N69-34960
NASA CR 104120

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Memorandum 33-301

Volume I

Tracking and Data System Support for Surveyor

Missions I and II

N. A. Renzetti

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JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

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Prepared Under Contract No. NAS 7-100
National Aeronautics and Space Administration

Preface

The work described in this report was performed by the Office of Tracking and Data Acquisition of the Jet Propulsion Laboratory.

This volume is the first 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 will cover the support of *Surveyors III* and *IV*; and Volumes III, IV, and V will record the tracking and data acquisition activities for *Surveyors V*, *VI*, and *VII*, respectively.

Acknowledgment

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

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

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

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

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

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Abstract

This report covers the Tracking and Data System (T&DS) activities for *Surveyors I* and *II*, 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 T&DS, the *Surveyor* Mission objectives are reviewed and descriptions of the *Atlas/Centaur* launch vehicle and of the spacecraft are included, as are synopses of the first two *Surveyor* flights. Associated equipment and activities of the three elements of the Deep Space Network—i.e., the Deep Space Instrumentation Facility, the Ground Communications Facility, and the Space Flight Operations Facility—in meeting the metric, telemetry, command, and tracking demands of the missions are documented. Tracking and telemetry summaries of the initial phases of the flights cover operations of the Goddard Space Flight Center, the Air Force Eastern Test Range, the Spacecraft Monitoring Facility at Cape Kennedy, 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, data transmission and reduction are presented.

Tracking and Data System Support for *Surveyor*

Missions I and II

I. Introduction

A history of the Tracking and Data System (T&DS) activities in support of the *Surveyor I* and *II* Missions is provided in this report. Four major administrative and functional elements were involved in the *Surveyor* Project support; the Jet Propulsion Laboratory was assigned overall management of the project, as well as responsibility for three of the four systems, which are listed below:

(1) Launch Vehicle System: Management responsibility for the *Atlas/Centaur* system was assigned to the NASA Lewis Research Center (LeRC); the Office of Space Science and Applications (OSSA) was the NASA Headquarters cognizant agency. (General Dynamics/Convair was the principal subcontractor for the launch vehicle.)

(2) Spacecraft System: Jet Propulsion Laboratory was given the management responsibility for this system by the OSSA. (Hughes Aircraft Company was the principal subcontractor for the spacecraft.)

(3) Tracking and Data System: Operating under the technical direction and management of JPL, the Deep Space Network (DSN) facility of the NASA Office of Tracking and Data Acquisition (OTDA) was responsible for spacecraft tracking and data acquisition from the near-earth phase of the flight to the end of the mission. From launch to near earth, the Air Force Eastern Test Range (AFETR) and some stations of the Manned Space Flight Network [(MSFN) under the cognizance of the NASA Goddard Space Flight Center (GSFC)] functioned as part of the TDS. The GSFC global ground communications network, NASCOM (for NASA Communications System), served during the entire mission; and the computer capability of that center was used during the early phase of the mission.

(4) Mission Operations System: Responsibility for mission operations of the project, including trajectory and orbit determinations, data handling, processing and interpretation, and command decisions, was also assigned to JPL by the OSSA. Operations were concentrated in the Space Flight Operations Facility (SFOF) at JPL.

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

The *Surveyor* Project served as the initial space project to have telecommunications provisions at S-band.

When the project was initiated in 1960, those responsible for the management of the frequency spectrum recommended that there be no further L-band projects such as *Ranger* and *Mariner II,* but that such future projects as *Surveyor* should be planned at S-band. In 1960, the plan was that the first flight of *Surveyor* would be in the fall of 1963. When it became apparent that this objective could not be met (in fact, *Surveyor I* was not launched until May of 1966), the actual first project to use S-band in flight was *Mariner* Mars 1964. The tracking and data acquisition experience with the latter mission is covered in Ref. 1.

The *Surveyor* Project provided the first spacecraft design that was wholly dependent on commands from the ground stations of the Deep Space Network 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 online other stations—rather than having, for example, such redundancy as two transmitter chains at each station. An example of the latter case is the MSFN configuration for *Apollo.*

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 Station to the Space Flight Operations Facility 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 Goldstone and up to 1100 bits/s from the overseas stations through the ground communication system into data processing systems in the SFOF. Prior to this project, teletype circuits served as the primary means for transferring data and for the conduct of spacecraft flight operations.

The *Surveyor* Project was the first deep space project to make extensive use of real-time high-speed (>50 bits/s) data processing in the IBM 7044–7094 system in the SFOF. This required, at times, two such strings to be fully operational for extended periods, especially during the transit flight to the lunar surface. The support for this requirement was successfully provided, requiring, however, considerable 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.

The development of the *Surveyor* spacecraft required use of equipment and facilities for compatibility testing culminating in an extensive series of tests at Goldstone with a telecommunication model of a *Surveyor* spacecraft. The availability of these facilities and the model spacecraft also provided a basis for extensive training of network personnel in the acquisition problems and 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), the Spacecraft Monitoring Station. This station is located in the vicinity of the launch pad and checkout facilities and was used in the final tests of compatibility between the flight spacecraft and the Deep Space Network.

The *Surveyor* Project made first 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 of processing telemetry and video data from the spacecraft. This equipment underwent considerable compatibility testing where it interfaced 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, as well. Stimulated, in part, by the need for extensive interface agreements because of the extensive use of mission-dependent equipment throughout the TDS, a system for the management of interface structure and documentation, configuration control practices and documentation, and operational documentation that reflected both mission-independent and mission-dependent procedures was developed to such a high degree that it has been applied to support of all subsequent flight projects.

Furthermore, the project provided the personnel to maintain and operate this mission-dependent equipment pending the training and transfer of responsibility to the onsite personnel. The project also provided onsite personnel for spacecraft control and data analysis should at any time there be 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 *Surveyor I* touchdown. The *Surveyor* spacecraft, radiating from the moon, provided an excellent far-field source for the 210-ft antenna pattern measurement. The higher performance capability of this station was also used to return 4400 bits/s telemetry during 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 (TPS) utilizing two PDP 7 computers[1] in the SFOF.

The *Surveyor* Project provided the first occasion for data decommutation of pulse code modulated (PCM) telemetry data by use of a combination of hardware and software. This function was also accomplished in the telemetry processing system in the SFOF and permitted automatic recognition of spacecraft data mode change from the telemetry system.

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 *Mariner* Venus 67 the multiple project usage of a computer string using the IBM 7044 redesigned data processing system in the SFOF and the communication processor in the Ground Communications Facility (GCF).

The *Surveyor* Project was the first spaceflight 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 ship and land stations and, in the later missions, from the MSFN stations at Carnarvon to DSS 42. It brought together close working relationships between the three supporting networks. This integration was achieved to a degree never before required 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.

The T&DS provided a real-time mission display capability in the SFOF for use during the course of each mission. An improved computer-driven real-time mission display capability was developed and used for the *Surveyor VII* flight.

B. Tracking and Data System

To meet its commitment to provide tracking and two-way communications with a space vehicle, the T&DS makes use of an extensive array of earth-based stations. For the *Surveyor* missions, the T&DS used three facilities: (1) The Air Force Eastern Test Range furnished data during the launch and near-earth phases for tracking and telemetry, for both booster and spacecraft. (2) Portions of the Manned Space Flight Network—stations at Bermuda, Grand Canary, Carnarvon, and Kano—operated under the GSFC Directorate for Tracking and Data Systems to assist with near-earth tracking and data acquisition. (3) The Deep Space Network acquired the spacecraft immediately after injection into the lunar trajectory and was solely responsible for spacecraft contact from then until the end of the mission. Three elements of the DSN provided capabilities to execute this task: (a) The Deep Space Instrumentation Facility (DSIF), comprising ten Deep Space Stations, tracked the spacecraft, received telemetry from (and partly processed some of the data), and transmitted commands to the spacecraft. (b) The Ground Communications Facility (GCF), comprising the DSN Goldstone–SFOF microwave link and the global NASCOM transmitted data, as required, to all facilities. The network ties in all the stations around the world with each other and with the Communications Center at GSFC (cognizant agency for NASCOM), and through that Center, the stations can be connected with one another for voice communications via the Station Conferencing and Monitoring Arrangement (SCAMA). (c) The Space Flight Operations Facility wherein real-time analysis of tracking and telemetry data (including video) were performed, orbital elements and look angles were computed, and information for making command decisions was provided.

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 AFB, while actual

[1]Manufactured by the Pacific Data Products.

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 the projects, programs and organizations that use the AFETR launch facilities. To meet the tracking and telemetry commitments during the countdown and launch phases, the AFETR used land based instrumentation sites, range instrumentation ships (RIS), and range telemetry aircraft.

2. ***Manned Space Flight Network.*** Under the direction of the GSFC, the Bermuda, Grand Canary, Carnarvon, and Kano stations of this worldwide network participated in tracking the *Surveyor* launch vehicle and spacecraft during the near-earth phase. In addition to the tracking and data acquisition contributions, in cooperation with GSFC, communications and computer support services were provided by the MSFN.

3. ***Deep Space Network.*** Prior to launch, the DSN operates the Cape Kennedy Spacecraft Monitoring Station (DSS 71, Fig. 1) during the final spacecraft checkout to verify compatibility. After launch, the DSN is responsible for two-way communications with unmanned spacecraft traveling from approximately 10,000 mi from earth to

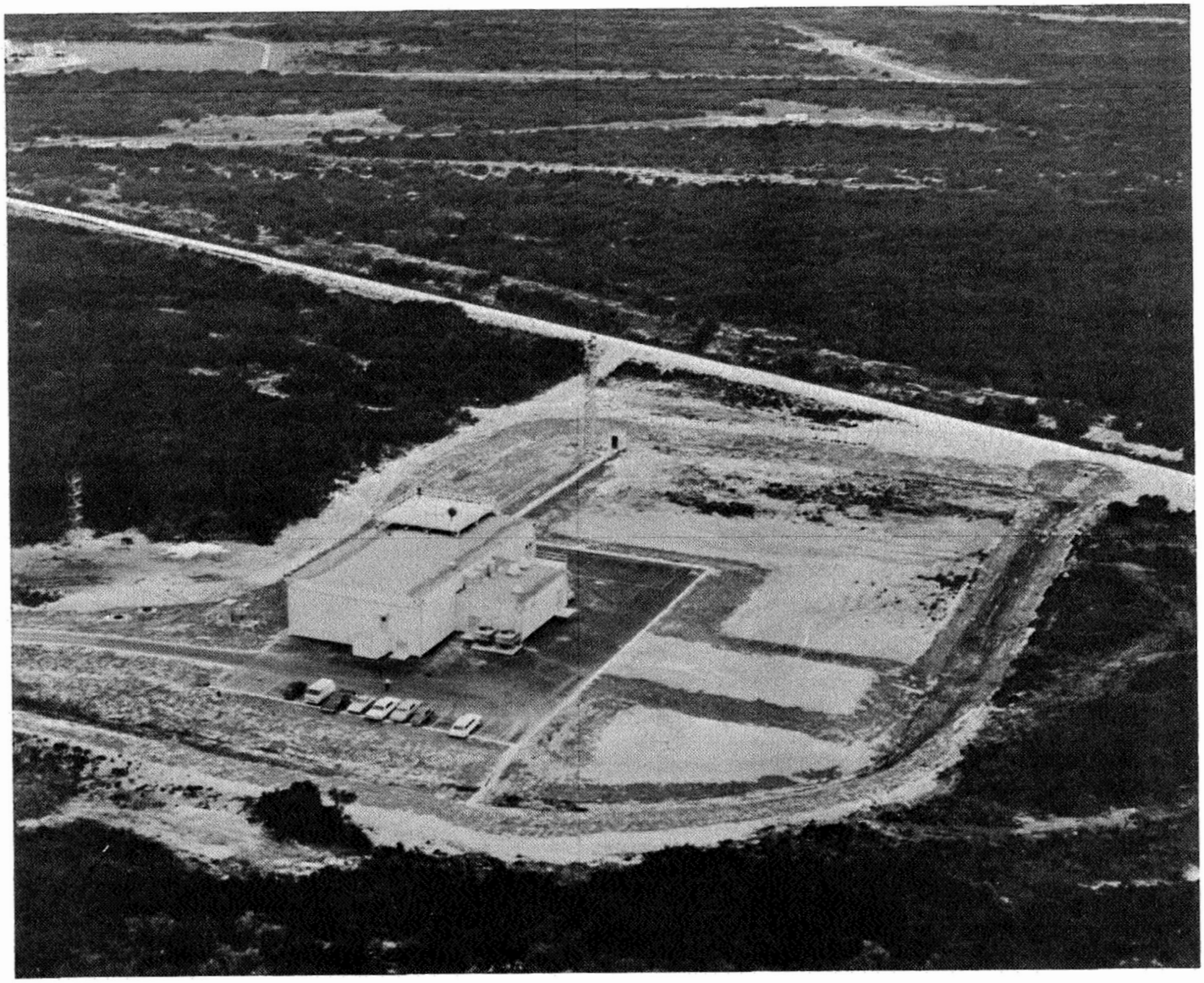


Fig. 1. Goldstone, Calif., Mars Station (DSS 14), 210-ft antenna

interplanetary distances. 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, and (4) the *Apollo* Project of the Manned Spacecraft Center, as backup to certain stations of the MSFN.

The Deep Space Stations are situated such that three prime stations may be selected 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. Locations of the ten Deep Space Stations in operation during the *Surveyor I* and *II* missions are given in Table 1.

Acquisition of a spacecraft signal may involve six different functions: (1) pointing the antenna at the spacecraft, (2) tuning to, and locking receivers to, the spacecraft transmitted frequency, (3) tuning and locking the ground transmitter to the spacecraft receiver frequency, (4) establishing range lock, where applicable, (5) synchronizing the telemetry system, and in some cases, (6) 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 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. Thus, tracking, telemetry, and control of the spacecraft is properly attained.

For the *Surveyor* Missions, the critical flight maneuvers and nearly all the picture-taking operations during each mission were commanded and recorded by the Pioneer Deep Space Station (DSS 11) at Goldstone, California, during view periods of that station. A few picture sequences were obtained by the Tidbinbilla Deep Space Station (DSS 42), near Canberra, Australia, and from the Johannesburg Deep Space Station (DSS 51), in South Africa. These three were the prime tracking and data acquisition stations for *Surveyors I* and *II*. Backup stations during this mission were the following: the Robledo Deep Space Station (DSS 61), near Madrid, Spain; the Ascension Island Deep Space Station (DSS 72); and two stations

Table 1. Deep Space Station (DSS) 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

at Goldstone, California—the Mars (210-ft antenna) Deep Space Station (DSS 14) and the Echo Deep Space Station (DSS 12).

C. Surveyor Mission

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

1. Mission flight objectives. There were three categories of specific flight objectives: primary, secondary, and tertiary. Prior to Mission A launch, a launch-hold criterion was established; the capability was required for all project systems to meet all objectives, (primary, secondary, and tertiary) before the launch would be permitted.

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

For *Surveyor I* and *II* missions, the primary objectives were the following:

(1) Demonstrate the capability of the *Surveyor* spacecraft to perform successful midcourse and terminal maneuvers and a 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 objective is highly desirable; however, the failure to achieve the secondary objective, while a serious matter, is not regarded as mission failure. The scheduled launch would probably be delayed—or rescheduled if conditions exist which seriously jeopardize or prevent achievement of the secondary objective—but a decision would be made at that time based on the circumstances.

The secondary flight objectives for *Surveyors I* and *II* were the following:

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

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

(3) Obtain inflight engineering data on the performance of the closed-loop terminal descent guidance and control system, consisting of the velocity and altitude radars, onboard 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 objective is considered a bonus. If developmental or launch, transit, and lunar (e.g., landing-site lighting) readiness conditions which affect the accomplishment of the tertiary objectives are not satisfactory, the scheduled launch will proceed as planned without major delays.

For *Surveyors I* and *II*, these objectives were:

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

(2) Obtain post-landing television 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:

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

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

(3) To obtain engineering data regarding performance of the spacecraft system that will aid in future space exploration.

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

Desired objectives were to achieve the capability of a minimum of lunar sunrise-to-sunset operation, minimum times of 3 h for A-21 and 20 h for A-21A (nonoperating mode) of predawn operation, and a minimum of 150 h (nonoperating mode) of post-sunset operation, with a 90-day period of operation.

2. *Flight description.* The *Surveyor* spacecraft were boosted to injection by the *Atlas/Centaur* launch vehicle from Launch Complex 36A at the AFETR. The ascent mode used for the *Surveyor I, II,* and *IV* missions was a direct ascent trajectory; for the *III, V, VI,* and *VII* missions, there was a parking orbit coast period before injection into the lunar transfer orbit. Direct-ascent trajectories are characterized by nearly continuous thrusting from liftoff to injection.

In the absence of a parking-orbit coast capability, injection was constrained to occur at an approximate 28-deg earth-centered, central angle from the launch site. Consequently, the true anomaly at injection had to 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 was required to be varied accordingly. Since payload capability was dependent on injection flight-path angle, the true anomaly at injection could not exceed limits that were dictated by the payload requirement for a given mission. In general, the lower true anomaly limit delayed the opening of the launch window until the required geometry was obtained. This prevented use of the lower launch azimuths on certain days in the launch period.

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

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

The nominal *Surveyor* trajectories are selected on the basis of the launch and impact parameters, described above, and the constraints imposed on them. The functional relationships involved in the selection of these parameters in trajectory design are presented in Fig. 2. This diagram shows the dependence of the parameters on the geometry of the lunar orbit and the mission-design constraints. The dependence of the output of the design (i.e., the launch windows and periods, impact speeds, and landing locations) on these parameters is shown.

When all the *Surveyor* launch constraints were fully satisfied, the *Atlas/Centaur* launch vehicle was ready for firing. Two seconds after liftoff, the *Atlas* autopilot rolled the vehicle to the required heading, and the pitch program was initiated after 15 s of vertical flight. When the axial thrust acceleration reached 5.8 *g* (approximately 142 s after liftoff), the *Atlas* booster engines were shut down and jettisoned. At *Atlas* propellant depletion, approximately 238 s after liftoff, the sustainer engine was shut down, and the *Centaur* main engine start sequence began. After the *Atlas* was jettisoned, the *Centaur* main engine ignited. Injection into the required lunar transfer trajectory occurred at *Centaur* main-engine shutdown, approximately 680 s after liftoff. Shortly after injection, a *Centaur* programmer command deployed the spacecraft landing gears and omnidirectional antennas and switched the spacecraft transmitter to high power. The spacecraft was then separated from the *Centaur.* At that time, the *Centaur* executed a retromaneuver to remove itself from the vicinity of the spacecraft and to prevent interference with the spacecraft Canopus sensor later in the flight.

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

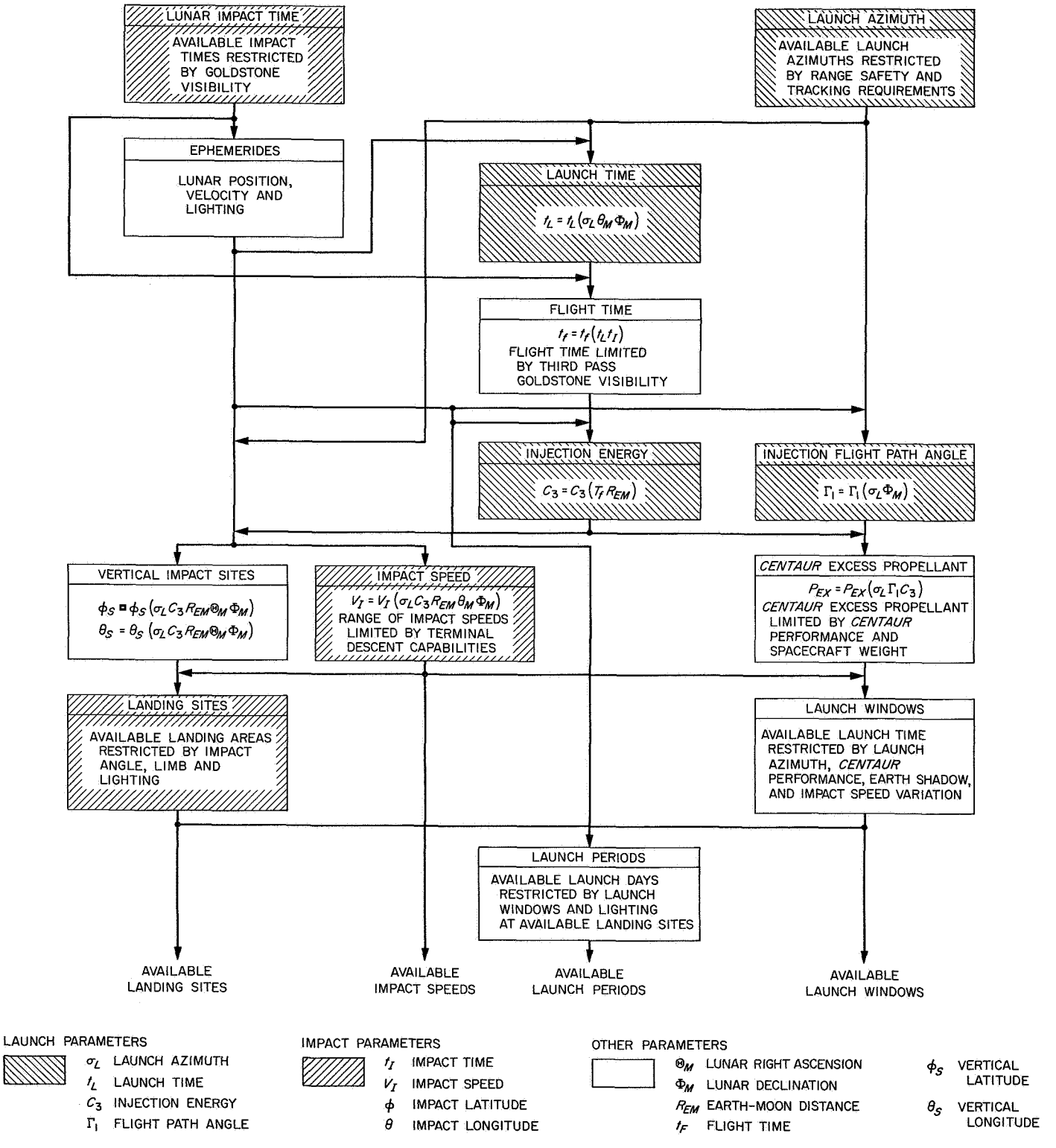


Fig. 2. *Atlas/Centaur/Surveyor* space vehicle configuration

After separation from the *Centaur*, spacecraft cold-gas jets nulled the rotational rates imparted during separation. The solar panels were automatically erected and the sun acquisition was also accomplished automatically. This was the standard condition of the spacecraft at the initial Johannesburg acquisition. For a nonstandard condition, this station was to send the commands to erect the solar panels and accomplish sun acquisition.

A midcourse correction maneuver, executed approximately 15 h after injection, provided the spacecraft with a trajectory that terminated at the desired point on the lunar surface called the terminal descent maneuver. This maneuver was computed at the SFOF from tracking information supplied by the DSS of the DSIF.

The terminal maneuver was initiated by pointing the vehicle thrust axis in a direction that is precalculated at the SFOF, to be aligned with the predicted velocity vector at main retroengine ignition for vertical approaches. For off-vertical angles, a small bias angle is sometimes introduced. Then, when distance to the lunar surface reached a preset value (about 60 mi) a pulse-type radar altimeter generated 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 were ignited.

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

The retroengine separated from the spacecraft after burnout at a nominal lunar altitude of 30,000 ft. Vernier engines then operated 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 were unlocked and properly oriented after landing. Postlanding television sequences were then selected in real time. Lunar touchdown time was adjusted for the target area to be observable from the Pioneer Deep Space Station (DSS 11) at Goldstone, California.

D. Surveyor Spacecraft

1. Design series. The *Surveyor* spacecraft was designed in two basic series. The A-21 series of spacecraft 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 scientific payload of various instruments. The primary purpose of the A-21A series was the collection and transmission of scientific data relative to the lunar environment.

2. Configuration. The general arrangement of the 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, television, and power subsystems. The flight-control subsystem provided attitude stabilization and control during all phases of the flight. The primary sun sensors and the Canopus sensor provided attitude reference during coast phases of the flight. Other elements of the flight-control subsystem included gas jets, and inertial reference unit, and associated electronics. The altitude-marking radar initiated the terminal descent phase by firing the vernier engines and main retrorocket engine. 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 receiver/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.

In addition to these subsystems, the first four *Surveyor* spacecraft carried an engineering payload. The 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

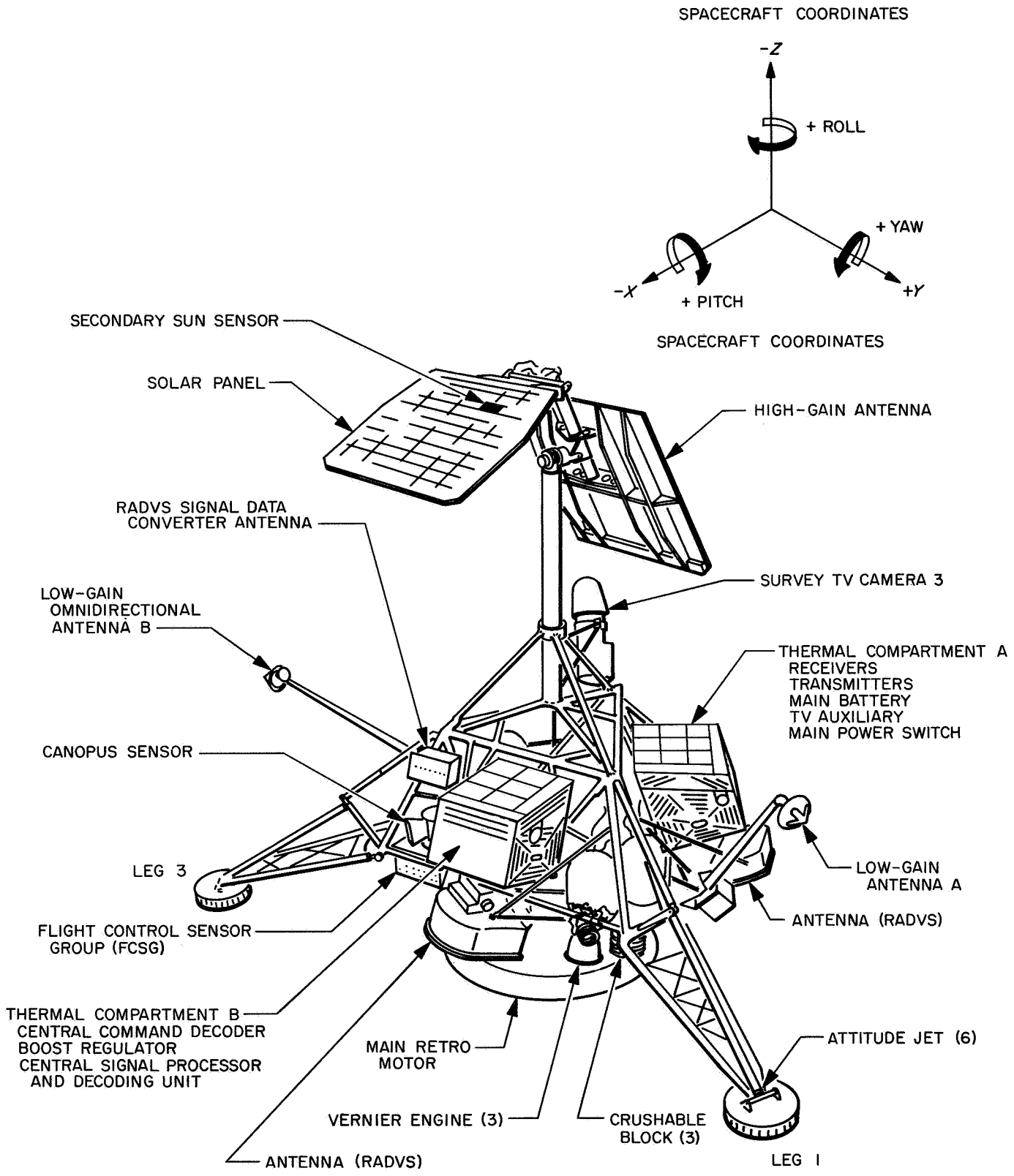


Fig. 3. *Surveyor* spacecraft configuration

of the system including the structure. The auxiliary engineering signal processor processed the sensor data for transmission.

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

As has already been mentioned, 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 this 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 terminal descent. During the terminal sequence, the propulsion system was controlled automatically by a radar system that measured attitude and velocity components with respect to the lunar surface.

The spacecraft derived its electrical power from a solar panel and from batteries for peak power requirements during transit, and after landing during the lunar night. It had a two-way communications 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 for orbit determination.

E. *Atlas/Centaur* Launch Vehicle

The two-stage launch vehicle (Fig. 4) consists of an *Atlas* first stage and a *Centaur* second stage. Both stages are of a constant 10-ft-diam stainless-steel shell construction that maintains its shape through pressurization without any internal stiffening. All main engines, plus the *Atlas* verniers, are gimbaled for directional control.

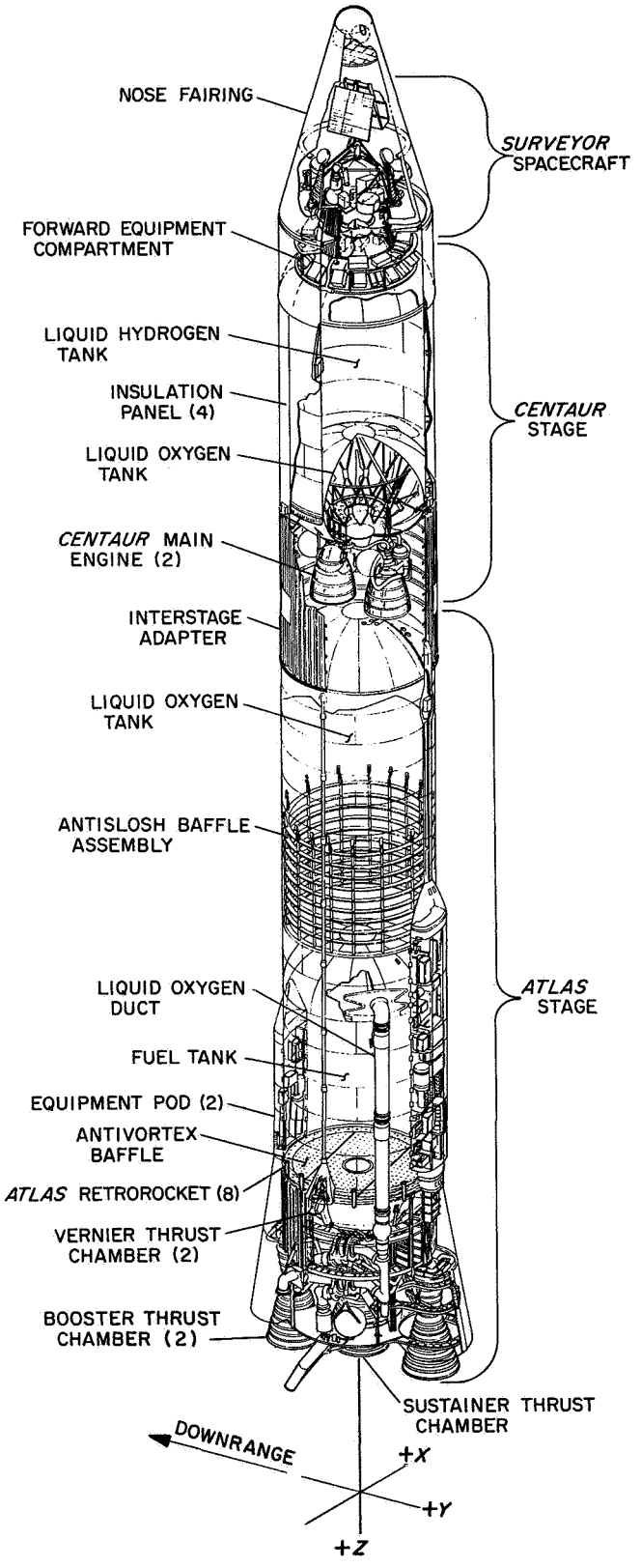


Fig. 4. Functional relationships between launch parameters, impact parameters, mission design constraints, and *Surveyor* trajectory design.

The gross weight of the 105-ft vehicle is approximately 300,000 lb at liftoff.

1. First stage. The first stage of the *Atlas/Centaur* vehicle is a modified version of the *Atlas D* used on many previous NASA and Air Force missions such as *Ranger, Mariner* and the *Orbiting Geophysical Observatory (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 burn a propellant combination of liquid oxygen and RP-1 kerosene, producing a total liftoff thrust of approximately 388,000 lb. The *Atlas* can be a 1½-stage vehicle; the 6000-lb booster section—consisting of the two booster engines, booster turbo pumps, and other equipment located in the aft section—is jettisoned after 2.5 min of flight. The sustainer and vernier engines continue to burn until propellant depletion. A mercury manometer propellant utilization system is used to control mixture ratio to minimize propellant residuals at *Atlas* burnout.

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

The *Atlas* contains a single VHF telemetry system, which transmits data on 118 first-stage measurements until *Atlas* separation. The system operates on a frequency of 229.9 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 are employed on the *Atlas* to provide the Range Safety Officer with means of terminating the flight by initiating engine cutoff and destroying the vehicle. The system is inactive after normal *Atlas* staging occurs. The AZUSA[2] tracking system has been deleted from the *Atlas* for *Surveyor* missions, leaving only the C-band tracking system on the *Centaur* stage.

[2]A short-baseline, continuous-wave, phase-comparison, single-station trading system.

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

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

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

sequence of programmed events during the *Centaur* phase of flight, including a series of commands required to be sent to the spacecraft prior to spacecraft separation.

The *Centaur* reaction-control system provides thrust to control the vehicle after powered flight. For small corrections in yaw, pitch, and roll attitude control, the system utilizes six individually controlled, fixed-axes, constant-thrust, hydrogen-peroxide reaction engines. These engines are mounted in clusters of three, 180 deg apart on the periphery of the main propellant tanks at the interstage adapter separation plane. Each cluster contains one 6-lb thrust engine for pitch control and two 3.5-lb thrust engines for yaw and roll control. In addition, four 50-lb thrust hydrogen peroxide engines are installed on the aft bulkhead, with thrust axes parallel with the vehicle axis. These engines are for use during retromaneuver and for executing larger attitude corrections, if necessary. The cluster engines were slightly modified from the design used on the previous flight (*A/C-8*), in that the large aluminum B-nut on the thrust chambers was replaced with a steel flange joint to effect a more positive seal.

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

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

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

Elements of a C-band system are contained on the *Centaur*, including a lightweight transponder, circulator, power divider, and two antennas, located under the insulation panels. The C-band radars on earth establish two-way communication with the flight equipment, and this total system provides angle and range data, properly time-tagged for the various users.

II. *Surveyor I* Mission Synopsis

The historic flight of *Surveyor I*, starting from Launch Complex 36A at Cape Kennedy and culminating in a soft landing on the level terrain of the moon's dry Sea of Storms, was accomplished in the period between May 30, 1966 and June 1, 1966.

Following a smooth countdown, launch was at 14:41:01 GMT,[3] on May 30, 1966 and proceeded through a journey of 63 h, 36 min, and 35 s. The flight was brought to a successful conclusion by the execution of a soft landing on the lunar surface at 18:17:37 GMT on June 1, 1966. The landing, characterized by the three landing legs touching the surface almost simultaneously, was so gentle that the receiver at Deep Space Station (DSS) 11 retained its phase-lock to the spacecraft transmitted signal. The spacecraft shock absorber strain gages indicated a low-level force as the spacecraft landed on the lunar surface. The only spacecraft malfunction which occurred throughout the flight was the failure of low-gain omnidirectional antenna A to extend. This condition corrected itself during either the terminal retro phase or at touchdown when the antenna deployed to its properly extended position.

Two seconds after liftoff, the *Atlas* autopilot rolled the vehicle to the required heading, and the pitch program was initiated after 15 s of vertical flight. At approximately 142 s after liftoff, the *Atlas* booster engine cut off (BECO) was jettisoned. Sometime before the sustainer and vernier engines burned out, a command from the *Centaur* programmer initiated ejection of the *Centaur* insulation panels and the spacecraft nose fairing. After sustainer and vernier engine cutoff (SECO/VECO), *Atlas/Centaur* separation occurred. After *Centaur* main engine ignition (MEIG), the vehicle accelerated on into the required lunar transit trajectory, then cut off. Shortly after injection, a *Centaur* programmer command deployed the spacecraft landing legs and the omnidirectional antennas, switched the spacecraft transmitter to high power, and finally, separated the spacecraft from the *Centaur*. The *Centaur* then executed a retro maneuver to remove itself from the vicinity of the spacecraft and prevent interference with the spacecraft Canopus sensor later in the flight.

[3]Greenwich mean time.

Two-way communications lock was achieved by DSS 51 in Johannesburg, South Africa. At liftoff plus 28 min, control of the mission was transferred from the AFETR to the SFOF at JPL, in Pasadena, California. Commands were transmitted to *Surveyor* to deploy omnidirectional antenna A, but telemetry indicated no change. Figure 5 shows the *Surveyor I* Earth Track.

Following separation at 14:53:38 GMT, the spacecraft executed the following planned automatic sequences: (1) the flight control subsystem, using cold-gas jets, nulled out the small rotational rates imparted by the separation springs and initiated a roll-yaw sequence to acquire the Sun; (2) the solar panels were erected and aligned perpendicular to the vehicle roll axis; and (3) Sun acquisition and lock followed, providing a fixed reference for orientation in the yaw and pitch axes. This was the standard condition of the spacecraft at the initial acquisition by DSS 51 at Johannesburg, South Africa. Johannesburg reported that spacecraft telemetry data looked good but that omnidirectional antenna A extension was not indicated.

Although the minor antenna failure was not expected to seriously jeopardize the mission from either the standpoint of communications or because of the slight change in spacecraft center of gravity, the exact position of the antenna remained undetermined. This was a concern until post-touchdown telemetry and signal strength revealed that it had deployed during either retroignition or upon spacecraft contact with the lunar surface.

In planning the midcourse maneuver, a new aiming point (2.33 deg south, 48.83 deg west) was chosen about 1 deg farther north than the original target to improve the probability of landing in a smooth region. During visibility of DSS 11, Goldstone, a roll-yaw maneuver sequence was conducted in preparation for midcourse velocity correction. Then, at 06:45 GMT on May 31, 1966, a velocity correction of 20:35 m/s was executed. Only a fraction of this velocity change was required to compensate for the injection error. The larger maneuver was selected to optimize the terminal descent conditions, which included main retro burnout velocity, vernier system propellant margin, and arrival time.

A sequence of commands, first standard and then nonstandard, was sent to the spacecraft to extend omnidirectional antenna A; the results were negative. Preliminary analysis of the effect of the omnidirectional antenna anomaly indicated the feasibility of designing a midcourse maneuver using omnidirectional antenna B.

In order to establish the spacecraft in the first coast phase attitude, it was necessary to acquire the star Canopus for fixed orientation in roll. Following establishment of two-way lock with the spacecraft, DSS 51 commanded the spacecraft to search for the star with the Canopus sensor. Acquisition was verified by telemetered data from the sensor, the output of which was used to generate a star map for comparison to known standard maps for the date of launch.

The midcourse correction maneuver is normally executed approximately 15 h after launch, following establishment of two-way lock between the spacecraft and DSS 11 at Goldstone, California. This maneuver is designed to place the spacecraft on a trajectory that will permit soft landing at the desired point on the lunar surface. The midcourse correction was computed at the SFOF, JPL, Pasadena, California, from tracking data transmitted via the NASA DSN.

Following execution of the midcourse velocity correction, the spacecraft was commanded to reacquire the sun and star, thereby returning to the optical control mode for the second coast phase. Reacquisition was accomplished by performing maneuvers of the same magnitude as those performed before midcourse thrusting, but in the opposite direction and in the reverse order.

As the first step in the terminal maneuver, the spacecraft roll axis was aligned such that the retro thrust vector was opposite the spacecraft velocity vector, with the spacecraft landing legs facing the lunar surface. The vernier thrust level and retro ignition delay time were commanded into the spacecraft programmer, and the altitude marking radar (AMR) power turned on. All radars were turned on approximately 5 min before predicted touchdown. An automatic flight control landing sequence was initiated by a *mark* signal from the enabled AMR at about 60 mi above the lunar surface. A few seconds later, at the end of programmed delay time, the vernier control engines and the main retro engine ignited. The retro engine separated from the spacecraft after burnout at a nominal lunar altitude of 30,000 ft; the vernier engines continued to burn, stabilizing the spacecraft while under control of the RADVS and slowing the spacecraft velocity to about 5 ft/s at a 13-ft altitude. The verniers were then cut off by the RADVS. The spacecraft fell free to a soft landing (touchdown) on the lunar surface.

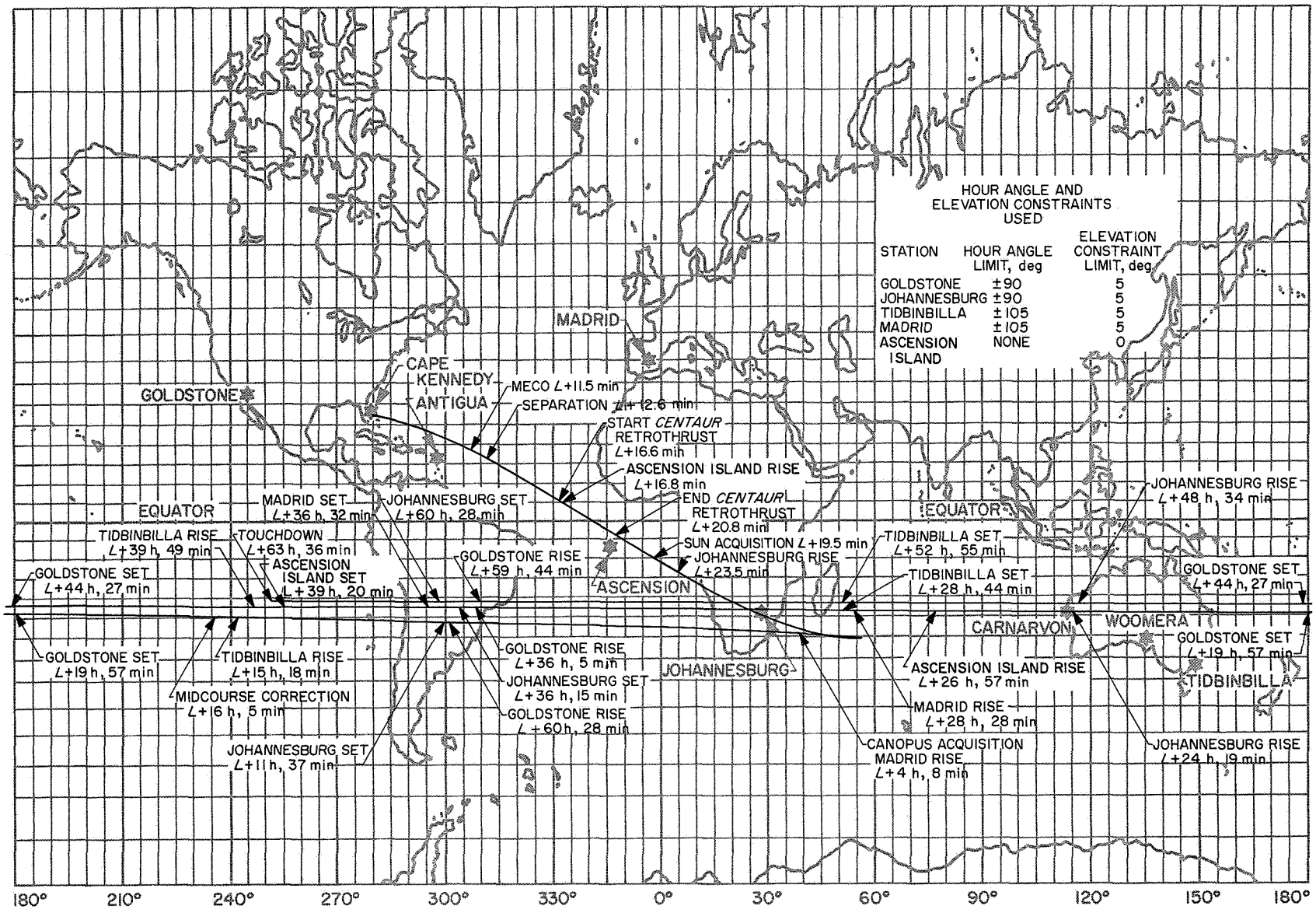


Fig. 5. *Surveyor I* earth track

The solar panel and planar array were unlocked and properly oriented after landing. During the standard post-touchdown activities, a 200-line TV picture of pad 3 was taken and a general assessment of post-touchdown condition of the spacecraft made. This completed the standard sequence of space flight events. Further TV sequences and spacecraft evaluation took place after completion of the standard flight operations sequence.

Four terminal maneuvers were considered and analyzed during the mission: three using omnidirectional antenna B, and one using omnidirectional antenna A. As in the case of the midcourse maneuver, a maneuver using omnidirectional antenna B was highly desirable. Three of the four maneuvers were also analyzed using omnidirectional antenna A antenna patterns for a non-extended position.

A roll-yaw-roll maneuver was selected. This maneuver used the final roll to optimize the antenna gain on omnidirectional antenna B for subsequent terminal descent data. Zero margins were predicted for this maneuver with an uncertainty of ± 3 dB in the margin. It was recommended that the maneuver be made in one-way even though adequate margins were available for transponder operation. Since one-way was required for the terminal descent sequence, it was operationally safer to go to one-way before the terminal maneuver.

The maneuver was executed using commutator mode 1, which contains no receiver automatic gain control (AGC) signals. Therefore, no data is available on the spacecraft receiver signal levels during the maneuver. DSIF receiver AGC data was available and the signal levels again followed the downlink predictions. Telemetry data at 1100 bits/s was maintained with no data dropouts, as predicted. During the first roll maneuver, a receiver/decoder index was noted indicating that one of the receivers experienced a severe drop in signal level. This posed no problem since all subsequent commands were accepted. The receiver–decoder index, however, is considered to be further evidence that omnidirectional antenna A had not deployed up to the time of this maneuver.

The transmitter was commanded to high power at 05:20 on day 153 and remained on until 07:19. The power output was 40.6 dBmW at turnon and decreased to 39.8 dBmW at turnoff. The transmitter was in high power for approximately 2 h.

The spacecraft altitude marking radar provided a mark signal that started the automatic descent sequence. After a delay of 7.826 s, the three liquid propellant vernier engines ignited, followed (after an additional 1.1-s delay) by ignition of the solid-propellant main retro motor at a lunar slant range of 246,635 ft and velocity of 8,565 ft/s. Main retro burnout occurred after the spacecraft had been decelerated to a velocity of 428 ft/s. After the solid motor case was ejected, the radar altimeter and RADVS became operational and controlled the final descent by throttling the vernier engines. The vernier engines were cut off when the spacecraft was 12 ft from the surface and traveling only 4 ft/s. The spacecraft free-fell the final 12 ft, touching the surface at 06:17:37 GMT on June 2, 1966, with a velocity of 12 ft/s. The three footpads contacted the surface nearly simultaneously (within 19 ms of each other) and penetrated the surface to a depth of a few inches. At least one of the three crushable blocks under the frame also made an imprint on the surface as the shock absorbers compressed at touchdown. Strain-gage readings indicated that the spacecraft rebounded about 2–12 in. above the surface before coming to rest.

The best estimate of the actual landing site, based upon preliminary analysis of post-touchdown tracking data, was -2.58-deg latitude and 316.65-deg longitude in the Ocean of Storms, about 9 mi from the modified aiming point. This result was in good agreement with landing site determinations which were based upon correlation of *Surveyor I* topographical photos with earth-based pictures.

On a scale of miles, the spacecraft landed on a relatively smooth, nearly level, bare surface, encircled by hills and low mountains, the crestlines of a few of which are visible along the horizon from the vantage point of the spacecraft survey camera (about 4 ft above the surface). On a finer scale, the terrain surrounding *Surveyor I* was a gently rolling surface composed of granular material of a wide-size range, studded with craters having diameters from a few inches to several hundred yards, and littered with fragmental debris ranging in size from less than 0.04 in. to more than a yard. The larger craters observed resemble those seen in the *Ranger* photographs in shape and distribution leading to the conclusion that the *Surveyor I* site is representative of a mare surface.

Touchdown occurred 57 h into the first lunar day (May 30–June 14, 1966), with about 5 h remaining in the view period of DSS 11 at Goldstone, California. After post-landing engineering-interrogations confirmed that all

CHARACTERISTIC AC-10
LUNAR INJECTION PARAMETERS

(FOR REFERENCE TRAJECTORY OF FOLLOWING CONDITIONS ONLY, ACTUAL AC-10 CONDITIONS VARIABLE):

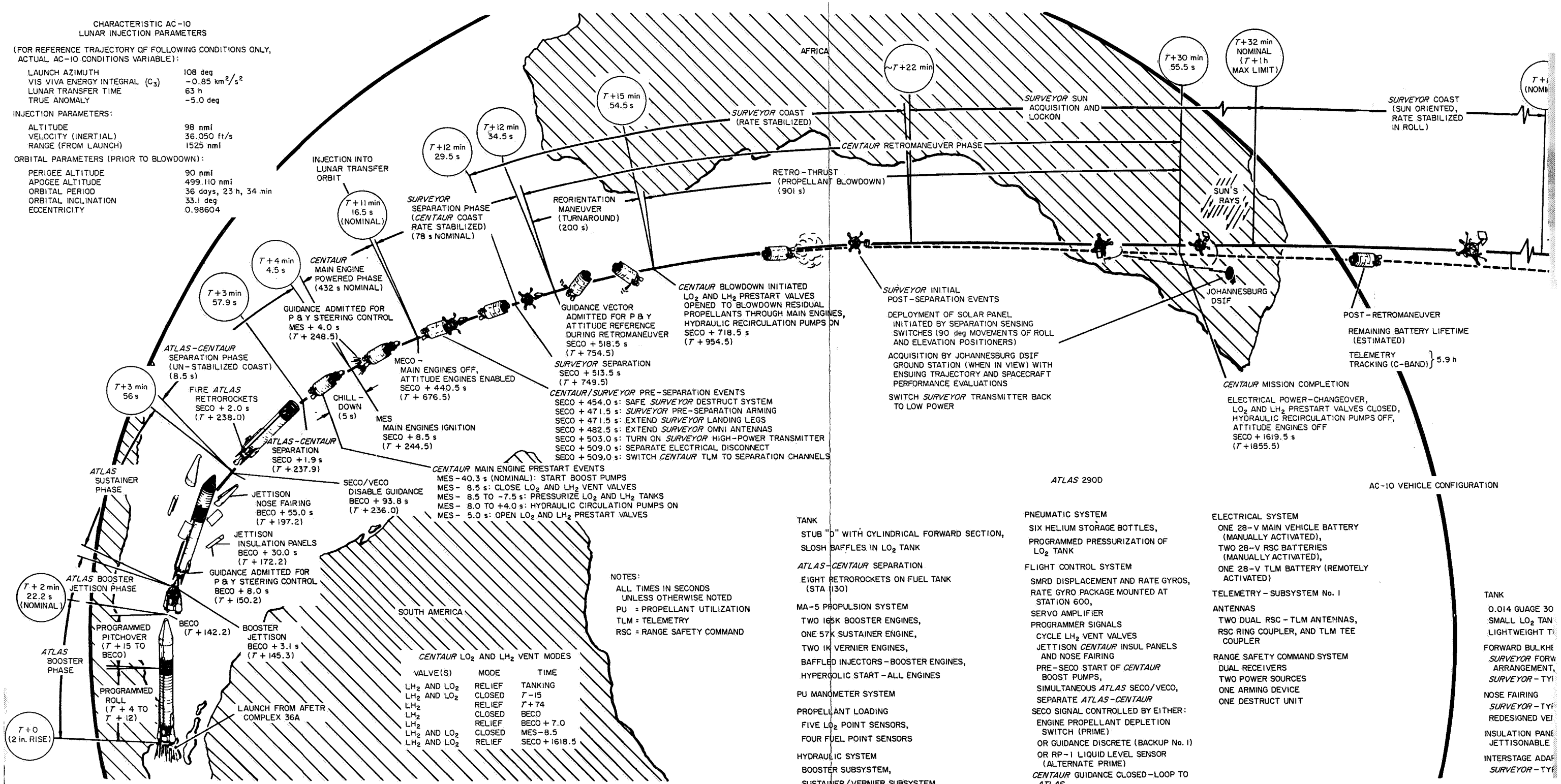
LAUNCH AZIMUTH	108 deg
VIS VIVA ENERGY INTEGRAL (C_3)	$-0.85\ km^2/s^2$
LUNAR TRANSFER TIME	63 h
TRUE ANOMALY	-5.0 deg

INJECTION PARAMETERS:

ALTITUDE	98 nmi
VELOCITY (INERTIAL)	36,050 ft/s
RANGE (FROM LAUNCH)	1525 nmi

ORBITAL PARAMETERS (PRIOR TO BLOWDOWN):

PERIGEE ALTITUDE	90 nmi
APOGEE ALTITUDE	499,110 nmi
ORBITAL PERIOD	36 days, 23 h, 34 min
ORBITAL INCLINATION	33.1 deg
ECCENTRICITY	0.98604



CENTAUR LO_2 AND LH_2 VENT MODES

VALVE(S)	MODE	TIME
LH_2 AND LO_2	RELIEF	TANKING
LH_2 AND LO_2	CLOSED	T-15
LH_2	RELIEF	T+74
LH_2	CLOSED	BECO
LH_2	RELIEF	BECO + 7.0
LH_2 AND LO_2	CLOSED	MES-8.5
LH_2 AND LO_2	RELIEF	SECO + 1618.5

NOTES:
ALL TIMES IN SECONDS UNLESS OTHERWISE NOTED
PU = PROPELLANT UTILIZATION
TLM = TELEMETRY
RSC = RANGE SAFETY COMMAND

AC-10 VEHICLE CONFIGURATION

ATLAS 290D

TANK
- STUB "D" WITH CYLINDRICAL FORWARD SECTION,
- SLOSH BAFFLES IN LO_2 TANK

ATLAS-CENTAUR SEPARATION
- EIGHT RETROROCKETS ON FUEL TANK (STA 1130)

MA-5 PROPULSION SYSTEM
- TWO 165K BOOSTER ENGINES,
- ONE 57K SUSTAINER ENGINE,
- TWO 1K VERNIER ENGINES,
- BAFFLED INJECTORS-BOOSTER ENGINES,
- HYPERGOLIC START-ALL ENGINES

PU MANOMETER SYSTEM

PROPELLANT LOADING
- FIVE LO_2 POINT SENSORS,
- FOUR FUEL POINT SENSORS

HYDRAULIC SYSTEM
- BOOSTER SUBSYSTEM,
- SUSTAINER/VERNIER SUBSYSTEM

PNEUMATIC SYSTEM
- SIX HELIUM STORAGE BOTTLES,
- PROGRAMMED PRESSURIZATION OF LO_2 TANK

FLIGHT CONTROL SYSTEM
- SMRD DISPLACEMENT AND RATE GYROS,
- RATE GYRO PACKAGE MOUNTED AT STATION 600,
- SERVO AMPLIFIER
- PROGRAMMER SIGNALS
  - CYCLE LH_2 VENT VALVES
  - JETTISON *CENTAUR* INSUL PANELS AND NOSE FAIRING
  - PRE-SECO START OF *CENTAUR* BOOST PUMPS,
  - SIMULTANEOUS *ATLAS* SECO/VECO,
  - SEPARATE *ATLAS-CENTAUR*
- SECO SIGNAL CONTROLLED BY EITHER:
  - ENGINE PROPELLANT DEPLETION SWITCH (PRIME)
  - OR GUIDANCE DISCRETE (BACKUP No. 1)
  - OR RP-1 LIQUID LEVEL SENSOR (ALTERNATE PRIME)
- *CENTAUR* GUIDANCE CLOSED-LOOP TO *ATLAS*

ELECTRICAL SYSTEM
- ONE 28-V MAIN VEHICLE BATTERY (MANUALLY ACTIVATED),
- TWO 28-V RSC BATTERIES (MANUALLY ACTIVATED),
- ONE 28-V TLM BATTERY (REMOTELY ACTIVATED)

TELEMETRY-SUBSYSTEM No. 1

ANTENNAS
- TWO DUAL RSC-TLM ANTENNAS,
- RSC RING COUPLER, AND TLM TEE COUPLER

RANGE SAFETY COMMAND SYSTEM
- DUAL RECEIVERS
- TWO POWER SOURCES
- ONE ARMING DEVICE
- ONE DESTRUCT UNIT

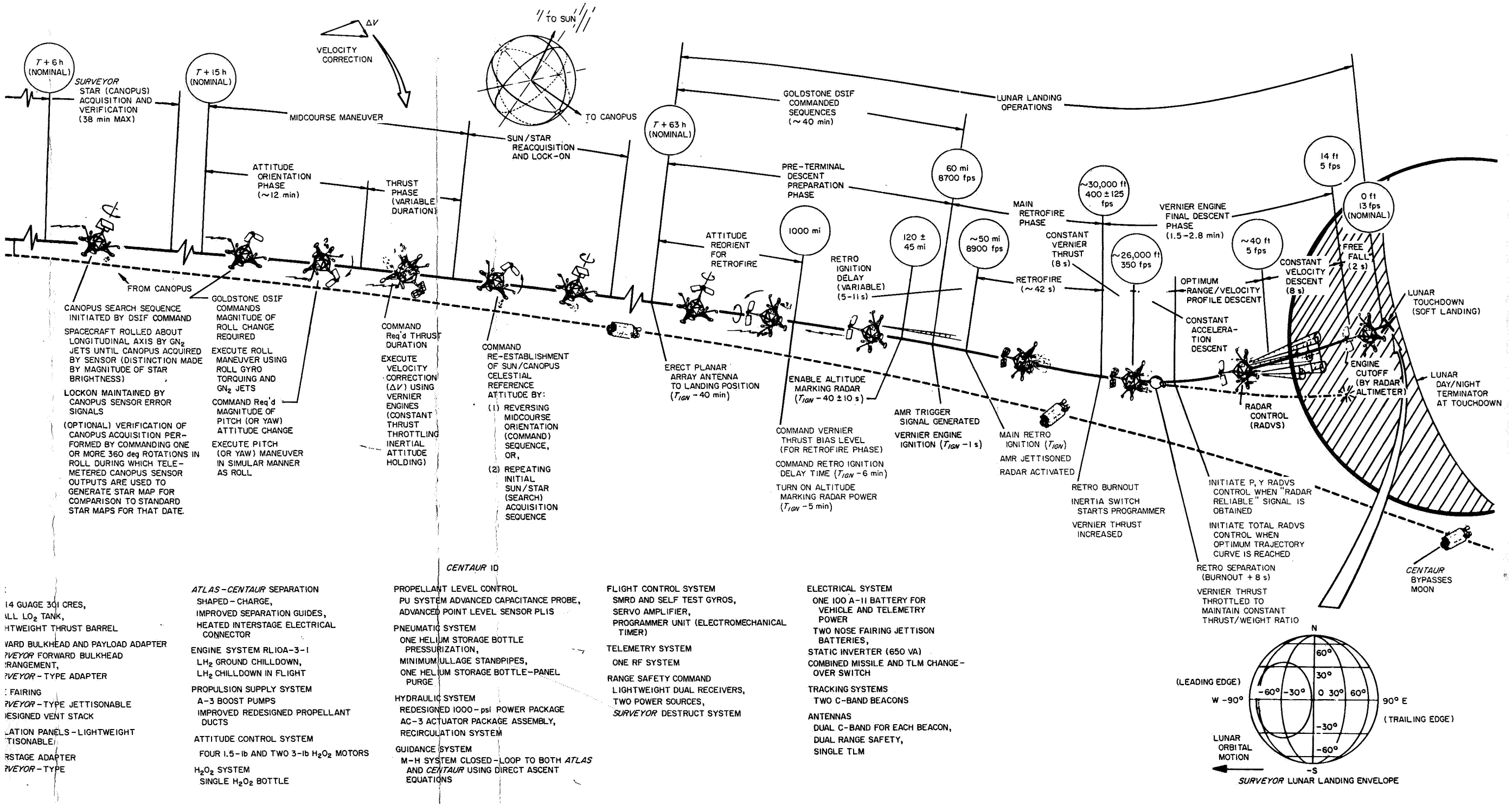
TANK
- 0.014 GUAGE 30
- SMALL LO_2 TAN
- LIGHTWEIGHT TI

FORWARD BULKHE
- *SURVEYOR* FORW ARRANGEMENT,
- *SURVEYOR* - TYI

NOSE FAIRING
- *SURVEYOR* - TYI
- REDESIGNED VEI

INSULATION PANE JETTISONABLE

INTERSTAGE ADAP
- *SURVEYOR* - TYI



CENTAUR ID

14 GUAGE 301 CRES,
ALL LO_2 TANK,
HTWEIGHT THRUST BARREL

WARD BULKHEAD AND PAYLOAD ADAPTER
RVEYOR FORWARD BULKHEAD
RANGEMENT,
RVEYOR - TYPE ADAPTER

FAIRING
RVEYOR - TYPE JETTISONABLE
ESIGNED VENT STACK

LATION PANELS - LIGHTWEIGHT
TISONABLE

RSTAGE ADAPTER
RVEYOR - TYPE

ATLAS-CENTAUR SEPARATION
- SHAPED-CHARGE,
- IMPROVED SEPARATION GUIDES,
- HEATED INTERSTAGE ELECTRICAL CONNECTOR

ENGINE SYSTEM RL10A-3-1
- LH_2 GROUND CHILLDOWN,
- LH_2 CHILLDOWN IN FLIGHT

PROPULSION SUPPLY SYSTEM
- A-3 BOOST PUMPS
- IMPROVED REDESIGNED PROPELLANT DUCTS

ATTITUDE CONTROL SYSTEM
- FOUR 1.5-lb AND TWO 3-lb H_2O_2 MOTORS

H_2O_2 SYSTEM
- SINGLE H_2O_2 BOTTLE

PROPELLANT LEVEL CONTROL
- PU SYSTEM ADVANCED CAPACITANCE PROBE,
- ADVANCED POINT LEVEL SENSOR PLIS

PNEUMATIC SYSTEM
- ONE HELIUM STORAGE BOTTLE PRESSURIZATION,
- MINIMUM ULLAGE STANDPIPES,
- ONE HELIUM STORAGE BOTTLE-PANEL PURGE

HYDRAULIC SYSTEM
- REDESIGNED 1000-psi POWER PACKAGE
- AC-3 ACTUATOR PACKAGE ASSEMBLY,
- RECIRCULATION SYSTEM

GUIDANCE SYSTEM
- M-H SYSTEM CLOSED-LOOP TO BOTH *ATLAS* AND *CENTAUR* USING DIRECT ASCENT EQUATIONS

FLIGHT CONTROL SYSTEM
- SMRD AND SELF TEST GYROS,
- SERVO AMPLIFIER,
- PROGRAMMER UNIT (ELECTROMECHANICAL TIMER)

TELEMETRY SYSTEM
- ONE RF SYSTEM

RANGE SAFETY COMMAND
- LIGHTWEIGHT DUAL RECEIVERS,
- TWO POWER SOURCES,
- *SURVEYOR* DESTRUCT SYSTEM

ELECTRICAL SYSTEM
- ONE 100 A-H BATTERY FOR VEHICLE AND TELEMETRY POWER
- TWO NOSE FAIRING JETTISON BATTERIES,
- STATIC INVERTER (650 VA)
- COMBINED MISSILE AND TLM CHANGE-OVER SWITCH

TRACKING SYSTEMS
- TWO C-BAND BEACONS

ANTENNAS
- DUAL C-BAND FOR EACH BEACON,
- DUAL RANGE SAFETY,
- SINGLE TLM

3

SURVEYOR SPACECRAFT – I CONFIGURATION

A-21 (ENGINEERING TEST MODEL)

STRUCTURE

- THIN-WALLED TUBULAR TRUSS SPACEFRAME OF 7075-T6 ALUMINUM ALLOY (POLISHED)
- FOLDABLE LANDING LEGS (3), EACH WITH SHOCK ABSORBER AND FOOT PAD
- CRUSHABLE LANDING BLOCKS (3)
- DEPLOYABLE OMNI ANTENNA BOOMS (2)
- ANTENNA/SOLAR PANEL MAST AND POSITIONER
- THERMAL CONTROLLED COMPARTMENTS A AND B

PROPULSION

- MAIN RETROROCKET (SOLID PROPELLANT):
  - 86-in. D SPHERICAL CASE, SEMI-IMBEDDED NOZZLE, JETTISONED AFTER BURNOUT
  - THRUST (FIXED): 8800 lb (MEAN)
  - PROPELLANT (COMPOSITE TYPE): PBAA (FUEL), AMMONIUM PERCHLORATE (OXIDIZER)
- VERNIER SYSTEM (LIQUID PROPELLANT):
  - THREE THRUST CHAMBERS (ONE GIMBALLED, TWO FIXED), RESTARTABLE, THROTTLEABLE
  - THRUST (VARIABLE): 30- TO 104-lb/CHAMBER
  - PROPELLANTS (HYPERGOLIC): MMH HYDRATE (FUEL), N_2O_2/NO (OXIDIZER)
  - SIX PROP. TANKS, POSITIVE EXPULSION BLADDERS
  - ONE HELIUM SUPPLY BOTTLE (1290 $in.^3$)

FLIGHT CONTROL

- INERTIAL REFERENCE UNIT (IRU): RATE GYROS (P, Y, R), LONG, ACCELEROMETER, INERTIA SWITCH
- OPTICAL SENSORS: ACQUISITION, PRIMARY AND SECONDARY SUN SENSORS, CANOPUS STAR SENSOR
- RADAR SENSORS: ALTITUDE MARKER RADAR (AMR), RADAR ALTIMETER AND DOPPLER VELOCITY SENSOR (RADVS) – 4-BEAM
- FLIGHT CONTROL ELECTRONICS: CONTROL CIRCUITS, DIGITAL PROGRAMMER, AC/DC POWER CONVERSION
- GN_2 P, Y, R ATTITUDE JETS, SUPPLY BOTTLE (412 $in.^3$)

ELECTRICAL POWER

- SUPPLY:
  - 3200 W-H, 22-V MAIN BATT (RECHARGEABLE)
  - 900 W-H, 22-V AUX BATT (NON-RECHARGEABLE)*
  - 792-CELL, 89-W (NOMINAL) OUTPUT SOLAR PANEL
- POWER MANAGEMENT:
  - CENTRAL POWER CONTROL UNIT
  - AUXILIARY BATTERY CONTROL UNIT*

TELECOMMUNICATIONS (S-BAND):

- REDUNDANT (2) RECEIVER/TRANSPONDERS
- REDUNDANT (2) TRANSMITTERS
- DUAL OMNI-DIRECTIONAL ANTENNAS
- SINGLE DIRECTIONAL HI-GAIN PLANAR ARRAY ANTENNA, EARTH TRACKING

COMMAND DECODING AND SIGNAL PROCESSING

- COMMAND DECODING:
  - REDUNDANT (2) CENTRAL COMMAND DECODERS
  - EIGHT SUBSYSTEM DECODERS
  - RECEIVER-DECODER SELECTOR
- SIGNAL PROCESSING:
  - CENTRAL SIGNAL PROCESSOR
  - ENGR SIGNAL PROCESSOR
  - AUXILIARY ENGR SIGNAL PROCESSOR*
  - SIGNAL PROCESSOR AUXILIARY
  - LOW RATE DATA AUXILIARY

TELEVISION

- TV CAMERA No. 3 (POST-LANDING SURVEY):*
  - VARIABLE FOCAL LENGTH, FOCUS, AND APERTURE SETTINGS: AZIMUTH AND ELEVATION SCANNING, COLOR FILTER INSERTIONS, 600 LINES/FRAME
- TELEVISION AUXILIARY UNIT

THERMAL CONTROL

- PASSIVE PROVISIONS:
  - SUPERINSULATION (CRUMPLED ALUMINIZED MYLAR SHEETS) ON MAIN RETRO, SELECTED PROP. TANKS, COMPARTMENTS A AND B, ELECTRICAL WIRING
  - RADIATOR SURFACE (VYCOR GLASS MIRRORS) ON COMPARTMENTS A AND B
  - THERMAL ISOLATION MOUNTS, THERMAL PAINT, SURFACE BUFFING, PLATING, ETC.
- ACTIVE PROVISIONS:
  - HEATERS IN COMPARTMENTS A AND B, GYROS, PROP. TANKS AND LINES
  - THERMAL SWITCHES: COMPARTMENT A (9) AND COMPARTMENT B (6)

ENGINEERING PAYLOAD (*SURVEYOR* ANALYSIS)

- ADDED ENGINEERING INSTRUMENTATION SENSORS
- ALL ITEMS DESIGNATED WITH •

SCIENTIFIC PAYLOAD (LUNAR EXPLORATION)

- (NONE)

Fig. 6. *Surveyor I* mission flight sequence

spacecraft systems had survived the landing, the first 200-scan-line picture was transmitted, about 35 min after touchdown. After 13 additional 200-line pictures were received, the solar panel was positioned to receive maximum solar power, and the high-gain antenna was pointed toward the earth for transmission of higher quality 600-line pictures. Goldstone received 133 600-line pictures during the remainder of its first post-touchdown *pass*, before it was necessary to command the spacecraft to an engineering telemetry mode for transfer to DSS 42 at Canberra, Australia. Table 2 shows the major milestones that were successfully accomplished by the *Surveyor I* flight. Figure 6 gives the flight sequence of the *Surveyor I* mission.

Table 2. *Surveyor I* mission milestones

Date and event	GMT	Time from launch
May 30, 1966		
Launch	14:40:01	0
Injection	14:52:30	11 min 29 s
Separation	14:53:38	12 min 37 s
Automatic sun acquisition completed	15:00:34	19 min 33 s
Automatic solar panel deployment completed	15:03:54	22 min 53 s
Spacecraft visibility at Johannesburg begun	15:04:31	23 min 30 s
Initial DSS acquisition (two-way lock) confirmed	15:08:41	27 min 40 s
First ground command sequence initiated	15:20:42	39 min 41 s
Canopus verification initiated	16:53:39	04 h 12 min 38 s
Canopus acquisition completed	18:13:20	04 h 32 min 19 s
First premidcourse attitude maneuver initiated	06:30:13	15 h 49 min 12 s
Midcourse thrust executed	06:45:03	16 h 45 min 03 s
Sun reacquired	06:54:51	16 h 13 min 51 s
May 31, 1966		
Canopus reacquired	07:00:55	16 h 19 min 54 s
June 1, 1966		
First terminal descent attitude maneuver initiated	05:36:46	62 h 55 min 45 s
Retro thrust direction properly positioned	05:43:47	63 h 02 min 46 s
Altitude marking radar mark generated	06:14:41	63 h 33 min 40 s
Vernier engine ignition	06:14:48	63 h 33 min 47 s
Retro engine ignition	06:14:49	63 h 33 min 48 s
Retro separation	06:15:40	63 h 34 min 39 s
Retro control initiated	06:15:42	63 h 34 min 01 s
Touchdown	06:17:36	63 h 36 min 36 s

Shortly after touchdown the spacecraft assessment began. Omnidirectional antenna A was selected for transmission at this time. The signal level at the DSS changed from −123.3 dBmW to −133 dBmW, exactly as predicted from the omniantenna patterns. Omnidirectional antenna B was thus selected for 200-line TV transmission.

Successful 200-line TV was transmitted with a margin of ~7.5 dB [which was equivalent to a signal-to-noise ratio (SNR) of ~13 dB]. Good quality 200-line TV was received by 07:07, approximately 49 min after touchdown.

The antenna and solar panel positioner (A/SPP) was checked for freedom of movement, and by 08:54 on Day 153 the positioning of the planar array toward the earth was begun. The planar array was positioned to within ~2 dB of the main lobe peak at which time it was decided to start taking 600-line TV pictures. The carrier signal level at the end of the positioning was ~ −119 dBmW with the spacecraft in low power and 1100-bits/s data being transmitted.

Successful 600-line TV was transmitted at 10:20. The margin was ~2.6 dB resulting in an SNR of ~14 dB for the 600-line TV pictures.

It was possible, by taking advantage of shading afforded by other elements of the spacecraft, to operate the spacecraft without exceeding the thermal limits during each remaining Goldstone pass of the first lunar day, except on June 8 and 9, 1966, when operations were suspended. In addition to a vast number of wide- and narrow-angle lunar surface pictures under varying lighting conditions, photographs were obtained of several bright stars in an effort to determine more accurately the location of the *Surveyor* spacecraft.[4] Pictures were also taken during and after the firing of bursts of nitrogen gas from the spacecraft attitude control jets in an unsuccessful attempt to disturb the lunar surface. A number of pictures were taken of the solar corona just after sunset. Over 10,000 pictures were received before the camera was secured after sunset of the first lunar day. The last of these pictures was successfully taken after the terminator has passed by increasing the exposure

[4]Because of the limited elevation range of the camera mirror, it was not possible to photograph the earth.

time to 4 min to permit sufficient earth-reflected light to illuminate the spacecraft footpad No. 2.

The spacecraft was in excellent condition as the first lunar day came to a close and, as a result, was secured in a configuration which was most favorable for its revival during the second lunar day.

Repeated attempts were made to communicate with the spacecraft beginning just before sunrise of the second lunar day, June 28, 1966. It finally responded on July 6, proving it had successfully survived the long, cold lunar night. The spacecraft solar panel was carefully commanded to a position to permit recharging of the battery, which had become very weak.

Shortly after resuming video operations on the second lunar day, a spacecraft battery anomaly occurred, causing an excessive rise in temperature. After emergency steps had been initiated to utilize what were believed to be the last few hours of spacecraft life, the battery returned to normal operation. It was then possible to continue picture taking sequences until the close of the second lunar day, July 14, 1966, when the operational phase of the *Surveyor I* mission was terminated.

The mission was a complete success, with all pre-mission objectives being achieved. Not only was the design integrity of the spacecraft proven, but the basic soundness of the operational plans, procedures, and techniques was established.

III. *Surveyor I* T&DS Mission Requirements

A. General

The T&DS support for the *Surveyor I* mission consisted of the committed facilities of: (1) the AFETR, (2) the GSFC and (3) the DSN. Figure 7 gives the *Surveyor I* Mission Project and T&DS Organization.

The Tracking and Data Acquisition (T&DA) requirements, for the *Surveyor I* mission, were placed on the T&DS by the NASA.

B. AFETR Tracking

The tracking coverage requirements placed upon the AFETR are treated in the following paragraphs. These requirements originate from the following areas: (1) the *Surveyor* mission requirements, (2) the launch vehicle requirements, and (3) range requirements.

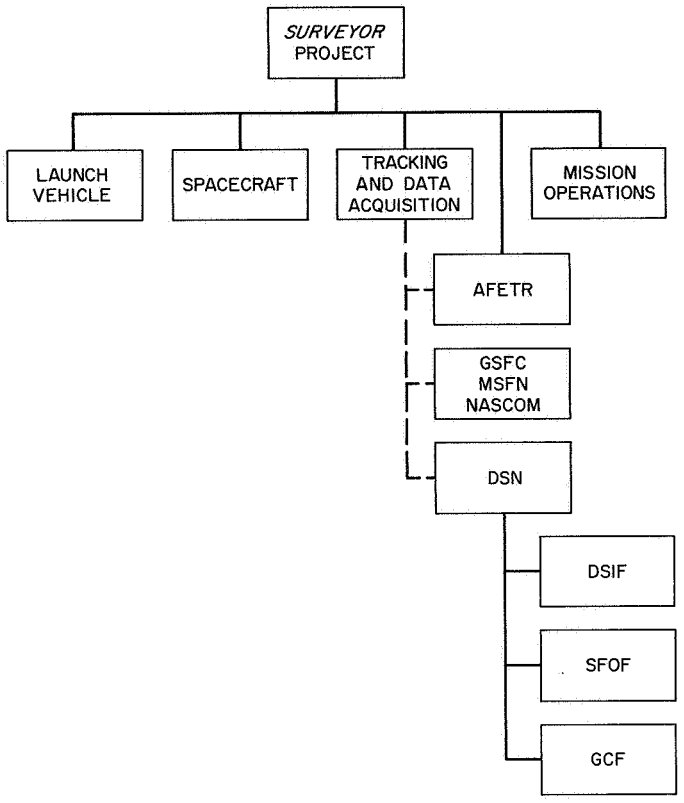


Fig. 7. *Surveyor I* project and T&DS organization

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

It is clear that the processing of AFETR raw data after injection is involved with, and conditional upon, the telemetry identification of certain events. The relative weighting of the different AFETR data types (e.g., range and angles with respect to DSIF data) was a task requiring more information than was available to AFETR. Hence,

it was important that raw data be supplied to the DSN. Therefore, these requirements stating that the *Centaur* orbit would be determined by AFETR and that raw tracking data would be furnished to the DSN during launch was greatly needed. Raw data can be defined as raw azimuth, elevation, and range points which have not been altered by smoothing, weighting, etc. One exception to this definition was exhibited by the desirability to correct the range instrumentation tracking ship (RIS) raw data for ship motion. However, ship range data is usually valuable even if ship motion has not been removed.

AFETR land and ship stations, MSFN stations, and DSN stations were expected to be utilized in providing required coverage. The key stations involved during the critical intervals of the near-earth phase are listed below. The first four stations have C-band radar, VHF telemetry, and S-band telemetry capabilities; capabilities of the other stations are as indicated:

(1) AFETR station at Antigua

(2) AFETR RIS *General Arnold*

(3) AFETR station at Ascension Island

(4) AFETR station at Pretoria, South Africa

(5) AFETR RIS *Coastal Crusader* (VHF and S-band only)

(6) AFETR RIS *Sword Knot* (VHF and S-band only)

(7) MSFN station at Kano, Nigeria (VHF only)

(8) DSS 72 at Ascension Island (S-band only)

(9) DSS 51 at Johannesburg, South Africa (S-band only)

All of these stations, except DSS 72, were committed to support the *Surveyor I* mission. DSS 72 supported the mission on an engineering basis only.

The requirements for tracking and telemetry coverage were placed in accordance with their importance to the successful accomplishment of the mission and were grouped into three classes. These classes are defined as follows:

Class I: Requirements reflect the minimum essential needs to ensure accomplishment to first priority flight test objectives. These are mandatory requirements which if not met, may result in a decision not to launch.

Class II: Requirements define the needs to accomplish all stated flight test objectives.

Class III: Requirements define the ultimate in desired support. Such support should enable the range user to achieve the flight test objectives earlier in the test program.

Table 3 shows the spacecraft system telemetry coverage requirements.

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

Table 3. Spacecraft system telemetry coverage requirements

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

[a]Requirement is only for recording the data.

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

AFETR tracking data were of particular importance for direct ascent trajectories because DSS 51 was the only committed DSIF station that could track the spacecraft for several hours after injection for most trajectories.[5] Thus, the AFETR data was to significantly improve the accuracy of the premidcourse orbit determination process. However, the data had to be more accurate for this process than for improving reliability. Table 4 shows the AFETR tracking data accuracy requirements for *Surveyor* orbit determination.

[5]However, there were some trajectories for which DSS 42, Canberra, had a short view-period, and some trajectories for which DSS 41 and 61, which were not committed to *Surveyor*, had short view-periods.

Table 4. AFETR tracking data accuracy requirements for *Surveyor* orbit determination

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

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

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

where

i error mode index

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

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

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

T_S time between successive data points

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

a. Metric data. The AFETR tracks the C-band beacon of the *Centaur* stage to provide metric data. Metric data requirements are:

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

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

(3) Transmission of in-flight trajectory data, by AFETR stations and appropriate RIS, required from liftoff to Loss of Signal (LOS), as well as other raw data which was provided the DSN by 100 wpm teletype (TTY). Processing raw DSN tracking data was also necessary in real or near-real time (NRT). Table 5 shows the tracking data required by AFETR.

b. Additional metric requirements. Requirements also included:

(1) Any continuous 60-s span between injection into transfer orbit and start of *Centaur* retromaneuver.

(2) Any continuous 60-s span after completion of *Centaur* retromaneuver.

(3) Delivery of data requested in decimal format via teletype to building AO in NRT.

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

2. VHF telemetry. Starting during the countdown, the AFETR was required to continuously receive and record *Atlas* (229.9-MHz link) telemetry until *Atlas/Centaur* separation and *Centaur* (225.7-MHz link) telemetry until shortly after spacecraft separation. Thereafter, *Centaur* telemetry was recorded as station coverage permitted until completion of the *Centaur* retromaneuver. All class I telemetry requirements were to be met using the facilities of Cape Kennedy, Grand Bahama Island, Antigua, RIS *General Arnold*, RIS *Coastal Crusader*, RIS *Sword Knot*, and Ascension. The coverage plan indicated some gaps in providing continuous coverage, but the requirement was only for coverage where available. The three range

Table 5. Tracking data required

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

instrumentation ships were to provide data on a limited commitment basis (in that they were still under engineering cognizance).

