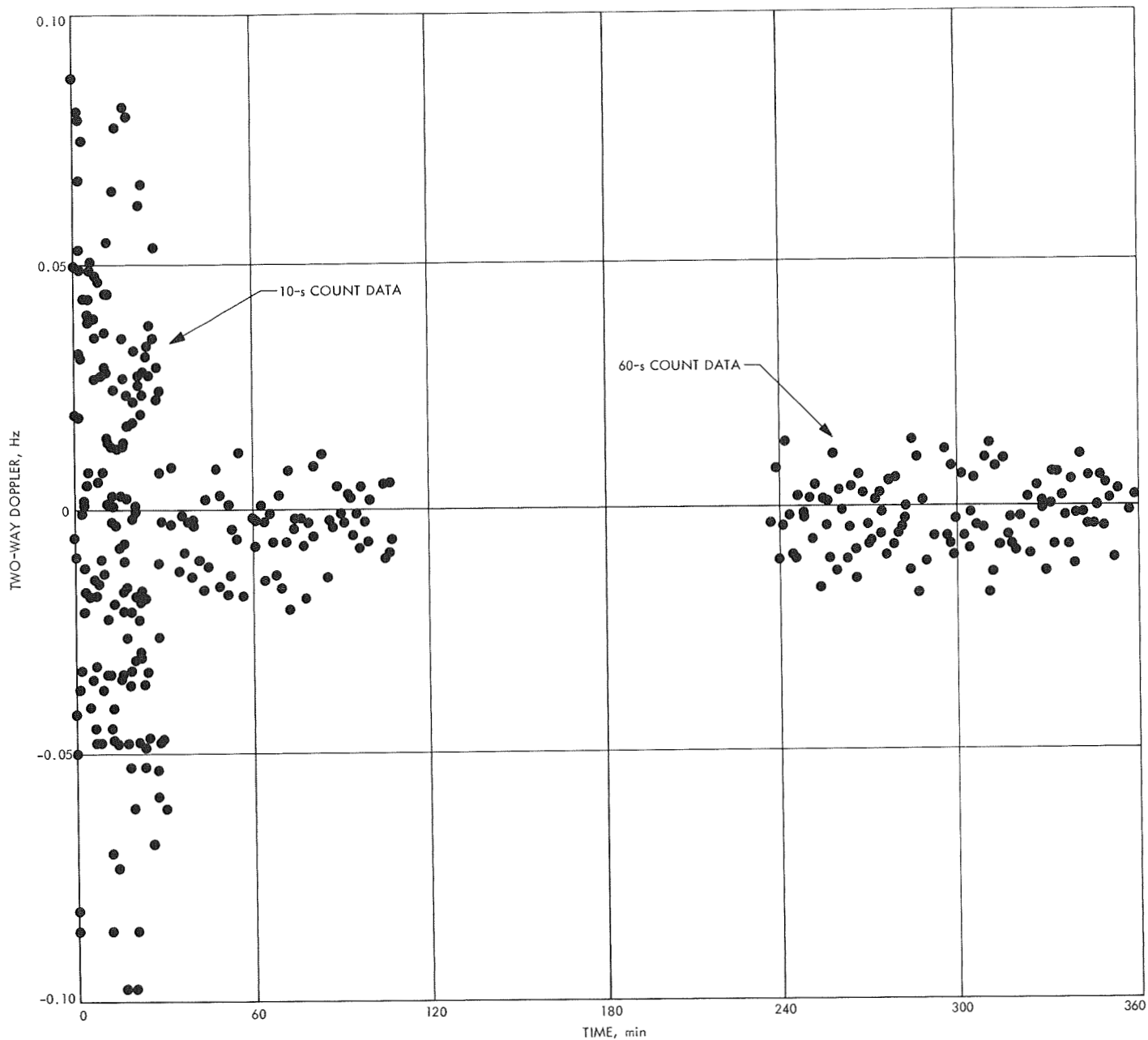


**Fig. 78. First pass two-way (CC3) doppler data received by DSS 51
(time from 08:14:00 GMT on November 7, 1967)**

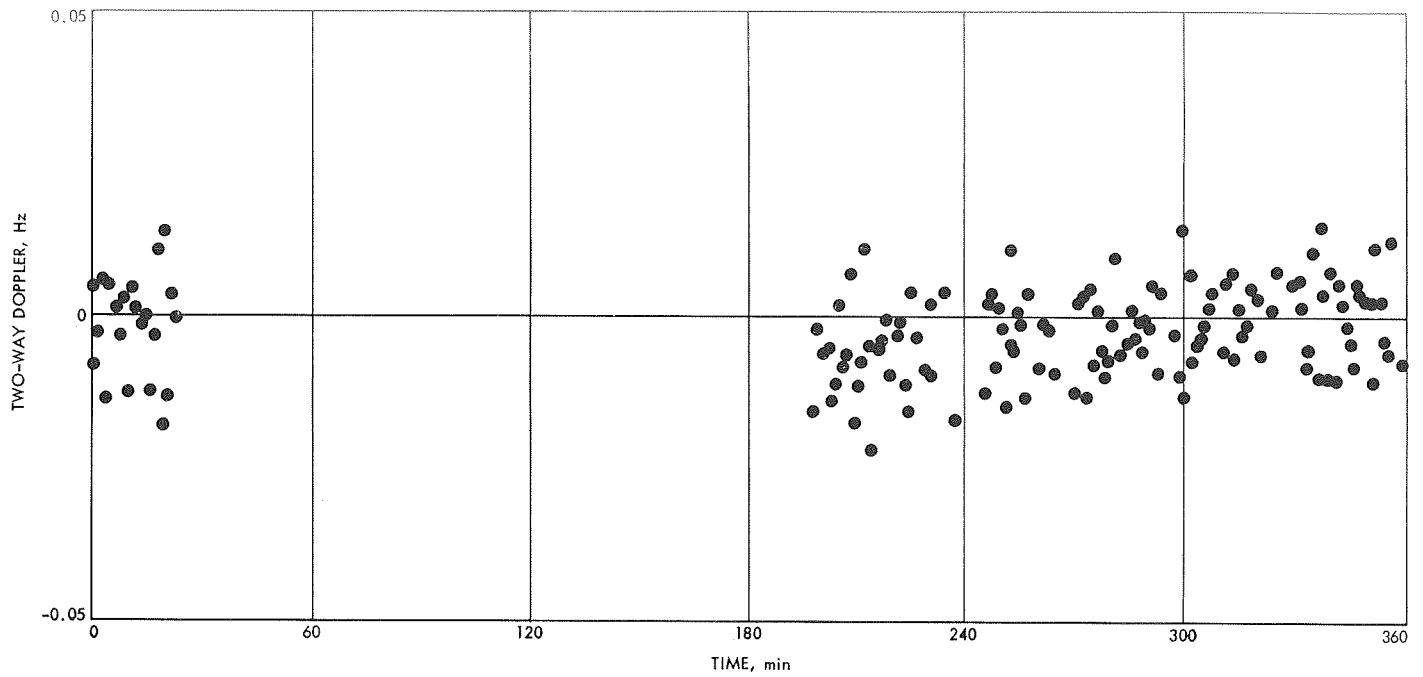


**Fig. 79. First pass two-way (CC3) doppler data received by DSS 51
(time from 14:14:00 GMT on November 7, 1967)**

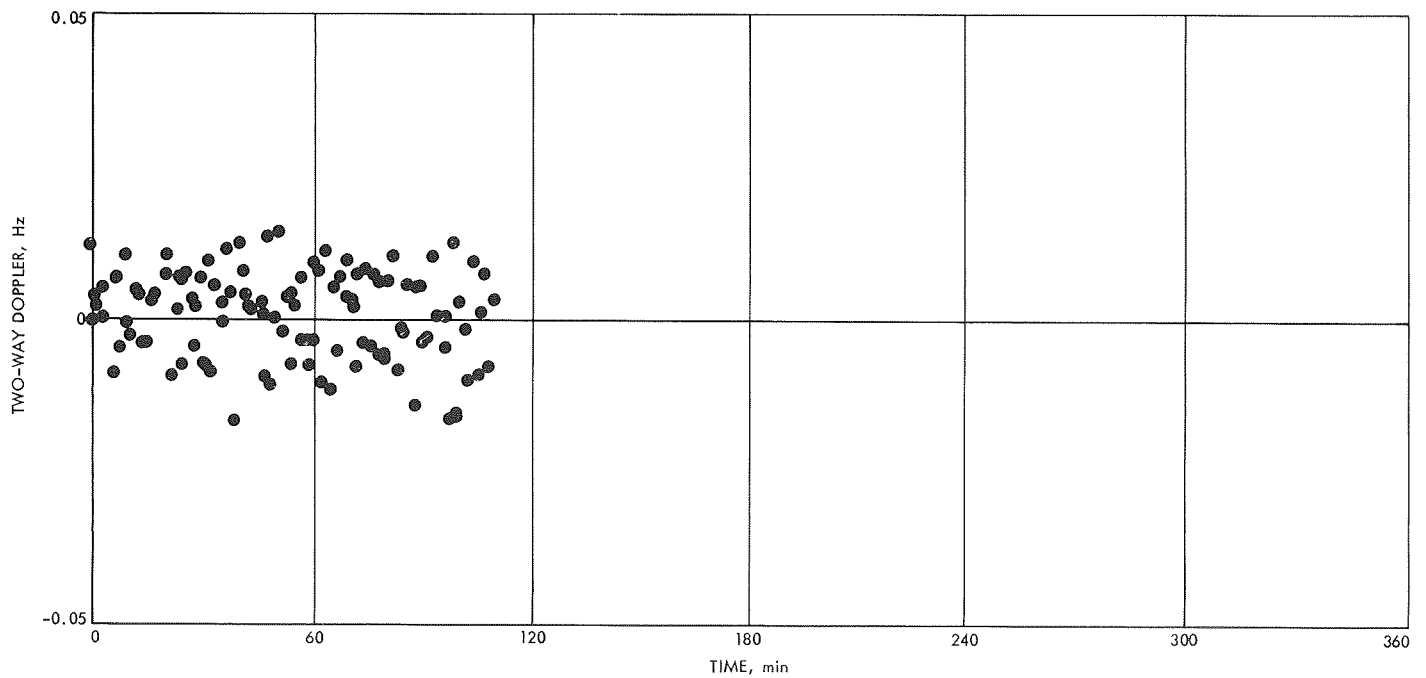


**Fig. 80. First pass two-way (CC3) doppler data received by DSS 51
(time from 20:14:00 GMT on November 7, 1967)**

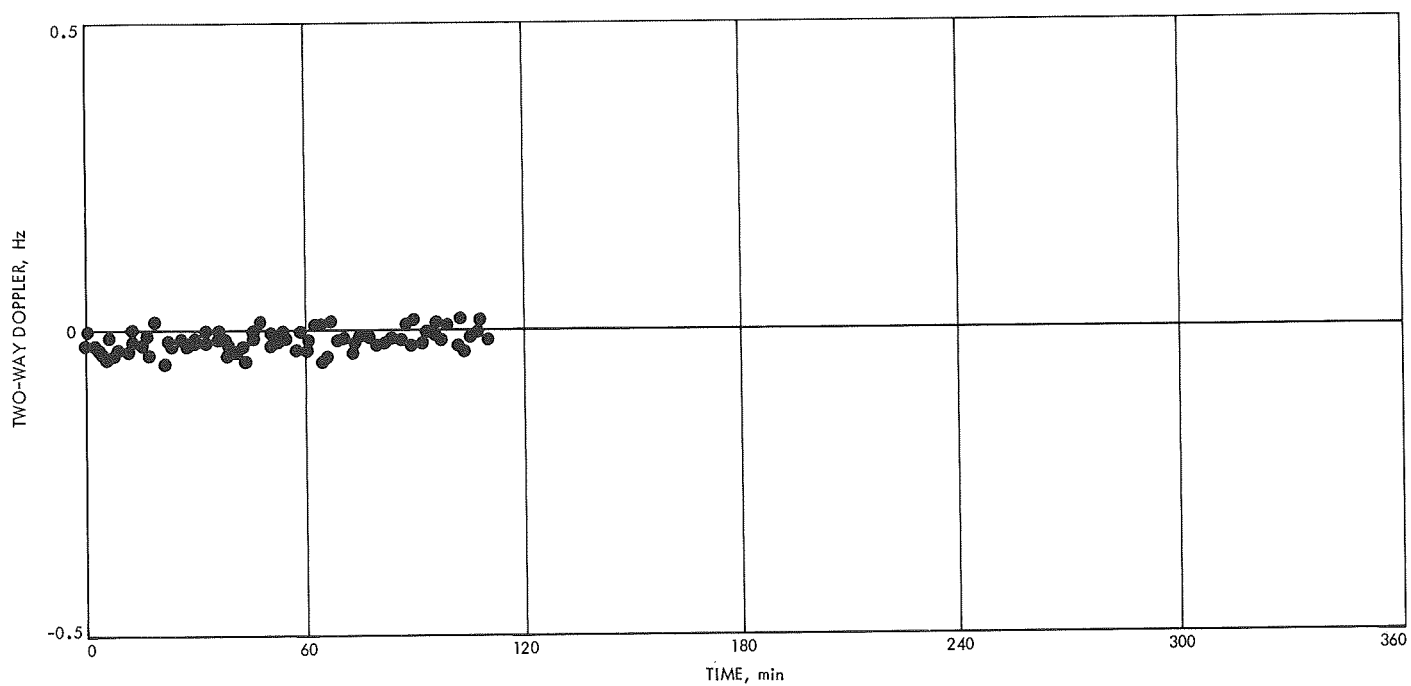


**Fig. 81. First pass two-way (CC3) doppler data received by DSS 42
(time from 10:13:00 GMT on November 7, 1967)**

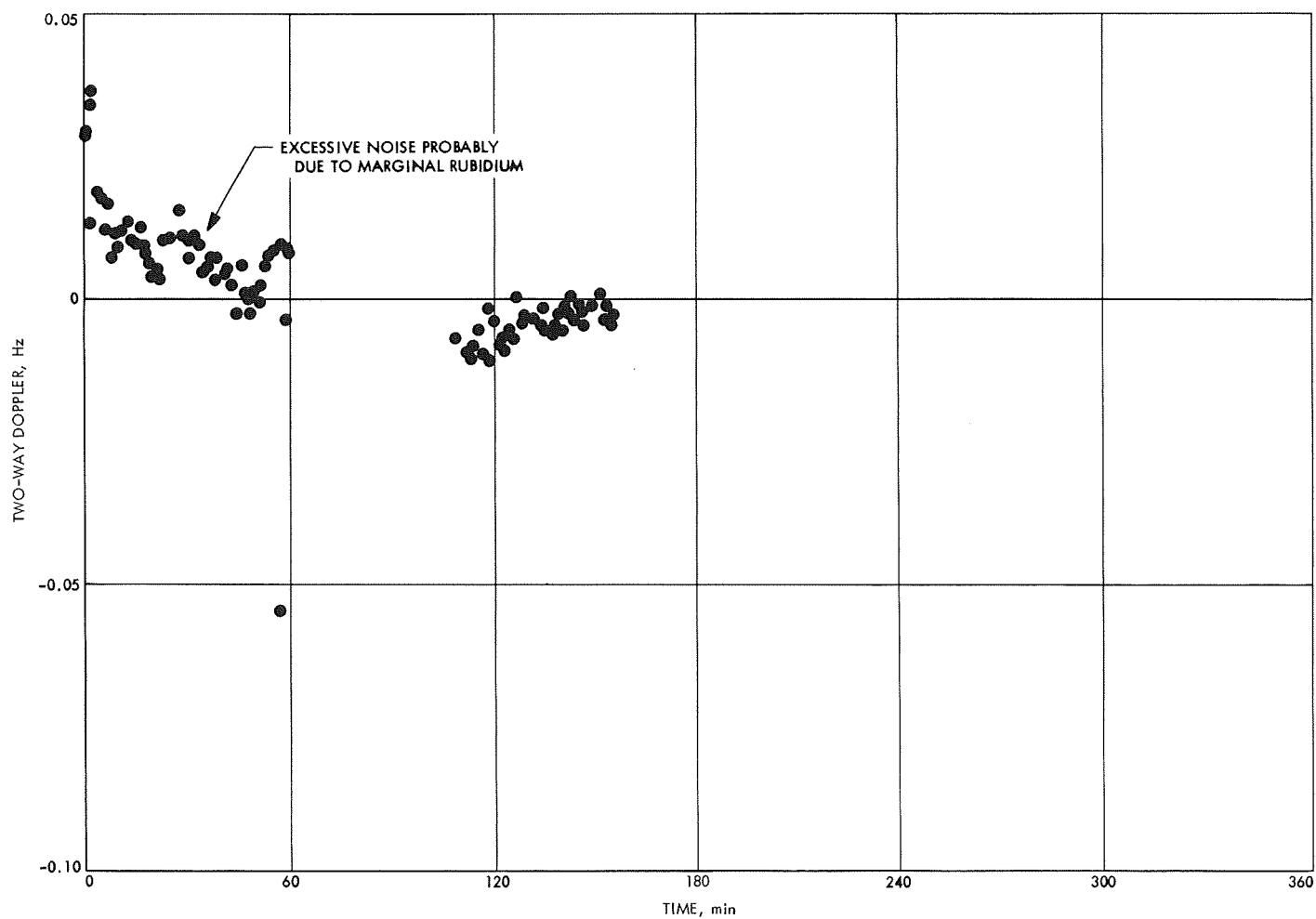


**Fig. 82. First pass two-way (CC3) doppler data received by DSS 61
(time from 14:47:00 GMT on November 7, 1967)**

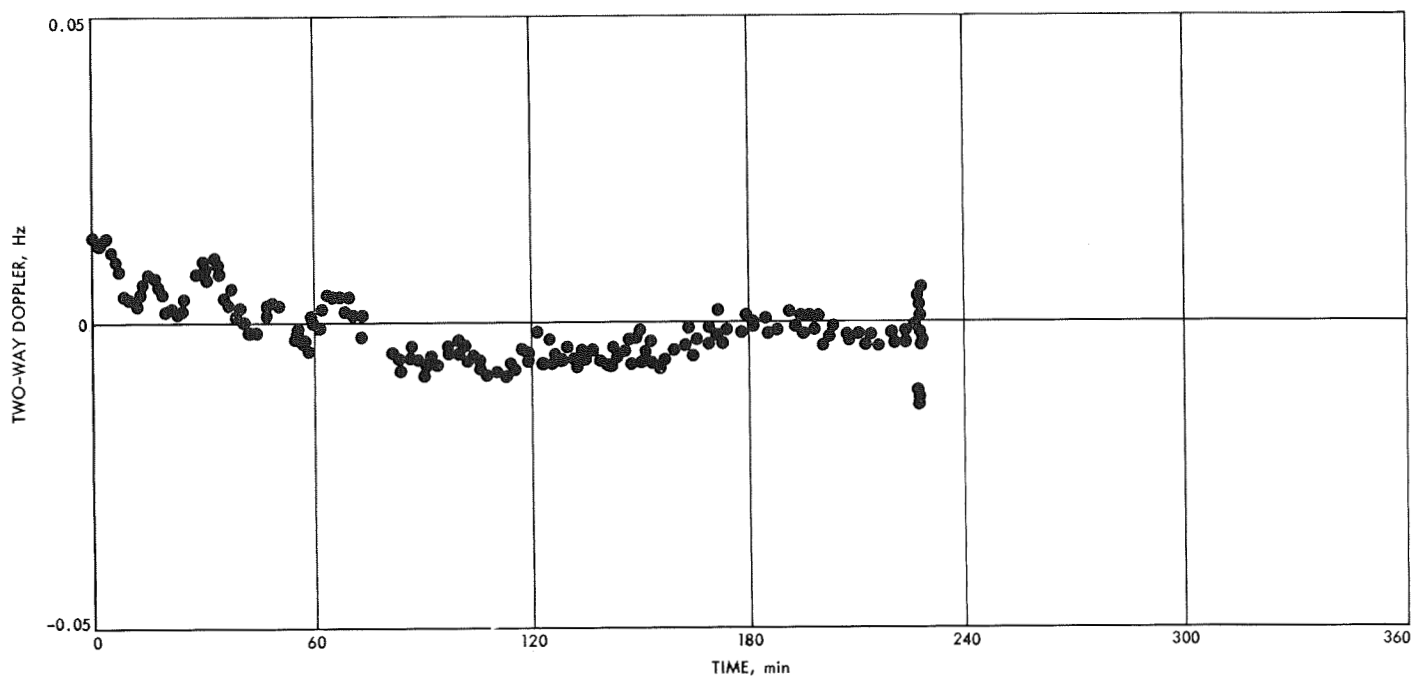


**Fig. 83. First pass two-way (CC3) doppler received by DSS 11
(time from 22:13:00 GMT on November 7, 1967)**

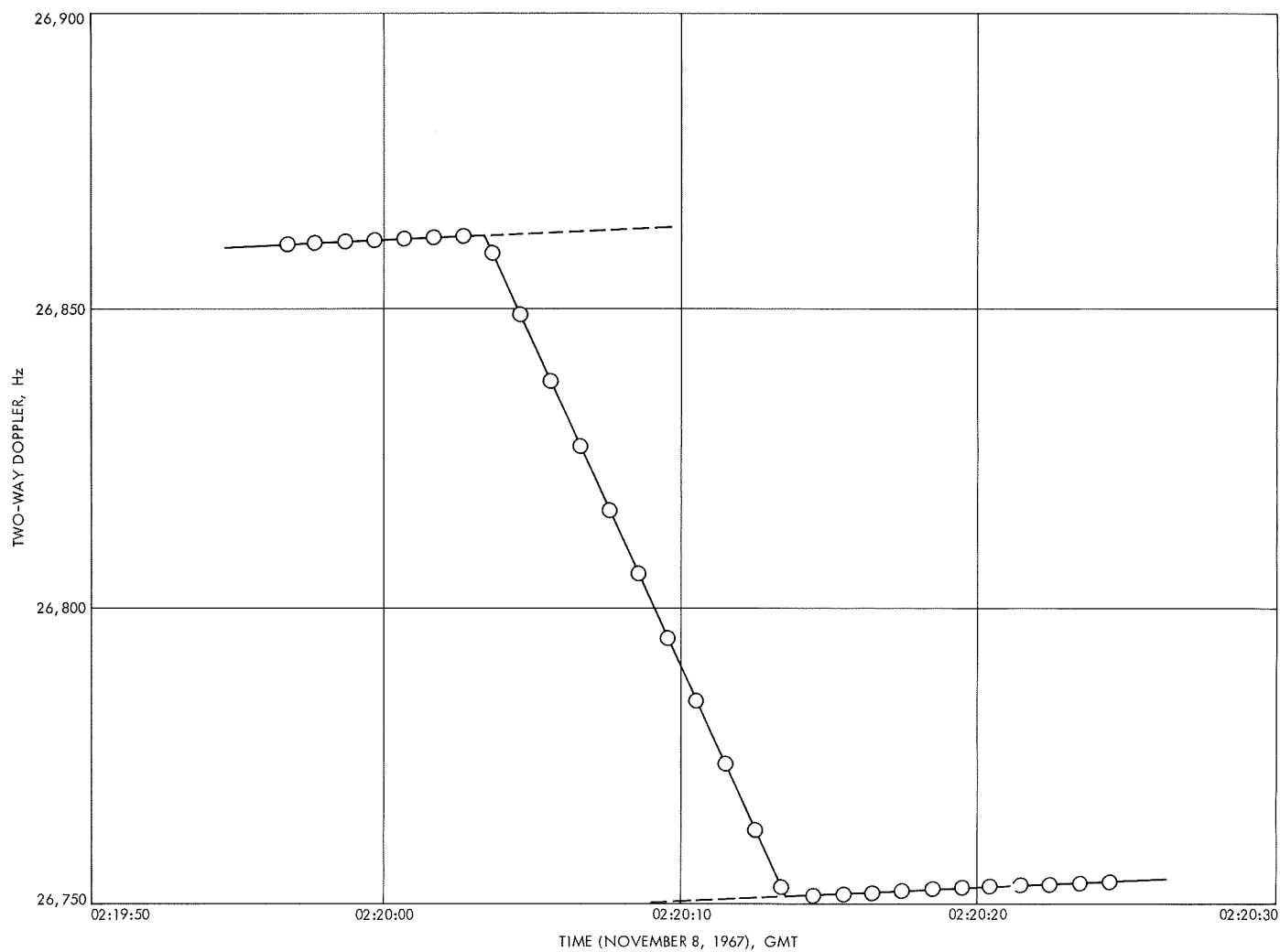


Fig. 84. Midcourse maneuver doppler, DSS 11

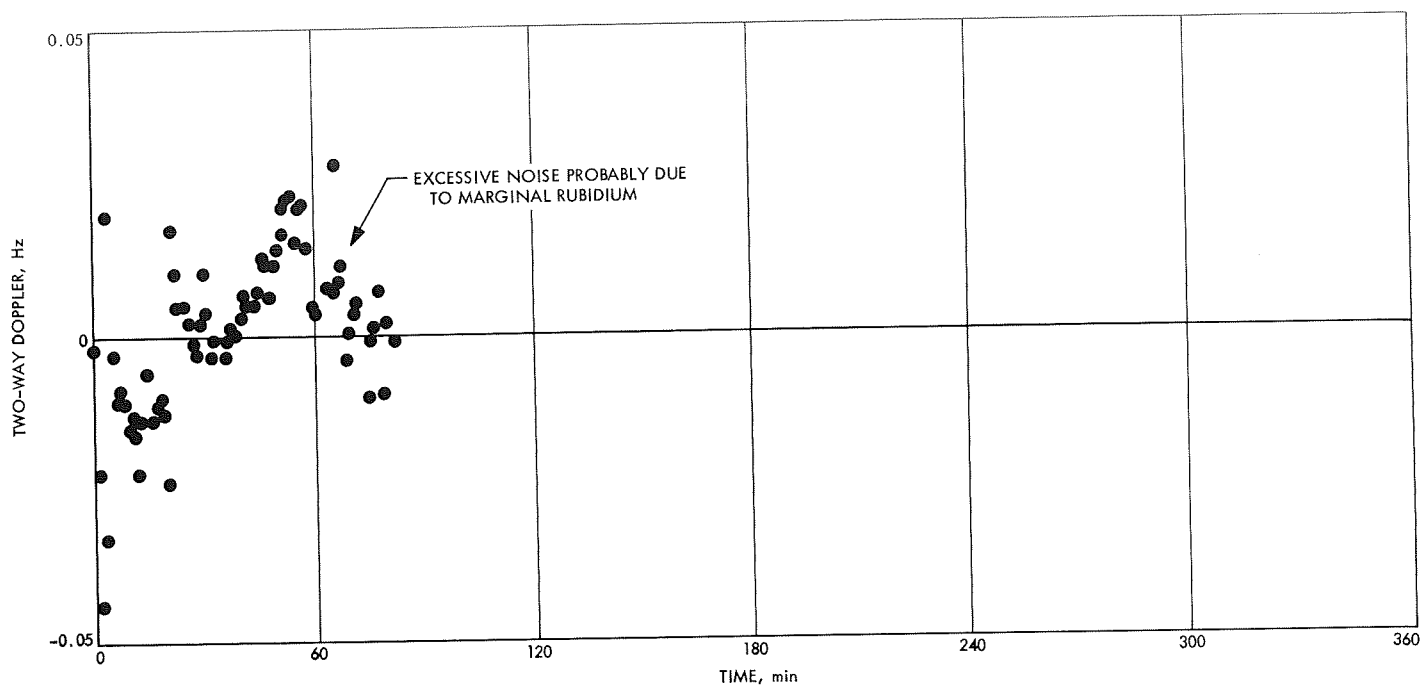


**Fig. 85. Second pass two-way (CC3) doppler data received by DSS 61
(time from 20:45:00 GMT on November 8, 1967)**

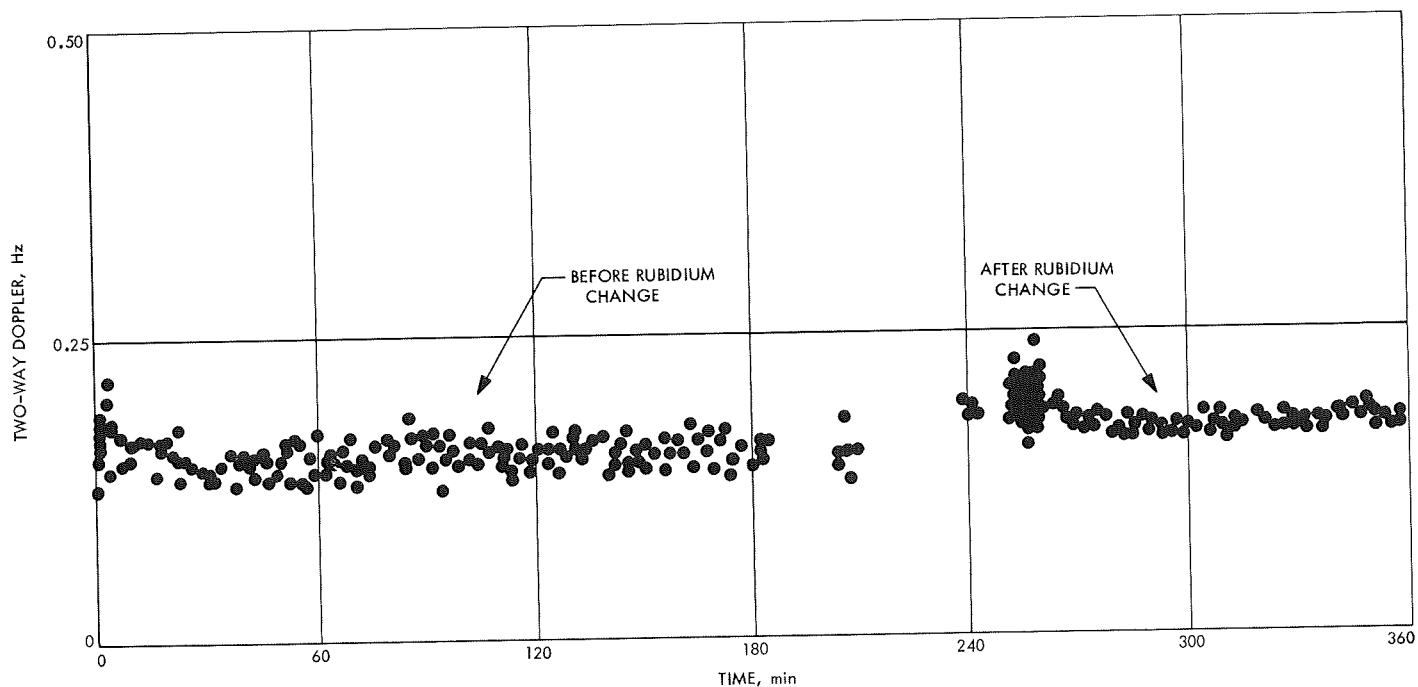


**Fig. 86. Third pass two-way (CC3) doppler data received by DSS 61
(time from 14:41:00 GMT on November 9, 1967)**

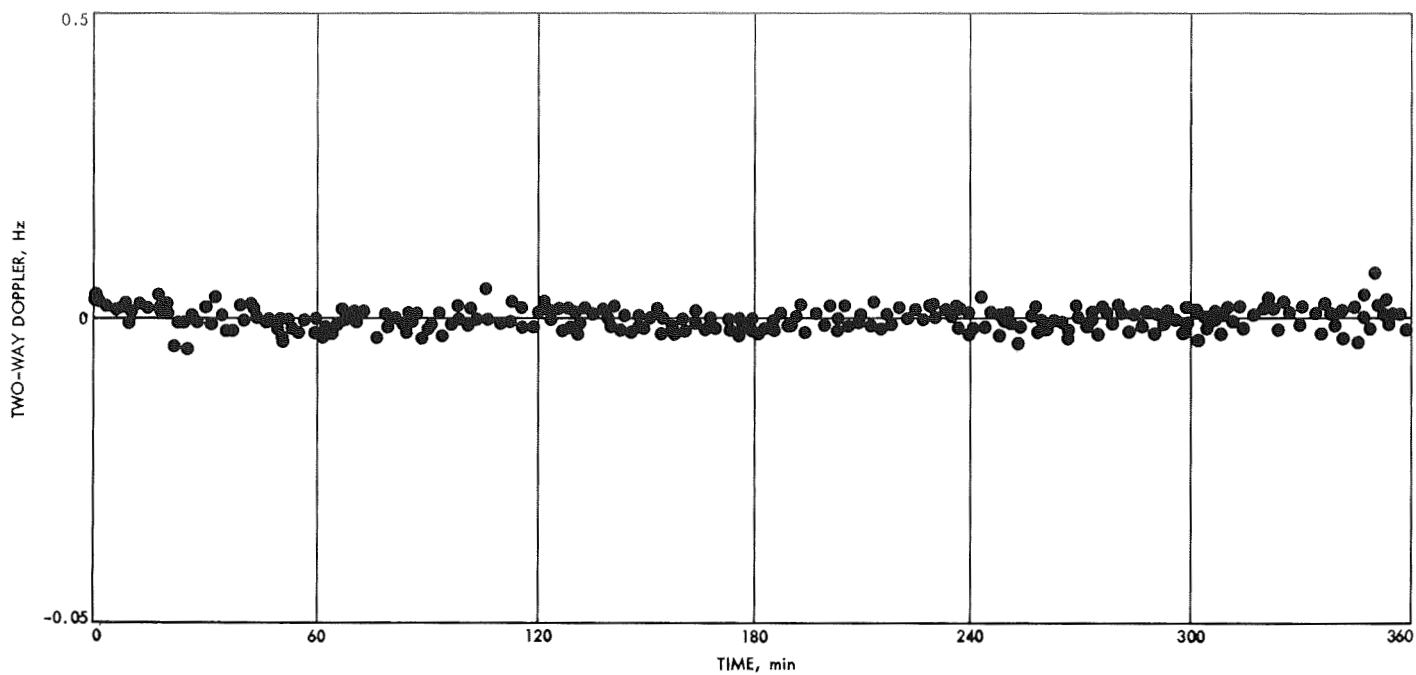


**Fig. 87. Second pass two-way (CC3) doppler data received by DSS 42
(time from 03:42:00 GMT on November 8, 1967)**

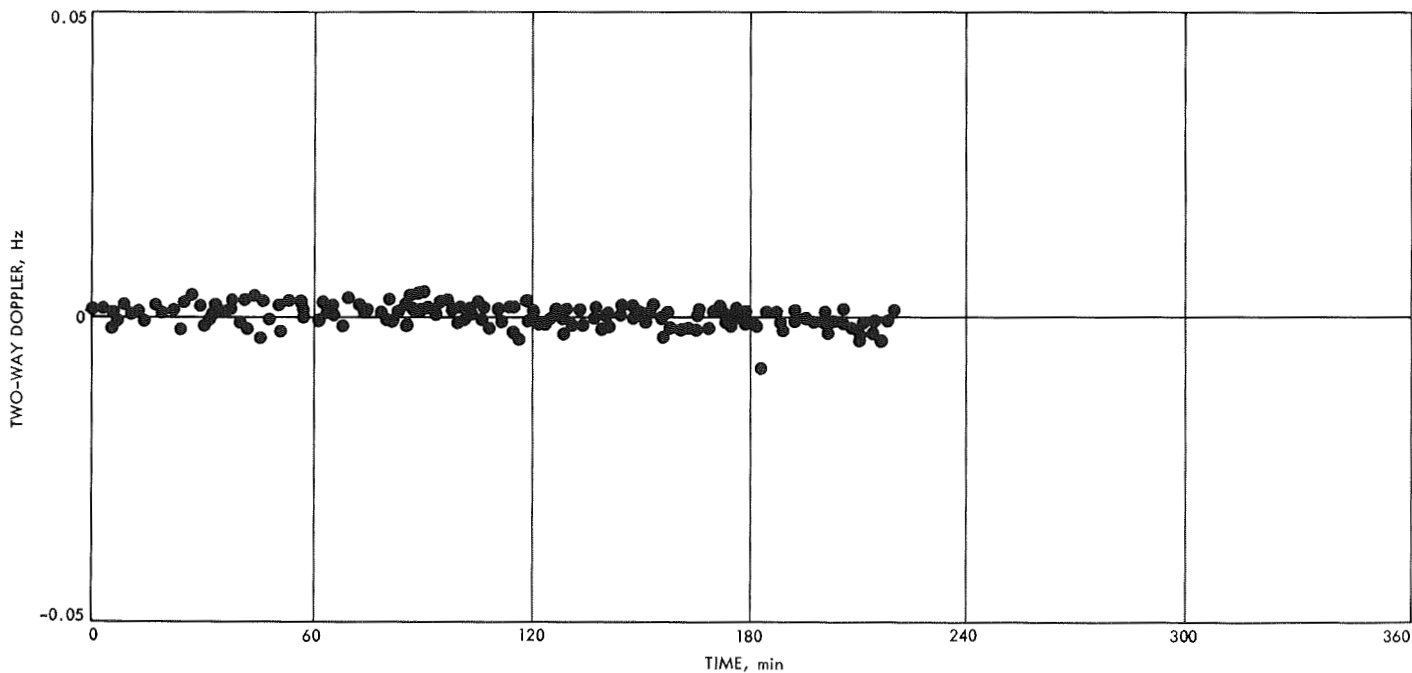


**Fig. 88. Second pass two-way (CC3) doppler data received by DSS 42
(time from 09:42:00 GMT on November 8, 1967)**

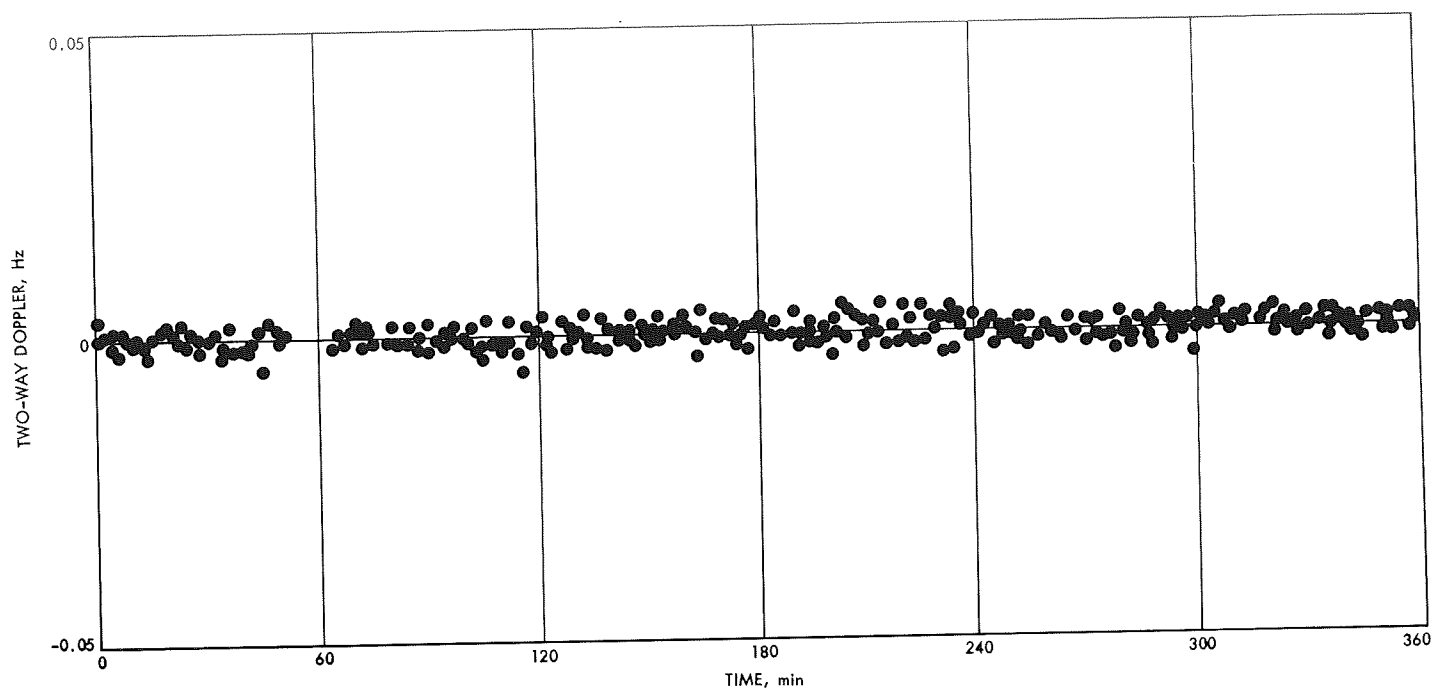


Fig. 89. Third pass two-way (CC3) doppler data received by DSS 42
(time from 05:42:00 GMT on November 9, 1967)

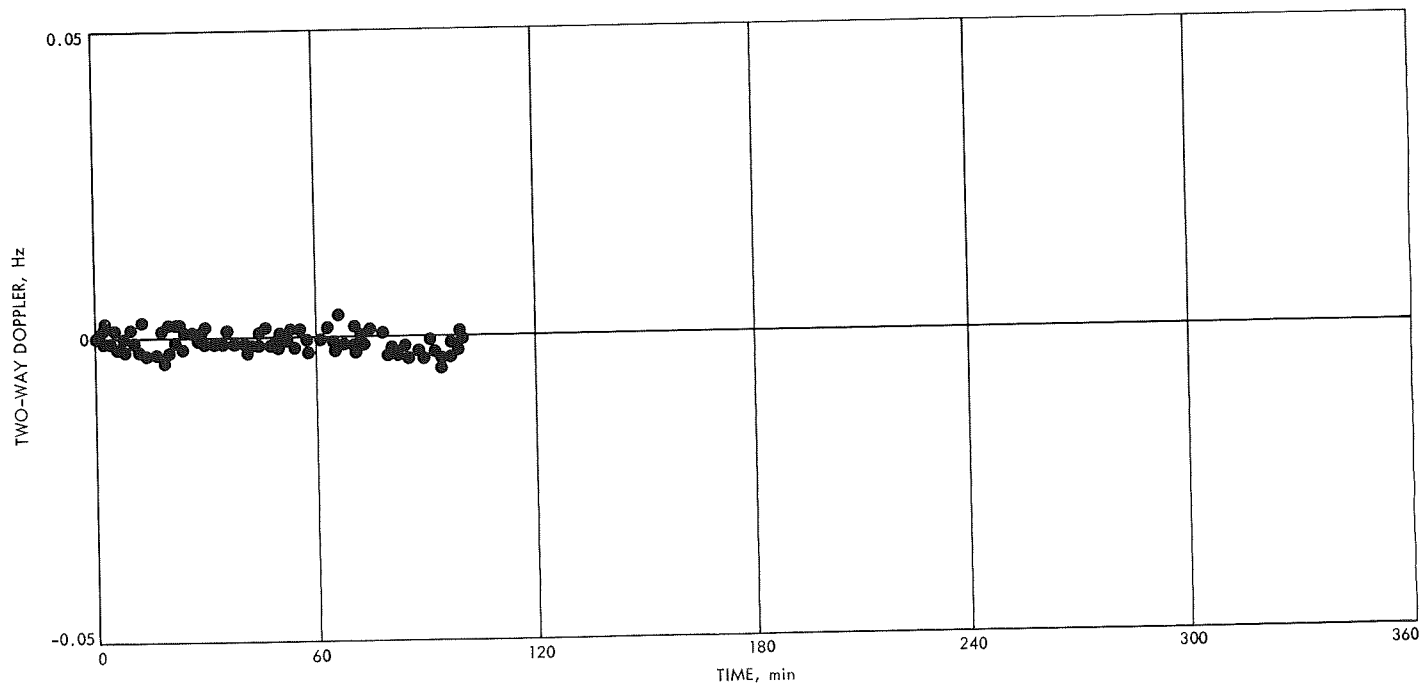


Fig. 90. Third pass two-way (CC3) doppler data received by DSS 42
(time from 11:42:00 GMT on November 9, 1967)