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

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

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

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

The following unclassified megahertz frequencies are listed with their locations:

(1) 229.9, telemetry, *Atlas*

(2) 225.7, telemetry, *Centaur*

(3) 414, command destruct, *Atlas* and *Centaur*

(4) 5690, receiver of the C-band transponder, *Centaur*

(5) 5675, transmitter of the C-band transponder, *Centaur*

(6) 2113 and 3125, command/spacecraft, building AO

(7) 2295, telemetry, spacecraft

3. S-band telemetry. S-band coverage follows:

(1) The AFETR receives and records *Surveyor* spacecraft S-band (2295-MHz) telemetry after the spacecraft transmitter high power is turned on until 15 min after injection. However, all S-band systems were used only on a limited basis as they were still under engineering control. Table 3 presents a detailed summary of the AFETR telemetry coverage requirements for the spacecraft data transmitted by the *Centaur* telemetry system and for the data transmitted by the spacecraft S-band telemetry system. Prelaunch requirements as well as data recording requirements are also shown in this table.

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

(3) Requirements for coverage of the spacecraft telemetry through the spacecraft S-band or *Centaur* links were placed on the AFETR. A similar coverage requirement was to transmit S-band telemetry data in real time to building AO from $T + 745$ s to $T + 1583$ s. Requirements also existed for coverage of the launch vehicle telemetry for vehicle evaluation. These latter requirements are placed only on the AFETR.

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

The computer data requirements for the pre-retromaneuver transfer orbit is summarized below:

(1) Single-station solution orbital elements and injection conditions. (Delivery requested via TTY to building AO in NRT after receipt of data at the RTCS facility.)

(2) Multiple-station solution orbital elements and injection conditions. [Delivery requested via TTY to building AO within 2 h after delivery of (1).]

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

(4) Quick mapping (B-plane) to lunar encounter. [Delivery requested via TTY to building AO immediately following (1).]

(5) Refined mapping to lunar encounter. [Delivery requested via TTY to building AO immediately following delivery of (2).]

(6) AFETR inter-range vector (IRV). (Concurrent delivery to building AO and DSS 72 via TTY requested in NRT after receipt of data at RTCS facility.)

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

Summarized computed data requirements for post-retromaneuver transfer orbit are:

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

(2) Multiple-station solution orbital elements and injection conditions. [Delivery requested via TTY to building AO within 2 h after delivery of (1).]

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

(4) Quick mapping (B-plane) to lunar encounter. [Delivery requested via TTY to building AO immediately following delivery of (1).]

(5) Refined mapping to lunar encounter. [Delivery requested via TTY to building AO immediately following delivery of (2).]

(6) AFETR IRV. (Concurrent delivery to building AO and DSS 72 via TTY requested within 30 min of receipt of data at RTCS facility.)

5. Communications requirements. The AFETR, as part of its operations, established tracking stations. This was especially needed by *Surveyor* with its requirement of real-time transmission of spacecraft telemetry data. However, with the AFETR functioning as designed, the communications system would be adequate to support *Surveyor I*. A possible exception is a state of RF *blackout* between a station and the Cape. Such an occurrence (only occasionally predictable) may cause a hold.

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

Surveyor real time data requirements are listed below:

(1) Requirements:

$T - 300$ s to Station 1 LOS.
$T + 300$ s to $T + 1583$ s.

(2) Data source:

VHF or S-band telemetry until S-band high power on.
S-band telemetry after S-band high power on.

(3) Data delivery:

Spacecraft data, 550-bits/s, from up to three AFETR stations or ships will be transmitted to building AO. One of the three 550-bits/s pulse code modulation (PCM) signals being provided to building AO will be decommutated by AFETR with six channels converted to analog and transmitted to building AO for display. Each station receiving or transmitting 550-bits/s spacecraft data was to decommutate the data train and convert specified channels to analog for monitoring or voice reporting of events as the status changed.

Certain real-time voice communications requirements were also imposed upon the AFETR for the *Surveyor I* mission. These were:

(1) To report by voice in NRT the initial AOS and the final LOS of each station of the telemetry link containing spacecraft data. Reports were to be time tagged to the nearest minute.[6] Report also by voice in near-real time any anomoly or unexpected occurrence during the station's view period. (Examples included, but were not limited to, loss of modulation or unexpectedly low received signal level.)

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

[6]Links to be reported would normally be the 225.7-MHz link prior to Spacecraft High Power ON, and the 2295-MHz link after Spacecraft High Power ON. Should there be a failure to acquire the 225.7-MHz link, reporting of the 2295-MHz link was to be substituted.

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

C. Goddard Space Flight Center

1. Tracking. The MSFN, managed by the GSFC, was to support the *Surveyor I* mission as follows.

a. Functions. MSFN was to provide:

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

(2) Telemetry receiving and recording of the *Centaur* links from Bermuda AOS until LOS at Kano.

(3) Real-time confirmation of certain mark events.

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

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

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

Table 6. MSFN instrumentation support

System \ Station		Bermuda	Grand Canary	Kano	Carnarvon	GSFC	MCC-K[a]
Acquisition aid		X	X	X	X		
C-band radar		X			X		
Unified S-band							
Telemetry	PAM/FM[b]	X	X	X	X		
	PCM/FM[c]						
	FM/FM						
	Magnetic tape	X	X	X	X		
	Real-time readouts	X	X	X			
	Displays	X	X	X			
Command	Digital						
	Tone	X[d]					
Voice (SCAMA)[e]		X	X	X	X	X	X
TTY		X	X	X	X	X	X
High-speed data		X			X	X	X
Doppler tracking							
Range safety		X					
Displays (building 14)						X	
Computer support						X	

[a]Mission Control Center, Cape Kennedy.
[b]Pulse amplitude modulation/frequency modulation.
[c]Pulse code modulation/frequency modulation.
[d]Range safety.
[e]SCAMA, signaling conferencing, and monitoring arrangement.

Table 6 lists the MSFN instrumentation requirements used to support the *Surveyor I* mission.

Bermuda, Grand Canary, and Kano were equipped to track the *Surveyor I* vehicle and provide RF inputs to the telemetry receivers. Performance recorders were required to record AGC and angle errors for postmission analysis. The MSFN requirements were to provide RF inputs from Bermuda AOS to Kano LOS.

b. Station requirements. Bermuda was to track the *Centaur* vehicle in conjunction with AFETR radars during the powered flight phase of the mission, and would transmit real-time, high-speed data to GSFC and to the RTCS at AFETR. Bermuda was also to transmit real-time, low-speed radar data to GSFC.

Carnarvon was to track the *Centaur* vehicle from AOS, occurring at approximately $T + 44$ min, to LOS. Vehicle view-time was expected to be about 3 h, or until C-band beacon radiation expired at approximately $T + 3.5$ h. Carnarvon would transmit real-time, low-speed radar data to GSFC from AOS to LOS. This data was to be reformatted and retransmitted to the RTCS at AFETR for approximately 15 min after *Centaur/Surveyor* separation.

Grand Canary was to track the *Centaur* vehicle from AOS, occurring at approximately $T + 18$ min, to LOS. Grand Canary was to transmit real-time, low-speed radar data to RTCS via GSFC.

2. VHF telemetry requirements. Bermuda, Grand Canary, and Kano were also equipped to decommutate, receive, and record telemetry. Capability for coverage was provided from Bermuda acquisition of signal through loss of signal at Kano. *Mark* event (see Table 7) readouts were required from all stations in real time or in as near real time as possible when the vehicle was in view of a station.

The Bermuda station had requirements to support the *Surveyor I* launch from *mark* events 6–11 on the *Centaur* link.

Grand Canary was required to confirm *mark* events 17–19.

Table 7. *Mark* events: Bermuda, Grand Canary, and Kano

Station	*Mark* No.	Events	Time (GET),[a] min/s	Link, MHz/channel segment, kHz	Description
Bermuda	6	*Atlas/Centaur* separation	241 (4:01)	225.7/30.0/1	Segment should increase from approx 0% at separation
	7	*Centaur* MEIG	250 (4:10)	225.7/0.96/continuous	C-2 chamber pressure goes from 0 to 75% of band
	8	*Centaur* MECO (Injection)	683 (11:23)	225.7/0.96/continuous	C-2 chamber pressure goes from approx 75 to 0% of band
	9	*Surveyor* landing gear extend command sent	714 (11:54)	225.7/3.0/7	Segment should go from 0 to 100% for 1 segment (signal is *integrated*)
	10	*Surveyor* omniantenna extend command sent	725 (12:05)	225.7/3.0/11	Same as *mark* 13
	11	*Surveyor* high power transmitter ON	745 (12:25)	225.7/3.0/12	Command (same as *mark* 13)
—[b]	12	*Centaur/Surveyor* electrical disconnect	751 (12:31)	225.7/40/continuous	Measurement goes open
—[b]	13	*Centaur/Surveyor* separation	756 (12:36)	225.7/3.0/16	Command (segment goes to approx 100%)
Grand Canary, Kano	17	Start *Centaur* blowdown	996 (16:36)	225.7/70N/12, 13, 18, 22	Pump inlet pressures increase from 0 to approx 20%
	18	End *Centaur* blowdown	1246 (20:46)	Same as *mark* 21	Pump inlet pressures decrease to 0%
	19	Power changeover switch	1246 (20:46)	225.7/4/continuous	400-Hz frequency goes 50% off scale

[a]Ground elapsed time.

[b]Vehicle is not in view at any station at this time.

Kano was required to provide telemetry coverage and confirm *mark* events 17–19 on the *Centaur* link.

Tananarive was not committed due to the excessive range during station view period.

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

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

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

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

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

D. Deep Space Network

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

The DSN requirements included S-band tracking and two- and three-way doppler coverage. DSN responsibilities were to obtain continuous spacecraft telemetry coverage from the first acquisition by Johannesburg (DSS 51) to the end of the mission. Three DSIF stations described below were required for this coverage. The full Goldstone Duplicate Standard (GSDS) S-band system in conjunction with the *Surveyor* Telemetry System was used at these stations.

With the quality of the tracking data defined by Table 8, it was possible to specify the tracking coverage required to meet the orbit determination accuracy requirements. Before presenting the tracking coverage requirements, however, it would be appropriate to delineate the ground rules upon which the tracking coverage analysis was based:

The most basic and paramount ground rule was that the primary objective of this effort was to maximize the

Table 8. DSN tracking data accuracy requirements

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

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

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

The requirements for allowable errors due to the orbit determination are specified below by classes.

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

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

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

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

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

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

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

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

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

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

1. Deep Space Instrumentation Facility. The DSIF was required to provide coverage for *Surveyor I* mission, by at least three prime stations on a 24-h/day basis from launch to lunar landing, and for the first lunar day and night. For succeeding lunar days and nights, the requirement was for 24-h/earth day coverage during the first 3 and last 2 earth days, and for 10-h/earth day in between.

The following deep space stations, all having 85-ft antennas, were committed as prime stations for supporting the *Surveyor I* mission:

Pioneer, Goldstone, California (DSS 11)
Tidbinbilla, Canberra, Australia (DSS 42)
Johannesburg, South Africa (DSS 51)
Cape Kennedy, Florida (DSS 71)

At Cape Kennedy the DSN was used to verify prelaunch compatibility of the spacecraft with the DSN during the prelaunch countdown.

In addition to the basic support provided by aforementioned prime stations, the following facilities support was provided for the *Surveyor I* mission.

DSS 61, Madrid Deep Space Communications Complex (DSCC), and DSS 72 were implemented to track on an engineering basis but were not committed to provide *Surveyor* mission support.

Facilities support was provided for mission-dependent equipment, including space for CDCs at all prime stations and for the Television Ground Data Handling System (TVGDHS) at DSS 11, Goldstone DSCC.

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

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

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

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

The angle tracking parameters that were required for all stations are as follows:

(a) Maximum angle tracking rate (both axes), 51 deg/min = 0.85 deg/s

(b) Maximum angular acceleration, 5.0 deg/s/s

(c) Tracking accuracy (one standard deviation), $\sigma = 0.14$ deg

(d) The system doppler tracking accuracy at the receiver carrier frequency for one standard deviation, 0.2 Hz = 0.03 m/s

The maximum doppler tracking rate depends on the loop noise bandwidth, and for phase error of 30 deg and strong signal (−100 dBmW) it is as follows:

Loop noise bandwidth, Hz	Maximum tracking rate, Hz
12	100
48	920
152	5000

The receiver characteristics for S-band and L/S-band stations are as follows:

(1) Noise temperature. The total effective system noise temperature including circuit losses when looking at or near the galactic pole is:

Traveling-wave masers, 55 ± 10°K
Parametric amplifier, 270 ± 50°K

(2) Loop noise bandwidth. The closed-loop noise bandwidth for various signal conditions is:

Threshold $2\beta_{L_0}$, 12, 48, or 152 Hz $^{+0\%}_{-20\%}$

Strong signals $2\beta_4$, 132, 274 or 518 Hz $^{+0\%}_{-20\%}$

(3) Threshold. Carrier lock will be maintained with an rms phase error due to noise of less than 30 deg when the ratio of carrier power to noise power in the closed-loop noise bandwidth is 6 dB or greater. Owing to the nature of the operation of the phase-lock loop, this condition requires the carrier power at the receiver input to be 9 dB greater than the value at threshold, which is defined as a carrier-to-noise power ratio of 0 dB in the threshold loop noise bandwidth $2\beta_{L_0}$.

Table 9. Raw tracking data required from DSIF stations

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

[a]Accuracy codes A, B, or C refer to the way that the data accuracies are broken down and are shown in Table 8.

a. Tracking. The DSIF tracking requirements were:

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

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

(3) Supply antenna pointing angles.

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

(5) Supply (24 h/day to touchdown first lunar day and night, first 3 and last 2 lunar days, and 10-h/earth day in between) tracking coverage.

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

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

(8) Supply tracking data in the form of punched paper tape at post-flight.

DSIF raw tracking data requirements are given in Table 9.

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

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

Table 10 gives the DSIF telemetry coverage requirements for *Surveyor I* mission.

c. Commands. Command transmission was another function provided by the DSIF. The transmission of approximately 250 commands to the spacecraft was required during the nominal sequence from launch to touchdown. This command requirement placed a second critical requirement for two-way communication with the spacecraft. Confirmation of the commands sent was processed

Table 10. DSIF telemetry coverage requirements for *Surveyor I* mission

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

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

by the OSDP computer and transmitted by TTY to the SFOF. The OSDP computer was capable of being used to verify command tapes punched on-site from TTY instructions received from the SFOF, but this function was not to be used for the *Surveyor I* mission.

d. Video data. It was required that video data be received and recorded on magnetic tape. This data was to be sent to the CDC, and at DSS 11 only, to the TVGDHS for photographic recording. In addition, video data from DSS 11 was to be sent in real time to the SFOF for magnetic and photographic recording by the TVGDHS.

After lunar landing, DSS 11 was to perform a special function. Two receivers were used for different functions. One provided a signal to the CDC, the other to the TVGDHS. (Signals for the latter system are the prime *Surveyor* Project requirement during this phase of a mission.)

e. Preliftoff capability requirements during launch countdown

DSS 11. A high degree of probability was required that, at the start of DSS 11 visibility, the following minimum capability would exist:

(1) Acquisition and tracking of *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 TTY to the appropriate communications terminal equipment at the site.

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

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

(7) At lunar landing two receivers were to be used, one to a CEC recorder, and the other to TVGDHS (prime requirement by project). This increased receiver reliability requirements at GSCS.

DSS 51. The following minimum capabilities were required from DSS 51:

(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 TTY to the appropriate communications terminal equipment at the site.

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

DSS 42. A high degree of probability was required that, at the start of DSS 42 visibility, the following minimum capability would exist:

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

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

Additional capabilities. In addition to the above support, the DSIF was required to provide the following:

(1) Facilities support for mission-dependent equipment, including space for CDCs at all prime stations and for the TVGDHS at DSS 11.

(2) Maintenance and operation of all mission-independent equipment.

(3) Maintenance and operation of some mission-dependent equipment.

(4) Logistic and spares support for mission-dependent equipment.

DSIF support requirements. The DSIF support requirements were to be satisfied in order for the DSN to support the requirements placed on it for tracking and telemetry coverage.

(1) Spacecraft telemetry calibrations of AGC and static phase error (SPE), received from the spacecraft had to be available at the station to ensure proper two-way acquisition.

(2) The following data requirements were to be met to enable prompt acquisition of the spacecraft signal:

(a) Reliable acquisition: first acquisition predictions to the DSIF had to be available at the SFOF at least 10 min before *first look;* however, these predictions were useful up to 10 min before end-of-station view.

(b) Angle accuracy (HA-Dec): at least ±3 deg for first acquisition and within ±0.2 deg for later passes.

(c) One-way doppler-frequency accuracy: within 1000 Hz at the signal frequency.

(d) Two-way doppler-frequency accuracy: within 1000 Hz at the signal frequency.

(e) Spacecraft data validated at launch (L) − 40 min and again at L − 20 min for both transmitter A and B and transponders A and B:

(1) One-way beacon frequency

(2) Spacecraft receiver center frequency at no-signal SPE

(3) Spacecraft transponder frequency at no-signal SPE

(4) Spacecraft receiver center frequency at zero SPE

(5) Spacecraft transponder frequency at zero SPE

(6) No-signal SPE voltage

(7) Narrow-band voltage-controlled auxiliary oscillator (NBVCXO) temperature

(8) Serial No. of spacecraft receiver

(9) Serial No. of spacecraft transmitter

2. Ground Communications Facility/NASCOM. The DSN GCF includes that portion of the NASCOM that supported the *Surveyor I* mission by providing communication paths between the various DSN tracking stations throughout the world and the SFOF. The GCF comprised the landlines, undersea cables, and radio circuits that carried teletype, voice, and high-speed data in real-time support of the *Surveyor I* mission. Figure 8 illustrates the configuration of the GCF in support of *Surveyor I* and the type of data carried over these circuits.

The GCF was required to transmit tracking, telemetry, and command data from the DSIF to the SFOF, and control and command functions from the SFOF to the DSIF by means of NASCOM facilities. It also transmitted simulated tracking data to the DSIF, and video data and baseband telemetry from DSS 11, Goldstone DSCC, to the SFOF.

The types and number of lines used were as described in the following:

a. Voice lines (one line available). Line was to be shared between the DSIF and *Surveyor* Project for administrative traffic.

b. Teletype lines (four available). Lines were connected to all prime sites for tracking data, telemetry, commands, and administrative traffic.

c. High-speed data line (one available). One line from each site to the SFOF for telemetry data transmission in real time.

d. Wideband data link. Wideband microwave to DSS 11, Goldstone DSCC; one 6-MHz line for video to the SFOF, and one duplex 96-kHz line.

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

The 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 the requirements of the *Surveyor* Project, dedicated a major portion of its mission-independent capabilities to the support of the *Surveyor I* mission. These capabilities included such operating functions as communications, displays, and data processing.

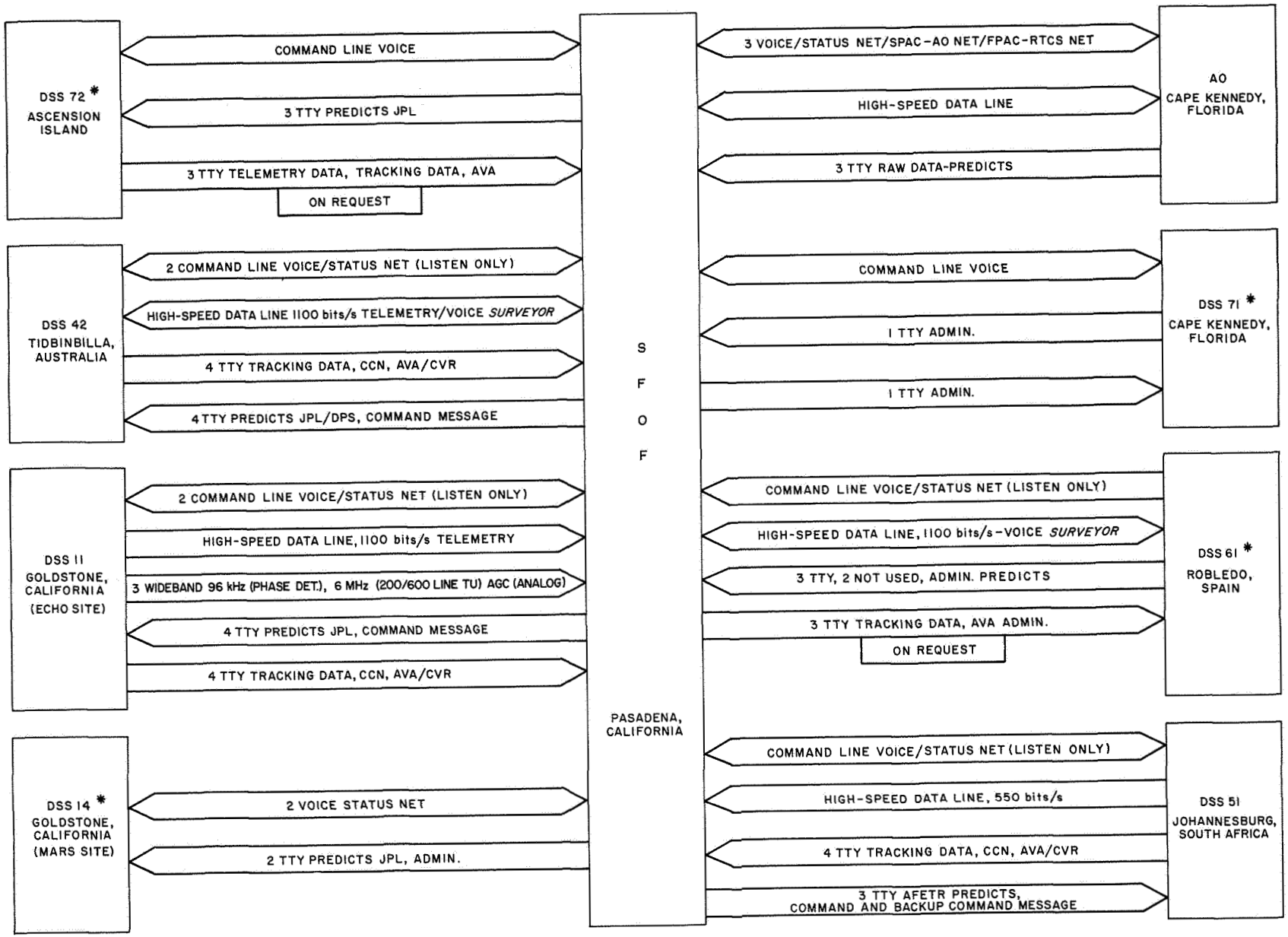
a. Communications. The DSN Intracommunications System (ICS) consists of those circuits, switching facilities, terminals, equipment, and personnel internal to the SFOF that are required to transmit, receive, and distribute various types of intelligence. The ICS is divided into nine subsystems as follows:

(1) Operational voice communications subsystem (OVCS).

(2) Operational status recording subsystem (OSRS).

(3) Operational public address subsystem (OPAS).

(4) Operational voice recording subsystem (OVRS).



* NONCOMMITTED STATION
AGC AUTOMATIC GAIN CONTROL
AO BUILDING AO AT AFETR
AVA AVERAGE ALARM
CCN COMMAND CONFIRMATION
CVR COMMAND VERIFICATION
DPS DATA PROCESSING STATION
SPAC SPACECRAFT PERFORMANCE ANALYSIS AND COMMAND
FPAC FLIGHT PATH ANALYSIS AND COMMAND
RTCS REAL TIME COMPUTER SYSTEM

Fig. 8. DSN Ground Communications Facility circuit configuration for *Surveyor I* mission

(5) Operational miscellaneous audio subsystem (OMAS).

(6) Operational teletype communications subsystem (OTCS).

(7) Television communications subsystem (TVCS).

(8) High-speed data subsystem (HSDS).

(9) Wideband communications subsystem (WBCS).

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

(1) Operations Area.

(2) Flight Path Analysis Area (FPAA).

(3) Mission Support Area No. 1A—Spacecraft Performance Analysis Area (SPAA).

(4) Mission Support Area No. 1B—Space Science Analysis Area (SSAA).

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

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

(2) Orbit determination.

(3) Midcourse maneuver computation and analysis.

(4) On-line telemetry processing.

(5) Command tape generation.

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

d. Facilities. Mission control facilities for *Surveyor I* and space in mission-dependent and mission-independent areas of the SFOF were provided as follows: Mission Control Room No. 1 and Mission Support Area No. 1, which included the SPAA and the SSAA, were devoted exclusively to the *Surveyor I* mission. Flight Path Analysis Area No. 1 was a shared area; however, the *Surveyor I* mission had its exclusive use during the flight. Common user areas included DSIF Net Control, the data processing area, and the Communications Center.

e. Preliftoff capability during launch countdown

SFOF requirements. The following minimum capabilities were required in the SFOF:

(1) One operational IBM 7288-7044 computer string in the mode III configuration.

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

(3) Diesel generators as the power source for all SFOF computers.

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

(5) Closed-circuit television displays of TTY data and line status.

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

Ground communications requirements. The following minimum communication capabilities were required among elements committed to the *Surveyor I* mission:

Circuit requirements between AFETR and SFOF were:

(1) Two voice lines.

(2) One high-speed data line.

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

Circuit requirements between DSS 51 and SFOF were:

(1) One voice line.

(2) Two duplex TTY lines.

There was a high degree of probability that at the start of DSS 11 visibility, the following circuits would be operational between DSS 11 and SFOF:

(1) One voice line.

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

(3) One duplex TTY line.

There was a high degree of probability that at the start of DSS 42 visibility, one duplex TTY line would be the minimum requirement between DSS 42 and SFOF.

IV. *Surveyor I* T&DS Flight Preparation

The T&DS had the responsibility of preparing for the *Surveyor I* mission by proper configuration and testing. Such preparation is treated in the following sections.

Table 11 gives an RF systems carrier-frequency summary. These RF systems are the frequencies to which the T&DS was configured for inflight support of the *Surveyor I* mission.

A. Configuration

The configurations of individual agencies within the T&DS are listed below.

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

a. Tracking. The prelaunch configuration of AFETR is shown in Table 12, complete with each station committed, and the radar and telemetry capabilities.

Table 11. RF systems carrier-frequency summary, *Surveyor I*

Stage	System	Subsystem or link	Frequency, MHz
Atlas	Telemetry	Subsystem 1	229.9
	Range safety command		414.0
Centaur	Telemetry	RF 1 (Subsystem 4)	225.7
	Tracking	C-band beacon	
		Interrogation	5,690.0
		Reply	5,765.0
	Range safety command		414.0
Surveyor	Telecommunications (S-band)	Telemetry link	2,295.0
		Tracking link	
		Receives	2,113.0
		Transmits	2,295.0
		Command link	2,113.0
	Altitude marking radar		9,300.0
	Range and doppler velocity sensor radar	Range sensor	12,900.0
		Doppler velocity sensor	13,300.0

Table 12. AFETR prelaunch configuration, *Surveyor I*

Station	Radar	VHF telemetry	S-band telemetry
Merritt Island	X		
Cape Kennedy	X	X	X
Patrick AFB	X		
Grand Bahama Island	X	X	X
Grand Turk	X		
Antigua	X	X	X
General Arnold	X	X	X
Coastal Crusader		X	X
Sword Knot		X	X
Ascension Island	X	X	X

A major element in the *Surveyor I* AFETR configuration was the positioning of the RIS. These ships were located (by launch day, time, azimuth criteria) as a projection of the coverage planned for the *Surveyor I* launch. Figure 9 gives the RIS configuration for the AFETR launch coverage which was necessary to meet the class I requirements as has been mentioned (see Section III, Table 3).

The acquisition aids at Bermuda, Grand Canary, and Kano were configured to track the vehicle and provide RF inputs to the telemetry receivers. Performance recorders were configured to record automatic gain control and angle errors for postmission analysis. The acquisition aids would provide telemetry RF inputs from acquisition of signal at Bermuda through loss of signal at Kano. The C-band radars at Bermuda and Carnarvon were to provide radar beacon tracking, magnetic tape recording at

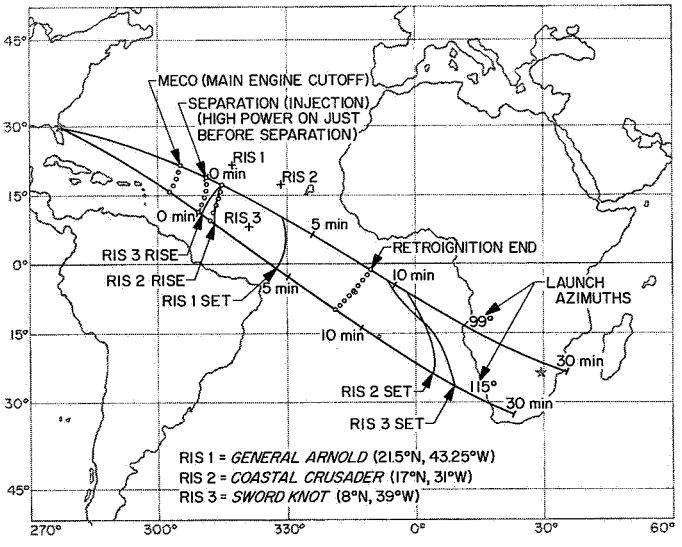


Fig. 9. Preliminary instrumentation coverage for May 30, 1966 launch, *Surveyor I*

a minimum of 10 points per second, and real-time data transmission to GSFC and AFETR. Bermuda configuration would track the *Centaur* vehicle in conjunction with the AFETR radars during the powered flight-phase of the mission, and transmit real-time, high-speed data to GSFC and to the RTCS at AFETR. Also Bermuda was to transmit real-time, low-speed radar data to GSFC.

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

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

(2) The C-band radar aboard the RIS *General Arnold.*

b. VHF telemetry. The AFETR resources committed to support the VHF telemetry requirements were Tel-2, Grand Bahama Island, Antigua, and Ascension, and the *General Arnold*, the *Coastal Crusader*, and the *Sword Knot*. The committed facilities expected to meet all class I requirements. The coverage plan in OD 3400 indicated some gaps in providing continuous coverage; however, requirements asked only for coverage where available.

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

A 3-ft S-band antenna with its associated downconverter, receiver, etc., was in place at Ascension. This system provided the S-band data from Ascension for the *A/C-8 Centaur* launch and was to back up the 30-ft antenna S-band system (TAA-3A). A similar backup system was later provided to Antigua. In addition, the *General Arnold* was to cover the early interval after high-power ON during the same interval that Antigua was to view.

The three ships were to provide S-band coverage on a limited data commitment. Confidence ran fairly high in these systems because the *Sword Knot* successfully provided S-band coverage for *A/C-8*, and the *Coastal Crusader* provided S-band support for *Pioneer*. The *General Arnold*, however, had not yet supported a live S-band mission.

At the prelaunch readiness meeting, the AFETR was experiencing problems in the area of S-band telemetry and ship support. The AFETR projected that these problems could be corrected before launch, and that all class I requirements would be met even though the S-band systems would support on a limited commitment basis only.

d. Real-Time Computer System. The RTCS configuration allowed for the use of information from AFETR radars, (pre- and post-retroignition data) and MSFN stations (post-retro data and post-injection data). The RTCS was to use this information to compute orbital elements and injection conditions which were to be transmitted to the SFOF. The RTCS was also to prepare DSS acquisition information from pre-retroignition orbital computations.

In addition, the RTCS was to transmit interrange vector messages and DSS 72 predicts directly to DSS 72. A *mapping to lunar encounter* message was also a requirement for both the pre- and post-retroignition orbits.

Following the single-station solutions, the RTCS was to compute and transmit to the SFOF pre- and post-retroignition recursive accumulative orbits. An I-matrix and a lunar mapping message based on each solution were to be included. Figure 10 gives the RTCS configuration for metric tracking and computed data flow.

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

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

The Tel-2 set was equipped to receive both S-band (low power) and VHF data before and after launch. From $L - 5$ until loss of signal, Tel-2 was to supply spacecraft data derived from the VHF link to AO. The input to the discriminator bank is shown in Fig. 11. Look-ahead data after launch were made available from Grand Bahama Island as shown in Fig. 11 also.

Grand Bahama Island (station 3) was configured to receive the VHF data link only. These data were to be transmitted to Tel-2 on the subcable 14.5-kHz subcarrier. Data could then be selected for transmission to the SFOF at any time after acquisition by Grand Bahama Island by selecting the time division multiplexer serial pulse code modulation data. At this point in time there

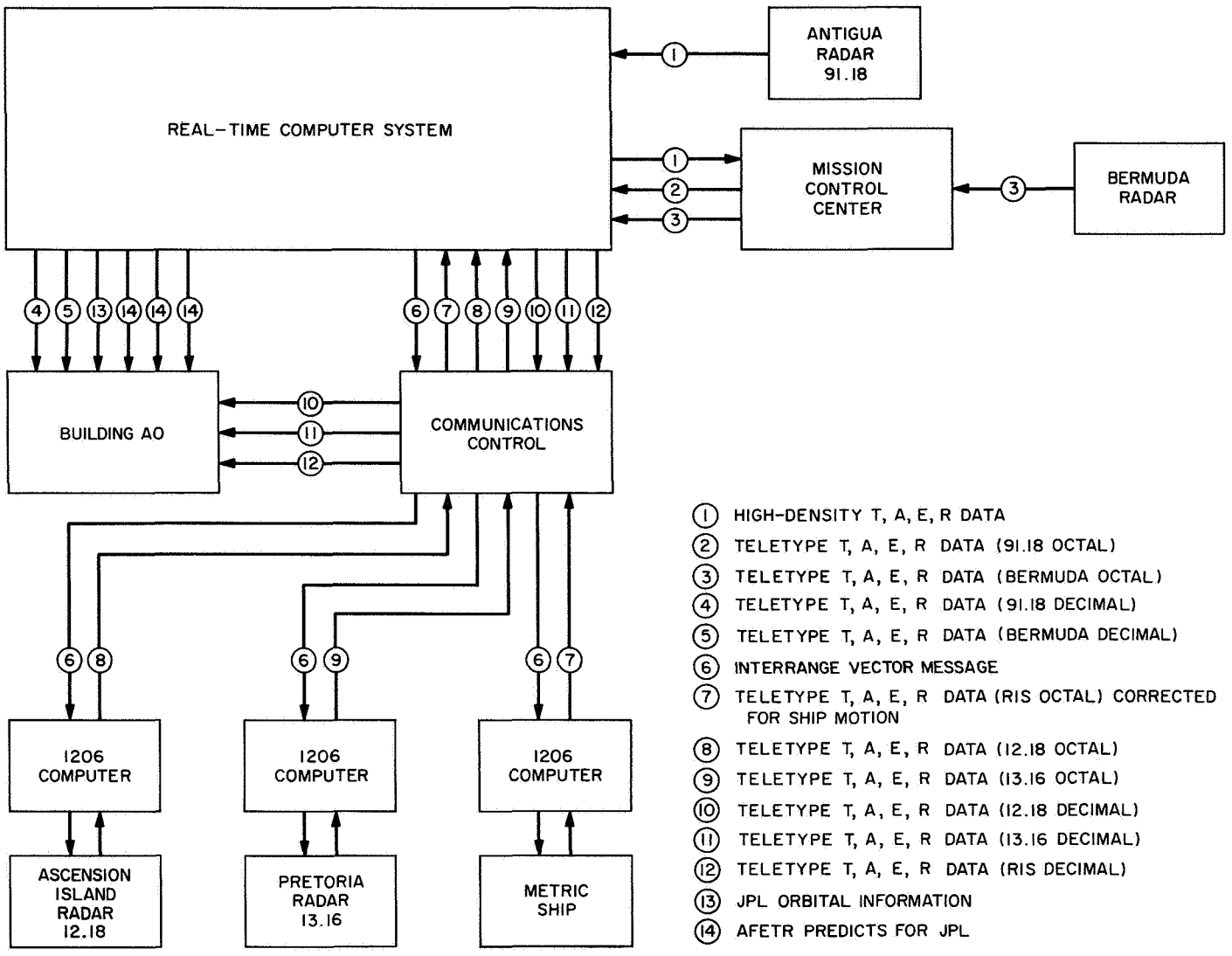


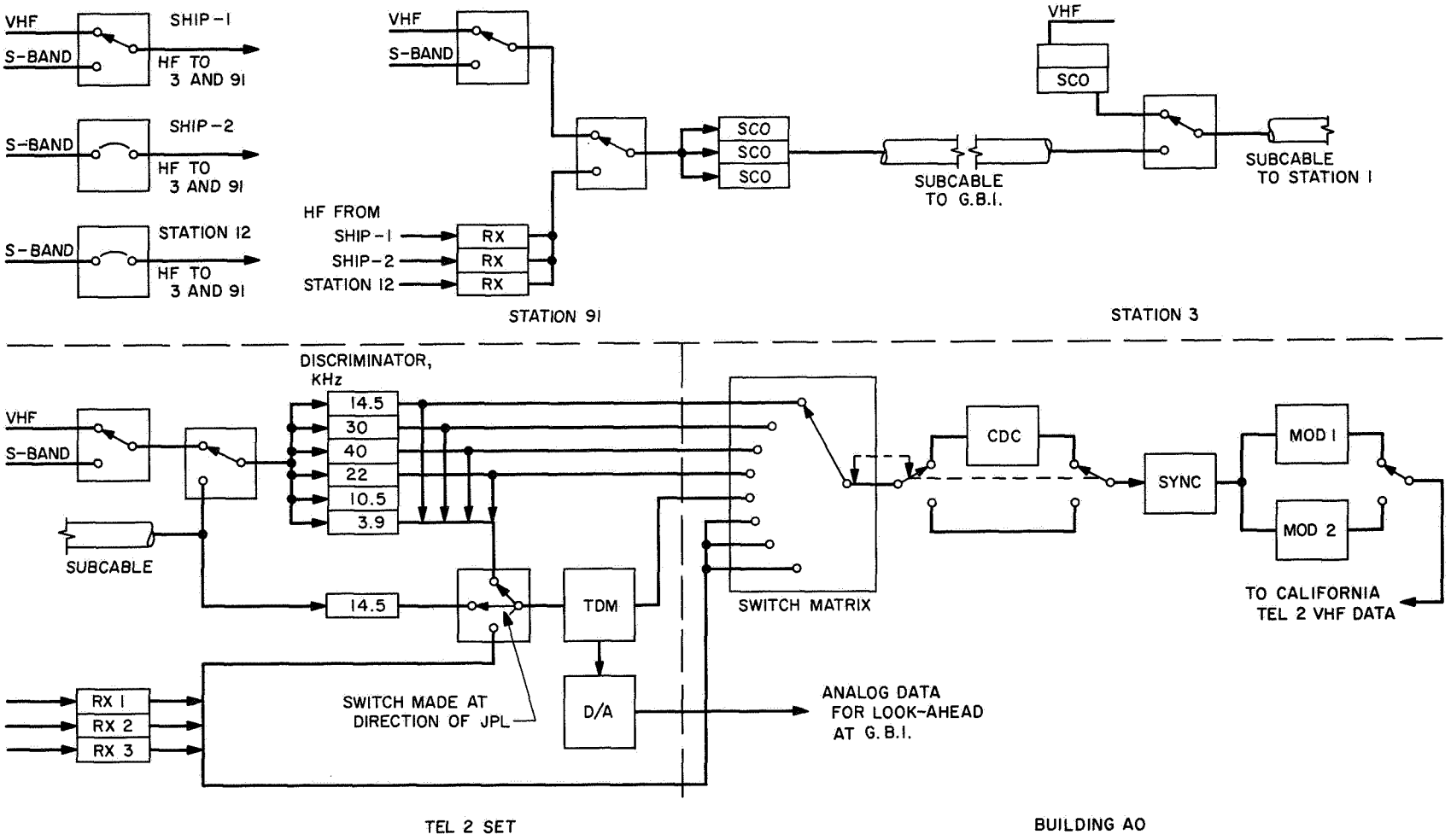
Fig. 10. RTCS configuration for metric tracking and computed data flow, *Surveyor I*

would be no look-ahead capability (because of subcable restrictions) until Antigua (station 91) acquisition, and verification that data from Antigua were of good quality. At this time, the switch was to be made at Grand Bahama Island to allow Antigua use of the 14.5-kHz subcarrier. Switch configuration at that time is shown in Fig. 12. When this switch occurred, the look-ahead capability was retrieved to a limited extent. At ship 1 acquisition, look-ahead data were to be obtained on the ship 1/Cape Kennedy high frequency link only.

Antigua (station 91) was configured to serve as a relay for three downrange stations: ship 1, ship 2, and Ascension Island (station 12). Until spacecraft separation, Antigua was committed to receive and retransmit all data received on the VHF link. At spacecraft separation, or *mark* event 15, whichever was observed first, Antigua would re-patch the subcarrier oscillator inputs so that downrange data could be relayed on 14.5-, 22-, 30-, and 40-kHz subcarriers.

The uprange ship 1 would be equipped to receive either S-band or VHF data links. If S-band signal strength were sufficient before *mark* event 15 to give good data quality, this link was to be used to obtain pulse code modulation data for retransmission.

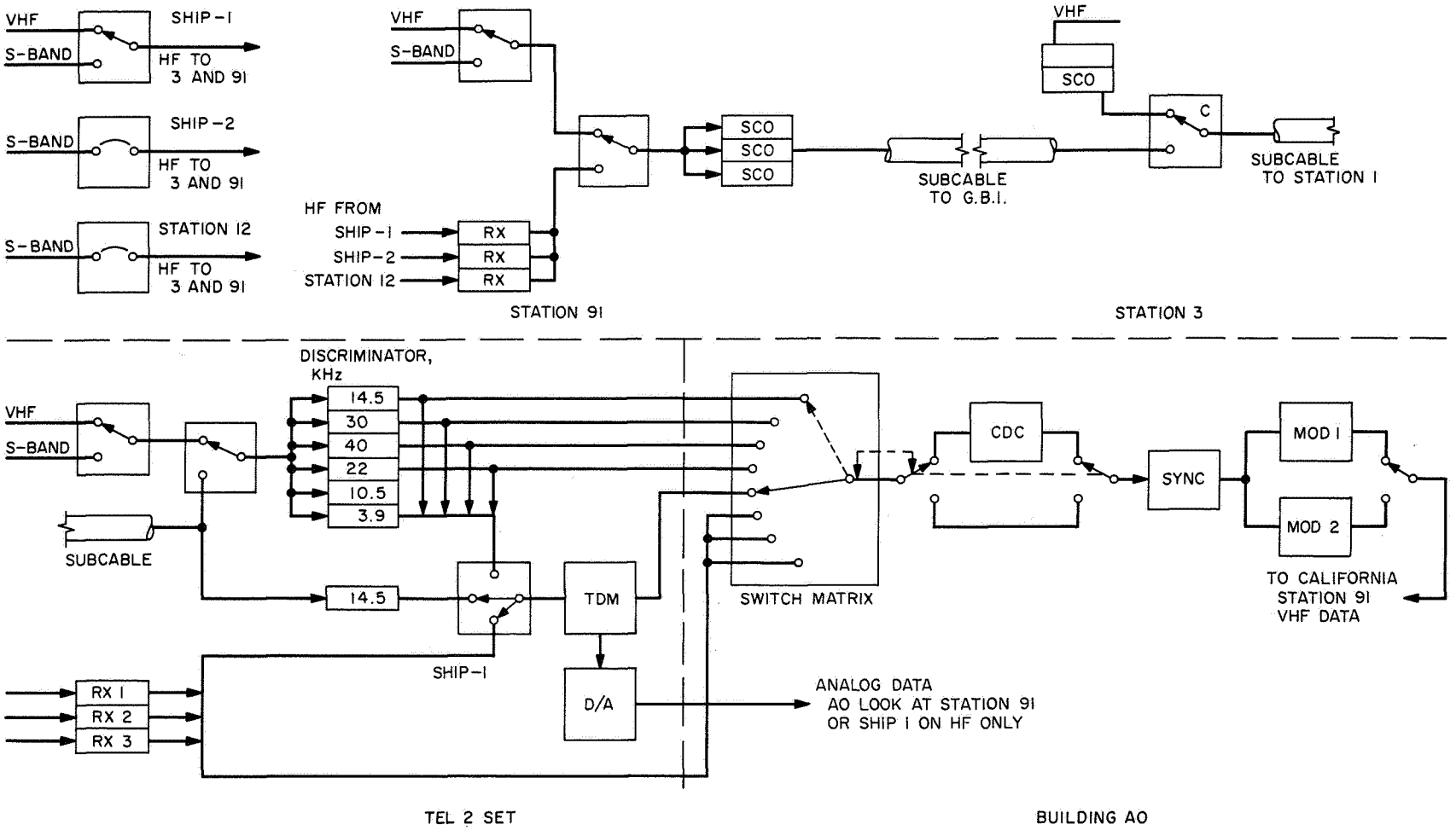
The remaining ships, 2 and 3, and station 12 were configured to receive S-band data and retransmit, either directly by high frequency or by high voltage relay, to Antigua. The configuration during tracking at station 12 is shown in Fig. 13.



STATIONS:
1 – CAPE KENNEDY AFS
3 – GRAND BAHAMA ISLAND
12 – ASCENSION ISLAND
91 – ANTIGUA

CDC – COMMAND AND DATA HANDLING CONSOLE
SCO – SUBCARRIER OSCILLATOR
D/A – DIGITAL – TO – ANALOG
TDM – TIME–DIVISION MULTIPLEXER
RX – RECEIVE SIDE OF DATA MODEM

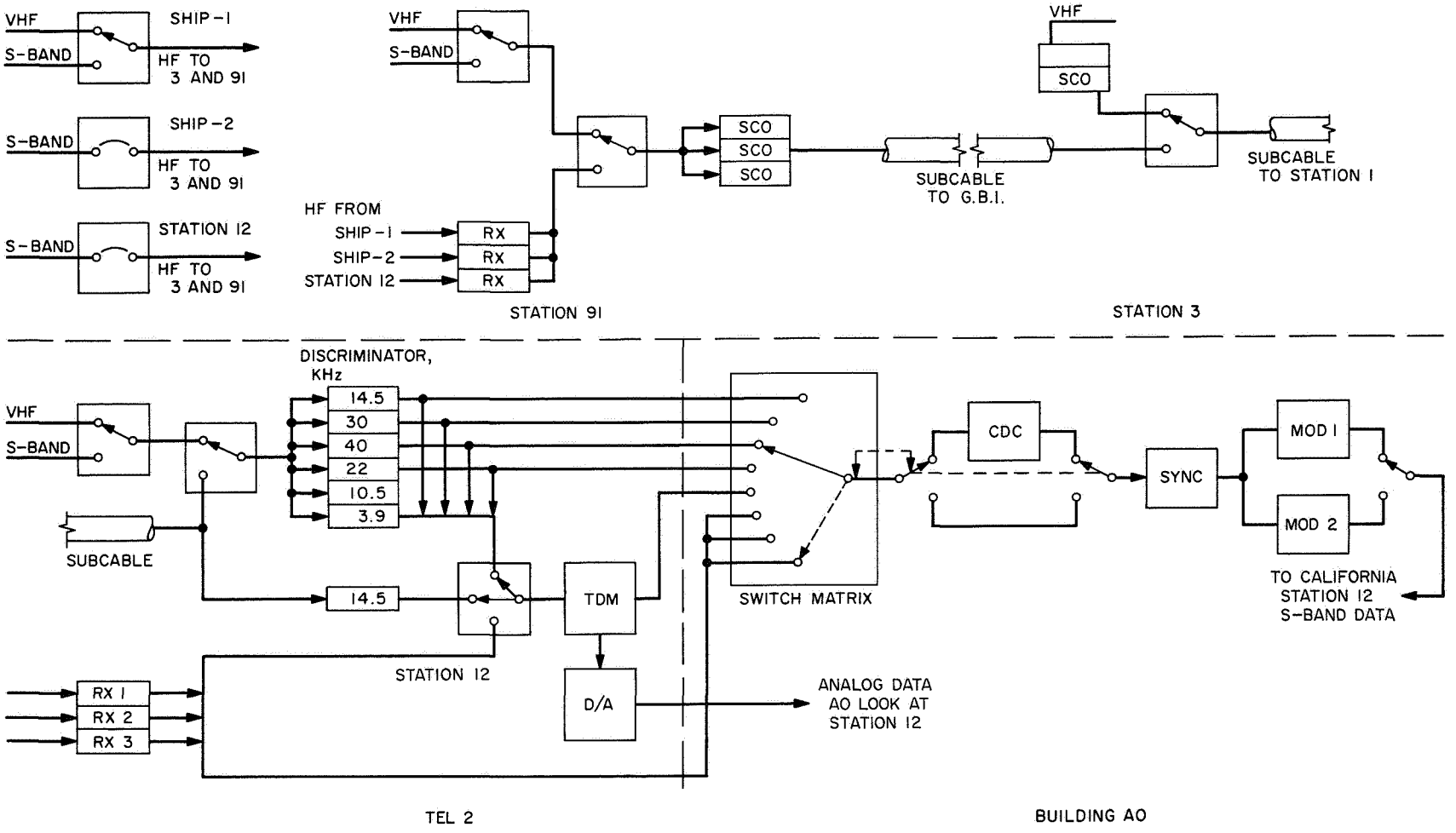
Fig. 11. Building AO from *L* − 5 to the Tel-2 set, *Surveyor I*



STATIONS:
1 – CAPE KENNEDY AFS
3 – GRAND BAHAMA ISLAND
12 – ASCENSION ISLAND
91 – ANTIGUA

CDC – COMMAND AND DATA HANDLING CONSOLE
SCO – SUBCARRIER OSCILLATOR
D/A – DIGITAL – TO – ANALOG
TDM – TIME–DIVISION MULTIPLEXER
RX – RECEIVE SIDE OF DATA MODEM

Fig. 12. Building AO from handover to Antigua acquisition, *Surveyor I*



STATIONS:
1 – CAPE KENNEDY AFS
3 – GRAND BAHAMA ISLAND
12 – ASCENSION ISLAND
91 – ANTIGUA

CDC – COMMAND AND DATA HANDLING CONSOLE
SCO – SUBCARRIER OSCILLATOR
D/A – DIGITAL – TO – ANALOG
TDM – TIME–DIVISION MULTIPLEXER
RX – RECEIVE SIDE OF DATA MODEM

Fig. 13. Building AO from handover to Ascension acquisition, *Surveyor I*

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

Table 13 indicates the GSFC network and equipment configuration used in supporting *Surveyor I.*

a. Tracking: (1) Grand Canary radar could not be used in tracking operations because of phasing problems with other radars in the TDS; (2) other MSFN stations at Carnarvon, Bermuda, Tananarive, and Kano were within configuration requirements to support some class 2 tracking of the launch vehicle and reception of VHF telemetry.

b. VHF telemetry. Telemetry coverage for decommutation, receive, and record was required from Bermuda, Grand Canary, and Kano. *Mark* event readouts were required from all stations in real time or in as near real time as possible when the vehicle was in view of a station. Telemetry coverage extended from acquisition of signal at Bermuda, through loss of signal at Kano. The MSFN stations at Bermuda, Grand Canary, Kano, and Tananarive were configured to receive and record the *Centaur* VHF link.

All MSFN radar data, from the radar having view, were to be provided in real time for processing in near-real-time orbital computations.

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

Nominal pointing data were to be generated and transmitted to Grand Canary, Kano, and Carnarvon before the scheduled launch date. Nominal pointing data for Bermuda were generated by the AFETR, and transmitted to Bermuda before the scheduled launch date. All scheduled simulations were fully supported by use of trajectory and orbital programs as required.

The GSFC computers were configured to receive in-flight trajectory data from liftoff to loss of signal by the AFETR stations and appropriate RIS. Data were to be transmitted via the Mission Control Center at Cape Kennedy, to the GSFC for computation of acquisition messages for MSFN stations.

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

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

DSS 11 (Pioneer), Goldstone DSCC, California.

DSS 42, Tidbinbilla, Australia (near Canberra).

DSS 51, Johannesburg, South Africa.

These prime stations were configured to provide tracking coverage on a 24-h-day basis, from launch to lunar landing, and for the first lunar day and night. For succeeding lunar days and nights, the configuration provided for 24-h-earth-day coverage during the first three and last two earth days and for 10-h earth-days in between.

In addition to the basic support provided by prime stations, the following facilities were configured to support *Surveyor I*:

(1) DSS 71, Cape Kennedy, to support RF compatibility tests with *Surveyor I* on the launch pad.

Table 13. GSFC network configuration, *Surveyor I*

Location	Acquisition	Telemetry	C-band radar	SCAMA	Telemetry	Radar high-speed data	Real-time readouts
Bermuda	X	X	X	X	X	X	X
Grand Canary	X	X		X	X		X
Kano	X	X		X	X		X
Carnarvon	X		X	X	X		X
GSFC				X	X	X	
Cape Kennedy				X	X	X	

(2) DSS 61, Madrid DSCC, and DSS 72, Ascension Island, were instrumented to track on an engineering basis. Facilities support was provided for mission-dependent equipment, including space for CDC consoles at all prime stations and for the TVGDHS at DSS 11, and Goldstone DSCC.

Maintenance and operation was provided for all mission-independent equipment. Logistic and spares support was provided for mission-dependent equipment.

Station capabilities. The tracking and telemetry coverage for the spacecraft following separation and throughout the mission was to be provided by the Deep Space Stations at Johannesburg, Canberra, and Goldstone. The 85-ft antenna configuration at these stations had certain maximum capabilities which could not be exceeded:

(1) Doppler

Frequency tuning range (maximum doppler shift), S-band ± 100 kHz.

Acquisition at frequency rates greater than 50 Hz virtually impossible.

(2) Angle tracking

Reliable acquisition: the tracking rate was not to exceed 0.4 deg/s. System maximum rate was 0.7 deg/s.

Multipath problems: (a) With the acquisition, angle tracking data are accurate to about 0.5 deg. Multipath effect results in poor angle-data at elevation angles of less than 10 deg; (b) with the 85-ft antennas, angle data are accurate to about 0.1 deg. Multipath effect results in poor angle-data at elevation angles of less than 2 deg.

S-band system. The DSIF S-band system was configured to provide effective support for *Surveyor I*. The ground station tracking modes were equipped with S-band Cassegrain monopulse horn feeds (SCM) for the masers, parametric amplifiers, and mixers. In addition, the antenna/front-end paramps and mixers had S-band acquisition aid antennas (SAA).

Table 14 gives the S-band and L/S-band antenna systems configuration.

Command and data handling console. The configuration and description of the CDC is provided on the following pages. The purpose of the CDC is to

(1) Provide general commands for control of the *Surveyor* spacecraft.

(2) Process and display telemetered spacecraft data.

(3) Process, display, and record television pictures taken by the spacecraft.

At the Deep Space Station, the CDC provides command, telemetry, and television functions through the DSIF antenna, transmitter, and receiver to *Surveyor* Project during a lunar mission. It also provides telemetry data for on-site data processing at the DSIF station and for relay to the SFOF at JPL for further analysis.

The CDC equipment is supplied in two configurations: those installed at a DSIF station for use during transit and lunar operations, and those used in conjunction with the system test equipment assembly (STEA) during testing and prelaunch operations.

1. Station layout: Station layouts and equipment configurations vary according to the use of the specific CDC equipment. The basic difference between the DSIF and STEA configurations is the addition of the system tester, the redundant units to DSIF equipment, and the on-site data processing interface, and the addition of preprogrammed automatic tape evaluation (PATE) to STEA equipment. The system tester simulates portions of the spacecraft during test, the redundant units provide back-up in case of malfunction, and the on-site data processing interface connects the equipment to SFOF through the DSIF facilities. The preprogrammed automatic tape evaluation equipment provides a rapid means of spacecraft checkout. A card tester rack is also supplied with the DSIF/CDC equipment. Magnetic tape recorders are not provided with CDC equipment used at the DSIF stations because the recorders provided as part of the station allowance may be used during operations. A typical DSIF station layout is shown in Fig. 19.

The CDC equipment used at the DSIF stations consists of 13 racks of equipment, three consoles, and a spare equipment rack. The consoles consist of the operators' console which provides operating positions for three operators and an overhead display, the *Surveyor* operations center (SOC) console which supplies an operating position for the man in charge of operations, and the input/output selection console which contains equipment used in transferring data and commands to and from the equipment and SFOF. In addition, two keyboard printers are mounted on this console.

Table 14. S-band and L/S-band systems configuration, *Surveyor I*

Station configuration	GSDS S-band	L/S conversion	Station configuration	GSDS S-band	L/S conversion
Antenna			Transmitter characteristics		
Tracking	85-ft parabolic	85-ft parabolic	Frequency (nominal)	2113 MHz	2113 MHz
Mount	Polar (HA-dec)	Polar (HA-dec)	Frequency channel	14b	14b
Beamwidth ±3 dB	~0.4 deg	~0.4 deg	Power, maximum	10 kW	10 kW
Gain, receiving	53.0 dB, +1.0, −0.5	53.0 dB, +1.0, −0.5	Tuning range	±100 kHz	±100 kHz
Gain, transmitting	51.0 dB, +1.0, −0.5	51.0 dB, +1.0, −0.5	Modulator, phase		
Feed	Cassegrain	Cassegrain	Input impedance	≧ 50 Ω	≧ 50 Ω
Polarization	Left hand[a] or right hand circular	Right hand circular	Input voltage	≦ 2.5 V peak	≦ 2.5 V peak
Maximum Angle tracking rate[a]	51 deg/min ± 0.85 deg/s	51 deg/min ± 0.85 deg/s	Frequency response (3 dB)	DC to 100 kHz	DC to 100 kHz
Maximum angular acceleration	5.0 deg/s/s	5.0 deg/s/s	Sensitivity at carrier	1.0 rad peak/V peak	1.0 rad peak/V peak
Tracking accuracy (1σ)	0.14 deg	0.14 deg	Output frequency		
Antenna			Peak deviation	2.5 rad peak	2.5 rad peak
Acquisition	2 × 2-ft horn	2 × 2-ft horn	Modulation deviation	±5%	±5%
Gain, receiving	21.0 dB ±1.0	21.0 dB ±1.0	Stability		
Gain, transmitting	20.0 dB ±2.0	20.0 dB ±2.0	Rubidium standard	Yes	Yes
Beamwidth ±3 dB	~16 deg	~16 deg	Stability, short-term (1σ)	1×10^{-11}	1×10^{-11}
Polarization	Right hand circular	Right hand circular	Stability, long-term (1σ)	5×10^{-11}	5×10^{-11}
Receiver	S-band	S-band	Doppler accuracy at F_{Lo} (1σ)	0.2 Hz = 0.03 m/s	0.2 Hz = 0.03 m/s
Typical system temperature	—	—	Data transmission, teletype		
With paramp	270 ±50°K	270 ±50°K	Angles	Near-real-time	Near-real-time
With maser	55 ±10°K	55 ±10°K	Doppler	Near-real-time	Near-real-time
Loop noise bandwidth	—	—	Telemetry	NA[c]	NA
Threshold ($2B_{Lo}$)	12, 48 or 152 Hz +0, −10%	12, 48 or 152 Hz +0, −10%	Command and data handling console		
Strong signal	120, 255, or 550 Hz +0, −10%	120, 255, or 550 Hz +0, −10%	Channel 2 discriminator	Yes	Yes
Frequency (nominal)	2295 MHz	2295 MHz	Command capability	NA	NA
Frequency channel	14 A	14 A			

[a] Goldstone only.
[b] Both axes.
[c] Not applicable.
Note: DSS 72 30-ft azimuth–elevation antenna characteristics differ from 85-ft hour angle–declination antennas.

2. Equipment racks: The equipment racks used for mounting the components in the various bays are standard 24 × 72-in. metal cabinets. Each rack is modified as necessary for proper component installation. Fourteen different equipment racks are provided for, but not necessarily included in, each CDC system. Some of the components are mounted in the rack on slide brackets to permit easy service access. Other components mount on the front of the rack with captive screws.

a. Demodulator rack: The demodulator rack mounts the input circuitry of the CDC, the low frequency oscillograph, and certain items of test equipment. One type of demodulator rack used at DSIF stations contains two demodulators to provide backup in case of malfunction. Another type of demodulator rack is used with STEA. The switching drawers used with the two versions of the demodulator rack vary because of the input characteristics and the number of demodulators provided. Included in the rack are the low frequency oscillograph control and recorder which are used to record data that is converted to analog form in the decommutators. Test equipment mounted in the rack includes the test oscilloscope, electronic counter, and oscilloscope transfer panel. Blank spaces on the front panel are covered by blank panels that vary according to the equipment configuration. A

blower provides ventilation in most racks but at some locations is replaced by the ventilation present in the false floor.

b. Discriminator rack: The discriminator rack mounts the discriminators used in separating the subcarriers and the high frequency oscillograph normally used in recording the outputs of six FM analog channels. One type of discriminator rack is used at the DSIF stations and another is used with STEA. The principal difference between the two racks is the use of ten discriminators in the DSIF version and seven in the STEA version. An FM calibrator in the rack is used in calibrating and adjusting the discriminators. The high frequency oscillograph mounted in the rack consists of the galvanometer amplifier which provides power amplification for the stylus needles of the oscillograph, and the high frequency recorder which performs the remainder of the oscillograph functions. A storage drawer is also provided in this rack. Ventilation is supplied either by a blower mounted in the rack or by piping from the false floor of the station. Blank panels are used to cover unoccupied space in the rack.

c. Buffer and patch rack: The buffer and patch rack mounts the components used in supplying buffered time and data, and patch facilities for the system. One type of rack is used in the DSIF stations and another is used with STEA, the main difference being the intersystem patch panels in the DSIF equipments which are replaced by a patch cord storage drawer in the STEA equipment. Two other patch panels are located in the rack. The telemetry display patch panel is a conventional type board used in patching various inputs and outputs together. The system display patch panel contains a patch board insert that may be released or locked in by a handle. Twenty prepatched inserts are available which are stored in a drawer in the rack. The time and data buffer unit occupies the top of the rack and is supplied with power from a unit mounted in the lower part of the rack. A blower provides ventilation in some of the racks; others are provided with ventilation through the false floor on which the equipment is mounted.

d. Command subsystem rack: The command subsystem rack mounts the units associated with the command subsystem and two units of the on-site data processing interface. One type of rack is used with the DSIF station and another is used with the STEA. The basic difference being the keyboard printer-coupler (Y-computer string buffer) that is present in the DSIF version. The top part of the rack holds the remote countdown display under which is mounted the command subcarrier oscillator. The command printer, tape reader, and tape spooler occupy the center section of the rack. The tape punch and keyboard printer-coupler which are part of the on-site data processing occupy the lower portion of the rack. A storage drawer is located at the bottom of the rack to accommodate the patchboards of the digital decommutator programmer patch panel. A blower provides ventilation in certain of the racks; others are provided with ventilation through the false floor on which the equipment is mounted. When the STEA configuration is used in conjunction with preprogrammed automatic tape evaluation equipment, a printer switch is mounted in the rear of the rack.

e. Television photo recorder rack: The TV photo recorder rack mounts the equipment necessary for recording the data received by the TV function. Two racks are supplied at the DSIF station to provide backup in case of malfunction. The photo recording monitor occupies the top portion of the rack with the kinescope placed immediately beneath. The photo recording camera is located about midway on the rack, with a door for access to the camera, kinescope, and frame and identification indicators. The camera power supply occupies the lower portion of the rack. A film-footage indicator is mounted on a strip across the center of the rack. A blower supplies ventilation for the rack.

f. Magnetic tape recorder rack: The magnetic tape recorder rack houses an Ampex FR600 magnetic tape recorder. This rack is supplied only with CDCs used with STEA.

g. System tester: The system tester, supplied only with DSIF equipment, consists of three racks of equipment. The equipment simulates the action of parts of the *Surveyor* spacecraft for CDC checkout and also provides certain pieces of test equipment for checking various CDC operations. All CDC equipment in the STEA configuration uses the spacecraft and certain STEA components to perform the CDC checks.

h. Computer interface rack: The computer interface rack, supplied only to the DSIF configuration, mounts equipment used to tie in the DSIF and on-site data processing (OSDP) computers. A spare tape reader and tape spooler for the command subsystem is also mounted in the rack. The top of the rack is occupied by the reader/punch/typewriter switching unit which switches tape readers, tape punches, and couplers within the command function and OSDP interface. Located below the redundant tape reader, spooler, and punch units, the computer patch panel provides patching facilities for connecting

units of the OSDP interface to the OSDP computers used in processing *Surveyor* telemetry data and command tape punching information received from SFOF through the DSIF communication link. The W-string keyboard-printer and punch-coupler, and the W-string reader-coupler are located in the rack. The coupler power supply provides operating voltages for the couplers. A blower provides ventilation for the rack.

i. Card tester rack: The card tester rack mounts test equipment used in checking the CDC system and is provided only with equipment used at the DSIF stations. The command generator card tester occupies the top of the rack, with the CDC card tester located immediately below. The telemetry converter and command buffer test set is located in the center of the rack. A blower at the bottom of the rack provides ventilation. Two card testers permit functional tests of most of the digital circuit cards used in the CDC.

j. Spare bay rack: The spare bay rack is provided with both the DSIF and STEA equipment for future use.

3. Consoles: The CDC equipment supplied to the DSIF stations contains three consoles: the operators' console, the input/output selection console, and the *Surveyor* operations center console. Only the operators' console is supplied with the CDC equipment used in conjunction with STEA.

a. Operators' console: The operators' console consists of the television console command console, telemetry console, and the elevated display bolted together to form one continuous console that accommodates three operators during a *Surveyor* operation. Each console has a center desk space with panels underneath. The space above the desks mounts displays and controls. The elevated display is bolted to the top of the three consoles and provides a mounting for various equipment used during operation. This display is supplied with various components according to its use with DSIF or STEA and the configuration of the STEA equipment.

b. Television console: The TV console supplies an operating position for the TV operator. The upper part of the console consists of the television viewing monitor and the video processor. Controls for the adjustment and control of the unit are located on the monitor and video processor. Consoles used with DSIF stations have two video processors for backup in case of malfunction during operations. The DSIF units also have two power supplies in the lower part which are backup for the power supplies mounted in the command console to supply power to the command generator in that console.

c. Command console: The command console supplies an operating position for the command operator. The upper arrangement of the console consists of the command generator which is used in controlling and displaying various operations of the command function. A keyboard extends from the lower right-hand corner of the command generator and supplies one of the methods for entering spacecraft commands. The lower part of the console is occupied by two power supplies that supply operating power to the command generator. Slightly different command generators are used in the DSIF and STEA equipment, the primary difference being the modification of the STEA generator for use with the preprogrammed automatic tape evaluation equipment.

d. Telemetry console: The telemetry console supplies an operating position for the telemetry operator. The upper part of the console consists of the telemetry display, which supplies 16 meters to display analog data derived from binary data, 5 digital readout tube (*nixie*) displays to display binary coded decimal data, and 16 indicator lamps to display spacecraft events. The lower part of the console contains blank panels. Plastic overlaps are available for use with the telemetry display and are matched to the prepatched programmer patch boards used with the programmer patch panel. This arrangement permits rapid shifting of displayed data. The callouts on these plastic overlaps match the patching of the patch boards in the overlaps, and the patchboards supplied with the DSIF equipment. The overlaps supplied with the STEA version are not lettered and may be marked with a china marking pencil to follow the patches made in test setups. Other than the plastic overlays, only minor differences exist between the console supplied with the DSIF equipment and that supplied with the STEA version.

e. Elevated display: The elevated display consists of a rack mounted on top of the operators' console that provides available space for equipment used in monitoring the *Surveyor* operation. Each display is equipped with a spectrum analyzer to monitor the input signal to the discriminators. Other displays vary according to ultimate use, either with DSIF or with the various versions of the STEA configuration.

f. *Surveyor* operations center console: The *Surveyor* operations center console provides an operating position for the man in charge of *Surveyor* operations. The console,

a desk-like frame with blank panel space for mounting display equipment, is centrally located in the *Surveyor* operations center. A remote control for the count-down clock is located on the console. The console is supplied only with the DSIF equipment.

g. Input/output selection console: The input/output selection console consists of two keyboard printers mounted on stands and separated by the input/output selection panel. Similar to a teletype which accepts incoming electrical pulses for printing and supplies outgoing electrical pulses from the keyboard, the printers may be used to apply information to or receive information from the on-site data processing computers or to punch tape on the tape punches. The input/output selection panel controls the operation of the reader–punch–typewriter switching unit in the computer interface. The console is supplied only with DSIF equipment.

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

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

Ground Communications Facility. The GCF is a particular configuration of NASCOM that includes the services, facilities, and equipment required to provide an integrated network for the DSN in the support of space flight operations and systems tests. The DSN Communications Center at JPL is a major end terminal of NASCOM and the major switching center of the GCF. The GCF thus interconnects the DSIF stations with the SFOF, as well as the various non-DSIF agencies with the SFOF.

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

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

For the *Surveyor I* mission, the GCF transmitted tracking, telemetry, and command data from the DSIF to the SFOF and provided control and command functions from the SFOF to the DSIF by means of NASCOM facilities. It also transmitted simulated tracking data to the DSIF, and video data and baseband telemetry from DSS 11, Goldstone DSCC, to the SFOF. Figure 14 illustrates the generalized routing of the GCF circuits.

Voice and teletype circuits in the GCF were configured as follows:

(1) Voice circuits: The GCF configured a system of four-wire engineered voice circuits to a majority of the sites in the network. Most of the voice circuits were routed via the GSFC switching center and comprised the SCAMA. Circuits were routed by hardwire and microwave wherever possible. Voice circuits to overseas points used the transoceanic cables or high-frequency radio links when cables

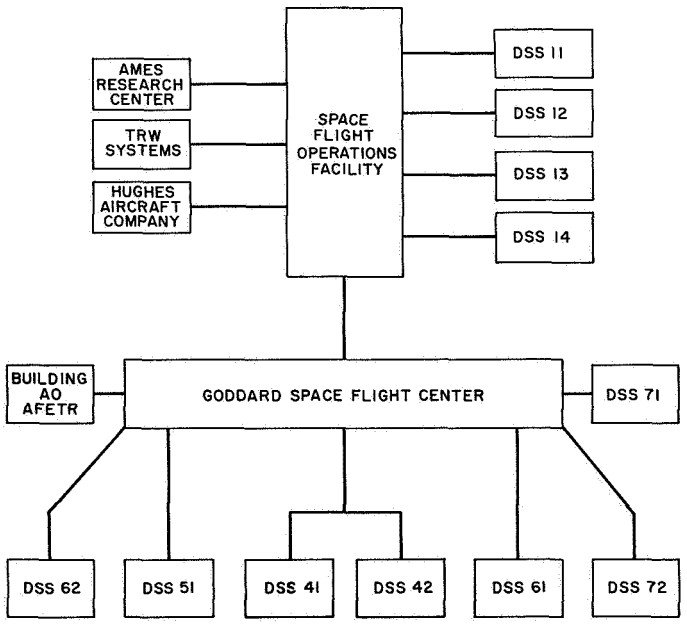


Fig. 14. Generalized DSN Ground Communications Facility circuit routing diagram

were not available. These circuits were to be used for operational and non-operational traffic. Both common user and private lines were provided.

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

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

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

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

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

The ICS configuration comprised the following subsystems:

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

(2) Operational teletype communications subsystem: The teletype subsystems were configured to serve two prime functions: (1) the transmission and receipt of non-operational traffic and (2) operational support. A block diagram of the operational teletype subsystem is shown in Fig. 15.

(3) Television communications subsystem (TVCS): As shown in the block diagram in Fig. 16, the TVCS was configured in three sections: (1) video inputs, (2) central controls, and (3) monitors. The TVCS performed the following functions: (1) area surveillance, (2) teletype presentation, (3) status and hard-copy display, (4) commercial television display, and (5) Goldstone DSCC video display.

(4) High-speed data subsystem: The DSN configured a system of high-speed data circuits for the purpose of transmitting spacecraft telemetry requiring a higher bit rate than that of teletype. These circuits were used solely for operational traffic. The HSDS provided a method of terminating the high-speed data circuits external to the SFOF and a method of interconnecting these circuits to various user areas.

The DSN Communications Center was equipped with 6 high-speed data modems (modulator-demodulator), any one of which could be connected to any external high-speed data circuit. Full-duplex capability was provided. Internally, the output (or input) of these modems was patchable to various internal circuits of either the TPS or the simulated data conversion center (SDCC).

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

The DSN Communications Center was configured to interconnect the 96-kHz circuit to Goldstone (full duplex) and to several areas of the SFOF, including TPS/TVGDHS and SDCC. In addition, the capability existed to interconnect the 6-MHz circuit to Goldstone (simplex) to the ground data handling area of the SFOF.

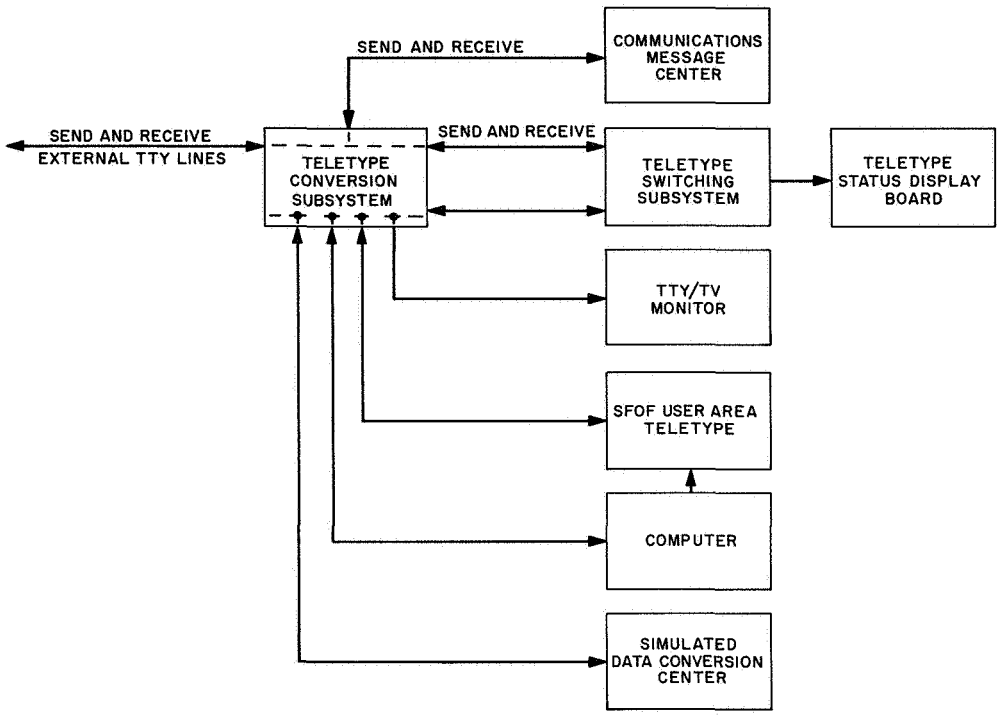


Fig. 15. Block diagram of operational teletype communications subsystem

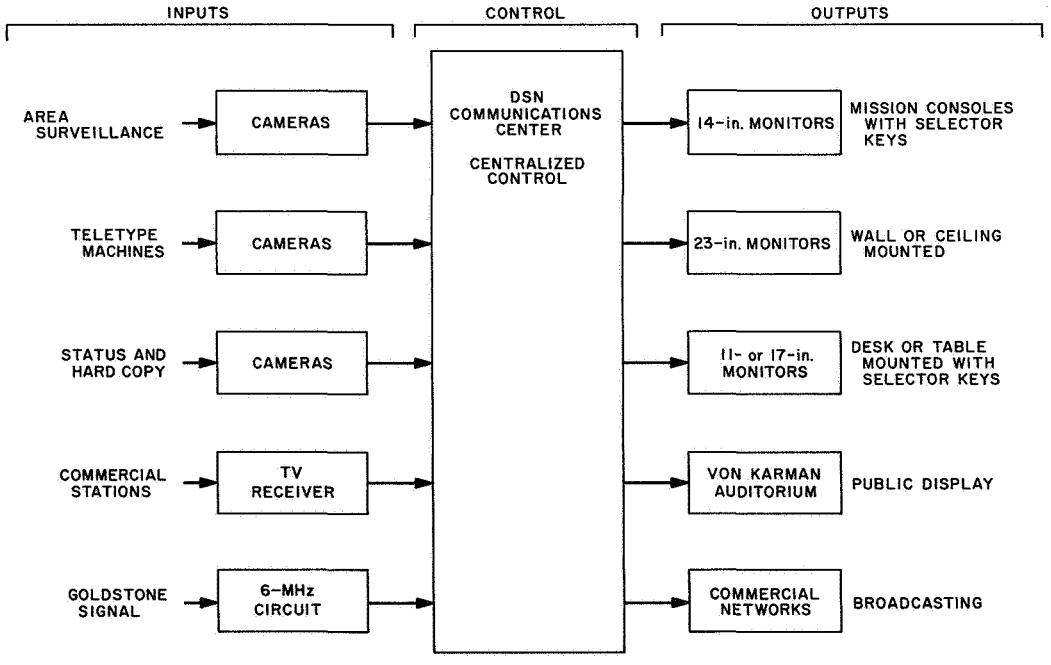


Fig. 16. Generalized capabilities of the DSN/ICS television communications subsystem

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

(1) Simulation data conversion center (SDCC): The prime function of the SDCC was the simulation of space flight data for use within the SFOF. These data were routed to various users throughout the SFOF and the DSIF network by means of the existing communications circuits and equipment. In this manner, operations personnel were exposed to conditions simulating the conditions that would exist during actual space flight operations. All means used to communicate with the DSIF (i.e., teletype, voice, high-speed data, and wideband circuits) were available for use to conduct simulations from the SDCC.

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

(3) Television ground data handling system (TVGDHS): The functions of the TVGDHS were to record television observations of the moon; to support NASA experiments and JPL scientists; and to support spacecraft tests, operations, and TV operational tests. The interface between the DSN Communications Center and the TVGDHS consisted of three wideband data lines, two of which were normally connected to the 6-MHz microwave line from Goldstone.

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

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

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

(7) Audio status display: This display indicated the status of all active voice or high-speed data circuits, audio bridges, and interconnections of modems to DSSs.

c. Space Flight Operations Facility. The SFOF, located at JPL, was the focal point of the DSN in supporting *Surveyor I.* From this building the operation of the entire DSN in support of tests and missions was controlled. All command, data processing, data analysis, communications and support functions were controlled therein. Capabilities existed to produce and/or control a number of tests/missions simultaneously. The SFOF is a flexible facility in which areas and hardware can be configured to meet the needs of various projects. The functions necessary to support space activities were performed through the following systems:

(1) DSN monitor system (DSN monitor area) in the SFOF: Monitored the operational status of all major hardware complexes in the SFOF data processing system; the status of the programs operating in the input/output (I/O) computer; and the flow of data among the processing components.

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

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

(4) Support system: Provided project requirements for all peripheral services such as technical area assistance, documentation, scheduling, data distribution,

reproduction and storage, access control, hardware supplies, and building services such as electrical, air-conditioning, and general plant maintenance.

(5) Simulation data conversion center: Provided a centralized facility within the SFOF for the conduct of DSN certification and training tests; for use in hardware and computer program validation and personnel training; as a means of generating prerecorded simulated data; and a source of real-time simulated data for insertion into DSS systems via NASCOM.

SFOF data processing system. The DSN configured a data processing system in the SFOF that performed the following functions for the *Surveyor I* mission:

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

(2) Orbit determination.

(3) Midcourse maneuver computation and analysis.

(4) On-line telemetry processing.

The DPS provided the data processing and data display equipment necessary to analyze the spacecraft engineering and scientific telemetry information and to execute the mission control operation. All programs operating in the DPS were the responsibility of the *Surveyor* Project. The DPS was divided into the following three subdivisions:

(1) Telemetry processing station: The TPS was used to receive and convert all high-speed telemetry data into a 36-bit format, whereupon it was transferred through the subchannels of the IBM 7288 to the analysis computers. The TPS configuration for *Surveyor I* consisted of one PDP-4 (programmed digital processor) and one PDP-7 computer. Both of these computers were thoroughly checked out prior to the mission.

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

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

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

SFOF facilities support. Certain areas within the SFOF were configured to provide effective support to the *Surveyor I* mission. These areas, which were used for operations flight path analysis and mission support, were equipped with displays as follows:

(1) Operations Area: Mission status board No. 1 display equipment in this area consisted of an Eidophor projector, TelePrompTer projector, mission events projector, flight path No. 1 digital display unit (DDU), special time displays (countdown/up clocks), and miscellaneous supporting display equipment.

(2) Flight Path Analysis Area: Displays in the FPAA included the maneuver board, orbital and mission parameters board, tracking data board, and a trajectory display board. Wall space not specifically devoted to particular displays was utilized for chalkboards and/or information boards.

(3) Mission Support Area No. 1A—Spacecraft Performance Analysis Area:

Displays in this area included:

(a) SPAA communications status display board (pre-formatted chalkboard)

(b) Spacecraft telemetry measurement display board (pre-formatted chalkboard)

(c) Flight sequence display board (formatted DDU/chalkboard)

(d) Mission status board Nos. 1 and 2 in the operations area (remotely actuated DDU board)

(e) Spacecraft model room, which was incorporated in the SPAA to permit visualization of the attitude of the spacecraft in the celestial sphere through which it was traveling.

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

(4) Mission Support Area No. 1B—Space Science Analysis and Command: Displays in the SSAA included the engineering sensor display (preformatted DDU/chalkboard) and the television identification display board (Fig. 17). Wall space not specifically devoted to particular displays was utilized for chalkboards and/or information boards for the use of technical personnel.