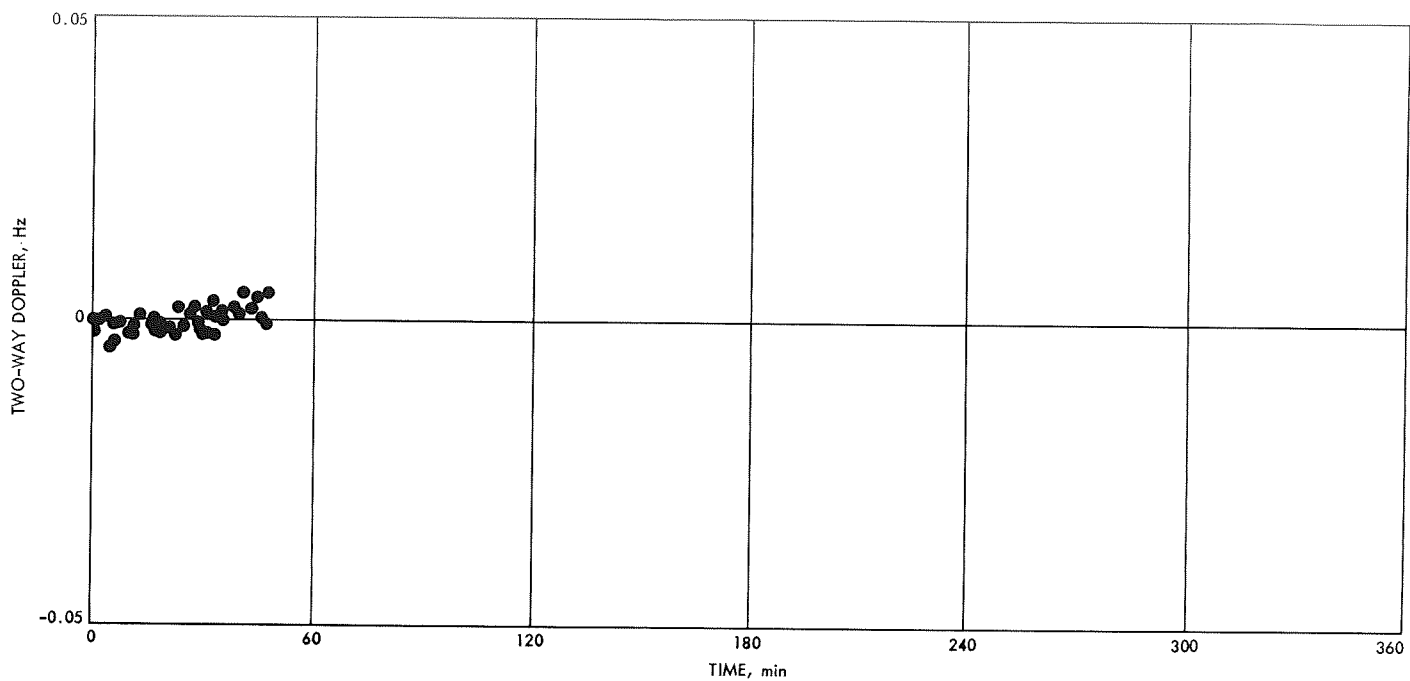


**Fig. 91. Postmidcourse maneuver doppler data received by DSS 11
(time from 02:45:00 GMT on November 8, 1967)**

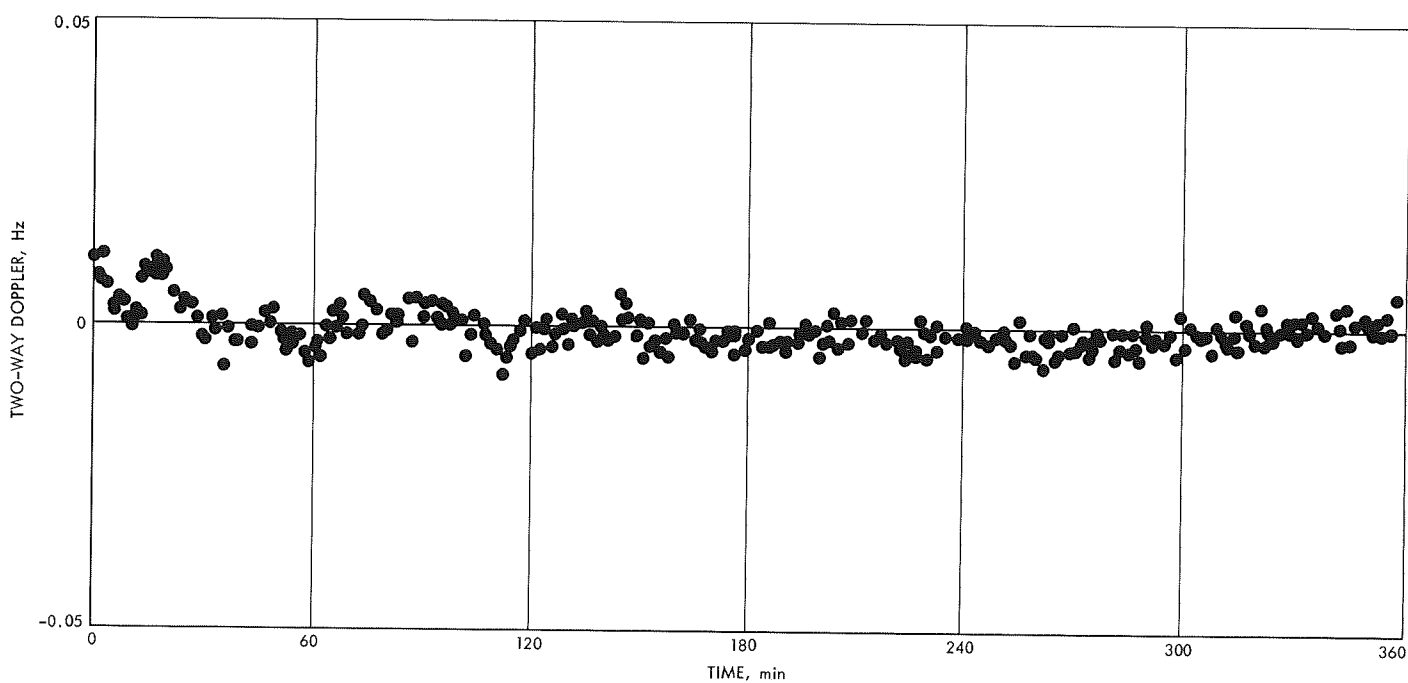


**Fig. 92. Second pass two-way (CC3) doppler data received by DSS 11
(time from 22:18:00 GMT on November 8, 1967)**

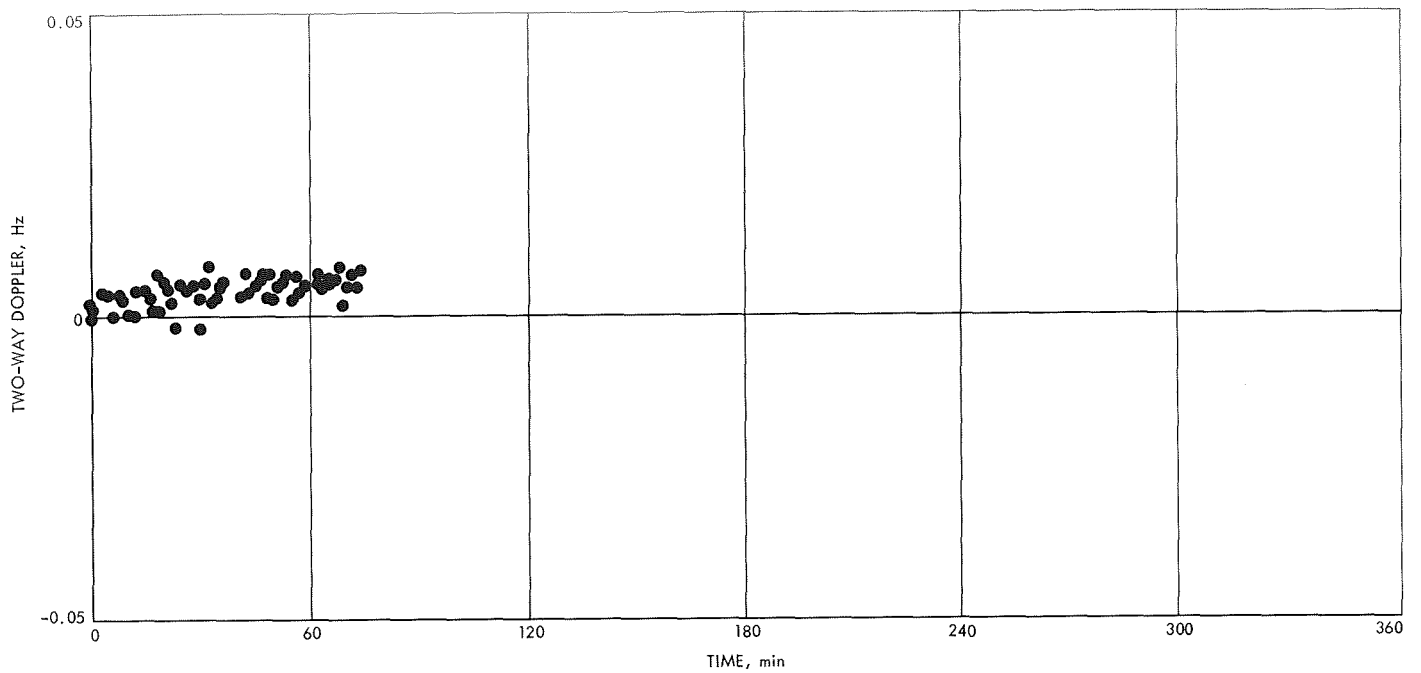


**Fig. 93. Second pass two-way (CC3) doppler data received by DSS 11
(time from 04:18:00 GMT on November 9, 1967)**

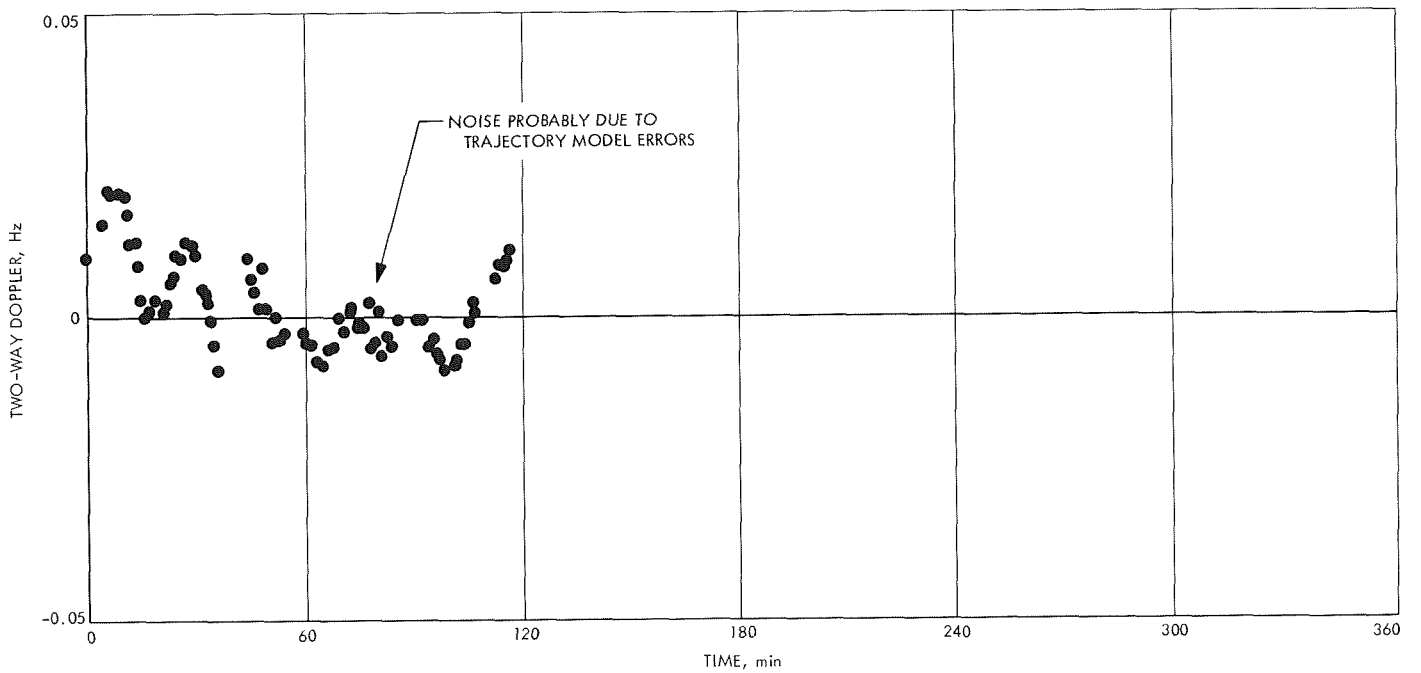


**Fig. 94. Third pass two-way (CC3) doppler data received by DSS 11
(time from 22:18:00 GMT on November 9, 1967)**

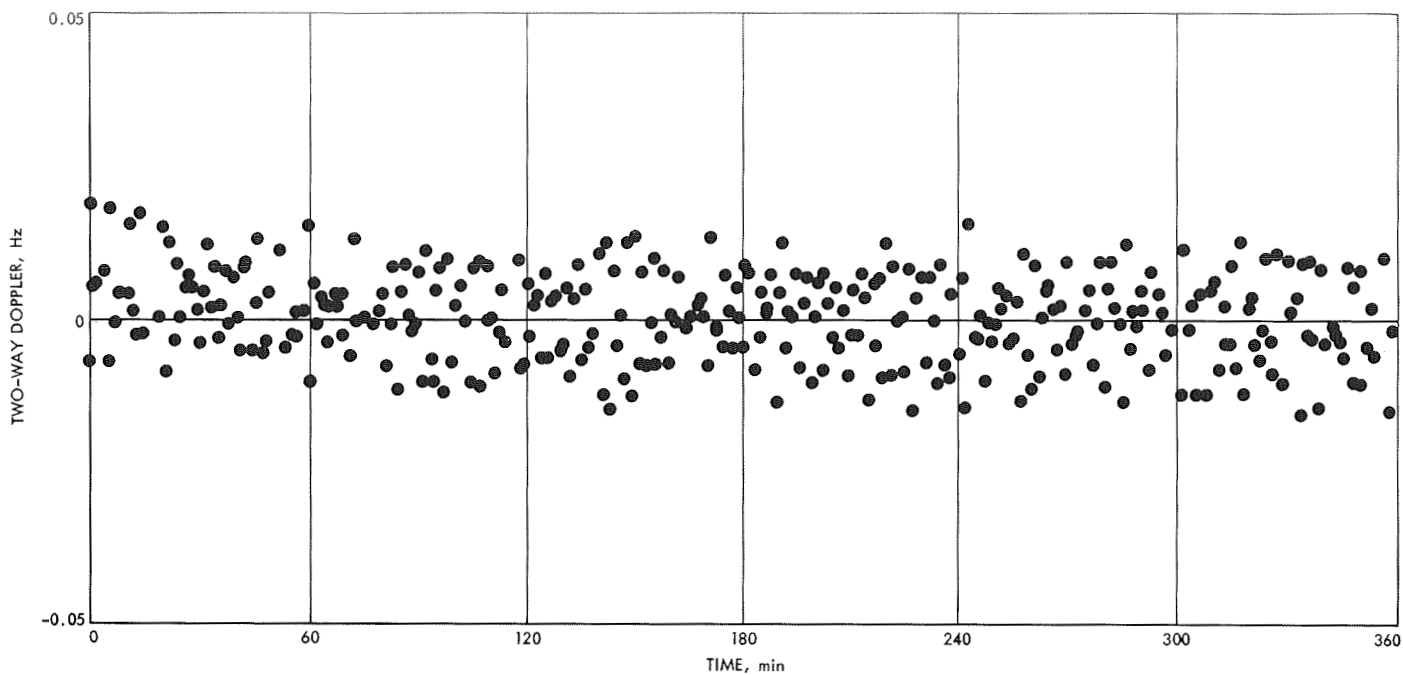


**Fig. 95. Postmidcourse maneuver doppler data received by DSS 51
(time from 13:33:00 GMT on November 8, 1967)**

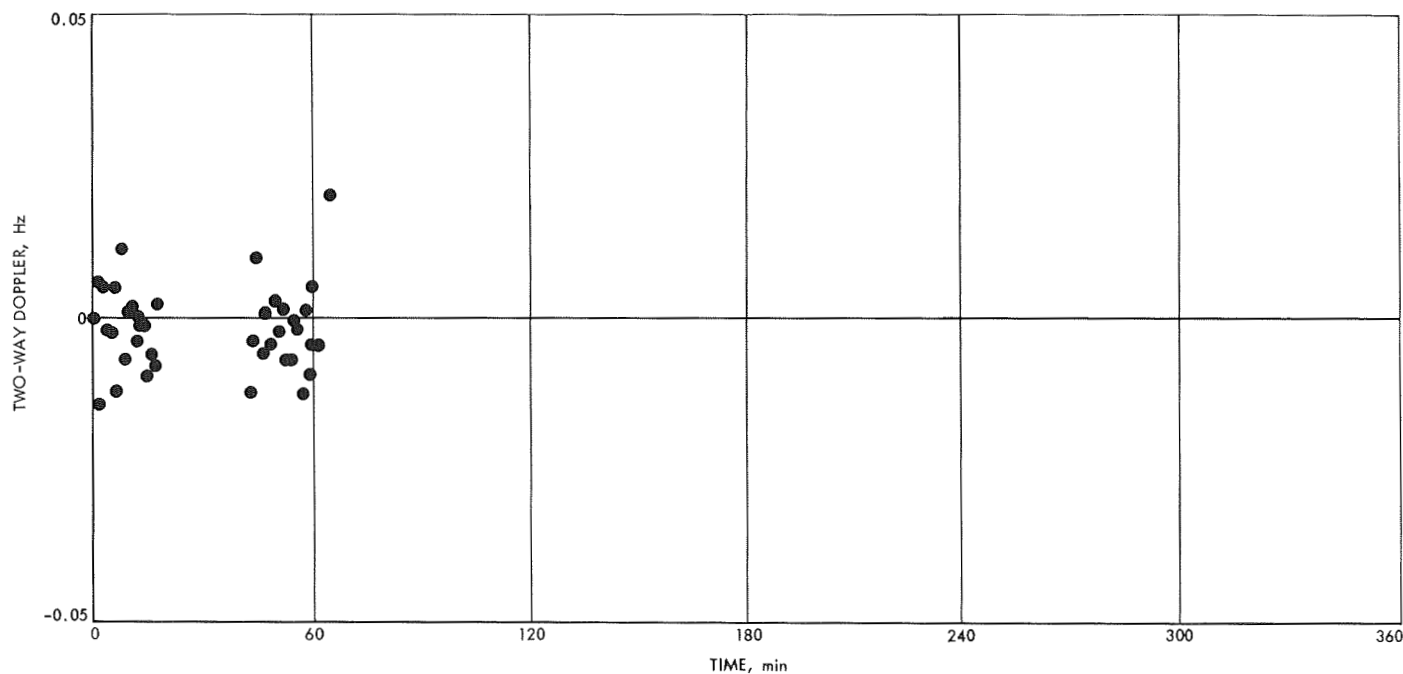


**Fig. 96. Second pass two-way (CC3) doppler data received by DSS 51
(time from 19:33:00 GMT on November 8, 1967)**

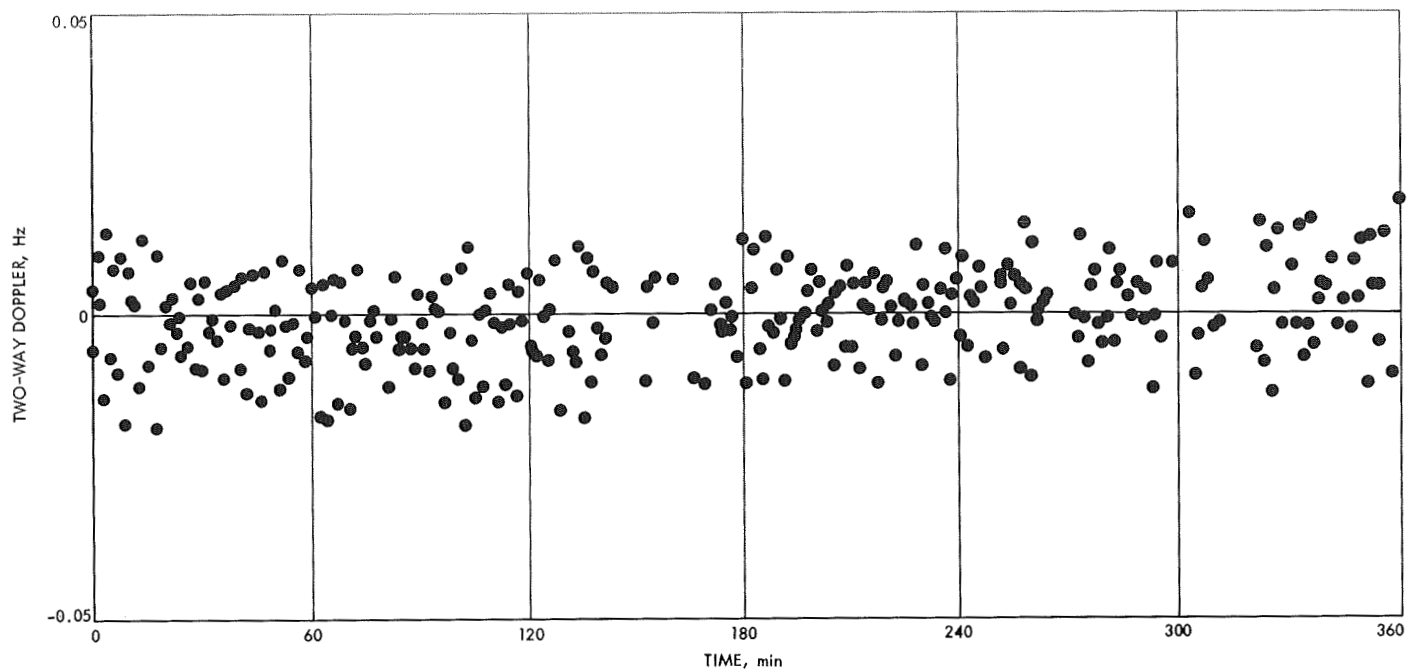


**Fig. 97. Third pass two-way (CC3) doppler data received by DSS 51
(time from 13:33:00 GMT on November 9, 1967)**

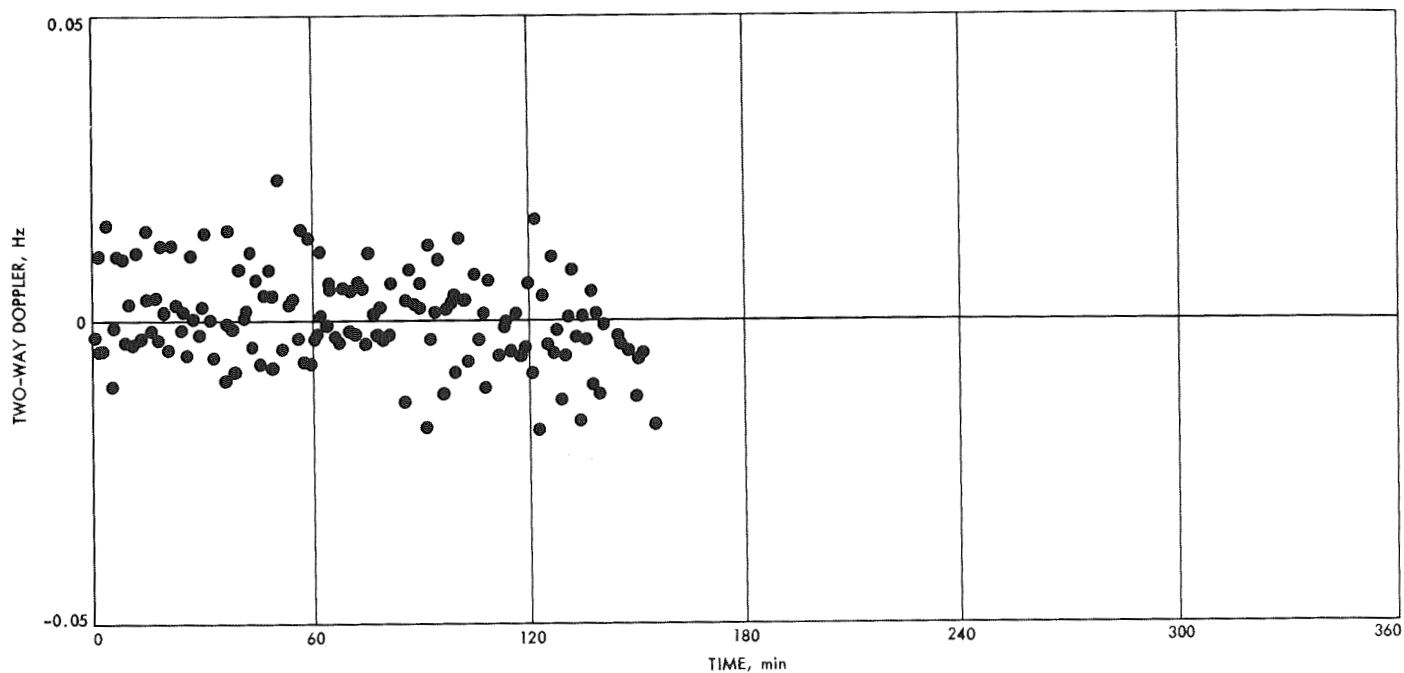


**Fig. 98. Third pass two-way (CC3) doppler data received by DSS 51
(time from 19:33:00 GMT on November 9, 1967)**

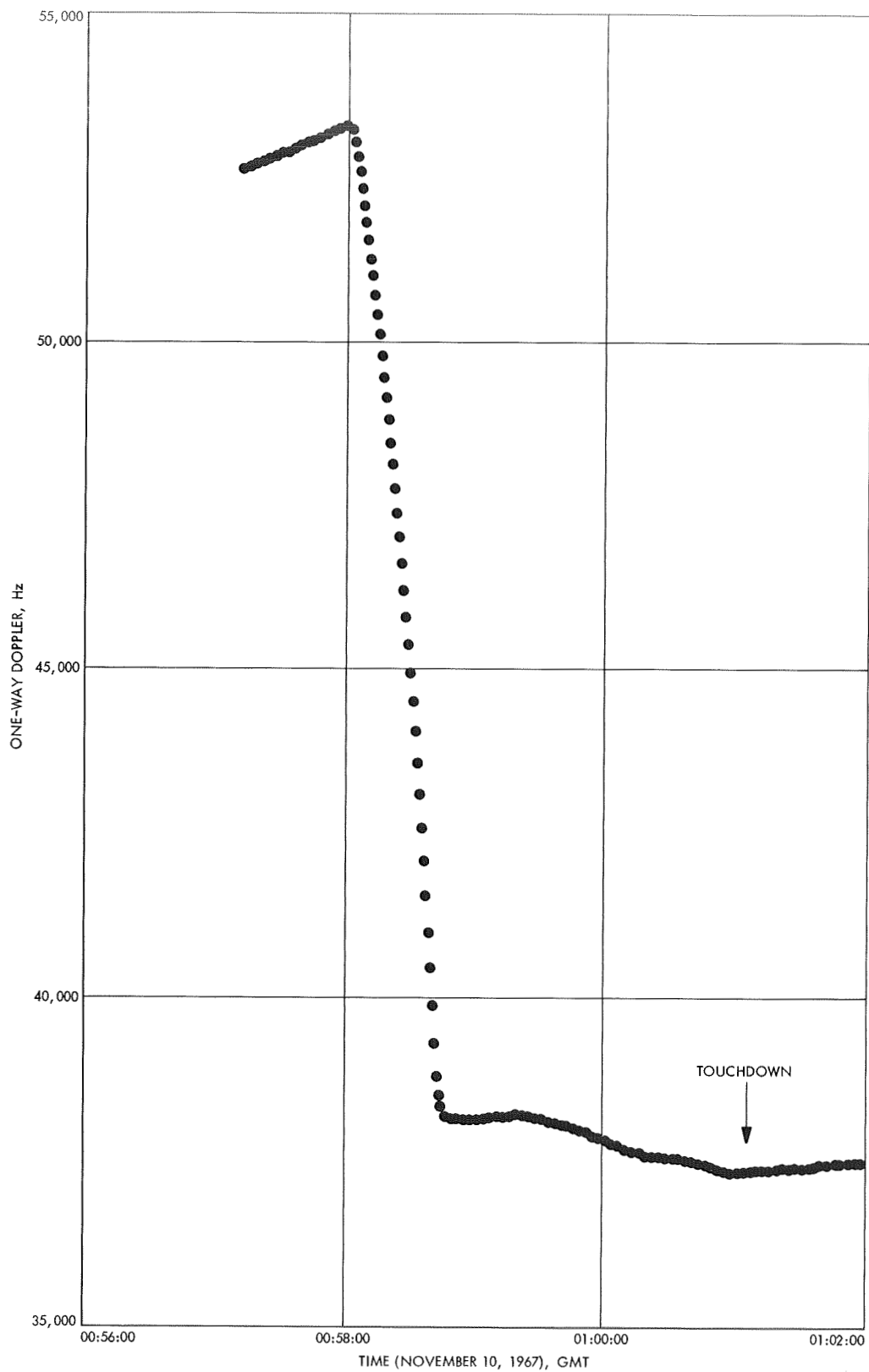


Fig. 99. Retrophase doppler data received by DSS 11

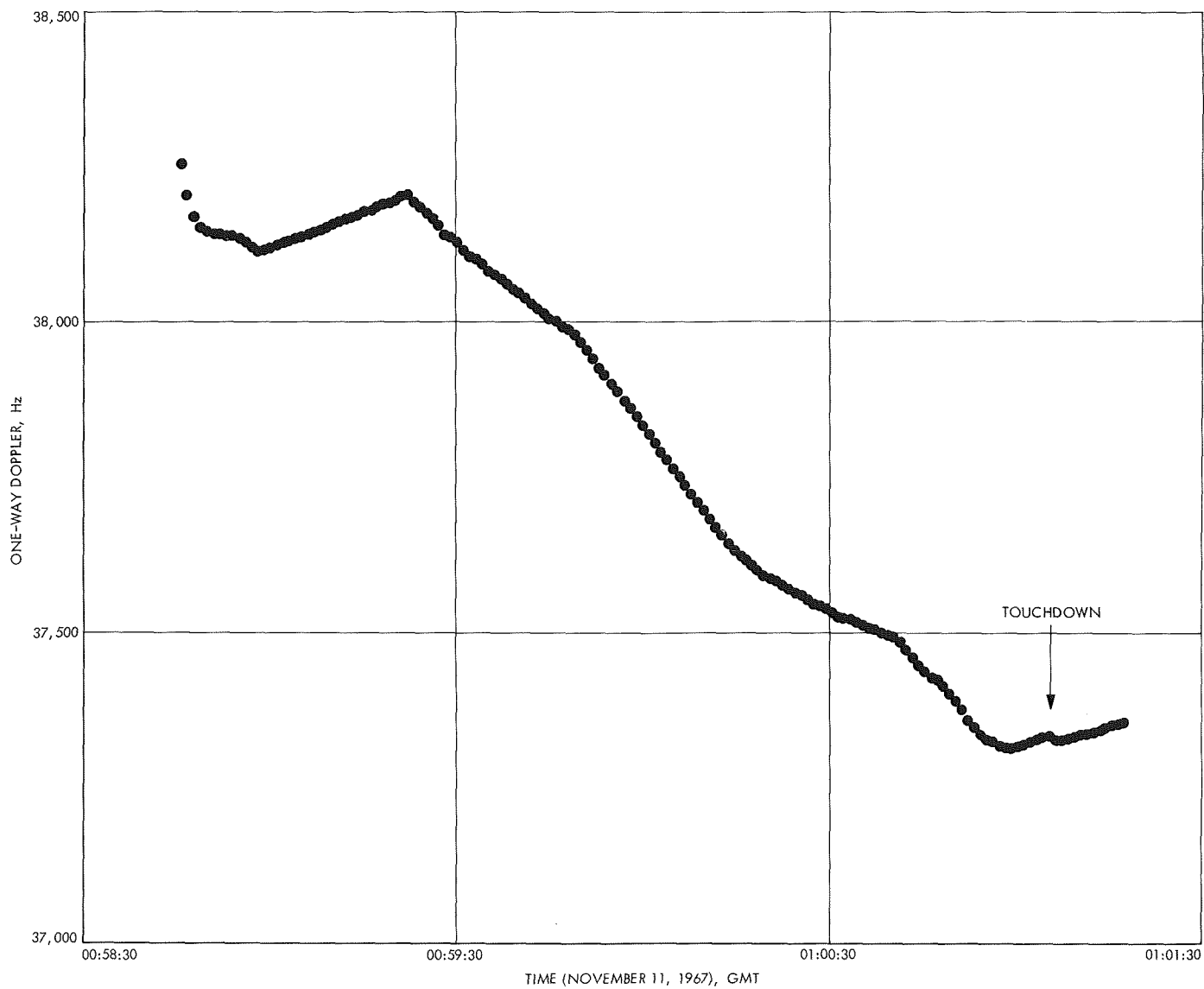


Fig. 100. Vernier phase doppler data received by DSS 11

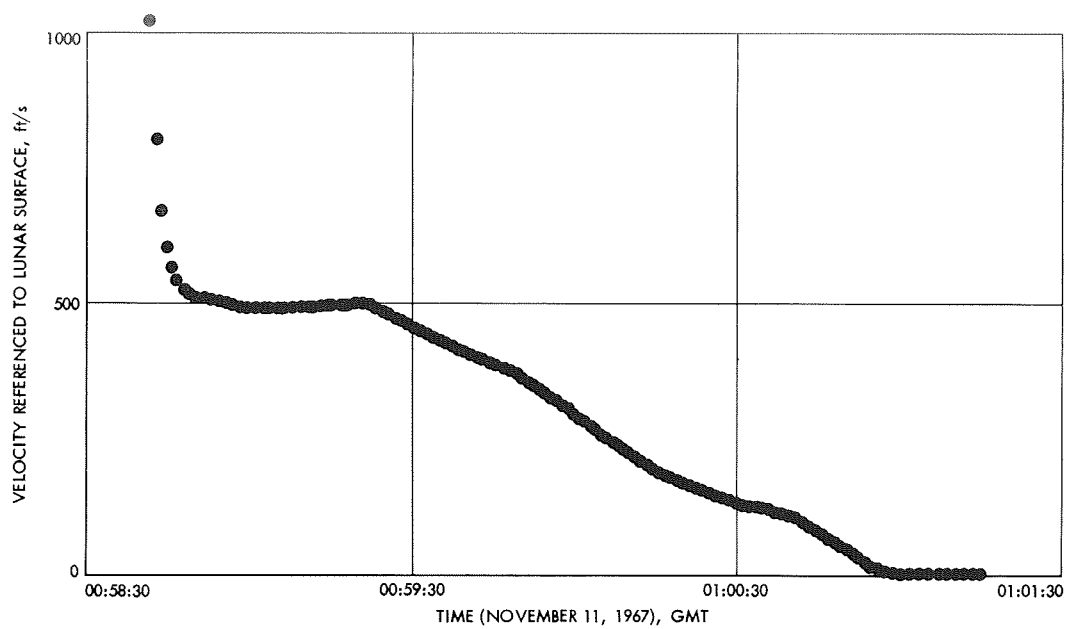


Fig. 101. Vernier phase velocity

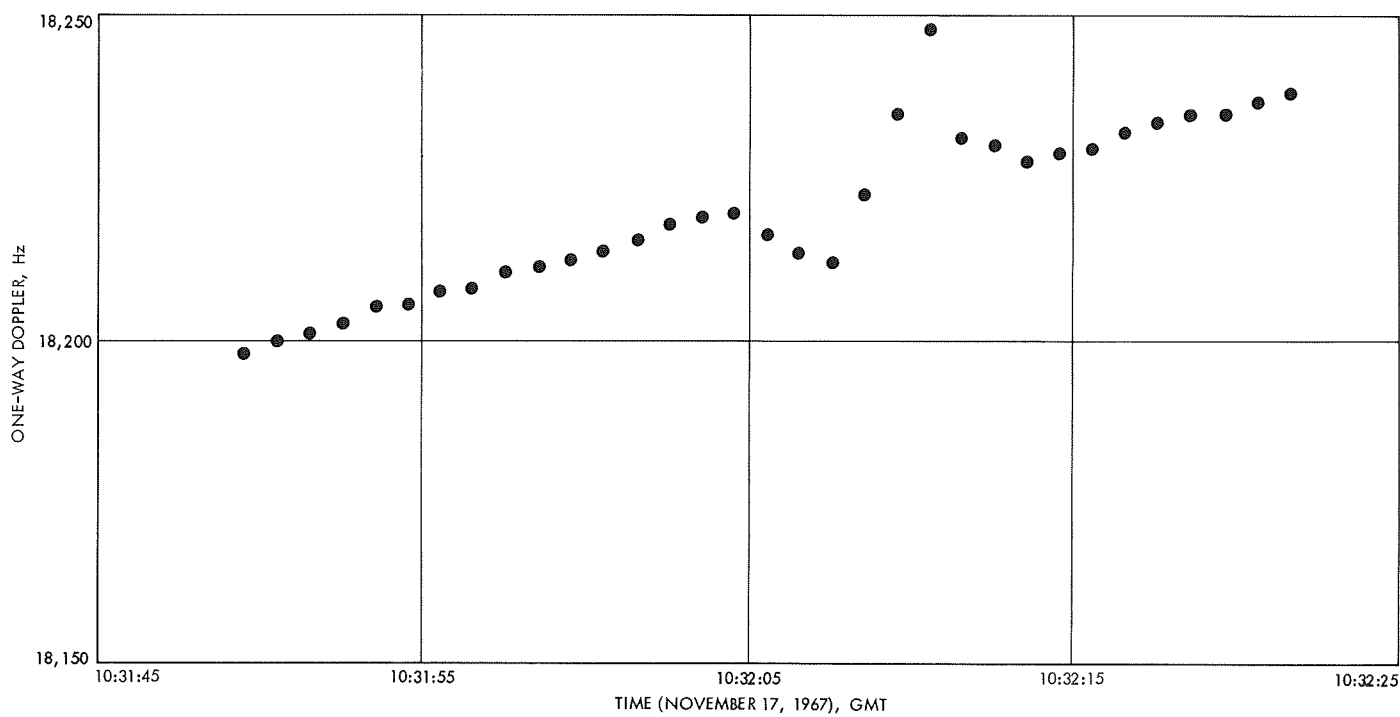


Fig. 102. Translation maneuver doppler data received by DSS 11

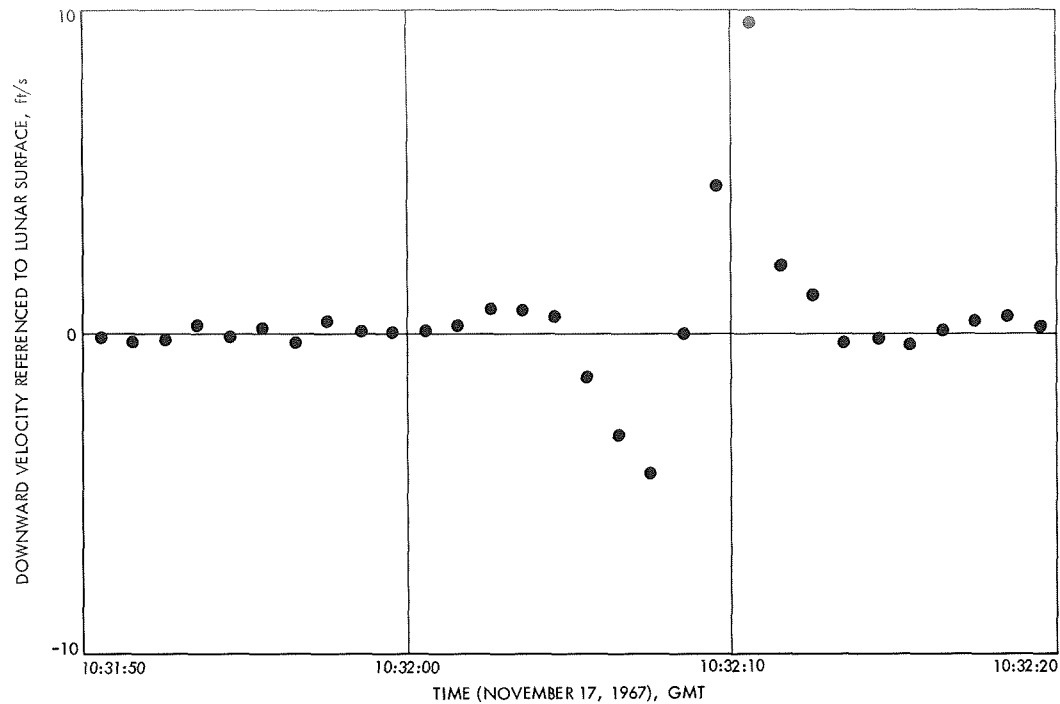


Fig. 103. Translation maneuver velocity

Table 63. Tracking data and predicts through touchdown

Time, GMT	One-way doppler frequency, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
00:56:26.5	1052079.60	11.63	2294986311.09	0.19218383E 01
00:56:27.5	1052090.53	10.93	2294986309.17	0.19230142E 01
00:56:28.5	1052104.15	13.62	2294986304.58	0.19241928E 01
00:56:29.5	1052114.84	10.69	2294986302.94	0.19253741E 01
00:56:30.5	1052126.44	11.60	2294986300.39	0.19265582E 01
00:56:31.5	1052138.49	12.05	2294986297.42	0.19277449E 01
00:56:32.5	1052150.96	12.46	2294986294.08	0.19289345E 01
00:56:33.5	1052162.74	11.78	2294986291.41	0.19301267E 01
00:56:34.5	1052173.23	10.40	2294986290.08	0.19313218E 01
00:56:35.5	1052185.87	12.64	2294986286.61	0.19325196E 01
00:56:36.5	1052197.42	11.55	2294986284.25	0.19337202E 01
00:56:37.5	1052210.03	12.61	2294986280.83	0.19349236E 01
00:56:38.5	1052221.57	11.54	2294986278.53	0.19361298E 01
00:56:39.5	1052234.14	12.57	2294986275.23	0.19373388E 01
00:56:40.5	1052246.80	12.66	2294986271.83	0.19385507E 01
00:56:41.5	1052258.24	11.44	2294986269.70	0.19397653E 01
00:56:42.5	1052269.78	11.54	2294986267.48	0.19409829E 01
00:56:43.5	1052282.02	12.24	2294986264.59	0.19422032E 01
00:56:44.5	1052293.85	11.83	2294986262.11	0.19434265E 01

Table 63 (contd)

Time, GMT	One-way doppler frequency, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
00:56:45.5	1052306.48	12.63	2294986258.89	0.19446526E 01
00:56:46.5	1052317.98	11.49	2294986256.78	0.19458817E 01
00:56:47.5	1052329.89	11.92	2294986254.30	0.19471136E 01
00:56:48.5	1052342.14	12.24	2294986251.52	0.19483484E 01
00:56:49.5	1052354.14	12.00	2294986248.98	0.19495862E 01
00:56:50.5	1052365.91	11.77	2294986246.72	0.19508269E 01
00:56:51.5	1052378.35	12.44	2294986243.78	0.19520706E 01
00:56:52.5	1052390.97	12.62	2294986240.72	0.19533172E 01
00:56:53.5	1052403.60	12.63	2294986237.66	0.19545668E 01
00:56:54.5	1052416.48	12.88	2294986234.36	0.19558194E 01
00:56:55.5	1052427.98	11.49	2294986232.48	0.19570749E 01
00:56:56.5	1052440.03	12.05	2294986230.05	0.19583335E 01
00:56:57.5	1052452.06	12.03	2294986227.67	0.19595951E 01
00:56:58.5	1052464.77	12.71	2294986224.66	0.19608598E 01
00:56:59.5	1052477.40	12.63	2294986221.73	0.19621274E 01
00:57:00.5	1052489.78	12.38	2294986219.08	0.19633981E 01
00:57:01.5	1052502.17	12.39	2294986216.44	0.19646719E 01
00:57:02.5	1052515.28	13.12	2294986213.09	0.19659487E 01
00:57:03.5	1052527.79	12.51	2294986210.37	0.19672287E 01
00:57:04.5	1052539.61	11.82	2294986208.39	0.19685117E 01
00:57:05.5	1052551.54	11.93	2294986206.30	0.19697979E 01
00:57:06.5	1052564.20	12.66	2294986203.52	0.19710871E 01
00:57:07.5	1052576.91	12.71	2294986200.72	0.19723795E 01
00:57:08.5	1052590.04	13.14	2294986197.48	0.19736751E 01
00:57:09.5	1052602.89	12.85	2294986194.56	0.19749738E 01
00:57:10.5	1052614.98	12.08	2294986192.45	0.19762758E 01
00:57:11.5	1052627.89	12.92	2294986189.52	0.19775809E 01
00:57:12.5	1052640.78	12.88	2294986186.67	0.19788892E 01
00:57:13.5	1052653.79	13.01	2294986183.69	0.19802007E 01
00:57:14.5	1052666.80	13.01	2294986180.73	0.19815154E 01
00:57:15.5	1052679.92	13.12	2294986177.72	0.19828334E 01
00:57:16.5	1052692.07	12.16	2294986175.67	0.19841547E 01
00:57:17.5	1052704.03	11.96	2294986173.84	0.19854792E 01
00:57:18.5	1052717.55	13.52	2294986170.50	0.19868069E 01
00:57:19.5	1052730.43	12.88	2294986167.81	0.19881380E 01
00:57:20.5	1052743.28	12.85	2294986165.17	0.19894724E 01
00:57:21.5	1052756.51	13.22	2294986162.19	0.19908101E 01
00:57:22.5	1052769.56	13.05	2294986159.41	0.19921511E 01
00:57:23.5	1052783.16	13.60	2294986156.09	0.19934954E 01