Facility support included operation of display devices, data distribution in the facility, supervision of access control, and building housekeeping functions. Mission-dependent equipment space and facility support were provided for the TVGDHS (located in the west wing of the second floor of the SFOF).

B. Tests

To ensure that all *Surveyor* missions would be successful, a large amount of testing had to be accomplished. Testing for the first *Surveyor* mission covered a period of some two and one-half years. This was no small task, as hundreds of scientists, engineers, technicians, and other personnel devoted thousands of man-hours to configure and reconfigure software and hardware to *Surveyor* Project specifications. Space limits the detailing of all tests performed; however, this section will give an understanding of the major testing that was carried out to support *Surveyor*.

1. CDC/DSIF receiver tests. During late 1963 and early 1964 a series of tests was conducted to determine the compatibility of the *Surveyor* command data console (CDC), the DSIF S-band receivers, and the *Surveyor* spacecraft system. As the need arose, other special tests on individual equipment were performed at later dates.

The tests were conducted at Hughes Aircraft Co., El Segundo, Calif. over the period of Nov. 11 through Dec. 2, 1963, by HAC personnel with periodic monitoring by a JPL engineering coordinator.

Figure 18 is a photograph of the equipment. The items may be identified by moving in a counterclockwise direction starting at the top left-hand side with the three racks containing the DSIF equipment. Next, the work bench with test equipment and rack-mounted RF spacecraft components, then the CDC console, and finally the CDC racks with telemetry error test equipment in front. To achieve the objectives mentioned below, the command, telemetry, and television subsystems were tested.

a. Test objectives. The primary objectives of the tests were:

(1) To determine overall functional compatibility between the CDC and the "feasibility model" DSIF receiver.

(2) To determine any necessary system changes required to correct significant deficiencies and incompatibilities.

Secondary objectives were:

(1) To determine the adequacy of the nominal complement of CDC test equipment.

(2) To collect further CDC test and maintenance data.

(3) To familiarize station personnel with closed loop operations and system characteristics.

(4) To obtain data relative to the system tester concept.

b. Summary of results. In general, overall functional compatibility was satisfactorily demonstrated. Command and data loops were closed extensively for the test. Telemetry and television data were displayed on the CDC console following CDC processing of the DSIF receiver output signal. The CDC command SCO output modulated the test transmitter, and the proper spacecraft reception was recorded.

The overall performance of each subsystem was compared with that of the others with the following result: best, command subsystem; next, telemetry subsystem; last, television subsystem. Consideration should be given, however, to the status of the actual hardware used for these tests, i.e., a combination of feasibility, prototype, breadboard, and production equipment.

Generally, the criterion for judging the performance of a particular subsystem consisted of noting the RF input level that results in satisfactory operation of the subsystem and then comparing this value with the minimum expected value, the decibel allocation and

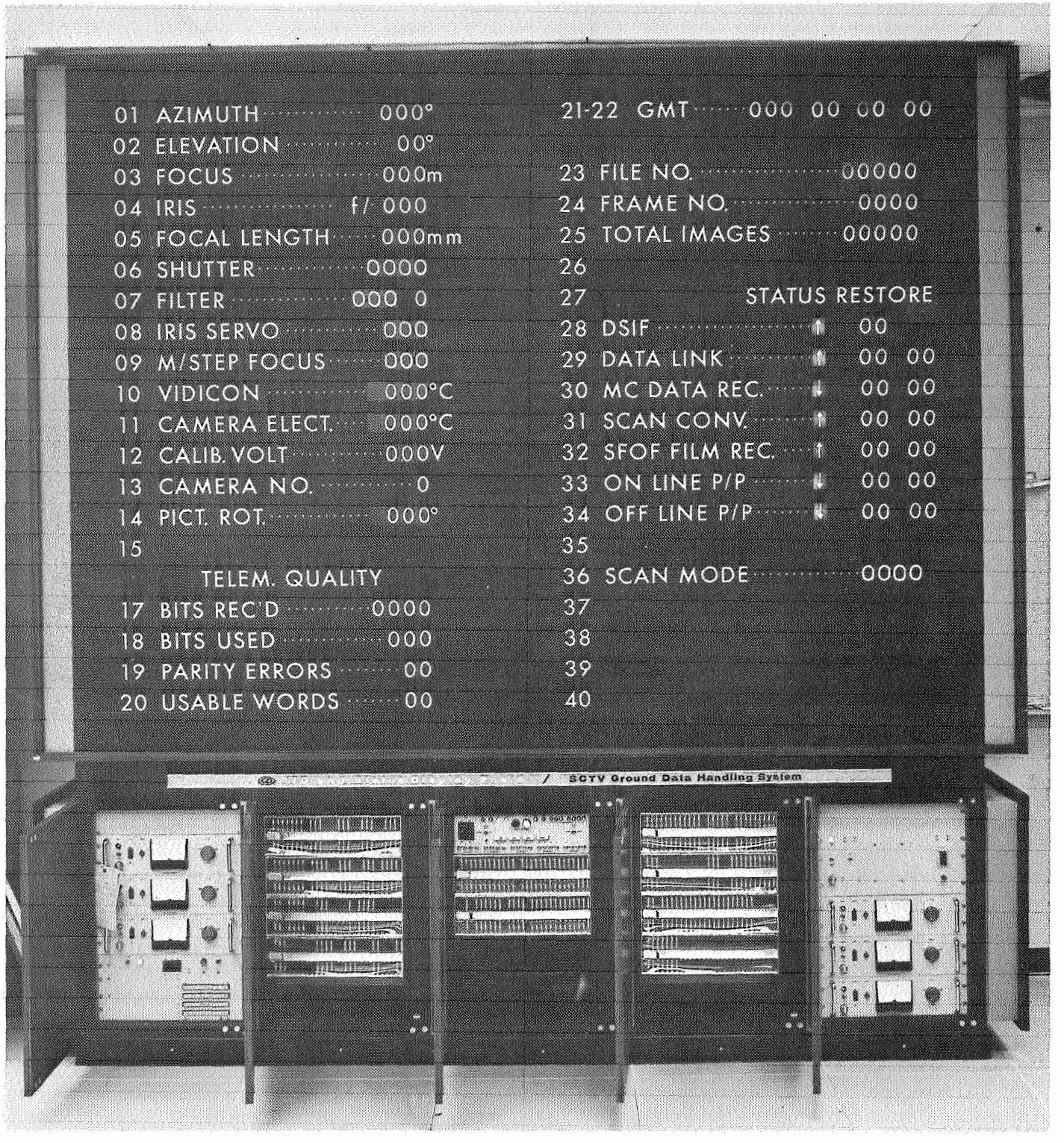


Fig. 17. *Surveyor* television identification display board, showing electronics

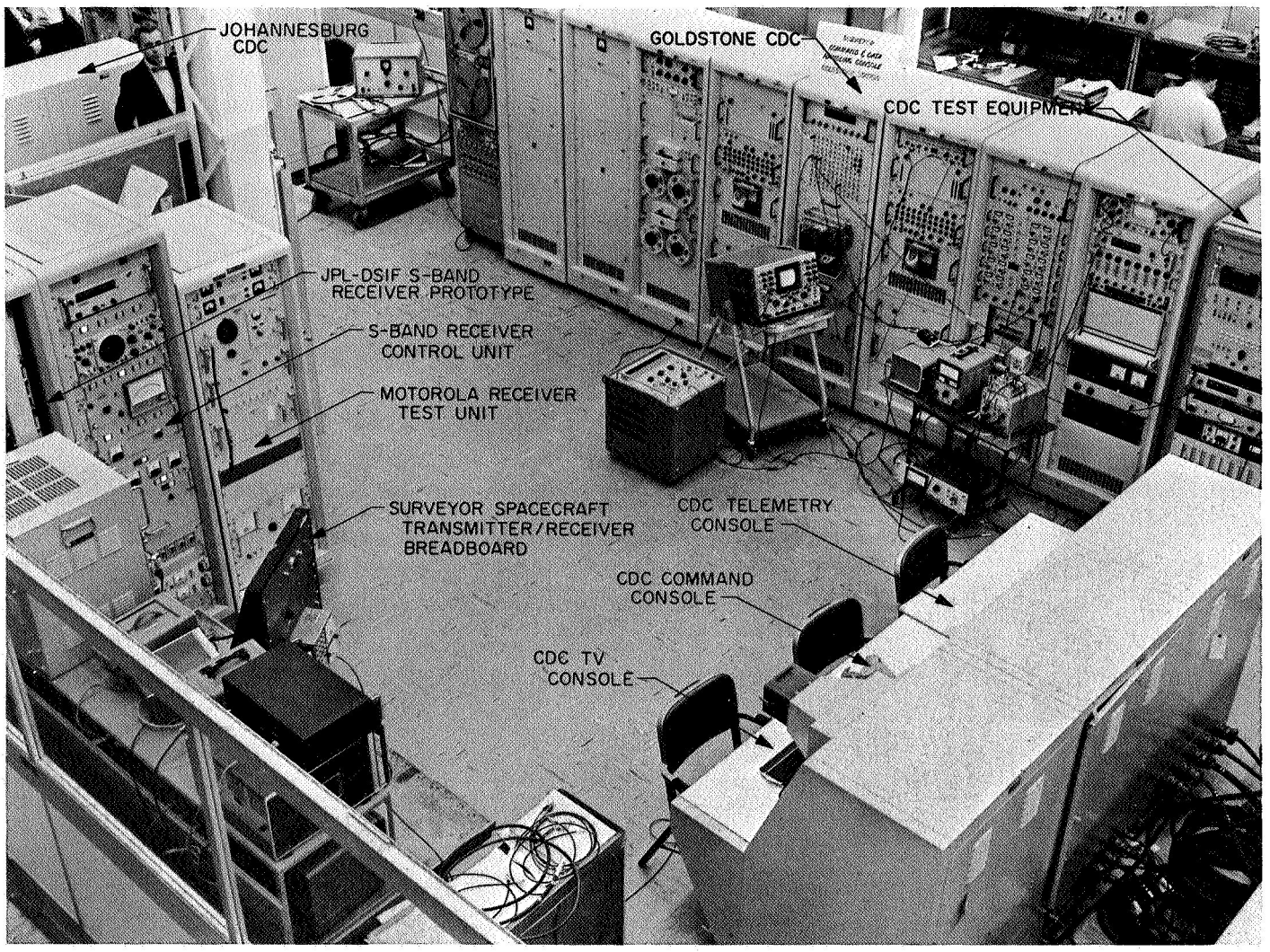


Fig. 18. DSIF S-band receiver prototype to *Surveyor* CDC integration test

margin summary. Satisfactory operation of the command and telemetry subsystems is indicated when the bit or word error rate does not exceed a specified value. (Two subsystems may differ because the error rate measurement for each was not instrumented in the same manner.) Television quality was originally to be a subjective judgment of the percent of video degradation. However, upon proceeding with the television tests, it immediately became apparent that loss of horizontal sync would be the determining factor for television threshold. Furthermore, the manner in which loss of horizontal sync manifested itself was in an erratic loss of complete horizontal sweeps rather than in an increasing jitter of adjacent sweeps. The net result was that a television threshold between the loss of a few horizontal sweeps and the complete loss of the monitor picture was to be determined within 3 dB for repeated changes of receiver input.

Space prohibits discussing in detail tests concerning each subsystem. However, based on the above criterion, the individual subsystem performance can be briefly stated as follows. For the command subsystem, an expected power level of −91.6 dBmW at the receiver input terminals was indicated. No perceptible error rate could be measured at this level. In fact, a word error rate of 10^{-3} (one error in a thousand words) does not occur until the input is reduced below −110 dBmW. Thus, command subsystem performance is very satisfactory.

For the telemetry subsystem, minimum expected receiver input levels of −121.8 and −117.7 dBmW, respectively, for intelligence bit rates of 550 and 4400 bit/s were indicated. For acceptable bit error rates of the order of 4.10^{-4}, the corresponding 550- and 4400-bit/s input levels (adjusted for 6.8 dB of carrier loss) were −121.7 and

−106.7 dBmW, which represent a marginal state and an unacceptable state, respectively. Because bit error rates and corresponding signal-to-noise ratios comparable with those obtained in the compatibility tests were measured with local noise injection for a non-RF path configuration, the above condition was attributed to the effects of the feasibility model DSIF receiver.

Television threshold occurred at an input level of approximately −84 dBmW, as compared with the value of −96.6 dBmW indicated. To correct this discrepancy it would appear that the receiver noise figure would have to be improved by 12.6 dB. The DSIF feasibility model receiver used during the tests had a noise figure of 33 dB; the improvement must occur to bring the noise figure down to a reasonable value. It was noted that the addition of a maser front-end would bring an improvement of almost 30 dB. Also important was the fact that the receiver IF bandwidth, as mechanized, proved excessive and unsymmetrical, resulting in a predetection signal-to-noise ratio degradation of almost 5 dB. Television performance was also compromised by slight over-modulation of the spacecraft transmitter and by poor synchronization of the viewing monitors.

It was felt that much useful information was obtained from these tests even though they were conducted in approximately half the originally allotted time. Data as extensive as desired were not obtained in all cases because of the compressed time schedule, mid-period receiver adjustments that resulted in noncomparable "before" and "after" data, and time spent investigating some of the feasibility model characteristics as an aid in interpreting the interface data.

c. Conclusions. The feasibility model receiver was not a sufficiently adequate representation of the DSIF interface described by the *Surveyor* Project to enable conclusive compatibility test results to be obtained.

General qualitative compatibility, however, was demonstrated for the TV, command, and telemetry subsystems, recognizing that differences existed between the equipment utilized and the final production hardware.

This test series proved quite valuable in familiarizing the test team with the DSIF equipment since little information was previously available.

Techniques for conducting future compatibility tests and specific test requirements for future tests became apparent.

A need for certain engineering changes to the equipment was also demonstrated during the tests; these were as follows:

(1) The DSIF receiver bandwidth was narrowed to 3.3 MHz.

(2) A modification of the CDC video processor to obtain more reliable TV sync was expedited.

(3) Both the output SNR and the demodulated video amplitude and the manual gain control (MGC) were brought to a common location. This enabled the operator to view the video waveform while manipulating the MGC control.

Several technical areas were uncovered that required further investigation and more quantitative data than available time would allow during this test operation. They were as follows:

(1) The 35-mm remote scope recorder film advanced many times per TV frame when the RF level was near the TV sync threshold. It was presumed it would do the same during the TV erase scans on the operational system, since no RF carrier was present then to suppress receiver noise. It became necessary to restrict this stepping so that film would not be exhausted before completion of a TV survey.

(2) The amplitude of the demodulated video varied with RF signal level and MGC setting. TV monitor and remote scope recording were both adversely affected by this.

(3) The demodulator output was observed to be significantly loaded at high frequencies. Both waveform distortion and amplitude rolloff in excess of the de-emphasis curve were noted. Switching off the telemetry discriminators at the CDC system patch panel eliminated the distortion and substantially improved the amplitude characteristic. (The TM discriminators are seldom used simultaneously with TV.) It is believed that most of the loading was due to an interconnecting cable capacity.

2. CDC/DSIF compatibility tests

a. Introduction. The CDC/DSIF compatibility tests were conducted at DSSs 11, 42, and 51 (Goldstone, Canberra-Tidbinbilla, and Johannesburg, respectively) during the second quarter of 1965. The basic purpose of these tests was to determine the engineering and functional compatibility between the mission-independent

equipment and the *Surveyor* mission-dependent equipment. These tests represented the final phase of the *Surveyor* equipment tests and followed the CDC installation, checkout, and prerequisite unit, subsystem, and system tests.

The tests were conducted in accordance with the DSIF Station Operations Plan, *CDC-DSIF Compatibility Tests*, and detailed test procedures, which were published and distributed. The plan and procedures were prepared for station operations personnel under the technical direction of, and as approved by, the *Surveyor* Project (equipment) personnel.

Quick-look reports were prepared at each station during the course of the testing period. After the completion of the tests at all stations, all quick-look reports were reproduced and bound in two volumes for distribution.

The following subsections present a summary report and a condensation with a limited analysis of the quick-look data.

Figure 19 shows the *Surveyor* command and data handling system that was installed at DSIF stations.

b. Test result summary. The general results and conclusions of the compatibility tests performed at the Deep Space Stations are summarized below with the detailed discussion of the results included in Sections IV-B-3 (Goldstone), IV-B-4 (Johannesburg), and IV-B-5 (Canberra):

TV/RF subsystem. There was no apparent RF interference with the DSIF equipment caused by RF leakage from the CDC.

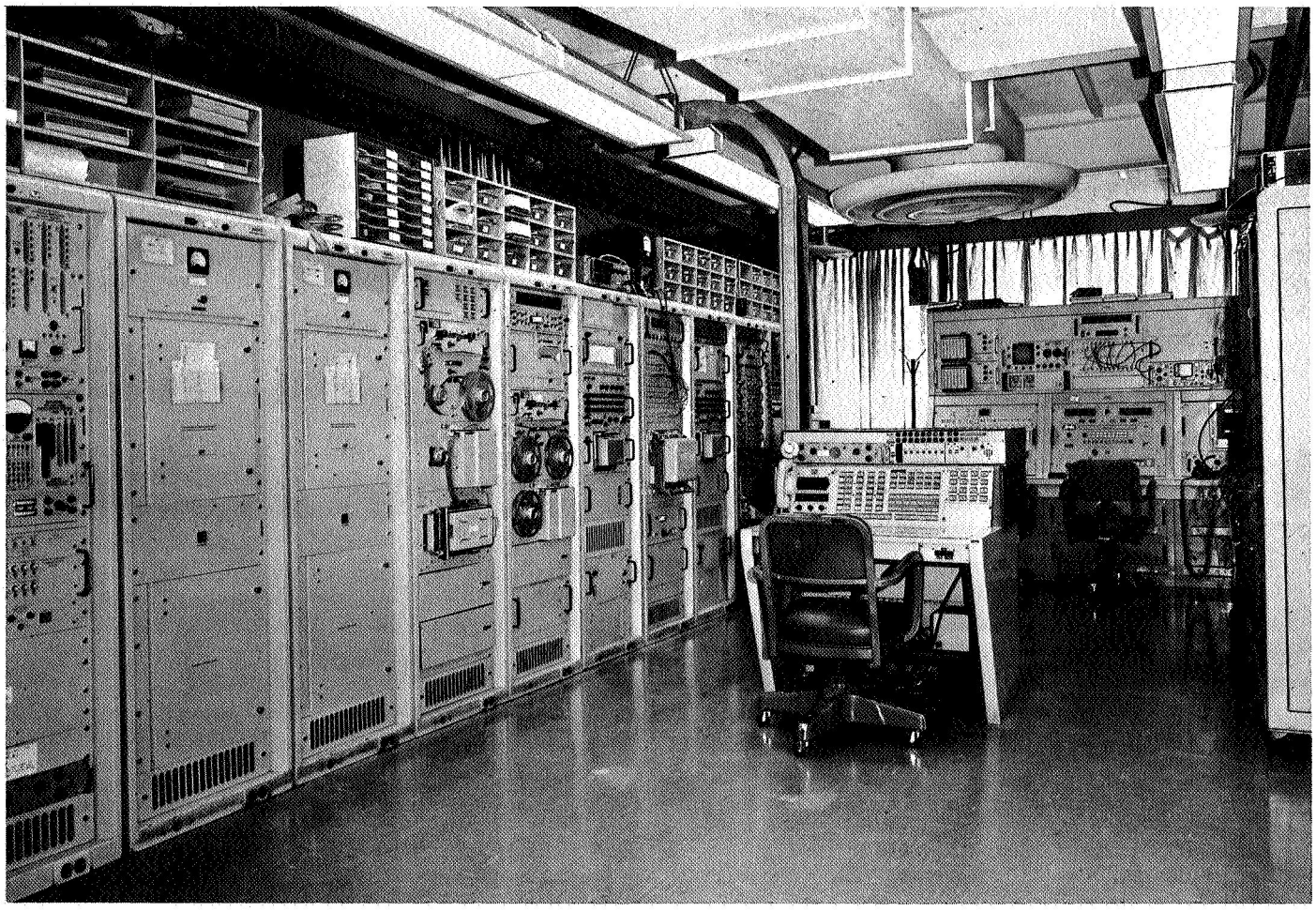


Fig. 19. *Surveyor* command and data handling system, DSIF installation

The RF calibration of the lines between the DSIF and the CDC was verified.

The various RF levels and thresholds were measured and determined to be within the tolerances specified in the decibel allocation and margin summary.

The television test patterns were obtained with some acceptable results. In some cases, the results were marginal because of interference from other systems. It was not possible to obtain successful recording and playback using the FR-800 tape recorder; however, this was later corrected.

Telemetry subsystem. The FM improvement in both the demodulator and discriminator was below the values specified in the test procedures. The tolerance values were reexamined for accuracy by considering all contributing elements of the system.

The bit error rates with and without the multiplexed channels were checked above and below threshold. Most results were within tolerances except for the 17.2-bit/s channel. Also, excessive data scatter and inconsistencies were noted, which will justify some further checking.

The results of the analog recordings tests of the CDC low-frequency and high-frequency oscillographs were acceptable.

Command subsystem. The command subsystem performed adequately at the specified RF levels. The command word error rate was within tolerance.

DSIF instrumentation. Problems were encountered in the use of the DSIF-supplied tape recorders. A complete investigation was required to cover operating specifications, alignment procedures, recording head wear determination, and equipment maintenance. The telecommunications tests resulted in some out-of-tolerance points at some frequencies with both the FR-800 and FR-1400 tape recorders. Cable length and line termination had some effect on the test results.

The DSIF CEC backup recorder performed satisfactorily after a minor modification was made on the discriminator output to prevent oscillating caused by the different recorder load. The CEC galvanometers were changed to ones with a frequency response of better than 1000 Hz to enable this unit to serve as a complete backup for the CDC high-frequency recorder.

The satisfactory operation of all CDC timing displays that originate from the DSIF sources was verified.

The CDC/OSDP interface was checked and satisfactory operations verified. Some operational problems with the computer program were encountered and most were corrected.

As a reference for the subsequent test, the following list of the compatibility test procedures by number and title is provided:

11-1	RF power calibration
11-2, 3	DSIF receiver output SNR ratio, telemetry error rates, recordings, and discriminator performance
11-4	Telecommunication link frequency response
11-5	TV horizontal sync
11-6	TV test pattern
11-7	Multiplexed telemetry
11-8	Two-way phase lock threshold
11-9	Command transmission and word error rate
11-10	Timing displays test
11-11	CDC/OSDP checkout
11-12	Composite system test

3. *Goldstone CDC/DSIF compatibility tests*

a. Test result summary. Compatibility tests 11-1 and 11-2 were performed at Goldstone during the period of March 15 to July 1, 1965. During this time the majority of the test procedures were written and revised to reflect the actual method of performing the tests. The original RF tests were conducted during the early morning hours to eliminate interfering with *Mariner* tracking.

In general the RF system was operated with the maser looking into the cryogenic load, which has a noise temperature of 97°K. Some tests were performed with the antenna pointing at deep space, which resulted in a noise temperature of about 45°K. When the antenna was pointed at the horizon, different values of noise temperature were obtained. In all instances in which an RF level comparison was made between data, the noise temperature was taken into account.

Telemetry subsystem. The telemetry subsystem tests were, in general, accomplished with little difficulty. The values obtained for some of the FM improvements in both the demodulator and discriminator fell considerably below the calculated (theoretical) values specified in the test procedures.

At the predicted RF levels the only telemetry channel not to specification for bit errors was the 17.2-bit/s channel. It had a high bit error rate, which was possibly due to the alignment of the PCM input card in the decommutator.

The multiplexer telemetry tests revealed that there was some interference between the channels, but this interference did not seem to affect the bit error rate or the analog telemetry output.

The RF calibration tests confirmed the lines feeding between the CDC into the DSIF systems. The spacecraft-to-CDC demodulator output frequency response was measured and found to agree very closely with the tolerances in the procedure up to 220 kHz. This is the TV bandwidth and the bandwidth of the demodulator output filter.

The downlink RF carrier threshold was measured at −167.4 dBmW. The two-way phase-lock threshold with no modulation on the DSIF transmitter was −127.7 dBmW in the system tester receiver. With modulation on the DSIF transmitter, the phase-lock threshold was −122.5 dBmW in the system tester receiver.

The FR-1400 tape recorder appeared to be difficult to align for obtaining consistent results. This difficulty was possibly a result of concurrent usage with *Mariner*. After the *Mariner* track was over, the recorder appeared to have an erratic frequency response caused by an intermittent connection in a cable. Subsequent tests using a terminated recording and playback line indicated the FR-1400 was adequate for the *Surveyor* mission.

Apparent alignment troubles were encountered with the FR-1400 video recorder. The on-off cycling of the spacecraft high-power transmitter caused very poor TV pictures from the recordings. This problem is still being investigated.

Command subsystem. The command subsystem had no word errors at an RF level of −113.7 dB at the system tester receiver. The noise figure was measured and found to be 10.0 dB. The receiver drifted over a period of time, so this had to be taken into account when running these tests.

Television subsystem. The operation of the television subsystem was very close to specification except for the interference present in the TV monitor.

Miscellaneous tests. The timing displays performed according to specification. The Goldstone OSDP test was performed after some minor modifications were made to the equipment. The OSDP checkout (compatibility test procedure 11-11) was also performed at Goldstone with the DSIF 42 and 51 reader couplers, punch and typewriter couplers, tape punches, input/output switching units, typewriters, telemetry converters, and the command buffers.

Summary. Many of the demodulator and discriminator FM improvements differed from the values given in compatibility test procedures 11-2 and 11-3. These tolerances were examined for validity.

Discriminator FM improvement factors do not consider the filters on the input of the spacecraft SCO or the effect of the output filter of the discriminator. The 33-kHz discriminator was tested using an 8980-Hz bandpass filter.

The FR-1400 and FR-800 tape recorders' frequency responses did not meet the specification in compatibility test procedure 11-4. A 75-Ω terminated line was installed on the FR-1400 recorder to improve the frequency response.

There was interference on the TV monitor which was subsequently resolved. This was 60-Hz interference from the power supplies.

The FR-800 tape recorder could not play back the 10-MHz IF into the demodulator to obtain a TV picture. Further tests with this recorder were made to make it useful for *Surveyor*.

b. Actual test results

RF power calibration (compatibility test procedure 11-1). The four parts of this test were as follows: (1) measuring attenuation of cabling to the DSIF area, (2) determining RF interference to the DSIF receiver by the CDC, (3) determining the amount of CDC test transponder leakage, and (4) measuring RF level to assure compatibility between the CDC and DSIF.

The first time this test was performed, the mean value of RF power measurements obtained from the DSIF-receiver AGC curve was 2.2 dB lower than the RF power measurements obtained by summing the system losses. The AGC lines were recalibrated and the difference was found to be 2.2 dB. Application of this correction factor to the data tapes should only be one point out of the

±1.5-dB range. The test was partially rerun at the lower signal levels and all points were within the specified tolerance (±1.5 dB).

DSIF receiver output SNR, telemetry error rates, recordings, and discriminator performance (compatibility test procedures 11-2 and 11-3). The test included checking the FM and PM receiver performance against the theoretical values, measuring the improvement factors for the demodulator and discriminators in all modes, and measuring the bit error rate of the PCM channels. Also included were tests to show that the FR-1400 has the capability to record the CDC telemetry signals and play them back satisfactorily.

The results of this test are as follows:

(1) The demodulator improvement in the FM-FM mode is shown plotted against RF level for the five different FM SCOs in Fig. 20. Table 15 shows the measured improvement, the theoretical improvement, and the difference. These results indicate the demodulator was performing considerably below the theoretical calculations or that the improvement factor calculations were not totally correct. Figure 21 illustrates the demodulator

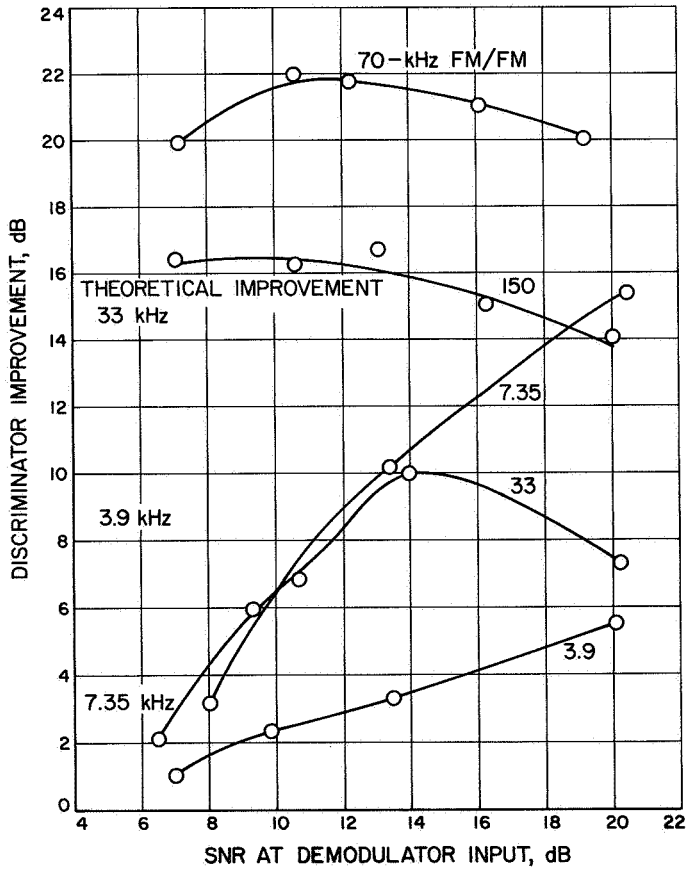


Fig. 20. FM discriminator improvement vs SNR at demodulator input

Table 15. Demodulator improvement (theoretical vs measured)

SCO, kHz	Measured improvement, dB	Theoretical improvement, dB	Difference from theory, dB
150	11.6	18.5 ±2	−6.9
	12.3		−6.2
	12.4		−6.1
	10.0		−8.5
70	5.2	14.5 ±2	−9.3
	4.6		−9.9
	4.4		−10.1
	0.7		−13.8
33	−3.1	13.5 ±2	−16.6
	−4.6		−18.1
	−4.5		−18.0
	−4.8		−18.3
7.35	−20.3	5.5 ±2	−25.8
	−23.8		−29.3
	−22.7		−28.2
	−21.4		−26.9
3.9	−12.8	−7.5 ±2	−5.3
	−10.4		−2.9
	−10.0		−2.5
	−6.7		+0.8

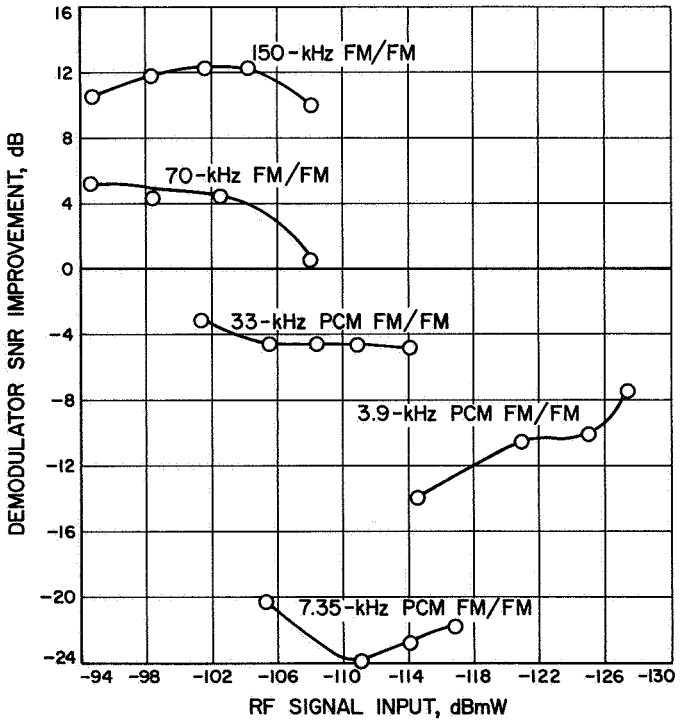


Fig. 21. Demodulator improvement

improvement. Figure 20 shows the FM discriminator improvement vs SNR demodulator input.

(2) The discriminator improvement for the FM-FM mode in Fig. 21 was plotted against SNR in the discriminator bandpass. The theoretical improvement is also shown in the same figure. Some of the discriminators have better-than-theoretical improvement and others are below theoretical improvement. This suggests that the theoretical figure had to be reexamined for the FM-FM mode.

(3) The discriminator improvement for the FM-PM mode is shown in Table 16 for a SNR in the discriminator bandpass of 16 dB. In all FM-PM modes the discriminator had less improvement than the theoretical value. These theoretical values also had to be examined for validity.

Table 16. Discriminator improvement FM/PM mode (theoretical vs measured)

SCO, kHz	Measured improvement, dB	Theoretical improvement, dB	Difference in theory, dB
0.560	−1.1	6	−4.9
0.960	1.8	5	−3.2
3.9	1.6	5	−3.4
3.9 SPA	1.4	5	−3.6
7.35	0	4	−4
33	1.9	14	−12.1
5.4	28.8	37	−8.2
2.3	20.8	21	−0.2

(4) The bit-error-rate test was an overall system test to check the operation of the PCM-FM-PM and PCM-FM-FM telemetry channels. The bit error rates for each PCM channel are given in Table 17, with the SNR in the discriminator bandpass as the reference point. With a postulated threshold SNR of 9 dB and a bit error rate of 3×10^{-3}, the only bit rate apparently out of tolerance is that of 17.2 bit/s with a bit error rate of 18.8×10^{-3} at a SNR of 9.0 dB. The poor results obtained in the bit error test could stem in part from the mechanization of the bit error checker. The time delay could not be adjusted to closer than ½ bit/s. Thus, a time delay error of ¼ bit/s was sometimes present. When excessive jitter was present, false errors were indicated when no errors were present in the PCM bit stream.

(5) During some of the PCM bit error tests the PCM and the modulated SCO were recorded on the FR-1400 at 15 in./s. The PCM track was then played back to compare the bit error rate and SNR in the discriminator bandpass with the original bit error rate and SNR, which was recorded. This test was to verify that the PCM data could be recorded on tape with no degradation in the bit error rate and no reduction in the SNR of the recorded SCO. (See Table 17.) The FR-1400 recording shows no increase in bit error rate in playback. The recorded SCO had an average loss in SNR of 0.2 dB. The FR-1400 tape recorder proved adequate at 15 in./s when 550 bit/s and the 3.0-kHz SCO were recorded.

Table 17. Bit error rate vs SNR in discriminator bandpass

SCO, kHz	Bit rate, bits/s	Mode	SNR in discriminator bandpass, dB	Bit error rate
33	4400	FM	29.2	0
7.35	1100	FM	22.0	0
3.9	550	FM	17.0	0
			13.3	0
			11.2	0.07×10^{-3}
3.9	550	PM	16.2	0
			10.3	0.11×10^{-3}
			7.7	5×10^{-3}
3.9	550	SPA PM	16.2	0
			12.3	0.02×10^{-3}
			7.3	4.65×10^{-3}
33	4400	FM	8.4	0.72×10^{-3}
			11.5	0
			16.5	0
7.35	1100	PM	16.0	0
			11.0	0.25×10^{-3}
			7.9	8.19×10^{-3}
0.96	137.5	PM	17.1	0
			11.3	0.05×10^{-3}
			8.1	7.2×10^{-3}
0.56	17.2	PM	9.0	18.8×10^{-3}
			11.7	1.83×10^{-3}
			15.3	0.1×10^{-3}
			17.0	0.08×10^{-3}

(6) During some of the PCM bit error tests the PCM and the modulated SCO were recorded on the FR-1400 at 15 in./s. The PCM track was then played back to compare the bit error rate and SNR in the discriminator bandpass with the original bit error rate and SNR, which was recorded. This test was to verify that the PCM data could be recorded on tape with no degradation in the bit error rate and no reduction in the SNR of the recorded SCO. (See Table 18.) The recorded SCO had an average loss in SNR of 0.2 dB. The FR-1400 tape recorder

Table 18. Bit error rate vs discriminator output[a]

SCO, 3.9 kHz	SNR in discriminator bandpass, dB	Discriminator output, V	Bit error rate
FM	11.2	13.5	0.07×10^{-3}
Playback	11.8	12.8	0.06×10^{-3}
PM	16.2	17.5	0
Playback	16.0	17.5	0
PM	7.7	8.2	5×10^{-3}
Playback	7.5	7.9	5.09×10^{-3}
SPA PM	16.2	17.6	0
Playback	16.0	17.5	0
SPA PM	7.3	8.3	4.65×10^{-3}
Playback	7.2	8.2	4.5×10^{-3}

[a]Tape recorder playback speed was 15 in./s.

proved adequate at 15 in./s when 550-bit/s and the 3.0-kHz SCO were recorded.

A summary of the results of this test is presented below:

(1) Inherent residual FM modulation on the WBVCXO of the system-tester transmitter precluded the measurement of carrier suppression by the DSIF wave analyzer.

(2) Many of the tolerances specified in the tables of the test procedure did not consider the inherent noise within the distributor bandpass.

(3) The FM improvement of the demodulator was less than that required by the test procedure.

(4) Discriminator tolerances specified in the tables of the test procedure did not consider the spacecraft input filters of the subcarrier oscillators or the attenuation characteristics of the discriminator output filters.

(5) The 33-kHz discriminator tolerances specified by the test procedure did not consider the latest change in the 33-kHz subcarrier deviation, i.e., ±1980 Hz.

(6) Excessive bit errors resulted when the demodulator gain was set at 20 dB or greater in the PM mode.

(7) Measured noise bandwidth of the discriminators was considered, and test procedure tolerances were corrected accordingly.

Telecommunication link frequency response (compatibility test procedure 11-4). The purpose of this test was to check the frequency response of the telemetry link from the spacecraft to the CDC demodulator. The system tester was used to simulate the spacecraft transmitter. The FR-800 predetection recorder was used to record the 10-MHz IF from the DSIF receiver. The FR-1400 postdetection recorder was run at 120 in./s to record the demodulator output. The FR-800 was played back into the demodulator, and the frequency response of the demodulator was checked at the output. The FR-1400 was played back, and the recorded demodulator output frequency was checked.

The results of this test are as follows:

(1) The telecommunication link frequency response is plotted in Fig. 22. Three points are out of tolerance as shown in Table 19.

(2) The FR-800 playback into the CDC demodulator is shown in Fig. 22. There were three points out of tolerance, and these are shown in Table 20. These points are very close to the tolerance edge, which indicates a major problem does not exist.

Table 19. Out-of-tolerance demodulator points

Frequency, kHz	Demodulator output, V	Theoretical value, V
200	1.52	1.32 ± 0.18
250	0.86	$1.11 \begin{smallmatrix} +0.16 \\ -0.21 \end{smallmatrix}$
300	0.70	$0.93 \begin{smallmatrix} +0.16 \\ -0.21 \end{smallmatrix}$

Table 20. Demodulator output vs frequency, with and without tape recorder

Frequency, kHz	Demodulator output without tape recorder in loop, V	Demodulator output with FR-800 playback, V
20	1.72 ± 0.05	1.64
220	1.33 ± 0.06	1.13
300	0.70 ± 0.057	0.765

(3) The original procedure and DSIF configuration left the FR-1400 record and playback lines unterminated. The length of the cable connecting the CDC with the FR-1400 was long, and this caused a severe attenuation of the high-frequency components. Figure 20 shows the unterminated recording. A 75-Ω termination was placed on the recording line, and more measurements were made. The results of these terminated tests and the unterminated test are normalized and plotted in Fig. 23. The results show that the 75-Ω termination on the recorder line improves the frequency response.

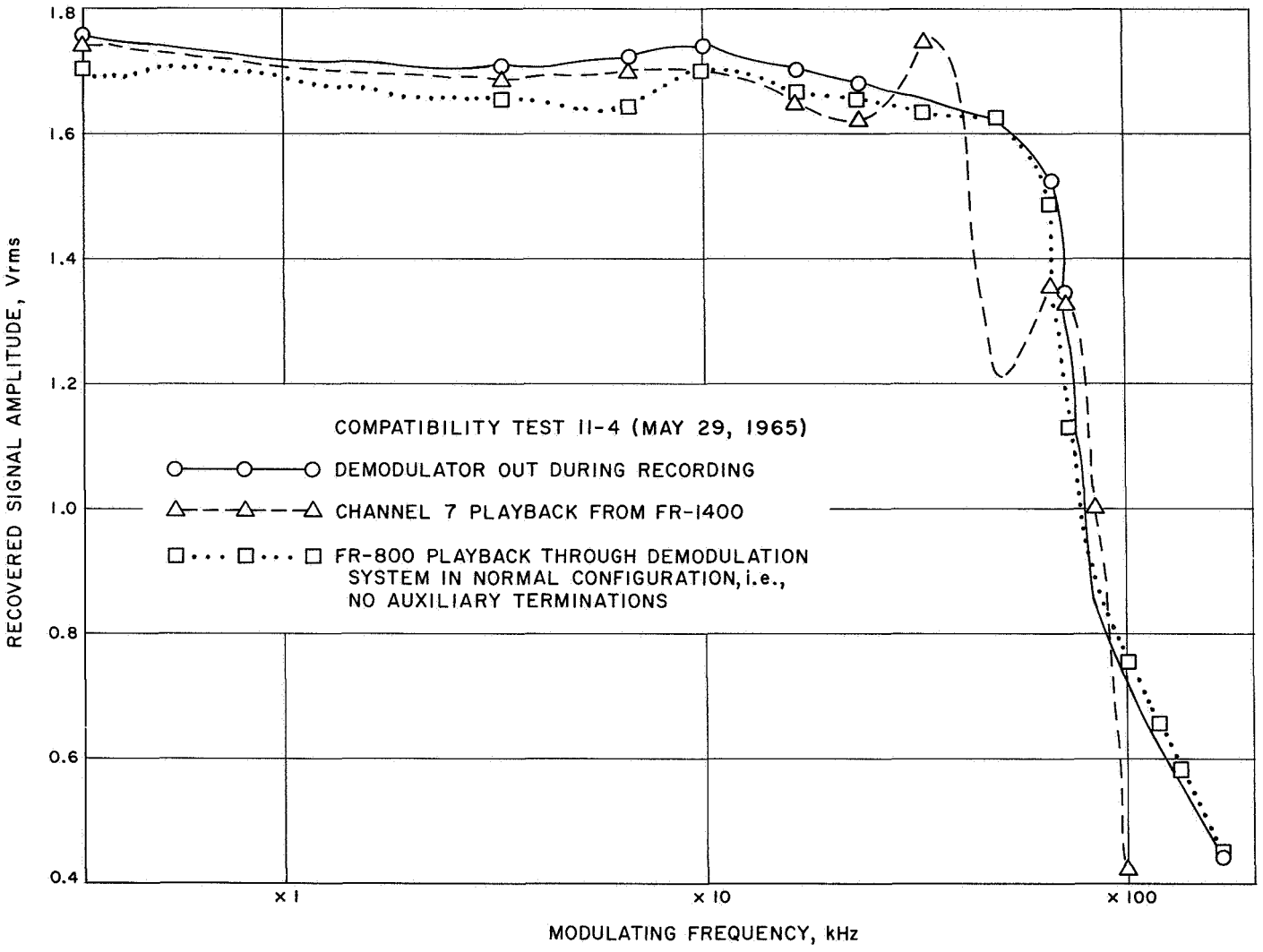


Fig. 22. Demodulating frequency response

A summary of the results of this test is as follows:

(1) The demodulator output had three points out of specification.

(2) The FR-800 playback also had three points out of specification.

(3) The FR-1400 recording and playback lines were terminated for better frequency response.

(4) The results of the tests were examined to determine if the frequency response of the link was adequate for the *Surveyor* mission.

TV horizontal sync (compatibility test procedure 11-5). The purpose of this test was to verify the performance of the PCM decommutator during TV operation and measure the TV horizontal sync jitter as a function of 10-MHz IF SNR.

Test results showed that no frame ID PCM errors occurred during FR-1400 recording and playback of 216 TV frames, which were measured at an IF SNR of 10.5 dB. Figure 24 is a plot of the peak-to-peak horizontal sync jitter that resulted at various IF SNRs. Figure 22 is a 35-mm photo of a graybar format taken at an IF SNR of 10.5 dB.

A summary of the test results is as follows:

(1) Interference patterns were noted. The source of this interference was internal to the recording monitor. Both 60-cycle and high-frequency interference,

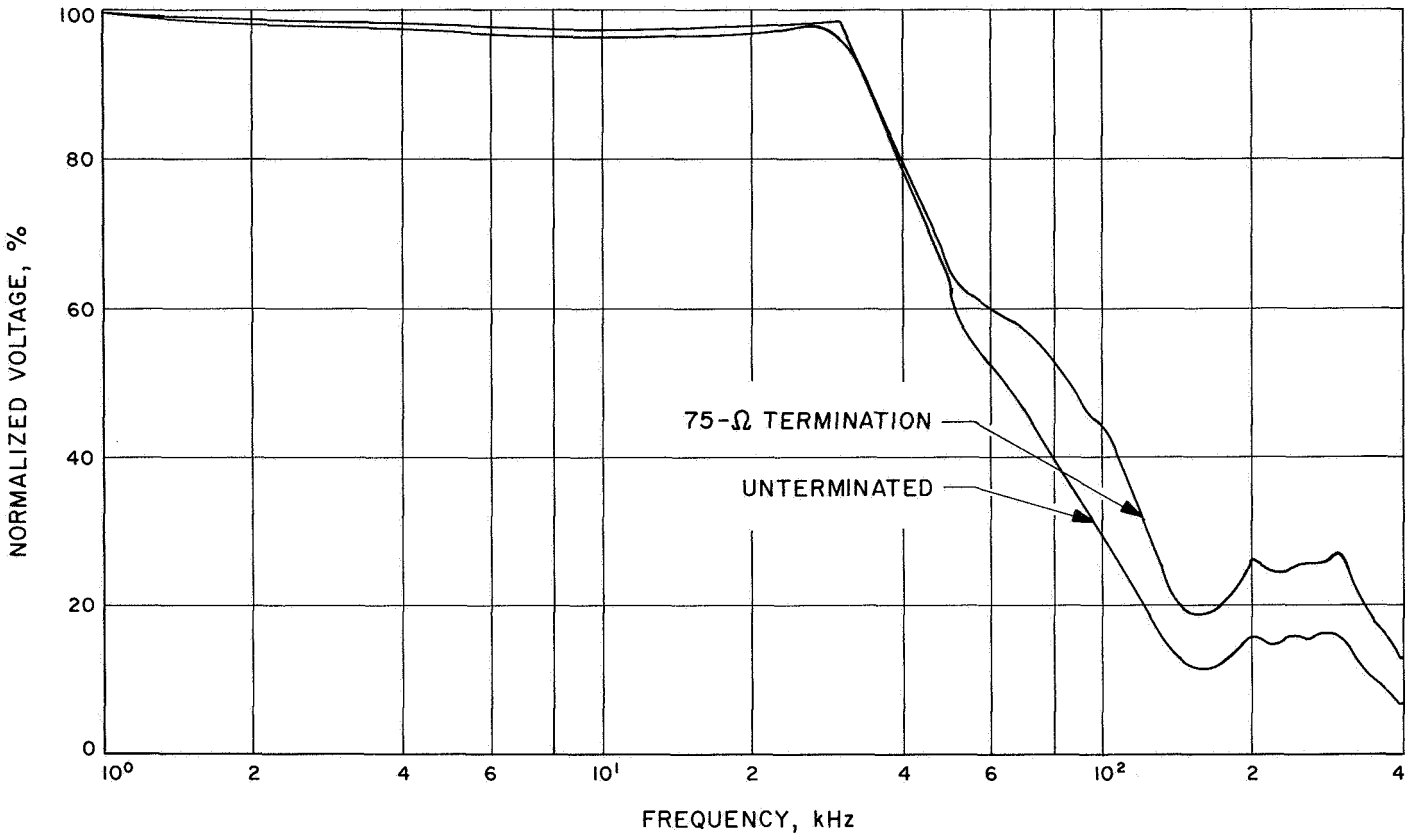


Fig. 23. Unterminated vs terminated test for FR-1400 recording

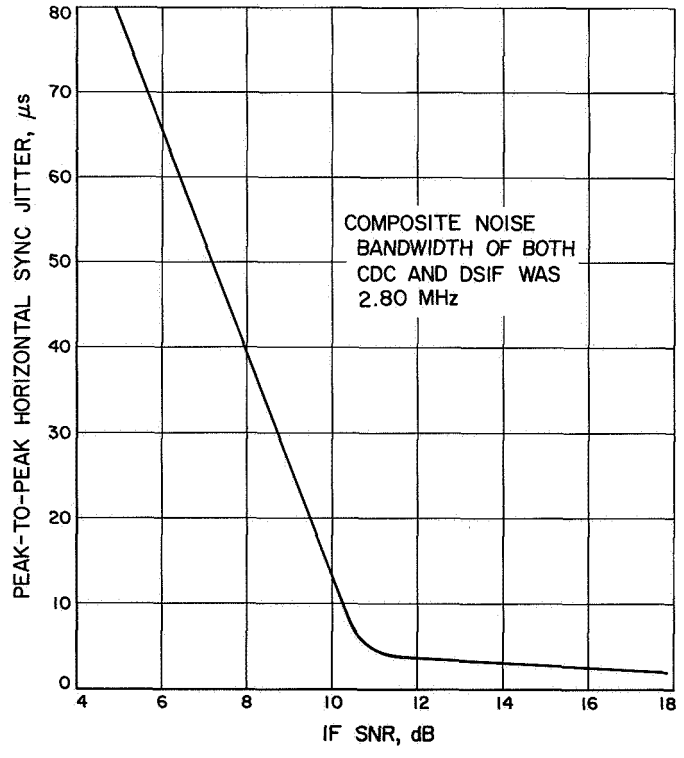


Fig. 24. Horizontal sync jitter vs IF SNR

Table 21. 4400-bits/s PCM/FM/FM multiplexed telemetry performance

Mode	SNR, dB						
	Demodulator input	Demodulator output	33-kHz bandpass	Discriminator output	52.4-kHz bandpass	Discriminator output	150-kHz bandpass
Playback	20	35.2	44.3	37.5	41.4	38.7	37.1
		23.4	19.7	25.2	18.8	15.8	32.9
Playback	13.3	29	40.7	36.9	38.7	38.4	36.1
		22.7	20.3	25.8	19.2	25.2	33.4
Playback	10.8	28.1	35.8	26.8	33.5	35.6	
		13.8	21.8	15.4	22.6	24.3	
Playback	7.2	22.9	35.5	19.2	25.3	27.4	
		15.2	23.3	12.5	25.0	20.3	

presumably from the CRT 14-kV supply, were present. As viewed with a projector, the interference pattern did not preclude the resolution of 10 gray scales.

(2) The measurement of horizontal sync jitter as called out in the procedure was somewhat subjective. The 8-μs value measured at an IF SNR of 10.5 dB might appear high. However, 600 resolution lines could be resolved during the TV pattern test (compatibility test procedure 11-6). At this time the allowable sync jitter had yet to be specified. When it was, it would be recommended that a method for measuring it in the field should also be specified.

(3) It took three recording attempts before a successful FR-1400 playback was obtained, including alignment of the wideband frequency modulator (WBFM) modules by the Ampex field representative.

TV test pattern (compatibility test procedure 11-6). This test was to verify the gray scale rendition and resolution capabilities of the TV system including checking the playback capabilities of the DSIF video and RF recorders. Some prerecorded FR-1400 scenes were also utilized as a modulation source.

The required resolution and gray scale rendition requirements were verified. In some instances the resolution was marginal because of the internal interference already noted. No successful FR-800 recordings were obtained, although five attempts were made.

As previously noted, internal recorder interference was also evident during compatibility test 11-6. Although present at all times, the interference was not as noticeable on some video formats. The BCDs and time clock appeared faint. The FR-800 recorder capability was yet to be demonstrated.

Multiplexed telemetry (compatibility test procedure 11-7). This test was to determine the bit error rate of the PCM channels when multiplexed with the analog telemetry channels. The DSIF CEC recorder and the CDC LF and HF oscillograph were checked for proper recording of the analog telemetry data.

The results of this test are as follows:

(1) The bit error rates were zero for all modes of operation except for 8.3 dB in the 7.35-kHz bandpass when the bit error rate was 5.9×10^{-3}. If 9 dB and a bit error rate of 3×10^{-3} were postulated for the threshold, the bit error rate could not be considered out of spec.

(2) The results of the multiplexed telemetry are given in Table 21 for the 33-kHz SCO and six accelerometer channels and in Table 22 for the 7.35-kHz SCO and strain gage channels.

(3) Multiplexing interference appeared to be present in the discriminator bandpass. The effect of this interference was a degradation in the improvement across the discriminator. The resulting SNR at the output of the discriminator was evaluated to see if the quality of the analog signal channels was adequate.

(4) Table 21 shows the resulting playback from the FR-1400. A loss of 10- to 18-dB appears in the various SNR measurements. This was a result of

Table 22. 1100-bits/s PCM/FM/FM multiplexed telemetry SNR performance

Demodulator output, dB	7.35-kHz bandpass, dB	Discriminator output, dB	5.4-kHz bandpass, dB	Discriminator output, dB
9.9	16.4	16.2	16.0	11.6
5.2	12.6	12.6	12.1	9.7
3.7	8.4	8.5	9.3	8.2

the degradation in the tape recorder, which limited the SNR on playback to a maximum of 25 dB when recording in the direct record mode.

(5) The resulting analog recording on the CDC LF and HF oscillographs was acceptable. There appeared to be a great deal of interference between channels. The improvement across the discriminators was in the negative direction, but the bit error rate was within specification.

(6) When the output of the discriminator was connected to the DSIF CEC, the discriminator oscillated. A prerelease engineering modification of inserting a 50-Ω resistor in series with the discriminator output was installed, and the resulting recordings were satisfactory.

A summary of the test results is as follows:

(1) The only problem encountered with the test was the oscillating discriminators, which has been corrected.

(2) The procedure neglected to check the CEC loading effect, on the CDC telemetry panel displays. Since DSS 51 reported some loading effect in their quick-look report, a special test was recommended to ascertain if this effect was present at Goldstone as well.

Two-way phase lock threshold (compatibility test procedure 11-8). This test was made to determine the minimum RF levels required to acquire and maintain two-way phase lock. It was conducted with several variations as reported below.

The acquisition threshold for the DSIF receiver was −168.2 dBmW for a transponder modulation index of 1.6 and −167.4 dBmW at a modulation index of 0.3. There was essentially no difference in these two levels because they are measured by the receiver AGC which is activated only by the carrier. The threshold of the transponder receiver was −127.7 dBmW for the continuous-wave case, and −122.5 dBmW when the DSIF transmitter modulation index was 1.6.

Two problems were initially encountered while trying to ascertain the transponder receiver threshold. Assuming that the receiver would be most sensitive at a static phase error of zero degrees, it was determined that the front panel meter was not an accurate indicator of this condition. The second problem follows from the first in that normal receiver drift results in slightly different acquisition threshold frequencies, which necessitated a level change-and-search procedure to ascertain the most sensitive point each time. Drift was not a problem once acquisition had been obtained because phase-loop-tracking maintains receiver lock to dropout signal level, which is lower than the acquisition level.

Command transmission and word error rate (compatibility test procedure 11-9). This test was made to verify that at a transponder receiver input level of −109 dBmW no greater command word error rate than 5×10^{-4} existed. The test also verified proper reception of a few selected commands.

Table 23 indicates the command word error rate that occurred at various receiver input levels. Proper FR-1400 playback of the CDC command SCO was also verified.

Though eventually corrected, trouble was initially encountered in trying to properly modulate the DSIF transmitter because of a unique configuration for the *Mariner* Project.

Timing displays test (compatibility test procedure 11-10). This test was made to verify the operation of all CDC timing displays that originate from DSIF sources. These displays are the GMT BCDs, the 28-bit time code with no carrier, and the 36-bit code with 1-kHz carrier.

Satisfactory operation of all CDC timing displays was verified.

CDC/OSDP checkout (compatibility test procedure 11-11). This test was made to verify that the OSDP equipment of the CDC and DSIF computer functioned properly. All interface signals at both the CDC and DSIF computer were observed and sketched.

Table 23. Command word error rate vs receiver input levels

Transponder receiver input SNR, dB	Command word error rate
−93.7	0
−98.7	0
−103.7	0
−108.7	0
−111.7	0
−113.7	0
−114.7	10.9×10^{-4}
−115.7	91×10^{-4}
−115.8	317×10^{-4}

After resolving the problems noted below, proper operation of the system was verified. The waveforms appear in the quick look report.

A summary of the problems encountered during this test is listed as follows:

(1) A non-utilized parallel input (PIN) lead was disconnected from the interface cable because other PIN signals triggered the computer.

(2) The System (SYS) signal from the computer had to be increased from +5 to +8 V.

(3) There were some operational problems with the computer program which were corrected.

(4) Changes to compatibility test procedure 11-11 were generated to reflect the above problem solutions.

Composite system test (compatibility test procedure 11-12). This test was made to spot-check key parameters in the compatibility tests 11-1 to 11-11.

The results agree very closely with the earlier test. No unexpected results were obtained.

4. Johannesburg CDC/DSIF compatibility tests

a. Test result summary. This series of tests was conducted during the period from May 17 through July 2, 1965. The suitcase receiver was originally installed approximately 1 wk prior to compatibility tests and to the best of our knowledge was never used to perform the functions which are required for *Surveyor.* Consequently a major effort was required to determine if the suitcase receiver could meet *Surveyor* requirements, if not why not, and what could be done to improve its performance. It was felt that this objective was accomplished during the tests; however, it did cost a significant amount of test time and considerable retesting effort.

All the tests were conducted using the maser and cryogenic load, which provided a system noise temperature of 100°K. No attempt was made to quantitatively test the paramp. Receiver threshold was approximately −168 dBmW with a system noise temperature of 110°K.

Equipment configuration was not changed during the tests in any way that would affect system performance. ECA 111889 (low-bit-rate improvement) was incorporated in both decommutators prior to the test. All bit error information was obtained with decommutator 1. No CDC equipment failures occurred during the tests that caused a delay in the tests or that have interrupted data during a mission. Considerable difficulty was encountered with the initial alignment of the receiver portion of the ground transponder.

Some time was lost through failure to interpret the test procedures properly. This was especially true in compatibility tests 11-2 and 11-3 when system testing was first conducted. However, all data presented reflect tests run per procedure and any data obtained with techniques other than those specified in the procedure were discarded. During most tests, data were superficially evaluated in order to ascertain if the results were reasonable. This made it possible to spot any bad data points immediately and to check the setup and readings before proceeding.

All test equipment calibrations were current and to the best standards available at the station, which were not always the same as those available at HAC. (No 10-MHz source was available at the station to calibrate the HP-3400A. However, it was calibrated at those frequencies available at the station.) The HP394A was not calibrated because of a lack of facilities both here and at the South African Bureau of Standards. Fixed attenuators were always added in series in order to maintain a dial reading above 70. If refinements to the data are required based upon the HP394A readings, the unit will have to be returned to El Segundo for calibration.

The interest, cooperation, and technical assistance of DSIF personnel in supporting a somewhat difficult test schedule was a significant factor in the completion of the tests on schedule.

Telemetry subsystem. The results of telemetry subsystem tests are as follows:

(1) Before successful FM/FM tests could be conducted, an isolation amplifier had to be installed between the 10-MHz IF and the crystal filter used in the AGC and phase lock loops.

(2) FM/PM data were not obtained with the isolation amplifier. Consequently the data should be improved slightly after its installation because of a smoothing of the passband characteristics and thus an elimination of sideband distortion.

(3) The effects of limiting in the suitcase receiver were first observed at −102 dBmW with the wideband mode and −109-dBmW in the 420-kHz mode. Signal-to-noise ratios greater than 16.5-dB could not be obtained in the wideband mode.

(4) Input signal levels for discriminator bandpass signal-to-noise ratios (corrected for system noise temperature differences) differ approximately 0.5 dB from those obtained at Goldstone.

(5) Demodulator FM improvement was lower than specification. Some of this discrepancy was because of 2.7 dB of noise contributed by the passband of the demodulator, which is 410 kHz instead of the required 220 kHz. This was caused by the highly nonlinear output of the demod wideband amplifier, which was present with normal system loading.

(6) Demodulator gain for FM/PM telemetry was set at +20 dB for compatibility tests 11-2 and 11-3 and at 0 dB for compatibility test 11-12. No disadvantages in using the +20 dB setting were noticed. At this setting, gain through the demodulator was measured to be approximately 18 dB.

(7) The signal-to-noise ratio of the suitcase receiver phase detector output vs input signal level showed a completely linear system of the signal levels tested.

(8) Discriminator FM improvement in general did not meet specifications although there were some exceptions.

(9) Bit error rates for the PM channels at 8 dB bandpass signal-to-noise ratios were less than 3×10^{-3} errors except for the 3.9-, 7.35-, and 0.560-kHz channels. The 0.560-kHz channel was significantly out of specification with an error rate of 7.8×10^{-3}.

(10) Theoretical RF input levels vs measured RF input levels for 3×10^{-3} bit errors compared remarkably well with no deviation greater than 0.7 dB other than the 0.560-kHz channel which required a signal level 2.8 dB greater than theoretical.

(11) In the FM/FM multiplexed telemetry test the 33-kHz SCO did not show any discriminator FM improvement although no bit errors were observed.

(12) In the FM/PM multiplexed telemetry test the 5.4-kHz SCO performance was poorer than anticipated. Bit error rates for the 7.35-kHz channel were higher than specification.

(13) Noise levels of the DSIF CDC and CDC low- and high-frequency oscillographs were satisfactory although telemetry display console output meter readings were affected by CEC input impedances.

(14) FR-1400 playback data were unacceptable because of worn heads. New heads were received and installed to improve performance.

Command subsystem. The results of the command system tests are follows:

(1) CDC transponder phase lock threshold (with command modulation applied) was measured at −126.6 dBmW with a receiver noise figure of 11.4 dB.

(2) Modulation levels of the command SCO required to give the correct modulation index of 1.6 were found to be 403 mV at the telemetry data patch panel and 375 mV at the DSIF modulator input.

(3) No command errors occurred at the levels specified in the test procedure.

(4) Command SCO playback from both the FR-1400 and FR-800 was satisfactory.

Television subsystem. The results of the television subsystem tests are as follows:

(1) All television tests were conducted with the isolation amplifier installed.

(2) Initially, the 3-dB bandwidth of the composite system (suitcase receiver plus demodulator switching drawer) was 2.69 MHz at the 3-dB points. Bypassing (for television only) the telemetry amplifier and an associated variable attenuator increased the receiver output bandwidth to over 6.4 MHz and the composite system bandwidth to 3.15 MHz at the 3-dB points, resulting in significantly reduced sync jitter.

(3) System frequency response appeared satisfactory up to the line driver at the demodulator output. However, the overall system response had the 3-dB point at 410 kHz instead of 220 kHz as required. The problem proved to be one of design associated with the demodulator line driver.

(4) Television films showed an interference pattern, apparently originating in the photo recorder.

(5) With the telemetry amplifier removed, the suitcase receiver was not contributing any degradation to the receiver picture over what would normally be expected due to noise at the various input signal levels. System performance was improved, however, by flattening the response of the demodulator line driver as explained in this section.

(6) On the basis of information available here, the suitcase receiver proved able to provide television picture quality equivalent to the Goldstone Duplicate Standard S-band system.

(7) Use of the 10-MHz spectrum analyzer was a great aid in optimizing television quality and FM/FM work in general.

(8) FR-1400 evaluation was unsuccessful due to worn heads.

(9) FR-800 performance was unsatisfactory for television reproduction; performance was satisfactory when only 10-MHz information was recorded and played back. However, when the transmitter was de-energized between frames, the time required for the FR-800 to lock up introduced considerable anomalies in the picture display. This appeared to be a basic design problem which was later resolved.

A summary of the results of the test is as follows:

(1) An isolation amplifier was installed between the 10-MHz IF and the crystal filter used in the AGC and phase-lock loops of the suitcase receiver.

(2) The telemetry amplifier of the suitcase receiver and its associated attenuation should be bypassed for optimized TV quality to be obtained from the suitcase receiver.

(3) A digital voltmeter was installed in the CDC console add-on for reading receiver AGC levels accurately.

(4) Feasibility of installing a 10-MHz spectrum-analyzer at the CDC to monitor the receiver 10-MHz IF was investigated. This item was installed as an on-line piece of equipment.

(5) Redesign of the demodulator output line drives to give a flat frequency response to 500 kHz with expected system loads was accomplished.

(6) The ability of the FR-800 to perform the requirements of the *Surveyor* mission was carefully examined.

(7) The interference pattern on television photo recorder pictures should be eliminated.

(8) Loading caused by the DSIF CEC recorder affects telemetry console meter readings. The following recommendations were made in the order of their desirability:

(a) Fabricate isolation amplifiers which will make decommutator analog output voltages independent of DSIF recorder loading.

(b) Eliminate the requirement for backup oscillograph recorder by the DSIF.

(c) Revise all affected test procedures such that DSIF recorder loading is present when calibration is made. Also ensure that this configuration is not changed during missions and mission simulations.

(9) Redefine specifications on demodulator and discriminator FM improvement. Specifications as per procedure in many cases could not be met with existing equipment, and consequently they tended to be ignored with the result that an actual equipment malfunction may be overlooked.

(10) Bit error rates for the 17.2-bit/s channel were too high (7.8×10^{-3} at 8 dB bandpass signal-to-noise ratio). Further redesign was necessary.

(11) It became apparent that the CDC–SDS interface cabling requirements needed to be defined. Only the 910 cables were checked during these tests.

(12) FR-1400 performance was retested with the new heads.

b. Actual test results

RF power calibrations (compatibility test procedure 11-1). The results of this test were as follows:

(1) Curves showing filter characteristics for the 4.5-, 20-, and 420-kHz and wideband outputs of the suitcase receiver are shown in Fig. 25 as an example. Also included with each curve is the measured 3-dB bandwidth and the calculated equivalent noise bandwidth. The wideband curve includes the CDC signal drawer filter without the receiver telemetry amplifier removed. The curves as plotted are of filter characteristics only and do not show the nonlinear passband caused by loading of the 10-MHz IF by the crystal filter.

(2) One graph of AGC vs receiver input levels was made for the Goldstone Duplicate Standard and Hughes transponders. Considerable data were obtained in this area with comparable results.

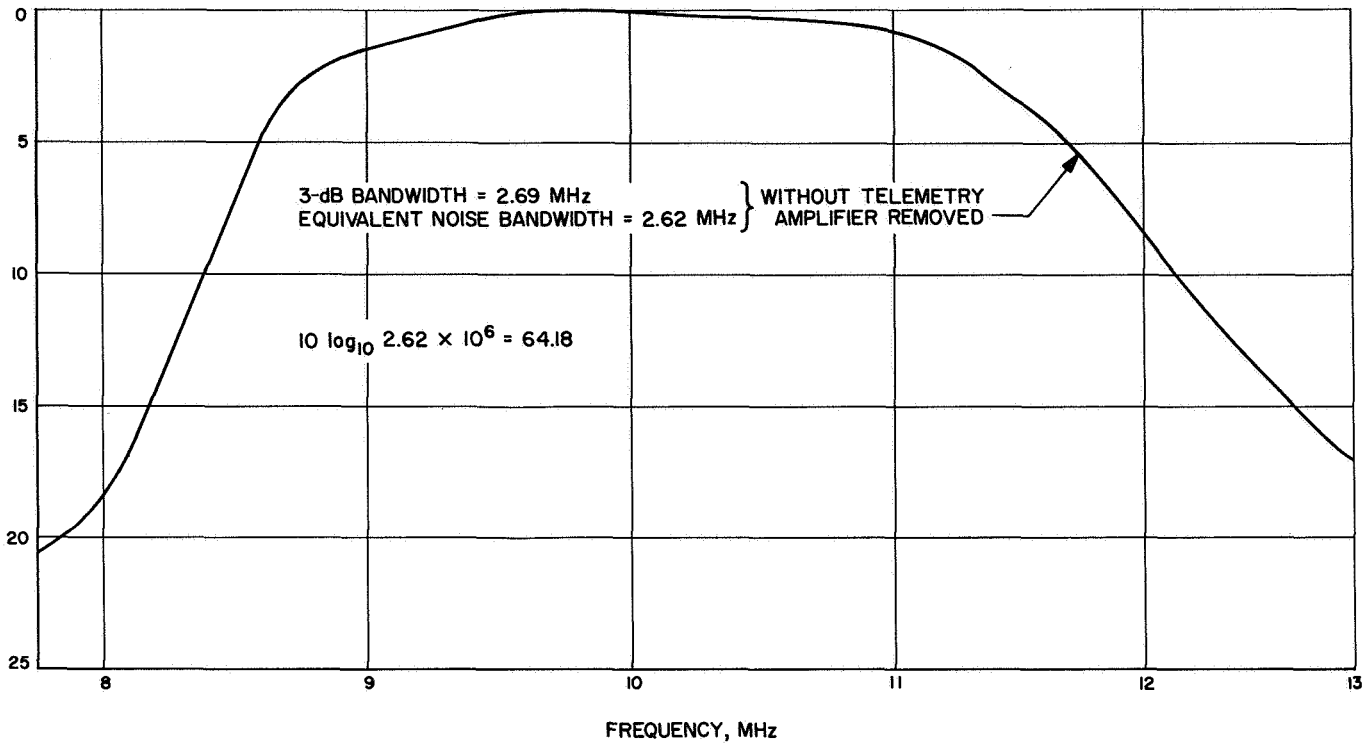


Fig. 25. Composite system bandwidth (includes CDC signal drawer filter) wideband mode

(3) All data were obtained with the cryogenic load and a system noise temperature of 100°K.

1. Results: The results of various aspects of the test are listed below.

a. Receiver threshold: A receiver threshold occurred between −168.0 and −168.5 dBmW with a system noise temperature of 110°K. Other measurements of receiver threshold varied between −167.0 and −168.5 dBmW, within 1 dB of theoretical. Receiver AGC fluctuates considerably at the lower signal levels, which, combined with a very long time constant, makes determination of the precise level of threshold difficult. The DSIF installed an in- and out-of-lock indicator on the suitcase receiver which helped somewhat. This indicator now interfaces with the DSIF spacecraft track light on the command generator.

b. Path loss measurements: The following path loss measurements were made:

(1) Test diplexer to maser = 39.9 dB.

(2) Test diplexer to paramp = 44.7 dB.

(3) Spiraline loss to test diplexer = 24.3 dB.

(4) Loss of 6-ft length of RG214 = 0.7 dB.

(5) Total S-band path loss from the transponder to maser = 64.9 dB.

(6) Total S-band path loss from the transponder to paramp = 69.7 dB.

(7) S-band path loss directly into the receiver mixer = 8.5 dB.

c. Measured vs theoretical noise power: After considerable difficulty, measured noise power vs theoretical noise power met the specifications provided in the procedure. There are no unresolved problems in this area. Table 24 summarizes the information.

The values shown in Table 25 were obtained on June 25 and are typical of noise power comparisons obtained after incorporation of the isolation amplifier.

Table 24. Summary of data of receiver mode vs noise bandwidth

Receiver mode	3-dB bandwidth	Measured noise bandwidth
Wideband	2.69 MHz	2.62 MHz
420 kHz	500 kHz	594 kHz
20 kHz	27.4 kHz	27.7 kHz
4.5 kHz	6.1 kHz	6.37 kHz

Table 25. DSIF receiver bandwidth vs noise power

DSIF Receiver bandwidth	Theoretical noise power (at 110°K), dBmW	Noise power from AGC, dBmW	Noise power by path loss method, dBmW
Wideband	−114.0	−114.5	−114.0
420 kHz	−120.5	−122.0	−121.0
20 kHz	−133.8	−134.8	−134.9
4.5 kHz	−140.1	−141.4	−141.4

d. RF input levels to maser: A very large amount of data have been obtained that compares receiver input levels as computed from the CDC transponder output power level and path loss measurements with the receiver AGC curve as calibrated by the Goldstone Duplicate Standard transponder. After initial difficulties were corrected, the two levels always were within 1.5 dB of each other. However, in most cases they were much closer.

e. Calibration of HP394A: Attempts were made to calibrate the HP394A with a Weinschel 640AS precision step attenuator. Results were erratic and it became apparent that calibrations closer than those provided on the dial face could not be obtained. The South African Bureau of Standards did not have the equipment necessary to calibrate this instrument.

f. RF interference: No OSE RF interference was observed, and RF leakage to the antenna could not be detected with the receiver.

2. Summary: A summary of various aspects of this test is presented below.

a. Theoretical vs measured noise power: A discrepancy between theoretical and measured noise power was apparent as a result of running this test but the problem was not resolved until a later time. The discrepancy noticed was that theoretical-vs-measured noise power was differing by up to 4 dB with the system apparently performing better than theoretical. Eventually it was discovered that the passband was highly nonlinear at the point where lockup was occurring; this resulted in a higher-than-average gain in the IF for the signal portion as compared with the noise portion of the spectrum. Consequently the system appeared to be performing better than theoretical. It turned out that the nonlinear passband was being caused by loading of the crystal filter which is used in the AGC and phase-lock loops.

Installation of an HP460AR wideband amplifier between the 10-MHz IF and the crystal filter eliminated the problem and measured noise power vs theoretical noise power came well within the specifications provided in the procedure. The improvement in the passband characteristics as viewed on a scope with the receiver driven by a sweep generator was quite dramatic.

b. Manual gain control (MGC): When the receiver arrived, it did not have provisions for MGC. However, during the installation phase, the DSN project engineer of JPL installed it based on instructions received from JPL. Some trouble was encountered and a higher reference voltage and less sensitive potentiometer were installed.

c. Drifting AGC curve: When the receiver was first tested it was noted that the AGC voltage drifted as much as 5 dB from day to day. Two things were discovered in respect to this:

(1) A faulty diode was discovered in the receiver AGC monitoring circuit

(2) The power supply voltage was −14.1 instead of −15 V.

Corrections of these two items have resulted in a fairly constant AGC curve, and drift is no longer considered a problem.

d. AGC time constant: The long time constant associated with the AGC voltage that was monitored proved to be significant factor in increasing the time required to run the tests and also made the precise determination of low signal level AGC voltages more difficult. An in- and out-of-lock indication was installed by DSIF personnel which helped in determining threshold.

e. Transponder output power: Difficulty was experienced in getting sufficient transponder power output to test receiver performance at higher signal levels, ECA111827 was installed, which bypassed the path loss attenuator in the transponder. Power output increased from −29.5 to −4.8 dBmW.

3. Conclusions: Conclusions drawn from the results of this test are as follows:

(1) No indication of phase lock due to transponder leakage was obtained in any antenna position.

(2) No RF interference from the OSE was observed.

(3) Theoretical noise power and measured noise power for both the path loss and AGC methods agreed

within the specifications of the test procedure once the isolation amplifier was installed.

(4) Receiver threshold was approximately −168 dBmW with the cryogenic load.

4. Recommendations: Recommendations resulting from this test are as follows:

(1) The isolation amplifier must be incorporated as a permanent part of the suitcase receiver in order to have an acceptable system.

(2) A digital voltmeter was installed in the console add-on (bay 12) for reading of AGC voltages. This was very useful during a mission for determining signal levels to a greater accuracy than is possible with only the meter in the command generator.

DSIF receiver output signal-to-noise ratio, telemetry error rate recordings, and discriminator performance (compatibility test procedures 11-2 and 11-3). This test is the most comprehensive single test in the series in that it provides all the data necessary to define system performance (with the exception of television) from RF input through bit error rates output. Consequently considerable data have been presented which will provide for any depth of analysis desired. The data included are listed as follows:

(1) Demodulator input signal-to-noise ratios, demodulator output signal-to-noise ratios, discriminator bandpass signal-to-noise ratios and discriminator output signal-to-noise ratios vs input signal levels for the FM/FM channels.

(2) Demodulator input/output signal-to-noise ratios, discriminator bandpass signal-to-noise ratios (unmodulated), discriminator bandpass signal-to-noise ratios (modulated), and discriminator output signal-to-noise ratios vs input signal levels for the FM/PM channels.

(3) Bit error rates vs discriminator bandpass signal-to-noise ratios for the PCM/FM/PM channels.

(4) Bit error rates vs input signal levels for each PCM/FM/PM channel.

(5) Tables showing all data plotted (Tables 26–30).

(6) Tables comparing all measured values with those given in the test procedure (Tables 30–42).

(7) Graph of receiver output voltage in the PM channel vs modulation index (Fig. 26).

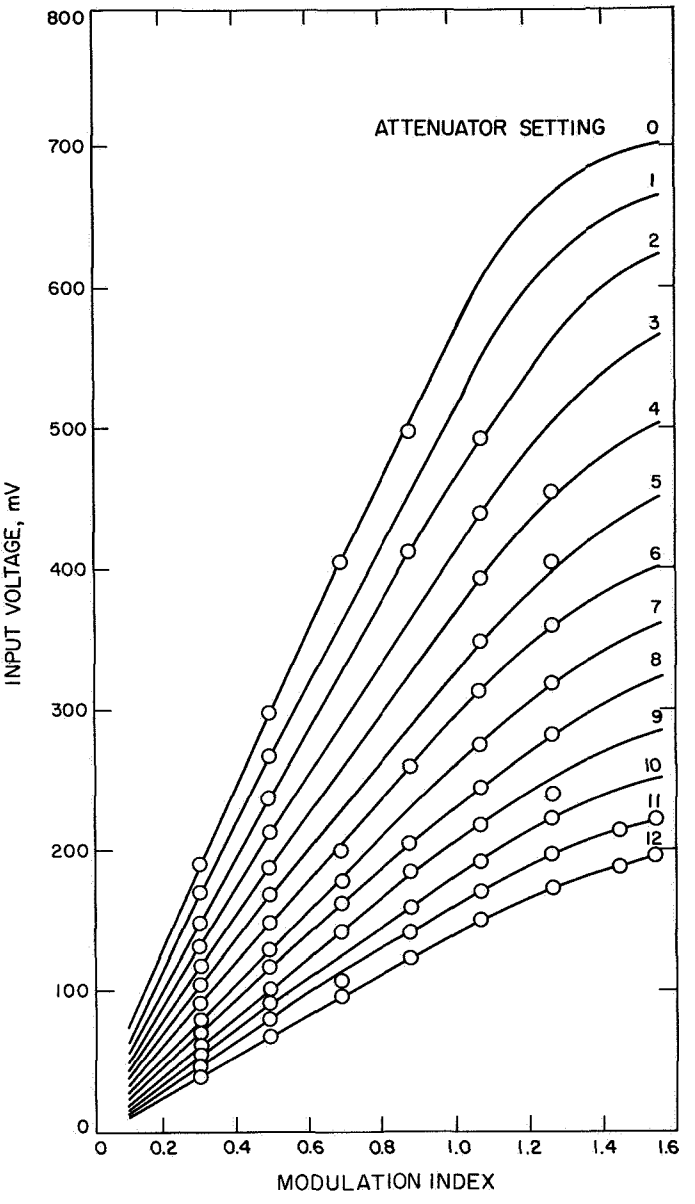


Fig. 26. Demodulator input PM channel voltage vs modulation index for different suitcase receiver output attenuator settings

All RF input levels shown on the graphs were derived by the path-loss method utilizing the HP394A variable attenuator. Readings were taken directly from the dial face. Facilities for calibrating the dial were not available at the station or in Johannesburg. The RF data in Tables 30–42 for the PM channels are from the AGC curves if a comparison between path-loss and AGC methods is desired. An AGC curve was obtained prior to each test period. A comparison between the signal levels obtained by the path-loss method vs AGC shows

that they were well within the 1.5-dB value specified in the test procedure.

Noise bandwidths for all channel selectors were measured prior to the test and are shown in Tables 30–42. These tables show only noise bandwidths for the channel selectors used. Noise bandwidths for all channel selectors are provided in the quick-look report for compatibility tests 11-2 and 11-3.

All modulation indexes for the FM/FM channels were corrected to reflect the actual sensitivity of the transponder as measured during unit tests. The tests were set up, however, assuming the nominal 250 kHz/V sensitivity, and consequently some of the modulation indexes, when corrected for the actual sensitivity, differ somewhat from those shown in the specifications. Specific sensitivities for each frequency are also shown in the tables.

When signal-to-noise ratios are computed from signal plus noise-to-noise ratios, as the latter approaches one, measurement accuracy must greatly increase in order to maintain the same accuracy in the computed signal-to-noise ratio. Consequently, when the signal-to-noise ratio drops below 0 dB, data points become successively more erratic since measurement accuracy does not exceed 0.1 dB for these tests. When demodulator in and out data points are examined, they must be interpreted in light of the discussion above. Demodulation in curves vs signal level for negative signal-to-noise ratios were drawn as straight lines and the failure of some of the data points to fall precisely on the line should not be interpreted as erratic data or performance.

All data was obtained with a 110°K system noise temperature. The FM/PM data was obtained with the suitcase receiver in its original condition, i.e., without the isolation amplifier between the 10-MHz IF and the crystal filter. Consequently the nonlinear bandpass characteristics of the receiver will affect the data somewhat because of sideband distortion.