00:57:24.5	1052795.33	12.17	2294986154.25	0.19948431E 01
00:57:25.5	1052808.96	13.63	2294986150.97	0.19961942E 01
00:57:26.5	1052821.73	12.77	2294986148.56	0.19975487E 01
00:57:27.5	1052833.71	11.98	2294986146.97	0.19989066E 01

Table 63 (contd)

Time, GMT	One-way doppler frequency, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
00:57:28.5	1052847.65	13.95	2294986143.45	0.20002679E 01
00:57:29.5	1052861.49	13.84	2294986140.06	0.20016326E 01
00:57:30.5	1052874.63	13.14	2294986137.39	0.20030007E 01
00:57:31.5	1052887.33	12.69	2294986135.20	0.20043723E 01
00:57:32.5	1052901.57	14.24	2294986131.47	0.20057473E 01
00:57:33.5	1052913.91	12.34	2294986129.70	0.20071259E 01
00:57:34.5	1052925.24	11.34	2294986128.94	0.20085079E 01
00:57:35.5	1052938.96	13.72	2294986125.83	0.20098935E 01
00:57:36.5	1052952.23	13.27	2294986123.20	0.20112825E 01
00:57:37.5	1052965.47	13.24	2294986120.59	0.20126752E 01
00:57:38.5	1052978.71	13.23	2294986118.05	0.20140713E 01
00:57:39.5	1052992.52	13.81	2294986114.98	0.20154711E 01
00:57:40.5	1053006.15	13.63	2294986112.08	0.20168744E 01
00:57:41.5	1053018.69	12.55	2294986110.30	0.20182813E 01
00:57:42.5	1053032.45	13.76	2294986107.34	0.20196919E 01
00:57:43.5	1053045.96	13.51	2294986104.66	0.20211061E 01
00:57:44.5	1053059.69	13.74	2294986101.78	0.20225239E 01
00:57:45.5	1053072.26	12.57	2294986100.09	0.20239454E 01
00:57:46.5	1053085.64	13.38	2294986097.61	0.20253705E 01
00:57:47.5	1053099.34	13.70	2294986094.86	0.20267994E 01
00:57:48.5	1053114.15	14.81	2294986091.02	0.20282319E 01
00:57:49.5	1053128.24	14.09	2294986087.94	0.20296682E 01
00:57:50.5	1053141.84	13.60	2294986085.36	0.20311082E 01
00:57:50.5	1053141.84	13.60	2294986080.23 ^a	0.20304378E 01
00:57:51.5	1053155.45	13.61	2294986077.53	0.20318622E 01
00:57:52.5	1053169.19	13.74	2294986074.81	0.20333040E 01
00:57:53.5	1053183.53	14.34	2294986072.09	0.20348200E 01
00:57:54.5	1053198.26	14.74	2294986069.39	0.20363927E 01
00:57:55.5	1053211.65	13.39	2294986066.67	0.20377865E 01
00:57:56.5	1053224.84	13.19	2294986063.95	0.20391542E 01
00:57:57.5	1053238.62	13.78	2294986061.25	0.20406004E 01
00:57:58.5	1053253.05	14.43	2294986058.53	0.20421316E 01
00:57:59.5	1053266.38	13.33	2294986055.81	0.20435168E 01
00:58:00.5	1053280.64	14.26	2294986053.11	0.20450284E 01
00:58:01.5	1053294.77	14.13	2294986050.39	0.20465182E 01
00:58:02.5	1053308.95	14.18	2294986047.70	0.20480189E 01
00:58:03.5	1053320.28	11.34	2294986044.98	0.20491445E 01
00:58:04.5	1053253.88	-66.40	2294986042.27	0.20401140E 01
00:58:05.5	1053043.47	-210.41	2294986039.56	0.20122765E 01
00:58:06.5	1052822.35	-221.13	2294986036.86	0.19830387E 01

^aFrequencies hereafter are extrapolated.

Table 63 (contd)

Time, GMT	One-way doppler frequency, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
00:58:07.5	1052589.89	-232.45	2294986034.14	0.19523175E 01
00:58:08.5	1052347.97	-241.93	2294986031.44	0.19203596E 01
00:58:09.5	1052096.22	-251.75	2294986028.73	0.18871235E 01
00:58:10.5	1051834.62	-261.60	2294986026.03	0.18525961E 01
00:58:11.5	1051564.14	-270.48	2294986023.33	0.18169104E 01
00:58:12.5	1051286.41	-277.73	2294986020.61	0.17802758E 01
00:58:13.5	1051002.05	-284.36	2294986017.92	0.17427797E 01
00:58:14.5	1050711.09	-290.96	2294986015.20	0.17044175E 01
00:58:15.5	1050413.62	-297.47	2294986012.50	0.16652047E 01
00:58:16.5	1050110.30	-303.32	2294986009.80	0.16252306E 01
00:58:17.5	1049800.73	-309.58	2294986007.09	0.15844364E 01
00:58:18.5	1049484.52	-316.20	2294986004.39	0.15427783E 01
00:58:19.5	1049160.10	-324.42	2294986001.69	0.15000471E 01
00:58:20.5	1048827.16	-332.95	2294985998.98	0.14562012E 01
00:58:21.5	1048483.80	-343.36	2294985996.30	0.14109986E 01
00:58:22.5	1048131.15	-352.65	2294985993.58	0.13645745E 01
00:58:23.5	1047767.61	-363.53	2294985990.87	0.13167347E 01
00:58:24.5	1047395.41	-372.20	2294985988.19	0.12677629E 01
00:58:25.5	1047011.54	-383.87	2294985985.48	0.12172641E 01
00:58:26.5	1046617.24	-394.30	2294985982.77	0.11654020E 01
00:58:27.5	1046213.03	-404.21	2294985980.08	0.11122509E 01
00:58:28.5	1045798.64	-414.39	2294985977.37	0.10577669E 01
00:58:29.5	1045373.06	-425.58	2294985974.69	0.10018215E 01
00:58:30.5	1044937.53	-435.53	2294985971.98	0.94457606E 00
00:58:31.5	1044490.32	-447.21	2294985969.28	0.88580153E 00
00:58:32.5	1044031.20	-459.12	2294985966.59	0.82547612E 00
00:58:33.5	1043558.37	-472.83	2294985963.89	0.76335770E 00
00:58:34.5	1043072.43	-485.94	2294985961.19	0.69952698E 00
00:58:35.5	1042572.05	-500.37	2294985958.50	0.63381163E 00
00:58:36.5	1042055.93	-516.13	2294985955.80	0.56603934E 00
00:58:37.5	1041524.72	-531.21	2294985953.09	0.49629299E 00
00:58:38.5	1040977.86	-546.85	2294985950.41	0.42450714E 00
00:58:39.5	1040418.82	-559.04	2294985947.70	0.35112679E 00
00:58:40.5	1039854.60	-564.22	2294985945.02	0.27707241E 00
00:58:41.5	1039291.36	-563.24	2294985942.33	0.20314674E 00
00:58:42.5	1038791.03	-500.33	2294985939.62	0.13743357E 00
00:58:43.5	1038486.31	-304.72	2294985936.94	0.97276252E-01
00:58:44.5	1038334.73	-151.58	2294985934.23	0.77123429E-01
00:58:45.5	1038251.19	-83.54	2294985931.55	0.65859312E-01
00:58:46.5	1038199.81	-51.37	2294985928.86	0.58798517E-01
00:58:47.5	1038168.47	-31.34	2294985926.16	0.54350892E-01

Table 63 (contd)

Time, GMT	One-way doppler frequency, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
00:58:48.5	1038149.57	-18.90	2294985923.48	0.51532681E-01
00:58:49.5	1038141.75	-7.82	2294985920.78	0.50158477E-01
00:58:50.5	1038139.29	-2.46	2294985918.08	0.49482281E-01
00:58:51.5	1038138.51	-0.78	2294985915.41	0.49032937E-01
00:58:52.5	1038137.26	-1.25	2294985912.70	0.48515975E-01
00:58:53.5	1038135.83	-1.43	2294985910.02	0.47979380E-01
00:58:54.5	1038131.10	-4.73	2294985907.33	0.47008712E-01
00:58:55.5	1038125.25	-5.85	2294985904.64	0.45891898E-01
00:58:56.5	1038118.08	-7.17	2294985901.95	0.44607125E-01
00:58:57.5	1038110.71	-7.37	2294985899.27	0.43291815E-01
00:58:58.5	1038111.48	0.77	2294985896.58	0.43040968E-01
00:58:59.5	1038116.93	5.45	2294985893.89	0.43403060E-01
00:59:00.5	1038121.12	4.20	2294985891.20	0.43599375E-01
00:59:01.5	1038124.47	3.35	2294985888.52	0.43686626E-01
00:59:02.5	1038127.04	2.57	2294985885.83	0.43669176E-01
00:59:03.5	1038130.60	3.55	2294985883.14	0.43784784E-01
00:59:04.5	1038133.78	3.18	2294985880.45	0.43848041E-01
00:59:05.5	1038137.52	3.74	2294985877.78	0.43987643E-01
00:59:06.5	1038141.91	4.38	2294985875.09	0.44210133E-01
00:59:07.5	1038146.37	4.47	2294985872.39	0.44439167E-01
00:59:08.5	1038150.38	4.00	2294985869.72	0.44615850E-01
00:59:09.5	1038154.72	4.34	2294985867.03	0.44829616E-01
00:59:10.5	1038159.20	4.48	2294985864.36	0.45065194E-01
00:59:11.5	1038161.85	2.66	2294985861.67	0.45063012E-01
00:59:12.5	1038164.54	2.69	2294985858.98	0.45063012E-01
00:59:13.5	1038168.77	4.23	2294985856.31	0.45265871E-01
00:59:14.5	1038172.83	4.06	2294985853.62	0.45444736E-01
00:59:15.5	1038177.31	4.48	2294985850.94	0.45680314E-01
00:59:16.5	1038182.06	4.75	2294985848.27	0.45950792E-01
00:59:17.5	1038185.73	3.67	2294985845.58	0.46079488E-01
00:59:18.5	1038188.67	2.94	2294985842.91	0.46114388E-01
00:59:19.5	1038192.90	4.22	2294985840.23	0.46317247E-01
00:59:20.5	1038198.26	5.36	2294985837.55	0.46666251E-01
00:59:21.5	1038199.60	1.34	2294985834.87	0.46491749E-01
00:59:22.5	1038189.82	-9.77	2294985832.19	0.44864516E-01
00:59:23.5	1038181.82	-8.00	2294985829.50	0.43468498E-01
00:59:24.5	1038172.36	-9.46	2294985826.84	0.41887072E-01
00:59:25.5	1038163.22	-9.15	2294985824.16	0.40338365E-01
00:59:26.5	1038151.16	-12.06	2294985821.47	0.38412297E-01
00:59:27.5	1038137.98	-13.18	2294985818.81	0.36344446E-01
00:59:28.5	1038131.83	-6.15	2294985816.12	0.35190550E-01

Table 63 (contd)

Time, GMT	One-way doppler frequency, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
00:59:29.5	1038123.78	-8.05	2294985813.45	0.33790170E-01
00:59:30.5	1038110.79	-12.99	2294985810.78	0.31744132E-01
00:59:31.5	1038100.97	-9.82	2294985808.09	0.30110355E-01
00:59:32.5	1038097.57	-3.40	2294985805.44	0.29318551E-01
00:59:33.5	1038089.51	-8.06	2294985802.75	0.27913808E-01
00:59:34.5	1038079.34	-10.17	2294985800.08	0.26236406E-01
00:59:35.5	1038071.69	-7.65	2294985797.41	0.24890558E-01
00:59:36.5	1038065.75	-5.94	2294985794.73	0.23765019E-01
00:59:37.5	1038057.72	-8.03	2294985792.06	0.22364638E-01
00:59:38.5	1038046.95	-10.77	2294985789.39	0.20610891E-01
00:59:39.5	1038040.55	-6.39	2294985786.72	0.19426458E-01
00:59:40.5	1038034.31	-6.24	2294985784.05	0.18259474E-01
00:59:41.5	1038025.07	-9.24	2294985781.37	0.16704223E-01
00:59:42.5	1038017.04	-8.03	2294985778.70	0.15306024E-01
00:59:43.5	1038009.12	-7.92	2294985776.05	0.13925276E-01
00:59:44.5	1038002.23	-6.89	2294985773.36	0.12673222E-01
00:59:45.5	1037996.59	-5.64	2294985770.69	0.11589127E-01
00:59:46.5	1037987.60	-9.00	2294985768.03	0.10066596E-01
00:59:47.5	1037981.15	-6.45	2294985765.36	0.88756182E-02
00:59:48.5	1037973.84	-7.30	2294985762.70	0.75755768E-02
00:59:49.5	1037962.00	-11.84	2294985760.03	0.56800467E-02
00:59:50.5	1037948.78	-13.22	2294985757.36	0.36034705E-02
00:59:51.5	1037935.06	-13.72	2294985754.70	0.14614559E-02
00:59:52.5	1037920.51	-14.55	2294985752.02	-0.78962246E-03
00:59:53.5	1037907.68	-12.83	2294985749.34	-0.28138480E-02
00:59:54.5	1037894.97	-12.71	2294985746.70	-0.48184420E-02
00:59:55.5	1037881.46	-13.51	2294985744.03	-0.69321000E-02
00:59:56.5	1037867.74	-13.72	2294985741.37	-0.90719332E-02
00:59:57.5	1037854.46	-13.28	2294985738.70	-0.11155053E-01
00:59:58.5	1037841.80	-12.65	2294985736.03	-0.13157466E-01
00:59:59.5	1037828.41	-13.39	2294985733.37	-0.15253674E-01
01:00:00.5	1037814.48	-13.93	2294985730.70	-0.17424045E-01
01:00:01.5	1037800.58	-13.89	2294985728.03	-0.19587872E-01
01:00:02.5	1037785.88	-14.71	2294985725.39	-0.21852038E-01
01:00:03.5	1037772.97	-12.91	2294985722.72	-0.23887170E-01
01:00:04.5	1037759.35	-13.62	2294985720.05	-0.26016097E-01
01:00:05.5	1037745.68	-13.67	2294985717.39	-0.28149386E-01
01:00:06.5	1037732.42	-13.26	2294985714.73	-0.30230325E-01
01:00:07.5	1037718.39	-14.02	2294985712.08	-0.32407240E-01
01:00:08.5	1037705.19	-13.20	2294985709.41	-0.34481635E-01
01:00:09.5	1037691.55	-13.64	2294985706.75	-0.36610562E-01

Table 63 (contd)

Time, GMT	One-way doppler frequency, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
01:00:10.5	1037677.21	-14.34	2294985704.09	-0.38831102E-01
01:00:11.5	1037663.72	-13.49	2294985701.44	-0.40938217E-01
01:00:12.5	1037650.80	-12.92	2294985698.77	-0.42975530E-01
01:00:13.5	1037635.78	-15.02	2294985696.12	-0.45283321E-01
01:00:14.5	1037625.03	-10.75	2294985693.45	-0.47037069E-01
01:00:15.5	1037616.01	-9.02	2294985690.80	-0.48561781E-01
01:00:16.5	1037609.88	-6.13	2294985688.14	-0.49709133E-01
01:00:17.5	1037600.32	-9.55	2294985685.48	-0.51305829E-01
01:00:18.5	1037593.34	-6.98	2294985682.84	-0.52562244E-01
01:00:19.5	1037585.65	-7.70	2294985680.17	-0.53916818E-01
01:00:20.5	1037579.95	-5.70	2294985677.52	-0.55007457E-01
01:00:21.5	1037575.38	-4.56	2294985674.87	-0.55949768E-01
01:00:22.5	1037568.41	-6.98	2294985672.20	-0.57208366E-01
01:00:23.5	1037561.12	-7.28	2294985669.55	-0.58508407E-01
01:00:24.5	1037555.92	-5.21	2294985666.91	-0.59533607E-01
01:00:25.5	1037549.50	-6.42	2294985664.25	-0.60720222E-01
01:00:26.5	1037543.39	-6.11	2294985661.61	-0.61863212E-01
01:00:27.5	1037536.76	-6.63	2294985658.94	-0.63076002E-01
01:00:28.5	1037531.64	-5.12	2294985656.28	-0.64092477E-01
01:00:29.5	1037527.67	-3.97	2294985653.64	-0.64956263E-01
01:00:30.5	1037521.63	-6.04	2294985650.98	-0.66090528E-01
01:00:31.5	1037515.90	-5.74	2294985648.33	-0.67187710E-01
01:00:32.5	1037514.00	-1.90	2294985645.69	-0.67778836E-01
01:00:33.5	1037510.03	-3.97	2294985643.03	-0.68646985E-01
01:00:34.5	1037506.03	-4.00	2294985640.37	-0.69517315E-01
01:00:35.5	1037501.40	-4.63	2294985637.73	-0.70466170E-01
01:00:36.5	1037498.07	-3.33	2294985635.08	-0.71247068E-01
01:00:37.5	1037493.77	-4.30	2294985632.44	-0.82152298E-01
01:00:38.5	1037489.55	-4.21	2294985629.78	-0.73050984E-01
01:00:39.5	1037485.55	-4.00	2294985627.14	-0.73919133E-01
01:00:40.5	1037482.01	-3.54	2294985624.50	-0.74726205E-01
01:00:41.5	1037474.80	-7.21	2294985621.84	-0.76015340E-01
01:00:42.5	1037461.73	-13.07	2294985619.19	-0.78070104E-01
01:00:43.5	1037449.15	-12.59	2294985616.55	-0.80059429E-01
01:00:44.5	1037437.74	-11.40	2294985613.91	-0.81893883E-01
01:00:45.5	1037426.78	-10.96	2294985611.27	-0.83669443E-01
01:00:46.5	1037417.85	-8.93	2294985608.61	-0.85183250E-01
01:00:47.5	1037410.99	-6.87	2294985605.97	-0.86424397E-01
01:00:48.5	1037401.62	-9.37	2294985603.33	-0.87994917E-01
01:00:49.5	1037390.80	-10.82	2294985600.69	-0.89750845E-01
01:00:50.5	1037378.12	-12.68	2294985598.03	-0.91755439E-01

Table 63 (contd)

Time, GMT	One-way doppler frequency, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
01:00:51.5	1037363.76	-14.36	2294985595.39	-0.93975980E-01
01:00:52.5	1037349.21	-14.55	2294985592.75	-0.96222695E-01
01:00:53.5	1037335.07	-14.13	2294985590.09	-0.98417061E-01
01:00:54.5	1037323.12	-11.95	2294985587.47	-0.10032132E 00
01:00:55.5	1037317.47	-5.65	2294985584.81	-0.10140323E 00
01:00:56.5	1037312.94	-4.53	2294985582.19	-0.10233900E 00
01:00:57.5	1037308.79	-4.15	2294985579.55	-0.10322678E 00
01:00:58.5	1037303.45	-5.34	2294985576.89	-0.10427161E 00
01:00:59.5	1037301.73	-1.72	2294985574.27	-0.10483874E 00
01:01:00.5	1037305.53	3.80	2294985571.62	-0.10468823E 00
01:01:01.5	1037309.42	3.89	2294985568.97	-0.10452682E 00
01:01:02.5	1037312.34	2.92	2294985566.34	-0.10448756E 00
01:01:03.5	1037315.01	2.67	2294985563.70	-0.10448319E 00
01:01:04.5	1037321.00	5.99	2294985561.06	-0.10404476E 00
01:01:05.5	1037319.96	-1.04	2294985558.42	-0.10452682E 00
01:01:06.5	1037314.19	-5.77	2294985555.78	-0.10562618E 00
01:01:07.5	1037314.40	0.22	2294985553.16	-0.10594247E 00
01:01:08.5	1037317.46	3.06	2294985550.52	-0.10588575E 00
01:01:09.5	1037320.02	2.56	2294985547.87	-0.10589666E 00
01:01:10.5	1037323.02	3.00	2294985545.25	-0.10584867E 00
01:01:11.5	1037325.37	2.35	2294985542.61	-0.10588575E 00
01:01:12.5	1037328.01	2.64	2294985539.97	-0.10588575E 00
01:01:13.5	1037331.32	3.30	2294985537.34	-0.10579632E 00
01:01:14.5	1037333.74	2.42	2294985534.70	-0.10582468E 00
01:01:15.5	1037337.03	3.29	2294985532.08	-0.10573961E 00
01:01:16.5	1037339.67	2.64	2294985529.44	-0.10573961E 00
01:01:17.5	1037341.91	2.24	2294985526.80	-0.10578978E 00
01:01:18.5	1037346.15	4.24	2294985524.17	-0.10558038E 00
01:01:19.5	1037348.48	2.34	2294985521.53	-0.10562182E 00
01:01:20.5	1037350.36	1.88	2294985518.91	-0.10571780E 00
01:01:21.5	1037353.97	3.61	2294985516.28	-0.10558910E 00
01:01:22.5	1037355.56	1.60	2294985513.64	-0.10572434E 00
01:01:23.5	1037358.77	3.20	2294985511.00	-0.10565236E 00
01:01:24.5	1037361.70	2.93	2294985508.39	-0.10561091E 00
01:01:25.5	1037365.04	3.34	2294985505.75	-0.10551930E 00
01:01:26.5	1037367.00	1.96	2294985503.12	-0.10560437E 00
01:01:27.5	1037369.18	2.18	2294985500.50	-0.10566326E 00
01:01:28.5	1037372.84	3.67	2294985497.86	-0.10553021E 00
01:01:29.5	1037375.47	2.63	2294985495.23	-0.10553021E 00
01:01:30.5	1037377.17	1.70	2294985492.61	-0.10565236E 00
01:01:31.5	1037379.47	2.30	2294985489.97	-0.10569598E 00