Table 26. Summary of compatibility tests 11-2 and 11-3

RF level path (HP loss method), dBmW	Theoretical noise power, dBmW	Demodulator input SNR, dB	Demodulator output SNR, dB	Bandpass SNR (SCO unmod), dB	Bandpass SNR (SCO mod), dB	Discriminator output SNR, dB	Bit error rate × 10^{-3}	Notes
				0.560-kHz FM/PM				
−144.6	−140.1 110°K	−5.9	−5.4	16.7	16.3	17.2	0	Modulation level = 920 mVrms
−149.6		−11.5	−11.5	11.7	11.1	11.7	0.04	Carrier suppression = 5.5 dB
−152.1		−13.3	−13.3	8.5	7.8	8.7	10.6	
−154.3		−16.4	−16.4	5.4	4.1	4.7		
				5.4-kHz FM/PM				
−130.6	−133.8 110°K	5.0	5.0		16.3	40.2		Modulation level = 1.11 Vrms
−136.0		−0.9	−0.9		10.6	35.2		Carrier suppression = 6.5 dB
−138.6		−3.9	−3.5		7.7	32.2		
−140.9		−7.0	−5.9		5.4	27.2		
				2.3-kHz FM/PM				
−127.4	−133.8 110°K	2.8	2.9	16.7	15.7	37.8		Modulation level = 455 mVrms
−132.9		−2.6	−2.3	11.6	10.7	32.4		Carrier suppression = 1.3 dB
−136.6		−5.9	−5.9	8.6	8.3	28.8		
−139.8		−10.2	−10.2	5.5	3.9	23.2		

Table 27. Summary of compatibility tests 11-2 and 11-3

RF level path (HP loss method), dBmW	Theoretical noise power, dBmW	Demodulator input SNR, dB	Demodulator output SNR, dB	Bandpass SNR (SCO unmod), dB	Bandpass SNR (SCO mod), dB	Discriminator output SNR, dB	Bit error rate $\times 10^{-3}$	Notes
				150-kHz FM/FM				
−93.0	−114.0 110°K	16.6	27.3		42.6	51.4		
−98.9		13.3	22.8		39.1	54.9		Modulating voltage = 1.27 Vrms
−103.2		10.3	19.1		37.1	54.1		Carrier suppression = 11 dB
−106.0		7.1	16.3		34.4	52.2		
				70-kHz FM/FM				
−93.1	−114.0 110°K	16.6	21.0		42.8	59.9		
−98.5		13.5	16.9		40.9	58.7		Modulating voltage = 570 mVrms
−102.0		11.1	13.8		37.9	56.9		
−106.0		7.4	9.9		32.0	51.4		
				33-kHz FM/FM				
−96.7	−120.5 110°K	20.6	21.1		41.8	54.2		
−106.6		13.2	12.8		37.3	47.3		Modulating voltage = 385 mVrms
−109.6		11.0	10.1		35.3	44.6	0	Carrier suppression = 8.5 dB
−112.8		7.4	6.8		31.4	39.5		
				7.35-kHz FM/FM				
−97.2	−120.5 110°K	20.7	−0.46		25.1	34.6		Modulating voltage = 35 mVrms
−106.6		13.2	−8.3		24.0	29.4		
−109.7		11.1	−11.5		23.8	26.8	0	
−112.9		7.2	−13.3		20.1	21.9		

Table 28. Summary of compatibility tests 11-2 and 11-3

RF level path (HP loss method), dBmW	Theoretical noise power, dBmW	Demodulator input SNR, dB	Demodulator output SNR, dB	Bandpass SNR (SCO unmod), dB	Bandpass SNR (SCO mod), dB	Discriminator output SNR, dB	Bit error rate $\times 10^{-3}$	Notes
				3.9-kHz FM/FM				
−113.7	−133.8 110°K	20.3	5.1		14.8	19.9	0	
−120.7		13.2	0		11.5	13.6	0	Modulating level = 18.5 mVrms
−123.6		10.9	−1.8		9.6	11.4	0.09	
Tape record playback					9.5	11.4	0.04	
−126.6		7.5	−3.9		7.3	8.6		
				3.9-kHz FM/PM				
−131.4	−133.8 110°K	3.8	3.8	16.4	15.4	16.7	0	Modulating level = 767 mVrms
Tape record playback							0	Carrier suppression = 2.7 dB
−135.9		−1.1	−0.86	11.4	10.75	11.8	0.24 0.21	
Tape record playback							0.19	
−138.6		−4.6	−4.6	8.5	7.8	8.6	4.45	
Tape record playback							4.82	
−141.7		−8.3	−7.6	5.7	4.6	5.5		
				3.9-kHz SPA FM/PM				
−120.7	−140.1 110°K	3.9	3.9	16.3	15.6	16.8	0	Modulating level = 200 mVrms
Tape record playback							0	
−124.7		0	−0.2	11.8	11.1	12.1	0.02	
Tape record playback							0.03	
−128.1		−3.5	−3.5	8.6	7.8	8.9	2.01	
Tape record playback							1.90	
−131.1		−7.6	−6.9	5.9	5.0	5.9	25.1	

Table 29. Summary of compatibility tests 11-2 and 11-3

RF level path (HP loss method), dBmW	Theoretical noise power, dBmW	Demodulator input SNR, dB	Demodulator output SNR, dB	Bandpass SNR (SCO unmod), dB	Bandpass SNR (SCO mod), dB	Discriminator output SNR, dB	Bit error rate $\times 10^{-3}$	Notes
				33-kHz FM/PM				
−120.7	−120.5 110°K	1.46	1.11	16.8	16.1	24.6	0	Modulation level = 1.12 Vrms
−125.7		−3.5	−4.2	11.5	10.9	19.3	0.04	Carrier suppression = 7.5 dB
−128.7		−6.4	−5.9	8.4	7.6	15.5	4.90 4.98 5.22	
−131.7		−9.1	−9.1	5.2	4.5	10.9	144	
				7.35-kHz FM/PM				
−126.5	−133.8 110°K	5.4	5.4	16.9	16.1	21	0	Modulation level = 660 mVrms
−131.5		0.6	0.4	11.8	10.9	13.8	0.19 0.18 0.14 0.12	Carrier suppression = 1.8 dB
−134.5		−3.6	−2.9	8.5	8.0	10.8	4.21 4.27	
−137.7		−6.4	−5.9	5.5	4.7	6.4		
				0.960-kHz FM/PM				
−137.4	−140.1 110°K	2.9	2.9	16.4	15.6	17.2	0	Modulation level = 900 mVrms
−141.8		−1.8	−1.8	11.7	11.1	12.3	0.04	Carrier suppression = 5.3 dB
−145.3		−5.9	−5.9	8.5	7.6	7.8	4.78 4.77	
−148.0		−9.1	−9.1	5.5	4.5	4.5		

Table 30. Noise bandwidth, 150-kHz FM/FM

Parameter	Row 2		Row 3		Row 4	
	Specification	Actual	Specification	Actual	Specification	Actual
Mode	Special test		Special test		Special test	
P_{signal}, dBmW	−97.5 ±2.5	−93.0[a]	−100.5 ±2.5	−98.7	−103.0 ±2.5	−108.2
Predetection BW (DSIF), MHz	3.3	3.3	3.3	3.3	3.3	3.3
Measured predetection noise BW, MHz	3.3	2.62	3.3	2.62	3.3	2.62
Δf_{sc}, Hz	5000	5000	5000	5000	5000	5000
Discriminator channel selector BW, Hz	9900	9900	9900	9900	9900	9900
Discriminator channel selector measured noise BW, kHz	—	10.5	—	10.5	—	10.5
Discriminator output BW, Hz	1050	1050	1050	1050	1050	1050
Transponder sensitivity, kHz/V	250	257	250	257	250	257
β_c	3.00	3.08	3.00	3.08	3.00	3.08
SNR_{IF}, dB	16 (+1, −0)	16.6	13 (+1, −0)	13.3	10.5 (+1, −0)	10.3
SNR_A, dB	35.1 ±2	27.3	31.8 ±2	22.8	28.8 ±2	19.1
SNR_B, dB	40.3 ±1	42.6	35.8 ±1	39.1	32.1 ±1	37.1
SNR_C, dB	above 50	51.4	above 50	54.9	above 50	54.1

[a]Signal level is high due to limiting in the receiver IF.

Table 31. Noise bandwidth, 70-kHz FM/FM

Parameter	Row 2		Row 3		Row 4	
	Specification	Actual	Specification	Actual	Specification	Actual
Mode	Special test		Special test		Special test	
P_{signal}, dBmW	−97.9 ±2.5	−93.1[a]	−100.7 ±2.5	−98.5	−103.4 ±2.5	−102.0
Predetection BW (DSIF), MHz	3.3	3.3	3.3	3.3	3.3	3.3
Measured predetection noise BW, MHz	3.3	2.62	3.3	2.62	3.3	2.62
Δf_{sc}, Hz	5000	5000	5000	5000	5000	5000
Discriminator channel selector BW, Hz	9900	10,500	9900	10,500	9900	10,500
Discriminator channel selector measured noise BW, Hz	—	11,550	—	11,550	—	11,550
Discriminator output BW, Hz	1050	1050	1050	1050	1050	1050
Transponder sensitivity, kHz/V	250	262	250	262	250	262
β_c	2.87	3.02[b]	2.87	3.02[b]	2.87	3.02[b]
SNR_{IF}, dB	16 (+1, −0)	16.6	13 (+1, −0)	13.5	10.5 (+1, −0)	11.1
SNR_A, dB	21.9 ±2	21.0	18.8 ±2	16.9	16.4 ±2	13.8
SNR_B, dB	39.6 ±1	42.8	35.5 ±1	40.9	32.4 ±1	37.9
SNR_C, dB	above 50	59.9	above 50	58.7	above 50	56.9

[a]Signal level is high due to limiting in the receiver IF.

[b]β_c was set up assuming a nominal transponder WBFM sensitivity of 250 kHz/V. The computed modulation index increased to 3.02 when recalculated with the actual transponder sensitivity of 262 kHz/V as measured during unit tests.

Table 32. Noise bandwidth, 33-kHz FM/FM

Parameter	Row 1		Row 2		Row 3	
	Specification	Actual	Specification	Actual	Specification	Actual
Mode, bits/s	4400	4400	4400	4400	4400	4400
Signal, dBmW	−100.9 ±2.5	−96.7[a]	−107.9 ±2.5	−106.6	−110.4 ±2.5	−109.6
Predetection BW (DSIF), kHz	420	420	420	420	420	420
Measured predetection noise BW, kHz	592.4	594	592.4	594	592.4	594
Δf_{sc}, Hz	4500	4500	4500	4500	4500	4500
Discriminator channel selector BW, Hz	8980	8570	8980	8570	8980	8570
Discriminator channel selector measured noise BW, Hz	—	10,240	—	10,240	—	10,240
Discriminator output BW, Hz	2200	2200	2200	2200	2200	2200
β_c	4.17	4.28	4.17	4.28	4.17	4.28
Transponder sensitivity, kHz/V	250	260	250	260	250	260
SNR_{IF}, dB	20 (+1, −0)	20.6	13 (+1, −0)	13.2	10.5 (+1, −0)	11.0
SNR_A, dB	34.1 ±2	21.1	26.7 ±2	12.8	24.5 ±2	10.1
SNR_B, dB	35.1 ±1	41.8	26.8 ±1	37.3	24.1 ±1	35.3
SNR_C, dB	above 50	54.2	51.3 ±2	47.3	49.3 ±2	44.6

[a]Signal level is high due to limiting in the receiver IF.

Table 33. Noise bandwidth, 7.35-kHz FM/FM

Parameter	Row 1		Row 2		Row 3	
	Specification	Actual	Specification	Actual	Specification	Actual
Mode, bits/s	1100	1100	1100	1100	1100	1100
P_{signal}, dBmW	−100.9 ±2.5	−97.2[a]	−107.9 ±2.5	−106.6	−110.4 ±2.5	−109.7
Predetection BW (DSIF), mHz	420	420	420	420	420	420
Measured predetection noise BW, mHz	592.4	594	592.4	594	592.4	594
Δf_{sc}, Hz	550	550	550	550	550	550
Discriminator channel selector BW, Hz	1102	1100	1102	1100	1102	1100
Discriminator channel selector measured noise BW, Hz	—	1234	—	1234	—	1234
Discriminator output bandwidth, Hz	550	550	550	550	550	550
β_c	1.67	1.74	1.67	1.74	1.67	1.74
Transponder sensitivity, kHz/V	250	258	250	258	250	258
SNR_{IF}, dB	20 (+1, −0)	20.7	13 (+1, −0)	13.2	10.5 (+1, −0)	11.1
SNR_A, dB	26.2 ±2	−0.46	18.7 ±2	−8.3	16.6 ±2	−11.5
SNR_B, dB	22.5 ±1	25.1	14.7 ±1	24.0	11.5 ±1	23.8
SNR_C, dB	28.1 ±2	34.6	27.0 ±2	29.4	26.8 ±2	26.8

[a]Signal level is high due to limiting in the receiver IF.

Table 34. Noise bandwidth, 3.9-kHz FM/FM

Parameter	Row 1		Row 2		Row 3	
	Specification	Actual	Specification	Actual	Specification	Actual
Mode, bits/s	550	550	550	550	550	550
Signal, dBmW	−114.3 ±2.5	−113.7	−121.3 ±2.5	−120.7	−123.8 ±2.5	−123.6
Predetection BW (DSIF), kHz	20	20	20	20	20	20
Measured predetection noise BW, kHz	27.6	27.7	27.6	27.7	27.6	27.7
Δf_{sc}, Hz	293	293	293	293	293	293
Discriminator channel selector BW, Hz	586	585	586	585	586	585
Discriminator channel selector measured noise BW, Hz	—	667	—	667	—	667
Discriminator output bandwidth, Hz	275	275	275	275	275	275
Transponder sensitivity, kHz/V	250	257	250	257	250	257
β_c	1.67	1.73	1.67	1.73	1.67	1.73
SNR_{IF}	20 (+1, −0)	20.3	13 (+1, −0)	13.2	10.5 (+1, −0)	10.9
SNR_A, dB	12.8 ±2	5.1	5.7 ±2	0	3.4 ±2	−1.8
SNR_B, dB	31.1 ±1	14.8	26 ±1	11.5	24.2 ±1	9.6
SNR_C, dB	19.8 ±2	19.9	16.5 ±2	13.6	14.6 ±2	11.4

Table 35. Noise bandwidth, 3.9-kHz SCO FM/PM

Parameter	Row 1		Row 2		Row 3	
	Specification	Actual	Specification	Actual	Specification	Actual
Mode, bits/s	550	550	550	550	550	550
M_{sc}	1.10	1.083	1.10	1.083	1.10	1.083
Bandwidth IF (DSIF), kHz	20	20	20	20	20	20
Nominal measured noise BW-IF (DSIF), kHz	27.6	27.7	27.6	27.7	27.6	27.7
P_{signal},[a] dBmW	−132.4 ±2.5	−130.5	−137.4 ±2.5	−135.2	−140.4 ±2.5	−138.3
$P_{carrier}$,[a] dBmW	−135 ±2.5	−133.2	−140 ±2.5	−137.9	−143 ±2.5	−141.2
Unmodulated SNR_B, dB	16 (+1, −0)	16.4	11 (+1, −0)	11.4	8 (+1, −0)	8.5
Modulated SNR_B, dB	—	15.4	—	10.75	—	7.74
Discriminator noise bandwidth, Hz	586	667	586	667	586	667
SNR_C, dB	20.4 ±2	16.7	15.75 ±2	11.33	12.74 ±2	8.65

[a]Obtained from AGC readings.

Table 36. Noise bandwidth, 3.9-kHz SCO SPA FM/PM

Parameter	Row 1		Row 2		Row 3	
	Specification	Actual	Specification	Actual	Specification	Actual
Mode, bits/s	550	550	550	550	550	550
M_{sc}	0.3	0.283	0.3	0.283	0.3	0.283
Bandwidth IF (DSIF), kHz	4.5	4.5	4.5	4.5	4.5	4.5
Nominal measured noise BW-IF (DSIF), kHz	5.7	6.37	5.7	6.37	5.7	6.37
P_{signal},[a] dBmW	−121.4 ±2.5	−119.7	−126.4 ±2.5	−124.7	−129.4 ±2.5	−127.8
$P_{carrier}$,[a] dBmW	−121.6 ±2.5	−120.1	−126.6 ±2.5	−125.0	−129.6 ±2.5	−128.1
Unmodulated SNR_B, dB	16 (+1, −0)	16.3	11 (+1, −0)	11.8	8 (+1, −0)	11.1
Modulated SNR_B, dB	—	15.6	—	11.1	—	7.84
Discriminator noise bandwidth, Hz	275	667	275	667	275	667
SNR_C, dB	21.2 ±2	16.8	16.7	12.15	13.44 ±2	8.87

[a]Obtained from AGC readings.

Table 37. Noise bandwidth, 33-kHz SCO FM/PM

Parameter	Row 1		Row 2		Row 3	
	Specification	Actual	Specification	Actual	Specification	Actual
Mode, bits/s	4400	4401	4400	4401	4400	4401
M_{sc}	1.60	1.585	1.60	1.585	1.60	1.585
Bandwidth IF (DSIF), kHz	420	420	420	420	420	420
Nominal measured noise BW-IF (DSIF), kHz	592.4	594	592.4	594	592.4	594
P_{signal},[a] dBmW	−121.2 ±2.5	−121.0	−126.2 ±2.5	−125.5	−129.2 ±2.5	−128.7
$P_{carrier}$,[a] dBmW	−128.2 ±2.5	−128.5	−133 ±2.5	−133.0	−136 ±2.5	−136.0
Modulated SNR_B, dB	16 (+1, −0)	16.8	11 (+1, −0)	11.5	8 (+1, −0)	8.4
Unmodulated SNR_B, dB	—	16.1	—	10.9	—	7.6
Discriminator noise bandwidth, Hz	8980	10,240	8980	10,240	8980	10,240
SNR_C, dB	30.1 ±2	24.6	24.9 ±2	19.3	21.6 ±2	15.5

[a]Obtained from AGC readings.

Table 38. Noise bandwidth, 7.35-kHz SCO FM/PM

Parameter	Row 1		Row 2		Row 3	
	Specification	Actual	Specification	Actual	Specification	Actual
Mode, bits/s	1100	1100	1100	1100	1100	1100
M_{sc}	0.935	0.934	0.935	0.934	0.935	0.934
Bandwidth (DSIF), kHz	20	20	20	20	20	20
Nominal measured noise BW-IF (DSIF), kHz	27.6	27.7	27.6	27.7	27.6	27.7
P_{signal},[a] dBmW	−127.6 ±2.5	126.6	−132.6 ±2.5	−131.2	−135.6 ±2.5	−134.2
$P_{carrier}$,[a] dBmW	−129.6 ±2.5	128.5	−134.6 ±2.5	−133.0	−137.6 ±2.5	−136.0
Unmodulated SNR_B, dB	16 (+1, −0)	16.9	11 (+1, −0)	11.8	8 (+1, −0)	8.5
Modulated SNR_B, dB	—	16.1	—	10.9	—	8.0
Discriminator noise bandwidth, Hz	1102	1234	1102	1234	1102	1234
SNR_C, dB	20.1 ±2	21	14.9 ±2	13.8	11.96 ±2	10.8

[a]Obtained from AGC readings.

Table 39. Noise bandwidth, 0.96-kHz SCO FM/PM

Parameter	Row 1		Row 2		Row 3	
	Specification	Actual	Specification	Actual	Specification	Actual
Mode, bits/s	137.5	137.5	137.5	137.5	137.5	137.5
M_{sc}	1.45	1.27	1.45	1.27	1.45	1.27
Bandwidth IF (DSIF), kHz	4.5	4.5	4.5	4.5	4.5	4.5
Nominal measured noise BW-IF (DSIF), kHz	5.7	6.37	5.7	6.37	5.7	6.37
P_{signal},[a] dBmW	−138.8 ±2.5	−137.8	−143.8 ±2.5	−142.2	−146.8 ±2.5	−146.3
$P_{carrier}$,[a] dBmW	−144 ±2.5	−142.3	−144 ±2.5	−146.8	−152 ±2.5	−150.6
Unmodulated SNR_B, dB	16 (+1, −0)	16.4	11 (+1, −0)	11.7	8 (+1, −0)	8.5
Modulated SNR_B, dB	—	15.6	—	11.1	—	7.6
Discriminator noise bandwidth, Hz	144	168	144	168	144	168
SNR_C, dB	20.6 ±2	17.2	16.1 ±2	12.3	12.6 ±2	7.8

[a]Obtained from AGC readings.

Table 40. Noise bandwidth, 0.560-kHz FM/PM

Parameter	Row 1		Row 2		Row 3	
	Specification	Actual	Specification	Actual	Specification	Actual
Mode, bits/s	17.2	17.2	17.2	17.2	17.2	17.2
M_{sc}	1.45	1.30	1.45	1.30	1.45	1.30
Bandwidth IF (DSIF), kHz	4.5	4.5	4.5	4.5	4.5	4.5
Nominal measured noise BW-IF (DSIF), kHz	5.7	6.37	5.7	6.37	5.7	6.37
P_{signal},[a] dBmW	−146.8 ±2.5	−145.0	−151.8 ±2.5	−149.5	−154.8 ±2.5	−152.5
$P_{carrier}$,[a] dBmW	−152 ±2.5	−150.2	−157 ±2.5	−154.5	−160 ±2.5	−157.8
Unmodulated SNR_B, dB	16 (+1, −0)	16.7	11 (+1, −0)	11.7	8 (+1, −0)	8.5
Modulated SNR_B, dB	—	16.3	—	11.1	—	7.8
Discriminator noise bandwidth, Hz	22.8	23.6	22.8	23.6	22.8	23.6
SNR_C, dB	22.3 ±2	17.2	17.1 ±2	11.7	13.8 ±2	8.7

[a]Obtained from AGC readings.

Table 41. Noise bandwidth, 5.4-kHz FM/PM

Parameter	Row 1		Row 2		Row 3	
	Specification	Actual	Specification	Actual	Specification	Actual
M_{sc}	1.60	1.57	1.60	1.57	1.60	1.57
Bandwidth IF (DSIF), kHz	20	20	20	20	20	20
Nominal measured noise BW-IF, kHz	27.6	27.7	27.6	27.7	27.6	27.7
P_{signal},[a] dBmW	−131.6 ±2.5	−132.5	−136.6 ±2.5	−137.5	−139.6 ±2.5	141.0
$P_{carrier}$,[a] dBmW	−138 ±2.5	−139.0	−143 ±2.5	−144.0	−146 ±2.5	−148.0
Unmodulated SNR_B, dB	16 (+1, −0)	[b]	11 (+1, −0)	[b]	8 (+1, −0)	[b]
Modulated SNR_B, dB	—	16.3	—	10.6	—	7.7
Discriminator noise bandwidth, Hz	810	925	810	925	810	925
SNR_C, dB	53.3 ±2	40.2	47.6 ±2	35.2	44.7 ±2	32.2

[a]Obtained from AGC readings.

[b]Not recorded.

Table 42. Noise bandwidth, 2.3-kHz FM/PM

Parameter	Row 1		Row 2		Row 3	
	Specification	Actual	Specification	Actual	Specification	Actual
M_{sc}	0.655	0.642	0.655	0.642	0.655	0.642
Bandwidth IF (DSIF), kHz	20	20	20	20	20	20
Nominal measured noise BW-IF, kHz	27.6	27.7	27.6	27.7	27.6	27.7
P_{signal},[a] dBmW	−126 ±2.5	−127.5	−131 ±2.5	−132.4	−134 ±2.5	−135.2
$P_{carrier}$,[a] dBmW	−129 ±2.5	−128.7	−134 ±2.5	−133.5	−137 ±2.5	−136.7
Unmodulated SNR_B, dB	16 (+1, −0)	16.7	11 (+1, −0)	11.6	8 (+1, −0)	8.6
Modulated SNR_B, dB	—	15.7	—	10.7	—	8.3
Disc noise bandwidth, Hz	546	394	546	394	546	394
SNR_C, dB	36.7 ±2	37.8	31.1 ±2	32.4	29.3 ±2	28.8

[a]Obtained from AGC readings.

The FM/FM data was obtained with the isolation amplifier installed. In wideband frequency modulation, excessive noise and signal distortion were introduced by small changes in VCO tuning and it would have been impossible to get any type of consistent data without their incorporation.

1. FM/FM and PCM/FM/FM tests: Results of various aspects of the FM/FM and PCM/FM/FM tests are listed below.

a. Demodulator FM improvement: The system did not meet the FM improvement figures given in the test procedure by a significant amount. As explained in detail in the section on compatibility test 11-5 (television horizontal sync), the output bandpass of the demodulator and its associated line driver was approximately 410 kHz wide at the 3 dB points as compared with 220 kHz according to the specification. This discrepancy contributes 2.7 dB more noise to the demodulator output, thus lowering the signal-to-noise ratio output by that amount. However, if this 2.7 dB is added to the output signal-to-noise ratio, demodulator FM improvement in most cases was still considerably below specifications.

b. IF signal-to-noise ratio linearity vs receiver input signal level: Investigation of the data indicated that effects of receiver IF limiting were apparent at lower signal levels than originally thought in the quick-look reports. Extreme limiting, i.e., the point at which the IF signal-to-noise ratio could not be increased with increases in signal level occurred at approximately 16.5 dB in the wideband mode which corresponded to an input signal level of −93 dBmW. However, the effects of limiting, i.e., where IF signal-to-noise ratio ceases to be directly proportional to input signal level, occurred at approximately −102 dBmW for the wideband and 420-kHz modes, respectively. For lower signal levels than the above, IF signal-to-noise ratio is directly proportional to the input signal level.

c. Input signal levels: Input signal required to give a given IF signal-to-noise ratio compares within approximately 0.5 dB with those obtained at Goldstone when corrected for differences in system noise temperature and slightly different IF signal-to-noise ratios, except for those signal levels where limiting occurs as previously explained. They could not be compared against the specifications given in the procedure since system noise temperature was not defined.

d. Bit error rates: No bit errors were observed in the 33- and 7.35-kHz channels as expected. The 3.9-kHz channel showed a 0.09×10^{-3} bit error rate for a bandpass signal-to-noise ratio of 9.6 as was also expected.

e. Discriminator output signal-to-noise ratios: The 150- and 70-kHz channels exceeded the specifications provided in the procedure. The 33-, 7.35-, and 3.9-kHz channels didn't meet specifications in all cases but in general were very close. (See Tables 52–54.)

2. FM/FM and PCM/FM/FM tests: Results of various aspects of the FM/FM and PCM/FM/FM tests are listed below.

a. Input signal levels: Input signal levels vs bandpass signal-to-noise ratios compared remarkably close (±0.4 dB in most cases) with Goldstone's after system noise temperature adjustments were made. However, for the lower frequency SCOs there was a slight bias of 0.5 to 1.0 dB towards a higher signal level. This was caused by the nonlinear passband which introduced sideband distortion. The area of maximum nonlinearity was at the point where carrier lock was obtained, which accounted for the lower frequency SCOs being most affected. The effect was small and very little system degradation resulted. However, when the isolation amplifier was installed, system performance in the PM mode slightly improved.

b. Demodulator gain: These tests were run with the demodulator gain set at +20 dB. Data were extremely consistent. All channels showed a gain of 18.1 ±0.2 dB with the exception of the 33-kHz channel, which showed a gain of 19.4 ±0.3 dB. No difficulties were apparent as a result of using the +20-dB-gain setting.

c. Receiver output vs modulation index: The receiver has an output attenuator that provides for 12 settings. Figure 26 plots output voltage vs attenuator setting vs modulation index. It can be seen that for each modulation index the output voltage can be varied over a considerable range.

d. Suitcase receiver phase detector signal-to-noise ratio output vs input signal level: Data showed a completely linear system.

e. Bandpass signal-to-noise ratios and discriminator FM improvement: Data varied with respect to the specifications provided in the procedure. All parameters were

compared with the specification in Tables 35–42. In general, FM improvement through the discriminators did not meet specifications.

f. Bit error rates: Table 43 compares bit error rates for an 8-dB bandpass signal-to-noise ratio.

Table 43. Channel vs bit error rate

Channel, kHz	Bit error rate
33	2.8×10^{-3}
7.35	4.2×10^{-3}
3.9	3.6×10^{-3}
3.9 SPA	1.5×10^{-3}
0.960	2.8×10^{-3}
0.560	7.8×10^{-3}

It was discovered that bit error rates could be improved somewhat by setting the input attenuator at a level slightly above the green area of the decommutator input level meter. However, all bit error test data shown were obtained by following the procedure prescribed by the test. A setup procedure was introduced for aligning the decommutator such that an input attenuator reading in the middle of the green area will result in minimizing the bit error rate being prepared.

Although a problem with system performance at the 17.2-bits/s bit rate existed, it was later resolved.

3. FR-1400 recordings: Data obtained with the FR-1400 during this test compared well with the original data as shown in Table 44.

Subsequent tests, however, have shown that FR-1400 performance was not acceptable. New heads were received and installed to alleviate this problem.

4. Summary: In summary the following items should be noted:

(1) Considerable difficulty was encountered in using the suitcase receiver in the WBFM mode. Excessive noise and signal distortion appeared in the WBFM telemetry channel and was greatly influenced by small changes in VCO tuning. The basic cause was distortion of the receiver IF passband characteristics because of loading by the crystal filter that is used in the AGC and phase lock loops. Temporary installation of an HP 460 AR wideband amplifier (with a gain setting of 1) between the 10-MHz IF and the filter corrected the distortion in the WBFM channel as well as correcting a long-standing discrepancy of theoretical vs measured noise power. Much time was spent sorting out this problem prior to conducting FM/FM tests.

Table 44. FR-1400 recordings of 3.9-kHz channel

3.9-kHz channel	Bandpass SNR, dB	Bit error rate	FR-1400 bit error rate
FM/FM	9.6	0.09×10^{-3}	0.04×10^{-3}
FM/PM	15.4	0	0
	10.8	0.21×10^{-3}	0.19×10^{-3}
	7.8	4.45×10^{-3}	4.82×10^{-3}
SPA FM/PM	15.6	0	0
	11.1	0.02×10^{-3}	0.03×10^{-3}
	7.8	2.01×10^{-3}	1.90×10^{-3}

(2) Output power from the transmitter portion of the CDC transponder would drift as much as 0.6 dB during a 2-h period. This drift was discovered early and a 4- to 5-h warmup period prior to conducting the test was provided that seemed to eliminate most of the difficulty, although at 0.1 to 0.2 dB drift was still present.

5. Conclusions: In an attempt to evaluate overall system performance, the curves of bit error rates vs receiver signal level inputs were plotted for the various channels. Theoretical input signal levels to produce a given bit error rate were computed as follows:

(1) Theoretical noise power in the disc bandpass was computed from the formula using the measured discriminator noise bandwidths and system noise temperature of 110°K.

(2) The modulation loss for each subcarrier was taken from the precomputed tables when applicable or computed from Bessel functions.

(3) The theoretical bandpass SNR was assumed to be 8 dB to give a bit error rate of 3×10^{-3}.

(4) The theoretical RF input level to give a 3×10^{-3} bit error rate was obtained by adding (1), (2), and (3) above.

(5) Actual receiver input levels to give a 3×10^{-3} bit error rate were used.

Data obtained in the above manner are tabulated in Table 45.

Table 45. Telemetry subsystem performance vs SCO channels

SCO channel, Hz	A Noise bandwidth	B Theoretical noise power in discriminator bandpass[a], dBmW	C Modulator loss, dB	D Bandpass SNR for 3×10^{-3} bit error rate, dB	E B + C + D (Theoretical RF input level for 3×10^{-3} bit error rate, dBmW	F Measured RF input level for 3×10^{-3} bit error rate, dBmW	G Difference between theoretical and measured (E − F), dB
33.0	10.24 kHz	−138.1	1.9	8	−128.2	−128.5	0.3
7.35	1.234 kHz	−147.3	4.6	8	−134.7	−134.4	0.3
3.9	667 Hz	−150.0	3.6	8	−138.4	−138.3	0.1
3.9 SPA	667 Hz	−150.0	13.6	8	−128.4	−128.5	0.1
0.960	168 Hz	−155.9	2.2	8	−145.7	−145.0	0.7
0.560	23.6 Hz	−164.5	2.2	8	−154.3	−151.5	2.8

[a]Theoretical noise power (dBmW) = −198.6 + 10 log (noise bandwidth) + 10 log (system noise temperature).

As can be seen, the difference between measured and theoretical RF input levels is extremely close, indicating that there are no gross errors in the system. The poorer performance obtained with the 0.560-kHz channel can be explained by the high bit error rate as shown by Table 42. The increased sideband distortion caused by the nonlinear passband of the suitcase receiver, which will tend to affect the low-frequency SCO, was also a contributing factor.

The following conclusions were drawn:

(1) The data show the S-band portion of the system was performing according to specifications, with the exception of IF limiting at high signal levels, and was equivalent to the GSDS S-band system once a permanent isolation amplifier was installed.

(2) CDC performance was in accordance with the equipment as designed, although performance parameters at times did not agree with the specifications provided in the test procedure.

6. Recommendations: It was recommended that an isolation amplifier as previously described be formally incorporated in the receiver. (This was done for FM/FM data to be obtained at this station.)

Telecommunication link frequency response (compatibility test procedure 11-4). The purpose of this test was to determine the video frequency response of the complete system from the video input at the test transponder through the RF link and the FM demodulator to the line driver output. This response was to match the demodulator output low pass filter characteristics quite closely since transponder response is essentially flat due to preemphasis being removed from the TV channel.

Certain anomalies were noticed in the test data that resulted in data in addition to that required by the test record. The following graphs are presented:

(1) Video frequency response curves of the system under various test conditions (Fig. 27).

(2) Demodulation line driver frequency response with various operating loads (Fig. 28).

(3) Effects of capacitive loading across demodulator line driver output (Fig. 29).

1. Results:

a. System video frequency response: Results of this test show that the system video bandwidth was too wide. Also shown was that the bandwidth varied with the load on the line driver output that buffers the demodulator output from the discriminators, FR-1400, and the television video processor. The bandwidth was specified to be 3 dB down at 220 kHz; whereas, it actually varied between approximately 300 and 420 kHz, depending on the loading caused by the particular system configuration being used.

The difficulty was caused by a rapidly rising line driver frequency response under normal load conditions. This offset the rolloff of the demodulator output filter and resulted in an extended video frequency response of the entire system. The expected result was a lower demodulator FM improvement as seen by the video processor and consequently a somewhat degraded TV picture quality.

Frequency response of the demodulator line driver was specified as flat ±0.5 dB from dc to 220 kHz, and down no more than 3 dB at 500 kHz. The actual response with normal system loading exhibited a gain of 0 dB from dc

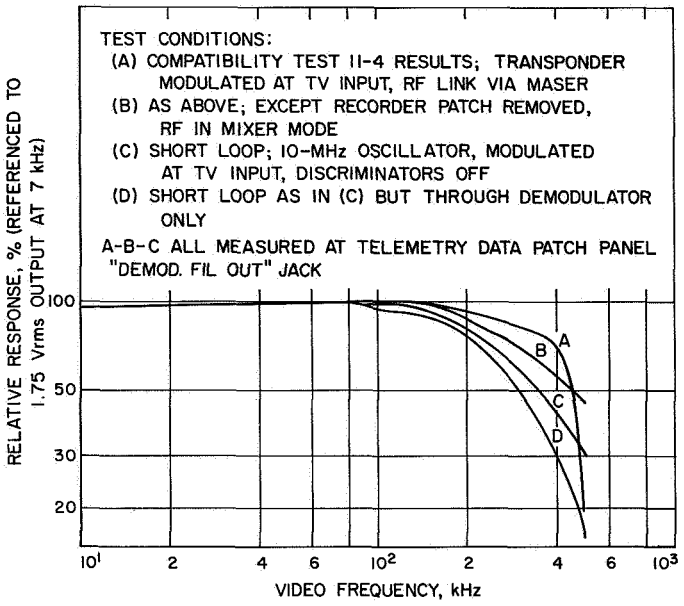


Fig. 27. Video frequency response checks

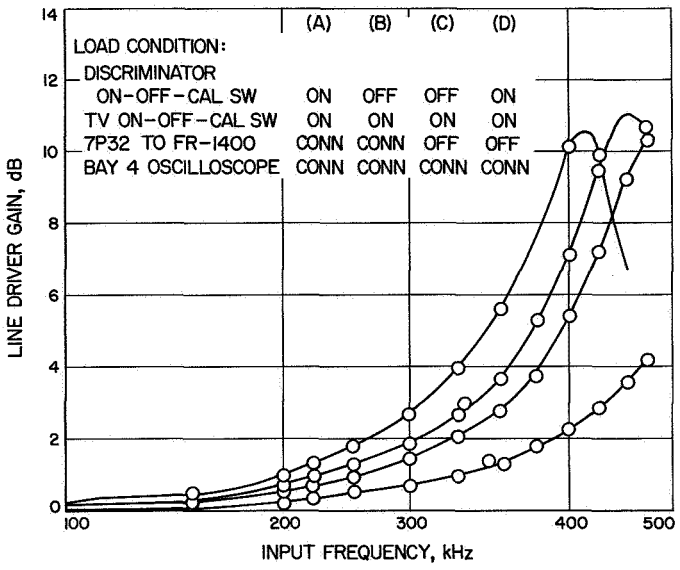


Fig. 28. Switching drawer line driver frequency response with various operational loads

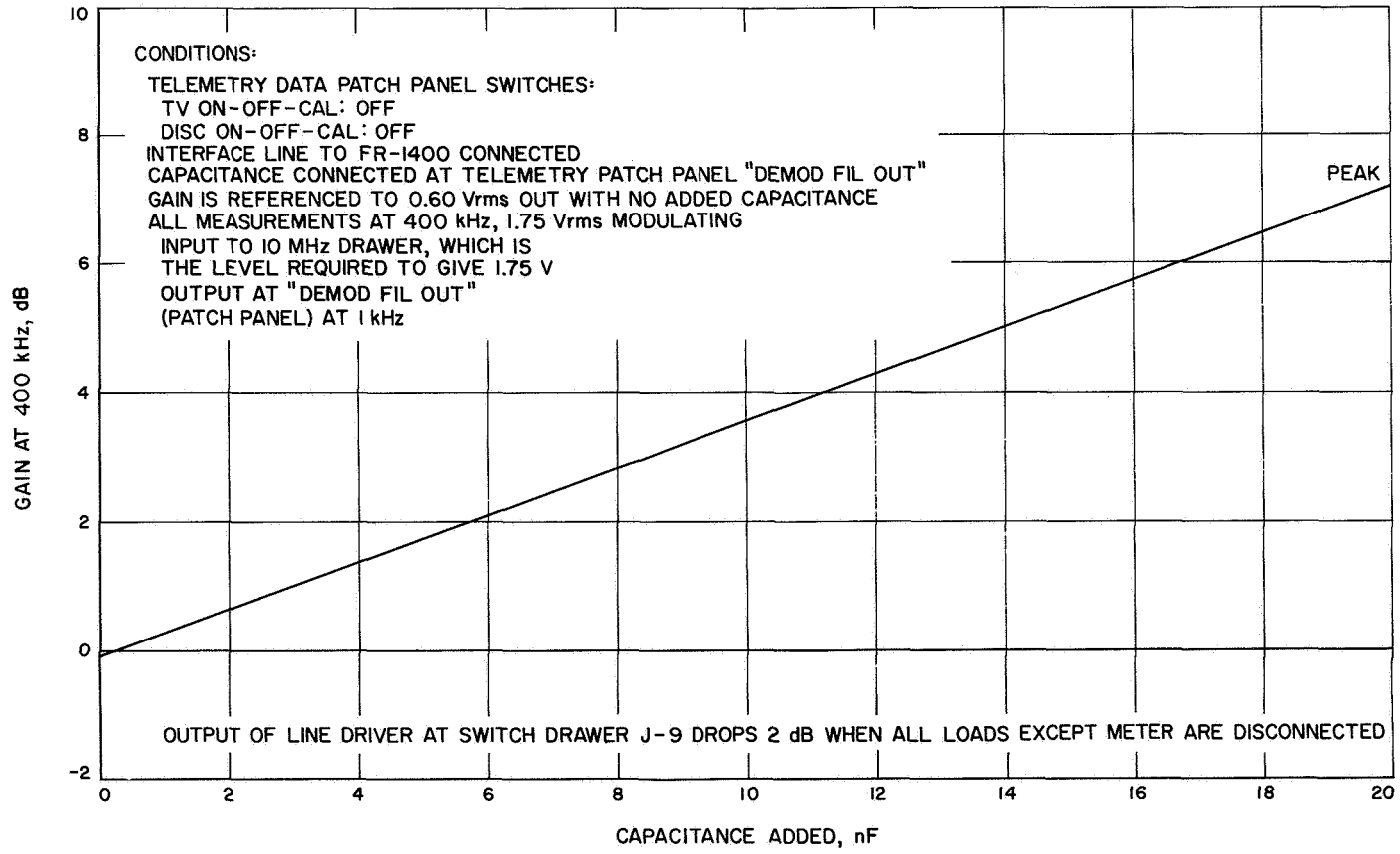


Fig. 29. Effect of added capacitance across line driver output

up to about 100 kHz, and then began a rapid increase in gain with frequency until a peak of approximately 10.5 dB was reached in the neighborhood of 500 kHz. This gain characteristic was a function of the capacitive loading upon the lined driver output. Therefore, changing the system load (for example by switching the EMR (Electro Mechanical Research) discriminators' off-line, or by disconnecting the CDC/DSIF interface cable to the FR-1400 recorder) changed the overall system frequency response by several dB at the higher frequencies. Both line drivers exhibited the same characteristics, so the problem was one of design, and not a malfunction. Figure 29 shows measured line driver response under various actual system loads. Figure 28 shows overall system frequency response under varying load conditions. The effect of adding pure capacitance at the demodulator-filtered-output jack of the telemetry data patch is also plotted in Fig. 28.

It was also determined that the problem could not be overcome by placing a 50-Ω load at the line driver output, so as to parallel the capacitive load with a resistive load. The response at the high frequencies was improved (i.e., decreased) roughly 1 to 2 dB at 400 kHz by addition of the 50-Ω load, but the gain was still approximately 4 dB higher than at 100 kHz.

No significant distortion was present at frequencies within the range of HP 330C distortion analyzer (maximum measured distortion was 3.5% at 20 kHz), and no distortion was visibly present on oscilloscope displays of the demodulator output at any frequency.

b. FR-1400 recordings. Frequency response data for the FR-1400 playback was not obtained because of faulty FR-1400 performance. Early playback attempts were extremely noisy, which precluded recording of results. Overheating of the drive motor on one FR-1400 at 120 in./s finally forced cancellation of tests with that machine. Further attempts were made using the alternate FR-1400 recorder at 120 in./s at a later date.

c. FR-800 recordings. FR-800 playback had a relatively high noise level during this test, which resulted in distortion measurements of up to 25%. It was believed that the measurements show a higher distortion than what was actually present. The oscilloscope displays of the demodulated playback indicated little distortion as such. An additional factor in the distortion measurements was that the only instrument available is the HP 300C distortion analyzer, which had a specified maximum frequency of 20 kHz (which allows accurate measurement of harmonics up to the fifth in the 100-kHz passband of the analyzer).

Subsequent attempts to obtain a clearer signal with the FR-800 playback were qualitatively more successful, particularly with a noise-free signal. However, any noise in the recorded signal seemed to be intensified during playback.

2. Summary:

(1) As described earlier, considerable time was spent in determining and defining the cause of the below-specification video response of the system due to the effects of loading on the demodulator output line driver.

(2) Problems with worn heads on the FR-1400 prevented obtaining acceptable playback data. Also, overheating of the drive motor at 120 in./s resulted in further tests at that speed at a later date.

(3) The HP 330C distortion analyzer would not measure the frequencies required by this test. Thus, at high frequencies oscilloscope observations had to be used for indications of signal distortion.

3. Conclusions:

(1) System frequency response appeared satisfactory up to the line driver at the demodulator output. However, the overall system response was badly distorted (with the 3-dB point occurring at 410 kHz instead of 220 kHz) by system loading on the line driver output.

(2) No significant distortion was present during record at frequencies within the distortion analyzer's capability, and none was visibly present on oscilloscope displays of the demodulator output at any frequency.

(3) The FR-800 seemed to intensify any noise present in the recorded signal. High distortion levels (up to 25%) were obtained with the distortion analyzer, although it was felt that the high noise level was causing erroneous readings since oscilloscope observations showed little distortion as such.

4. Recommendations:

(1) The demodulator output line driver should be modified to provide the proper frequency response (flat ±0.5 dB from dc to 220 kHz, and down no more than 3 dB at 500 kHz) under actual system loading conditions.

(2) Engineering investigations proceeded to determine if the FR-800 was capable of meeting the requirements of *Surveyor* tape recording. A procedure

was prepared, detailing how to obtain the required results. They were obtained.

TV horizontal sync (compatibility test procedure 11-5). There are several ways in which sync jitter can be defined, and a comparison of results from the three stations must be evaluated in terms of the definition used. The following method was used at the Johannesburg station:

(1) Data were obtained in terms of peak-to-peak jitter. (See Table 46.)

(2) All horizontal sync jitter for the first several lines was ignored. The reason for this is that there was an excessive displacement (delay) on the first several lines, which invalidates all subsequent jitter measurements in the frame if not separated.

Because of the critical nature of the placement of the TV video spectrum within the 3-MHz passband of the receiver, a Singer Metrics SPA-3 spectrum analyzer was used to place the video spectrum precisely within the 10-MHz IF passband by tuning the receiver VCO. Using this technique it was possible to optimize the video spectrum relative to the IF passband.

Table 46. Peak-to-peak sync jitter

IF SNR, dB	Jitter, μs		
	(A) BW = 2.69 MHz	(B)BW = 3.15 MHz	
		100% of sync pulses	90% of sync pulses
4.5	90	30	20
6.5	30	10	8
8.5	12	8	5
10.5	7	4	2
12.5	3	2.5	1.3
16.5	1.4	1.0	0.7

Sync jitter data is plotted in Fig. 30.

1. Statements:

(1) Measured sync jitter is tabulated below under two test conditions. Condition A, which is the data obtained from the test record, was run with a composite system bandwidth of 2.69 MHz measured at the output of the CDC 10-MHz filter. Condition B was run with the suitcase receiver temporarily modified to provide a system composite 3-dB bandwidth of 3.15 MHz. Sync jitter was substantially improved by this modification.

(2) An examination of PCM bit error rates revealed that no PCM errors occurred at 10.5 dB when measured directly (i.e., without recording). No PCM was recovered from the FR-1400 before its use was suspended.

(3) Photorecorder picture analysis showed that all requirements for TV gray bar photo analysis were met successfully.

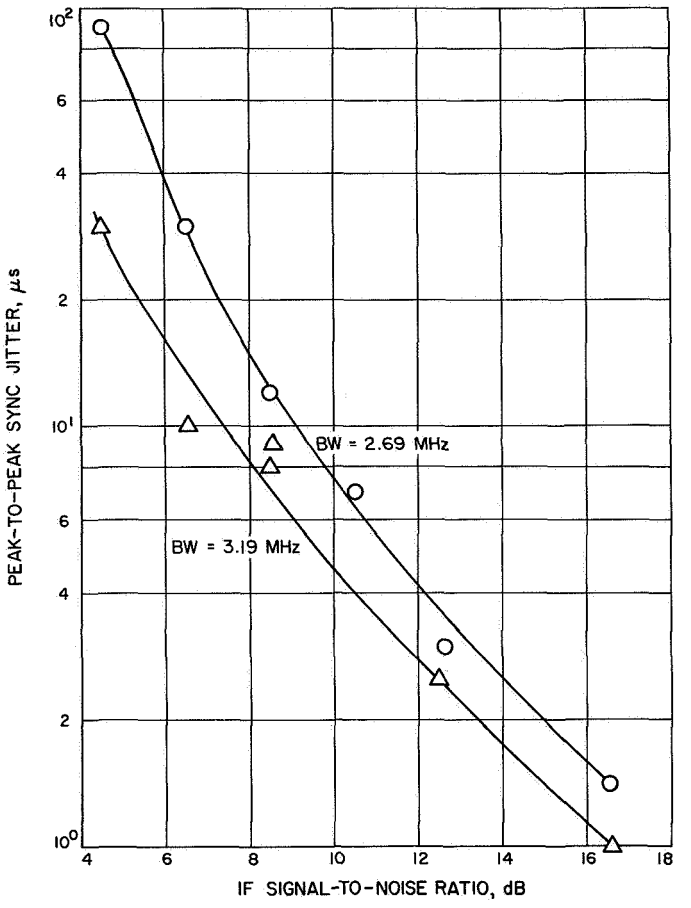


Fig. 30. Peak-to-peak sync jitter vs IF SNR

2. Summary:

a. Suitcase receiver performance: When preliminary tests of sync jitter and overall TV picture quality were run, it was apparent that the suitcase receiver would not deliver pictures of reasonable quality. (TV reception had not been one of the requirements of the original suitcase receiver, however.)

Additional trouble was also encountered in the FM telemetry tests, which resulted in excessive demodulator output noise. Therefore, the causes of the FM telemetry degradation through noise were investigated, as well as the source of the bandwidth limitations plus noise that prevented useful TV reception. Fortunately, the problems

were such that the equipment could be fairly easily modified to obtain better performance. Before any formal TV tests were run, the suitcase receiver had been modified (from the configuration it had when delivered to Johannesburg) in the following ways:

(1) Manual gain control had been added.

(2) The phase-lock and automatic gain control loops had been temporarily isolated from the telemetry channel by connecting in a Hewlett-Packard 460 AR wideband amplifier to prevent the AGC crystal filter from distorting the telemetry passband.

The sync jitter as recorded in the test record was then measured. Subsequent to the measurement, a third change was made to that receiver to broaden the system bandpass as seen looking back from input to the CDC 10-MHz filter. This was accomplished by simultaneously bypassing (for WBFM operation only) two successive stages which follow the receiver 10-MHz selectable filters. These stages are the wideband telemetry amplifier with a gain of approximately 40 dB and the 30- to 42-dB WBFM variable attenuator at the amplifier output. The amplifier was responsible for narrowing the receiver bandwidth from something over 6.4 MHz (at the filter output) down to 3.4 MHz at the amplifier output. Its removal increased the system composite IF bandwidth as measured at the output of the CDC 10-MHz filter from 2.69 to 3.15 MHz (which is essentially the CDC filter bandwidth). (All bandwidths given above were at the 3-dB points.)

b. FR-1400 recordings: No successful FR-1400 playbacks were obtained due to extreme noise on the playback data. Attempts to improve the quality included head replacement and WBFM realignment on the FR-1400. A problem of drive motor overheating was also encountered at 120 in./s. At the direction of JPL, all tests at 120 in./s were then postponed until a later date. These were subsequently successful.

c. Photorecorder film interference pattern: TV films showed an interference pattern, apparently originating in the photo recorder.

d. Receiver IF limiting: Receiver IF limiting has been documented in the compatibility test procedure 11-4 test section. The same type of limiting was observed during these tests.

3. Conclusions: Certain allowable sync jitter is specified, but measured jitter was better than Goldstone quicklook results. This difference could be influenced by a certain degree of subjectivity that is inherent in this type of measurement. But it is more likely due to a difference in receiver VCO tuning, since that is a very critical factor in sync jitter. The method used to tune the VCO in this test was to observe the demodulated TV signal on an oscilloscope, while tuning the VCO for approximately equal noise at the demodulated video sync level and at the white level. Noise at the center of the band tends to be slightly less than at the edges, and the sync jitter increases sharply as the sync level begins to go over the low-frequency edge of the 10-MHz passband.

The results of this test indicate that the suitcase receiver, with the relatively simple modifications made for these tests, would provide TV sync stability which is comparable to the GSDS S-band receiver.

TV test patterns (compatibility test procedure 11-6). The purpose of this test was to check the degradation of a video signal after it had passed through the RF link and had been photographed with the CDC photo recorder. Degradation is checked by comparing the photo recorder photo quality obtained via the RF link with results obtained when the same signal is hardlined to the video processor. Two test signal sources are prescribed: (1) the CDC test set TV signal generator and (2) a prerecorded video test tape containing recordings of the actual spacecraft camera outputs, to be played back on the FR-1400.

The direct 35-mm recording tests were run completely on two separate dates. The reason for repeating the test was that the receiver IF 3-dB bandwidth had been broadened from 2.69 to 3.15 MHz, and the system had demonstrated a substantial improvement in sync jitter when operated with the wider bandwidth.

The system video bandwidth was also much too wide on both tests, being close to 410 kHz instead of 220 kHz. An attempt to isolate and correct the problem before the second test resulted in tracking the trouble to the line drivers in the demodulator switching drawer. However, modification of the line drivers was necessary to correct the problem. Further improvement in TV quality was achieved by correcting the system video response. All attempts at tape-recording the video signals failed, as did the attempts to play back the prerecorded tapes. These were later conducted with measured success.

1. Results:

a. Photo evaluation: Enlargements of the 35-mm negatives from the tests at both IF bandwidths were examined

closely. Special effort was made to identify (1) signs of sync jitter and (2) visible background noise in the photo. Photos from each IF bandwidth were first compared with the hardline photos, and then the photo for the 3.15-MHz bandwidth was compared with that from the 2.69-MHz IF bandwidth. The photo-by-photo evaluation is summarized below.

b. Gray bar results: Severe degradation was evident at 7 dB because of sync jitter and background noise, with the IF BW = 2.69 MHz. When the IF BW was increased to 3.15 MHz at 7-dB SNR, the gray bar was greatly improved, but of course it still showed noise and jitter. At 10.5 dB for either BW, very little degradation could be detected, and none was detectable at higher SNRs. An interference pattern was present in all pictures, including the hardline.

A graybar enlargement for IF SNRs of 7 and 10.5 dB was accomplished. Scope camera pictures at hardline and at 10.5 dB were also obtained.

c. 300 lines vertical resolution: The only degradation visible at 7 dB was some background noise with both BWs. There was some visible noise at 10.5 dB in the 2.69-MHz BW. No degradation was otherwise visible at SNRs of 10.5 dB or better.

d. 600 lines vertical resolution: This check was insensitive to sync jitter, but seems a good indicator of background noise. There was considerable noise at 7 dB with both IF BWs, but no difficulty in discerning the individual lines. Some noise was still detectable at 10.5 dB (both BWs). At 13 dB there were possible traces of noise, although it could not be positively identified. No degradation was detectable at 20 dB. The 600 vertical resolution lines at SNRs of 7, 10.5, and 13 dB were recorded.

e. 300-lines horizontal resolution: Jitter and background noise severely degraded the picture at 7-dB and 2.69-MHz IF BW. With the 3.15 BW at 7 dB the picture was still badly degraded, but was definitely improved over the 2.69-MHz BW. Estimated rms jitter at 10.5 dB was about ¼ of a line width, with peaks in tuning the receiver VCO. It was very advantageous for the spectrum analyzer to be left on line at all times for normal TV reception. (However, one factor making its continued use less critical during the tests was the minimum VCO frequency attainable always gave the best picture, as discussed below.)

It was determined by use of the spectrum analyzer that the best VCO frequency was one that displaced the TV spectrum farthest toward the high-frequency side of the predetection filter passband. The unmodulated carrier was displaced about 0.25 MHz at that VCO frequency, i.e., it fell at 10.25 MHz rather than at 10.00 MHz. (Neither the test transponder nor the receiver is at fault to necessitate such tuning. The unmodulated carrier falls at approximately 10 MHz in the IF when the VCO frequency is at the center of its tuning range, and the transponder S-band frequency with no modulation is 2294.998 MHz.)

The above VCO tuning gives the best TV picture because it takes the sync pulse off the steeply rising low-frequency edge of the CDC 10-MHz predetection filter. This, of course, pushes the PCM somewhat down on the high-frequency side, but the high-frequency side rolls off at a slower rate than the low-frequency side. The center of the predetection filter used in this test is also not centered at exactly 10 MHz, which also makes it desirable to tune to the high side of the passband. This slight nonsymmetry is indicated in Table 47.

Table 47. 10-MHz IF rolloff vs frequency[a]

dB point	Low-frequency side	High-frequency side
1	1.30	1.41
2	1.40	1.57
3	1.46	1.71
4	1.52	1.83

[a]MHz from 10-MHz reference frequency to passband edge at indicated dB point.

The final factor that makes tuning to the high side desirable is that the PCM data is not affected by a slight degradation in SNR, whereas the sync pulse is very sensitive to such tuning.

Any slight degradation at the white level is usually immaterial for viewing lunar scenery, since that scenery is not pure white.

2. Summary:

a. FR-1400 and FR-800: Recorder problems made it impossible to record and playback the demodulated or 10-MHz IF TV signals.

b. Receiver IF bandwidth: The 10-MHz IF bandwidth had to be widened by bypassing two stages in the receiver in order to obtain the specified IF bandwidth for TV. (TV capability was not required of the suitcase receiver as delivered to Johannesburg.)

c. CDC line driver frequency response: Distortion of the CDC tester/DSIF/CDC system video response had to be isolated before compatibility test 11-6 could be considered a valid check of system capability.

d. Graybar resolution in photos: Although 10 shades of gray could easily be resolved on the 35-mm films, they could not be reproduced simultaneously in the photographic enlargements.

e. PCM interference on TV signal: Some PCM spikes appeared on the video signal. This apparently came in via the PCM gating unit. It did not appear to degrade the received picture quality, however.

f. Receiver limiting: The receiver began to limit at about −102 dBmW which made it necessary to set up the IF SNR differently from what was called out in the procedure. Therefore, IF SNRs at 13 and 20 dB were set up through use of the HP 39A dial, referred to the noise power measured in the RF calibration.

3. Conclusions: The TV test pattern as transmitted over the RF link and recorded on 35-mm film appeared to be of reasonable quality even with the system video response broadened by the video line drivers. Some further improvement was to be expected if the line driver frequency response were corrected. The suitcase receiver was not believed to be contributing any degradation to the received picture over what would normally be expected because of noise at the various input signal levels.

Multiplexed telemetry (compatibility test procedure 11-7). The FM/FM portion of these tests was conducted utilizing the isolation amplifier, whereas the FM/PM portion did not utilize the isolation amplifier.

Curves showing signal-to-noise ratios at the demodulator input, output, S-band cassegrain diplexer (SCD) bandpass, and SCD output vs input signal levels for the 4400-bits/PCM FM/FM multiplexed with six FM/FM accelerometer channels and the 1100-bit/s PCM FM/PM multiplexed with three FM-FM strain gage channels are shown in Figs. 31 and 32, respectively.

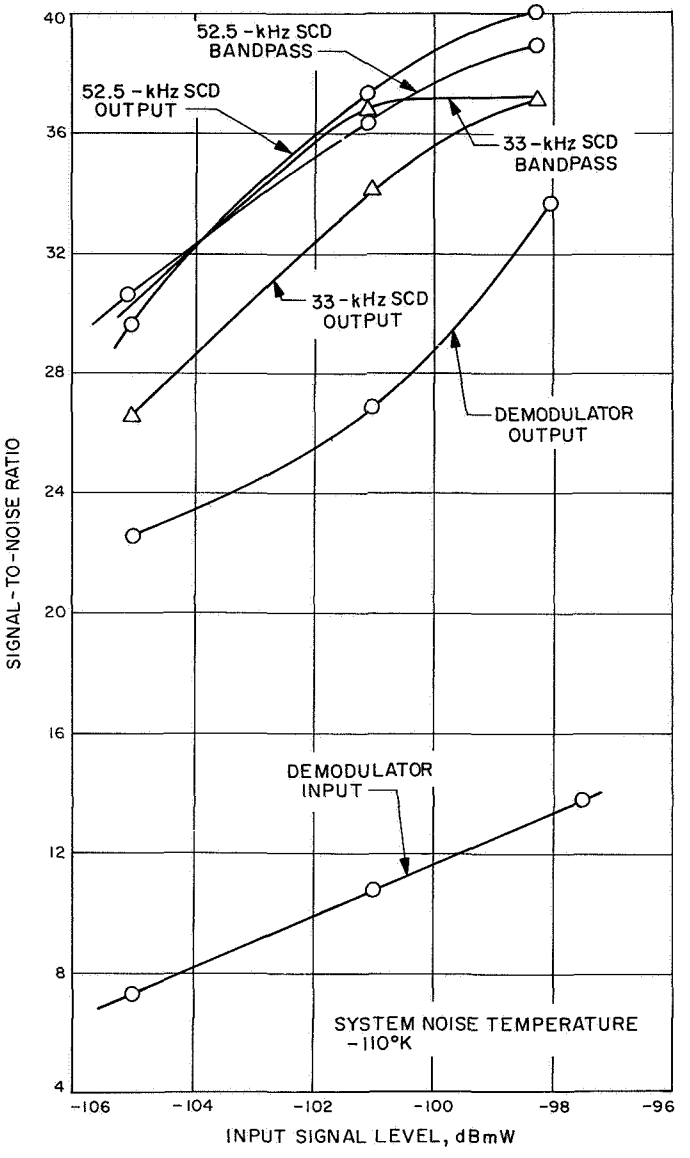


Fig. 31. System performance of 4400-bits/s PCM FM-FM, multiplexed with six FM/FM accelerometer channels

Table 48. 4400-bits/s PCM FM/FM multiplex

Signal level, dBmW	SNR, dB						Bit error rate × 10^{-3}
	Demodulator input	Demodulator output	52.5-kHz SCD bandpass	52.5-kHz SCD bandpass	33.0-kHz SCD bandpass	33.0-kHz SCD output	
−98.2	13.2	32.9	38.9	40.0	37.1	36.9	0
−101.4	10.4	26.1	35.9	36.8	36.5	33.4	0
−105.2	7.1	22.5	30.4	29.0	30.0	26.6	0

(1) Signal results. The SNR range of the 4400-bits/s PCM FM/FM multiplex is shown in Table 48. In the wideband mode the suitcase receiver IF output cannot be increased above 16.5 dB because of receiver limiting. Consequently it was impossible to obtain data for the first portion of this test, which specified a 20-dB IF SNR.

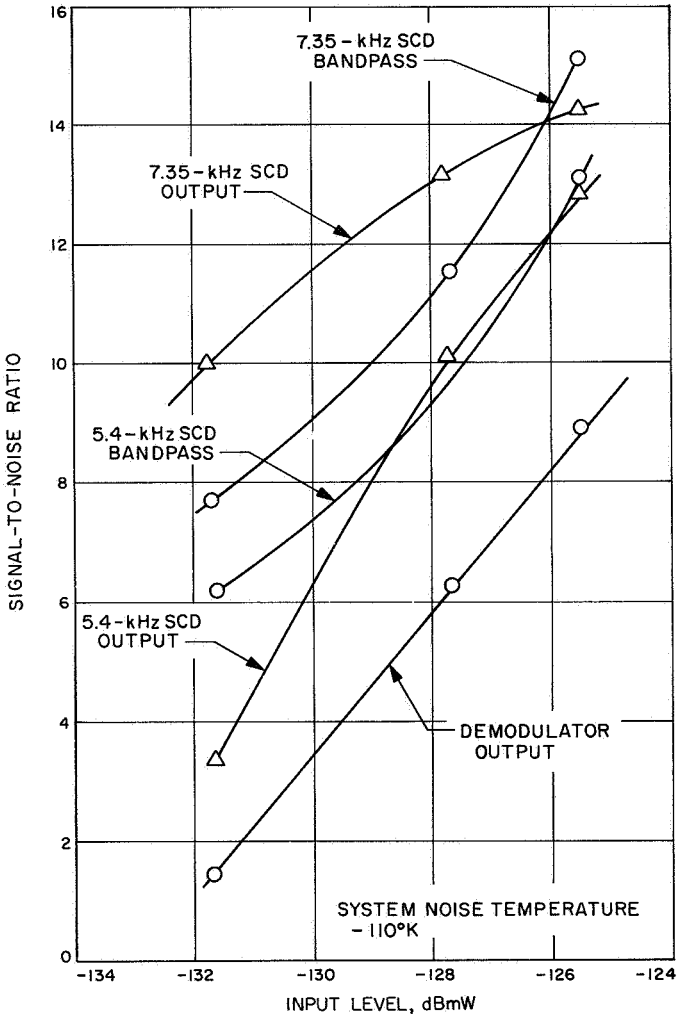


Fig. 32. System performance of 1100-bits/s PCM FM-FM multiplexed with three FM/FM strain gage channels

The 33-kHz SCD did not show any FM improvement at the three IF SNRs tested. However, no bit errors occurred at the levels tested, indicating that system performance was adequate.

The output bandwidth of the demodulator was 3 dB down at 410 kHz instead of 220 kHz as per the demodulator unit specifications. The wider output bandwidth will lower demodulation FM improvement and must be considered when comparing the values shown with theoreticals. However, the wider bandwidth does not significantly affect system performance at the bandpass and output of the SCDs.

Demodulator input signal-to-noise is directly proportional to input signal level at the points tested.

The SNR range for the 1100-bit/s PCM FM/FM multiplex is shown in Table 49. The 5.4-kHz SCD showed significantly less FM improvement during these tests than during the single-channel tests. In order to obtain better comparative data, a short loop test with the system tester was conducted, exactly duplicating the subcarrier modulating voltage present during compatibility test 11-7 except that only the 5.4-kHz SCO was utilized. The results are seen in Table 50. Consequently it can be seen that multiplexing does degrade 5.4-kHz SCD performance significantly.

Command buffer spot checks and input–output equipment interface checks are a repeat of compatibility procedure 11-11. These were an identical retest of the equipment performance tested in the earlier procedure.

TV bit error rate tests were rerun, tieing in the telemetry converter to the digital instrumentation system (DIS) equipment.

A combined test, transmitting in both the uplink and the downlink, is run during which both telemetry data and command data are processed by the DIS equipment.

Table 49. 1100-bits/s PCM FM/PM multiplex

Signal level, dBmW	SNR, dB						Bit error rate $\times 10^{-3}$
	Demodulator input	Demodulator output	5.4-kHz SCD bandpass	5.4-kHz SCD output	7.35-kHz SCD bandpass	7.35-kHz SCD output	
−125.5	—	8.9	13.0	12.8	15.2	14.2	0
−127.6	—	6.3	9.8	10.1	11.6	13.2	0.29
−131.6	—	1.5	6.2	3.3	7.8	10.1	11.20

Table 50. 5.4-kHz SCD FM improvement

Carrier	Bandpass SNR	SCD output SNR
11-7 multiplex	9.8	10.1
	6.2	3.3
Short loop–single SCD	9.8	12.9
	6.2	7.0

Equipment results

(1) Final phase-lock thresholds were better than those measured in compatibility procedure 11-8 test due to a realignment of the transponder receiver between the two tests. Threshold with carrier only was −125.9 dBmW.

(2) Single-channel telemetry tests were all run with the demodulator gain switch set to 0 dB instead of 20 dB as in compatibility procedures 11-2 and 11-3; this may explain the different levels of SNR measured at the demodulator input and demodulator output between these tests and compatibility procedures 11-2 and 11-3 tests. SNRs at discriminator outputs all agree very closely to compatibility procedures 11-2 and 11-3 test results with the exception of the 0.560-kHz SCO.

(3) In both multiplexed tests the results agree very closely with those obtained during compatibility tests 11-7. The noise measurements differed slightly due to the method of measurement. (See quick-look report.) The maximum noise measured amounted to 0.4% of full-scale deflection and was not considered a problem.

(4) The telemetry converter operated completely satisfactorily in processing all data to the DIS computer; however, the bit error rates detected vary from those of the CDC bit error detector by a considerable amount, which is a function of the decommutator going out of lock.

(5) Every time the decommutator loses lock, it fails to send a correlation pulse to the telemetry converter. This is used in the telemetry converter to inhibit transfer of the sync word, to reset the odd/even flip-flop, and to send frame sync 17 to the computer. As a result, the frame sync word is transferred, and all the bits or words are shifted one word. Also, the computer doesn't know where in the frame it is without frame sync and the frame ends up looking too long or too short.

(6) In this test configuration, the computer also counts approximately 10% more bits than the CDC counter. This is because of the parity flag bit which makes 12 bits/word instead of 11 bits/word. The parity flag is held at zero for these tests.

(7) Because of the difficulty encountered with the decommutator losing lock at low SNRs, and the fact that the computer counts 10% more bits, the number of bit errors detected by the computer in this series of tests was meaningless.

(8) All items of the command interface tests and the input–output interface tests checked out satisfactorily.

(9) Zero bit error rates were obtained in both the CDC and the DIS computer for the TV PCM bit error tests.

(10) The two-way transmission tests resulted in zero errors for both the uplink and the downlink transmissions. During the transmission tests all data was transferred via the telemetry converter and the command buffer simultaneously to the DIS computer. Operation of the telemetry converter and the command buffer interface was completely satisfactory.

Summary. In summary:

(1) The proper frequency for the transponder phase lock drifted considerably during the setup for the tests, resulting in difficulty in both the two-way phase lock tests and the combined 33-kHz SCO FM/PM command tests.

(2) It was necessary to use the L- to S-band receiver to provide a frequency count of the DSIF receiver VCO since this is not brought out on the suitcase receiver.

Conclusions. The conclusions were:

(1) When the tests are to be run using the tester transponder in two-way phase lock, the unit should be turned on and allowed to warm up for 1 shift prior to testing.

(2) Near discriminator threshold, it is difficult to exactly duplicate test conditions. However, considering the problems involved and in light of the results obtained, these tests substantiate previous test results and indicate no major discrepancies.

(3) No new problem areas were uncovered during the composite system tests.

FM/PM multiplex test. Bit error rates for the 7.35-kHz SCO were 0.29 and 11.20 per thousand at SNRs of 11.6 and 7.8, respectively. The 11.20 bit error rate for a 6.7 SNR in the 7.35-kHz SCD bandpass is felt to be an error. Possibly the discriminator was not balanced, the decommutator input attenuator set incorrectly, or the bit error detector not properly set up. In any event, the reading did not represent true system performance since the 1100-bits/s multiplex portion of compatibility test 11-12 for a 7.35-kHz BP SNR of 7.8 gave a bit error rate of 3.49 per thousand. This number was much more consistent with data obtained during other tests.

Input signal levels for a given bandpass SNR may be slightly higher than nominal (> 0.7 dB). (Since no data were provided in the test procedure, the comparison cannot be made.) The nonlinear passband present in the suitcase receiver introduced sideband distortion. Installation of the isolation amplifier would result in lower receiver input levels for given discriminator bandpass SNRs.

All FR-1400 playback data are included in the quick-look report. The data are not summarized in this report since it is quite erratic because of worn heads on the recorders. New heads have been received and spot checks to verify recorder performance were made and verified.

Noise measurements were made on all eight of the low-frequency oscillograph lines at the CDC telemetry data patch panel and the DSIF CEC oscillograph. When the measurements were made, the lines were interrupted. Approximately 1.7 mV was present at the CDC on all lines and 6.3 mV at the CEC, indicating that more noise is introduced from the CEC. However, 6.3 mV of noise on the CEC channels is considered insignificant for a 0- to 10-V deflection.

There was one difficulty introduced by the CEC interface. The CEC has a switchable input impedance which varies between 10^3 and 10^6 Ω. The higher the input impedance, however, the smaller the maximum possible trace deflection. The maximum deviation for a 10^6 Ω input impedance is 1 in. A 1-MΩ load on the decommutator analog outputs, however, causes the analog output meters on the telemetry display console to change by 0.75%. Complete data are shown in Table 51.

The data clearly indicate that the telemetry console meters had to be calibrated with the CEC oscillograph connected and that no changes in channel allocation can be made subsequent to the calibration. (This effect was also reflected in the appropriate unit and subsystem test procedures.)

Table 51. CEC input impedance vs deflection

CEC input impedance setting, Ω	CEC maximum deflection, in.	Telemetry display console meter change, %
107	$< 1/4$	nil
5×10^6	$< 1/4$	0.25
2×10^6	1/4	0.35
10^6	1	0.75
10^5	> 1	2.5
10^4	$>> 1$	10
10^3	$>> 1$	$>> 10$

Maximum noise on any one line of the DSIF CEC–CDC high-frequency oscillograph recording was 22 mV, which is considered acceptable for mission requirements.

1. Summary: No major problems were encountered in running the tests. Considerable time was spent with the FR-1400 to determine if it would give satisfactory results with the then-existing heads.

2. Conclusions: Since no specifications were provided in the procedure, there is nothing with which to compare results other than the compatibility procedure 11-12 test results. Such a comparison shows that the data are fairly consistent. Specific conclusions are as follows:

(1) The 4400-bits/s PCM multiplex appears good in that the bit error rate was zero for the 3 input levels tested.

(2) Bit error rates for the 1100-bits/s PCM multiplex are considered to be lower than the data show.

(3) The 5.4-kHz SCD FM improvement appears to be considerably reduced under the conditions present in this test.

(4) Input levels for given SNRs in the SCD bandpasses for the FM/PM multiplex test may be reduced up to 0.7 dB once the suitcase receiver isolation amplifier is installed. It is possible that the sideband distortion caused by the nonlinear suitcase receiver passband is causing the poor 5.4-kHz SCD performance.

(5) Demodulators FM improvement is somewhat lower than expected due to a wider than spec output passband. It is felt that this has not affected the final output performance figures.

(6) Noise on the CDC low- and high-frequency oscillographs and the DSIF CEC oscillograph is acceptable.

Two-way phase-lock thresholds (compatibility procedure 11-8). Two-way phase-lock tests were performed to determine the threshold for phase-locking both the DSIF receiver on the downlink and the transponder receiver on the uplink.

Included as part of the test was the determination of the frequency band at which the transponder would obtain phase-lock. This was then used to establish the transponder receiver center frequency for making threshold measurements.

1. Results: It was necessary to use the L- to S-band receiver to provide a frequency count of the DSIF receiver VCO since this is not brought out on the suitcase receiver. Doppler information during the actual mission was also to be obtained from the L- to S-band receiver.

Threshold measurements made on both DSIF receivers (L- to S-band and suitcase) with the cryogenic load indicated a threshold of approximately −168 dBmW.

CDC transponder phase-lock threshold (without command modulation applied) was measured at −126 dBmW with a measured receiver noise figure of 11.4 dB.

2. Summary:

(1) It was necessary to use the L- to S-band receiver as well as the suitcase receiver to obtain some of the data required.

(2) The frequency band over which uplink phase-lock could be best obtained was not reliably indicated by the CDC transponder AFC/static phase error (SPE) meter, and the optimum band also tended to drift with time. To overcome this, the best exciter VCO frequency was determined independent from the SPE indication.

(3) The 10-dB attenuation at the HP 394A input was reduced to 3 dB to obtain a readable indication on the 431B power meter.

3. Conclusions: Transponder receiver and DSIF receiver phase-lock could be achieved at signal levels lower than expected spacecraft levels.

Command transmission and word error rate (compatibility test procedure 11-9). The command transmission tests were primarily concerned with the compatibility of the CDC command generation subsystem, the DSIF transmitter, the receiver section of the system tester transponder, the ground command decoder, and the DSIF recorders.

Functional tests were performed to establish the CDC input level required to obtain the correct DSIF modulation index and the corresponding carrier suppression.

Word error tests were conducted on the commands transmitted to determine the threshold and sensitivity levels of the transponder receiver.

The command SCO was recorded and played back with both the FR-1400 and FR-800 to verify satisfactory performance of the recording interface.

Table 52 shows a tabulation of the word error rate at successive receiver input levels. Figure 33 shows the same results along with theoretical SNRs in the first IF.

Table 52. Word error rate vs receiver input levels

Transponder receiver input level, dBmW	Command word error rate
−94.5	0
−99.3	0
−104.3	0
−109.5	0
−111.0	0
−114.0	0
−115.0	0
−115.5	1×10^{-4}
−116.3	25.8×10^{-4}
−117.4	158.0×10^{-4}

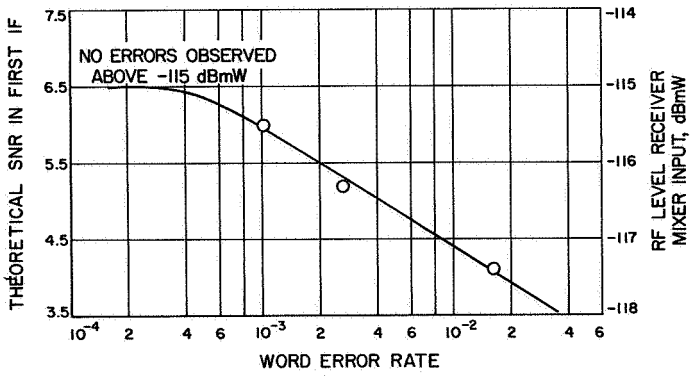


Fig. 33. Word error vs RF level and theoretical SNR

1. Results:

(1) Modulation levels of the command SCO required to give the correct modulation index of 1.6 (carrier suppression 6.8 dB) were measured at the CDC telemetry data patch panel and at the DSIF modulator input and found to be 403 and 375 mV, respectively.

(2) Receiver noise figure was measured at 11.4 dB. Word error test results show the transponder receiver to be operating at lower input signal levels than expected. As no word errors occurred at compatibility procedure test levels (lowest of −122 dBmW + noise level −3 dB), additional tests were run to determine the signal level that word errors would occur. It was found that threshold occurs at approximately (−122 dBmW + noise level −4.5 dB) −114.1 dBmW.

(3) FR-1400 and FR-800 recordings showed the same waveshape on playback as was recorded. No degradation in the signal was noted.

2. Summary:

(1) The transponder receiver required some realignment before the compatibility tests could be run satisfactorily. This could not be accomplished during unit test as a stable S-band signal source was not available. However, it was later run satisfactorily.

(2) The DSIF modulation input had a phase shifter that was used for *Mariner*. This was modified so that the phase shifter was bypassed for *Surveyor*.

(3) The DSIF termination impedance for non-GSDS command inputs when the non-GSDS modulation input was not being used was changed from 2,000 to 50 Ω.

3. Conclusions:

(1) Modulation levels of the Command SCO required to give the correct modulation index of 1.6 were within the specified tolerance (375 ±10 mV).

(2) Command transmissions originating with the CDC command subsystem, transmitted through the RF link, and received by the CDC transponder receiver at signal levels lower than specified with no word error rates demonstrated the operational compatibility of the command interface.

(3) The recording interface had no problem in that no degradation in the recorded signal was noted.

Timing displays test (compatibility test procedure 11-10)

(1) GMT BCD interface lines were all checked to determine that the right logic levels appeared on the right lines for a given time condition.

(2) The GMT readout at CDC bays 2 and 7 were checked at intervals of ½ h to assure proper operation of the CDC remote readout.

(3) The command printer in bay 9 was checked for proper printout of GMT from the time and data buffer unit.

(4) Recordings and measurements were made of the 28-bit code and the 36-bit code serial time from the DSIF.

1. Results:

(1) After a minor change in the signal return line (see compatibility test 11-11) all logic levels were correct and the remote readouts in the CDC bay 2 and 7 were correct.

(2) The GMT printout on the command printer had a minor error which was corrected (see compatibility procedure test 11-11), and all GMT printouts were satisfactory.

(3) Both the 28- and the 36-bit code were checked out and adjusted as necessary to meet specifications.

2. Summary:

(1) The GMT BCD display in the CDC grounded the 20-days digit of the DSIF. This was corrected by moving the ground wire at the time code generator connector from *-j* to pin *T* and leaving *-j* open as it is not used for *Surveyor*.

(2) The parallel display at the CDC combined with the many other DSIF displays caused an overload on the DSIF clock. This was corrected by adding a parallel clock synchronized with the main clock.

(3) The 36-bit code serial time required an adjustment of the amplitude and a component replacement before it worked properly and met specifications.

(4) A miswire in bay 7 required fixing to get the proper logic level to bay 9 and the command printer so that GMT would print correctly.

3. Conclusions: All timing interfaces (parallel and serial time) were thoroughly checked out and operating

within specifications. The CDC equipment proved compatible with the DSIF equipment.

CDC/OSDP checkout (compatibility test procedure 11-11).

(1) All CDC (OSDP subsystem)/DIS interface lines were measured for noise levels and signal characteristics. Any deviation from expected signal characteristics or abnormal appearing signals were investigated.

(2) The telemetry converters were thoroughly tested, using all combinations of *Surveyor* frame lengths and bit rates, including jitter simulation, for proper operation between the CDC and the DIS equipment.

(3) The command buffer was tested, using both states of each bit transmitted, for proper operation between the CDC and the DIS equipment.

(4) All input–output equipment was exercised in all modes of operation to verify compatible operation.

(5) Although compatibility test procedures did not provide for checkout with both computers (procedures called out test with either 910 or 920 but not both), additional tests were made with the other computer after completion of formal compatibility tests.

1. Results:

(1) All CDC (OSDP subsystem)/DIS interface lines were plotted for each condition of each signal. These are presented in the data included in the quick-look report for compatibility test procedure 11-11. All signal characteristics were as expected.

(2) The telemetry converters' operation was completely satisfactory under all frame lengths, bit rates, and jitter conditions.

(3) The command buffer operated normally under all test conditions.

(4) All input–output equipment operated satisfactorily and performed each operation as instructed by the DIS computer(s).