Table 63 (contd)

Time, GMT	One-way doppler frequency, Hz	Difference, Hz	Auxiliary oscillator frequency, Hz	Range rate, km/s
01:01:32.5	1037382.12	2.66	2294985487.36	-0.10568944E 00
01:01:33.5	1037384.38	2.25	2294985484.72	-0.10573961E 00
01:01:34.5	1037386.44	2.06	2294985482.11	-0.10581377E 00
01:01:35.5	1037389.78	3.35	2294985479.47	-0.10571998E 00
01:01:36.5	1037393.15	3.36	2294985476.84	-0.10562400E 00
01:01:37.5	1037394.99	1.84	2294985474.22	-0.10572434E 00
01:01:38.5	1037397.62	2.63	2294985471.59	-0.10572434E 00
01:01:39.5	1037400.54	2.92	2294985468.97	-0.10568726E 00
01:01:40.5	1037404.08	3.54	2294985466.34	-0.10556511E 00
01:01:41.5	1037409.20	5.11	2294985463.72	-0.10524228E 00
01:01:42.5	1037411.53	2.34	2294985461.09	-0.10527718E 00
01:01:43.5	1037413.90	2.36	2294985458.48	-0.10530990E 00
01:01:44.5	1037417.07	3.18	2294985455.84	-0.10524228E 00
01:01:45.5	1037418.98	1.91	2294985453.23	-0.10533389E 00
01:01:46.5	1037421.81	2.83	2294985450.61	-0.10530553E 00
01:01:47.5	1037424.95	3.13	2294985447.98	-0.10524010E 00
01:01:48.5	1037427.97	3.02	2294985445.37	-0.10518338E 00
01:01:49.5	1037430.33	2.36	2294985442.75	-0.10521828E 00
01:01:50.5	1037433.49	3.16	2294985440.12	-0.10514848E 00
01:01:51.5	1037436.76	3.27	2294985437.52	-0.10506341E 00
01:01:52.5	1037439.91	3.15	2294985434.89	-0.10499361E 00
01:01:53.5	1037442.93	3.02	2294985432.28	-0.10494126E 00
01:01:54.5	1037445.38	2.45	2294985429.66	-0.10496307E 00
01:01:55.5	1037448.06	2.68	2294985427.03	-0.10495871E 00
01:01:56.5	1037451.35	3.29	2294985424.42	-0.10486710E 00
01:01:57.5	1037452.51	1.16	2294985421.80	-0.10505905E 00
01:01:58.5	1037455.52	3.01	2294985419.17	-0.10500888E 00
01:01:59.5	1037458.13	2.61	2294985416.56	-0.10500888E 00
01:02:00.5	1037460.19	2.05	2294985413.94	-0.10508523E 00
01:02:01.5	1037463.57	3.39	2294985411.33	-0.10498271E 00

Table 64. Actual vs hypothetical doppler, DSS 11

Time, GMT	Doppler frequency, Hz	Hypothetical doppler frequency at lunar surface, Hz	Difference, Hz	Velocity referenced to lunar surface, ft/s
00:56:08.5	1051870.15	1036485.21	15384.94	6593.52
00:56:09.5	1051881.69	1036488.03	15393.66	6597.26
00:56:10.5	1051892.15	1036490.86	15401.29	6600.53
00:56:11.5	1051903.66	1036493.69	15409.97	6604.25
00:56:12.5	1051915.82	1036496.51	15419.31	6608.25

Table 64 (contd)

Time, GMT	Doppler frequency, Hz	Hypothetical doppler frequency at lunar surface, Hz	Difference, Hz	Velocity referenced to lunar surface, ft/s
00:56:13.5	1051926.78	1036499.34	15427.44	6611.74
00:56:14.5	1051939.38	1036502.17	15437.21	6615.93
00:56:15.5	1051950.51	1036504.99	15445.51	6619.48
00:56:16.5	1051961.57	1036507.82	15453.75	6623.01
00:56:17.5	1051973.47	1036510.64	15462.83	6626.91
00:56:18.5	1051985.21	1036513.47	15471.74	6630.73
00:56:19.5	1051997.07	1036516.29	15480.78	6634.60
00:56:20.5	1052008.98	1036519.11	15489.86	6638.49
00:56:21.5	1052020.36	1036521.94	15498.42	6642.16
00:56:22.5	1052032.85	1036524.76	15508.09	6646.30
00:56:23.5	1052044.66	1036527.58	15517.08	6650.15
00:56:24.5	1052055.50	1036530.41	15525.09	6653.59
00:56:25.5	1052067.97	1036533.23	15534.74	6657.72
00:56:26.5	1052079.60	1036536.05	15543.55	6661.50
00:56:27.5	1052090.53	1036538.87	15551.65	6664.97
00:56:28.5	1052104.15	1036541.69	15562.45	6669.60
00:56:29.5	1052114.84	1036544.52	15570.33	6672.97
00:56:30.5	1052126.44	1036547.34	15579.10	6676.74
00:56:31.5	1052138.49	1036550.16	15588.34	6680.69
00:56:32.5	1052150.96	1036552.98	15597.98	6684.83
00:56:33.5	1052162.74	1036555.80	15606.94	6688.67
00:56:34.5	1052173.23	1036558.62	15614.61	6691.96
00:56:35.5	1052185.87	1036561.44	15624.44	6696.16
00:56:36.5	1052197.42	1036564.26	15633.17	6699.91
00:56:37.5	1052210.03	1036567.08	15642.96	6704.10
00:56:38.5	1052221.57	1036569.89	15651.67	6707.84
00:56:39.5	1052234.14	1036572.71	15661.43	6712.02
00:56:40.5	1052246.80	1036575.53	15671.27	6716.24
00:56:41.5	1052258.24	1036578.35	15679.90	6719.93
00:56:42.5	1052269.78	1036581.16	15688.61	6723.67
00:56:43.5	1052282.02	1036583.98	15698.04	6727.71
00:56:44.5	1052293.85	1036586.80	15707.05	6731.57
00:56:45.5	1052306.48	1036589.61	15716.87	6735.78
00:56:46.5	1052317.98	1036592.43	15725.55	6739.50
00:56:47.5	1052329.89	1036595.25	15734.65	6743.40
00:56:48.5	1052342.14	1036598.06	15744.07	6747.44
00:56:49.5	1052354.14	1036600.88	15753.26	6751.37
00:56:50.5	1052365.91	1036603.69	15762.21	6755.21
00:56:51.5	1052378.35	1036606.51	15771.84	6759.34
00:56:52.5	1052390.97	1036609.32	15781.65	6763.54

Table 64 (contd)

Time, GMT	Doppler frequency, Hz	Hypothetical doppler frequency at lunar surface, Hz	Difference, Hz	Velocity referenced to lunar surface, ft/s
00:56:53.5	1052403.60	1036612.14	15791.47	6767.75
00:56:54.5	1052416.48	1036614.95	15801.54	6772.06
00:56:55.5	1052427.98	1036617.76	15810.22	6775.78
00:56:56.5	1052440.03	1036620.58	15819.46	6779.74
00:56:57.5	1052452.06	1036623.39	15828.68	6783.70
00:56:58.5	1052464.77	1036626.20	15838.57	6787.94
00:56:59.5	1052477.40	1036629.01	15848.39	6792.14
00:57:00.5	1052489.78	1036631.82	15857.95	6796.24
00:57:01.5	1052502.17	1036634.64	15867.53	6800.35
00:57:02.5	1052515.28	1036637.45	15877.84	6804.76
00:57:03.5	1052527.79	1036640.26	15887.53	6808.92
00:57:04.5	1052539.61	1036643.07	15896.54	6812.78
00:57:05.5	1052551.54	1036645.88	15905.66	6816.69
00:57:06.5	1052564.20	1036648.69	15915.51	6820.91
00:57:07.5	1052576.91	1036651.50	15925.41	6825.15
00:57:08.5	1052590.04	1036654.31	15935.73	6829.58
00:57:09.5	1052602.89	1036657.12	15945.78	6833.88
00:57:10.5	1052614.98	1036659.93	15955.05	6837.86
00:57:11.5	1052627.89	1036662.74	15965.16	6842.19
00:57:12.5	1052640.78	1036665.54	15975.24	6846.51
00:57:13.5	1052653.79	1036668.35	15985.44	6850.88
00:57:14.5	1052666.80	1036671.16	15995.64	6855.25
00:57:15.5	1052679.92	1036673.97	16005.95	6859.67
00:57:16.5	1052692.07	1036676.77	16015.30	6863.68
00:57:17.5	1052704.03	1036679.58	16024.45	6867.60
00:57:18.5	1052717.55	1036682.39	16035.16	6872.19
00:57:19.5	1052730.43	1036685.19	16045.24	6876.51
00:57:20.5	1052743.28	1036688.00	16055.29	6880.81
00:57:21.5	1052756.51	1036690.80	16065.70	6885.28
00:57:22.5	1052769.56	1036693.61	16075.95	6889.67
00:57:23.5	1052783.16	1036696.41	16086.74	6894.30
00:57:24.5	1052795.33	1036699.22	16096.11	6898.31
00:57:25.5	1052808.96	1036702.02	16106.93	6902.95
00:57:26.5	1052821.73	1036704.83	16116.90	6907.22
00:57:27.5	1052833.71	1036707.63	16126.07	6911.15
00:57:28.5	1052847.65	1036710.43	16137.22	6915.93
00:57:29.5	1052861.49	1036713.24	16148.26	6920.66
00:57:30.5	1052874.63	1036716.04	16158.59	6925.09
00:57:31.5	1052887.33	1036718.84	16168.48	6929.33
00:57:32.5	1052901.57	1036721.65	16179.92	6934.23

Table 64 (contd)

Time, GMT	Doppler frequency, Hz	Hypothetical doppler frequency at lunar surface, Hz	Difference, Hz	Velocity referenced to lunar surface, ft/s
00:57:33.5	1052913.91	1036724.45	16189.46	6938.32
00:57:34.5	1052925.24	1036727.25	16197.99	6941.97
00:57:35.5	1052938.96	1036730.05	16208.91	6946.65
00:57:36.5	1052952.23	1036732.85	16219.38	6951.14
00:57:37.5	1052965.47	1036735.65	16229.82	6955.61
00:57:38.5	1052978.71	1036738.45	16240.25	6960.09
00:57:39.5	1052992.52	1036741.25	16251.26	6964.80
00:57:40.5	1053006.15	1036744.05	16262.10	6969.45
00:57:41.5	1053018.69	1036746.85	16271.84	6973.62
00:57:42.5	1053032.45	1036749.65	16282.80	6978.32
00:57:43.5	1053045.96	1036752.45	16293.51	6982.91
00:57:44.5	1053059.69	1036755.25	16304.45	6987.60
00:57:45.5	1053072.26	1036758.05	16314.22	6991.78
00:57:46.5	1053085.64	1036760.84	16324.80	6996.32
00:57:47.5	1053099.34	1036763.64	16335.69	7000.99
00:57:48.5	1053114.15	1036766.44	16347.71	7006.14
00:57:49.5	1053128.24	1036769.24	16359.01	7010.98
00:57:50.5	1053141.84	1036772.03	16369.81	7015.61
00:57:51.5	1053155.45	1036774.83	16380.62	7020.24
00:57:52.5	1053169.19	1036777.63	16391.56	7024.93
00:57:53.5	1053183.53	1036780.42	16403.10	7029.88
00:57:54.5	1053198.26	1036783.22	16415.04	7035.00
00:57:55.5	1053211.65	1036786.01	16425.64	7039.54
00:57:56.5	1053224.84	1036788.81	16436.03	7043.99
00:57:57.5	1053238.62	1036791.60	16447.02	7048.70
00:57:58.5	1053253.05	1036794.40	16458.66	7053.69
00:57:59.5	1053266.38	1036797.19	16469.19	7058.20
00:58:00.5	1053280.64	1036799.99	16480.66	7063.12
00:58:01.5	1053294.77	1036802.78	16491.99	7067.97
00:58:02.5	1053308.95	1036805.57	16503.38	7072.85
00:58:03.5	1053320.28	1036808.36	16511.92	7076.51
00:58:04.5	1053253.88	1036811.16	16442.73	7046.86
00:58:05.5	1053043.47	1036813.95	16229.52	6955.49
00:58:06.5	1052822.35	1036816.74	16005.61	6859.52
00:58:07.5	1052589.89	1036819.53	15770.36	6758.70
00:58:08.5	1052347.97	1036822.32	15525.64	6653.83
00:58:09.5	1052096.22	1036825.12	15271.11	6544.74
00:58:10.5	1051834.62	1036827.91	15006.71	6431.43
00:58:11.5	1051564.14	1036830.70	14733.44	6314.31
00:58:12.5	1051286.41	1036833.49	14452.92	6194.09

Table 64 (contd)

Time, GMT	Doppler frequency, Hz	Hypothetical doppler frequency at lunar surface, Hz	Difference, Hz	Velocity referenced to lunar surface, ft/s
00:58:13.5	1051002.05	1036836.28	14165.78	6071.03
00:58:14.5	1050711.09	1036839.07	13872.03	5945.14
00:58:15.5	1050413.62	1036841.86	13571.77	5816.45
00:58:16.5	1050110.30	1036844.64	13265.66	5685.26
00:58:17.5	1049800.73	1036847.43	12953.29	5551.39
00:58:18.5	1049484.52	1036850.22	12634.30	5414.68
00:58:19.5	1049160.10	1036853.01	12307.10	5274.45
00:58:20.5	1048827.16	1036855.80	11971.36	5130.57
00:58:21.5	1048483.80	1036858.58	11625.22	4982.22
00:58:22.5	1048131.15	1036861.37	11269.77	4829.89
00:58:23.5	1047767.61	1036864.16	10903.45	4672.89
00:58:24.5	1047395.41	1036866.95	10528.46	4512.18
00:58:25.5	1047011.54	1036869.73	10141.81	4346.47
00:58:26.5	1046617.24	1036872.52	9744.72	4176.30
00:58:27.5	1046213.03	1036875.30	9337.73	4001.87
00:58:28.5	1045798.64	1036878.09	8920.56	3823.08
00:58:29.5	1045373.06	1036880.87	8492.19	3639.50
00:58:30.5	1044937.53	1036883.66	8053.87	3451.65
00:58:31.5	1044490.32	1036886.44	7603.88	3258.79
00:58:32.5	1044031.20	1036889.23	7141.97	3060.83
00:58:33.5	1043558.37	1036892.01	6666.35	2857.00
00:58:34.5	1043072.43	1036894.79	6177.63	2647.55
00:58:35.5	1042572.05	1036897.58	5674.48	2431.91
00:58:36.5	1042055.93	1036900.36	5155.57	2209.52
00:58:37.5	1041524.72	1036903.14	4621.58	1980.67
00:58:38.5	1040977.86	1036905.92	4071.94	1745.11
00:58:39.5	1040418.82	1036908.71	3510.12	1504.33
00:58:40.5	1039854.60	1036911.49	2943.12	1261.33
00:58:41.5	1039291.36	1036914.27	2377.09	1018.75
00:58:42.5	1038791.03	1036917.05	1873.98	803.13
00:58:43.5	1038486.31	1036919.83	1566.48	671.35
00:58:44.5	1038334.73	1036922.61	1412.12	605.19
00:58:45.5	1038251.19	1036925.39	1325.79	568.20
00:58:46.5	1038199.81	1036928.17	1271.64	544.99
00:58:47.5	1038168.47	1036930.95	1237.52	530.36
00:58:48.5	1038149.57	1036933.73	1215.84	521.07
00:58:49.5	1038141.75	1036936.51	1205.24	516.53
00:58:50.5	1038139.29	1036939.29	1200.00	514.28
00:58:51.5	1038138.51	1036942.07	1196.44	512.76
00:58:52.5	1038137.26	1036944.85	1192.41	511.03
00:58:53.5	1038135.83	1036947.62	1188.21	509.23

Table 64 (contd)

Time, GMT	Doppler frequency, Hz	Hypothetical doppler frequency at lunar surface, Hz	Difference, Hz	Velocity referenced to lunar surface, ft/s
00:58:54.5	1038131.10	1036950.40	1180.70	506.01
00:58:55.5	1038125.25	1036953.18	1172.07	502.31
00:58:56.5	1038118.08	1036955.95	1162.13	498.05
00:58:57.5	1038110.71	1036958.73	1151.98	493.70
00:58:58.5	1038111.48	1036961.51	1149.97	492.84
00:58:59.5	1038116.93	1036964.28	1152.64	493.99
00:59:00.5	1038121.12	1036967.06	1154.07	494.60
00:59:01.5	1038124.47	1036969.83	1154.64	494.84
00:59:02.5	1038127.04	1036972.61	1154.43	494.75
00:59:03.5	1038130.60	1036975.38	1155.21	495.09
00:59:04.5	1038133.78	1036978.16	1155.62	495.26
00:59:05.5	1038137.52	1036980.93	1156.59	495.68
00:59:06.5	1038141.91	1036983.71	1158.20	496.37
00:59:07.5	1038146.37	1036986.48	1159.89	497.10
00:59:08.5	1038150.38	1036989.25	1161.12	497.62
00:59:09.5	1038154.72	1036992.03	1162.69	498.29
00:59:10.5	1038159.20	1036994.80	1164.40	499.03
00:59:11.5	1038161.85	1036997.57	1164.28	498.98
00:59:12.5	1038164.54	1037000.34	1164.20	498.94
00:59:13.5	1038168.77	1037003.12	1165.66	499.57
00:59:14.5	1038172.83	1037005.89	1166.94	500.12
00:59:15.5	1038177.31	1037008.66	1168.66	500.85
00:59:16.5	1038182.06	1037011.43	1170.63	501.70
00:59:17.5	1038185.73	1037014.20	1171.53	502.08
00:59:18.5	1038188.67	1037016.97	1171.70	502.16
00:59:19.5	1038192.90	1037019.74	1173.16	502.78
00:59:20.5	1038198.26	1037022.51	1175.75	503.89
00:59:21.5	1038199.60	1037025.28	1174.32	503.28
00:59:22.5	1038189.82	1037028.05	1161.78	497.90
00:59:23.5	1038181.82	1037030.82	1151.01	493.29
00:59:24.5	1038172.36	1037033.58	1138.78	488.05
00:59:25.5	1038163.22	1037036.35	1126.86	482.94
00:59:26.5	1038151.16	1037039.12	1112.03	476.58
00:59:27.5	1038137.98	1037041.89	1096.09	469.75
00:59:28.5	1038131.83	1037044.66	1087.18	465.93
00:59:29.5	1038123.78	1037047.42	1076.36	461.30
00:59:30.5	1038110.79	1037050.19	1060.60	454.54
00:59:31.5	1038100.97	1037052.96	1048.01	449.15
00:59:32.5	1038097.57	1037055.72	1041.85	446.51

Table 64 (contd)

Time, GMT	Doppler frequency, Hz	Hypothetical doppler frequency at lunar surface, Hz	Difference, Hz	Velocity referenced to lunar surface, ft/s
00:59:33.5	1038089.51	1037058.49	1031.02	441.87
00:59:34.5	1038079.34	1037061.25	1018.09	436.32
00:59:35.5	1038071.69	1037064.02	1007.67	431.86
00:59:36.5	1038065.75	1037066.78	998.97	428.13
00:59:37.5	1038057.72	1037069.55	988.17	423.50
00:59:38.5	1038046.95	1037072.31	974.64	417.70
00:59:39.5	1038040.55	1037075.08	965.48	413.78
00:59:40.5	1038034.31	1037077.84	956.47	409.92
00:59:41.5	1038025.07	1037080.60	944.47	404.77
00:59:42.5	1038017.04	1037083.37	933.68	400.15
00:59:43.5	1038009.12	1037086.13	923.00	395.57
00:59:44.5	1038002.23	1037088.89	913.34	391.43
00:59:45.5	1037996.59	1037091.65	904.94	387.83
00:59:46.5	1037987.60	1037094.41	893.18	382.79
00:59:47.5	1037981.15	1037097.18	883.97	378.84
00:59:48.5	1037973.84	1037099.94	873.91	374.53
00:59:49.5	1037962.00	1037102.70	859.30	368.27
00:59:50.5	1037948.78	1037105.46	843.32	361.42
00:59:51.5	1037935.06	1037108.22	826.84	354.36
00:59:52.5	1037920.51	1037110.98	809.53	346.94
00:59:53.5	1037907.68	1037113.74	793.94	340.26
00:59:54.5	1037894.97	1037116.50	778.47	333.63
00:59:55.5	1037881.46	1037119.26	762.20	326.66
00:59:56.5	1037867.74	1037122.02	745.73	319.60
00:59:57.5	1037854.46	1037124.77	729.68	312.72
00:59:58.5	1037841.80	1037127.53	714.27	306.11
00:59:59.5	1037828.41	1037130.29	698.12	299.19
01:00:00.5	1037814.48	1037133.05	681.43	292.04
01:00:01.5	1037800.58	1037135.80	664.78	284.90
01:00:02.5	1037785.88	1037138.56	647.31	277.42
01:00:03.5	1037772.97	1037141.32	631.65	270.71
01:00:04.5	1037759.35	1037144.07	615.28	263.69
01:00:05.5	1037745.68	1037146.83	598.85	256.65
01:00:06.5	1037732.42	1037149.59	582.83	249.78
01:00:07.5	1037718.39	1037152.34	566.05	242.59
01:00:08.5	1037705.19	1037155.10	550.09	235.75
01:00:09.5	1037691.55	1037157.85	533.70	228.73
01:00:10.5	1037677.21	1037160.61	516.60	221.40
01:00:11.5	1037663.72	1037163.36	500.36	214.44

Table 64 (contd)

Time, GMT	Doppler frequency, Hz	Hypothetical doppler frequency at lunar surface, Hz	Difference, Hz	Velocity referenced to lunar surface, ft/s
01:00:12.5	1037650.80	1037166.11	484.69	207.72
01:00:13.5	1037635.78	1037168.87	466.91	200.11
01:00:14.5	1037625.03	1037171.62	453.41	194.32
01:00:15.5	1037616.01	1037174.37	441.64	189.27
01:00:16.5	1037609.88	1037177.13	432.75	185.46
01:00:17.5	1037600.32	1037179.88	420.44	180.19
01:00:18.5	1037593.34	1037182.63	410.71	176.02
01:00:19.5	1037585.65	1037185.38	400.26	171.54
01:00:20.5	1037579.95	1037188.14	391.81	167.92
01:00:21.5	1037575.38	1037190.89	384.50	164.78
01:00:22.5	1037568.41	1037193.64	374.77	160.62
01:00:23.5	1037561.12	1037196.39	364.74	156.31
01:00:24.5	1037555.92	1037199.14	356.78	152.90
01:00:25.5	1037549.50	1037201.89	347.61	148.97
01:00:26.5	1037543.39	1037204.64	338.75	145.18
01:00:27.5	1037536.76	1037207.39	329.37	141.16
01:00:28.5	1037531.64	1037210.14	321.50	137.79
01:00:29.5	1037527.67	1037212.89	314.78	134.91
01:00:30.5	1037521.63	1037215.63	306.00	131.14
01:00:31.5	1037515.90	1037218.38	297.51	127.51
01:00:32.5	1037514.00	1037221.13	292.87	125.52
01:00:33.5	1037510.03	1037223.88	286.15	122.64
01:00:34.5	1037506.03	1037226.63	279.41	119.74
01:00:35.5	1037501.40	1037229.37	272.03	116.58
01:00:36.5	1037498.07	1037232.12	265.95	113.98
01:00:37.5	1037493.77	1037234.87	258.90	110.96
01:00:38.5	1037489.55	1037237.61	251.94	107.97
01:00:39.5	1037485.55	1037240.36	245.20	105.08
01:00:40.5	1037482.01	1037243.10	238.91	102.39
01:00:41.5	1037474.80	1037245.85	228.95	98.12
01:00:42.5	1037461.73	1037248.59	213.14	91.34
01:00:43.5	1037449.15	1037251.34	197.81	84.77
01:00:44.5	1037437.74	1037254.08	183.66	78.71
01:00:45.5	1037426.78	1037256.83	169.96	72.84
01:00:46.5	1037417.85	1037259.57	158.29	67.84
01:00:47.5	1037410.99	1037262.31	148.68	63.72
01:00:48.5	1037401.62	1037265.06	136.57	58.53
01:00:49.5	1037390.80	1037267.80	123.00	52.72
01:00:50.5	1037378.12	1037270.54	107.58	46.11
01:00:51.5	1037363.76	1037273.28	90.48	38.78

Table 64 (contd)

Time, GMT	Doppler frequency, Hz	Hypothetical doppler frequency at lunar surface, Hz	Difference, Hz	Velocity referenced to lunar surface, ft/s
01:00:52.5	1037349.21	1037276.03	73.18	31.36
01:00:53.5	1037335.07	1037278.77	56.31	24.13
01:00:54.5	1037323.12	1037281.51	41.62	17.84
01:00:55.5	1037317.47	1037284.25	33.22	14.24
01:00:56.5	1037312.94	1037286.99	25.95	11.12
01:00:57.5	1037308.79	1037289.73	19.06	8.17
01:00:58.5	1037303.45	1037292.47	10.98	4.71
01:00:59.5	1037301.73	1037295.21	6.52	2.79
01:01:00.5	1037305.53	1037297.95	7.58	3.25
01:01:01.5	1037309.42	1037300.69	8.73	3.74
01:01:02.5	1037312.34	1037303.43	8.91	3.82
01:01:03.5	1037315.01	1037306.17	8.84	3.79
01:01:04.5	1037321.00	1037308.90	12.10	5.18
01:01:05.5	1037319.96	1037311.64	8.32	3.56
01:01:06.5	1037314.19	1037314.38	-0.19	-0.08
01:01:07.5	1037314.40	1037317.12	-2.71	-1.16
01:01:08.5	1037317.46	1037319.85	-2.39	-1.03
01:01:09.5	1037320.02	1037322.59	-2.57	-1.10
01:01:10.5	1037323.02	1037325.33	-2.31	-0.99
01:01:11.5	1037325.37	1037328.06	-2.69	-1.15
01:01:12.5	1037328.01	1037330.80	-2.79	-1.20
01:01:13.5	1037331.32	1037333.54	-2.22	-0.95
01:01:14.5	1037333.74	1037336.27	-2.53	-1.09
01:01:15.5	1037337.03	1037339.01	-1.97	-0.85
01:01:16.5	1037339.67	1037341.74	-2.07	-0.89
01:01:17.5	1037341.91	1037344.47	-2.57	-1.10
01:01:18.5	1037346.15	1037347.21	-1.06	-0.46
01:01:19.5	1037348.48	1037349.94	-1.46	-0.63
01:01:20.5	1037350.36	1037352.68	-2.31	-0.99
01:01:21.5	1037353.97	1037355.41	-1.44	-0.62
01:01:22.5	1037355.56	1037358.14	-2.58	-1.10
01:01:23.5	1037358.77	1037360.87	-2.11	-0.90
01:01:24.5	1037361.70	1037363.61	-1.91	-0.82
01:01:25.5	1037365.04	1037366.34	-1.30	-0.56
01:01:26.5	1037367.00	1037369.07	-2.07	-0.89
01:01:27.5	1037369.18	1037371.80	-2.62	-1.12
01:01:28.5	1037372.84	1037374.53	-1.69	-0.72
01:01:29.5	1037375.47	1037377.26	-1.79	-0.77
01:01:30.5	1037377.17	1037379.99	-2.83	-1.21

Table 64 (contd)

Time, GMT	Doppler frequency, Hz	Hypothetical doppler frequency at lunar surface, Hz	Difference, Hz	Velocity referenced to lunar surface, ft/s
01:01:31.5	1037379.47	1037382.72	-3.26	-1.40
01:01:32.5	1037382.12	1037385.45	-3.33	-1.43
01:01:33.5	1037384.38	1037388.18	-3.81	-1.63
01:01:34.5	1037386.44	1037390.91	-4.48	-1.92
01:01:35.5	1037389.78	1037393.64	-3.86	-1.65
01:01:36.5	1037393.15	1037396.37	-3.22	-1.38
01:01:37.5	1037394.99	1037399.10	-4.11	-1.76
01:01:38.5	1037397.62	1037401.83	-4.21	-1.80
01:01:39.5	1037400.54	1037404.55	-4.01	-1.72
01:01:40.5	1037404.08	1037407.28	-3.20	-1.37
01:01:41.5	1037409.20	1037410.01	-0.81	-0.35
01:01:42.5	1037411.53	1037412.73	-1.20	-0.51
01:01:43.5	1037413.90	1037415.46	-1.56	-0.67
01:01:44.5	1037417.07	1037418.19	-1.11	-0.48
01:01:45.5	1037418.98	1037420.91	-1.93	-0.83
01:01:46.5	1037421.81	1037423.64	-1.83	-0.78
01:01:47.5	1037424.95	1037426.36	-1.42	-0.61
01:01:48.5	1037427.97	1037429.09	-1.12	-0.48
01:01:49.5	1037430.33	1037431.81	-1.48	-0.64
01:01:50.5	1037433.49	1037434.54	-1.05	-0.45
01:01:51.5	1037436.76	1037437.26	-0.50	-0.22
01:01:52.5	1037439.91	1037439.99	-0.08	-0.03
01:01:53.5	1037442.93	1037442.71	0.22	0.09
01:01:54.5	1037445.38	1037445.43	-0.06	-0.02
01:01:55.5	1037448.06	1037448.16	-0.09	-0.04
01:01:56.5	1037451.35	1037450.88	0.47	0.20
01:01:57.5	1037452.51	1037453.60	-1.09	-0.47
01:01:58.5	1037455.52	1037456.32	-0.80	-0.34
01:01:59.5	1037458.13	1037459.04	-0.91	-0.39
01:02:00.5	1037460.19	1037461.77	-1.58	-0.68
01:02:01.5	1037463.57	1037464.49	-0.91	-0.39
01:02:02.5	1037465.92	1037467.21	-1.29	-0.55
01:02:03.5	1037469.09	1037469.93	-0.83	-0.36
01:02:04.5	1037471.84	1037472.65	-0.80	-0.34
01:02:05.5	1037475.87	1037475.37	0.50	0.21
01:02:06.5	1037480.62	1037478.09	2.54	1.09
01:02:07.5	1037483.17	1037480.81	2.36	1.01
01:02:08.5	1037485.71	1037483.53	2.18	0.94
01:02:09.5	1037488.56	1037486.24	2.32	0.99
01:02:10.5	1037491.67	1037488.96	2.71	1.16

Table 64 (contd)

Time, GMT	Doppler frequency, Hz	Hypothetical doppler frequency at lunar surface, Hz	Difference, Hz	Velocity referenced to lunar surface, ft/s
10:31:44.5	1018190.78	1018191.34	-0.57	-0.24
10:31:45.5	1018193.05	1018192.90	0.15	0.06
10:31:46.5	1018193.52	1018194.45	-0.93	-0.40
10:31:47.5	1018197.19	1018195.97	1.22	0.52
10:31:48.5	1018199.37	1018197.48	1.89	0.81
10:31:49.5	1018198.44	1018198.96	-0.52	-0.22
10:31:50.5	1018200.03	1018200.43	-0.40	-0.17
10:31:51.5	1018201.09	1018201.88	-0.79	-0.34
10:31:52.5	1018202.80	1018203.31	-0.51	-0.22
10:31:53.1	1018205.25	1018204.72	0.54	0.23
10:31:54.5	1018205.74	1018206.11	-0.37	-0.16
10:31:55.5	1018207.77	1018207.48	0.29	0.12
10:31:56.5	1018208.06	1018208.83	-0.77	-0.33
10:31:57.5	1018210.90	1018210.16	0.73	0.31
10:31:58.5	1018211.51	1018211.48	0.03	0.01
10:31:59.5	1018212.73	1018212.77	-0.05	-0.02
10:32:00.5	1018214.06	1018214.05	0.01	0.00
10:32:01.5	1018215.76	1018215.31	0.45	0.19
10:32:02.5	1018218.16	1018216.55	1.62	0.69
10:32:03.5	1018219.25	1018217.77	1.49	0.64
10:32:04.5	1018219.97	1018218.97	1.00	0.43
10:32:05.5	1018216.58	1018220.15	-3.56	-1.53
10:32:06.5	1018213.81	1018221.31	-7.50	-3.22
10:32:07.5	1018212.07	1018222.45	-10.38	-4.45
10:32:08.5	1018222.88	1018223.58	-0.70	-0.30
10:32:09.5	1018235.07	1018224.68	10.39	4.45
10:32:10.5	1018248.02	1018225.77	22.25	9.54
10:32:11.5	1018231.54	1018226.84	4.70	2.02
10:32:12.5	1018230.55	1018227.88	2.67	1.14
10:32:13.5	1018227.99	1018228.91	-0.92	-0.40
10:32:14.5	1018229.35	1018229.92	-0.58	-0.25
10:32:15.5	1018229.95	1018230.91	-0.96	-0.41
10:32:16.5	1018232.06	1018231.88	0.18	0.08

Glossary

AFETR	Air Force Eastern Test Range	ODGX	orbit data generator program
AFC	automatic frequency control	ODPX	orbit determination program
AGC	automatic gain control	ORT	operational readiness test
AMR	altitude marking radar	OSAS	on-site alpha scattering (program)
APC	automatic phase control	PCM	pulse code modulation
AOS	acquisition of signal	PLIM	postlaunch instrumentation message
ASEC	alpha scattering electronics compartment	PM	phase modulation
ASI	alpha scattering instrument	PRDX	JPL predicts program
ASSH	alpha scattering sensor head	RADVS	radar altimeter and doppler velocity sensor
A/SPP	antenna and solar panel positioner	RIS	range instrumentation ship
BECO	booster engine cutoff	RTCS	real-time computer system
CDC	command data console	SCAMA	signaling, conferencing, and monitoring arrangement
CKAFS	Cape Kennedy Air Force Station	SCO	subcarrier oscillator
DPES	direct-ascent powered flight simulator	SECO	sustainer engine cutoff
DSIF	Deep Space Instrumentation Facility	SFOF	Space Flight Operations Facility
DSN	Deep Space Network	SM/SS	soil mechanics/surface sampler
DSS	Deep Space Station	SOCP	<i>Surveyor</i> on-site computer program
FPAC	flight-path analysis and command (group)	SPAC	spacecraft performance analysis and command (group)
FM	frequency modulation	SRT	system readiness test
GCF	ground communications facility	TDA	tracking and data acquisition
GSFC	Goddard Space Flight Center	TDH	tracking data handling
HAC	Hughes Aircraft Co.	TDM	time division multiplex
HPPS	Hughes post processor	TDPX	tracking data processor program
ICS	intracomunications system	TDS	Tracking and Data System
I/O	input/output	TRJX	JPL trajectory program
KSC	Kennedy Space Center	TTY	teletype
LOS	loss of signal	VCO	voltage-controlled oscillator
MECO	main engine cutoff	VCXO	voltage-controlled crystal oscillator
MEIG	main engine ignition	VECO	vernier engine cutoff
MES	main engine start (<i>Centaur</i>)	WBVCXO	wideband voltage-controlled crystal oscillator
MSFN	Manned Space Flight Network		
MTGS	midcourse and terminal guidance		
NASCOM	NASA Communications Network		