(5) In checkout of the CDC/OSDP and input–output equipment with the 910 and 920 computers, the same set of cables was used and moved to either the 910 or 920 computer. The second set of cables was not used for two reasons. (1) There was no callout to check the equipment with the second computer and computer personnel (JPL) preferred to use as few new variables as possible. (2) Other program-oriented equipment was using the computer input connectors so that both sets of *Surveyor* cables could not be left connected to the computers.

2. Summary:

(1) Before beginning compatibility test procedure 11-11 tests, it was necessary to complete those engineering changes that had not been already incorporated into the equipment.

(2) Two minor wiring errors were found and corrected in the interrupt circuits for the tape reader drive in the *W* buffer.

(3) In measuring the interface signals, one circuit appeared abnormal. Investigation revealed a bad input card in the computer; this was then corrected.

3. Composite system test (compatibility test procedure 11-12):

(1) The composite system test provides a spot check on various parameters measured in compatibility test procedures 11-1 to 11-11 tests.

(2) Two-way phase-lock is a recheck of compatibility test procedure 11-8, which is to establish the threshold level for two-way phase-lock.

(3) Single-channel telemetry tests spot-check the DSIF telemetry data processing equipment and each of the 5 discriminators at signal to noise levels of 8 dB in the discriminator bandpass. This is a recheck of tests run in compatibility test procedures 11-2 and 11-3. The results of discriminator performance are tabulated in Tables 53–58. The bit error performance was added to the bit error vs signal level curve of compatibility test procedures 11-2 and 11-3 and included in this section (see Fig. 34). The tests (compatibility test procedure 11-7) were spot-checked by the 1100-bits/s PCM FM/PM multiplexed with three FM/PM strain gage channels at only one SNR of 8 dB in the discriminator bandpass. The results of the discriminator performance are tabulated in Table 59.

(4) The tests (compatibility test procedure 11-7) were spot-checked by the 4400-bits/s PCM FM/FM accelerometer channels. The results of the discriminator performances are tabulated in Table 60. Noise measurements of the CEC recorder interface lines were also repeated during these tests.

Table 53. Telemetry SCO channel vs bit error rate

Telemetry channel, kHz	RF level,[a] dBmW	SNR demodulator in	SNR demodulator out	SNR bandpass		SNR discriminator out	Bit errors in 10^5 transmitted bits	
				Unmodulated	Modulated		CDC	Computer
33	−126.1	−7.62	−11.5	8.6	7.6	16.7	239	485
7.35	−133.7	−2.9[b]	−2.9	8.6	7.8	8.5	222	414
3.9	−138.5	−6.37	−6.70	8.6	7.8	8.9	240	341
0.960	−144.9	−5.41	−5.86	8.6	7.8	8.9	316	484
0.560	−152.4	−16.4	−13.3	8.4	7.6	12.2[b]	236[b]	1156

[a]RF level is path loss method of calculation.

[b]Questionable data.

Table 54. 33-kHz SCO FM/PM performance

Parameter	Specification	Actual
Mode, bits/s	4400	4400
M_{SC}	1.60	1.51
Bandwidth IF (DSIF), kHz	420	420
Nominal measured BW-IF (DSIF), kHz	592.4	594
P_{signal}, dBmW	−129.2 ±2.5	−127.2
$P_{carrier}$, dBmW	−136 ±2.5	−133.3
SNR_B (dB) (unmodulated subcarrier)	8 (+1.0, −0)	8.6
SNR_B (dB) (modulated subcarrier)	—	7.6
Discriminator noise bandwidth, Hz	8,980	10,240
SNR_C, dB	21.6 ±2	16.7

Table 55. 7.35-kHz SCO FM/PM performance

Parameter	Specification	Actual
Mode, bits/s	1100	1100
M_{SC}	0.935	0.932
Bandwidth IF (DSIF), kHz	20	20
Nominal measured BS-IF (DSIF), kHz	27.6	27.7
P_{signal}, dBmW	−135.6 ±2.5	−134.0
$P_{carrier}$, dBmW	−137.6 ±2.5	−136.2
SNR_B (dB) (unmodulated subcarrier)	8 (+1.0, −0)	8.6
SNR_B (dB) (modulated subcarrier)	—	7.8
Discriminator noise bandwidth, Hz	1102	1234
SNR_C, dB	11.8 ±2	8.5

Table 56. 3.9-kHz SCO FM/PM performance

Telemetry channel	Specification	Actual
Mode, bits/s	550	550
M_{SC}	1.10	1.092
Bandwidth IF (DSIF), kHz	20	20
Nominal measured BW-IF (DSIF), kHz	27.6	27.7
P_{signal}, dBmW	−140.4 ±2.5	−138.8
$P_{carrier}$, dBmW	−143 ±2.5	−141.8
SNR_B (dB) (unmodulated subcarrier)	8 (+1.0, −0)	8.6
SNR_B (dB) (modulated subcarrier)	—	7.8
Discriminator noise bandwidth, Hz	586	667.37
SNR_C, dB	12.8 ±2	8.9

Table 57. 0.960-kHz SCO FM/PM performance

Telemetry channel	Specification	Actual
Mode, bits/s	137.5	137.5
M_{SC}	1.45	1.27
Bandwidth IF (DSIF), kHz	4.5	4.5
Nominal measured BW-IF (DSIF), kHz	5.7	6.37
P_{signal}, dBmW	−146.8 ±2.5	−146.0
$P_{carrier}$, dBmW	−152 ±2.5	−150.5
SNR_B (dB) (unmodulated subcarrier)	8 (+1.0, −0)	8.6
SNR_B (dB) (modulated subcarrier)	—	7.8
Discriminator noise bandwidth, Hz	144	168.24
SNR_C, dB	12.8 ±2	8.9

(5) Telemetry converter interface checks with the DIS equipment were run in conjunction with the above bit error checks for each discriminator.

Table 58. 0.560-kHz SCO FM/PM performance

Telemetry channel	Specification	Actual
Mode, bits/s	17.2	17.2
M_{SC}	1.45	1.20
Bandwidth IF (DSIF), kHz	4.5	4.5
Nominal measured BW-IF (DSIF), kHz	5.7	6.37
P_{signal}, dBmW	−154.8 ±2.5	153.7
$P_{carrier}$, dBmW	−160 ±2.5	158.0
SNR_B (unmodulated subcarrier), dB	8 (+1.0, −0)	8.4
SNR_B (modulated subcarrier), dB	—	7.6
Discriminator noise bandwidth, Hz	22.8	23.6
SNR_C, dB	13.6 ±2	12.2

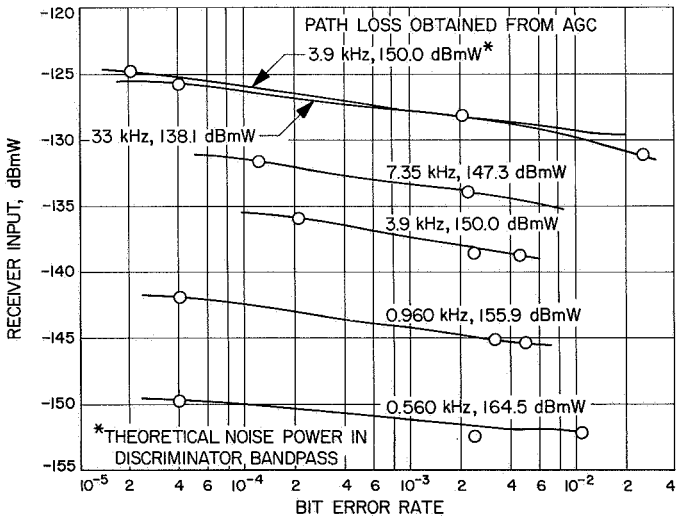


Fig. 34. Bit error rates vs input signal levels

5. *Canberra CDC/DSIF compatibility tests*

a. Test results summary. The results of the compatibility tests were satisfactory checks of the DSIF/CDC interface except as noted in this report. The tests could have been more effective for the following factors:

(1) The test schedule was much too brief and did not allow time to fully analyze the results as the test progressed.

(2) All prerequisite calibrations were not completed which left doubts as to the quantitative value of some of the data.

(3) Also because of other commitments, the station personnel were not able to preview the test procedure or monitor the test performance with their normal thoroughness.

The original objectives of the compatibility tests were to determine the compatibility status and station readiness for the subsequent scheduled tests and ultimately for the *Surveyor I* mission. This was not completely accomplished and required further evaluation of test results, rerunning of some tests, and the performance of additional tests before all of the test objectives were fully satisfied.

Telemetry subsystem. Results indicate the telemetry subsystem bit error rates, demodulator FM improvement, and discriminator FM improvements did not approach their theoretical predictions. Results did compare favorably with the dB control document using the RF carrier power as a reference.

A spot check of performance vs the dB control is given in Table 61.

Table 59. 1100-bits/s PCM FM/FM multiplexed telemetry bit error rate

SCO, kHz	RF level, dBmW	SN demodulator input	SN demodulator output	SN bandpass	SN discriminator output	Bit errors in 10^5 transmitted bits	
						CDC	Computer
7.35	131.9	+0.6	+0.4	7.4	8.2	349	712
5.4	—	—	—	7.8	3.8	—	—

Table 60. 4400-bits/s PCM FM/FM multiplexed telemetry bit error rate

SCO, kHz	RF level, dBmW	SN demodulator input	SN demodulator output	SN bandpass	SN discriminator output	Bit errors in 10^5 transmitted bits	
						CDC	Computer
33	101.9	10.6	27.1	36.4	33.2	0	0
52.5	—	—	—	35.2	34.2	—	—

Table 61. Measured vs calculated system performance

Bit rate, bits/s	SCO frequency, kHz	Power input for 8.0 dB discriminator bandpass SNR, dBmW	11-7, 11-2 power level for 8.0 ±1.0 dB discriminator bandpass SNR, dBmW[a]	Performance margin, dB
Postacquisition, 550	3.9	−116.4	−127.9	11.5 (15.3)
Low-power interrogation, 4400	33	−125.7	−128.6	2.9 (6.7)[a]
Low-power interrogation, 1100	7.35	−123.8	−134.5	10.7 (14.5)
Low-power interrogation, 550	3.9	−134.7	−139.4	4.7 (8.5)
Low-power interrogation, 137.5	0.96	−138.9	−146.8	8.1 (11.9)
Low-power interrogation, 17.2	0.56	−146.7	−153.8	7.0 (10.8)
Vernier descent PM, 1100 + strain gages	7.35	−124.5	−133.7	9.3 (13.0)

[a]DSIF receiver connected to cryogenic load, add −3.8 dB for antenna at zenith.

In all the tests, FR-1400 frequency shift module (FSM) and DR results were obtained with no errors in the Barker Sync Word. DR was considered satisfactory with the following two exceptions:

(1) The 1100-bits/s vernier descent and strain gages PM multiplex telemetry (compatibility test 11-7) had excessive noise on the output of the 5.4 kHz discriminator.

(2) The test plan did not test the 4400-bits/s and the 33-kHz SCO at 3¾ in./s.

Command subsystem

(1) Transmission by the DSIF transmitter were detected by the transponder fed ground command decoder, and proper command decoding was demonstrated by compatibility tests 11-9 and 11-12.

(2) At signal levels called for in the test plans, no command errors were detected. Further measurements of the command word error rate are given in the quick-look report of compatibility test 11-9.

(3) The results from compatibility tests 11-8, 11-9, and 11-12 indicated the requirement for additional evaluation of DSIF transmitter performance. The transponder receiver was tested with the DSIF transmitter instead of the other way round; i.e., the transponder receiver was used as a calibrated device to measure the DSIF transmitter performance.

(4) The test procedures were ambiguous, primarily due to the lack of knowledge about the transponder receiver and the center frequency. Phase-lock amplitude thresholds were difficult to locate in order to determine the receiver center frequency before each test. It was seen to be simpler to zero the static phase error when the meter and drive circuit is suitable.

Television subsystem

(1) Proper gray scale rendition, horizontal and vertical resolution, and PCM telemetry decoding were demonstrated at IF SNR of 10.5 dB and greater. At 10.5-dB SNR, proper recording and playback at the FR-1400 was demonstrated. Additional video noise and picture degradation during playback was noted. No quantitative measurements were taken. No telemetry bit errors were observed in either the closed loop or FR-1400 playback. The measurement of horizontal sync jitter is shown in Fig. 35.

(2) No successful 10-MHz IF recordings using the FR-800 were obtained. It was demonstrated at a later date.

DSIF 42 comments

1. FR-800: A 3.3-MHz bandwidth was required for recording 10-MHz IF, TV video information. The

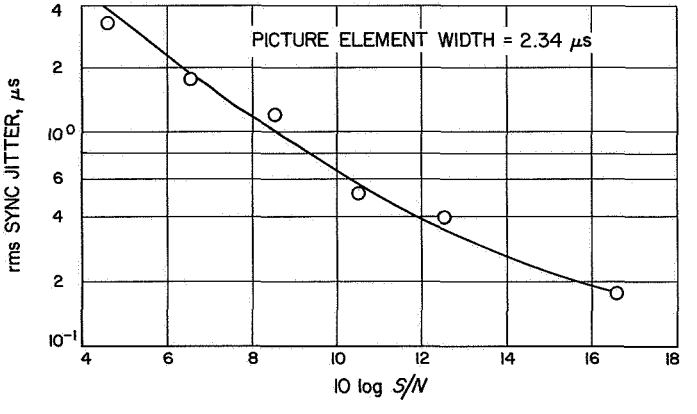


Fig. 35. Jitter vs 10 log S/N, 15 June 1965

specification called for was 1.65 MHz, but no satisfactory recordings were obtained, as mentioned earlier in this report.

2. FR-1400: There were some inconsistencies and questions concerning the documentation for use of this recorder. These were investigated and cleared up.

3. Discussion: The performance of the FR-1400 is summarized as follows:

(1) Direct record at 3¾ in./s satisfactory up to 1100 bits/s.

(2) FSM tested to 1100 bits/s.

(3) WBFM tested at 60 in./s; satisfactory on TV video information.

These results were obtained on one machine that had been fitted with new recording heads. The compatibility could be made less marginal by using the 3¾-in./s FSM electronics at a recording speed of 7½ in./s for FSM. More tests were suggested and performed to establish the typical performance of the FR-1400.

RF system

(1) Good and consistent results were obtained on the downlink using the *Surveyor* test transponder at S-band. Results were stable and within specification. There was confidence that the SNRs were realistic. (See the CDC section for the figures obtained.)

(2) There was only one set of telemetry outlets from the receiver available at that time. This was corrected when the RF J-box was installed.

(3) The two-way phase-lock test was to be expanded to verify whether the doppler frequency shift affects the command system or not.

(4) The CDC transponder should be a known calibrated representation of the spacecraft. This phase-lock test was improved by including a means of assessing the ability of the loop to acquire and remain in lock under expected maximum doppler rate conditions.

A complete review and evaluation was required to assure that the recording requirements are within the practical capabilities of the recorders (including allowance for head wear) when used for multimission purposes.

b. Summary

FR-1400

(1) The recording requirements were reviewed to ensure that the requirements were within the practical capabilities of the recorders to be used for multimission purposes.

(2) A study was initiated to determine the effect of head wear. The study included degradation of signal-to-noise ratio and frequency response for WBFM and DR, and bit error rate for FSM.

(3) A running time log was suggested and kept on each head.

(4) A prerecorded test tape was made available to facilitate alignment.

(5) Further study was required to determine adequate setup and alignment time before mission usage.

(6) Full recording subsystem tests including bit error rates at mission required speeds was performed.

TV photo recorder

(1) The clock brightness and the uniformity of the data lamp lighting was improved.

(2) All test procedures were corrected to reflect the optimum brightness and contrast setting determined in the unit tests.

(3) The brightness and contrast potentiometers were very coarse. Provision was made for finer adjustments.

(4) Evaluation of the effect of the brightness drift as a function of temperature and warmup time was made.

System tester transponder

(1) Provision of front panel monitoring points for the receiver AFC, AGC, static phase error, and dynamic phase error was made.

(2) Provision for on-site capability for measurement of receiver noise figure was made. DSS 42 presently had an HP H63-340B/BR noise figure meter modified for 50-MHz measurements. A modification kit, to allow additional retuning of the noise figure meter IF amplifiers to pass the transponder receiver 47.8-MHz IF signal, was suggested.

(3) Equipment and information to calibrate the receiver (so that it can be used to quantitatively

assess the uplink, including the command system and the transmitter) at representative power levels and frequencies were suggested.

Command

(1) Investigation commenced on the command SCO recording level of the FR-800. The FR-800 replay was clipped and distorted.

(2) Standardization of a tape type for use in the command tape readers and punches was made. A bias level for one type of tape did not work well with another.

(3) Further quantitative measurements were made of the DSIF transmitters performance. There was a wide difference in results obtained in all three station two-way phase-lock threshold tests.

(4) Change of dummy load in DSIF (command) modulation input selector to 50 Ω was made.

Television

(1) Changing the CDC demodulator output to be symmetrical about 0 V, thereby utilizing the full dynamic range of the FR-1400 WBFM capability (6-dB SNR improvement) was recommended. The change required redesign of the PCM television input card in the digital decommutator to accept new television PCM level. All other circuits were ac-coupled.

(2) A fix for FR-800 performance with the spacecraft television transmitter signal was investigated, as was FR-800 recording requirements and specifications.

(3) Compatibility test 11-4 results, transponder transmitter TV input, and the CDC demodulator were examined.

(4) Television picture quality using FR-1400 playback was investigated, as well as termination of FR-1400 playback lines.

Telemetry

(1) FR-1400 recording was not attempted in the 4400-bits/s 33-kHz SCO spacecraft telemetry mode at 3¾ in./s. The compatibility at this mode was tested.

(2) Investigation of the FR-1400 playback degradation of the discriminator signal to noise ratios when in the multiplex telemetry WBFM mode was initiated.

(3) The stability of the digital decommutator oscillator at 17.2 bits/s was investigated. Not all of the 17.2-bits/s low-data-rate bit errors were related to the system signal-to-noise ratio. In the PCM telemeter subsystem test 151, it was impossible to lock the digital decommutator at the low bit rate with only one transition every 16 bits.

(4) Measurement was made of the 4400-bits/s 33-kHz SCO bit error rate vs discriminator bandpass input SNR and DSIF receiver input power when the proper (33 ±1.98 kHz) flight discriminator channel selectors are received. The 33 ±4.5-kHz discriminator channel selectors were used for the tests.

(5) A retest of the 4400-bits/s computer bit error program with input–output unit generated interrupt pulses was made.

(6) A composite two-way test was required including telemetry, command, and doppler at maximum doppler rates.

(7) Selected tests to demonstrate compatibility with the paramplifier were repeated.

(8) Recalculation of the discriminator FM improvements using the measured input and output filter response was accomplished.

(9) The HP 394A attenuator was recalibrated. Error analysis indicated a possible consistent error of 0.5 dB.

(10) The CDC installation of 47-Ω resistors in discriminator outputs to DSIF was made.

(11) A study was made of the 5-dB offset of PCM bit error rates above theoretical.

c. Test results

RF power calibrations (compatibility test procedure 11-1). For the RF calibration section of this procedure, the measured input signal agreed within 0.61 dB of the *KTB* figure (defined on next page) when the 3.3-MHz BW filter was selected for receiver 2. This section was run with the receiver switched to the cryogenic load. As stated in the quick-look report on compatibility test 11-1 the 3.3-MHz BW was not known, it has subsequently been measured and found to be 2.96 MHz. During the series of signal level checks the power level as indicated by the receiver AGC voltage agreed with the power level as measured at the transponder output plus the attenuation and cable losses within 1.3 dB. For this series of checks

the specification was that the power levels were to agree within 1.5 dB. The results of this test are as follows:

(1) In the individual rack RFI check, the DSIF receiver 2 threshold was determined to be −174.9 dBmW.

(2) During the transponder leakage RFI checks, it was not necessary to phase-lock the DSIF receiver; this indicated good RFI shielding.

(3) While using the 420-kHz BW filter the *KTB* figure agreed with the measured input signal within 1.2 dB. During the series of signal level checks the power level as indicated by the receiver AGC voltage agreed with the measured signal level within 1.4 dB. The specification was 1.5 dB.

(4) In using the 20-kHz BW filter the *KTB* figure was 2.4 dB below the measured input signal and out of specification. In the quick-look report the input level determined by the AGC was inadvertently used rather than the measured signal level. Through the series of signal level checks the power, as indicated by the receiver AGC voltage, agreed with the measured signal level within 1.2 dB.

(5) With the 4.5-kHz BW filter selected the *KTB* figure was 1.6 dB below the measured input signal. The series of signal level checks revealed the power level, as indicated by the receiver AGC voltage, agreed with the measured signal level within 1.0 dB.

(6) In the other compatibility tests where the receiver was switched to the cryogenic load, the RF precalibration checks were well within the 2-dB specification.

(7) Table 62 gives the downlink 10-MHz bandwidths on receivers 1 and 2.

(8) The measured BWs represent the width of a rectangle with area equal to the area under the power-response-vs-frequency curve and height equal to the response at exactly 10 MHz. Most of the response curves were double-peaked. These bandwidths were intended to be those at the CDC 10-MHz demodulator input. The data from which these curves were obtained was taken by the DSIF staff in May 1965. Errors in these numbers were estimated to be less than 0.8 dB.

Table 62. Downlink 10-MHz bandwidths

Nominal frequency	Receiver 1		Receiver 2	
	Measured BW	10 $\log_e$ BW, dB	Measured BW	10 $\log_e$ BW, dB
4.5 kHz	7.92 kHz	39.0	6.46 kHz	38.1
20 kHz	27.6 kHz	44.4	31.6 kHz	45.0
420 kHz	642 kHz	58.1	624 kHz	57.95
3.3 MHz	2.96 MHz[a]	64.7	2.96 MHz[a]	64.7

[a]Included CDC 3.3-MHz filter.

DSIF receiver output SNR, telemetry error rates, recordings, and discriminator performance (compatibility test procedures 11-2 and 11-3). This test was performed to verify the DSIF-CDC output signal-to-noise ratio for both FM and PM modes of operation. A check of the demodulator FM performance was demonstrated in these tests. Telemetry bit error rate tests were performed at bit rates of 4400, 1100, 550, 137.5, and 17.2 bits/s each at a SNR of 16, 11, and 8 as measured in the discriminator bandpass (PM). A comparison bit error rate test was conducted utilizing the RF-1400 tape recorder for the 3.9-kHz SCO with both low modulation index (0.3) and normal modulation index (1.10) on the test transmitter. The overall DSIF-CDC telemetry channel performance operating near threshold was a main objective of this test.

The results for this test are as follows:

(1) The summary of test results for compatibility tests 11-2 and 11-3 was tabulated in a special form for ease of comparison of results at the various signal-to-noise ratios. These tables were presented in the quick-look report.

(2) In addition to the tables discussed previously, curves are shown in Fig. 36 representing bit error rate vs 10 log (SL/NB), where S = power in first sidebands, L = bit length, N = noise power, B = noise bandwidth, and NB = noise density = KT (Boltzmann's constant times temperature in °K).

(3) Conclusions that may be drawn from these curves indicate that, in general, the bit error rates for the various signal-to-noise ratios and bit rates are grouped around 5 dB from theoretical. The significance of this offset from ideal is a subject for further study.

(4) Deviation from the procedure existed in the following cases:

(a) Carrier suppression was measured at the unattenuated output of HP 394A at the CDC using the Lavoie spectrum analyzer. This was true for each case where the carrier suppression measurements were required in the FM mode.

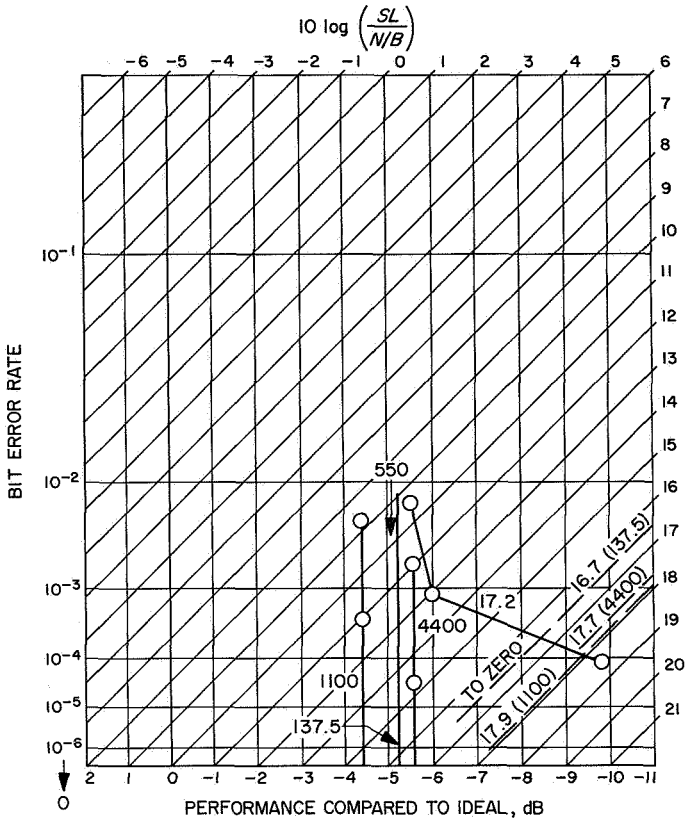


Fig. 36. Bit error rates vs *SL N/B*

(b) The PM/TM gain was required to be set at 30 dB. The provisions on the panel were for 0, 20, and 40 dB. The setting at a gain of 20 dB was used.

(c) A buffer amplifier (bay 15) was included between the PCM simulator output and the FR-1400 tape recorder input. During playback, J2, J3, and J4 at the rear of the PCM simulator had to be removed to allow access to the bit error detector and decommutator inputs.

(5) The results of FR-1400 DR 3¾-in./s tape playback of 550 bits/s, 3.9-kHz SCO PCM telemetry indicated negligible degradation from the recorded closed loop.

Telecommunication frequency response (compatibility test procedure 11-4). This test was a check on the wideband FM telemetry channel with the DSIF 10-MHz output driving the CDC demodulator.

1. Results:

(1) The CDC transponder was directly sine-wave modulated with frequencies from 1 to 500 kHz, at a constant 10-V peak-to-peak, giving a deviation of ±1.25 MHz, and the resulting S-band FM/FM signal was adjusted to a strong signal level of −96.5 dBmW at the DSIF master input.

(2) The filtered demodulator output was monitored at each frequency.

(3) In addition, the DSIF recording ability was checked by recording the demodulator output signals on the FR-1400 tape recorder, the 10-MHz IF (via the up/down converter) on the FR-800, and comparing the playback with the direct readings.

2. Summary:

(1) The TV telecom link frequency response was generally out of spec, but later responded well after adjustment.

(2) There was also a sharp dip in the demodulator output response curve, which could have been due to overmodulation of the transponder at this frequency. This would conceivably give rise to amplitude modulation of the signal with consequent drop in demodulator input.

(3) The FR-1400 playback frequency response dropped off badly at high frequencies. This was due to CDC line being unterminated.

(4) The FR-800 performed well as the results of pretest frequency check indicated. During the actual test the recorder failed at 150 kHz, but the results obtained up to this point were good, and promised to follow the "dummy-run" values closely.

3. Conclusions:

(1) It was found that the telecom link frequency response was 3 dB down at approximately 300 kHz on direct and about 120 kHz on FR-1400 WBFM playback at 60 in./s.

(2) The test procedure provided no problems and was easily followed.

TV horizontal sync (compatibility test procedure 11-5). The results of this test are as follows:

(1) At +10.5-dB SNR in the 2.96-MHz bandpass (which is equivalent to −111.7 dBmW signal at the maser with a noise temperature of 165°K), the rms line-to-line sync jitter is estimated at 0.34 pixel.[7]

[7]Pixel = width of one picture element = 1/600 of a line.

However, the jitter measurement accuracy was low and was estimated at +60%, −40%. There was no frame ID PCM error observed even at 6.5-dB SNR.

(2) The tape recording and playback of the video-WBFM and PCM-FSM was investigated. The poor illumination in the TV frame ID box was corrected.

(3) Table 63 shows the 90% group width of measured horizontal synchronization.

Table 63. Estimated 90% group width of measured horizontal sync[a]

SNR, dB	Estimated 90% spread, μs	Calculated rms, μs
4.5	11	3.3
6.5	6	1.8
8.5	4	1.2
10.5	1.7	0.52
12.5	1.3	0.4
16.5	0.6	0.18

[a]A +50%, −30% accuracy might be expected on the time values.

TV test pattern (compatibility test procedure 11-6). During the performance of this TV test all photo recording was done with the white level CRO cathode current adjusted to 2.2 μA. In an earlier subsystem test it was ascertained that the 2.2-μA value, produced a graybar photo where all ten levels were discernible while using the TV signal generator. As a matter of interest our TV photo recorder serial number 49004 required a CRO cathode current white level adjustment of 2.75 ±0.25 μA for best rendition of the ten gray levels.

The results of the test are as follows:

(1) The 60-Hz modulation appearing on the TV recording was resolved by shielding a video input wire in the video processor which was cabled in the harness carrying 60-Hz power.

(2) There was a noticeable jitter on the horizontal resolution lines recording with an IF signal-to-noise ratio of 7 dB.

(3) Incorporation of ECA 111111 in the TV signal generator greatly improved the quality of the TV recordings.

(4) No success was obtained on FR-800 playback; however, results indicated that FR-1400 performed satisfactorily with some (unmeasured) degradation.

(5) Figure 35 gives the rms sync jitter vs 10 log S/N at DSS 42 Canberra, June 15, 1965.

Multiplex telemetry (compatibility test procedure 11-7). The purpose of this test is to check the performance of the FM/FM and FM/PM multiplex channels and the compatibility of the CDC-DSIF oscillograph recordings. These tests were performed primarily to determine the bit error rates of the 4400-bit/s PCM FM/FM channel when multiplexed with the six FM/FM accelerometer channels and the 1100-bits/s PCM FM/PM channel when multiplexed with three FM/PM strain gage channels. A secondary purpose of the compatibility test procedure 11-7 test was to check the compatibility of the DSIF CEC and CDC low- and high-frequency oscillographs.

The results of this test are as follows:

(1) All FM multiplex recordings on the FR-1400 were made at a tape speed of 60 in./s. The PM tests were run at 3¾ in./s.

(2) The FR-1400 60-in./s direct record playback indicated a large degradation of the signal-to-noise ratio at both the discriminator input bandpass and output. No alignment at 60 in./s at the recorder was attempted prior to running the test due to tracking commitments and a tight time schedule.

WBFM test results are summarized in Table 64. All bandpass-signal-to-noise ratios are for the SCO unmodulated at center frequency.

In summary, the DSIF CEC did not have the capabilities to record 1 kHz. The high-frequency oscillograph compatibility tests were run at 100 Hz.

The FR-1400 3¾ in./s direct record playback of the PM multiplexed telemetry indicated satisfactory results except for signal-to-noise degradation at the 5.4-kHz discriminator output. This portion was later retested. Results are summarized in Table 65.

Two-way phase-lock threshold (compatibility test procedure 11-8). The results of this test are as follows:

(1) Keeping the CDC ground transponder receiver in phase lock 50% of the time required about −136.3 dBmW of unmodulated DSIF power at the mixer input. With modulation on at a carrier suppression of 6.6-dB, an additional 6.6 dB power was required. Keeping the DSIF receivers in phase-lock 50% of the time required about −170 dBmW (determined directly from the AGC curves) of center frequency carrier power at the maser, regardless of the modulation. The transponder receiver center frequency drifted a few kHz (at S-band) which

Table 64. WBFM telemetry including FR-1400 60-in./s direct record performance

Discriminator frequency		Discriminator SNR, dB							
		Bandpass	Output	Bandpass	Output	Bandpass	Output	Bandpass	Output
33 kHz	Direct	40.8	29.7	39.6	29.3	36.0	28.1	27.7	21.7
	Playback	33.1	27.2	33.1	26.9	31.0	27.1	25.5	21.1
	Playback degradation	7.8	2.5	6.5	2.4	5.0	1.0	2.2	0.6
52.5 kHz	Direct	34.8	39.1	34.4	38.2	31.8	35.6	26.8	29.5
	Playback	29.8	34.0	29.8	33.4	27.6	32.9	25.3	28.5
	Playback degradation	5.0	5.1	4.6	4.8	4.2	3.0	1.5	1.0
RF input level[a]		−93.3 dBmW		−101.7 dBmW		−104.8 dBmW		−107.7 dBmW	

[a]DSIF receiver connected to cryogenic load, add −3.8 dB for antenna at zenith.

Table 65. PM telemetry including FR-1400 3¾-in./s direct record performance

	Units	Direct	P.B.	Degradation	Direct	P.B.	Degradation	Direct	P.B.	Degradation
7.35-kHz discriminator bandpass SNR	dB	15.9	14.3	1.6	12.7	12.7	0.0	8.5	7.9	0.6
Discriminator output SNR	dB	18.8	17.1	1.7	13.0	12.7	0.3	8.7	8.6	0.1
1100-bits/s bit error rate	$\times 10^{-3}$	0.00	0.00		0.022	0.032		8.2	9.2	
5.4-kHz discriminator bandpass SNR	dB	16.1	15.0	0.9	12.3	11.6	0.7	8.0	7.7	0.3
Discriminator output SNR	dB	20.4	11.4	9.0	12.3	9.0	4.3	7.3	5.9	1.4
RF input level[a]	dBmW	−125.7 dBmW			−129.7 dBmW			−125.5 dBmW		

[a]DSIF receiver connected to cryogenic load, add −3.8 dB for antenna at zenith.

made it difficult to find. Also, the transponder receiver would lock up on a command subcarrier sideband if given a change with the DSIF transmitter away from the receiver center frequency. Because of this, the test required three runs on separate days before true results were obtained.

(2) It was found test points for suitable AGC, AFC, and SPE voltages needed to be brought to the ground transponder front panel.

(3) The two-way phase-lock test procedure was rewritten to fit the particular threshold characteristics of the CDC-DSIF system before it was used again. (The procedure was very difficult to follow and to obtain consistently good results.)

(4) The two-way phase-lock threshold test was originally run on May 25, 1965. After some comparison of results it was obvious that in the transponder phase-lock computation the receiver had either drifted or the DSIF transmitter frequency was offset slightly from the receiver bandpass center frequency.

(5) Initially the receiver had a warmup period of about 1 h and was run with the cover off to allow monitoring of the phase error. The test was rerun after the receiver had been on for several days and all covers were in place. The difference in the center frequencies for the two tests was 3.798 kHz at S-band. This resulted in a difference of 20 dBmW on the transponder phase lock threshold computation with the DSIF unmodulated and the system tester modulated at a modulation index of 0.3.

(6) The downlink phase-lock computation with the DSIF unmodulated and the system tester modulated at a modulation index of 1.6 was −171.3 dBmW during the first run and −168.3 dBmW on the rerun.

(7) During the first run the DSIF receiver was connected to the antenna at zenith, during the second the receiver was connected to the cryogenic load.

(8) The uplink phase-lock threshold computation with the DSIF modulation index at 1.6 and the system tester modulation index at 1.6 resulted in −120.26 dBmW during the first run and −129.7 dBmW on the rerun.

Command transmissions and word error rate (compatibility test procedure 11-9). The results of this test are as follows:

(1) The command word error rate was about 0.008 with −121.0 dBmW and about 0.5 with −122.9 dBmW of DSIF klystron power into the CDC ground transponder receiver mixer. The transpond mode was off.

(2) Unless the test was run at a signal level low enough to create some errors, there was no quantitative measure of threshold, and indeed there was no doubt as to whether the error measuring system was even working.

(3) The approved test procedure required long error counting intervals at high signal levels where the error rate was too low to measure. The procedure did not require measurements at signal levels where the word error rate could be measured.

(4) The dummy load in the DSIF (command) modulation input selector was changed from 2000 to 50 Ω in order to match the input impedance of the DSIF ×3 multiplier and phase modulator. The FR-800 tape recorder was overmodulated by the command SCO signal. However, it worked within the limits of the test.

Timing displays (compatibility test procedure 11-10). The DSIF supplies three forms of time code signals for use with the CDC. These are:

(1) Serial 36-bit code, at 100 pulses/s on 1-kHz carrier.

(2) Serial 28-bit code at 2 pulses/s without 100-Hz carrier.

(3) Parallel BCD time.

1. Results:

(1) The 28- and 36-bit time codes were checked on an oscilloscope for pulse amplitude and, in the case of the 36-bit code, for maximum and minimum amplitude of the 1-kHz carrier. Then the traces on the respective oscilloscope were examined for timing and data accuracy.

(2) The BCD timing signals were compared for accuracy with the equivalent DSIF time readouts, and in addition, the dc signal levels were measured at three "spot" times, the DSIF astro data timing generator being held at these times for the duration of the measurements.

(3) During the test itself, only one minor item required attention. One of the BCD signals was low in amplitude and was a result of a fault in a line feeding DSIF equipment from the astro data generator in parallel with the CDC.

(4) Prior to carrying out the test, however, it was noticed that the BCD readout was not indicating correctly. This was due to incorrect wiring in the system junction module and was remedied before the test commenced.

2. Conclusions:

(1) The test procedure was adequate in describing a method for checking out the DSIF CDC timing signal compatibility.

(2) The test results were good, proving that the signals were, in fact, compatible. All final results were within specification.

CDC/OSDP checkout (compatibility test procedure 11-11). Compatibility test 11-11 was performed at Canberra DSS 42 without encountering unusual difficulties. Problems and equipment failures located during the performance of the test were considered minimal.

Summary. The following difficulties arose during performance of the test:

(1) In various steps of testing, the computer failed to output data to the CDC typewriters.

(2) Character differences existed between the SDS computer typewriter and the CDC typewriters.

(3) Both paper punches failed to operate normally.

(4) Tape reader 2 had no output from track 4.

(5) Tape reader 2 had no output.

(6) CDC typewriters ran open when addressed through *W* buffer coupler.

(7) Reader-punch-typewriter switching unit had weak and missing switch illumination.

(8) Both paper punches were oil-soaked when uncrated.

2. Conclusions: Results obtained in performing compatibility test 11-11 indicated that no serious interface problems existed between the CDC and DSIF OSDP equipment. Some degree of waveform distortion was noted, particularly in pulse rise time; however, the equipment functioned in a normal manner.

3. Recommendations:

(1) Most of the problems noted herein were found to be caused by simple component failure. These discrepancies were repaired and properly documented. Problem 1 above, however, was the result of a mistake in the test procedure. It was recommended that the test procedure be amended as per change request submitted from this station.

(2) One potential problem area was noted on the tape readers. Only about 0.1 in. of clearance existed between the exciter lamp housing and the front exciter lamp socket. This end of the socket has −25 V dc on it. Pressure could be exerted on the lamp housing causing it to short out the lamp socket. It was recommended that insulating material be placed on the inside surface of the housing adjacent to the lamp socket.

(3) A temporary modification was incorporated into the tape readers at DSS 42 to ensure greater reliability.

Composite system test (compatibility test procedure 11-12). This test procedure was difficult to perform. The results are summarized and interpreted in the quick-look report. However, no new major problems were found in this test.

The main problem concerning the test procedure was that many measurements were compared to the signal-to-noise ratio in a subcarrier discriminator predetection bandpass. It was found that composite or overall system performance could be better measured by comparing the RF input power to the output signal quality. The output signal quality could be measured by (1) bit or word error rates for digital signals, (2) photo recordings for TV, and (3) frequency responses and peak-to-peak signal to rms noise ratios (through a calibrated filter) for analog telemetery. The measurement of signals and noise at intermediate points within the system can be good for fault tracing, but they obscure the overall performance measurements.

6. T-21/Goldstone compatibility test. In addition to the foregoing compatibility tests between the DSIF and the CDC, a series of tests between the T-21 spacecraft and Goldstone (DSS 11) began in August 1965.

These tests involved the T-21, DSS 11, the CDC, and the SFOF. The testing was designed to establish mutual compatibility between each of the aforementioned elements of the TDS. A photograph of the T-21 spacecraft is shown in Fig. 37. This spacecraft was located in the Goldstone Spacecraft Test Facility, built specially for this testing, which was completed in July 1965. The Spacecraft Test Facility is shown in Fig. 38.

Testing commenced at DSS 11 on Aug. 2, 1965 and was conducted over a 9-wk period through Oct. 8, 1965.

This section presents a statement of the accomplishments achieved, the problems encountered during the engineering compatibility tests, and a narrative of the results of the mission independent portion of the operator training tests. The objectives of the various engineering compatibility tests are listed, along with a brief discussion of the test results. It reviews the planned and actual test schedule and summarizes the problems encountered that are considered to be unrelated to the compatibility (or incompatibility) of the *Surveyor* SFOS. Included here are RF link problems, equipment failures, and test constraints. Schedule and procedural problems are discussed in general terms.

There is a listing of the problems uncovered (or reconfirmed) that were considered to reflect on the compatibility of the various elements of *Surveyor* SFOS. The problems are grouped according to the test sequence in which they appeared. However, they were generally recurrent throughout the tests. There is a summary of the results of the mission independent operator training tests.

a. Test objectives. The purpose of this section is to review the objectives of the T-21/SFOS compatibility tests at Goldstone and to briefly state the degree to which they were attained.

Spacecraft/DSIF/CDC verification test. The objective of this test was to demonstrate, prior to the initiation of the engineering compatibility tests, that there were no gross system incompatibilities that might preclude the successful accomplishment of those tests.

No insurmountable incompatibilities were found as a result of this test.

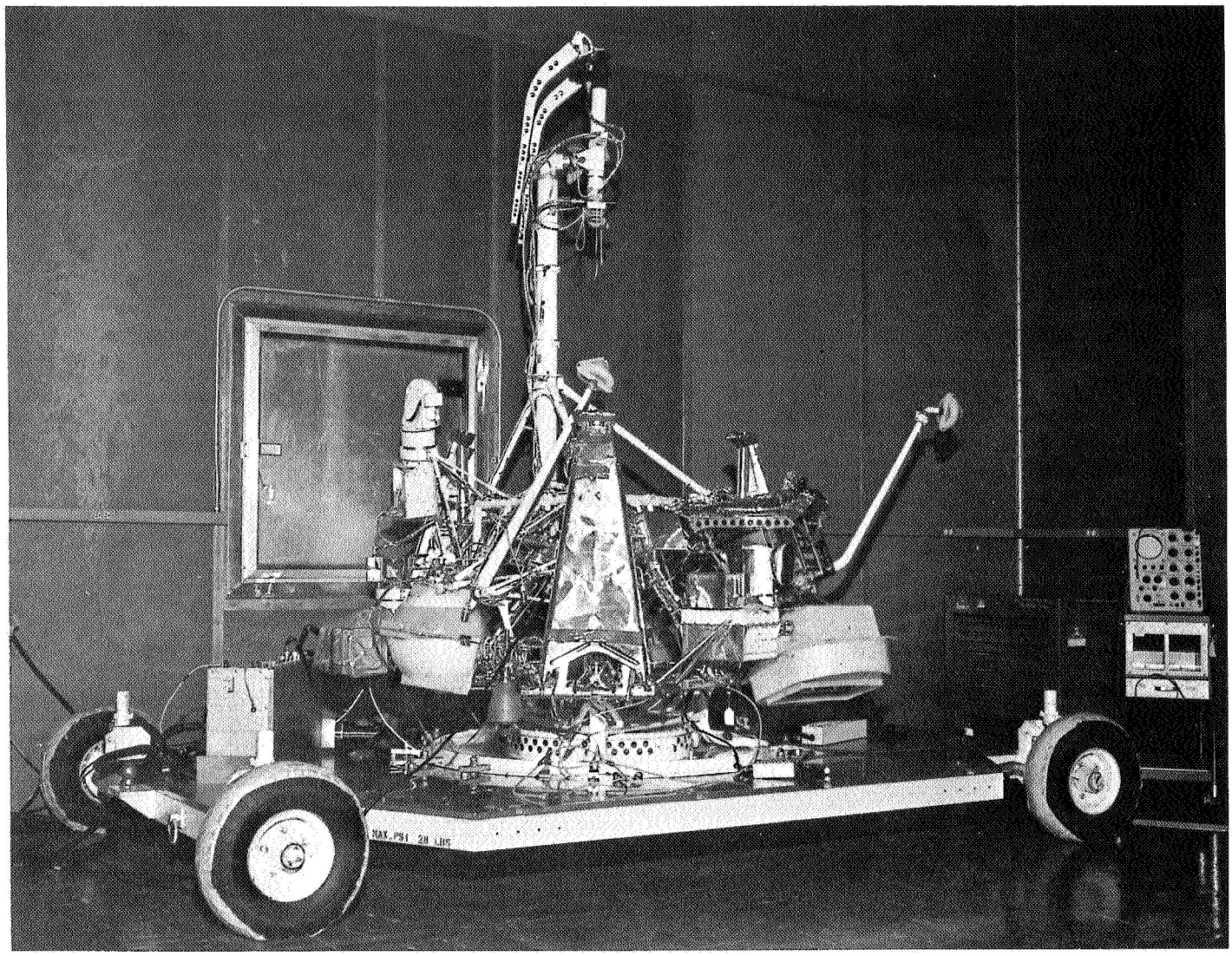


Fig. 37. *Surveyor* T-21 spacecraft

RF compatibility tests. The objective was to demonstrate the ability of the DSIF S-band system to communicate with the spacecraft for all spacecraft RF system configurations.

The results demonstrated the basic compatibility of the *Surveyor* spacecraft and DSIF RF systems. Spacecraft and ground receiver phase-lock thresholds were generally found to agree with specified or theoretical values to within the measurement accuracy. Spacecraft receiver AFC and phase-lock tuning ranges were found to exceed specification. No spurious responses were found on uplink or downlink signals. All spacecraft RF system configurations were acquired.

Command compatibility tests. The objective was to demonstrate the ability of the DSIF/CDC to command the spacecraft in both spacecraft receiver operating modes, APC and AFC.

Preliminary analysis of the test data indicated that the command word error rate falls within the tolerance allowed about the specified figure with at least 90% confidence. Little difference in command word error rate was observed between the APC and AFC receiver modes. Nor was any significant difference in error rate found for these receiver modes for the various DSIF transmitter frequencies that might operationally be used during a mission relative to the spacecraft receiver's AFC center frequency or phase-lock best lock frequency.

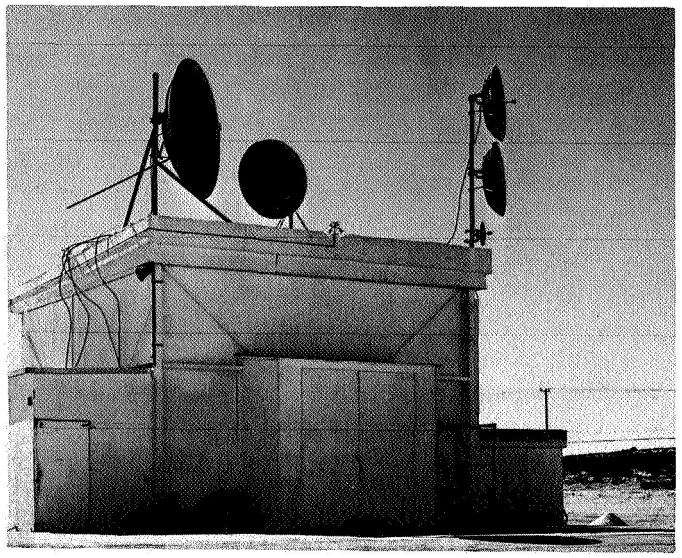


Fig. 38. *Surveyor* spacecraft test facility, Goldstone

Telemetry compatibility tests. The objective was to demonstrate the ability of the DSIF and CDC equipment to receive, detect, process, display, and record the spacecraft telemetry data in all spacecraft telemetry modes.

Except for the 4400-bits/s–33-kHz SCO channel which was known to be nonflight-equivalent, all telemetry subcarrier power levels and signal-to-noise ratios generally met specification. As expected, the PCM telemetry error rates failed to meet specification. This is a known problem of long standing. No new problems were discovered. All spacecraft telemetry modes were tested including PCM/FM/PM low- and high-power modes, PCM/FM/FM, PCM/FM/FM and analog/FM/FM multiplex, and PCM/FM/PM and analog/FM/PM multiplex.

Television engineering compatibility tests. The objective was to obtain the necessary data to allow a quantitative assessment to be made of the performance of the spacecraft TV system and of the effects, if any, of the ground TV processing and recording subsystems on the quality of the TV pictures.

Sufficient data were obtained to allow the required analyses to be made. Only preliminary analysis has been made to date. The real-time performance of the DSS 11 CDC TV subsystem and of the television GDHS was satisfactory in both the normal and 200-line TV modes. It was, however, necessary to build a special noise quieting circuit for the CDC to prevent noise triggering of the video processor during 200-line TV camera off times. Major problem areas are the inability to obtain high quality recordings of the predetected TV signal on the DSIF FR-800 tape recorder, and the degradation of the predetected TV signal after transmission over the DSS 11 to SFOF microwave line.

Television functional compatibility tests. The objective was to provide SSAC personnel an opportunity to practice *Surveyor* post-landing survey command sequences, to provide experience in the real-time analysis of, and response to, actual spacecraft TV pictures, and to demonstrate the ability of the *Surveyor* TV ground equipment to provide the necessary high-quality TV data required by the SSAC personnel.

All specified test sequences were ultimately accomplished. The degree to which the objectives were met is a matter of conjecture. The greatest benefit of the tests was in emphasizing the effects of the problem areas discovered here and during the engineering tests.

b. Test conduct problems. During the course of the T-21/SFOS tests a number of problem areas arose. For purposes of discussion, they may be separated into the following categories: (1) schedule, (2) procedural, and (3) technical. The first two classes of problems will be discussed in this section. The last class of problems, the technical ones may be further divided into compatibility and noncompatibility problems. The compatibility problems are those which, if not resolved, could affect the performance of the SFOS during a mission. The noncompatibility problems are those related in one way or another to the test configuration. They are discussed in this section.

Schedule problems. The requirement to conduct the T-21/SFOS tests for 20 h each day through the greater portion of the engineering tests had at least two adverse effects. First, insufficient time was left for routine system maintenance and calibration in the DSIF and CDC areas. This resulted in more time having to be given over to these functions from the T-21 test time as part of the station countdown procedure. Secondly, the extended test days resulted in people being spread rather thinly. This was especially true among members of the test conduct team with the result that the test conductor had to serve also as the real-time data evaluator and official record keeper. As a consequence, the latter two functions were not adequately accomplished. The most obvious evidence of this is a set of cryptic and often incomplete notes.

It is recommended that future tests of this type be performed on not more than a 10-h per day basis. Further, the necessary area countdown procedures should be scheduled to be complete by the start of the daily compatibility tests and not be considered a part of the tests. In this way two 8-h shifts would provide for the 10-h test day and leave 6 h for the daily countdown. The third 8-h shift would be available as necessary for system maintenance and calibration.

Procedural problems. During the conduct of the T-21/SFOS compatibility tests, a number of procedural deficiencies became obvious. Some were merely minor annoyances such as unnumbered pages, failure to carry over procedure step numbers from one page to the next, and typographical errors. Others were more serious and included actual procedure errors, the most common of which was missing commands in command sequences establishing a required spacecraft configuration. The most serious deficiencies were that the procedures did not always include specified results for parameters to be measured and that they lacked adequate descriptions of the test configurations required in each major system area.

The preceding paragraph discusses the deficiencies in the T-21/SFOS compatibility test procedures. A related problem was the general lack of detailed procedures on a subsystem level to implement certain repetitive steps of the compatibility test procedures. As far as obtaining the required data was concerned, the lack of subsystem procedures was compensated for by the experience of the operators. However, should certain data points be questioned during detailed analysis of the test data, the absence of a written procedure to refer back to may prove unfortunate.

It is recognized that a perfect test procedure is something that can only be approached asymptotically. However, most of the problems discussed in the above paragraphs can be avoided by allowing more lead time for the preparation of the test procedures. Also, getting the procedures out in the field sooner would allow time for the subsystem cognizant personnel to generate the required detailed subsystem procedures.

Noncompatibility problems. As previously stated, the problems in this category are related in some manner to the test conduct or configuration and as such would not occur during a mission. One possible exception is equipment failures, which are included here. However, pending further analysis of the failures, they must be considered random occurrences. In addition to equipment failures, the noncompatibility problems include RF link problems and test constraints.

RF link problems. One problem was that the RF link path loss found to vary from day to day by as much as 3 dB. To solve this problem, the RF link was reconfigured and recalibrated on Aug. 30. Following this, the path loss varied by less than 1 dB from nominal.

Another problem was that power at spacecraft receiver input, as determined from AGC, was observed to fluctuate by as much as 10 dB on a short term basis. This problem was also cured by reconfiguration of RF link between screen room and DSS 11. Following this, uplink power was very stable.

7. T-21/DSS 11, 42, and 51 personnel training

a. Introduction. During the latter part of the T-21 test period, at Goldstone, a series of tests were conducted, specifically directed towards training DSIF personnel. Such personnel from the prime stations, designated to support the *Surveyor I* mission, were integrated into Goldstone crews to gain experience with T-21 operational characteristics.

For the early part of the tests a sequence of events was used which exercised all possible modes of the spacecraft generally in the order in which they occur in a mission. Emphasis was placed on spacecraft–DSIF–CDC interaction rather than on data evaluation.

For the latter part of the tests a real sequence of events was used on a condensed time scale. These tests were run from the SFOF using the correct Space Flight Operations staff and procedures.

The tests were arranged such that each of three stations participated in a sample of all the tests, and were thus exposed to all the spacecraft DSIF situations.

b. Results. Early in the tests it became apparent that there was a need for a standard set of DSIF subprocedures, by which DSIF reaction to demands for spacecraft action could be defined and controlled. Such a set of subprocedures was developed, evaluated, and incorporated in the sequence of events used for all the latter tests. As the tests proceeded, various deficiencies in the standard sequence of events became apparent and these were rewritten to permit smoother operation.

The disadvantages of one voice line for both command and net control soon became apparent and led to a complete reevaluation of the relative authorities and responsibilities of net control and SFOF in conducting station operations.

In general, no serious difficulties in spacecraft operation were encountered, although setting the DSIF receiver for correct tuning and video output with the spacecraft in 200-line TV mode required extremely close coordination between Space Flight Operations Director (SFOD), SOC, and Station Receiver Operator.

During the final tests several artificial faults were inserted in the spacecraft, unknown to the DSIF or SFOF personnel, to simulate unexpected nonstandard situations. Most of these were detected, and the correct actions taken to maintain spacecraft/ground communications.

c. Conclusions

(1) The Operator Training Tests proved to be much more useful for both DSIF and SFOF than was originally thought. The importance of this kind of training for all projects was strongly emphasized.

(2) The necessity for a set of DSIF subprocedures to be integrated into the mission sequence of events was thoroughly demonstrated.

(3) The problems arising from the use of one voice line for both mission-dependent and mission-independent traffic could clearly be appreciated by a test of this kind.

(4) In the course of these training tests the DSIF receiver operators learned to interpret and to anticipate the spacecraft reaction to various commands in real time. This experience proved invaluable in dealing with nonstandard situations when they occurred.

(5) The training tests did not reveal any serious operational incompatibilities between the DSIF and *Surveyor*. It should be borne in mind, however, that these were static tests and although conducted on a real-time basis lacked the dynamic tracking situations that exist in a real mission.

(6) It was recommended that in future tests, a greater proportion (50% at least) of the available test time should be devoted to operational compatibility testing.

8. Surveyor I/MOS compatibility test

The results of the *Surveyor I*/mission operations system compatibility test performed at the Air Force Eastern Test Range on several days during the weeks of April 18 and April 25, 1966, are presented in this section. The total effort was divided into two parts: (1) *Surveyor I*/Tel-2 compatibility and (2) *Surveyor I*/DSS 71 compatibility. The first was essentially a functional compatibility test, similar to those conducted by the SFOD, but much more limited in scope. The primary objectives were satisfied on a noninterference basis.

The *Surveyor I*/DSS 71 compatibility test was begun on April 19 as scheduled and was continued on April 20 when more time was required. Since this test was the most complex, required the most time, and yielded the most quantitative results, it is given the most extensive coverage.

The preparation of the spacecraft for the tests, by the *Surveyor I* test team, and their efficient performance during the tests, resulted in all primary test objectives being met.

The overall smoothness and precision evinced during the testing indicated a high degree of dedication and professional competence.

a. Test objectives

Surveyor I/Tel-2 compatibility test. The primary objective of this portion of the *SurveyorI*/MOS compatibility test was to demonstrate the ability of a typical range receiver facility, represented by Tel-2, to receive, detect, and transmit to building AO, the *Surveyor I* telemetry data received via the *Centaur* VHF and spacecraft S-band RF links.

A secondary objective was to measure certain Tel-2 receiver and telemetry subsystem parameters and to collate these with error rate measurements at the STEA-CDC to determine the degree to which the telemetry data recovery equipment approached expected performance.

Surveyor I/DSS 71 compatibility test. The primary objective of this portion of the *Surveyor I*/MOS compatibility test was to demonstrate the ability of a typical DSIF station, represented by DSS 71, to acquire a command configuration with the *Surveyor I* spacecraft. This involved measuring those spacecraft and ground RF systems' parameters that relate to the command link. Such parameters include transmitter and receiver frequencies,

receiver thresholds, and receiver acquisition and tracking ranges.

A secondary objective of this test was to obtain measurements of the *Surveyor I* telemetry modulation parameters to verify the precomputed numbers provided for this purpose, thereby gaining further confidence in the telemetry subsystem's performance predictions that are based upon them.

b. Test descriptions

Surveyor I/Tel-2 compatibility. The MOS requirements for this test as contained herein were forwarded to the AFETR as revisions to OR 3410 and OR 3430. These specified the range support required during the AC-10 propellant tanking/EMI test and the AC-10 J-FACT test, respectively. The test objectives were met on a noninterference basis and required no special test configurations or procedures. The test was essentially a functional compatibility test for the purpose of demonstrating the ability of the STEA-CDC decommutator to acquire lock with the serial PCM obtained from either the *Centaur* or *Surveyor I* RF links via the Tel-2 VHF or S-band receivers, respectively. The signal to the decommutator was switched between the Tel-2 receiver output (after discrimination of the PCM from the subcarrier) and the TDM-1 decommutator reconstructed PCM output. At Tel-2, receiver and telemetry system performance parameters were recorded per the ORs and a tape recording made of the telemetry subcarrier in the Mission A format specified in PRD 3400. At the STEA in building AO, a computer dump of the spacecraft telemetry was made for each input configuration in lieu of an error rate measurement.

Surveyor I/DSS 71 compatibility test. During this test on April 19 and 20, 1966, the *Surveyor I* spacecraft was encapsulated in the shroud and mounted on the AC-10 launch vehicle on pad 36A and this assemblage enclosed by the service tower. On April 19 the directional RF link between the service tower and building AO was operational. DSS 71, being within the beamwidth, thus communicated with the spacecraft through this link. It was a rather one-sided conversation as no command modulation was applied to the DSS 71 transmitter during this test. On April 20, the directional link was not operational because the omnidirectional antenna pickup horns on the service tower were not in place, having been stowed to allow removal of the tower during the EMI test. Thus the link between DSS 71 and the spacecraft was via the omnidirectional antenna through the shroud. This resulted in about 18 dB less signal on the uplink and downlink so that the so-called strong signal uplink tests were not performed at a very strong signal at all. However, this had negligible effect on the test conduct or results. On the contrary, the relatively more stable RF path that resulted made signal power measurements easier to come by. On April 19, using the directional link, signal level fluctuations of ± 1 dB and as much as ± 2 dB were common. On April 20, the typical variation was ± 0.5 dB.

The DSS 71 configuration during this test was as shown in Fig. 39. The variable attenuators between the antenna and the transmitter and receiver were for the purpose

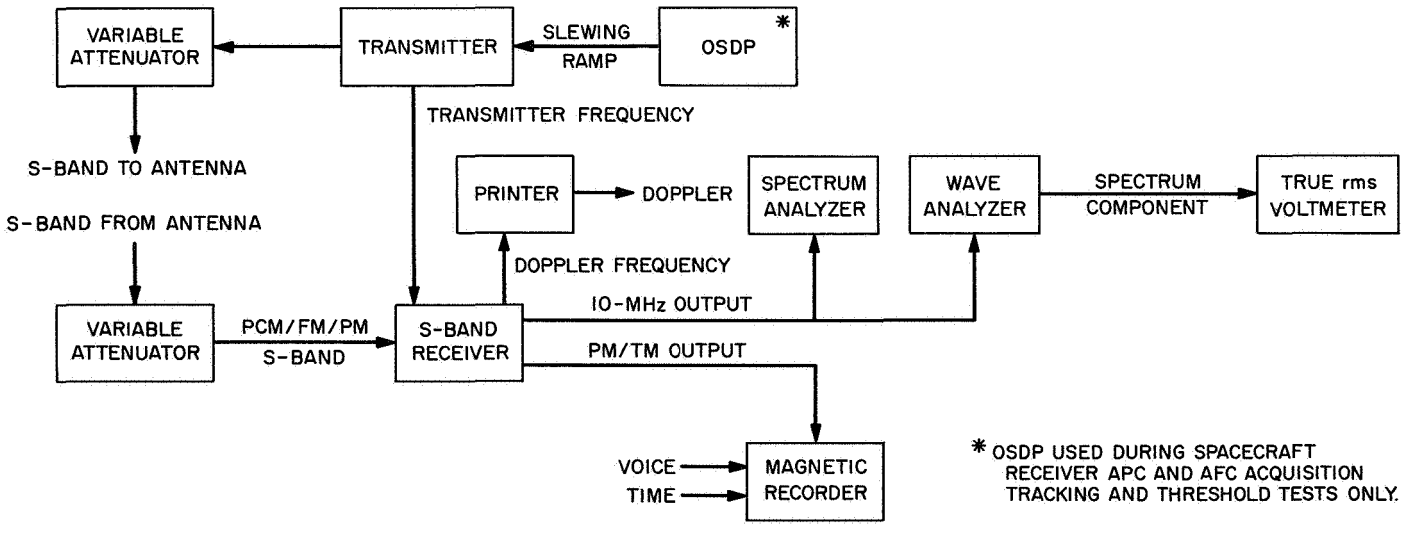


Fig. 39. DSS 71 test configuration

of performing threshold tests of the spacecraft and DSS 71 receivers. The printer was used to print out an apparent biased doppler frequency during the NBVCXO frequency drift test. The spectrum analyzer provided a means of observing the spectral content of the WBVCXO during the WBFM test. The wave analyzer and rms voltmeter (actually the meter was 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 including a special one to obtain sample telemetry data during the telemetry error rate test. The use of the OSDP to control the DSS 71 transmitter frequency represented an innovation to the test procedure and was devised by the station personnel. This technique was especially useful during the phase-lock tuning range test and the APC and AFC acquisition frequencies tests. The computer was programmed to slew the transmitter frequency linearly in time at a prescribed rate. In the phase-lock mode tests, the desired spacecraft reaction resulted in loss of downlink lock which automatically stopped the computer from tuning the transmitter further. In the AFC mode tests, the STEA telemetry engineer reported the occurrence of the desired spacecraft response and the computer was stopped manually. It is felt that this technique represents a significant improvement over the manual procedures followed in the past in terms of the accuracy attainable. It is planned to investigate this technique further before the compatibility tests with *Surveyor II* in order to make optimum use of it.

The lack of a CDC at DSS 71 at that time meant that all uplink tests were performed with an unmodulated transmitter, since the CDC command SCO is the source of command modulation for *Surveyor*. Thus, the results of the various uplink tests are probably optimistic, in particular the threshold determinations at the APC and AFC tracking limits and the APC phase-lock tracking range. However, it was felt that valid conclusions could be drawn in terms of nominal mission performance.

Surveyor I/Tel-2 compatibility test. The STEA-CDC satisfactorily demonstrated the ability to synchronize with the *Surveyor I* spacecraft telemetry received from both the *Centaur* VHF link and the spacecraft S-band link. For each RF configuration, the input to the CDC decommutator was patched to the Tel-2 receiver output and the TDM-1 decommutator in the Tel-2 telemetry processing station. In each case, synchronization of the decommutator was readily accomplished. It should be remembered that the test conditions here did not duplicate the worst case expected. The worst case occurs when the spacecraft telemetry is transmitted from the downrange receiver sites to building AO via the HF data link. The test did serve to show that no new problems are introduced by the RF link.

1. VHF link telemetry: The STEA CDC decommutator successfully acquired lock with the mode 5, 550-bits/s serial PCM telemetry received via the Tel-2 receiver output and the TDM-1 decommutator. A computer dump of the spacecraft commutator was made in lieu of a parity error rate test. The requirement to verify lock of the DSN high-speed data transmission equipment was deleted because the primary communications system between building AO and the SFOF is a nonsynchronous one. The sample magnetic tape recording mode at Tel-2 of the VHF receiver output (before discrimination) was played back at the SFOF telemetry processing station with no problems encountered.

The STEA-CDC decommutator successfully acquired lock with the spacecraft telemetry received via the *Centaur* VHF link. Telemetry data recorded on magnetic tape at Tel-2 was recoverable at the telemetry processing station in the SFOF.

2. S-band link telemetry: The same comments that appear in the preceding paragraph apply here also with the exception that the telemetry was received via the *Surveyor* spacecraft S-band RF link and the Tel-2 S-band receiver.

The STEA-CDC decommutator successfully acquired lock with the *Surveyor I* telemetry received via the spacecraft S-band link. Telemetry data recorded on magnetic tape at Tel-2 was recoverable at the TPS in the SFOF.

Downlink tests

1. Spurious signals: Spurious signals are present only in the high-power mode of the spacecraft transmitter. In every case they are more than 30 dB below carrier power and therefore will be below receiver threshold at initial acquisition based on predicted received carrier levels at that time.

2. Telemetry modulation parameters: *Surveyor I* telemetry modulation parameters fall within the limits specified if allowance is made for the measurement uncertainty due to RF signal fluctuations. There is no measurable change in carrier suppression when the analog-to-digital converter is off (unmodulated subcarrier) as opposed to when it is on.

3. DSS receiver performance: There is no apparent degradation in DSS receiver performance as a function of spacecraft telemetry mode.

4. NBVCXO frequency drift: The maximum rate of change of the transmitter B NBVCXO due to temperature is 3.1 Hz.

5. WBVCXO frequency: The frequency of the transmitter B WBVCXO is 2295.037024 MHz at 80°F. No spurious signals were observed in the spectrum within 20 dB of the carrier.

6. Telemetry subcarrier frequencies: A sample recording of the 0.560- and 33-kHz telemetry subcarriers indicates that the SCO center frequencies are within specification.

Uplink tests

1. Spacecraft receiver phase-lock threshold: Receiver A meets the nominal threshold specification of −128.6 dBmW given at best lock frequency and at ±70 kHz from best lock. Receiver B meets specification only at best lock frequency.

2. Spacecraft receiver AFC threshold: Both *Surveyor I* receivers meet or exceed the nominal threshold specification of −120.8 dBmW at center frequency and at ±40 kHz from center frequency.

3. Spacecraft receiver phase-lock tracking range: Both spacecraft receivers appear to have adequate phase-lock tracking ranges for nominal *Surveyor I* mission requirements.

4. Spacecraft receiver best lock frequency: Test results indicate that nominal best lock frequencies for receivers A and B are:

2113.312800 MHz for receiver A at 77°F[8]

2113.314437 MHz for receiver B at 80°F

5. Spacecraft receiver center frequency: Test results indicate that nominal center frequencies for receivers A and B are:

2113.302336 MHz for receiver A at 77°F

2113.303007 MHz for receiver B at 80°F

c. Surveyor I/DSS 71 compatibility test. It can be generally said that the *Surveyor I* spacecraft and DSS 71 systems met or exceeded specification in all areas tested. One possible exception is the spacecraft receiver B phase lock thresholds at ±70 kHz from best lock frequency. The spacecraft equipment specification does not specifically state that the phase-lock thresholds at ±70 kHz must be the same at best lock frequency however. It was felt that receiver B phase-lock thresholds are adequate to the frequency extremes likely to be required during Mission I so that no adverse effects to the command link may be expected from this cause.

One important unknown in evaluating the results of the uplink tests is the effect command modulation would have on the measured values of spacecraft receiver thresholds and acquisition and tracking frequencies. It is reasonable to expect some degradation but the extent is unknown.

Spurious signals. The test plan specified searching for spurious signals in the down link spectrum under four conditions, i.e., (1) two-way phase lock, low-power mode, (2) two-way phase lock, high-power mode, (3) one-way phase lock, high-power mode, transponder power on, and (4) one-way phase lock, high-power mode, transponder power off.

For transmitter B, all four tests were performed except that during the last one, only a spot check was made to verify in a cursory way that the spectrum corresponded to that obtained in the second and third tests. For transmitter A, only the second and third tests were performed and during these, all spurious signals 30 dB or more below the carrier level were ignored.

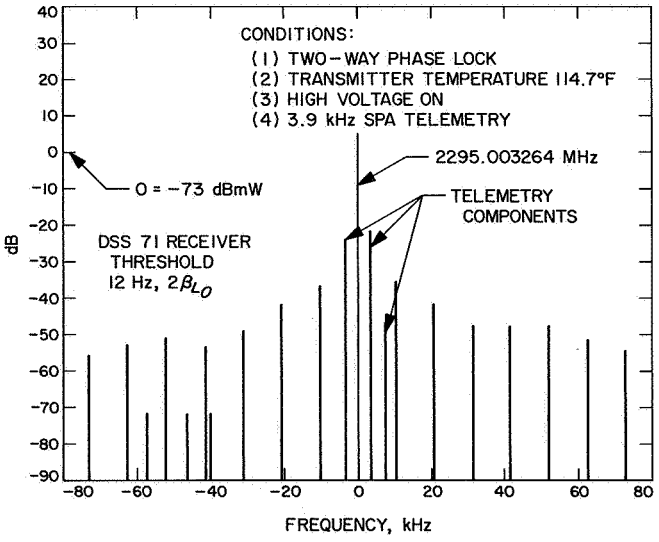


Fig. 40. Spurious signals test results plot

[8]Compartment A lower tray temperature V-16.

The test results for transmitter B are given in Tables 66, 67, and 68. Figure 40 is a plot of the data from Table 67. The spectrum has the characteristic of narrowband frequency modulation and may be due to phase jitter of the NBVCXO in the high-power mode. The unsymmetrical spacing of the spurious signals relative to the carrier in Table 69 is due to the carrier frequency drift of the transmitter in the high-power mode when not phase-locked to the ground transmitter frequency. The carrier was the last signal measured, therefore all spectrum components are displaced in the positive frequency direction.

It is obvious from the test results that the spurious signals are a function of the transmitter power mode and

Table 66. Spurious signals test results

Spacecraft transmitter B SNR 20 — April 19, 1966

Test conditions: (1) Low-power mode
(2) 3.9 kHz SPA telemetry
(3) Two-way phase lock

Test step	DSS receiver VCOX3, MHz	Δf, kHz	Power, dBmW	Relative power, dB	Remarks
002.006	70.156383	0	−92	0	Carrier
	70.156277	−3.39	−113	−21	Telemetry component
	70.156258	−4.00	−115	−23	Telemetry component
	70.156510	+4.06	−113	−21	Possible telemetry component
	70.156527	+4.61	−115	−23	Possible telemetry component
	70.156622	+7.65	−145	−53	Possible telemetry component

Table 67. Spurious signals test results

Spacecraft transmitter B SNR 20 — April 19, 1966

Test conditions: (1) High-power mode
(2) 3.9 kHz SPA telemetry
(3) Two-way phase lock

Test step	DSS receiver VCOX3, MHz	Δf, kHz	Power, dBmW	Relative power, dB	Remarks
002.013	70.156352	0	−73	0	Carrier
	70.156243	−3.45	−97	−24	Telemetry component
	70.156030	−10.30	−110	−37	
	70.155705	−20.70	−115	−42	
	70.155380	−31.10	−122	−49	
	70.155096	−40.19	−145	−72	
	70.155053	−41.57	−127	−54	
	70.154889	−46.82	−145	−72	
	70.154726	−52.03	−124	−51	
	70.154562	−57.28	−145	−72	
	70.154399	−62.50	−126	−53	
	70.154071	−72.99	−129	−56	
	70.156471	+3.81	−95	−22	Telemetry component
	70.156584	+7.42	−120	−47	Telemetry component
	70.156682	+10.56	−109	−36	
	70.157006	+20.93	−115	−42	
	70.157330	+31.30	−121	−48	
	70.157655	+41.70	−121	−48	
	70.157979	+52.06	−121	−48	
	70.158304	+62.46	−125	−52	
	70.158629	+72.86	−128	−55	

Table 68. Spurious signals test results

Spacecraft transmitter B SNR 20 — April 19, 1966

Test conditions: (1) High-power mode
(2) 3.9 kHz SPA telemetry
(3) One-way phase lock
(4) Transponder power on

Test step	DSS receiver VCOX3, MHz	Δf, kHz	Power, dBmW	Relative power, dB	Remarks
002.017	70.155891	0	−75	0	Carrier
	70.155802	−2.85	−99	−24	Telemetry component
	70.155586	−9.76	−112	−37	
	70.155256	−20.32	−117	−42	
	70.154927	−30.85	−120	−45	
	70.154596	−41.44	−121	−46	
	70.154431	−46.72	−132	−57	
	70.154265	−52.03	−121	−46	
	70.154097	−57.41	−131	−56	
	70.153932	−62.69	−122	−47	
	70.156062	+5.47	−90	−15	Telemetry component
	70.156273	+12.22	−111	−36	
	70.156597	+22.59	−117	−42	
	70.156921	+32.96	−119	−44	
	70.157244	+43.30	−121	−46	
	70.157568	+53.66	−122	−47	
	70.157729	+58.82	−132	−57	
	70.157890	+63.97	−122	−47	
	70.158051	+69.12	−131	−56	
	70.158211	+74.24	−124	−49	

are independent of which NBVCXO is in use (i.e., whether the transmitter/receiver is in one-way or two-way phase-lock). The spurious signals should present no problem during initial DSIF acquisition of the spacecraft. The received carrier power at that time is predicted to be about −140 dBmW so that the spurious signals will be below receiver threshold.

For transmitter A, all spurious signals were 30 dB or more below carrier level and were thus not recorded.

According to the test plan, the measurement of carrier suppression and sideband power was done with the spacecraft analog-to-digital converter off in order to obtain a fixed subcarrier frequency. Thus the measured upper and lower sideband frequencies correspond approximately to the SCO lower band edge frequencies. This is also true of the strain gage channels as the strain gage power was not commanded on. When the analog-to-digital converter was commanded back on prior to going on to the next test step, the carrier power was monitored to determine if any change in carrier suppression would result due to the modulated subcarrier. None was observed.

Carrier suppression and sideband power level. The results for this test are presented in Table 69. The specified values for carrier suppression and P_s/P_t (total first-order sideband power relative to the unmodulated carrier) are given. Except in two cases (shown shaded) the results indicate that the *Surveyor I* modulation parameters fall within the allowed bounds, if the measurement uncertainty is taken into account. The two cases shown shaded are considered questionable because the discrepancies in measured carrier suppression and sideband power are contradictory. That is, a greater than expected value of carrier suppression (less power in the carrier) should be accompanied by a relatively greater value of P_s/P_t and vice versa. For example, observe the results of step 002.051. Note, however, that in the two instances questioned, just the opposite of the expected happened.

There is an apparent anomaly in the frequencies measured in test step 002.062. Note here that the upper and lower sidebands for the 5.4-kHz subcarrier are not symmetrically displaced about the carrier as are the other subcarriers in the multiplexed group. The probable explanation is that there is an intermodulation component of

Table 69. Carrier suppression and subcarrier sideband power test results

Test step	SCO center frequency, kHz	Measured sideband frequency, kHz		Carrier suppression, dB		P_s/P_t, dB		Transmitter
		Upper	Lower	Measured[a]	Specification	Measured	Specification	
002.029	3.9 (SPA low power)	3.674	3.678	[b]	$-0.2\ ^{+0.04}_{-0.03}$	-14 ± 0.5	$-13.6\ ^{+0.8}_{-0.9}$	B
		3.685	3.684	[b]	$-0.2\ ^{+0.04}_{-0.03}$	-12.5 ± 0.5	$-13.6\ ^{+0.8}_{-0.9}$	A
002.081	3.9 (SPA high power)	3.601	3.599	[b]	$-0.2\ ^{+0.04}_{-0.03}$	-14 ± 1	$-13.6\ ^{+0.8}_{-0.9}$	B
002.039	0.560	0.555	0.555	-7 ± 2	$-5.3\ ^{+1.1}_{-1.6}$	-4 ± 2	$-2.2\ ^{+0.3}_{-0.4}$	B
		0.553	0.553	-5 ± 1	$-5.3\ ^{+1.1}_{-1.6}$	-2 ± 1	$-2.2\ ^{+0.3}_{-0.4}$	A
002.051	7.35 MX	6.955	6.990	-7 ± 1.5	$-4.5\ ^{+0.8}_{-1.1}$	-5.5 ± 2	$-7.0\ ^{+1.0}_{-1.4}$	B
	1.7 MX	1.555	1.565			-9.5 ± 1.5	$-11.3\ ^{+1.3}_{-1.7}$	
	3.0 MX						$-11.3\ ^{+1.3}_{-1.7}$	
	5.4 MX	5.165	5.185			-10.3 ± 1.5	$-11.3\ ^{+1.3}_{-1.7}$	
		6.984	6.986	-5 ± 0.5	$-4.5\ ^{+0.8}_{-1.1}$	-7.5 ± 1	$-7.0\ ^{+1.0}_{-1.4}$	A
		1.566	1.567			-12 ± 1	$-11.3\ ^{+1.3}_{-1.7}$	
		2.773	2.775			-12.3 ± 1	$-11.3\ ^{+1.3}_{-1.7}$	
		5.190	5.192			-13 ± 1	$-11.3\ ^{+1.3}_{-1.7}$	
002.062	3.9 MX	3.706	3.707	-5.5 ± 0.5	$-5.7\ ^{+1.1}_{-1.0}$	-6 ± 0.5	$-5.9\ ^{+1.0}_{-1.1}$	B
	1.7 MX	1.566	1.566			-12 ± 0.5	$-12.3\ ^{+1.7}_{-1.8}$	
	3.0 MX	2.774	2.774			-13 ± 0.5	$-12.3\ ^{+1.7}_{-1.8}$	
	5.4 MX	5.273	5.191			-14.5 ± 0.5	$-12.3\ ^{+1.7}_{-1.8}$	
		3.706	3.707	-4.5 ± 0.5	$-5.7\ ^{+1.1}_{-1.0}$	-4.8 ± 0.5	$-5.9\ ^{+1.0}_{-1.1}$	A
		1.566	1.566			-11.5 ± 0.5	$-12.3\ ^{+1.7}_{-1.8}$	
		2.774	2.774			-12 ± 0.5	$-12.3\ ^{+1.7}_{-1.8}$	
		5.273	5.191			-14.3 ± 0.5	$-12.3\ ^{+1.7}_{-1.8}$	
002.072	33	31.744	31.712	-6.5 ± 0.5	$-6.8\ ^{+1.5}_{-2.0}$	-1.5 ± 0.5	$-1.9\ ^{+0.2}_{-0.3}$	B
		31.840	31.552	-6 ± 0.5	$-6.8\ ^{+1.5}_{-2.0}$	-1 ± 0.5	$-1.9\ ^{+0.2}_{-0.3}$	A

[a]Tolerances due to RF variations.

[b]Not measurable.

nearly the same amplitude in the vicinity of the actual subcarrier (for example 3.706 + 1.566 = 5.272 kHz is a candidate).

The performance of this test was complicated by the RF signal fluctuations experienced, particularly on April 19 when transmitter B was tested. Therefore in each case, the recorded value represents the operator's best estimate of the average reading and peak-to-peak signal level variation. Where measurement tolerances are not given, they should be assumed to be ±0.5 dB.

In summary, the results of this test indicated that the received, relative signal power for the telemetry channels during the *Surveyor I* mission would fall within the limits predicted.

DSS 71 receiver threshold. During the tests involving spacecraft transmitter B, the DSS 71 receiver threshold was measured as a function of several downlink telemetry modes. During the transmitter A tests, the receiver threshold was measured only for the case of the 0.560 kHz (17.2 bits/s) telemetry channel modulating the carrier. The results of these threshold tests are given in Table 70. It is seen that the measured thresholds were from 6 to 12 dB below what one would predict based on a definition of threshold as a 0 dB signal-to-noise ratio in the receiver's phase-lock loop noise bandwidth. This discrepancy between measured and theoretical values of receiver threshold is attributed to leakage around the variable attenuator between the DSS 71 antenna and receiver input. There was no evidence of any degraded performance by the receiver when receiving any of the various spacecraft telemetry modes.

Spacecraft receiver phase-lock threshold. The results of this test together with those from the receiver AFC threshold test discussed in the next paragraph, are given in Table 71 and plotted in Figs. 41–44 for receivers B and A, respectively. It would appear from these results that only receiver A met the specified carrier phase lock threshold at best lock frequency as well as at the specified ±70-kHz tracking limits. Receiver B was found to meet specification only at its best lock frequency. Further, at their respective best lock frequencies, the receiver A phase-lock threshold was about 9 dB below that of receiver B. Part of this disparity may be attributed to the greater RF signal variations experienced during the receiver B tests. About 2 dB of the difference could reasonably be attributed to this factor. During a similar test of both receivers on April 21 using the RF STEA transmitter, the difference between receivers was about 5 dB with receiver A still yielding better performance.

The difference in phase-lock thresholds between receivers A and B is probably of little practical significance.

Table 70. DSIF receiver threshold test results

Test step	Telemetry mode, kHz	Strong signal			Threshold			Spacecraft transmitter
		Attenuator		P_c/AGC	Attenuator		P_c/calc	
		Dial	dB	dBmW	Dial	dB	dBmW	
002.034	3.9 SPA	6	6	−92	69	67	−153	B
002.046	0.560	6	6	−98	66	64	−156	B
	0.560	6	6	−93	69	67	−154	A
002.057	7.35, 1.7, 3.0, 5.4 MX	6	6	−95	67	65	−154	B
002.067	3.9, 1.7, 3.0, 5.4 MX	6	6	−96	71	69	−159	B
002.075	33	6	6	−98	69	67	−159	B

Note: Theoretical threshold equals:

$P_c = -198.6$ dBmW + 10 log (1100) + 10 log (12)

where 11000 = receiver system noise temperature

12 = receiver PLL bandwidth

$\therefore P_c = -147.4$ dBmW

Table 71. Spacecraft receiver threshold test results

Test step	Receiver[a]	Mode	Strong signal				Threshold				Remarks
			Attenuator		Receiver AGC		Attenuator		Receiver *input*	Specification	
			Dial	dB	Data number	dBmW	Dial	dB	dBmW	dBmW	
003.007	B	APC	18	17.8	212	−100	50	48.7	−131	$-128.6\ ^{+3.3}_{-1.1}$	At best lock frequency
	A	APC	6	6	340	−118	30	29	−140	$-128.6\ ^{+3.3}_{-1.1}$	At best lock frequency
003.010	B	APC	6	6	133	−89	43	42	−125	Unknown	At +70 kHz from best lock
	A	APC	6	6	350	−120	16	15	−129	Unknown	At +70 kHz from best lock
003.013	B	APC	18	17.8	191	−98	41	40.1	−120	Unknown	At −70 kHz from best lock
	A	APC	6	6	342	−118	23	22	−134	Unknown	At −70 kHz from best lock
003.038	B	AFC	18	17.8	213	−100	42	41	−123	$-120.8\ ^{+3.3}_{-1.1}$	At +40 kHz from center frequency
	A	AFC	6	6	340	−118	14	13	−125	(at center frequency)	At +40 kHz from center frequency
003.042	B	AFC	18	17.8	196	−98	41	40.1	−120	$-120.8\ ^{+3.3}_{-1.1}$	At −40 kHz from center frequency
	A	AFC	6	6	340	−118	15	14	−126	(at center frequency)	At −40 kHz from center frequency

[a]Receiver B temperature = 80°F; receiver A temperature = 77°F.

With command modulation applied, the command signal power would nominally be 6.8 dB above the carrier power. Since the command threshold (5×10^{-4} word error rate) occurs typically at −114 dBmW, it is evident that for either receiver the command link performance will be determined by that of the command channel rather than of the carrier, at least to command threshold. Also, barring a drastic change in either receiver's best lock frequency during the mission, there should be no need to operate them at any frequency other than at or near their respective best lock frequencies when in the transponder mode.

The results presented here must be viewed with some caution. Since there was no CDC at DSS 71 all uplink tests were performed with no command modulation applied to the DSS 71 transmitter signal. It is possible that the carrier phase lock thresholds, at least at the ±70-kHz excursions, would have been different from those obtained here if the DSS 71 transmitter were modulated by the command channel.

Spacecraft receiver AFC threshold. As previously stated, the results from this test are given in Table 71 and plotted in Figs. 41 and 42. Both were found to meet the specified threshold at ±40 kHz from the receivers' respective center frequencies. It was verified that the AFC threshold at center frequency was at least as good as at band edge for each receiver.

From the results of this test it appears that during command sequences with the spacecraft receiver in the AFC mode, both receivers should perform equally well.

Spacecraft receiver phase-lock tracking range. The results of this test are summarized in Table 63 and are shown pictorially in Fig. 43, superimposed with the results of the APC and AFC acquisition frequencies tests discussed in subsequent paragraphs. This test was performed only for receiver B and at a spacecraft received carrier level of −124 dBmW, roughly 7 dB above threshold. The tracking range was found to be from +40 to −37 kHz about the best lock frequency. The spacecraft equipment specification states that the phase-lock tracking range shall be ±70 kHz but does not specify the signal level at which this capability shall exist. Previous tests with the T-21 spacecraft have shown that at strong signal levels (about −100 dBmW) the phase-lock tracking range exceeds ±70 kHz.

In a practical sense it can be inferred from the APC and AFC threshold lines superimposed on Fig. 42 that the maximum phase lock-tracking range receiver B would require, would be about −11 kHz from best lock frequency. This would be required if receiver B were phase

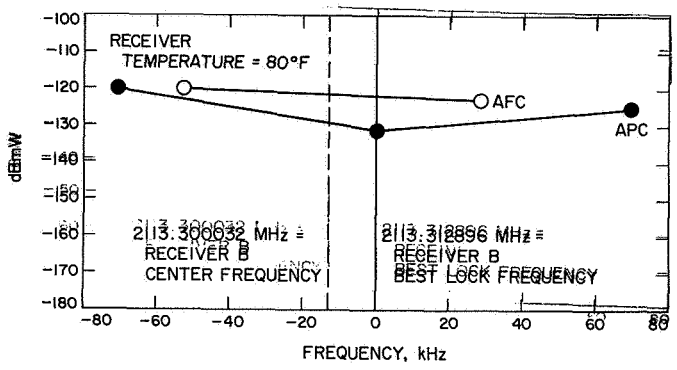


Fig. 41. *Surveyor I* receiver B AFC threshold test

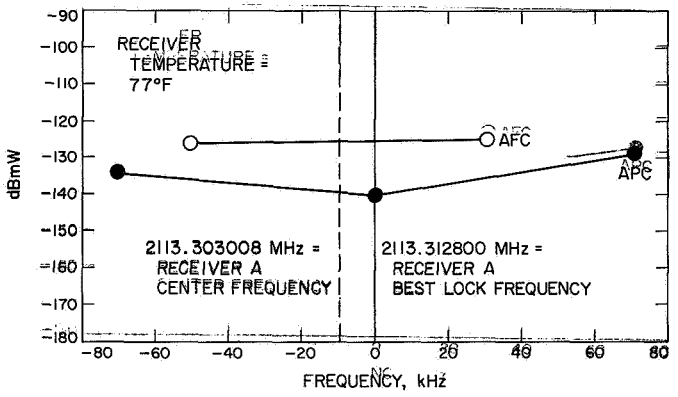


Fig. 42. *Surveyor I* receiver A AFC threshold test

locked to the ground transmitter with the latter tuned to the AFC center frequency of receiver A. Note however that this tuning range would only be required down to −125 dBmW, AFC threshold of receiver A. At this point the command link would be more than 3 dB below threshold. Now, from the results of the phase-lock threshold test for receiver A it seems likely that its phase-lock tracking range at any given signal power will exceed that of receiver B. Therefore it is concluded that the spacecraft receivers' phase-lock tracking ranges are adequate in the absence of any drastic changes in either receiver's best lock or AFC center frequencies.

Again it is likely that with the command modulation applied to the ground transmitter, the phase-lock tracking range would be narrower than obtained in this test. However, it is felt that the above conclusion would still be valid but that the margin would be reduced.

Spacecraft receiver phase-lock acquisition frequencies. The results of this test are contained in Tables 72 and 73 and in Figs. 43 and 44 (fortunately understanding these

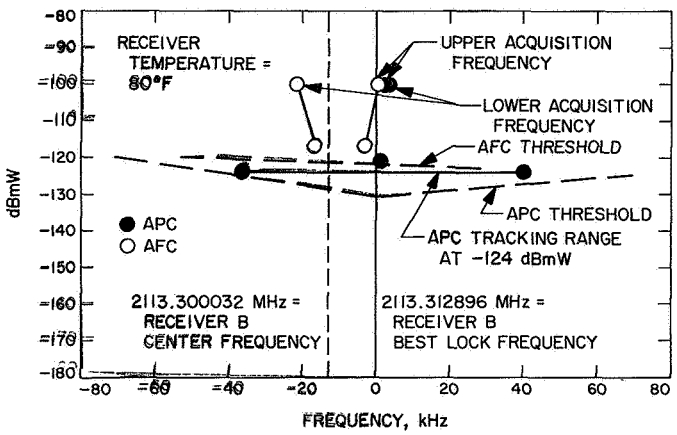


Fig. 43. *Surveyor I* receiver B acquisition and tracking frequencies

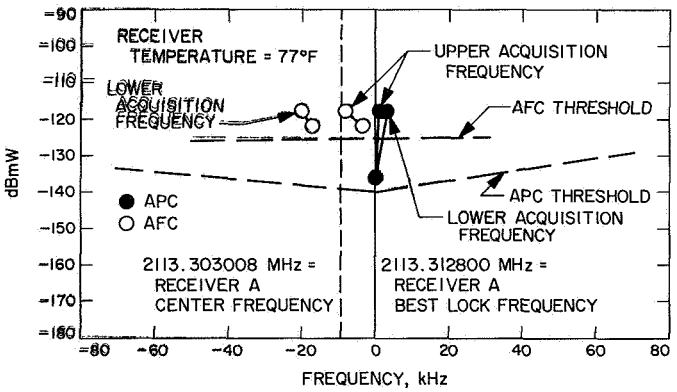


Fig. 44. *Surveyor I* receiver A acquisition frequencies

figures is not a prerequisite to launching the spacecraft). The convention used in these figures is as follows: The lower acquisition frequency is the frequency at which the spacecraft transponder acquires phase lock when the DSS transmitter is tuned toward best lock frequency starting at a frequency lower than best lock frequency. The upper acquisition frequency is obtained in a corollary fashion. The usual overlap, wherein the lower acquisition frequency is higher than the upper acquisition frequency, is easily seen in the results for the strong signal level case. Near threshold the lower and upper acquisition frequencies are the same and are nominally the receivers' best lock frequencies. The results of this test seem to indicate that receiver B best lock frequency is 2113.314048 MHz rather than 2113.312896 MHz as used throughout the tests. This is consistent with the fact that the receiver B no-signal SPE was about −1 kHz from where it was expected to be. Recall that the best lock frequency is taken as that ground transmitter frequency that results in the same SPE as for the no-signal

Table 72. Spacecraft receiver B acquisition and tracking frequencies test results

1. Phase lock mode—strong signal case (test steps 003.026–0.029)
   a. Test conditions
      (1) Spacecraft receiver temperature: 80°F
      (2) DSS 71 transmitter attenuator: 18 dial = 17.8 dB
      (3) Spacecraft receiver input power: 208 dn = −100 dBmW
   b. Lower acquisition frequency
      (1) DSS 71 transmitter frequency: 2113.316352 MHz
      (2) Spacecraft receiver AGC: 205 dn = −99.2 dBmW
      (3) Spacecraft receiver SPE: 527 dn = +2 kHz
   c. Upper acquisition frequency
      (1) DSS 71 transmitter frequency: 2113.315008 MHz
      (2) Spacecraft receiver AGC: 220 dn = −101.2 dBmW
      (3) Spacecraft receiver SPE: 532 dn = +0.5 kHz
2. Phase lock mode—weak signal case (test steps 003.023–0.024)
   a. Test conditions
      (1) Spacecraft receiver temperature: 80°F
      (2) DSS 71 transmitter attenuator: 40 dial +39.2 dB
      (3) Spacecraft receiver input power (calculated): −121 dBmW
   b. Lower acquisition frequency
      (1) DSS 71 transmitter frequency: 2113.314048 MHz
      (2) Spacecraft receiver AGC: 345 dn = −122.6 dBmW
      (3) Spacecraft receiver SPE: 533 dn = +0.3 kHz
   c. Upper acquisition frequency
      (1) DSS 71 transmitter frequency: 2113.314048 MHz
      (2) Spacecraft receiver AGC: 345 dn = −122.6 dBmW
      (3) Spacecraft receiver SPE: 532 dn = +0.5 kHz
3. AFC mode—strong signal case (test steps 003.040 and 0.043)
   a. Test conditions
      (1) Spacecraft receiver temperature: 80°F
      (2) DSS 71 transmitter attenuator: 18 dial = 17.8 dB
      (3) Spacecraft receiver input power: 213 dn = −100 dBmW
   b. Lower acquisition frequency
      DSS 71 transmitter frequency: 2113.291199 MHz
   c. Upper acquisition frequency
      DSS 71 transmitter frequency: 2113.313567 MHz
4. AFC mode—weak signal case (test step 003.046)
   a. Test conditions
      (1) Spacecraft receiver temperature: 80°F
      (2) DSS 71 transmitter attenuator: 36 dial = 35 dB
      (3) Spacecraft receiver input power (calculated): −117 dBmW
   b. Lower acquisition frequency
      DSS 71 transmitter frequency: 2113.296095 MHz
   c. Upper acquisition frequency
      DSS 71 transmitter frequency: 2113.309919 MHz
5. Spacecraft receiver phase-lock tracking range—near threshold (test step 003.018)
   a. Test conditions
      (1) Spacecraft receiver temperature: 80°F
      (2) DSS 71 transmitter attenuator: 42 dial = 41 dB
      (3) Spacecraft receiver input power (calculated): −124 dBmW
   b. Lower frequency limit
      (1) DSS 71 transmitter frequency: 2113.276416 MHz (−36.5 kHz)
      (2) Spacecraft receiver SPE: 629 dn = 41.4 KHz
   c. Upper frequency limit

Table 72 (contd)

      (1) DSS 71 transmitter frequency: 2113.353120 MHz (+40.2 kHz)
      (2) Spacecraft receiver SPE: 423 dn = +38.8 kHz
   d. Tracking range
      (1) Frequency upper–frequency lower = 76.704 kHz (from DSS 71 transmitter frequencies)
      (2) Frequency upper–frequency lower = 81.2 kHz (from spacecraft receiver SPE telemetry)

Table 73. Spacecraft receiver A acquisition frequencies test results

1. Phase-lock mode—strong signal case (test steps 003.026–0.029)
   a. Test conditions
      (1) Spacecraft receiver temperature: 77°F
      (2) DSS 71 transmitter attenuator: 6 dial = 6 dB
      (3) Spacecraft receiver input power: 345 dn = −118.5 dBmW
   b. Lower acquisition frequency
      (1) DSS 71 transmitter frequency: 2113.315776 MHz
      (2) Spacecraft receiver AGC: 327 dn = −115 dBmW
      (3) Spacecraft receiver SPE: 517 dn = +5.4 kHz
   c. Upper acquisition frequency
      (1) DSS 71 transmitter frequency: 2113.313952 MHz
      (2) Spacecraft receiver AGC: 330 dn = −115.8 dBmW
      (3) Spacecraft receiver SPE: 525 dn = +2.5 kHz
2. Phase lock mode—weak signal case (test steps 003.023–0.024)
   a. Test conditions
      (1) Spacecraft receiver temperature: 77°F
      (2) DSS 71 transmitter attenuator: 25 dial = 24 dB
      (3) Spacecraft receiver input power (calculated): −136 dBmW
   b. Lower acquisition frequency
      (1) DSS 71 transmitter frequency: 2113.312800 MHz
      (2) Spacecraft receiver AGC: 395 dn = (off scale)
      (3) Spacecraft receiver SPE: 531 dn = +0.8 MHz
   c. Upper acquisition frequency
      (1) DSS 71 transmitter frequency: 2113.312800 MHz
      (2) Spacecraft receiver AGC: 394 dn = (off scale)
      (3) Spacecraft receiver SPE: 524 dn = +3 kHz
3. AFC mode—strong signal case (test steps 003.040 and 0.043)
   a. Test conditions
      (1) Spacecraft receiver temperature: 77°F
      (2) DSS 71 transmitter attenuator: 6 dial = 6 dB
      (3) Spacecraft receiver input power (estimated): −118 dB
   b. Lower acquisition frequency
      DSS 71 transmitter frequency: 2113.292736 MHz
   c. Upper acquisition frequency
      DSS 71 transmitter frequency: 2113.304640 MHz
4. AFC mode—weak signal case (test step 003.046)
   a. Test conditions
      (1) Spacecraft receiver temperature: 77°F
      (2) DSS 71 transmitter attenuator: 10 dial = 10 dB
      (3) Spacecraft receiver input power (calculated): −122 dBmW
   b. Lower acquisition frequency
      DSS 71 transmitter frequency: 2113.295520 MHz
   c. Upper acquisition frequency
      DSS 71 transmitter frequency: 2113.309152 MHz

case. If one collates the various receiver B SPE data obtained during all tests with the corresponding DSS 71 transmitter frequencies and takes the average, the best lock frequency obtained in this way is 2113.314437 MHz ±700 Hz at 80°F. The SPE data obtained for receiver A is somewhat erratic; therefore, the best estimate of the receiver A best lock frequency is the value used throughout the test, viz. 2113.312800 MHz at 77°F. It is felt that the results of the phase lock acquisition frequencies test confirm this value.

The difference between the receiver A and B best lock frequencies given here and those published previously is attributed to the difference in temperature references used. The temperature reference used in accumulating the previous data was essentially that of the frequency determining elements of the transmitters and receivers. The temperature reference used during these compatibility tests was that of the compartment A tray bottom.

Spacecraft receiver AFC acquisition frequencies. Refer again to Tables 72 and 73 and Figs. 43 and 44 for the results of this test. In the AFC mode, there is no crossover of upper and lower acquisition frequencies as there was in the APC mode. The spacecraft receiver acquires AFC control as soon as it detects a signal within its IF bandwidth. As expected (at least for receiver B) the AFC acquisition range at strong signal is greater than at near threshold signal levels due to the finite slope of the skirts of the IF filter response curve. The upper acquisition frequency for receiver A at strong signal is felt to be a bad data point. It is attributed to the possibility that the DSS 71 computer operator did not hear the first report of AFC acquisition by the STEA telemetry engineer. This is not important as it is the AFC acquisition range near threshold that is of interest because it provides a verification of the spacecraft receiver's IF bandwidth. The results of this test yield a value of 13.8 kHz for receiver B and 13.6 kHz for receiver A. The dB control tables specifies a value of 13.9 kHz as nominal. The results of this test also indicate that the AFC center frequencies for receivers B and A are 2113.303007 and 2113.302336 MHz at 80 and 77°F, respectively. These agree reasonably well with the values used during these tests which were obtained as the uplink frequency yielding the no-signal AFC data number. Either set of frequencies could be used with no adverse effects.

The AFC center frequency obtained during these tests may be compared with those obtained for receivers B and A. The values given are 2113.309182 and 2113.304738 MHz, respectively. The discrepancy for receiver A is acceptable. However, that for receiver B is not. Since the numbers given in the reference were not obtained by direct measurement but rather were derived indirectly, the exact reason for the large discrepancy is not known.

NBVCXO frequency drift. The results of this test are plotted in Fig. 45. Although the scale of the ordinate masks the effect, immediately upon switching the spacecraft transmitter to high power, there was a +20-Hz step change in NBVCXO frequency. The exponential rise

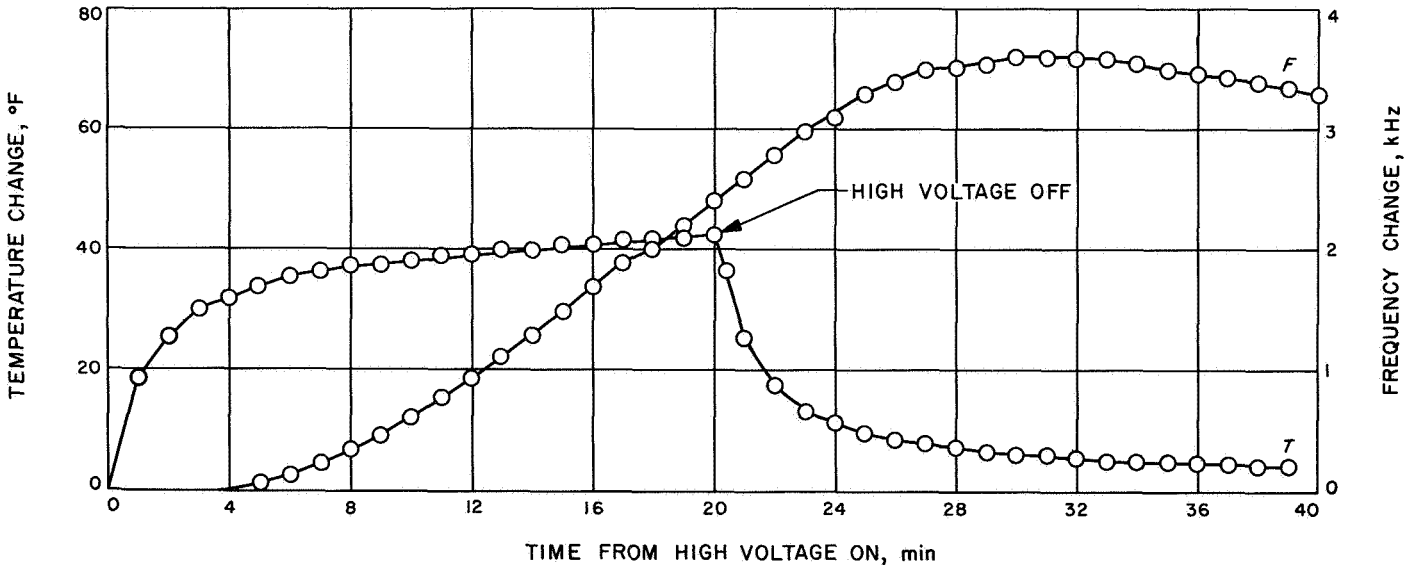


Fig. 45. *Surveyor I* NBVCYO frequency drift rate

and decay of transmitter temperature with high voltage on and off is clearly seen. The thermal lag of the transmitter frequency is also obvious. The maximum rate of change of frequency can be shown to be approximately 3.1 Hz.

WBVCXO frequency. This test was performed only for spacecraft transmitter B and consisted of measuring the transmitter frequency and of searching the received spectrum on a spectrum analyzer for spurious signals.

The transmitter B WBVCXO frequency was measured at 2295.037024 MHz. No spurious signals were observed in the spectrum analyzer display of the signal within 20 dB of the carrier.

Telemetry error rate. The FR-1400 recording made during this test was played back into the CDC at DSS 11 on May 5. Figure 46 shows the test configuration during playback. While making the recording at DSS 71, the procedure was modified in that the receiver attenuator was adjusted to produce a theoretical signal-to-noise ratio of 13 dB in the appropriate discriminator's bandpass filter, using values of the latter from the DSS 11 CDC. (The test procedure had specified 11 dB.) The measured modulation parameters were used to calculate the carrier power required and the receiver attenuator adjusted accordingly. Based on measured values of received carrier power during each of the four recording samples, the PCM subcarrier signal-to-noise ratios were as shown in Table 74.

Table 74. Subcarrier signal-to-noise ratio during telemetry error rate test

Test step	Telemetry subcarrier, kHz	P_c, dBmW	P_s/P_n, dB
005.003	0.560	−132	15
005.008	7.35 and strain gage SCOs, kHz	−118	10
005.015	33 SCO low power	−111	12
005.022	33 SCO high power	−111	12

If one were to use spec values for the modulation parameters, the recorded signal-to-noise ratios would be 15, 8, 12, and 12 dB, respectively.

On playback of the recording, the measured values of signal-to-noise ratios for the 0.560- and 33-kHz SCOs were 20 dB or more in each case. Discriminator and decommutator lock were readily accomplished. During playback of the 7.35-kHz SCO (with multiplexed strain gage SCOs) the measured signal-to-noise ratio was 10.4 dB. However, neither discriminator nor decommutator lock was obtained. This together with the appearance of the signal on an oscilloscope indicated that the actual signal-to-noise ratio was below that measured. The reason for the large discrepancies between the calculated signal-to-noise ratios at the time the recording was made

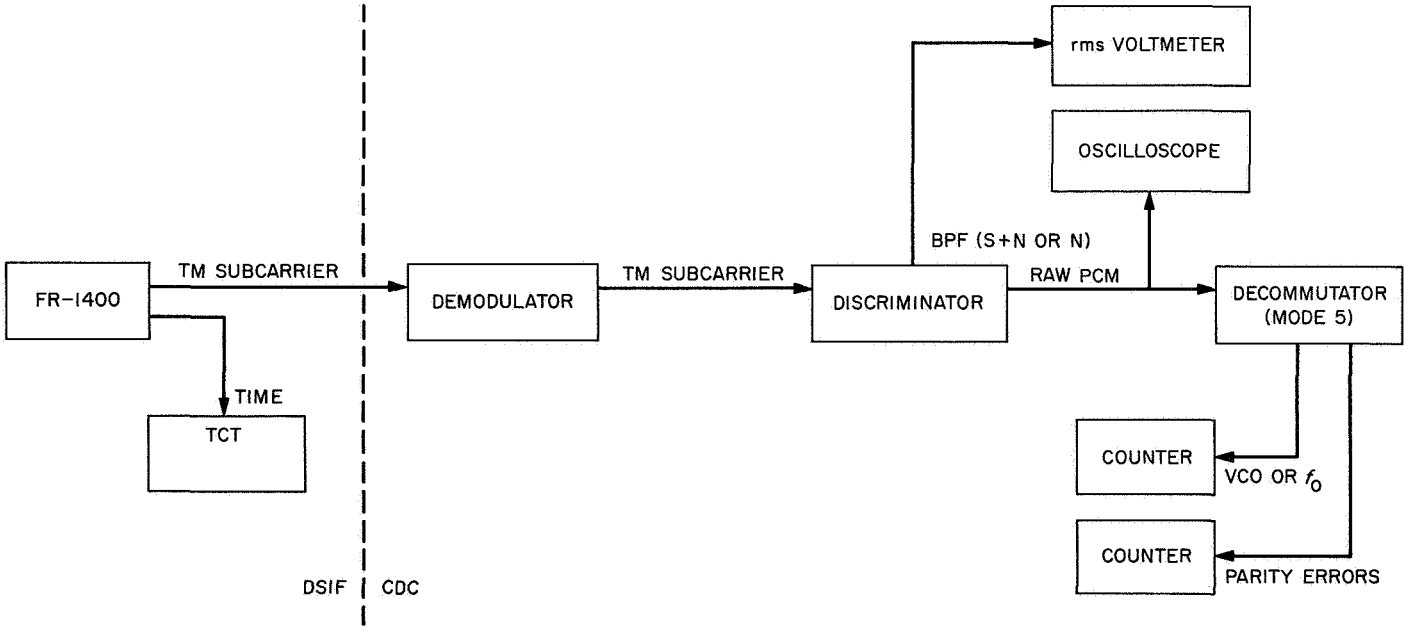


Fig. 46. Test configuration *Surveyor I* MOS test tape playback at DSS-11

and those measured during playback is unknown. Because of the discrepancies in the measured signal-to-noise ratios, the parity error rates were not measured.

The outputs of the 0.560- and 33-kHz discriminators were displayed on an oscilloscope to determine if any shift or non-symmetries were present in the waveforms. For the 0.560-kHz subcarrier, the entire waveform appeared to be shifted −0.25 V out of a zero-to-peak swing of 2.5 V. This corresponds to a center frequency shift of −0.86 Hz or about −0.15%, which is within the spec value of ±0.2%. No adjustment of the CDC discriminator balance was required in order to achieve decommutator lock. For the 33-kHz SCO, the offset was about +0.15 V except when alternate ones and zeros were transmitted at which time the offset was +0.25 V. This latter offset corresponds to a center frequency shift of +198 Hz or about +0.6%. This is slightly out of the spec value of ±0.5%, but again, no adjustment of the CDC discriminator balance was required to allow the decommutator to acquire lock. The measured bit rates corresponding to the 0.560- and 33-kHz SCOs were 17.2 and 4392, respectively. The latter represents an error of about −0.2%.

It remains necessary to further analyze the tape recorded signals as well as the procedures used during recording and playback in order to determine the reason for the discrepancies between recorded and reproduced signal-to-noise ratios.

V. *Surveyor I* Flight Support

A. General

The T&DS, provided by the AFETR, GSFC, and the DSN, for the *Surveyor I* mission is 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.

At liftoff all *Atlas* engines were ignited and the vehicle was released approximately 1.25 s later. Approximately 2 s after launch the vehicle began to roll to the flight azimuth preset before launch. The flight azimuth was preset from 80 to 115 deg.

The pitch program began at approximately $T + 15$ s. *Atlas* booster cutoff was initiated by the *Centaur* Guidance System which started a programmer subroutine to shut down the two booster engines and jettison the booster section. The nose fairing and insulation panels were jettisoned during the *Atlas* sustainer phase of the flight. The sustainer engine was then shut down by propellant depletion. *Atlas* vernier engines were shut down at the same time as the sustainer followed by *Atlas/Centaur* separation 1.9 s later. The *Atlas* retro-rockets then fired approximately 0.1 s after separation.

The *Centaur* guidance system was operating closed loop. As *Surveyor I* was a direct ascent trajectory there was only one *Centaur* burn. The end of powered flight MECO +5 s occurred at about 98 nautical miles (nmi) altitude, 1512 nmi downrange. (The perigee altitude of earth-to-moon transfer orbit was 90 nmi nominally.) Shortly after injection into the transfer trajectory, the spacecraft landing gear and omnidirectional antenna were extended and locked. The foregoing was successfully accomplished with the exception of the deployment of omnidirectional antenna A which stuck in an effort at deployment. The spacecraft telemetry transmitter high power was then turned on. At *Centaur/Surveyor* electrical disconnect, spacecraft telemetry 550 bits/s data stream on the 225.7-MHz VHF link ceased. *Centaur/Surveyor* mechanical separation followed shortly. The spacecraft rotational velocities at separation were not to exceed a total angular vector sum of 3.0 deg/s (including *Centaur* residual angular rates). Within 45 s after separation, the cold gas jet system reduced the spacecraft tumbling rates to 0.1 deg/s. *Centaur*/spacecraft separation was followed by a reorientation maneuver by the *Centaur* stage to remove it from the field of view of the spacecraft Canopus sensor.[9] The *Centaur* then underwent a relatively small deceleration by propellant blowdown.

Beginning at lift-off, spacecraft telemetry data were received, recorded and re-transmitted in real time to building AO at Cape Kennedy, for display and retransmission to the SFOF for evaluation of the spacecraft status. Up to three sources of digital spacecraft telemetry were received at the Cape from downrange stations.

The *Centaur* 225.7-MHz telemetry link was transmitting in real time for analysis of in-flight performance.

Near-real-time reports by stations indicated the completion of designated events and certain aspects of spacecraft performance (within azimuth headings) as indicated by telemetry. The RTCS computed the orbital parameters of the orbit, computed DSN acquisition data from specified stations and projected the transfer orbits to lunar encounter. In addition to making computations based on

[9]This reorientation was a minimum-energy maneuver and might be in any direction at random.

radar tracking data, orbital parameters were also computed upon telemetered *Centaur* inertial guidance data. Throughout these computations, in-flight radar tracking data was sent to the SFOF from the AFETR, as close to real time as was feasible for use in SFOF computations and to GSFC for computing MSFN acquisition data. The RTCS performed such special DSN acquisition and orbital computations as were required to produce progressive in-flight analysis of the mission.

At *Centaur* separation, the DSN had acquisition of *Surveyor I* spacecraft and successfully tracked the midcourse maneuver through terminal descent to touchdown. The DSN used two- and three-way doppler methods on S-band frequencies to track the spacecraft.

B. Countdown

During countdown operations, those factors acting to constrain the launch window or period were continually evaluated for consideration in the launch or hold decision.

At $T - 154$ min, RF propagation problems interfered with the retransmission of tracking and telemetry data from the RIS *General Arnold.* However, an adequate quantity of tracking data was available from Antigua for the AFETR/RTCS to compute DSS 51 acquisition information, and in the event Antigua data was lost DSS 51 predicts based on Ascension post-retroignition tracking data would have been acceptable. By 40 min into the 60-min built-in hold at $T - 90$ min, both tracking and telemetry retransmission problems had cleared up.

An electrical storm between San Salvador and Grand Turk interrupted both HF and subcable tracking data transmission links from key downrange stations; however, telemetry transmission was still good. During the 21-min built-in hold at $T - 5$ min, the tracking data transmission problems clear up.

Both digital trackers on the RIS *General Arnold* experienced failures at $T - 60$ s; nevertheless, the countdown was permitted to proceed to launch. All DSIF stations were within nominal performance specifications and all communication circuits were up during the countdown.

C. Liftoff to DSIF Acquisition

1. AFETR. The AFETR performed supporting functions in accordance with its Program Support Plan (PSP), for *Surveyor I* during the countdown and launch phase of the mission. The AFETR support configuration is shown in

Table 75. AFETR support configuration

Station	Radar	VHF telemetry	S-band telemetry
Merritt Island	X		
Cape Kennedy	X	X	X
Patrick AFB	X		
Grand Bahama Island	X	X	X
Grand Turk	X		
Antigua	X	X	X
General Arnold	X	X	X
Coastal Crusader		X	X
Sword Knot		X	X
Ascension Island	X	X	X

Table 75. (AFETR Pretoria station supported *Surveyor I* operations without commitment.)

AFETR tracking, VHF, S-band telemetry and RTCS support are described below.

a. Tracking. Figures 47 and 48 show the radar data coverage intervals that were provided. As can be seen from the difference between the top bar, which shows the total expected coverage, and the bottom bar, which shows the actual interval of data, the class I commitment was not met after *Centaur* MECO. MECO occurred at 689 s, 6 s later than nominal. Antigua loss of signal was expected to be at 729 s, but actually occurred at 690 s. There was no commitment for metric data beyond Antigua.

b. VHF telemetry. Figure 49 shows the expected VHF telemetry coverage versus that actually provided. VHF coverage was continuous from $T - 4500$ s to $T + 5940$ s, which is more than predicted. However, since the *Centaur* stage was not roll-attitude-stabilized, the expected coverages are based on not having an antenna null of less than a specified number of dB. This uncertainty in antenna gain, of course, could easily result in more or less coverage than expected.

There was a requirement to transmit the *Centaur* VHF link in real time to Cape Kennedy from Grand Bahama Island and Antigua. This was not met at Antigua due to an operator patching error. However, because of the overlapping coverage given from Grand Bahama Island, only 84 s of data were lost.

c. S-band telemetry. The S-band receive and record requirement was from $T + 775$ s until $T + 1583$ s (injection $+15$ min). The TAA-3A antennas (30-ft S-band

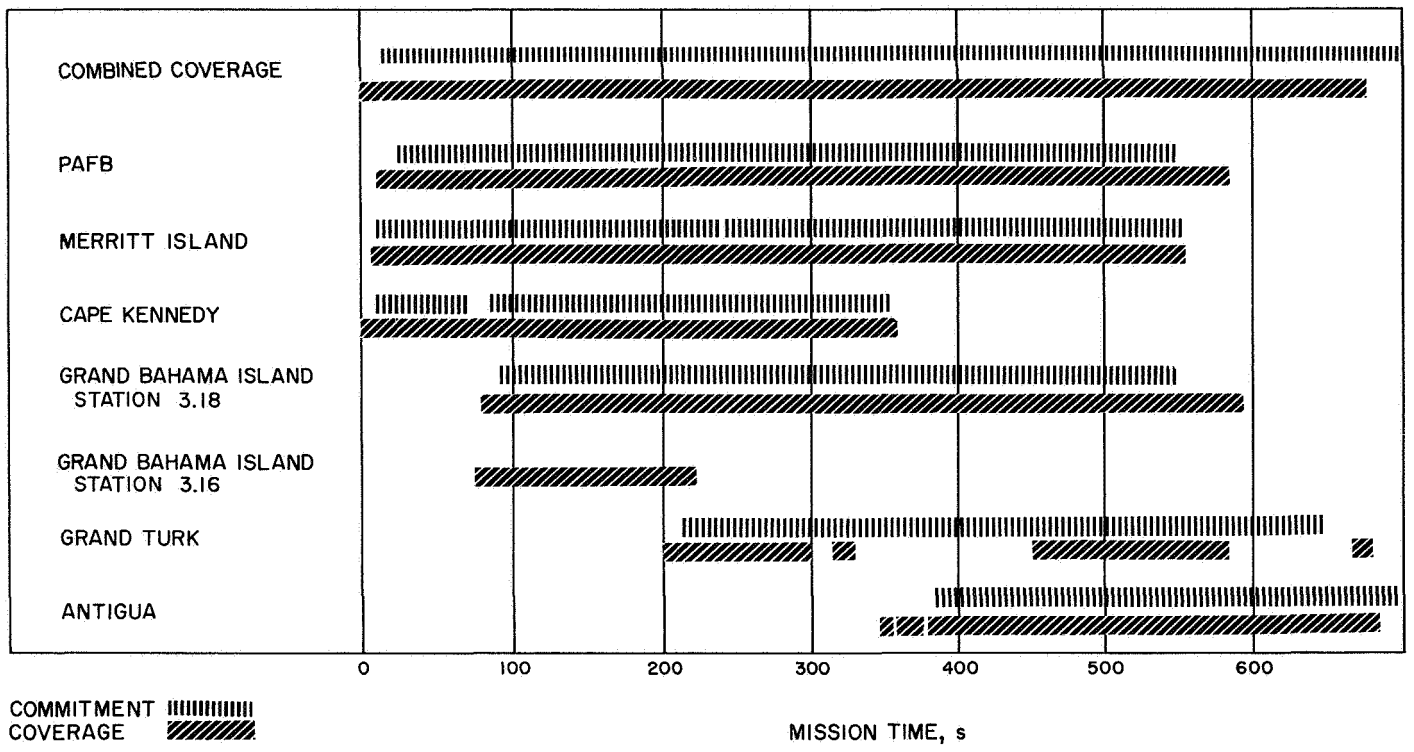


Fig. 47. Radar tracking coverage, before spacecraft separation

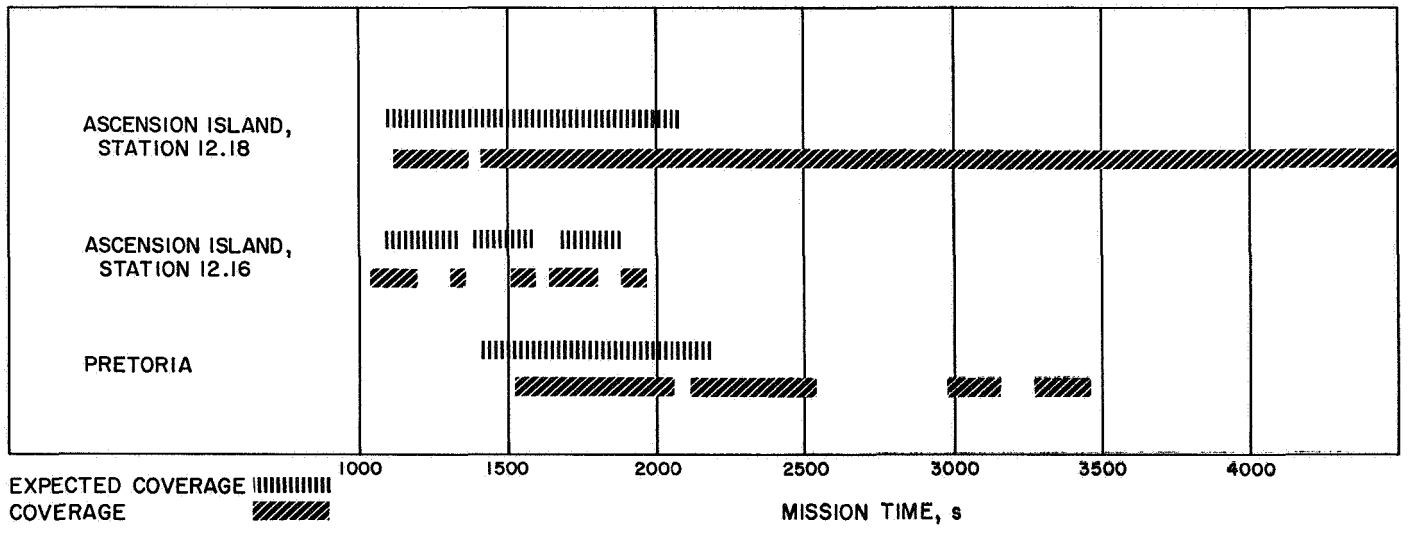


Fig. 48. Radar tracking coverage, after spacecraft separation

systems), which occasioned so much concern prior to launch, provided excellent support.

The ships did not all perform as planned. Figure 50 shows the S-band telemetry interval that was received and recorded. The top bar is a composite of all the stations. Data were received and recorded from $T - 4500$ s to $T + 2376$ s with the following exceptions:

(1) Dropouts, from 75 to 122 s and from 240 to 413 s during a class II interval.

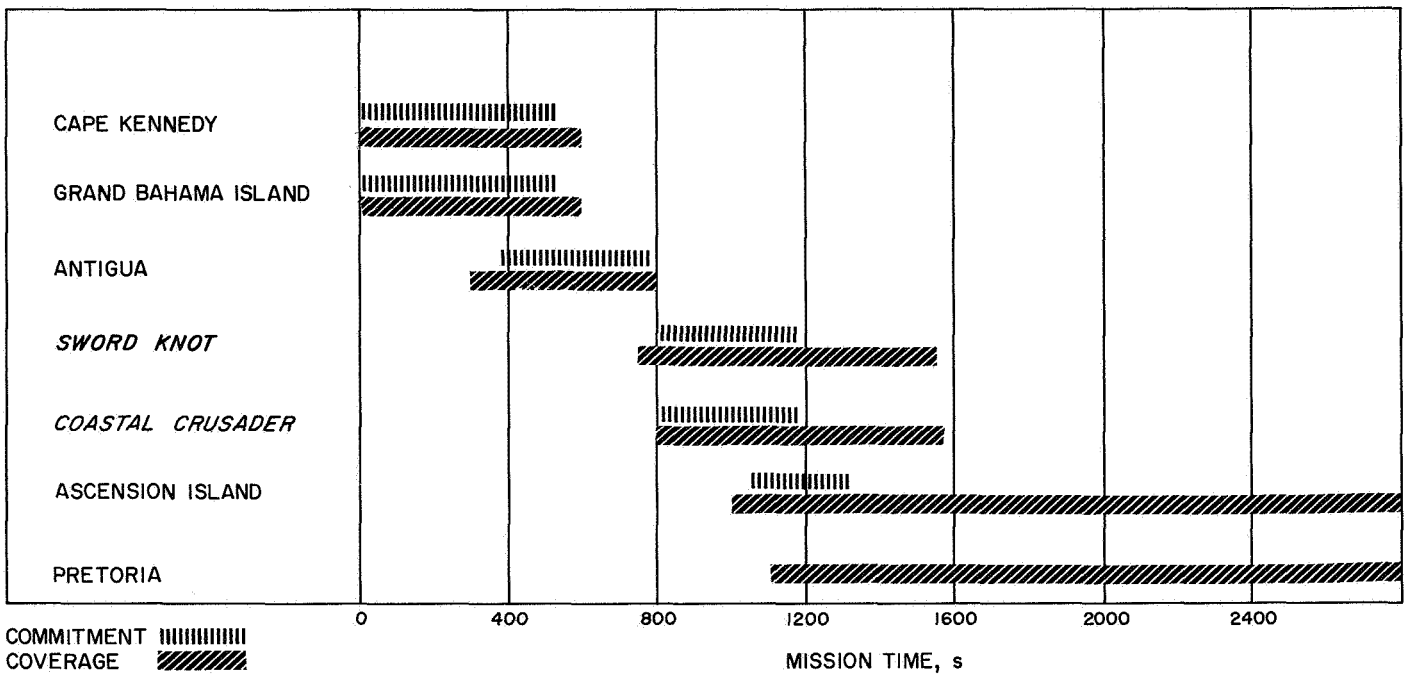


Fig. 49. VHF telemetry coverage

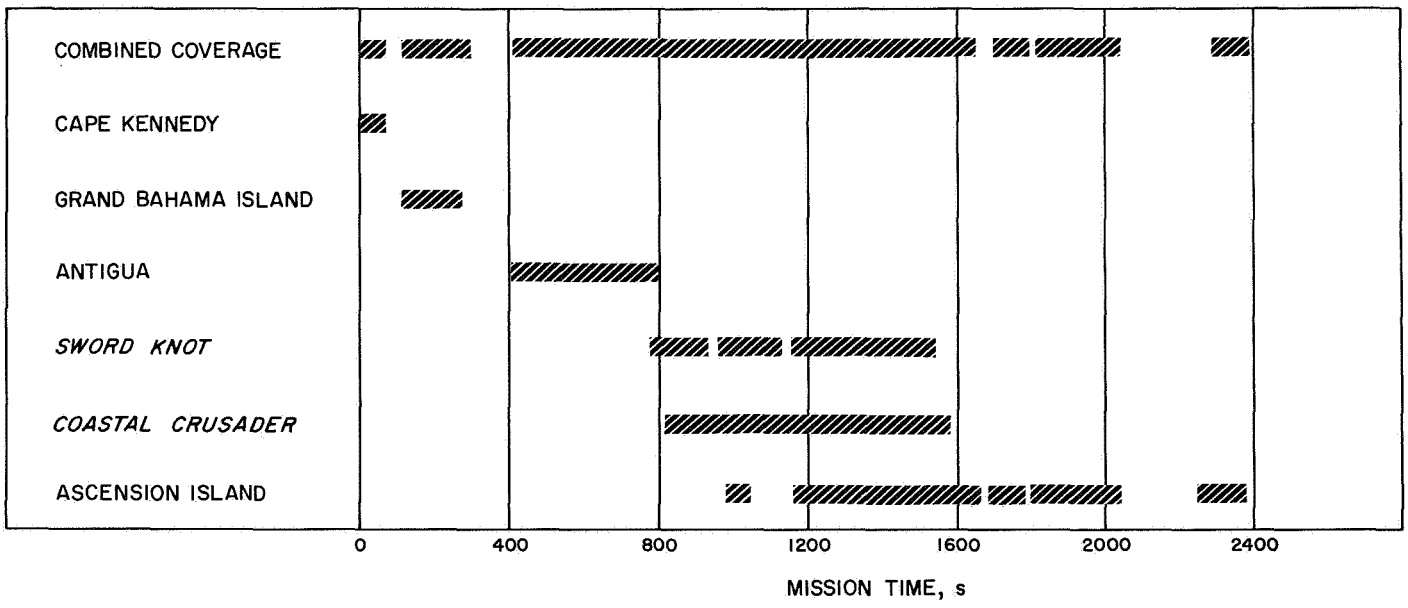


Fig. 50. S-band telemetry coverage

(2) Poor quality, less than 10^3 bit error rate, at 770–788, 941–1018, 1188–1199, and 2119–2319 s.

The *General Arnold* did not record any data of useful quality. She obtained receiver lock-up, but no time division multiplex decommutation (TDM lock). The system checked out all right during post-flight tests. There have been aircraft flybys since the launch, and the ship acquired the signal and tracked the aircraft. Engineers checked out every possibility in order to assure support for *Lunar Orbiter* which utilizes the same S-band system.

The AFETR had a requirement to transmit the S-band telemetry data in real time to building AO from $T + 745$ s to $T + 1583$ s. The top bar in Fig. 51 shows the S-band data that was transmitted in real time to building AO. There were a few small intervals during which dropouts occurred. Data was transmitted until $T + 2404$ s with the following exceptions:

(1) Dropouts, at 770–778, 941–1018, and 2119–2319 s.

(2) Poor quality, less than 10^3 bit error rate, at 1498–1514, 1534–1555, 1619–2119, and 2319–2404 s.

As stated above, the *General Arnold* was not able to lock up its TDM, and therefore could not transmit any data. The *Coastal Crusader* did not retransmit any real-time data due to a patching error in the telemetry system. The input to the TDM was patched from the tape recorder, as it is during a simulation, instead of from the receiver as it should have been for a flight. Operational instructions and procedures were reviewed to see if they were adequate.

d. RTCS. Due to a lack of tracking coverage from Antigua during the period between *Centaur* MECO and the retromaneuver start, the RTCS was unable to compute a meaningful orbit until Ascension data was available.

Ascension rise occurred after the start of the retromaneuver. An orbit was then computed from Ascension data, and DSS 51 predicts based on this orbit were generated.

The AFETR generated DSS 72 predicts, and the IRV message was transmitted to the Deep Space Stations. Based on the limited metric data available, the RTCS did very well in meeting requirements. There were no problems in this area.

2. *GSFC.* Acquisition aid coverage was good at Bermuda and Grand Canary where the vehicle was in range, and poor at Kano and Carnarvon, where excessive range was encountered. Auto track was not attempted at any of the MSFN stations due to low elevation angles.

a. Tracking. A list of the AOS times, LOS times, maximum signal strength (S/S) in microvolts, elevation in degrees, total track time in seconds, and signal quality of the acquisition aid coverage is shown in Table 76.

b. VHF telemetry. Mark events were recorded and the nominal and actual event times are shown in Table 77. The MSFN telemetry supported well. There were no equipment failures or discrepancies during the operation. All problems encountered are discussed in the following paragraphs.

The Bermuda Station decommutated and displayed the range safety parameters on the *Atlas* 229.9-MHz link. The Bermuda Station was required to confirm *mark* events 6

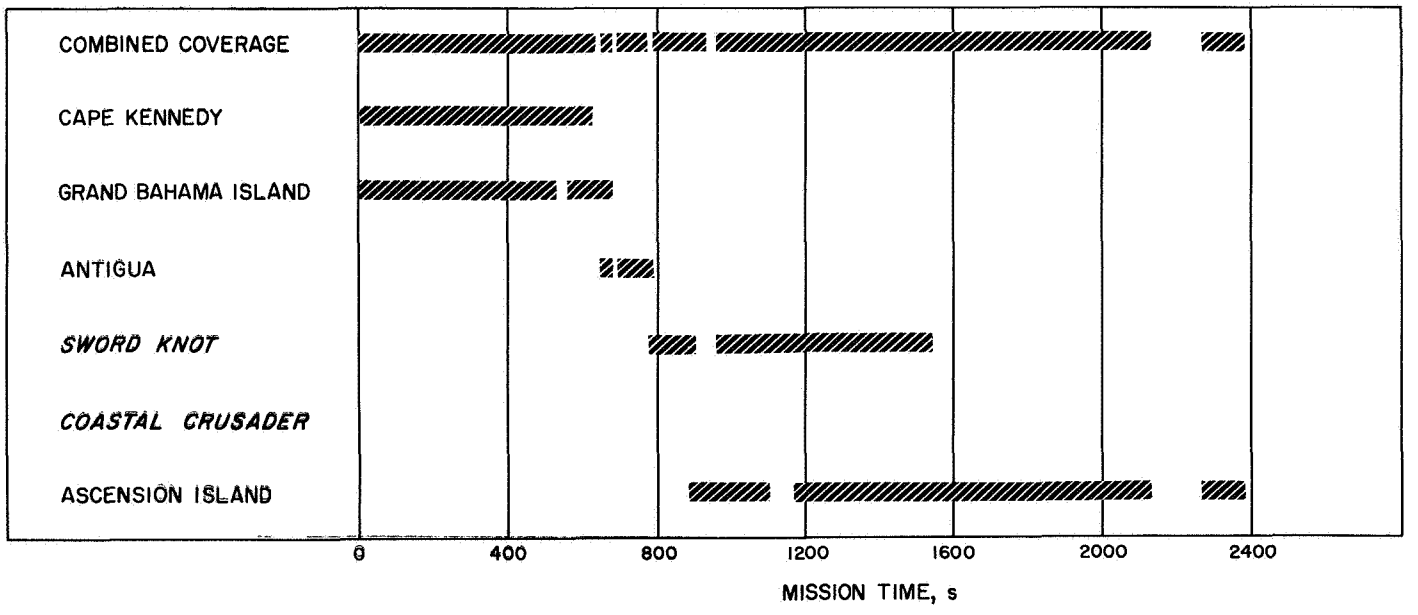


Fig. 51. Real-time data transmission

Table 76. Acquisition aid coverage

Station	Acquisition aid No.	AOS, GMT	LOS, GMT	Max S/S, μV	Elevation, deg	Track, s	Signal quality
Bermuda	1	14:44:27	14:52:33	6	0.79	486	Good
Bermuda	2	14:44:27	14:52:35	7	3.78	488	Good
Grand Canary	1	14:59:53	15:05:12	7	2.0	319	Good
Grand Canary	2	14:59:53	15:05:12	7	2.0	317	Good
Kano	1	15:02:45	15:25:28	1	0.0	1363	Unusable
Carnarvon	1	15:03:00	—	2	0.0	—	—
Carnarvon	2	—	—	—	—	—	—

Table 77. In-flight event times

Mark event	Actual time, GMT	Nominal $L+$ time	Actual $L+$ time	Δ_t
Liftoff	14:41:00.990			
1	14:43:23.2	143.0	142.2	−0.8
2	14:43:26.6	146.0	145.6	−0.4
3	14:43:57.2	177.0	176.2	−0.8
4	14:44:24.0	204.0	203.0	−1.0
5	14:45:00.27	239.0	239.3	+0.3
6	14:45:02.77	241.0	241.8	+0.8
7	14:45:12.95	250.0	252.0	+2.0
8	14:52:30.3	683.0	689.3	+6.3
9	14:52:56.5	714.0	715.5	+1.5
10	14:53:06.7	725.0	725.7	+0.7
11	14:53:26.4	745.0	745.4	+0.4
12	14:53:33.3	751.0	752.3	+1.3
13	14:53:38.1	756.0	757.1	+1.1
14	14:53:40.5	761.0	759.5	−1.5
17	14:57:37.0	996.0	996.0	0.0
18	15:01:48.7	1246.0	1247.7	+1.7
19	15:01:59.5	1246.0	1258.5	+12.5

(see Section III-C-2) through 11 on the *Centaur* 225.7-MHz link. *Mark* events 8 through 11 were not confirmed due to loss of signal, not due to station malfunctions. The only problem encountered at Bermuda was decommutation of commutated channel 9 on the *Centaur* 225.7-MHz link [RSC (range safety control)/AGC voltages]. The System Operations Support Section at GSFC was apprised of a possible decommutator rate limitation problem by the Bermuda Station Maintenance and Operations (M&O) prior to launch, and was subsequently instructed to attempt lock-on of the channel 9 commutator. The commutator rate was 30 segments/s. While TDS-400 decommutator has a design limitation of approximately 33 segments/s, the decommutator apparently will not lock-on a 30-segment/s signal degraded by noise through an RF link. Except for the decommutation problem, telemetry coverage at Bermuda was considered good.

Grand Canary was required to confirm *mark* events 17 through 19 on the *Centaur* 225.7-MHz link. *Mark* event 17 was not confirmed because the event occurred prior to Grand Canary AOS. *Mark* events 18 and 19 were confirmed as required. Because of the invalid pointing data received at Grand Canary, a loss of some data (*mark* event 17) could have resulted. Grand Canary reported that decommutator lock-up was not accomplished in time to confirm *mark* event 18 in real time. The problem resulted from a response to a Grand Canary query stating that the polarity of the channel 18 PAM wavetrain was positive while the polarity was in fact negative. However, decommutator lock should have been accomplished as the decommutator system had provisions for polarity determination and polarity reversal which could be utilized in a matter of seconds to attain lock-up of either a positive or negative PAM wavetrain. Except for the polarity problems, telemetry coverage at Grand Canary was considered good.

Kano was required to confirm *mark* events 17 through 19 on the *Centaur* 225.7-MHz link. None of the *mark* events was confirmed. Because of the launch azimuth, the vehicle passed far south of Kano at an extreme range which altered the anticipated view time considerably. Maximum signal strength was one microvolt, and therefore decommutator lock was not obtainable, and no valid data was obtained. Although no equipment problems were encountered, telemetry coverage at Kano was considered poor. (See Table 78 telemetry coverage.)

A list of the AOS times, LOS times, S/S in microvolts (μV), total track time in seconds, signal quality, *mark* events required, and *mark* events confirmed during the mission are also shown in Table 78.

D. DSIF Acquisition to Midcourse Maneuver

The *Surveyor I* mission spacecraft was launched from Complex 36 of the Cape Kennedy facilities of the AFETR on May 30, 1966 (day 150). Liftoff occurred at

Table 78. MSFN telemetry coverage

Station	AOS, GMT	LOS, GMT	Max S/S, μV	Track, s	Signal quality	*Mark* events	
						Required	Confirmed
Bermuda	14:44:34	14:52:30	4.0	476	Good	6, 7, 8, 9, 10, 11	6, 7
Grand Canary	14:59:57	15:04:38	10.0	281	Good	17, 18, 19	18, 19
Kano	15:02:45	15:25:28	1.0	1363	Poor	17, 18, 19	None

14:41:00.990 GMT[10] in hours, minutes and seconds, and injection into the lunar transfer orbit occurred at 14:52:30.3. The spacecraft high-power transmitter was turned on at 14:53:26.4, *Centaur*/spacecraft separation was effected at 14:53:38.1, and *Centaur* retro was initiated at 14:53:40.5. The spacecraft was tracked by the prime *Surveyor* DSIF stations at Johannesburg (DSS 51), Canberra (DSS 42), and Goldstone (DSS 11), and by backup DSIF stations at Ascension Island (DSS 72) and Madrid (DSS 61) from shortly after injection until lunar touchdown at 06:17:35.7 on June 2, 1966.

The following steps detail how the DSIF provided the *Surveyor I* mission with tracking, telemetry and command data support:

(1) Following liftoff DSS 71, utilizing its manually controlled 4-ft antenna until 14:44:15, observed no anomalies in signal levels or frequencies transmitted from the spacecraft.

(2) DSS 72 obtained a nominal one-way acquisition of the spacecraft at a signal level of −138 dBmW at 14:58:59. Maximum signal level reported was −93 dBmW at 15:01:30 when spacecraft high power was turned on. DSS 72 reported that spacecraft telemetry did not confirm that omnidirectional antenna A was extended.

(3) DSS 51 performed spacecraft acquisition at nominal frequency and signal level on the given launch azimuth. Acquisition was at 15:04:50 at a signal level of −121 dBmW on the S-band acquisition aid (SAA). The S-band cassegrain monopulse (SCM)/master signal level at 15:06:28 was −88 dBmW. DSS 51 utilized its transmitter battle short from 14:59 through acquisition to 15:22. DSS 51 had to retransmit a command when a previous command was not accepted by the spacecraft.

(4) The DSS 51 *Surveyor* Operations Chief (SOC) reported that spacecraft telemetry indicated that omnidirectional antenna A was not extended, but all other spacecraft systems were normal. Commands to extend omnidirectional antenna A were transmitted without response. Spacecraft-1 Receiver A received-signal levels did not indicate an immediate problem.

(5) DSS 51 did experience problems with its L-S receiver in maintaining lock at 15:47. The voltage-controlled oscillator (VCO) was replaced with a spare and no further trouble of this nature was experienced at the station. The trouble was attributed to a power line transient.

(6) The 102-deg launch azimuth afforded a short view period to DSS 42 from 16:52 to 17:08; however, elevation angles for the pass were less than 8 deg. Signal levels of this view period averaged −52 dBmW.

(7) DSS 61 tracked the *Surveyor I* spacecraft three-way, for training purposes, from 18:28 to 02:14 of Day 151. All signal levels were nominal. There were no failures or anomalies during this pass.

(8) DSS 11 acquired *Surveyor I* three-way at 02:12 and two-way at 02:16. Signal levels were nominal. Problems were encountered at 03:12 with doppler data in the form of excessive noise. Module B-15 in Counter 2 was replaced to eliminate the problem.

E. Midcourse Maneuver to Terminal Descent

DSS 11 utilized the transmitter battle short from 05:48 through midcourse maneuver at 06:43 to 07:14. The midcourse maneuver was performed in two-way coherent mode without any loss of lock. Signal levels were nominal throughout the pass. End of track was at 10:40 of day 151.

DSS 42 acquired the spacecraft three-way at 0616 and backed up DSS 11 through midcourse at 06:45 where a negative doppler shift of 234 cycles was noted. Station transfer to DSS 42 from DSS 11 occurred at 09:00 and all signal levels were nominal during the pass. Transfer to DSS 51 was made at 15:10.

[10]All times referred to are GMT unless otherwise noted.

DSS 42 experienced trouble with the digital instrumentation system (DIS) *Surveyor* on-site computer program (SOCP) at approximately 16:5. The program had to be restarted several times during the ensuing hour. The problem was diagnosed to be a faulty interrupt from the high-speed data line (HSDL) modem. Control of the spacecraft was transferred from DSS 51 back to DSS 42 at 17:00, and back again to DSS 51 at 18:50. DSS 42 one-way set was at 19:27.

DSS 51 pass 2 acquisition of *Surveyor I* was at 15:00 on day 151. Control of the spacecraft was transferred from DSS 42 at 15:10. Spacecraft control was transferred back to DSS 42 at 17:00 and returned to DSS 51 at 18:50. This was in support of Flight Path Analysis and Command (FPAC). At 17:58, a tube in the transmitter heat-exchange temperature regulator at DSS 51 failed. The tube was replaced which in turn corrected the problem. All signal levels were nominal throughout the pass. Spacecraft control was transferred to DSS 11 at 02:35 and end of track was at 02:49 of day 152.

DSS 61 tracked Spacecraft-1 pass No. 2 from 19:05 of day 151 to 03:13 of day 152. No anomalies occurred during the pass and all signal levels were normal. DSS 11 pass No. 2 acquisition was at 02:26 with two-way transfer from DSS 51 at 02:35. The station experienced difficulty at 02:30 with its doppler and also in maintaining lock. At 03:18 the transmitter was turned off for repairs. A faulty transmitter VCO selector coax switch was isolated as the problem. This switch was bypassed with a short length of coax, since only one VCO was being utilized, and the transmitter was back on at 06:12. An early transfer to DSS 42 was effected at 07:10 to enable DSS 11 to correct its erratic transmitter problem.

Pass No. 2 acquisition at DSS 42 occurred at 06:51 of day 152. Spacecraft control was transferred from DSS 11 at 07:10. All signal levels were nominal and no failures or anomalies were experienced during this pass. Transfer to DSS 51 was at 17:00 and spacecraft set was at 19:40.

DSS 51 acquired three-way at 1514 and transferred spacecraft control from DSS 42 at 17:00. All signal levels were nominal and no failures or anomalies were experienced during the pass. Transfer to DSS 11 was accomplished at 02:45 of day 153 and spacecraft set was at 03:11.

DSS 11 acquired Spacecraft-1 three-way at 02:25 on pass No. 3, the touchdown pass. Transfer from DSS 51 was completed at 02:45 at nominal signal level and the transmitter battle short was employed at 05:13 in preparation for the terminal maneuver, touchdown, and initial video sequences.

The transmitter VCO frequency was decreased by 170 Hz at 05:15 which corresponded to spacecraft receiver best-lock frequency at touchdown. This was to enable rapid reacquisition of the uplink if it was lost at retro or touchdown.

There was much confusion at this particular time on the DSS 11 voice line. The station reported its X_A (ground transmitter VCO frequency) change in frequency and asked for confirmation by Track. The SOC reported a different polarity of the X_A and Spacecraft Performance Analysis and Command (SPAC) reported a different magnitude of the change. Meanwhile BUSS-1, the Communications Chief, was on the net trying to command the spacecraft. Track Advisor quickly evaluated the change and determined that the polarity and magnitude were correct and so advised DSS 11. DSS 11 was then ready for commanding and the voice line was officially transferred to the command net.

F. Terminal Descent to Touchdown

The spacecraft was commanded to change its orientation approximately ½ h before touchdown so that the main retro-thrust was aligned with the velocity vector. At a slant range of approximately 60 mi, the AMR generated a signal which initiated the ignition of the vernier engines and the main retro engine. In addition, the RADVS were turned on. The thrust provided by the main retro removed the bulk of the spacecraft velocity. When the main retro engine burned out, it was jettisoned and the doppler radar subsystem became effective. The remaining spacecraft velocity was removed, during the final phase of the descent, by the vernier engines under control of the RADVS in accordance with the preprogrammed altitude versus velocity schedule. Shortly before landing, the vernier engines were shut off and the vehicle free-fell to the lunar surface.

The terminal maneuver was started at 05:36 and completed at 05:50. Receiver VCO frequencies were increased by 130 Hz at 05:57 to compensate for a decrease in doppler frequency from retro to touchdown. Receiver No. 1 (TVGDHS Receiver) was switched to manual gain control (open loop) at 06:01.20 to enable recording of strain gauge data. Retro time was 06:14:50. Receiver No. 2 SPE increased from a negative 14 kHz at retro to zero at touchdown. Touchdown time was 06:17:53. No loss of receiver lock occurred during this sequence.

G. Touchdown to End of Mission

The DSIF continued to track the spacecraft on the lunar surface from touchdown until approximately 30 h after lunar nightfall, lunar nightfall occurring at about 15:15:00, June 14, 1966. Actual station tracking periods until touchdown, together with nominal view periods, may be seen in Table 79.

The first 200-line video picture was taken at 06:52. Several more 200-line pictures were then taken before erecting the solar panel and planar array, and at 07:06 the battle short was turned off. Routine 600-line video and various engineering sequences were performed during the remainder of the DSS 11 pass which ended at 11:39 on day 153.

DSS 42 acquired Spacecraft-1 at 07:08. The station reconfigured for 200-line pictures at 07:29 and monitored eight 200-line pictures commanded by DSS 11. From 09:45 to 11:16, the station monitored 115 DSS 11-commanded 600-line pictures.

Spacecraft control was transferred from DSS 11 to DSS 42 at 11:25. Planar array positioning was completed during this pass as well as Project-directed interrogation. Transfer from DSS 42 to DSS 51 was effected at 17:40 and end of track was at 02:01.

DSS 11 was utilized as the prime commanding station for television during the lunar phase of the mission. Both DSS 42 and DSS 51 did, however, command and receive 600-line television pictures during pass No. 5. Reports indicate that these pictures were of good quality.

Table 80 indicates the TV pictures made by commands from prime tracking stations.[11] Table 81 shows the first and second lunar day operations sequences.

The phenomenal performance of the *Surveyor I* spacecraft was officially terminated at the end of the second lunar day. However, successful operations were conducted on subsequent lunar days thus providing much greater data than had been originally anticipated.

H. Summary of DSIF Station Operations for *Surveyor*

Table 82 is a summary of DSIF station operations for *Surveyor I* mission. A description of the tabular columns follows.

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

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

[11]Does not include second lunar day or subsequent operations.

Table 79. DSIF nominal view periods vs actual tracking

Date	DSIF station	Nominal rise	Nominal set	Nominal view period[a]	Acquisition by station	Loss of signal by station	Actual view period
May 30, 1966	72	14:58:33	05:33:03[b]	$14^h34^m30^s$	14:58:59	05:29:00	$14^h30^m01^s$
	51	15:04:51	02:17:37[b]	$11^h12^m46^s$	15:04:50	02:21:10	$11^h16^m20^s$
	42	16:39:55	17:16:00	$00^h36^m05^s$	16:51:56	17:08:43	$00^h16^m47^s$
	61	18:01:16	02:52:05[b]	$08^h50^m49^s$	18:28:25	02:14:33	$07^h46^m08^s$
May 31, 1966	11	02:13:14	10:36:58	$08^h23^m44^s$	02:24:02	10:40:02	$08^h16^m00^s$
	42	05:59:47	19:26:52	$13^h27^m05^s$	06:16:32	19:27:27	$13^h10^m55^s$
	51	15:00:28	02:59:09[b]	$11^h58^m41^s$	15:00:28	03:01:00	$12^h00^m32^s$
	61	18:32:59	03:49:05[b]	$09^h16^m06^s$	19:05:29	03:13:18	$08^h07^m49^s$
June 1, 1966	11	02:24:58	11:16:32	$08^h51^m34^s$	02:26:48	11:21:00	$08^h54^m12^s$
	42	06:53:21	19:38:13	$12^h44^m52^s$	06:51:03	19:40:11	$12^h49^m08^s$
	51	15:14:53	03:10:20[b]	$11^h55^m27^s$	15:14:38	03:11:25	$11^h56^m47^s$
June 2, 1966	11	02:25:47	11:34:21	$09^h08^m34^s$	02:25:14	11:39:02	$09^h13^m48^s$
	42	07:10:36	20:12:30	$13^h01^m54^s$	07:08:19	20:11:00	$13^h02^m41^s$

[a]Based on horizon mask for all stations except DSSs 61 and 72, which are based on 0-deg elevation. This accounts for large discrepancy in nominal versus actual view periods at DSS 61.

[b]Set occurs on next day.

Table 80. Prime tracking stations TV commands

Pass No.	Date, 1966, GMT	Event	Number of TV pictures		
			DSS 51	DSS 11	DSS 42
3	June 2	Soft landing 06:17:37 GMT (June 2)		145	
				13 (includes 13 200-line)	
4	June 3			863	
5	June 3/4		3	395	
6	June 4/5			646	(includes 13 200-line)
7	June 5/6			867	263[a]
8	June 6/7	Lunar noon, 06:17 GMT (June 7)		1048	
9	June 7/8				
10	June 8/9				
11	June 9/10			1759	
12	June 10/11			1373	
13	June 11/12			1363	
14	June 13			1321	
15	June 14/15	Start lunar night, 15:12 GMT (June 14)		520[b]	
16	June 15/16				
17	June 16	Spacecraft power turned off by DSS 11 20:31:00 GMT (June 16)			
		Station total →	3	10,300	13
		Grand total →		10,316	

[a]Received during DSS 11 transmission and DSS 11/42 mutual view period.

[b]Last picture was of Pad 2 by earth light (after lunar sunset). Exposure was f4.0 at 4 min.

Table 81. First and second lunar day operations sequence

First lunar day

June 2, 1966

- Post-touchdown standard sequence for turning off power to systems used during terminal descent.
- First pictures (200-line) using standard sequence (survey of pads 2 and 3).
- Solar panel and high-gain antenna erection test.
- First 600-line pictures (360 deg constant range survey).
- Wide-angle survey of one sector (54 deg).
- Narrow-angle survey of two sectors (18 deg each).

June 3, 1966

- Wide-angle survey of five sectors (54 deg each—360 deg total).
- Survey of pad 2 area.
- Narrow-angle surveys of 14 sectors (18 deg each).
- Color survey of pad 2.

June 4, 1966

- DSS 51 video training survey (3 pictures).
- Surveys of pads 2 and 3 and crushable block 1 and 2 imprints.
- Color survey.
- DSS 42 video training survey.
- N_2 gas jet/surface reaction study.

June 5, 1966

- Surveys of pad 2 color test chart, pads 2 and 3, and crushable block 3 imprint.
- Narrow-angle survey of 10 sectors (18 deg each).
- Color survey of Rock A.
- Wide-angle survey of 4 sectors (54 deg each).
- Mapping survey of star Sirius.
- Survey of Pads 2 and 3.
- DSS 42 200-line TV thermal study.

June 6, 1966

- (Lunar noon 06:17 GMT)
- Surveys of pad 2 color test chart, pads 2 and 3, crushable block 1 and 3 imprints.

June 6, 1966 (contd)

- N_2 gas jet/surface reaction study.
- Wide-angle color survey (360 deg total).
- Mapping survey of stars Sirius and Canopus.
- Wide-angle color survey (360 deg total).
- Survey for earth search.

June 7, 1966

- Surveys of pad 2 color test chart, and pads 2 and 3.
- Wide-angle survey (360 deg total).
- Narrow-angle color survey of 6 sectors (18 deg each).
- Surveys of pad 2 color test chart, and pads 2 and 3.

June 8 and 9, 1966

- No operations during lunar noon.

June 10, 1966

- Surveys of pad 2 color test chart.
- Wide-angle survey (360 deg total).
- Surveys of Rocks A and B (color), helium bottle (color), focus ranging profile, and crushable block 1 imprint.
- Narrow-angle survey of 9 sectors (18 deg each).
- Search survey of planet Venus.

June 11, 1966

- Survey of pad 2 color test chart.
- Wide-angle survey (360 deg total).
- Narrow-angle survey (360 deg total).
- Survey of crushable block 1 imprint, omnidirectional antenna B locking strut and auxiliary battery.
- Search survey of star Arcturus.
- Survey of compartment A top, and omnidirectional antenna B color test chart.
- Narrow-angle color survey of one sector.
- Color survey of compartment B top.
- Surveys of landing legs 2 and 3.
- Mapping survey of star Sirius.

Table 81 (contd)

First lunar day (contd)

June 12, 1966

Survey of omnidirectional antenna B color test chart.
Wide-angle survey (300 deg total).
Narrow-angle survey (330 deg total).
Narrow-angle color survey of pads 2 and 3.
Three focus ranging profiles.
Horizon scan, and wide- and narrow-angle azimuth scans.

June 13, 1966

Wide- and narrow-angle horizontal surface scan.
Survey of crushable block 3 imprint.
Narrow-angle surveys of 2 sectors.
Survey of omnidirectional antenna B color test chart.
Wide-angle survey (300 deg total).
Narrow-angle survey (270 deg total).

June 14, 1966

Survey of omnidirectional antenna B color test chart.
Wide-angle survey (360 deg total).
Narrow-angle survey of 5 sectors (18 deg each).
Horizon scans at sunset.
(Start lunar night 15:12 GMT)
Survey of solar corona.
Pad 2 earthshine picture (4-min exposure).

June 15 and 16, 1966

Engineering interrogations only until spacecraft telemetry was commanded off at 20:31 GMT.

Second lunar day

June 28 to July 6, 1966

Spacecraft did not respond to commands.

July 7, 1966

Solar panel positioning for increased charge rate.
Camera status verification (24 pictures).

July 8, 1966

Surveys of pad 2, compartment A top, and crushable block imprint.
Attempt to fire vernier engines.
Horizon scans at three azimuths.
Surveys of pad 3, crushable block 3 imprint, and auxiliary battery.
Approach TV camera turn-on (no video transmitted).

July 9 to 11, 1966

No camera operation because of excessive battery temperature.

July 12, 1966

Survey of rock B.
Horizon scan.
Wide-angle survey (360 deg total).
Repeated surveys of compartments A and B tops.
Repeated surveys of advancing spacecraft shadow.
Repeated surveys of crushable block 3 imprint.
Surveys of pads 2 and 3.
Survey of omnidirectional antenna B color test chart.

July 13, 1966

DSS 42 and DSS 51 surveys of spacecraft shadow at hourly intervals.
Surveys of omnidirectional antenna B color test chart, and pads 2 and 3.
Mirror/filter wheel dust determination.
Narrow-angle survey of 4 sectors.
Survey of compartment A top.
Narrow-angle survey of 2 sectors.
Survey of pad 2.

July 14, 1966

DSS 51 solar corona survey attempt (200-line).

[a]Other than routine engineering interrogations. All picture sequences are 600-line unless otherwise noted.

Table 82. Summary of DSIF operations for *Surveyor I* mission

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time				
Pass No. 1 — Launch pass								
71	150 150	14:41:00 14:44:15	1 Total	00:03:15 00:03:15	066.0 125.4 140.0			Liftoff occurred at 14:41:00.9.
72	150 151	14:58:33 05:29:00	1 3 Total	00:16:27 14:14:00 14:30:27	093.0 141.4 147.0			Range receiver power supply failed.
51	150 151	15:04:50 02:21:10	1 2 4 Total	00:03:21 11:07:45 00:03:51 11:14:57	088.0 127.0 135.3	77		Station operated on SAA paramp for first 98 s, then switched to SCM maser. Station accomplished two-way lock 3 min, 21 s after acquisition. Acquisition aid receiver failed due to unknown cause. Receiver was replaced. Power failure in receiver rack caused Receiver No. 1 to switch off. Power was restored and Receiver No. 1 locked up but dropped lock every few seconds. Spare VCO was installed and receiver returned to normal. When the 60-Hz circuit breaker was reset after tripping, a very high phase jitter occurred. Apparently instability of VCO output caused receiver to lose phase lock. After replacing VCO, fault did not reoccur. Telemetry indicated that omnidirectional antenna A had not extended. Spacecraft was transferred to DSS 11 on day 151 at 02:16.
42	150 150	16:51:56 17:08:43	3 Total	00:16:47 00:16:47	150.0 151.0 160.0			Spacecraft was below horizon during track.
61	150 151	18:28:25 02:14:33	3 Total	07:46:08 07:46:08	104.2 128.8 134.1			DIS computer program for AGC would not load properly; output was garbled. Program was finally loaded properly at 18:30:31.
14	151 151	02:07:38 10:29:22	3 Total	08:21:44 08:21:44	105.5 126.6 169.0			Station received glitches on a 1-MHz reference from DSS 11.
11	151 151	02:12:03 10:40:00	1 2 3 Total	00:03:57 06:44:02 01:34:07 08:22:06	117.0 134.9 144.5	84		Tracking data handling (TDH) was turned off to check doppler problem. Module B-15 was replaced in Counter No. 2. Midcourse maneuver was performed. Spacecraft was transferred to DSS 42 on day 151 at 09:00.

[a]Ground mode: refer to Table 83.

Table 82 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total Time				
42	151 151	06:16:32 19:27:27	2 3 Total	08:00:00 05:10:55 13:10:55	116.4 138.8 140.5	3		*Scientific Data Systems (SDS) 910 computer hung up several times.* No further trouble was encountered after a switch was made to SDS 920 with same modem. Spacecraft was transferred to DSS 51 on day 151 at 15:10 and 18:50.
Pass No. 2								
51	151 152	15:00:28 03:00:27	2 3 Total	07:46:00 02:23:57 10:09:57	139.0 138.8 141.5	10		Tube failure occurred in heat-exchanger temperature regulator of transmitter water cooler. Spacecraft was transferred to DSS 42 on day 151 at 17:00 and to DSS 11 on day 152 at 02:35.
61	151 152	19:05:29 03:13:18	3 Total	08:07:49 08:07:49	141.0 141.2 144.0			Signal level of both receivers fluctuated ±4 dBmW for 21 min and became steady thereafter.
14	152 152	02:25:10 11:05:00	3 Total	08:39:50 08:39:50	134.4 135.0 152.0			Station received large glitches on 1-MHz reference from DSS 11.
11	152 152	02:26:48 11:21:00	1 2 3 Total	02:07:01 02:27:52 04:19:10 08:54:03	143.2 143.8 150.0	8		At 02:55, problem developed with doppler 22-MHz tripler output. Isolation amplifier and tripler became inoperative. Tripled output of exciter VCO was then used as doppler extractor input. An early transfer was effected at 07:10 to DSS 42 and station was released from recording three-way doppler. After release, doppler problem was isolated to faulty exciter VCO selector module.
42	152 152	06:51:03 19:40:11	2 3 Total	09:50:00 02:58:41 12:48:41	142.4 143.3 144.5	26		An extensive investigation was performed to reproduce OSDP fault previously reported. Investigation was without success. At 05:30 SFOF had difficulty locking up on Modem B. Local tests did not indicate a fault and later tests with SFOF Modem B also indicated no fault. Apparently line trouble occurred during first test. Spacecraft was transferred to DSS 51 on day 152 at 17:00.
Pass No. 3 — First lunar day								
51	152 153	15:14:38 03:11:25	2 3 Total	09:45:00 02:11:47 11:56:47	142.8 143.8 146.4	11		Spacecraft was transferred to DSS 11 on day 153 at 02:45.
61	152 153	19:05:58 03:29:00	3 Total	08:23:02 08:23:02	— 145.2 —			Due to DSS 51 marginal signal level, DSS 61 was requested to send high speed modem data. Tracking reports were not required.

Table 82 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time				
11	153 153	02:25:14 11:39:00	0 1 2 3 Total	01:53:44 00:13:57 06:39:58 00:19:36 09:07:15	096.5 132.9 156.0	56	132 13 (Mode 2)	Touchdown Pass: Station Manager had authority to change from DSS 11 transmitter to DSS 12 transmitter during period from retro minus 29 min to touchdown plus 4 min, 40 s. At all other times this change was not to be made unless ordered by the SFOD. Tracking reports were now required every hour. Touchdown occurred at 06:17:37. Spacecraft was transferred to DSS 42 on day 153 at 11:25.
14	153 153	02:29:54 11:21:00	3 Total	08:47:06 08:47:06	108.2 120.4 136.8			
42	153 153	07:08:19 20:11:00	2 3 Total	06:12:05 06:47:39 12:59:44	097.0 116.3 151.3	590	132 (Mode 3) 10 (Modes 2 and 3)	At 07:30, an anomaly appeared in the receiver in the CDC; in engineering TV Mode, a bias of 1 volt was present in system. At 10:30, three poor TV pictures were received because antenna did not follow predicts. This was caused because antenna was inadvertently left in auto track, an operator error. At 21:29, after post calibrations, a failure occurred in the maser cryogenics. Investigation indicated apparent crosshead, helium line, or main compressor fault. Spacecraft was transferred to DSS 51 on day 153 at 17:40.
Pass No. 4								
51	153 154	15:27:30 03:58:00	2 3 Total	09:43:29 02:47:01 12:30:30	115.5 117.6 120.7	30	3	Prior to pass, a breakdown occurred in high voltage power supply smoothing capacitor. Spacecraft was transferred to DSS 11 on day 154 at 03:24.
11	154 154	03:21:42 12:15:00	0 2 3 Total	04:46:00 02:21:29 00:02:18 07:09:47	095.7 119.2 152.0	4833	863	Spacecraft was transferred to DSS 12 on day 154 at 12:06:20.
42	154 154	07:38:37 19:37:00	2 3 Total	06:28:23 05:29:41 11:58:04	093.5 117.9 121.0	6		Prior to the pass, closed cycle refrigerator (CCR) compressor valve on maser was replaced. Vacuum was obtained using a vac-ion pump, and compressor purged by being run closed cycle. Rubidium 77 was replaced with 49. Paramp was used for pass. Paramp gain drifted by 2.5 dB. It was suspected that klystron was not peaked during countdown. Spacecraft was transferred to DSS 51 on day 154 at 18:35. Track ended at 19:37 instead of 21:05, with SFOD approval, to repair maser.

Table 82 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time				
Pass No. 5								
51	154 155	16:31:56 05:00:00	2 4 5 Total	09:40:54 00:24:08 02:23:00 12:28:02	118.5 119.3 120.2	60	4	At 14:20, AIS code generator failed. Spacecraft was transferred to DSS 11 on day 155 at 04:40. Station commanded TV pictures.
11	155 155	04:33:33 12:58:00	0 2 3 Total	00:34:57 01:59:50 06:16:18 08:51:05	095.8 111.8 125.7	1080	395	Station performed gas jet experiment. Spacecraft was transferred to DSS 42 on day 155 at 10:25 and 12:40.
42	155 155	08:18:00 22:18:00	2 3 4 5 Total	07:13:00 05:16:00 00:36:00 00:55:00 14:00:00	097.9 116.1 159.0	680	21 294 (Mode 2)	Maser was used for this pass. No overflow of oil occurred from first separator on the CCR compressor. Second stage was hotter than normal, 185°F. Maser gain and reserve refrigeration capacity was satisfactory. Station commanded TV pictures. Spacecraft was transferred back to DSS 11 on day 155 at 11:20. After return of spacecraft to DSS 42, it was transferred to DSS 51 at 19:35. Control of antenna was lost in aided track and it had to be braked when declination approached the horizon. Action was caused by an unbalance in servo. Antenna HA delivery hose in pump room developed a large bulge and had to be replaced.
Pass No. 6								
51	155 156	17:23:46 05:47:44	2 5 Total	10:03:00 02:20:48 12:23:48	115.0 117.3 119.0	5		Station was unable to perform TV picture sequence as planned as poor communications delayed start, and no TV brown tapes were held on site. Spacecraft transponder turned off by command 0124 and suitcase receiver tuning was thought to be on sideband. Transmitters kept on track synchronized frequency (synfreq.) Voice communications were out from 03:25 to 04:15. At 04:59 transponder was turned on by command 01:22, but three transmissions of command 02:31 were not received by spacecraft. Uplink indication looked normal at CDC. Command modulation was turned off and transmitter was tuned to X_A. Normal two-way lock was then achieved. Preliminary findings were that prior to transponder turn-off, SPE was approximately 4 kHz and spacecraft receiver had drifted back to center frequency, thus preventing correct uplink on track synfreq. At 12:45, CEC galvanometer 5 failed and had to be replaced. At 15:33, an RF drive failure occurred during countdown. Cable fault was rectified. At 15:56, Dynamic Phase Error Receiver No. 2 stopped recording on CEC oscillographic recorder.

Table 82 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time				
Pass No. 6 (contd)								
								Station conducted a TV engineering determination, (temperature profile of chassis No. 4 (TV-16)). Spacecraft was transferred to DSS 11 on day 156 at 05:45.
11	156 156	05:29:49 13:48:00	1 2 3 4 Total	04:04:49 02:54:44 00:18:40 00:50:40 08:08:53	094.6 118.1 129.9	4372	646	Prior to pass, high voltage power supply was replaced. Spacecraft was transferred to DSS 42 on day 156 at 13:35.
42	156 156	09:13:25 23:18:41	1 2 3 4 5 Total	00:11:00 07:23:50 02:01:28 01:21:51 03:06:32 14:04:41	096.0 116.7 117.1	988	13 (Mode 2)	At 07:00, collimating tower remote control cables were damaged by earthworks. Repairs were made prior to precalibrations. Rubidium 77 was still under repair and No. 49 was being used as prime. Since No. 49 had not been updated, a 33-Hz error resulted in 1-way and 3-way doppler readings. Spacecraft was transferred to DSS 51 on day 156 at 22:25. At 22:30 doppler counter errors were discovered. A circuit card was changed. Tests proved system was satisfactory. During Pass 6, three dropouts of "millions" digits were noted.
Pass No. 7								
51	156 157	18:15:50 06:42:00	1 2 5 Total	00:51:54 08:05:02 03:29:03 12:25:59	115.1 117.7 119.3	20		Prior to pass, deviation frequency appeared to be non-linear. As replacement of galvanometer 5 prior to pass would have resulted in inaccuracies due to long warm-up time, replacement was not made. On day 157 at 00:30, FR-1400 recorders were adjusted for use with Scotch 3M tape instead of Memorex tape. Spacecraft was transferred to DSS 11 at 06:30.
11	157 157	06:20:09 15:52:55	2 3 4 Total	03:35:05 01:19:22 03:33:10 08:27:37	093.5 117.2 148.6	7876	867	Spacecraft was transferred to DSS 42 at 14:40.
42	157 158	10:12:45 00:05:00	2 3 5 Total	09:00:02 01:35:56 03:15:26 13:51:24	101.3 116.8 135.2	300	263 (Mode 2)	At 13:30, discovery was made that antenna angle error channels on CEC recorder were not switched on. This situation was corrected immediately. At 13:44, video data was received. An unsuccessful attempt was made to receive earth pictures. Polaroid photos were no longer mandatory. Prior to transfer to DSS 51, during change of transmitter VCO frequency, BAD DOPPLER switch was not selected; operator error. Spacecraft was transferred to DSS 51 at 23:40. During DSS 11 overlap period, 263 pictures were received.

Table 82 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time				
Pass No. 8								
51	157 158	19:14:22 07:33:40	1 2 5 Total	00:08:47 09:03:16 04:48:16 14:00:19	116.5 128.2 145.0	1656		At 01:32, the transmitter 22-MHz distribution amplifier was replaced. Spacecraft was transferred to DSS 11 on day 158 at 07:15.
11	158 158	07:04:29 15:55:40	0 2 3 4 Total	00:56:10 04:03:57 00:10:31 03:32:50 08:43:28	093.8 125.4 159.0	9345	1048	Prior to pass, CDC Tape Reader No. 2 and vac-ion pump on maser refrigeration equipment became inoperative. Station accomplished simultaneous wide-band frequency modulation (WBFM) checks with DSS 42. Spacecraft was transferred to DSS 42 on day 158 at 15:48.
42	158 159	11:16:00 00:40:00	1 2 5 Total	03:45:02 06:51:58 02:47:00 13:24:00	095.9 109.9 120.8	67		Prior to pass, there was excessive noise on FR-1400 Recorder A at 60 in./s. Recorder B checked out and used for video sequences. IMP was not addressing Alpha A/D converter. AGC section was not used from 13:08 to end of pass because of a suspected program fault. During pass, precommand status reports changed from once each half hour to once each hour. At 15:45, the transmitter was turned on in error. Transfer time had been voice amended to day 158 at 15:48 but operator did not hear instructions to wait. Transmitter was switched off at 15:45:03. There was no effect on spacecraft. Station performed three modified optional sequence 7 engineering interrogations, and accomplished simultaneous WBFM checks with DSS 11. Station was verbally notified that battery charge was to be terminated only if pressure became excessive, and not solely because of voltage. Spacecraft energizing pressure 3 (EP-3), rate 1, binary coded decimal (BCD) count in last 90 min. was going down at 00:30. Spacecraft was transferred to DSS 51 on day 158 at 22:40.

Table 82 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time				
Pass No. 9								
51	158	19:59:40	2	09:15:02	115.8	30		Prior to pass, a wiring fault in cable form to VCO 8 prevented recording of dynamic phase error for Receiver 2 on IRIG 8. Fault was traced to poor pin connection on Amphenol micro-socket, and corrected.
	159	08:24:58	5	03:10:16	116.5			
					118.2			
			Total	12:25:18				Station performed five modified optional sequence 7 engineering interrogations.
								Spacecraft was transferred to DSS 11 on day 159 at 07:55.
11	159	07:35:50	2	08:55:00	117.5	3158		Spacecraft was transferred to DSS 42 on day 159 at 16:50.
	159	16:58:00	3	00:27:10	125.6			No TV pictures were taken this day, due to lunar high noon period.
					156.0			
			Total	09:22:10				Station conducted engineering interrogation.
42	159	12:12:00	2	06:40:00	116.1	18		Prior to pass, the FR-1400 Recorder A capstan end play caused noise. This was repaired, along with flywheel bearing which required replacement.
	160	01:16:00	4	06:24:00	137.8			
					156.8			Due to patch error, no recording was made of hot line for first 28 min.
			Total	13:04:00				No temperature trends were noted at this time.
								Four modified Optional Sequence No. 7s were performed.
								Spacecraft was transferred to DSS 51 at 159/23:30. X_A was biased at plus 100 Hz. Predict set 80A was used.
								With transmitter off, station monitored track-directed spacecraft receiver test with DSS 51.
								Receiver A lock frequency was repeatable and almost identical when approached from either side.

Table 82 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time				
Pass No. 10								
51	159 160	20:51:00 09:08:21	1 2 5 *Total*	00:19:30 08:59:56 02:18:45 11:38:11	144.3 145.6 146.5	20		Four Modified Optional Sequence No. 7s were performed. Spacecraft was transferred to DSS 11 on day 160 at 08:30.
11	160 160	08:09:00 18:04:45	2 3 Total	08:45:10 01:09:50 09:55:00	117.5 132.6 148.5	4000		No TV pictures were taken due to lunar high noon period. Telecommunications, threshold experiments and two Optional Sequence No. 7s were performed. At 17:30, SFOF was evacuated for 15 min. due to fire that started when a generator overspeed motor burned out. Spacecraft was transferred to DSS 42 on day 160 at 17:15.
42	160 160	13:07:00 01:44:20	2 4 5 Total	06:15:02 05:34:12 00:46:22 12:35:36	116.8 116.9 117.0	15		Prior to pass, mission-dependent equipment (MDE) command and data handling console (CDC) command Verification Punch No. 1 became unserviceable and began garbling data. At 14:16, station recorded DSS 11 telecommunications experiment, but could not pick up 7.35-kHz sub-carrier oscillator in FM telemetry 20-kHz bandwidth. Three Optional Sequence No. 7s performed. Clear cooling trend was noted in compartments A and B. Station was in control of spacecraft during SFOF fire from 17:30 to 17:45. Spacecraft was transferred to DSS 51 at 23:30.
Pass No. 11								
51	160 161	21:34:34 09:52:00	1 2 5 Total	00:43:44 06:07:37 05:29:05 12:20:26	*099.0* 116.8 119.4	*15*	*80 (Mode 2)*	*Spacecraft was transferred to DSS 72 on day 161 at 00:35, 02:05, and 04:10, and to DSS 11 at 08:40.* Station received 600-line TV pictures during overlap with DSS 11.
72	161 161	00:14:00 05:00:02	2 3 Total	03:31:49 01:14:13 04:46:02	128.0 132.0 149.0			Station accomplished two-way acquisition and tracking. After initial transfer from DSS 51, equipment was returned to wrong track synfreq, and then corrected. Spacecraft was transferred back to DSS 51 on day 161 at 01:45, 03:40, and 05:00. At 02:57:30, a tripped interlock caused transmitter to turn off. Power was restored immediately.

Table 82 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time				
Pass No. 11 (contd)								
11	161 161	08:33:02 19:06:30	1 2 3 4 Total	01:43:05 01:14:55 00:12:45 07:06:32 10:17:17	096.0 117.5 145.0	12000	1759	At 06:00, a beam failure in one of the relay stations between Goldstone and JPL caused a breakdown in 6-MHz transmissions. Western Union engineers repaired line and it was again operational at 08:05. Spacecraft was transferred to DSS 42 at 19:00.
42	161 162	14:06:00 02:10:00	2 4 5 Total	05:29:58 03:15:14 03:12:19 11:57:31	096.4 116.9 117.0	17	600 (Mode 2)	Prior to pass, at 18:15, MDE CDC command Verification Punch No. 1 was placed back into service. Three Optional Sequence No. 7 low-power interrogations were accomplished. At 23:45, SOC at DSS 42 transmitted command 0306, turning off the optimum charge regular (OCR). On day 162 at 03:45, SOC 51 was requested to turn OCR back on again. Spacecraft was transferred to DSS 51 at 00:30. At 01:48:20, a blown 15-A fuse in HA power panel caused antenna to stop. Fuse was replaced.
Pass No. 12								
51	161 162	22:26:20 10:39:20	1 2 5 Total	00:39:58 06:18:42 05:12:58 12:11:38	102.5 117.4 118.1	22	52 (Mode 2)	Prior to pass a leak developed in heat exchanger water pump assembly at 17:10. After exchange of pump, service was restored at 19:30. Spacecraft was transferred to DSS 61 on day 162 at 01:50. At 03:45, SOC at DSS 51 sent command 0306, to turn on OCR. At 04:22:35, receiver lost lock due to transmitter failure caused by a leaking safety release valve. Water was added to system and relief valve was bypassed. At 05:10, battle short was turned on; at 05:46 battle short was turned off. Spacecraft was transferred to DSS 11 on day 162 at 09:15.
61	162 162	01:08:45 05:50:00	1 2 3 Total	00:40:49 01:45:02 02:11:36 04:37:27	116.4 117.0 162.3			No CDC or analog instrumentation subsystem (AIS) equipment was used during this pass. Two-way acquisition and tracking were accomplished. Spacecraft was transferred back to DSS 51 on day 162 at 03:35.
11	162 162	09:01:53 17:36:00	2 3 4 Total	01:41:08 00:19:05 06:25:10 08:25:23	096.5 117.9 143.8	10100	1373	Prior to pass, power supply in TV -11 film recorder became inoperative and a substitute power supply was used during the pass. Another problem developed on 6-MHz line between Goldstone and JPL and existed from 06:20 to 07:10. This appeared to be another relay station beam failure.

Table 82 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time				
Pass No. 12 (contd)								
11 contd								FR-1400A motor drive amplifier became inoperative and had to be bypassed. Reel 2 of FR-800 contained 1590 ft of bad frames. Spacecraft was transferred to DSS 42 on day 162 at 17:30. Station was scheduled to track until 19:58:24, but was released from tracking at 17:36 due to manpower stresses.
42	162 163	15:01:41 24:00:00	1 2 3 5 Total	00:02:01 06:00:00 01:16:44 01:38:42 08:57:27	115.3 116.0 142.0	71		Spacecraft was transferred to DSS 51 on day 162 at 23:30. DIS alpha magnetic tape unit failed to record the interim monitor program (IMP) during the pass. All switches were in their correct positions, but tape had not moved off file marker. Program and tape unit were checked after the pass, but no fault or reason was found for loss of data. Three Optional Sequences No. 7 low-power interrogations were performed. Station was scheduled to track until 02:37, but was released at 24:00 due to manpower stresses.
Pass No. 13								
51	162 163	23:13:10 11:07:00	1 2 5 Total	00:01:35 06:17:54 05:33:19 11:52:48	115.6 116.4 118.5	237	100 (Mode 2)	At 23:30 station clocks were found to be 9 s slow, and were corrected. Pass times were adjusted accordingly. Spacecraft was transferred to DSS 72 on day 163 at 02:00, 04:10, and 06:15, and to DSS 11 at 09:45. SCAMA console power supply failed during post calibrations, rendering all SCAMA circuits inoperative.
72	163 163	01:40:00 07:00:02	2 3 Total	03:55:06 01:24:56 05:20:02	128.0 128.5 146.0			Paramp was used for tracking. Two-way acquisition and tracking was accomplished. Spacecraft was transferred to DSS 51 on day 163 at 03:45, 05:35, and 07:00.
11	163 163	09:32:00 20:58:20	1 2 3 4 Total	00:08:14 03:58:22 00:39:30 06:14:14 11:00:20	097.0 111.8 148.7	10611	1363	FR-800 monitor light indicated intermittent recording. Adjustment was made to correct this problem. Bad film magazine was found in the 70mm recorder and replaced. Spacecraft was transferred to DSS 42 on day 163 at 20:52.
42	163 164	15:57:00 03:06:00	1 2 3 5 Total	01:13:17 02:52:52 05:01:46 01:55:27 11:03:22	115.8 116.5 130.0	35		At 19:45, transmitter body flow interlock tripped while transmitter was in standby operation. Coolant leakage was found near heat exchanger pump. Leak was fixed temporarily and tank refilled with coolant. Transmitter was again operational at 21:50, however, off time had delayed the transfer so that DSS 11 commanded spacecraft transponder off. Two Optional Sequences No. 7 low-power interrogations were performed. Spacecraft was transferred to DSS 51 on day 164 at 01:00.

Table 82 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time				
Pass No. 14								
51	164 164	00:06:40 11:40:00	1 2 5 Total	00:30:43 06:51:08 04:11:17 11:33:08	115.3 116.3 117.4	64	16 (Mode 2)	Spacecraft was transferred to DSS 61 on day 164 at 02:15, 04:10, and 06:22. Transfer of spacecraft to DSS 11 was at 10:15. Five Operation Sequence No. 7s were accomplished. At 06:13:41, transmitter tripped off, causing loss of up-link. DSS 61 attempted to acquire two-way lock. Cause of transmitter failure was traced to leaking water pump in heat exchanger. As no spares were available, operation throughout pass was sustained by filling the heat exchanger system every 15 min. *During overlap with DSS 11, 16 excellent TV pictures were obtained.*
61	164 164	01:54:21 07:00:00	1 2 3 Total	00:11:50 02:12:04 02:41:22 05:05:16	116.4 *** 161.5			Spacecraft was transferred to DSS 51 at 03:40 and 04:56. Station acquired spacecraft in two-way lock at 06:22. This was a real time request for transfer made by DSS 51. Transmitter was turned off at 06:24:40 without transfer.
11	164 164	10:00:39 21:42:00	2 3 4 Total	03:19:58 00:18:19 08:02:29 11:40:46	092.5 116.7 119.4	7614	1321	Spacecraft was transferred to DSS 42 at 21:38.
42	164 165	16:58:00 03:33:00	2 3 4 5 Total	05:09:23 01:25:36 00:12:04 03:46:31 10:33:34	090.5 111.4 116.0	444		Two low-power interrogations were accomplished. Spacecraft was transferred to DSS 51 on day 165 at 03:00. Type 5374 35mm film was used in the CDC camera due to lack of correct film.
Pass No. 15								
51	165 165	00:58:32 12:06:00	2 5 Total	07:40:00 03:27:26 11:07:26	116.6 116.8 117.1	25	100 (Mode 2)	Spacecraft was transferred to DSS 11 on day 165 at 10:40.
11	165 165	10:27:40 19:51:21	1 2 3 Total	00:12:07 07:46:20 00:12:20 08:10:47	096.5 130.8 158.0	5000	520 (Mode 3)	Non-essential power on spacecraft was turned off at 18:10. Lunar night began at 18:12. Station was scheduled to track until 22:25, but at 20:00 the Space Flight Operations Director for *Surveyor* (ACE-1) gave permission to end tracking for this pass.

Table 82 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time				
Pass No. 15 (contd)								
42	165 166	18:00:00 03:50:02	0 1 2 3 Total	02:48:56 00:19:01 01:15:21 00:29:00 04:52:18	135.0 140.2 143.3	109		Paramp was used during pass because of maser breakdown. This breakdown was due to a malfunctioning No. 1 oil separator which caused excessive amount of oil to enter compressor tank. Compressor then ran hot. No spacecraft transfer to this station was accomplished. Station transmitter turned on at 20:45. Six lunar night low-power interrogations were performed. Spacecraft was transferred to DSS 51 on day 166 at 03:50.
Pass No. 16								
51	166 166	02:05:00 12:27:22	0 2 5 Total	06:06:13 01:18:29 00:37:04 08:01:46	142.1 142.6 143.2	73		SOC at DSS 51 was instructed to interrogate spacecraft every hour in case of loss of all communications with SFOF. Spacecraft was transferred to DSS 11 on day 166 at 12:15.
11	166 166	12:06:55 22:35:00	0 1 2 3 Total	09:05:05 00:48:15 00:12:00 00:21:29 10:26:49	142.3 142.5 143.6	96		Station performed 10-min engineering tests every hour until 19:30, after which tests were taken on battery every 2 h. Spacecraft was transferred to DSS 42 on day 166 at 22:22. At 22:35 ACE-1 released station from scheduled tracking-termination time of 23:15:00.
42	166 167	20:09:58 04:22:45	4 5 Total	00:31:34 00:37:24 01:08:58	139.6 141.6 143.0	30		Maser was still inoperative and CCR compressor under repair. Hourly precommand status was not applicable with transmitter off. Four low-power lunar night interrogations were completed. Spacecraft was transferred to DSS 51 on day 167 at 02:55.
Pass No. 17								
51	167 167	03:05:52 12:53:00	0 2 4 5 Total	05:42:22 01:51:45 01:20:16 00:52:55 09:47:18	140.8 141.4 142.1	80		Seven low-power interrogations were conducted. Spacecraft was transferred to DSS 11 on day 167 at 12:00.
11	167 167	11:49:57 20:32:00	2 3 Total	00:10:03 08:32:00 08:42:03	141.0 141.8 142.4	100		Battery power was on for 1 h, followed by 10 min of engineering verification tests, after which battery was shut down for 2 h. Spacecraft power was turned off at 20:31:00.
42	168							Maser was still not operating and paramp gain instability of 0.2 dB peak-to-peak was observed and under investigation. Station was released from tracking at 20:00.

Table 82 (contd)

No. DSS	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time				
Pass No. 29 — Second lunar day								
11	180							Station unsuccessfully attempted to reacquire spacecraft from day 180 at 00:06 to same day at 04:17.
Pass No. 30								
11	180 181							Second unsuccessful attempt was made to reactivate spacecraft from day 181 at 00:17 to 06:25.
Pass No. 31								
11	182							Third unsuccessful attempt was made to reacquire spacecraft from day 182 at 02:32:35 to 06:33:29. All commands were sent to spacecraft in all four receiver/decoder combinations.
Pass No. 32								
11	183							Fourth unsuccessful attempt was made to acquire spacecraft from day 183 at 03:30 to 08:00.
Pass No. 33								
42	184							On day 184 at 05:50, Alpha Computer was serviceable except for TTY input. Beta Computer was faulty on TTY input and output. Alpha Computer was used during the pass. An unsuccessful RF search was made for spacecraft from day 184 at 08:10 to 12:55.
Pass No. 34								
42	185							Alpha Computer was still not working. Another unsuccessful attempt was made to reacquire spacecraft from day 185 at 09:25 to 13:00.
Pass No. 35								
42	186							Prior to track time, TTY data input to Beta Computer did not function. After, track anomaly was isolated to a patching error. Spacecraft reactivation was attempted from day 186 at 10:26 to 14:59. Although attempt was unsuccessful, at 12:11:24 CEC Receiver No. 1 signal-level track jumped to approximately —160 dBmW and after 40 s gradually returned to rest. Phenomenon was investigated and it was found that by hitting manual gain control (MGC) button on the receiver console, the effect was repeated. It was therefore assumed that no spacecraft signal had been received.

Table 82 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time				
				Pass No. 36				
42	187 187	11:29:10 23:47:00	1 2 3 4 Total	00:39:50 08:31:52 00:46:58 01:18:50 11:17:30	117.0 141.4 154.0	3281		Monitor program was not loaded prior to pass due to operator error and could not be loaded during the pass due to operator inexperience. After performing RF search procedures, command modulator and command NBVCXO were turned on and commands were completed at 11:28:34. Receiver No. 1 locked up at 11:29:10 with approximately —139 dBmW signal level and X_A of 3825. At 11:36, decommutator locked at 137.5 bits/s, Mode 4. Extreme difficulty was experienced in confirming spacecraft status as there was high parity error rate and receivers and decommutator were only intermittently in lock. Receiver No. 1 (prime) was switched to 12-Hz loop bandwidth to minimize errors, and Receiver No. 2 was switched to 48-Hz loop bandwidth to hold a steady down-link lock. At this time spacecraft transmitter frequency appeared to be extremely erratic. First two steps of logic tree procedures were performed. Initial telemetry readouts indicated a +32°F battery temperature and discharge of approximately 1.5 A. Discharge quickly increased to 25 A and potential dropped from 14.5 to 12.5 V. SOC 42 requested permission to command off all non-essential spacecraft services. Because there was no response to these commands, SOC 42 requested permission to initiate spacecraft shutdown. The spacecraft did not respond to this command either. Later, all spacecraft currents were observed to be full scale, suggesting that the X50 current amplifier was malfunctioning due to a regulated 25-V bus. Permission was requested to turn on transponder, and at 12:27 Transponder A was turned on. At 12:58, permission was granted to return X_A to 3800. This was reached at 13:07. At 13:08:38, both receivers went out of lock, indicating up-link phase lock. Although spacecraft may have been in two-way lock from about 12:37, telemetry was considered doubtful and phase lock was not confirmed until 13:09. At 13:29, solar panel repositioning was begun, and by 13:55 batteries were being charged. Spacecraft appeared to settle down and telemetry returned to normal. Spacecraft was transferred to DSS 51 on day 187 at 23:00.
14	187 187	11:29:30 15:31:54	3 Total	04:02:24 04:02:24	136.0 137.1 139.0			Station performed unscheduled tracking after DSS 42 reacquired spacecraft.

Table 82 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time				
Pass No. 37								
51	187 188	19:25:00 07:45:45	2 5 Total	03:35:00 01:13:00 04:48:00	119.0 123.5 128.0	53		Spacecraft was tracked two-way from day 187 at 23:00 to day 188 at 00:13, at which time transmitter was turned off. At 01:50, transmitter was turned back on but spacecraft could not be reacquired. Station suggested that reacquisition may have been prevented when the command was sent to turn off non-essential loads. It was thought that possibly the 29-V non-essential/solar voltage in the battery charge regulator (BCR) had caused the OCR to shut off. (Non-essential/solar voltage is used in voltage limiter circuit that shuts off the OCR.) If the analysis was correct, then all current would have been supplied from the main battery, and when the station attempted to turn on the spacecraft transmitter, the load would have been too great for the batteries at that time. This theory was substantiated by fact that momentary signal had been received. Station felt situation could be corrected if the OCR were turned on again or placed in bypass mode.
11	188 188	07:51:14 16:58:12	0 2 3 4 Total	03:01:09 00:31:36 00:08:09 04:19:02 07:59:56	098.1 125.9 163.0	776	24	At rise time, station could not reacquire spacecraft. DSS 61 reported a weak signal of —160 dBmW with a doppler deviation of +18.7 kHz. DSS 11 searched around this frequency, but could not get a two-way lock with spacecraft. At first station could not command on Transmitter A due to spurious oscillations (though this was accomplished later and transmitter functioned properly). Spacecraft Transmitter B was commanded on and responded. Station received 21 Polaroid pictures. Spacecraft was transferred to DSS 42 on day 188 at 16:50.
42	188 188	11:57:50 23:50:52	0 1 2 3 4 5 Total	00:44:37 01:34:13 02:17:34 02:04:33 00:09:29 01:14:26 08:04:52	097.0 118.4 125.0	203	24 (Mode 2)	Prior to track, the Alpha Computer developed a timing input fault. Two engineering interrogations were performed about 2 h apart. During second interrogation, spacecraft was commanded to Mode 5. Spacecraft was transferred to DSS 51 on day 188 at 23:40.
Pass No. 38								
51	188 189	21:17:43 08:27:00	1 2 5 Total	00:06:25 04:46:53 01:30:46 06:24:04	116.3 132.9 149.5	118		A power level test was performed at 200 W, and a best-lock frequency test was performed on both spacecraft receivers. Station switched to SCM paramp on day 189 at 02:30 due to a defective valve in maser crosshead that allowed coolant to escape to the atmosphere. Spacecraft was shut down without transfer.

Table 82 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time				
Pass No. 38 (contd)								
11	189 189	07:13:22 17:48:00	0 2 3 4 Total	00:13:50 10:08:23 00:08:00 00:04:23 10:34:36	117.0 132.7 148.5	938		CEC oscillograph chart drive was inoperative from 14:40 to 16:42. TDH transmitter-distributor machine 1 (TD-1) (TTY) was inoperative at 16:09. DSS 14 personnel calibrated their antenna from 09:00 to 11:30 and from 13:00 to 15:30. Spacecraft was transferred to DSS 42 on day 189 at 17:40.
42	189 190	12:52:10 00:38:00	2 3 4 5 Total	02:02:56 04:44:44 04:10:29 00:27:58 11:26:07	096.0 128.3 140.0	1337	38	Serious interrupt difficulties occurred with W computer string buffer while OSDP redefining was being performed. Standard restart was performed. HSDL outage occurred with no explanation other than possible modem or line faults. Buss 1 Chief was notified that, due to increased battery temperature and decreased battery pressure, spacecraft battery would fail within 5 hours. Considerable panel stepping was accomplished. Attempt was made to ignite spacecraft vernier engines, but as flight control thrust phase power could not be turned on, attempt was unsuccessful. Unsuccessful attempt was made to take a normal TV picture using approach TV camera. Spacecraft was transferred to DSS 51 on day 190 at 00:15.
Pass No. 39								
51	189 190	21:09:39 08:41:30	1 2 4 Total	07:10:11 01:15:08 03:06:32 11:31:51	097.0 111.0 151.3	2460	27 (Mode 2)	Undetected fault in heat exchanger caused transmitter to trip off. Transmitter was turned off on day 190 at 01:36:30 to allow DSS 61 to acquire spacecraft in two-way mode. This occurred at 01:54. Spacecraft was transferred to DSS 61 on day 190 at 04:05. Station transmitter was again turned on at 06:53 and back off at 08:08:08.
61	190 190	00:09:00 05:07:40	0 2 3 Total	00:05:40 01:30:25 03:22:35 04:58:40	118.0 134.0 150.0	38		Doppler counter was not operating properly throughout pass. Command modulation was not connected correctly in transfer cabinet. Error was discovered when station attempted to send commands at 01:59:18. Transmitter RF load flow interlock opened about 10 s prior to transfer from DSS 51 on day 190 at 02:20. An RF flow adjustment was made. Station transmitter was turned on at 04:05 and back off at 05:02. Interim Antenna Positioning System drove antenna from spacecraft track. Cause was undetermined.

Table 82 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time				
Pass No. 39 (contd)								
11	190 190	07:36:57 08:11:26	1 3 4 5 Total	00:11:26 03:13:39 00:16:52 00:04:53 03:46:50	144.0 146.8 149.6	390		Five engineering interrogations were accomplished during pass.
42	190 190	07:06:00 22:57:00	0 4 5 Total	03:11:00 01:19:00 01:01:00 05:31:00	141.0 145.8 148.3	90		Three engineering interrogations were performed during pass. During second interrogation a down link could not be established with spacecraft Transmitter A. Transmitter B was then used. Third interrogation was conducted normally, on Transmitter A. During the pass, battery temperature and pressure decreased slightly. Spacecraft was transferred to DSS 51 on day 190 at 22:50.
Pass No. 40								
51	191 191	00:56:12 09:31:20	0 1 2 Total	06:49:20 00:01:41 01:29:30 08:20:31	142.5 145.2 149.3	467		Due to AIS operator oversight, VCO 6 switch was left in test position after precalibrations. This resulted in loss of Receiver No. 2 AGC at recorder. Receiver No. 2 dynamic phase error was not recorded, due to faulty input, possibly in AIS area. Five engineering interrogations were accomplished during this pass, and solar panel was repositioned. Battery temperature continued to decrease after solar panel was repositioned normal to sun. It was estimated that 13.5 Ah were added to battery. Spacecraft Transmitter A was on for 1 h, 12 min, and Transmitter B was on for 37 min. Spacecraft was transferred to DSS 11 on day 191 at 09:15.
11	191 191	09:15:00 18:00:02	0 3 Total	07:08:00 01:33:42 08:41:42	140.5 143.4 147.4	139		Five engineering interrogations were conducted during this pass. No solar stepping occurred. Battery voltage increased from 24.7 to 25.4 V while battery temperature dropped 2 to 120°, with a charge current of 1.1 A. Spacecraft was transferred to DSS 42 on day 191 at 18:00.
42	191 192	17:31:00 00:18:32	0 4 Total	05:30:24 01:16:58 06:47:22	140.0 142.0 146.6	99		Three engineering interrogations were performed. Two were performed normally with Transmitter A. On third interrogation, down link could not be established with Transmitter A, and Transmitter B had to be used. During turn off, command was sent that placed Transmitter B on planar array and Transmitter A on omni array so normal turn-on sequence (Transmitter A) could be performed for next interrogation. Battery pressure and temperature remained constant at 12 psia and 120°.

Table 82 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time				
				Pass No. 41				
51	191 192	23:51:43 08:45:04	0 1 4 Total	06:24:31 00:25:28 01:21:12 08:11:11	144.5 146.3 148.0	112		Four engineering interrogations were accomplished. To turn on Transmitter A for first interrogation, four sets of commands were sent, with modulation interrupts in between, without success. As a result, Transmitter B was turned on and Mode 5 data was monitored longer than normal to fulfill Track request to monitor spacecraft AGC and automatic frequency control (AFC). Normal shutdown was then accomplished. Transmitter B was used in remaining three interrogations. An estimate was made that battery charge increased by 13.4 Ah. Spacecraft was transferred to DSS 11 on day 192 at 08:45.
11	192 192	08:45:00 20:01:49	0 3 5 Total	09:04:33 02:00:37 00:11:49 11:16:59	140.2 143.4 147.4	145		At 13:53, computer IMP program stopped and could not be restarted. An investigation was made to find cause. At 19:33:05, tripped arc detector caused a transmitter failure. Transmitter was reset. At 15:40:10, CEC oscillograph paper take-up reel bound and was reset. Six engineering interrogations were accomplished. Spacecraft status at this time was: Compartment B thermal switches were opened with stabilized compartment temperature of 55°. Compartment A temperatures were stabilized at 72° on top and 92° on bottom. Battery pressure had increased 3 psi to 18 psia, but temperature and current were constant at 118° and 1.1 A. Potential fluctuated slightly, then increased to 25.9 V. No solar stepping occurred. Spacecraft was transferred to DSS 42 on day 192 at 19:50.
42	192 193	19:23:00 01:59:00	0 1 2 3 4 Total	01:19:30 00:27:00 01:37:12 00:28:35 03:42:30 07:34:47	091.5 110.8 145.5	2880		Two engineering interrogations were performed. Average Alarm Mode was not fully entered by I/O operator on first engineering sequence. Average Alarm was not transmitted by DSS 42 comm for first engineering sequence and most of second sequence. IMP magnetic tape record was bad from 23:30 to 00:43. Dirty tape heads were suspected. Maser helium pressure was decreasing. Spacecraft status at this time was: During pass, considerable stepping of the panels was accomplished, moving +172 deg along roll axis and +60 deg along solar axis. During stepping, solar panel moved from sun's rays and battery voltage dropped to about 17 V. This led to speculation regarding battery condition.

Table 82 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time				
Pass No. 41 (contd)								
42 contd								Bit rate was increased to 1100 bit/s. Spacecraft transmitter was put on planar array and transponder was turned on just prior to transfer. Spacecraft was transferred to DSS 51 on day 193 at 01:30.
Pass No. 42								
51	192 193	23:40:41 04:00:00	1 2 5 Total	01:11:09 02:29:15 00:37:26 04:17:50	120.8 121.4 122.0			Maser warmed up due to failure of a crosshead inlet valve bearing. Station switched to paramp at 02:28:42. Although the station was scheduled to track until 10:28, tracking was terminated at 04:00 to allow maser repairs.
61	193 193	04:33:05 13:30:19	1 2 3 Total	00:02:28 04:28:45 04:16:25 08:47:38	117.0 118.0 119.0			Datex declination readout became inoperative. At 07:25:45 the transmitter turned off when collector flow opened. Spacecraft was transferred to DSS 11 on day 193 at 09:10.
11	193 193	08:58:59 20:57:00	0 2 3 4 5 Total	05:04:16 03:03:58 00:17:23 02:06:10 01:05:23 11:37:10	096.2 113.0 127.8	1500	257	TTY machine E failed at 10:32:00. Spacecraft was transferred to DSS 42 on day 193 at 19:45.
42	193 194	19:36:18 02:28:00	2 3 4 Total	03:55:22 00:52:07 01:50:59 06:38:28	099.2 112.3 119.7	401	98 14 (Mode 2)	Fourteen shadow progression pictures were taken during joint viewing period with DSS 51, with that station controlling the spacecraft. Most of DSS 42 pictures were also of shadow progressions and were of good quality. Spacecraft status at this time was: At end of the pass, battery pressure was approximately 48 psia and increasing at about 3 psia/h. Confirmation was made that repositioning of solar panel should ease situation. Spacecraft was transferred to DSS 51 on day 194 at 01:15.
Pass No. 43								
51	194 194	00:30:50 10:54:06	1 4 5 Total	03:33:20 08:30:02 01:09:04 10:12:26	099.0 114.5 134.0	592	139 37 (Mode 2)	Paramp was used during pass as maser was still down for maintenance. Maser cooled down at 11:50:00. Due to operator oversight, a switch was left open causing line 1 to have no voice label. This was corrected on day 193 at 21:38. There were numerous drops of receiver lock from 01:15 to 09:45 due to TV shadow progression sequences at hourly intervals. Spacecraft was transferred to DSS 11 on day 194 at 09:45.

Table 82 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	TV pictures received	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time				
Pass No. 43 (contd)								
11	194 194	09:39:28 21:48:30	0 2 3 4 Total	03:53:55 07:22:03 00:06:59 00:23:53 11:46:50	098.1 117.7 145.0	5557	334	At 15:02, FR-800 take-up reel malfunctioned, and at 18:25, FR-1400A take-up reel malfunctioned. At 21:38, with command modulation off, receiver lost lock and up-link was lost. This occurred during X_A tuning, and the reason was unknown. Station retuned to regain up/down-links. Transfer was delayed from scheduled time of 21:45. Spacecraft was transferred to DSS 42 on day 195 at 21:47.
42	194 195	18:02:00 03:08:00	2 3 5 Total	03:59:02 04:02:58 01:03:00 09:05:00	124.0 134.5 145.0	108	8 (Mode 2)	During mutual viewing period with DSS 51, eight emergency TV pictures were recorded. Polaroids indicated that these were of poor quality. Solar panel was stepped to about 10 deg from vertical. Deterioration of spacecraft batteries was evident in latter portion of pass. Spacecraft was transferred to DSS 51 on day 195 at 01:46.
Pass No. 44								
51	195 195	01:28:00 07:35:00	2 5 U Total	00:34:14 00:12:53 05:19:53 06:07:00	120.0 132.5 145.5	461	9	Maser was used during this pass. Station was unable to get corona photographs. Station had sent commands for 14 pictures, but only received nine. First two showed lunar surface near horizon, and last one showed glare from sun. Receiver went out of lock for video sequence on day 195 at 02:15:07. At 02:15:07, it was apparent that spacecraft was dying, as tracking ground mode at this point was uncertain. As a result, station discontinued indication of ground mode. Last reported spacecraft battery voltage was 15.2 V.
61	195 195	02:01:12 13:30:00	3 U Total	00:15:48 11:13:00 11:28:48	122.0 137.0 152.0			Station dropped receiver lock on day 195 at 02:17. Station then conducted unsuccessful search procedures until 13:30.

Totals	Commands sent	TV pictures taken (Command)	TV pictures received (Non-command)
1st lunar day	86,167	10,341	1,747
2nd lunar day	22,145	899	110
Grand total	108,312	11,240	1,857

2. Time from acquisition to end of track, GMT. 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 through 5, are defined in Table 83. A *U* indicates that the ground mode was unknown. At the end of each station entry is the total tracking time in all modes.

Table 83. Ground modes

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

4. Ground received signal level, −dBmW (max/avg/min). The ground received signal level column contains three notations for each station's entry. These figures are, respectively, the maximum, average, and minimum signal level received at the indicated station. The values are given in minus decibles relative to 1 mW (−dBmW).

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

6. TV pictures received. Unless otherwise indicated, these figures represent 600-line television pictures received by a station while the spacecraft was under its command. Non-command 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).

I. Space Flight Operations Facility

1. Communications. Overall communications support for the SFOF/DSIF lines was adequate for the mission except for voice breakdowns to and from DSS 51. These breakdowns presented many problems during spacecraft commanding and spacecraft analysis. The sharing of voice lines between DSIF Net Control and Mission Control worked well.

A procedure was implemented on the *Surveyor I* mission that provided for backfeeding the *Surveyor* Command Net on the back side of the HSDL to the noncommanding stations. This provided the noncommanding stations with accurate information on the event in progress. DSS 51 had only half-duplex HSDL and did not have the capability to receive on the incoming side. As a result, the backfed *Surveyor* Command Net used the NASCOM voice line when not required by DSIF Net Control. It was recommended that DSS 51 be provided with a better voice line and a full-duplex HSDL for supporting later missions.

a. Communications systems. All operations voice communications system units installed in each console in DSIF Net Control were not identical except for the intercom. The consoles had one mission control net, which during this mission was overloaded much of the time. The mission control net for *Surveyor* was the *Surveyor* Control Net.

The closed-circuit television (CCTV) system in the SFOF was overburdened. *Pioneer* and *Lunar Orbiter* missions were active at some time during the *Surveyor I* mission and an insufficient number of TTY TV monitors were available to display all circuits.

b. Internal nets. The operations consoles in DSIF Net Control did not have standardized CCTV selection and the information available was not adequate. The following recommendations were made to improve internal net operations for future missions: (1) To relieve overloading of the DSIF Net Control, the *Surveyor* Coordination Net should be made available for use by the Track Chief. (2) A mission-dependent intercom system should be made available to relieve the workload on the *Surveyor* Control Net. (3) The SFOF TTY TV monitor system should be expanded, and the CCTV selectors should be redesigned and standardized for all consoles in DSIF Net Control, to allow any mission to be operated from any console with greater efficiency.

c. Video. Real-time video data presented within the SFOF came from DSS 11 via microwave and was appropriately demodulated by the SFOF television ground data handling system (TVGDHS). A variety of signal interfaces

existed that compromised performance. Therefore, when circumstances indicated a deteriorated performance, each interface was interrogated as appropriate. A good indicator of system integrity, observable within the space science analysis and command (SSAC), was signal capture of the frequency demodulator. In the absence of high-carrier-strength signals from the spacecraft, the demodulator output would represent random noise of uniform spectral density centered at band center. When nominal-carrier-strength television signals were received, the demodulator should be well captured by the signal and exhibit frequency deviations consistent with pre-mission calibration. Loss of GCF microwave signals from DSS 11 or improper patching of predetection signals were identified by comparison of the output with the appropriate indicator, and in those rare cases of GCF problems in which spacecraft signals were involved, the DSS 11 command and data handling console and/or the prime site recording equipment at TV-11 were investigated by voice report. Camera performance continued in an uninterrupted mode when it was ascertained that the difficulty was due to ground equipment existing after the TV-11 microwave interface. If an extensive outage was indicated spacecraft camera sequences were evaluated to defer those operations that might precipitate difficulty, such as solar glare, in the absence of proper data display. Any difficulties experienced with synchronization line driving or display interfaces were handled in real time by standard techniques.

Prime mission recording of television data was made at TV-11 and backup mission recording at the SFOF TVGDHS. When trouble of a correctable nature was encountered with any recording medium, an attempt was made to suspend the video sequence until repair could be made. In those circumstances in which lengthy repair was anticipated, a priority rank was assigned to the type of recording involved, and its effect upon overall mission performance was evaluated to determine if video operation should continue unaffected, be modified, or be suspended pending repair. Magnetic tape and film utilization was increased by manually suspending recording during those times in a picture-taking sequence when no data were being transmitted. By starting the recording in this manner, an enhancement of data reduction was made, since each reel of tape contained less dead time.

2. Data processing system.

a. Computer. The DPS was initialized before launch into the dual mode 2 computer configuration. The dual mode 2 capability consisted of two separate and complete computer strings, each composed of an IBM 7094 and an IBM 7044 computer and a 1301 disk file located in the loop area of the SFOF. On-line control of each computer string was exercised through two inquiry stations (input/output consoles) in the FPAC area by the I/O console operators.

To facilitate scheduling and time sharing of program runs, one computer string (7094-7044X) was assigned as the active (A) string and the other (7094-7044Y) as the backup (B) string. During critical phases of the mission, i.e., launch, premidcourse, and preterminal phases, the mission-dependent editor programs normally running on the backup string were inhibited to preclude interference with the essential FPAC computations.

Actual FPAC computer runs during the mission had certain interruptions or delays to be overcome. This information was compiled from the records and notes logged during the mission. Appropriate action was taken to resolve each problem.

b. Telemetry data. Processing of telemetry data started with the *Surveyor* on-site computer program at DSS 11, 42, or 51. Its function was to edit, format, and output telemetry data over the HSD or TTY lines. With the exception of average alarm data, all SOCP output was coded in such a manner that it had to be processed by computers at the SFOF before it could be interpreted by analysts. Average alarm data were transmitted over a teletype line and were human readable both at the DSS sites and the SFOF.

The high speed data were processed by three computers in the SFOF. The SOCP was the source of HSDL data received at the SFOF. At the telemetry processing station (TPS) the high-speed data were formatted and input to the *Surveyor* TPS program, which was coded for both a PDP-7 (programmed digital processor) and a PDP-4 computer.

The real-time display capability comprised the major portion of telemetry processing in the SFOF. The IBM 7094 editor and EDRS (engineering data reduction) programs processed incoming high-speed data on a bulk basis. However, EDRS was not run very often, and the IBM 7044 output was the source of information used in the Spacecraft Performance Analysis and Command (SPAC) and the Space Science Analysis and Command (SSAC) groups for decision making.

The real-time system ran well during the mission. Prior to the flight, all known discrepancies in both the SOCP

and the IBM 7044 system were documented. These were either of a minor nature or they were avoided by operational means. None of them adversely affected mission performance.

There were some problems, however. At DSS 42 the SOCP failed six times during the first pass. This problem was corrected by loading the program into the SDS 920 backup computer. (Later this was shown to be a memory parity problem in the SDS 910.) At DSS 11 the SOCP was reloaded in an attempt to correct a command verification problem; this did not clear up the problem. (It later turned out that the problem was induced by a poor TTY line.) The IBM 7044 system outputting to SPAC "went down" once during transit and required three minutes to become operational again.

The processing of telemetry data in the IBM 7094 was hampered by equipment problems. Eight times during the mission, program runs were aborted because of faulty card readers. In spite of this problem, however, 29 successful telemetry runs were completed on the 7094.

The high-speed data were of such excellent quality that it was necessary to use teletype only twice during the transit phase, and the total time for which TTY was used as a telemetry source was less than one hour. One of the major surprises during the mission was the high quality of the high-speed data line from DSS 51. The HSDL would remain operational when all other means of communication with the site were not working.

As in the case of high-speed data, the SOCP was the source of all TTY data used during the mission. The two outputs were average alarm and raw telemetry data encoded for TTY transmission. The raw TTY telemetry was entered into the IBM 7044, bypassing the TPS, where it is decommutated. After the data were decommutated, the 7044 processed and logged TTY data in the same manner as high-speed data. The IBM 7094 user programs did not process TTY telemetry. Because of the high quality of HSDL data, telemetry was sent by teletype for only short periods during the mission. When it was used, it was processed correctly. Average alarm data, which were transmitted continuously during the mission, bypassed all of the computers in the SFOF and were displayed on a 60-wpm TTY printer in the SPAC area. This operation presented no problems during the mission.

c. Tracking data. Tracking data were formatted for teletype transmission by the tracking data handling system (TDHS) at each DSS. The data were received by the Communications Center in the SFOF and then patched into the DPS. The IBM 7044 logged the information, displayed it on request, and placed it on disk for processing by the 7094. User programs in the 7094 then used the data for orbit determination. Having determined the orbit, the FPAC group then ran a user program to analyze the trajectory and determine the midcourse correction required.

Raw tracking data were obtained from disk by the 7094 editor, separated from telemetry data, and then written into sequential disk buffers for processing by the tracking data processor (TDP). In order for the editor to properly process the data, identification was achieved by means of a preamble inserted into the data by the TDHS at the DSS. Unfortunately, the preambles were not inserted frequently during the mission; in some cases only once per pass. As a result, much of the data were lost to the editor. The data were retrieved by reading tracking data cards into the TDP. These cards were punched by IBM 047s in the FPAC area. The 047s were installed as a backup because of previous difficulties in retrieving "lost" tracking data. To a large extent, this problem can be alleviated if the stations introduce preambles into the data stream frequently. The optimum time appears to be every 15 minutes.

Some difficulties were encountered in the processing of DSS 72 data, which had a different format than the standard DSS format. This problem was overcome during the *Surveyor I* mission and so did not affect later missions.

Processing in the IBM 7094s was hampered by both hardware and software problems, the hardware being the more serious. The user area card readers were faulty and often rejected good card decks. This required the input of card decks many times or restarting programs in order to input data. Further, this aggravated a previously undiscovered software error that also required numerous program restarts that would not have occurred had the card readers been working well.

The direct data channel between the IBM 7044 and 7094 was a source of problems, both software and hardware. The software problem caused the 7094 system to "blow up" occasionally when it was at the "idle" stop. When this occurred, the 7094 system required a restart; however, it did not "blow up" the program runs. The hardware problem was most evident on the prime FPAC string. It degraded severely just prior to midcourse. Immediately following midcourse, the X-string (7044/7094

mode II computers) was turned over to IBM for maintenance. They found a hardware "bug," corrected it, and returned the system to operational use within 2½ hours.

The I/O console in the FPAA failed four times during the mission. This was a serious failure, since this was the one user area device that could not be replaced immediately. Maintenance personnel were able to effect temporary repairs three times. When it failed the fourth time, an operational technique was used to get around the problem. Other peripheral devices such as SC 3070 printers, administrative printers, and plotters required maintenance or replacement during the mission, but these problems were not as serious as those previously mentioned.

d. Command data. Two types of command processing were done during the mission: (1) command log and (2) command verification. In the command log process, when commands were transmitted to the spacecraft, they were also input to the SOCP. The SOCP time-tagged the commands, when command rates permitted, and formatted the data for transmission over TTY circuits to the SFOF, where the data were input to the IBM 7044. On request, the 7044 output the commands on a 3070 printer. This processing presented no problems during the mission.

Command verification was originally designed to be a joint OSDP/7094 function; however, for the *Surveyor I* mission it was limited to an OSDP function only. In this option, commands were transmitted via TTY circuits to the DSS from the SFOF. The command data were input to the OSDP, which converted the five-level code to a seven-level code and punched a command tape on the CDC tape punch. The tape was then placed on a CDC tape reader and read back into the OSDP. The OSDP converted the commands back to a five-level code and transmitted it, via TTY circuits, to the SFOF. The returned commands were compared manually with the outgoing commands, and if they compared correctly, the command tape was considered to be verified. This procedure was extremely dependent on the quality of the teletype lines used. On occasion, TTY lines had to be switched before the command could be verified. A software problem in the OSDP was uncovered during the mission that required additional dummy commands to be added to the end of a command tape before the tape could be verified. This problem was put under study.

Table 84 lists command confirmation data lost during the *Surveyor I* mission operations. The main cause of loss

Table 84. Command confirmation data loss, SPAC commands

Mission day	Number of failures attributable to:						Total daily omissions	Number of commands recovered via TTY or voice from DSS
	TTY lines	TTY preamble	7044 computer	DSS computer	3070 bulk printer unavailability	Undetermined		
150					13		13	7
151					7		7	7
152					1		1	
153	3					2	5	2
154	3		28		1	10	42	
155	203				98	40	341	83
156		6		2	1	10	19	2
157					3	5	8	
158	2				3	185	190	
159					1327		1327	
160							0	
161							0	
162							0	
163		3			1		4	3
164						19	19	
165		12				14	26	6
166		19	10		2	16	47	25
167		2				16	18	16
TOTAL	211	42	38	2	1457	317	2067	151

was the unavailability of the 3070 bulk printer as an output device for command enable reject (CER) during some of the spacecraft commanding periods. When the bulk printer being used for command confirmation was required by the SSAC or SPAC groups to output other data, command confirmation data were considered low priority and dropped from the printer. The majority of the lost commands were "stepping commands" that occurred during a two-hour period on day 159. The 1326 stepping commands lost during that period constituted 92% of all commands lost because of the unavailability of an output printing device. On day 158, when there were 190 failures, 97% of those lost were stepping commands. On day 155, when there were 341 failures, 155 (46%) were stepping commands. The failure of the teletype network accounted for a large number of command omissions, about 10% of the total. Loss of data from undetermined causes accounted for about 15% of the total. Specific problems with command confirmation data are listed below:

(1) When the interlock command (3617) appeared in the command confirmation data, it printed out as having been erroneously transmitted as a magnitude command if it preceded an actual magnitude command. However, when 3617 preceded an ordinary interlocked command, it correctly printed out as having been transmitted as a direct command.

(2) During a station transfer when a command confirmation (CCN) TTY line was activated or whenever a new preamble reactivated the CCN TTY link, the command confirmation data sometimes printed out numerous commands, most of which were illogical and erroneous. This was also apparent when the TTY line was time-shared for tracking reports.

(3) At the completion of a sequence of commanding, there were many instances when the OSDP equipment failed to terminate the CCN message properly, and the last few commands of the message would fail to print out. The carriage return or end-of-message designator is apparently required for a CER buffer flush.

(4) An improper CCN message header or preamble was noted a few times and caused loss of command confirmation data until it was corrected. In many instances of data dropout the commands were confirmed from the DSIF via TTY or voice.

e. Surveyor command preparation computer. The *Surveyor* command preparation computer program was used to construct and display midcourse and terminal-descent command messages. The program processed data without problems, thereby providing an output which was very useful in cross-checking keyboard command messages and backup tapes.

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

The *Surveyor I* mission included a very successful flight and an outstanding performance by the spacecraft. Unfortunately, the T&DS did not perform as well. Most of the T&DS prime stations experienced many problems. It probably could be said that if *Surveyor I* had not made a nominal flight, these problems would have rendered the conduct of space flight operations quite difficult. The performances of the AFETR, the GSFC, and the DSN are separately evaluated in the following sections.

A. Air Force Eastern Test Range

In general, most of the class I and class II requirements were met.

1. Tracking. The *General Arnold* reported metric capability at approximately 4 min before launch (T − 4 min). At T − 2 h, digital tracker 1 (DT-1) had been repaired by replacing a blocking oscillator circuit card, after which DT-1 performed satisfactorily in preflight checks using a test video input. Postflight investigation revealed that the output polarity of the replacement card was incorrect, thus preventing lockon. DT-2 had failed prior to pickup of range count and could not be repaired in time to support the flight. Therefore the *General Arnold* radar was not operational.

As stated in Section V-C, the Antigua radar lost track at T + 690 s. Although no beacon malfunction occurred, the signal strength went to zero. The problem involved a balance point shift, which caused the servo to drive the antenna off of the target. This problem occurs under certain conditions of antenna patterns and trajectory. Possibly the two radiating C-band antennas on the vehicle contributed to the problem. Also, the possibility of interference between the *General Arnold*, which was attempting to track, and Antigua was not completely ruled out.

2. VHF telemetry. The VHF telemetry coverage was more than predicted. The requirement to transmit the *Centaur* VHF link in real time to Cape Kennedy from Antigua was not met because of an operator patching error.

3. S-band telemetry. S-band telemetry data were received and recorded from $T - 4500$ to $T + 2376$ s with the following exceptions:

(1) Dropouts, from 75 to 122 s, and from 240 to 413 s during a class II interval.

(2) Dropouts, and/or a low quality signal from 1623 to 1671 s, from 1741 to 1796 s, and from 2033 to 2290 s.

As stated in Section V-C, the *General Arnold* did not record any usable data. There was a brief interval of receiver lockup, but no TDM-2 lock was obtained. Postflight investigation revealed a connector with a bent center pin in the coaxial line from the antenna assembly to the preamplifiers.

4. Real-time computer system. The required RTCS services were met in a routine manner by the existing facilities of the RTCS. Although no significant problems occurred in this area, the RTCS was unable to compute a meaningful orbit until Ascension Island data were available. Ascension Island rise occurred at the start of the retromaneuver. An orbit was then computed from Ascension Island data, and Johannesburg Deep Space Station (DSS 51) predicts based on this orbit were generated.

The AFETR/RTCS generated the Ascension Island Deep Space Station (DSS 72) predicts, and the IRV message was transmitted to DSS 72. Considering the metric data available, the RTCS met the support requirements well.

B. Goddard Space Flight Center

1. Tracking (C-band). Bermuda provided radar beacon tracking, magnetic tape recording (at a minimum of 10 points/s), and real-time data transmission to the GSFC and AFETR. Carnarvon did not provide usable data.

2. VHF telemetry. The MSFN telemetry support was well performed. There were no equipment failures or discrepancies during the operation. Bermuda was required to confirm *mark* events 6 through 11 on the *Centaur* link, but *mark* events 8 through 11 were not confirmed because of loss of signal. The only problem encountered at Bermuda was the decommutation of commutated channel 9 on the *Centaur* link because of degradation by RF-link noise. Except for the decommutation problem, telemetry coverage at Bermuda was considered good.

Grand Canary was required to confirm *mark* events 17 through 19. *Mark* event 17 was not confirmed because the event occurred prior to Grand Canary acquisition of signal, but *mark* events 18 and 19 were confirmed as required. *Mark* event 17 could have been lost because of the invalid pointing data received at Grand Canary. Grand Canary reported that decommutator lockup was not accomplished in time to confirm *mark* event 18 in real time because of a polarity problem in the channel wave train. Except for the polarity problem, telemetry coverage at Grand Canary was considered good.

Kano was required to confirm *mark* events 17 through 19 on the *Centaur* link. None of these *mark* events were confirmed. Because of the launch azimuth, the vehicle passed far south of Kano at an extreme range that altered the anticipated view time considerably. Maximum signal strength was low, and therefore neither decommutation lockon nor valid data were obtained. Although no equipment problems were encountered, telemetry coverage at Kano was considered poor.

3. Data handling. Data were provided by MSFN stations at Bermuda, Grand Canary, Kano, and Carnarvon in accordance with the requirements of the Network Operations Plan. Kano failed to record the 100-kHz reference on telemetry tape. Otherwise, the supporting stations recorded and shipped data within acceptable time frames and in good condition.

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

5. Computer support. Nominal pointing data generated by GSFC computers were supplied to Carnarvon only, because the data did not contain view times for Grand Canary and Kano. During the minus count, GSFC computers generated and furnished pointing data to Grand Canary, Kano, and Carnarvon. These pointing data were not valid because they were generated for an 84-deg launch azimuth, and the actual launch azimuth was 102.285 deg. Real-time acquisition messages were sent to Carnarvon only. These messages were furnished by RTCS computers and transmitted late in the pass. Performance of computer support was considered poor.

C. Deep Space Network

The overall quality of data taken by the DSN was good. Of the three prime stations, DSS 51 and the Tidbinbilla Deep Space Station (DSS 42) functioned

almost perfectly and took excellent data. The Pioneer Deep Space Station (DSS 11), on the other hand, had significant problems during its first and second passes. On the first pass, T&DA, monitoring DSS 11 data in near-real time, found that DSS 11 data had a noise figure about 10 times higher than expected (a running standard deviation of about 0.080 Hz instead of 0.008 Hz). Shortly thereafter it was noticed that one of the digits in the doppler counter was always even. This malfunction was traced to the appropriate station 11 equipment and corrected. Approximately 1 h of pre-midcourse data was lost while this problem was being corrected. The problem encountered during the second pass was far more serious, and DSS 11 was unable to supply any usable doppler data for the entire pass. The problem was eventually traced to a faulty exciter voltage-controlled oscillator (VCO) selector at DSS 11. Even considering the loss of data at DSS 11, the overall quality of the DSN-provided data was well within the requirements to meet commitments.

1. Deep Space Instrumentation Facility. All of the DSIF prime and engineering practice stations reported *go* status during the countdown. All measured station parameters were within nominal performance specifications and communications circuits were up.

Figure 52 is a profile of the DSIF mission activity up to lunar touchdown. This figure contains the view periods each station tracked the spacecraft plotted against time in hours.

a. Tracking. The signal levels received at the prime stations are shown in Fig. 53. They compare favorably with the predicted values. A 2-dB discrepancy between the reported levels from DSS 11 and the other stations is

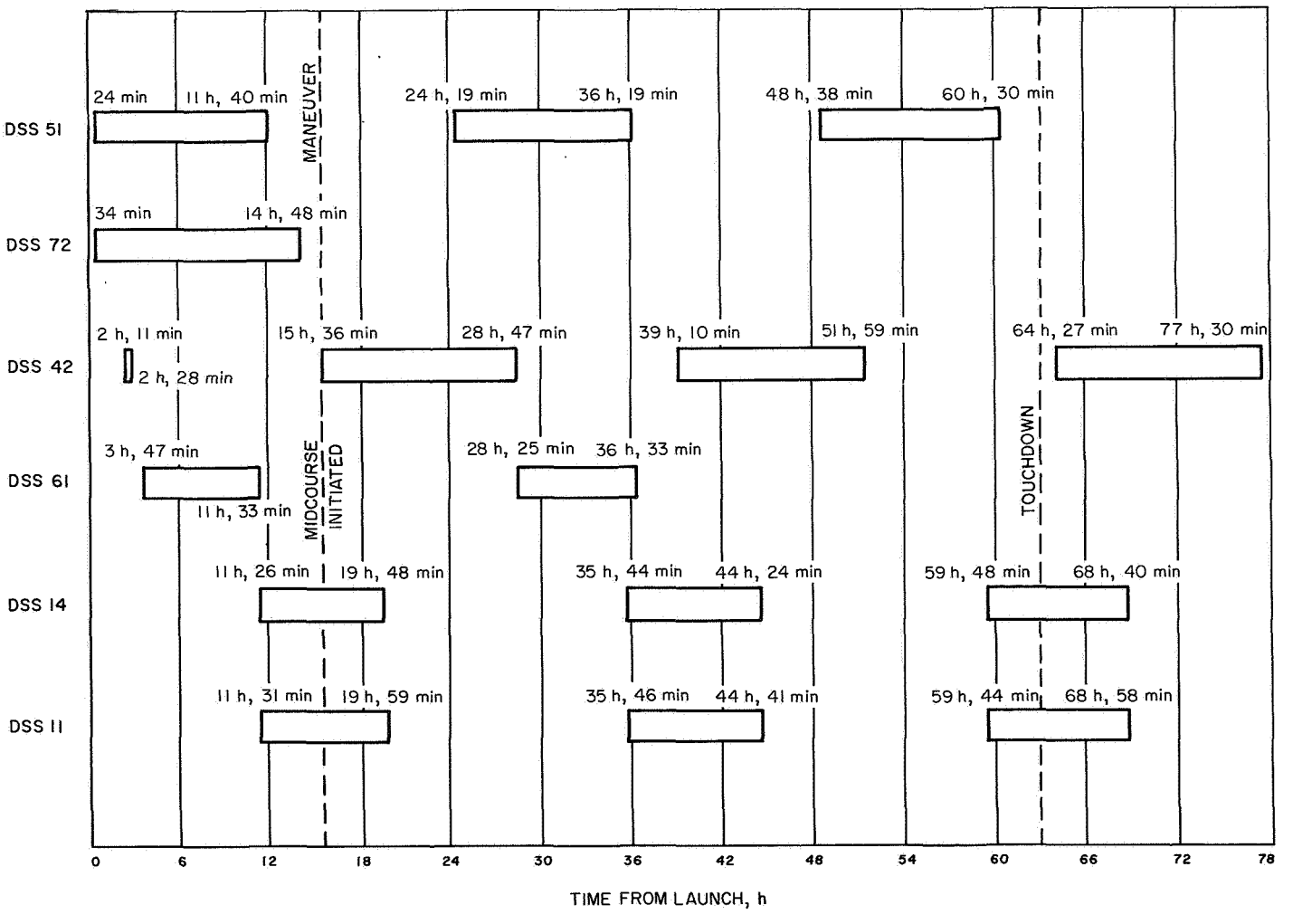


Fig. 52. DSIF station view periods

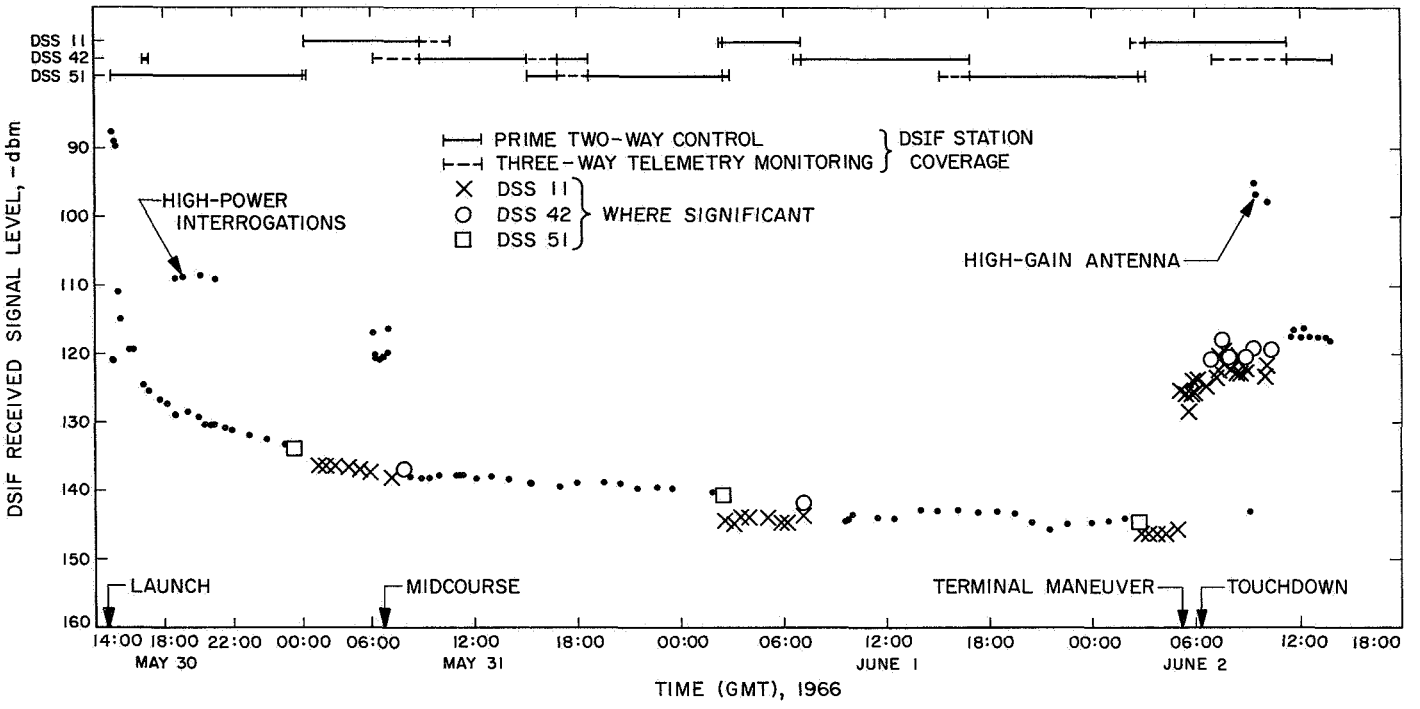


Fig. 53. DSS-received signal levels

apparent. These data were compiled from the tracking and post-tracking reports and are therefore not continuous, but probably sufficient to indicate performance in general. The actual tracking time logged by each DSS station is indicated in Table 85.

Throughout the mission, from launch through touchdown, and to the end of the first lunar day, all stations remained within performance specifications except where significant anomalies caused the complete shutdown of the equipment affected. The anomalies encountered during the *Surveyor I* mission are shown in Table 86.

During the critical touchdown sequence, both the DSS 11 and the Goldstone DSCC receivers remained in lock, using loop bandwidths of 152 and 12 Hz, respectively.

Figure 51 gives the earth track traced by *Surveyor I*. Specific events such as sun and Canopus acquisition, midcourse maneuver, touchdown, and the rise and set times for the various stations are included.

Spacecraft center frequencies. To generate and supply spacecraft predictions to the DSN tracking stations for purposes of spacecraft acquisition, aided track, and station-to-station transfers of the spacecraft, it was essential that the spacecraft transmitter (one-way) center frequency and spacecraft transponder (two-way) center frequency be accurately known. The nominal values for these frequencies are 2295 MHz (at carrier level) for the transmitter center frequency and 22.013670 MHz (at station VCO level) for the transponder center frequency. Normally, these frequencies are measured months before the mission for use in the Preflight Predictions Document, and measured several times in the last 10 h of the countdown for use in the real-time predictions.

Normally, the SDA group would use the latest frequencies available during the mission. However, because the measurement at $T - 5$ min was received only by voice, and because the SPAC group advised SDA that they had some doubts about the validity of the $T - 5$ min measurement, the decision was made to use the $T - 50$ min frequency measurements. The center frequencies measured at $T - 50$ min were 2294.994627 MHz for transmitter B, and 22.013669 Hz for transponder B; these values were used in all real-time predictions until spacecraft touchdown. It was later verified by SPAC that the accuracy of the $T - 5$ min measurements was doubtful.

Spacecraft predictions. Spacecraft predictions, which are composed of time-tagged station observables such as pointing angles, one-way doppler, two-way doppler, and

Table 85. DSIF stations actual tracking times

DSS	Pass	Track time, min	RF outage, min	Decomm outage, min	RF in lock, %	Decomm in lock, %	DSS	Pass	Track time, min	RF outage, min	Decomm outage, min	RF in lock, %	Decomm in lock, %
71	*L*	142	0	0	100	100	42	9	724	6.9	0	99.05	100
72	*L*	870	0	0	100	100	11	9	562	0	0	100	100
61	1	466	0	2.6	100	99.44	51	10	737	0	0	100	100
51	1	676	1.9	9.3	99.72	98.62	42	10	757	0.6	0	99.92	100
11	1	508	17.2	0	96.61	100	11	10	596	0	0	100	100
42	1	791	8.3	3.9	98.95	99.51	51	11	737	0.6	0	99.92	100
51	2	721	0.8	0	99.89	100	42	11	724	0.3	0	99.96	100
61	2	488	0	0	100	100	72	11	286	0	0	100	100
11	2	535	0	0	100	100	11	11	633	0	0	100	100
42	2	769	0	0	100	100	51	12	733	8.8	53.4	98.80	92.71
51	3	717	0	0	100	100	61	12	281	0.4	0	99.86	100
42	3	783	18.0	218.5	97.70	72.09	42	12	538	0	0	100	100
11	3	554	0	0	100	100	11	12	492	0	0	100	100
51	4	751	0	0	100	100	51	13	714	0	0	100	100
42	4	719	27.4	0	96.19	100	72	13	320	0	0	100	100
11	4	534	0	0	100	100	11	13	686	0	0	100	100
51	5	748	25.6	0	96.58	100	42	13	669	1.4	0	99.79	100
42	5	840	7.2	0	99.14	100	51	14	694	0	0	100	100
11	5	505	0	0	100	100	61	14	306	0	0	100	100
51	6	744	0	0	100	100	42	14	635	0.8	0	99.87	100
42	6	245	1.5	0	99.39	100	11	14	701	0	0	100	100
11	6	498	0	0	100	100	51	15	667	1.5	666.7	99.78	90.04
51	7	926	0.5	549.1	99.95	40.70	42	15	590	324.5	0	45.00	100
42	7	832	5.5	0.7	99.34	99.92	11	15	571	0	0	100	100
11	7	513	0	0	100	100	51	16	623	565.5	3.6	9.23	99.42
51	8	739	1.1	15.2	99.85	97.94	42	16	500	200.8	5.8	59.84	97.11
42	8	804	0	0	100	100	11	16	628	0	0	100	100
11	8	531	0	236	100	55.56	51	17	587	275.5	0.2	53.07	99.97
51	9	745	0	0	100	100	11	17	522	NA[a]	NA[a]	—	—

[a]Not applicable.

Table 86. Summary of DSIF anomalies, *Surveyor I* mission

DSS	Pass	Time (GMT)	Anomaly	Probable cause	Immediate reaction	Effect on mission	Current action	Comments
51	1	15:21	Rejection of command 0316, major sequence 0040	Insertion of monitor jack on FR-1400 tape recorder	Retransmit command	Not affected	Stations to be advised of correct operational procedure. Additional recorder modules requested to eliminate need for patching	Retransmitted command accepted. Circuit interaction being investigated. Availability of nonshorting jacks being investigated
51	1	15:45	Receiver drops lock	VCO instability caused by circuit breaker trip in receiver rack	Spare VCO installed	Intermittent data for 8 min	Investigate problem under TFR 51-RCV-029	Suspect overload due to additional monitor equipment
51	1	17:25	Dec angle hitch on antenna	Insufficient servo bandwidth	Increase dec bandwidth to 0.05 Hz	Temporary reduction in signal level	Specifically correct servo bandwidths in the future	Station must use discretion in coping with real-time conditions
11	1	03:12	Noisy doppler data	Partial failure of doppler counter	Replace module B.15 in counter No. 2	70 min of lost tracking data		Random failure
42	1	16:45	No telemetry data on HSDL	Faulty interrupt from HSDL modem or defect in SOCP	Restart program and change from 910 to 920	Temporary loss of high-speed data	Investigate problem under TFR 42-DIS-033-5	Random failure
51	2	17:58	Failure of heat exchanger temperature regulator	Tube failure	Replace tube	Transmitter out for 58 min	Investigation proceeding under TFR 51-TXR-021	DSS 42 overlap
11	2	02:26	Unable to maintain good two-way doppler data	Defective coax relay in exciter VCO selector	Bypass coaxial relay	Loss of tracking data	Document fix	Early transfer to DSS 42
42	4		Defective maser	Leaks in CCR system	Transfer to paramp for one pass	Not affected. Good video data on paramp	Repair CCR and cool down	Common failure
51	8	01:28	Loss of transmitter drive	Faulty 22-MHz distribution amplifier	Replace distribution amplifier	Transmitter off for 14 min	None	Random failure
42	11	01:48	Antenna stopped	Blown 15A fuse in HA power panel	Replace fuse	Antenna stopped for 12 min	Investigate under TFR 42-ANT-011-S	Random failure
51	12	05:03	Transmitter outage	Leak in safety relief valve	Top up cooling water supply and bypass relief valve	Transmitter out for 48 min	Investigate under TFR 51-TXR-024	Common failure
42	13	19:45	Transmitter interlock tripped off	Leak in heat exchanger pump gasket	Repair gasket and refill tank	Delayed transfer to DSS 11	Investigate under TFR 42-TXR-012-S	Common failure
51	14		Transmitter interlock tripped off	Leak in heat exchanger pump gasket	Top up tank every 15 min to end of pass	Not affected	Investigate under TFR 51-TXR-025	Common failure
42	16		Inoperative maser	Oil leak in compressor	Transfer to paramp	Not affected	Undertake thorough maintenance of compressor	Common failure

best-lock ground transmitter frequency, are more or less routinely provided to the DSN tracking stations to insure the success of spacecraft acquisitions, aided track, and station handovers of the spacecraft. However, during the launch phase, the provision of accurate predictions to DSS 51 and other tracking stations becomes a critical matter because of the crucial need for early acquisition and command of the spacecraft. For first acquisition at DSS 51 there were three distinct sets of predictions available:

(1) Preflight Predictions Document.

(2) Predictions 5 min before launch ($L - 5$ min) based on actual launch azimuth.

(3) AFETR predictions based on actual tracking data.

Although both the preflight predictions and $L - 5$ min predictions are generated before launch, the $L - 5$ min predictions have two important advantages: they are based on updated frequency information, and they are generated for the exact actual launch azimuth. Because of these two factors, the $L - 5$ min predictions were generated and sent to DSS 51 with the suggestion that they be used instead of the Preflight Predictions Document. Finally, about 5 min before rise at DSS 51, predictions from AFETR based on actual tracking data became available, and SDA was faced with the decision of whether to have DSS 51 use the $L - 5$ min predictions or the AFETR predictions. At this time, a comparison of the two predict sets showed a large variance, and it became essential to decide which was the more accurate set. Based on the facts that AFETR voiced strong doubt about the convergence of their orbit, and, at the same time, that DSS 72 reported their track was very close to the nominal predictions, it was decided that the $L - 5$ min predictions were the best set. DSS 51 was instructed to use this set.

DSS 51 used the $L - 5$ prediction set and was able to acquire very quickly and with no attendant difficulties. From this point until touchdown, predictions were supplied to all active DSN tracking stations on a routine basis. After touchdown, predictions could no longer be generated in the normal manner because the spacecraft's motion was no longer a free-flight trajectory. This problem was solved by writing an ephemeris tape of the moon's center in a format compatible with the prediction program, calculating the position difference between the spacecraft and the moon's center, and approximating this difference by making a small change in the position of the tracking stations as input to the prediction program.

First acquisition at DSS 51. First acquisition of the *Surveyor I* spacecraft by DSS 51 was both nominal and very fast. The $L - 5$ min predictions indicated a rise over the station's horizon mask at 15:04:39 GMT. DSS 51 reported good one-way doppler data at 15:04:51, and good two-way data at 15:08:31. Thus, DSS 51 was able to get good one-way data only seconds after spacecraft rise, and good two-way data in less than 4 min after rise.

RF tracking performance. The DSIF stations provided continuous angular and doppler tracking data on the *Surveyor I* spacecraft from initial acquisition by DSS 51 at 15:04:51 GMT on May 30, 1966 until lunar touchdown at 06:17:35.7 on June 2, 1966, and continued to track the spacecraft on the moon's surface after lunar nightfall. In general, the overall quality of the tracking data was quite good. Data types used (before touchdown) in the ODP were angular data taken during the first pass over DSS 51 and the Robledo Deep Space Station (DSS 61), two-way doppler data taken during the first and third passes over DSS 11, two-way doppler data taken during all three passes over DSS 51 and DSS 42, and three-way (with DSS 51) doppler data taken during the first pass over DSS 61. The relative quality of tracking data taken during each pass and at each station can be obtained by comparing the standard deviations, the root mean squares, and the first moments of the data listed in Table 87. Changes in the quality of similar 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 follow:

PROR	Predict orbit
ICEV	Injection conditions evaluation orbit
PREL	Preliminary pre-midcourse orbit
DACO	Data consistency orbit
LAPM	Last pre-midcourse orbit
PRCL	Pre-midcourse cleanup orbit
POST	Post-flight analysis orbit
N POM	Nth post-midcourse orbit
X	Computer string X
Y	Computer string Y

Table 87. Summary of DSS tracking data used in *Surveyor I* orbit computations

Orbit identification	DSS	Data type	Start data time, mo/day–GMT	End data time, mo/day–GMT	No. of points	Std deviation[a]	Rms[a]	Mean error[a]	Data sample rate, s
PROR YA	51	CC3[b]	5/30–15:08:46	5/30–15:44:31	167	0.0649	0.0653	−0.0067	10
		HA[c]	5/30–15:08:21	5/30–15:45:01	172	0.0135	0.0329	−0.0300	
		Dec[d]	5/30–15:08:21	5/30–15:45:01	173	0.0091	0.0129	−0.0092	
ICEV XA	51	CC3	5/30–15:08:46	5/30–16:45:31	213	0.0463	0.0464	−0.0032	10 and 60
		HA	5/30–15:08:21	5/30–16:46:01	222	0.0120	0.0489	−0.0475	
		Dec	5/30–15:08:21	5/30–16:46:01	223	0.0099	0.0234	−0.0212	
PREL XA	51	CC3	5/30–15:08:46	5/30–15:39:56	162	0.0506	0.0506	0.0004	10
		HA	5/30–15:08:31	5/30–15:40:01	166	0.0092	0.0590	−0.0583	
		Dec	5/30–15:08:31	5/30–15:40:01	166	0.0074	0.0093	−0.0057	
		CC3	5/30–15:42:31	5/30–17:29:31	74	0.0099	0.0099	−0.0008	60
		HA	5/30–15:42:01	5/30–17:30:01	82	0.0094	0.0474	−0.0465	
		Dec	5/30–15:42:01	5/30–17:30:01	81	0.0182	0.0388	−0.0342	
DACO XA	51	CC3	5/30–15:08:46	5/30–15:39:56	162	0.0510	0.0510	−0.0004	10
		HA	5/30–15:08:31	5/30–15:40:01	166	0.0103	0.0610	−0.0601	
		Dec	5/30–15:08:31	5/30–15:40:01	166	0.0089	0.0089	−0.0003	
		CC3	5/30–15:42:31	5/30–18:50:31	126	0.0139	0.0143	−0.0030	60
		HA	5/30–15:42:01	5/30–18:51:01	146	0.0092	0.0517	−0.0509	
		Dec	5/30–15:42:01	5/30–18:51:01	143	0.0142	0.0363	−0.0334	
		CC3	5/30–18:51:46	5/30–19:21:06	55	0.0446	0.0447	0.0031	10
		HA	5/30–18:51:41	5/30–19:21:11	57	0.0014	0.0607	−0.0607	
		Dec	5/30–18:51:41	5/30–19:21:11	57	0.0020	0.0389	−0.0388	
		CC3	5/30–19:24:31	5/30–21:58:31	152	0.0093	0.0093	0.0003	
		HA	5/30–19:24:01	5/30–21:59:01	154	0.0039	0.0605	−0.0604	
		Dec	5/30–19:24:01	5/30–21:59:01	154	0.0032	0.0438	−0.0437	
DACO XB	51	CC3	5/30–15:08:46	5/30–15:39:36	162	0.0504	0.0504	−0.0005	10
		CC3	5/30–15:42:31	5/30–18:50:31	126	0.0119	0.0119	0.0003	60
		CC3	5/30–18:51:46	5/30–19:21:06	55	0.0446	0.0446	−0.0008	10
		CC3	5/30–19:24:31	5/30–21:58:31	152	0.0092	0.0092	−0.0001	
DACO XC	51	CC3	5/30–15:42:31	5/30–18:50:31	126	0.0119	0.0119	0.0003	60
		CC3	5/30–18:51:46	5/30–19:21:06	175	0.0527	0.0527	−0.0012	10
		CC3	5/30–19:24:31	5/30–21:59:31	152	0.0092	0.0092	0.0003	

[a]CC3 and C3 in Hz; HA and dec in deg.
[b]CC3 = two-way doppler.
[c]HA = local hour angle.
[d]Dec = declination.

Table 87 (contd)

Orbit identification	DSS	Data type	Start data time, mo/day–GMT	End data time, mo/day–GMT	No. of points	Std deviation[a]	Rms[a]	Mean error[a]	Data sample rate, s
DACO YA	51	CC3	5/30–15:08:46	5/30–15:39:56	162	0.0504	0.0504	−0.0006	10
		CC3	5/30–15:42:31	5/30–18:50:31	126	0.0119	0.0119	−0.0002	60
		CC3	5/30–18:51:46	5/30–21:18:31	266	0.0670	0.0670	0.0011	10 and 60
	61	C3[e]	5/30–19:23:32	5/30–21:06:32	73	0.0087	0.0088	−0.0015	60
		C3	5/30–21:07:32	5/30–21:18:32	11	0.0071	0.0078	0.0032	
DACO YB	51	CC3	5/30–15:08:46	5/30–15:39:56	162	0.0531	0.0514	−0.0035	10
		HA	5/30–15:08:31	5/30–15:40:01	166	0.0108	0.0625	−0.0616	
		Dec	5/30–15:08:31	5/30–15:40:01	166	0.0093	0.0096	0.0023	
		CC3	5/30–15:42:31	5/30–18:50:31	126	0.0126	0.0185	−0.0135	60
		HA	5/30–15:42:01	5/30–18:51:01	146	0.0092	0.0523	−0.0515	
		Dec	5/30–15:42:01	5/30–18:51:01	144	0.0847	0.0885	−0.0256	
		CC3	5/30–18:51:46	5/30–21:18:31	146	0.0749	0.0753	−0.0078	10 and 60
		HA	5/30–18:51:41	5/30–21:19:01	149	0.0031	0.0610	−0.0609	
		Dec	5/30–18:51:41	5/30–21:19:01	149	0.0036	0.0431	−0.0411	
	61	HA	5/30–19:36:02	5/30–20:41:02	65	0.0154	0.0295	−0.0252	
		Dec	5/30–19:36:02	5/30–20:41:02	65	0.0238	0.0570	−0.0518	
		HA	5/30–21:06:02	5/30–21:06:02	1	0.0000	0.0100	−0.0100	
		Dec	5/30–21:06:02	5/30–21:06:02	1	0.0000	0.0962	−0.0962	
		HA	5/30–21:07:02	5/30–21:19:02	13	0.0127	0.0231	−0.0193	
		Dec	5/30–21:07:02	5/30–21:19:02	13	0.0132	0.0892	−0.0882	
DACO 1.5	51	CC3	5/30–15:08:46	5/30–15:39:56	162	0.0505	0.0505	−0.0011	10
		CC3	5/30–15:42:31	5/30–18:50:31	124	0.0120	0.0120	0.0003	60
		CC3	5/30–18:51:46	5/30–19:20:56	55	0.0446	0.0446	−0.0007	10
		CC3	5/30–19:24:31	5/31–01:23:31	309	0.0085	0.0085	−0.0001	
LAPM XB	11	CC3	5/31–02:24:32	5/31–03:34:47	35	0.0399	0.0401	0.0046	60
	51	CC3	5/30–15:08:46	5/30–15:39:56	162	0.0504	0.0504	−0.0010	10
		CC3	5/30–15:42:31	5/30–18:50:31	124	0.0125	0.0128	−0.0027	60
		CC3	5/30–18:51:46	5/30–19:20:56	55	0.0446	0.0449	−0.0049	
		CC3	5/30–19:24:31	5/31–01:39:31	325	0.0089	0.0089	−0.0033	
		CC3	5/31–01:40:31	5/31–02:16:31	21	0.0105	0.0131	−0.0133	
LAPM XC	11	CC3	5/31–03:34:27	5/31–05:00:32	59	0.0126	0.0388	0.0366	60
	51	CC3	5/30–15:08:46	5/30–15:39:56	162	0.0508	0.0508	−0.0007	10
		CC3	5/30–15:42:31	5/30–18:50:31	124	0.0127	0.0154	−0.0088	60
		CC3	5/30–18:51:46	5/30–19:20:56	55	0.0447	0.0457	−0.0097	
		CC3	5/30–19:24:31	5/31–01:39:31	325	0.0093	0.0093	−0.0011	
		CC3	5/31–01:40:31	5/31–02:16:31	21	0.0105	0.0159	−0.0119	

[e]C3 = three-way doppler.

Table 87 (contd)

Orbit identification	DSS	Data type	Start data time, mo/day–GMT	End data time, mo/day–GMT	No. of points	Std deviation[a]	Rms[a]	Mean error[a]	Data sample rate, s
LAPM XD	11	CC3	5/31–03:34:27	5/31–06:01:32	109	0.0091	0.1110	−0.1110	60
	51	CC3	5/30–15:42:31	5/30–18:50:31	124	0.0130	0.0218	−0.0175	
		CC3	5/30–18:51:46	5/30–19:20:56	55	0.0446	0.0503	−0.0232	
		CC3	5/30–19:24:31	5/31–01:39:31	325	0.0088	0.0283	−0.0269	
		CC3	5/31–01:40:31	5/31–02:16:31	21	0.0105	0.0326	−0.0308	
LAPM ■B	11	CC3	5/31–02:24:32	5/31–03:47:32	83	0.0455	0.0529	0.0270	60
	51	CC3	5/30–15:08:46	5/30–15:39:56	162	0.0506	0.0506	−0.0008	10
		CC3	5/30–15:42:31	5/30–18:50:31	126	0.0126	0.0131	−0.0035	60
		CC3	5/30–18:51:46	5/30–19:21:06	55	0.0446	0.0450	−0.0059	
		CC3	5/30–19:24:31	5/31–01:39:31	348	0.0094	0.0094	0.0006	
		CC3	5/31–01:42:31	5/31–02:16:31	17	0.0114	0.0151	−0.0098	
PRCL XA	11	CC3	5/31–03:34:27	5/31–06:18:32	183	0.0171	0.0658	−0.0636	60
		CC3	5/31–06:25:16	5/31–06:29:57	24	0.0183	0.0437	−0.0397	10
	51	CC3	5/30–15:08:46	5/30–15:39:56	162	0.0556	0.0556	−0.0023	10
		CC3	5/30–15:42:31	5/30–18:50:31	124	0.0127	0.0356	−0.0333	60
		CC3	5/30–18:51:46	5/30–19:20:56	55	0.0446	0.0517	−0.0261	
		CC3	5/30–19:24:31	5/31–01:39:31	325	0.0089	0.0192	−0.0170	
		CC3	5/31–01:40:31	5/31–02:16:31	21	0.0105	0.0255	−0.0233	
PRCL XB	51	CC3	5/30–15:08:46	5/30–15:39:56	162	0.0505	0.0505	−0.0009	10
		CC3	5/30–15:42:31	5/30–18:50:31	124	0.0120	0.0120	0.0003	60
		CC3	5/30–18:51:46	5/30–19:20:56	55	0.0446	0.0446	−0.0007	
		CC3	5/30–19:24:31	5/31–01:39:31	325	0.0085	0.0085	0.0000	
		CC3	5/31–01:40:31	5/31–02:16:31	21	0.0105	0.0105	−0.0009	
POST 17[z]	11	CC3	5/31–03:34:27	5/31–06:18:32	182	0.0109	0.0110	0.0001	60
		CC3	5/31–06:25:16	5/31–06:29:57	24	0.0182	0.0187	0.0003	10
	51	CC3	5/30–15:12:56	5/30–15:39:56	121	0.0408	0.0408	−0.0019	10
		CC3	5/30–15:42:31	5/30–18:50:31	123	0.0089	0.0089	0.0000	60
		CC3	5/30–18:51:46	5/30–19:20:56	52	0.0400	0.0400	0.0009	
		CC3	5/30–19:24:31	5/31–01:39:31	325	0.0085	0.0085	0.0001	
		CC3	5/31–01:40:31	5/31–02:16:31	21	0.0104	0.0104	0.0001	

[z]Current best estimate of premaneuver orbit, as of June 9, 1966.

Table 87 (contd)

Orbit identification	DSS	Data type	Start data time, mo/day–GMT	End data time, mo/day–GMT	No. of points	Std deviation[a]	Rms[a]	Mean error[a]	Data sample rate, s
1 POM XA	11	CC3	5/31–06:46:07	5/31–08:58:32	184	0.0415	0.0416	−0.0028	10 and 60
	42	CC3	5/31–09:04:32	5/31–14:22:32	313	0.0190	0.0190	0.0003	60
1.2 POM	11	CC3	5/31–07:04:32	5/31–08:58:32	94	0.0049	0.0049	0.0000	60
	42	CC3	5/31–09:04:32	5/31–15:08:32	317	0.0184	0.0184	0.0000	60
	51	CC3	5/31–15:15:31	5/31–16:25:31	71	0.0086	0.0086	0.0000	60
2 POM XA	11	CC3	5/31–07:04:32	5/31–08:58:32	94	0.0055	0.0055	−0.0003	60
	42	CC3	5/31–09:04:32	5/31–18:49:32	411	0.0051	0.0051	0.0000	60
	51	CC3	5/31–15:15:31	5/31–20:05:32	145	0.0083	0.0083	0.0001	60
2 POM XB	42	CC3	5/31–07:04:32	5/31–18:49:32	411	0.0048	0.0048	0.0000	60
	51	CC3	5/31–15:15:31	5/31–20:05:32	145	0.0083	0.0083	0.0000	60
2 POM XC	11	CC3	5/31–07:04:32	5/31–08:58:32	94	0.0046	0.0046	0.0000	60
	42	CC3	5/31–09:04:32	5/31–18:49:32	411	0.0048	0.0048	−0.0001	60
2 POM XD	11	CC3	5/31–07:04:32	5/31–08:58:32	94	0.0057	0.0057	−0.0001	60
	42	CC3	5/31–09:04:32	5/31–18:49:32	411	0.0050	0.0050	−0.0001	60
	51	CC3	5/31–15:15:31	5/31–21:26:32	224	0.0090	0.0090	0.0000	60
3 POM XB	11	CC3	5/31–07:04:32	5/31–08:58:32	94	0.0051	0.0057	0.0024	60
	42	CC3	5/31–09:04:32	5/31–18:49:32	411	0.0064	0.0067	−0.0021	60
	51	CC3	5/31–15:15:31	6/01–02:18:32	458	0.0087	0.0087	0.0007	60
4 POM XE	11	CC3	5/31–07:04:32	5/31–08:58:32	94	0.0051	0.0051	0.0006	60
	42	CC3	5/31–09:04:32	5/31–18:49:32	411	0.0051	0.0051	−0.0002	60
		CC3	6/01–07:15:32	6/01–16:20:31	520	0.0053	0.0053	0.0003	60
	51	CC3	5/31–15:15:31	6/01–02:18:32	458	0.0085	0.0085	0.0000	60
4 POM XG	11	CC3	5/31–07:04:32	5/31–08:58:32	94	0.0068	0.0068	0.0010	60
		CC3	6/01–02:57:32	6/01–03:08:32	12	0.0068	0.0221	0.0210	60
		CC3	6/01–03:41:32	6/01–04:26:32	35	0.0070	0.0117	−0.0093	60
	42	CC3	5/31–09:04:32	5/31–18:24:32	390	0.0055	0.0055	−0.0001	60
		CC3	5/31–18:25:32	5/31–18:48:32	20	0.0053	0.0081	−0.0061	60
		CC3	6/01–07:15:32	6/01–07:29:32	15	0.0041	0.0057	0.0039	60
		CC3	6/01–07:30:32	6/01–16:58:32	537	0.0054	0.0054	−0.0002	60
	51	CC3	5/31–15:15:31	5/31–15:34:31	20	0.0090	0.0090	0.0009	60
		CC3	5/31–15:35:31	6/01–02:18:32	436	0.0086	0.0086	−0.0002	60
		CC3	6/01–02:27:32	6/01–22:02:32	225	0.0093	0.0093	0.0006	60

Table 87 (contd)

Orbit identification	DSS	Data type	Start data time, mo/day–GMT	End data time, mo/day–GMT	No. of points	Std deviation[a]	Rms[a]	Mean error[a]	Data sample rate, s
4 POM XH	11	CC3	5/31–07:04:32	5/31–08:58:32	94	0.0066	0.0138	0.0122	60
		CC3	6/01–02:57:32	6/01–03:08:32	12	0.0065	0.0075	0.0037	60
		CC3	6/01–03:41:32	6/01–04:26:32	35	0.0056	0.0189	−0.0180	60
	42	CC3	5/31–09:04:32	5/31–18:24:32	390	0.0087	0.0087	0.0006	60
		CC3	5/31–18:25:32	5/31–18:48:32	20	0.0055	0.0178	−0.0169	60
		CC3	6/01–07:15:32	6/01–07:29:32	15	0.0041	0.0150	0.0145	60
		CC3	6/01–07:30:32	6/01–16:58:32	537	0.0068	0.0099	0.0072	60
	51	CC3	5/31–15:15:31	5/31–15:34:31	20	0.0089	0.0091	−0.0016	60
		CC3	5/31–15:35:31	6/01–02:18:32	436	0.0090	0.0105	−0.0054	60
		CC3	6/01–02:27:32	6/01–22:02:32	225	0.0092	0.0092	−0.0006	60
5 POM XA	11	CC3	5/31–07:04:32	5/31–08:58:32	94	0.0063	0.0114	0.0095	60
	42	CC3	5/31–09:04:32	5/31–18:24:32	390	0.0089	0.0090	0.0016	60
		CC3	5/31–18:25:32	5/31–18:48:32	20	0.0053	0.0160	−0.0151	60
		CC3	6/01–07:15:32	6/01–07:29:32	15	0.0041	0.0088	0.0077	60
		CC3	6/01–07:30:32	6/01–16:58:32	537	0.0089	0.0109	0.0063	60
	51	CC3	5/31–15:15:31	5/31–15:34:31	20	0.0089	0.0091	−0.0016	60
		CC3	5/31–15:35:31	6/01–02:18:32	436	0.0091	0.0107	−0.0056	60
		CC3	6/01–00:29:32	6/01–02:27:32	367	0.0097	0.0097	−0.0004	60
5 POM YB	11	CC3	5/31–07:04:32	5/31–08:58:32	94	0.0064	0.0113	0.0093	60
	42	CC3	5/31–09:04:32	5/31–18:24:32	390	0.0088	0.0090	0.0017	60
		CC3	5/31–18:25:32	5/31–18:48:32	20	0.0053	0.0160	−0.0151	60
		CC3	6/01–07:15:32	6/01–07:29:32	15	0.0040	0.0083	0.0073	60
		CC3	6/01–07:30:32	6/01–16:58:32	537	0.0091	0.0110	0.0063	60
	51	CC3	5/31–15:15:32	5/31–15:34:31	20	0.0089	0.0091	−0.0017	60
		CC3	5/31–15:35:31	6/01–02:18:32	436	0.0091	0.0107	−0.0056	60
		CC3	6/01–00:34:32	6/01–02:27:32	372	0.0096	0.0097	−0.0004	60
5 POM YC	11	CC3	6/02–02:52:32	6/02–03:02:32	11	0.0054	0.0054	−0.0008	60
	51	CC3	6/02–00:35:32	6/02–02:28:32	107	0.0116	0.0116	0.0002	60
FINAL XA	11	CC3	6/02–02:52:32	6/02–03:37:32	44	0.0405	0.1920	−0.1880	60
	51	CC3	6/02–00:35:32	6/02–02:28:32	104	0.0145	0.0204	−0.0143	60
FINAL XB	11	CC3	6/02–02:52:32	6/02–03:37:32	44	0.0048	0.0048	−0.0004	60
		CC3	6/02–03:38:32	6/02–05:01:32	63	0.0040	0.0040	−0.0002	60
	51	CC3	6/02–00:35:32	6/02–02:28:32	102	0.0093	0.0094	−0.0005	60

Table 87 (contd)

Orbit identification	DSS	Data type	Start data time, mo/day–GMT	End data time, mo/day–GMT	No. of points	Std deviation[a]	Rms[a]	Mean error[a]	Data sample rate, s
FINAL XC	11	CC3	6/02–05:52:32	6/02–03:37:32	44	0.0049	0.0050	0.0009	60
		CC3	6/02–03:38:32	6/02–05:28:32	78	0.0041	0.0041	−0.0002	60
	51	CC3	6/02–00:35:32	6/02–02:28:32	102	0.0093	0.0093	0.0000	60
FINAL YB	11	CC3	6/02–02:52:32	6/02–03:37:32	46	0.0046	0.0047	0.0006	60
		CC3	6/02–03:38:32	6/02–05:06:32	74	0.0042	0.0042	−0.0005	60
	51	CC3	6/02–00:35:32	6/02–02:28:32	106	0.0092	0.0092	−0.0003	60
20 POST	11	CC3	5/31–07:14:32	5/31–08:58:32	89	0.0048	0.0183	0.0176	60
		CC3	6/02–02:52:32	6/02–03:37:32	44	0.0066	0.0373	0.0367	60
		CC3	6/02–03:38:32	6/02–05:28:32	72	0.0260	0.0263	−0.0035	60
	42	CC3	5/31–09:04:32	5/31–18:24:32	385	0.0163	0.0165	0.0026	60
		CC3	5/31–18:25:32	5/31–18:48:32	20	0.0053	0.0077	−0.0056	60
		CC3	6/01–07:15:32	6/01–07:29:32	15	0.0041	0.0095	−0.0085	60
		CC3	6/01–07:30:32	6/01–16:58:32	537	0.0078	0.0086	−0.0036	60
	51	CC3	5/31–15:15:31	5/31–15:34:31	20	0.0089	0.0122	0.0083	60
		CC3	5/31–15:35:31	6/01–02:18:32	436	0.0099	0.0134	−0.0090	60
		CC3	6/01–02:27:32	6/02–02:28:32	474	0.0099	0.0113	0.0055	60

In general, DSIF station operations during the *Surveyor I* mission were effectively implemented. This is best judged by the fact that the DSN was able to provide high-quality data to the orbit determination group such that they were able to meet all orbital accuracy requirements for such events as the midcourse maneuver and retromotor ignition backup. From the time of first acquisition of the spacecraft over DSS 51 until the time of lunar touchdown, the spacecraft was almost continuously in two-way lock (two notable exceptions are described in the subsections below titled "Pre-midcourse phase, doppler tracking" and "Post-midcourse phase"). Station transfers were rapid and efficiently executed, and a minimum of good data was lost.

1. Pre-midcourse phase, angular tracking: In general, doppler data yield far greater accuracy in the determination of a spacecraft orbit than do angle data. Therefore, during most of the *Surveyor I* mission, doppler data were used almost exclusively in the orbit determination process. The one exception was the launch phase, when little doppler data were available, and a quick determination of the orbit required the use of both doppler and angle data. Angle data from DSS 51 and DSS 61 were used in the ODP during the pre-midcourse phase of the mission. Analysis of the first-pass angle data from DSS 51 indicates that the present correction polynomials in the ODP used to describe the systematic angular pointing error are still not entirely adequate. These correction polynomials attempt to remove optical pointing error, but past mission experience indicates that they do not remove total pointing error.

First-pass angle data from DSS 51 show fairly constant biases of −0.05 deg in declination and −0.06 deg in hour angle. The angle data from the first pass over DSS 61 are uncorrected because correction polynomials are not yet available for DSS 61. These data indicate a bias of approximately −0.03 deg in hour angle and −0.05 deg in declination, and in both angles the standard deviation of the data appears excessively high. Angle data residuals for the first pass over DSS 51 are presented in Figs. 54, 55, and 56, and for the first pass over DSS 61 in Fig. 58. DSS 72 tracked the spacecraft during this phase, and azimuth and elevation residuals are presented in Figs. 58 and 59. The angle data from DSS 72 were not used in any inflight orbits.

2. Pre-midcourse phase, doppler tracking: DSS 51, the first prime station to see the spacecraft after injection, began taking good two-way, 10-s count doppler data at 15:08:31 GMT. The station switched to 60-s count at 15:41:01, and then returned to 10-s count between 18:51:31 and 19:23:03, which covered the time of Canopus acquisition. DSS 51 then continued to take good two-way doppler until 02:17:01 on May 31, 1966, at which time DSS 11 began to transmit in the two-way mode. The data taken during the first pass at DSS 51 were quite good, showing a standard deviation of approximately 0.05 Hz for 10-s count data, and 0.01 Hz for 60-s count data. The doppler residuals for this pass at DSS 51 are presented in Figs. 54, 55, and 56.

During the pre-midcourse phase, both DSS 61 and DSS 72 tracked the spacecraft in the three-way doppler mode. The three-way doppler data from DSS 61 were used by the orbit determination group in their data consistency orbit (DACO YA) to check the accuracy of the DSS 51 data. This orbit showed the standard deviation of the DSS 61 60-s count three-way data to be about 0.008 Hz. The results of this orbit indicated that the data taken at DSS 51 and DSS 61 were consistent with each other, thereby increasing the confidence in the quality of the data from the prime station, DSS 51. Three-way doppler residuals from DSS 61 are presented in Fig. 57, and three-way doppler residuals from DSS 72 are presented in Figs. 58 and 59.

The early doppler data from DSS 72 show a drift in the doppler residuals from approximately +25 Hz to −9 Hz, and the residuals then stabilized at approximately −9 Hz. Preliminary analysis of these data indicates that the drift in the data before 21:05:12 was due to a clock error (of approximately 24 s) at DSS 72, although this was not indicated in the station tracking reports. The reason for the large bias (−9 Hz) in the doppler after this time is still under investigation.

The first 70 min of data from the first pass over DSS 11 were lost due to a "stuck" digit in the doppler counter. This problem was noticed approximately 20 min after two-way lock at DSS 11 when the results of a near-real-time data monitor program indicated the standard deviation of the data to be approximately 10 times larger than that expected for good data. The error in the data was quickly traced to the "stuck" digit in the doppler counter and about 40 min were required by DSS 11 to correct the problem. The loss of this particular data was quite significant as the orbit determination group needed this block of data for the midcourse maneuver orbit, and, had the first-pass DSS 51 data been in error, the

midcourse maneuver could have been jeopardized. At approximately 03:30 GMT on May 31, 1966, DSS 11 began taking good two-way doppler and continued until the time of midcourse maneuver. Pre-midcourse two-way doppler residuals from DSS 11 are presented in Fig. 60.

3. Midcourse maneuver: Early analysis of the spacecraft orbit indicated that a midcourse maneuver over the first pass at DSS 11 would be highly advantageous, and therefore the maneuver was executed. Engine ignition was programmed for 06:45:00.0 on May 31, 1966, with a burn time of 20.80 s. The results of the maneuver as seen in the two-way doppler data over DSS 11 are presented in Fig. 61.

4. Post-midcourse phase: All post-midcourse orbit computations used only two-way doppler from the prime stations, DSS 11, DSS 42, and DSS 51. Good two-way data were taken during this entire phase with one major exception. The entire second pass over DSS 11 produced little good doppler data due to the failure of an exciter VCO selector. The loss of good doppler data was held to a minimum by effecting an early transfer of the spacecraft to DSS 42 and, because the second pass over DSS 11 was not a critical phase, the loss of these data did not result in any significant changes in the final pre-retro orbits. An extremely slight improvement in the final pre-retro orbit uncertainties might have resulted, however, if these data had not been lost.

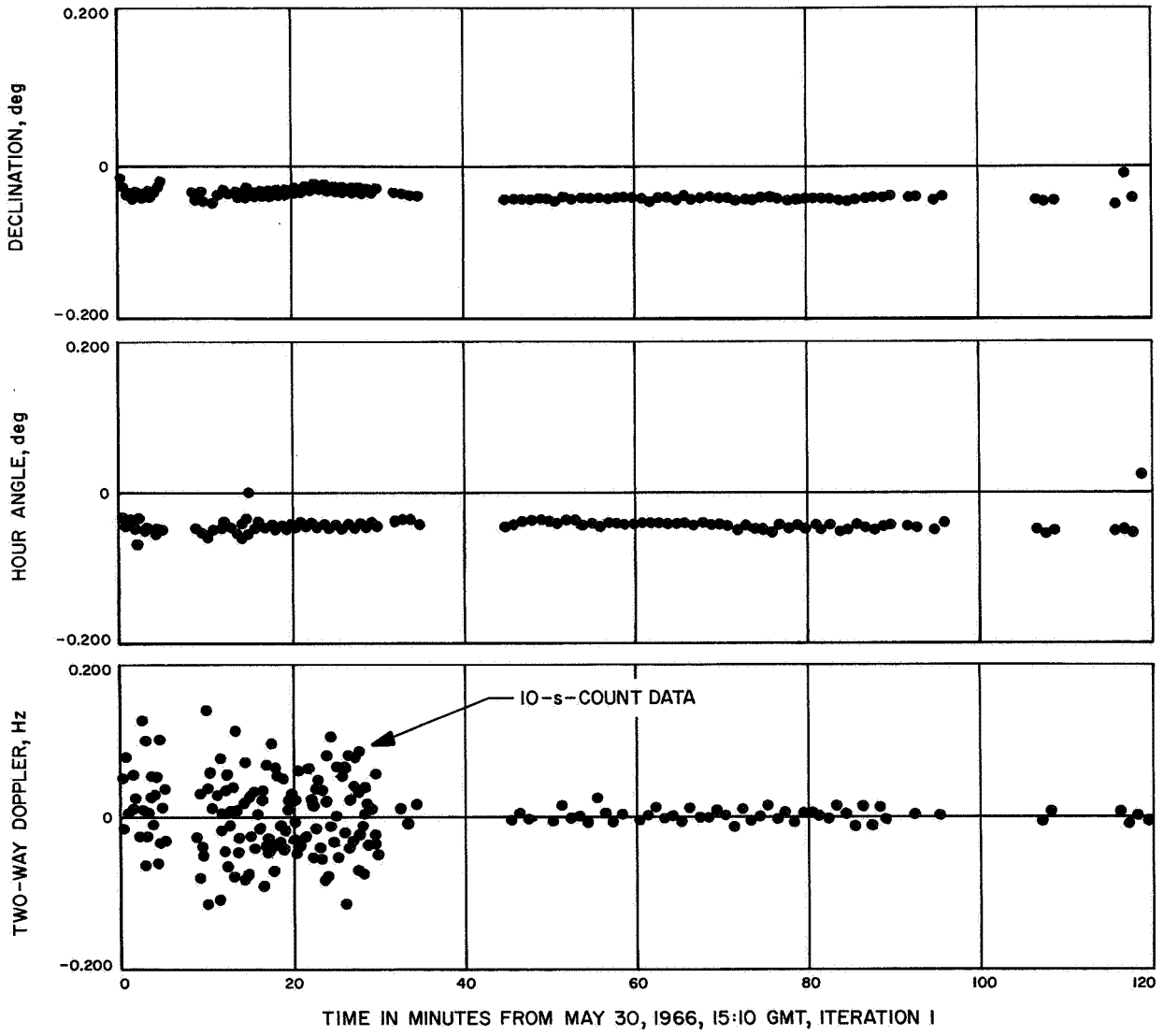


Fig. 54. DSS 51 two-way doppler, hour angle, and declination residuals, first pass; start 15:10 GMT

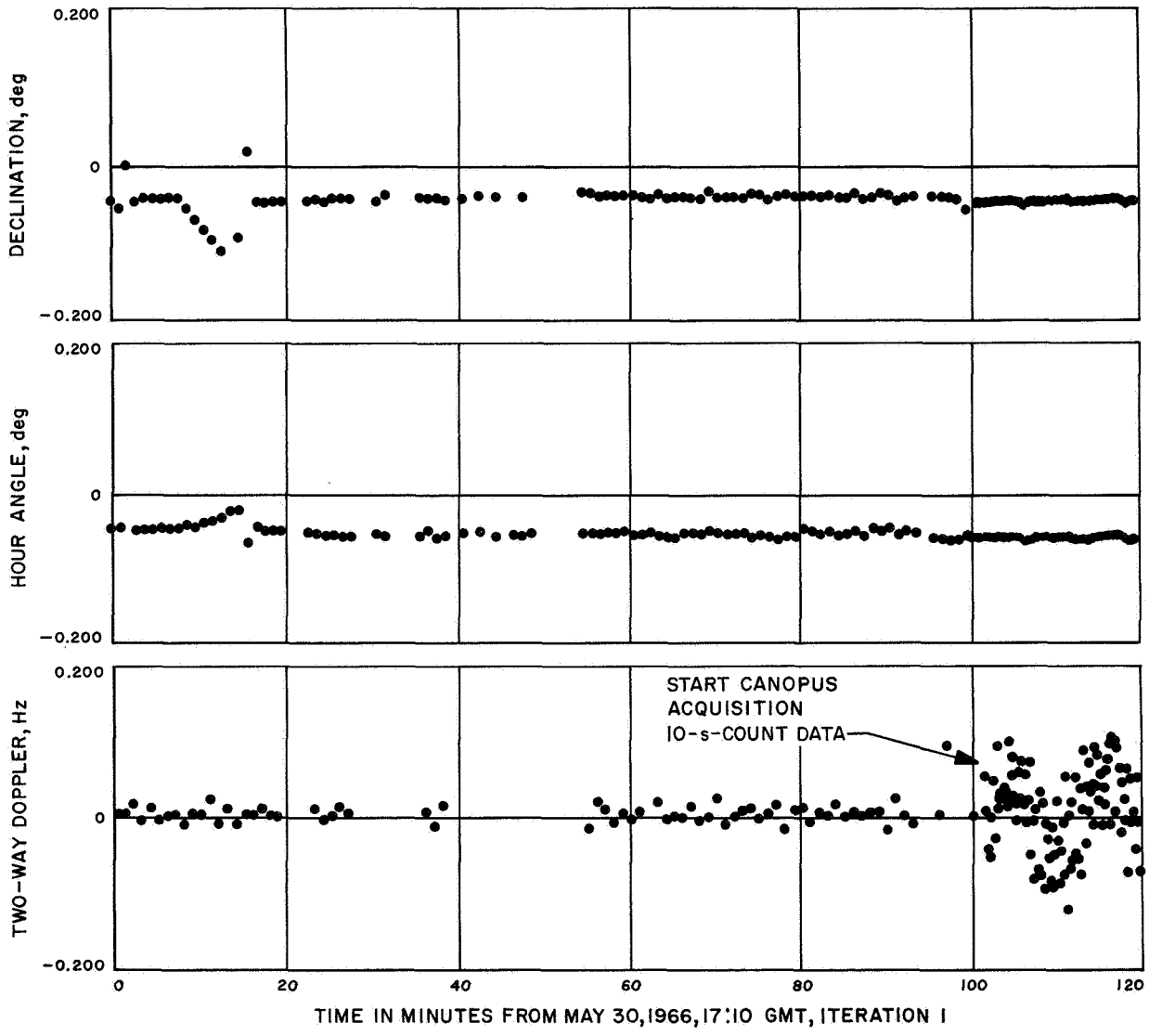


Fig. 55. DSS 51 two-way doppler, hour angle, and declination residuals, first pass; start 17:10 GMT

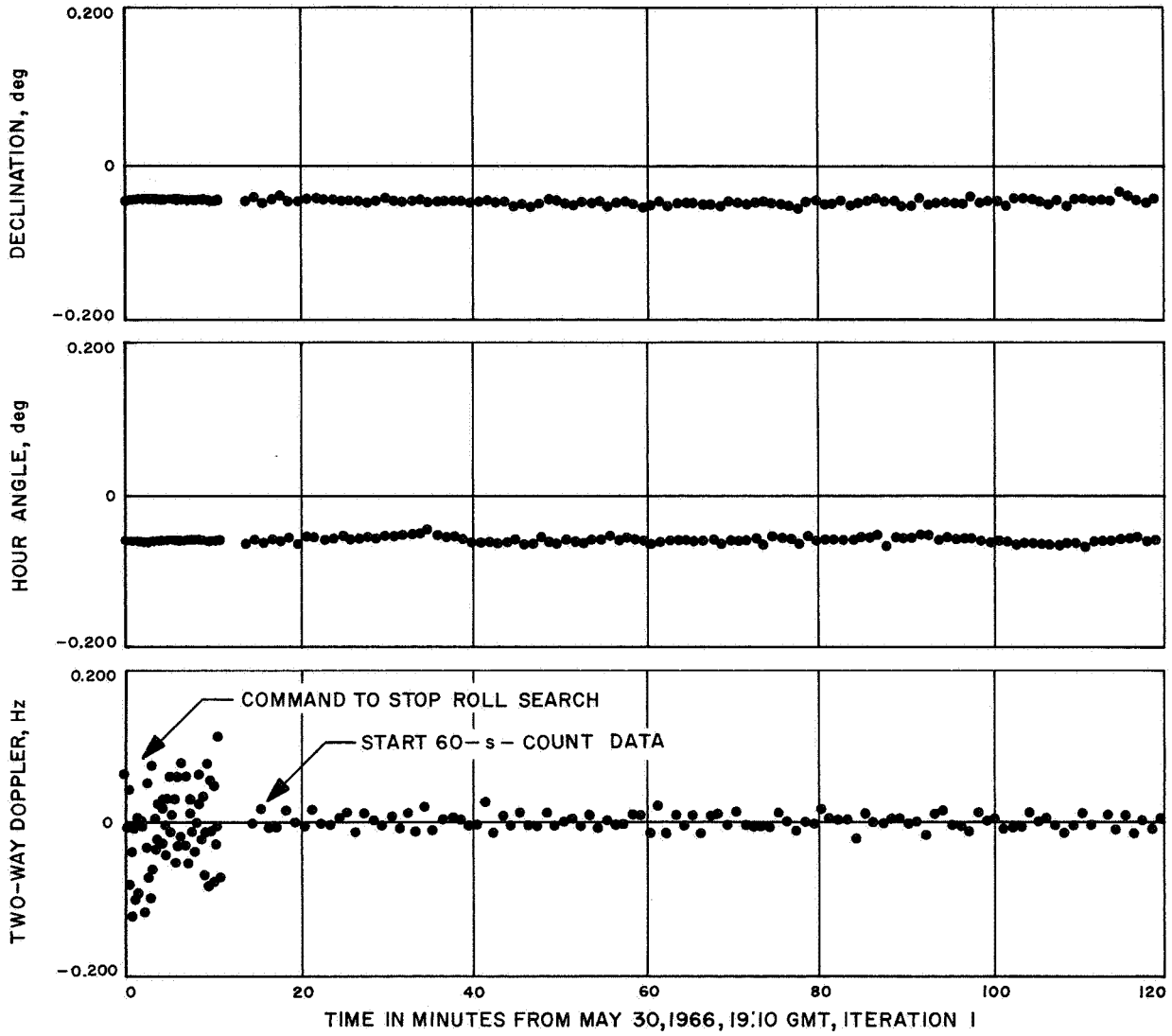


Fig. 56. DSS 51 two-way doppler, hour angle, and declination residuals, first pass; start 19:10 GMT

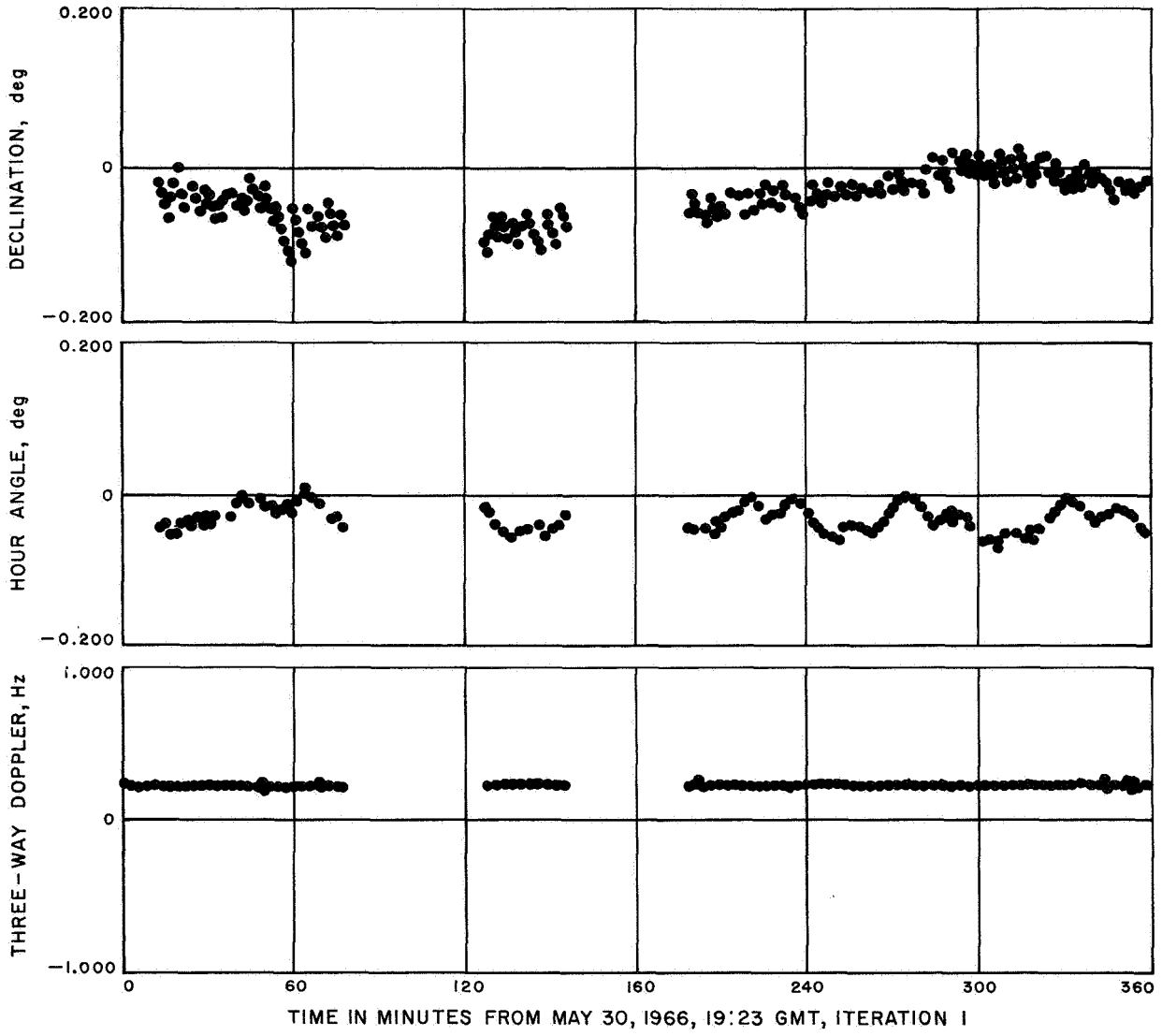


Fig. 57. DSS 61 three-way doppler, hour angle, and declination residuals, first pass; start 19:23 GMT

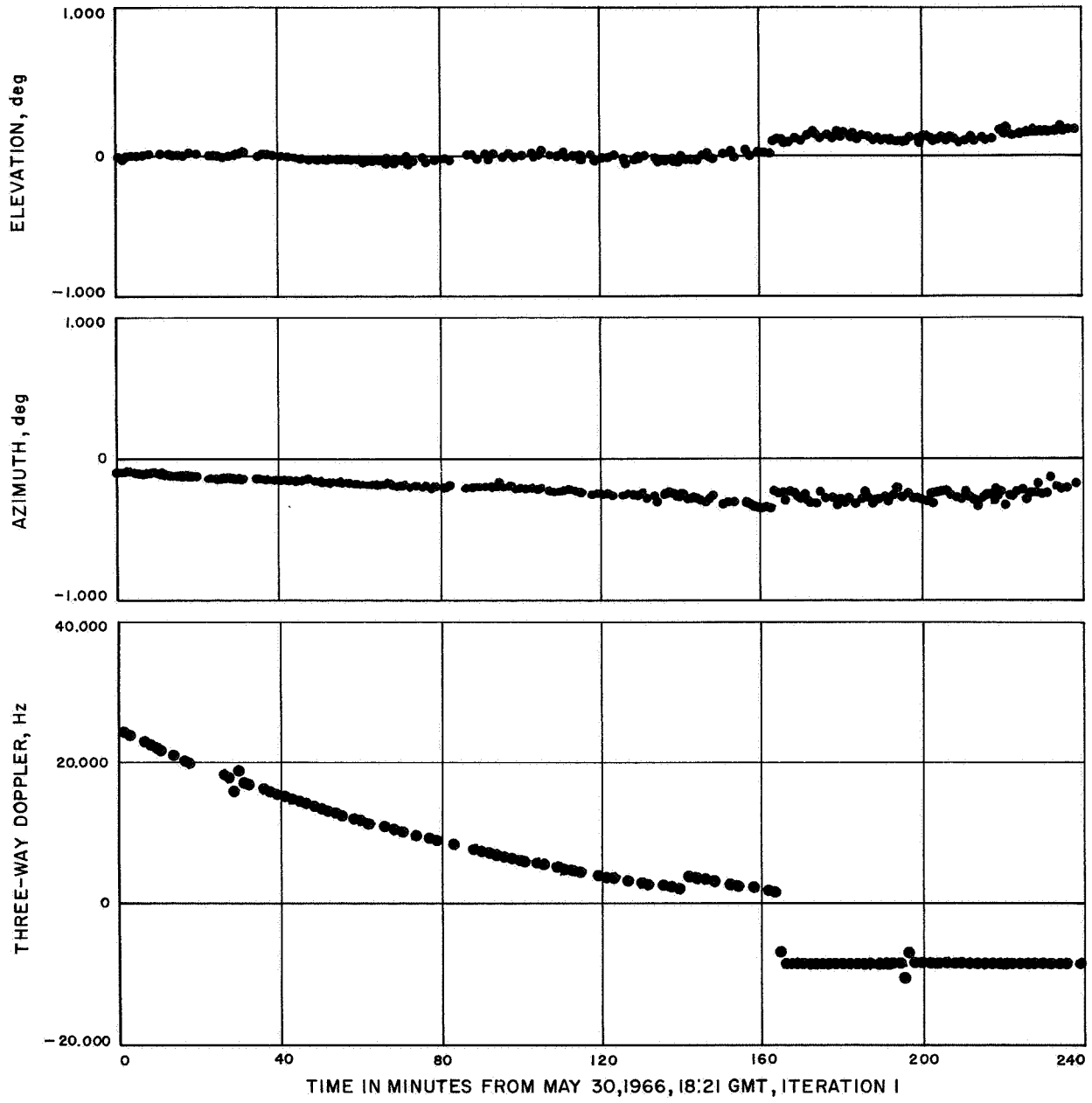


Fig. 58. DSS 72 three-way doppler, azimuth, and elevation residuals, first pass; start 18:21 GMT

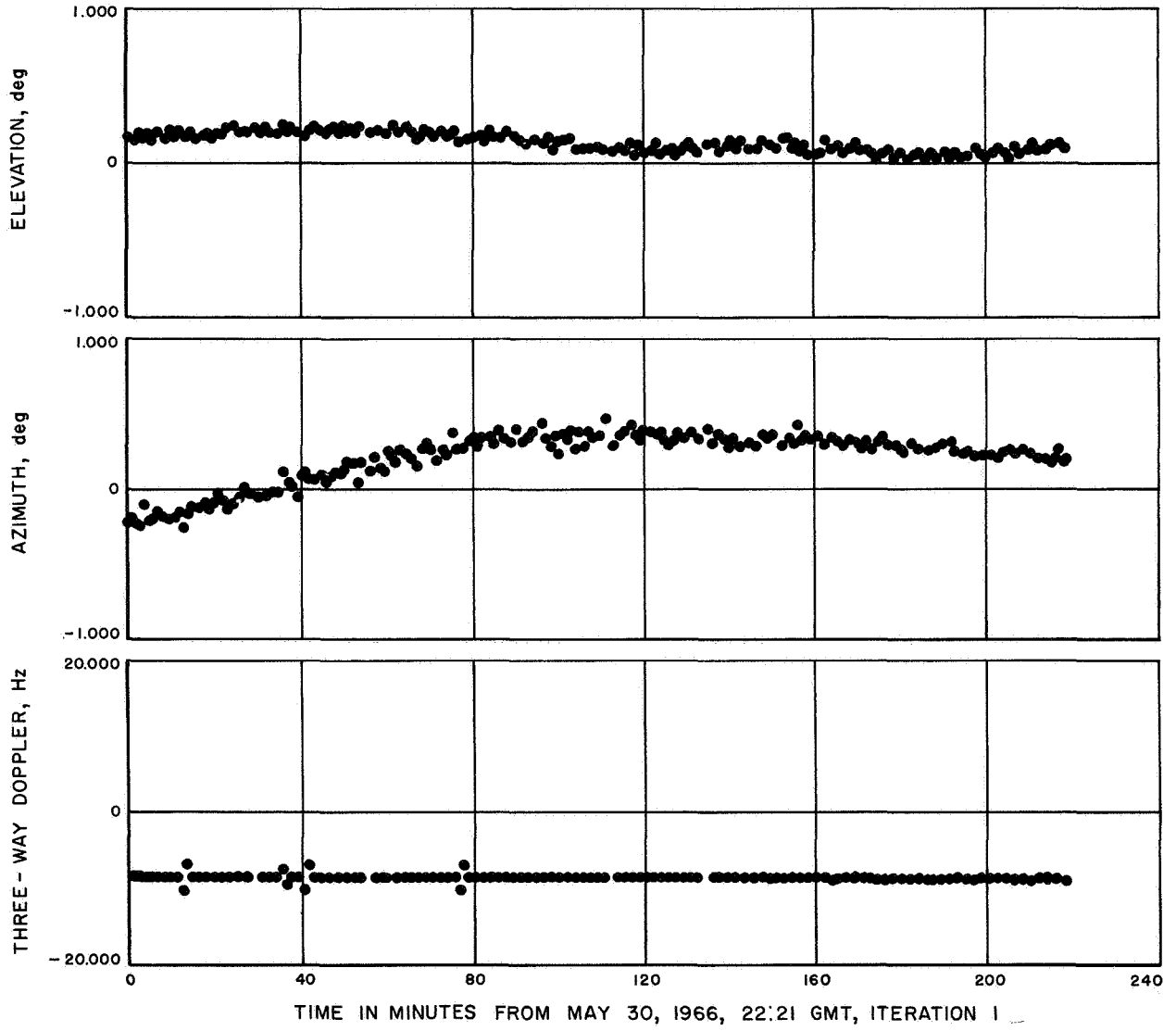


Fig. 59. DSS 72 three-way doppler, azimuth, and elevation residuals, first pass; start 22:21 GMT

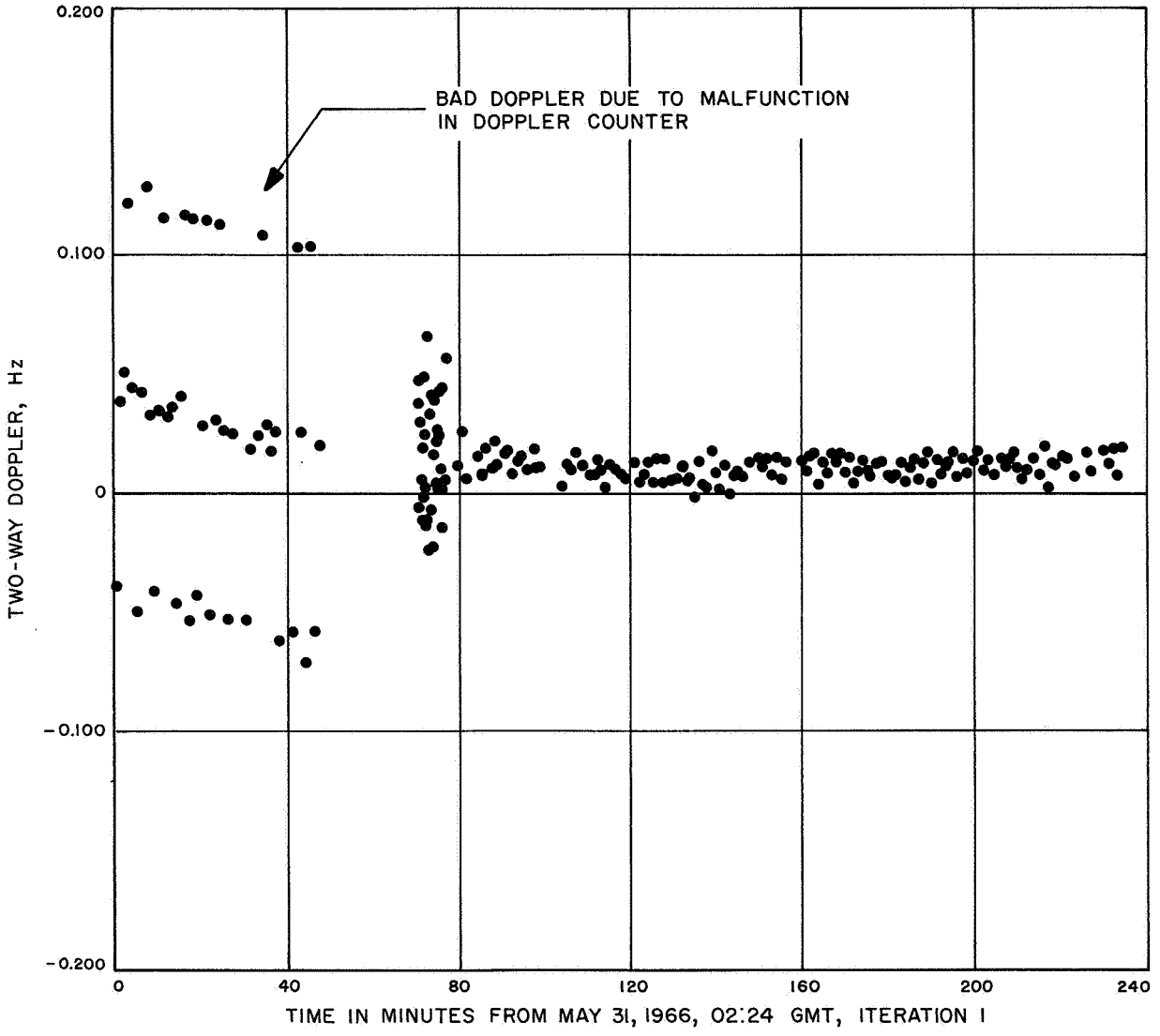


Fig. 60. DSS 11 two-way doppler residuals, first pass; start 02:24 GMT

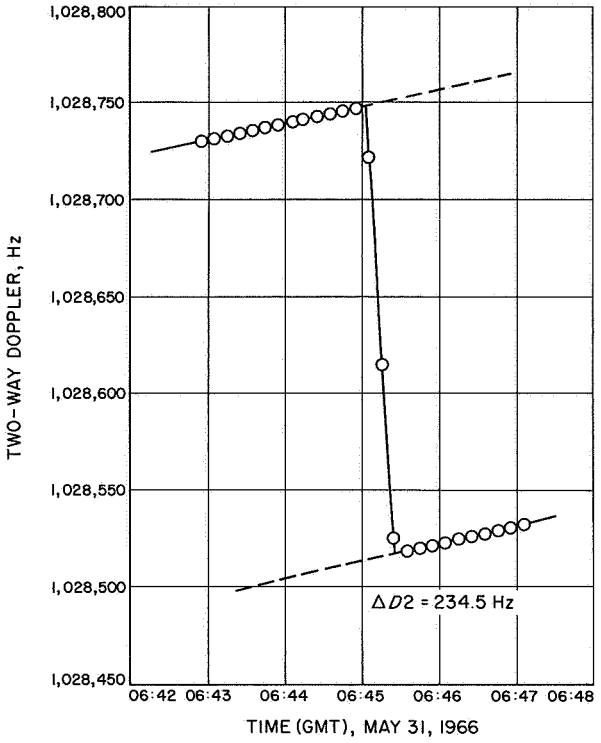


Fig. 61. DSS 11 midcourse maneuver doppler data

All doppler residuals obtained for the post-midcourse phase are detailed in Figs. 62 through 70. The slight effect of a gyro-drift check on the doppler data from DSS 42 during its second pass is identified in Fig. 66. The last several hours of two-way doppler at DSS 11 before retro (Fig. 70) show a rather strange drift, but so far only the possibility of a slight model error in the ODP has been hypothesized to explain this abnormality in the data. Doppler residuals for the post-midcourse maneuver phase are available for DSS 11 in Figs. 62 and 70, for DSS 42 in Figs. 63, 66, and 67, and for DSS 51 in Figs. 64, 65, 68, and 69.

5. Retroengine burn phase: Final inflight calculations by the orbit determination group indicated retroengine ignition at 06:14:44.0 GMT on June 2, 1966. The results of the retroengine burn as seen in the one-way doppler data at DSS 11 are presented in Fig. 71. The results of the vernier engine burn in the one-way doppler are presented in Fig. 72.

b. Telemetry. The DSIF provided telemetry coverage 24 h per day, from acquisition (L + 17 min) through flight and lunar operations, until spacecraft touchdown. Bit-rate modes 1 through 5 and TV were fully exercised to receive engineering data from *Surveyor I*. Sampling formats of commutator modes 1, 2, and 3 were provided for the following critical periods: (1) midcourse maneuver and correction: mode 1, (2) terminal descent using high-gain antenna: mode 2, and (3) terminal descent using omnidirectional antenna: mode 3. For miscellaneous telemetry requirements, a sampling format of commutator mode 4 was established. Baseband telemetry data were decommutated and processed using on-site data processing computers. Such data were transmitted to the SFOF in near real time, using high-speed data modems.

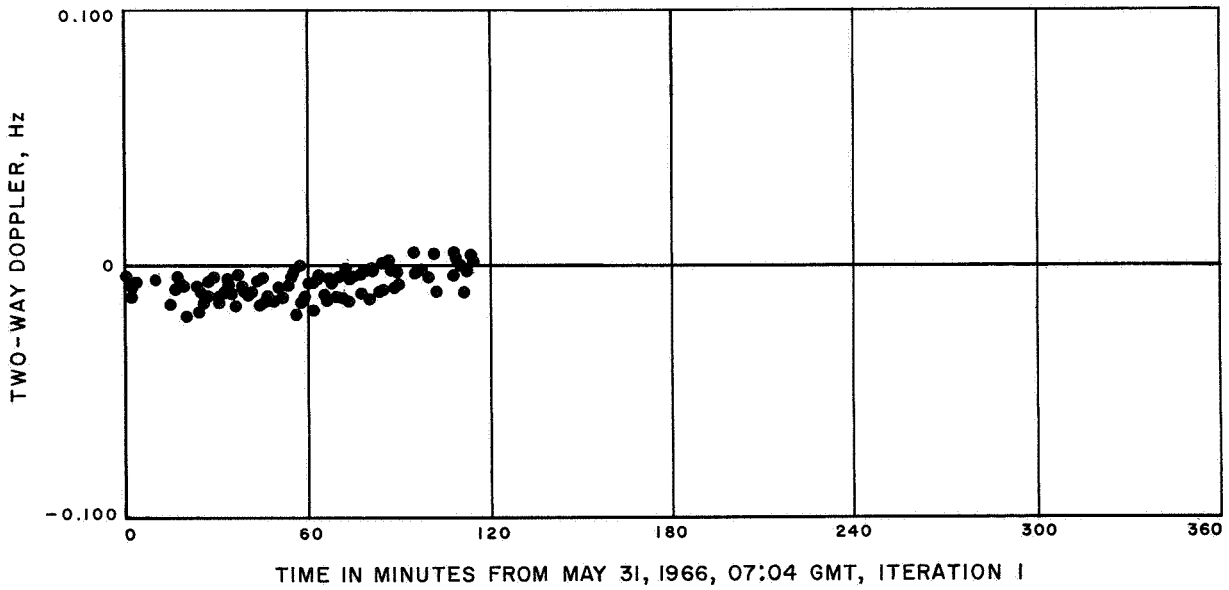


Fig. 62. DSS 11 two-way doppler residuals, first pass; start 07:04 GMT

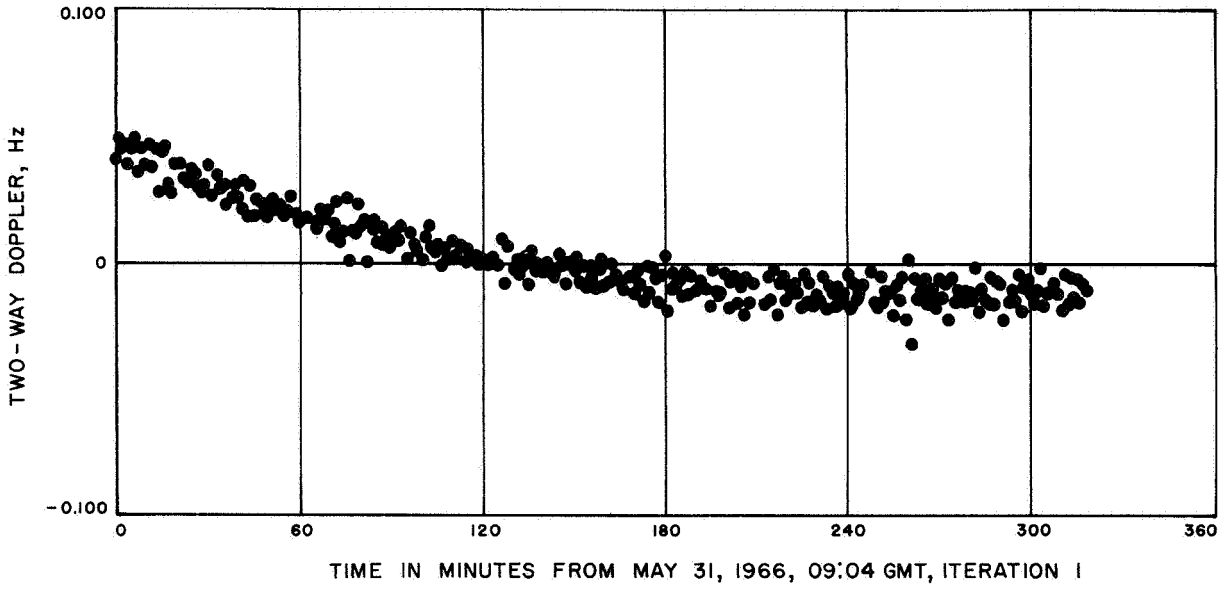


Fig. 63. DSS 42 two-way doppler residuals, first pass; start 09:34 GMT

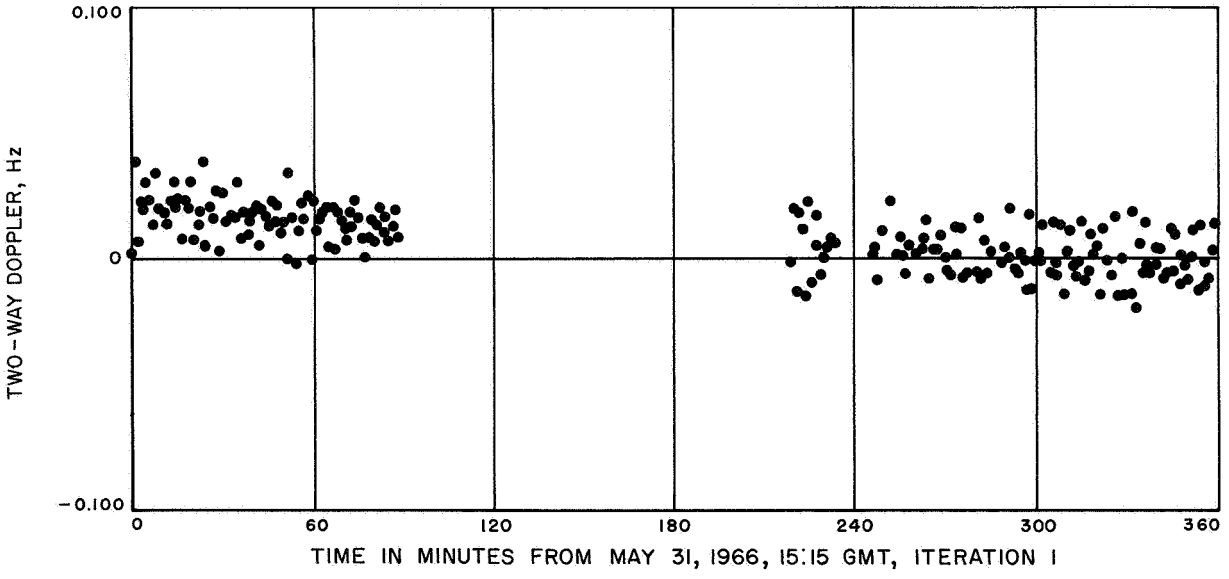


Fig. 64. DSS 51 two-way doppler residuals, second pass; start 15:15 GMT

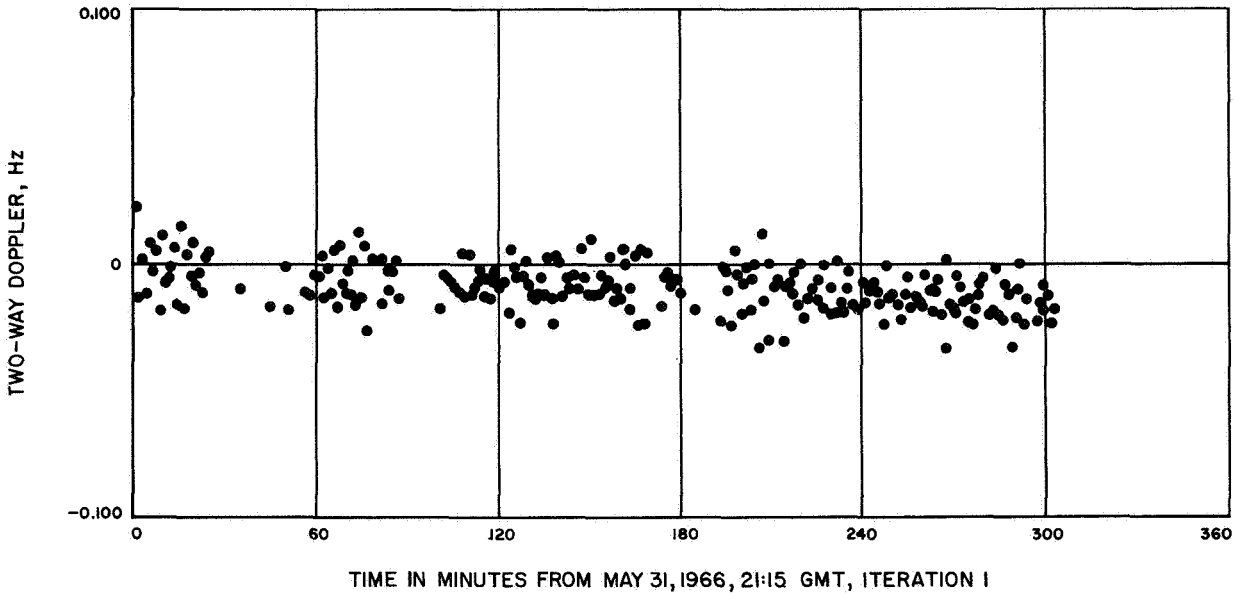


Fig. 65. DSS 51 two-way doppler residuals, second pass; start 21:15 GMT

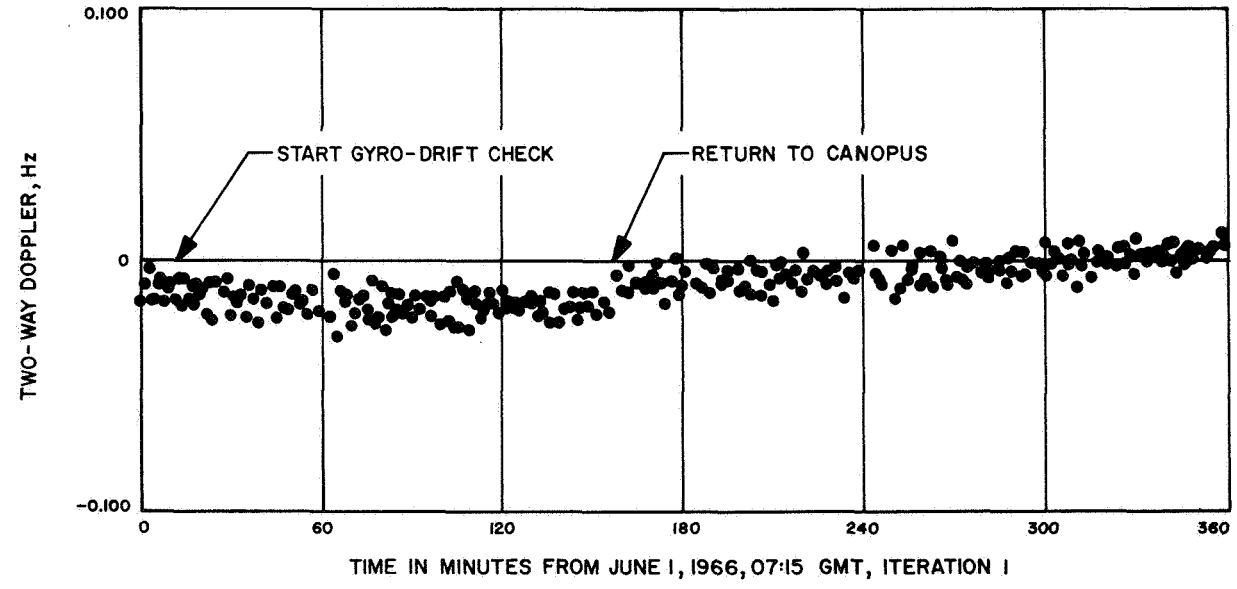


Fig. 66. DSS 42 two-way doppler residuals, second pass; start 07:15 GMT

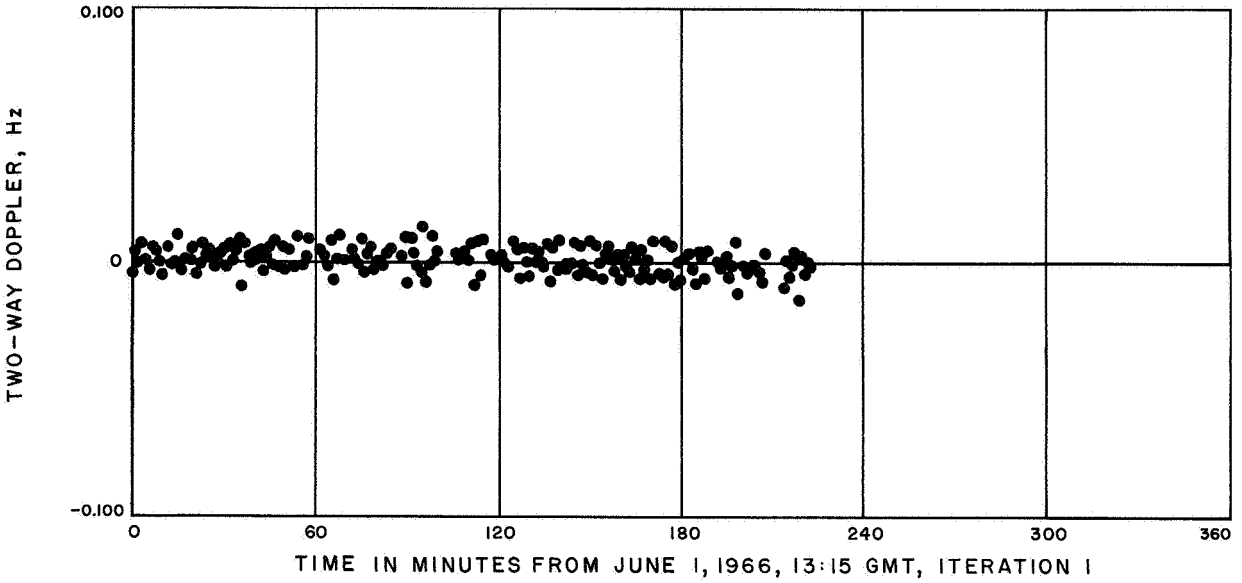


Fig. 67. DSS 42 two-way doppler residuals, second pass; start 13:15 GMT

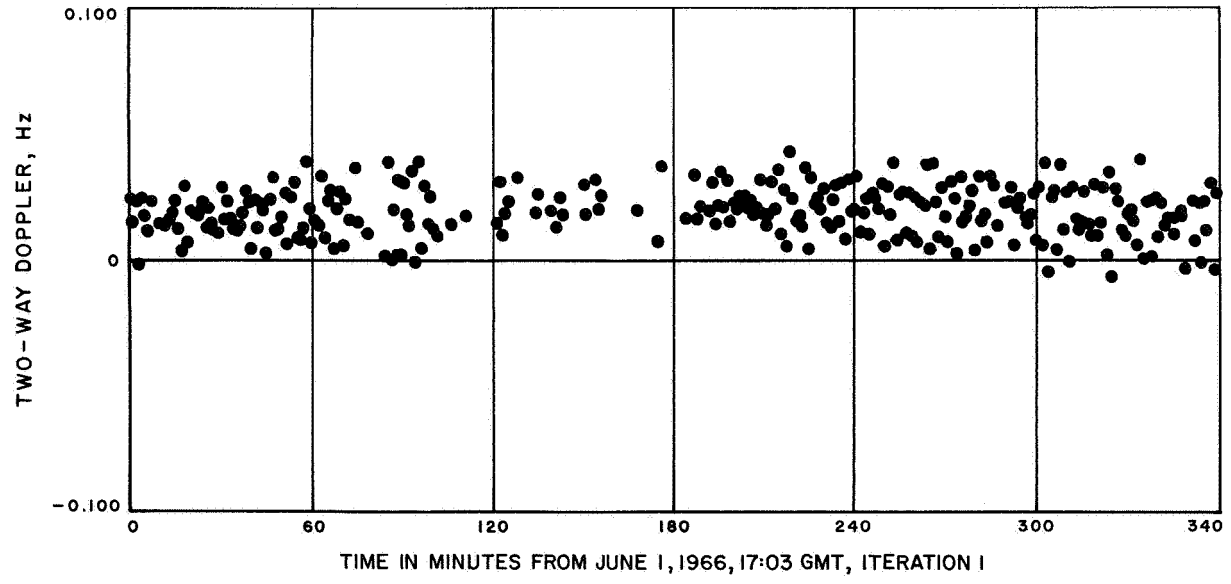


Fig. 68. DSS 51 two-way doppler residuals, third pass; start 17:03 GMT

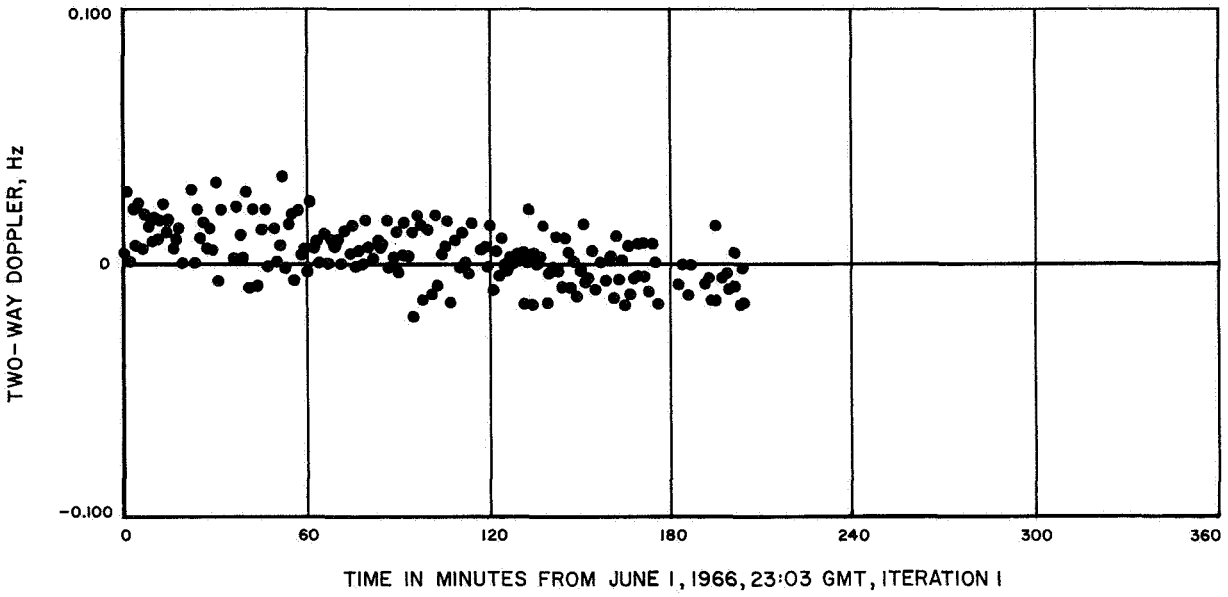


Fig. 69. DSS 51 two-way doppler residuals, third pass; start 23:03 GMT

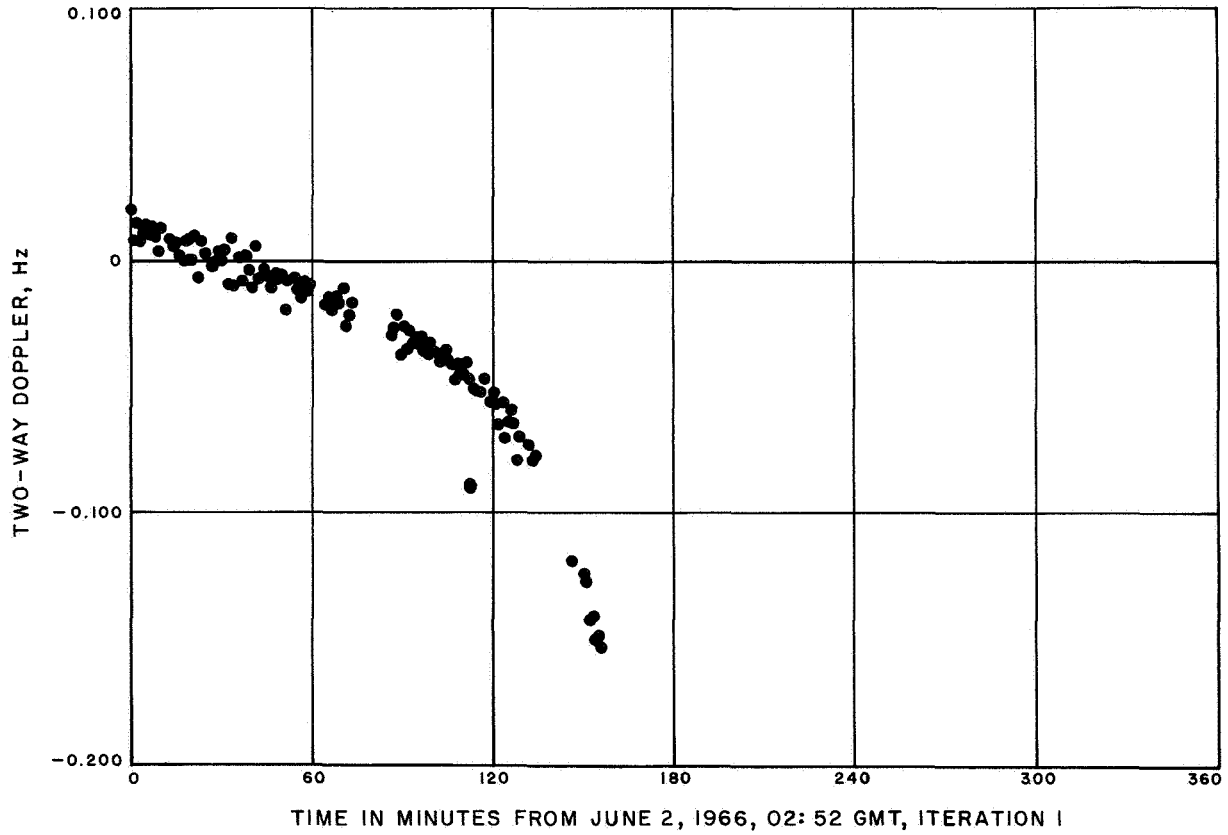


Fig. 70. DSS 11 two-way doppler residuals, third pass; start 02:52 GMT

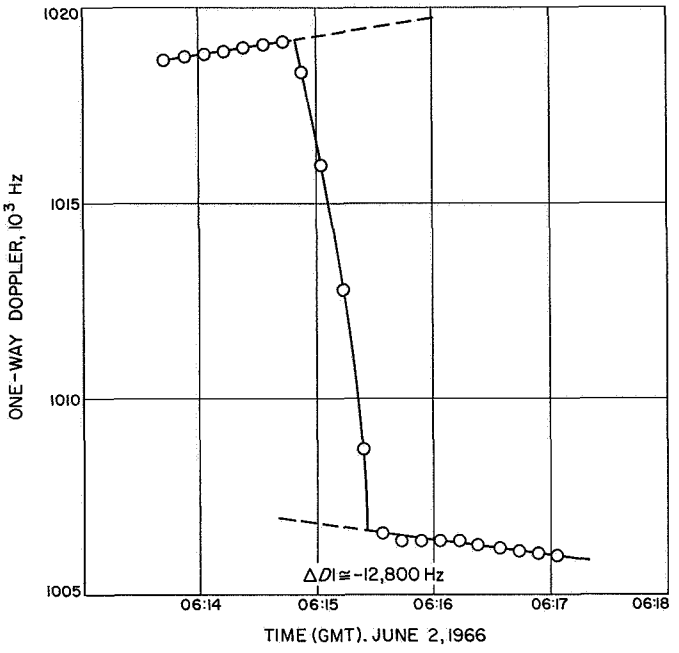


Fig. 71. DSS 11 main retroburn phase doppler

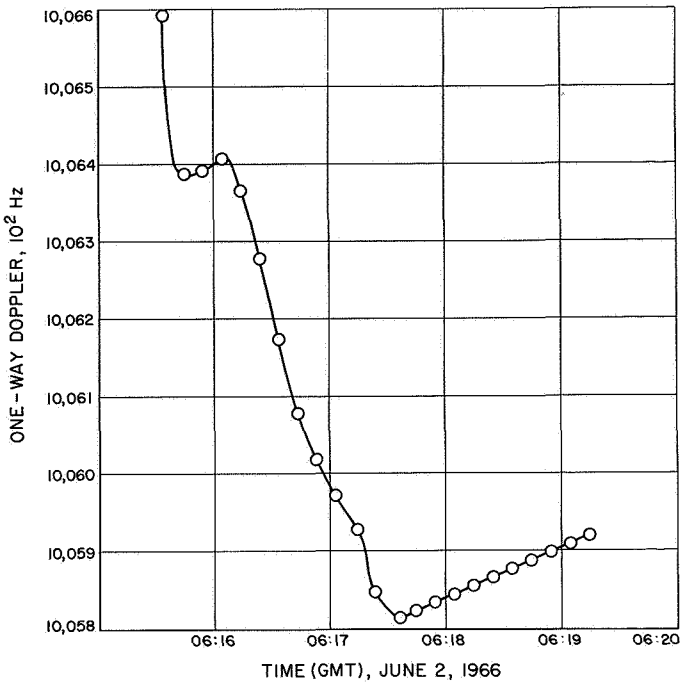


Fig. 72. DSS 11 vernier engine phase doppler

c. Commands. Table 88 is a tabulation of commands transmitted by the prime stations during each spacecraft pass (not including second lunar day operations). Table 89 indicates the individual DSIF tracking passes and totals for each DSS.

d. Video data. The outstanding success of the *Surveyor I* mission is well attested to by the good quality pictures of lunar selenography.

2. Ground Communications Facility/NASCOM. The Ground Communications Facility provided all required support for the *Surveyor I* mission. New communications procedures requested by *Surveyor* Project Office were successfully implemented. All circuits performed with a consistently high degree of reliability, as shown in Table 90.

a. Voice lines. The voice circuits supplied to the *Surveyor* Project performed almost perfectly during the entire mission. The most noteworthy event to report is the "back door" voice circuit to the South African station (DSS 51, Johannesburg) which was to be operational for the *Surveyor II* mission. This alternate voice circuit routing via Australia helped reduce the number and duration of circuit outages during subsequent *Surveyor* missions.

b. Teletype lines. The teletype lines performed flawlessly during the *Surveyor I* mission.

c. High-speed data lines. The *Surveyor* Project was the first flight project to utilize extensively the HSDL from the overseas stations, and these performed very well. The South African circuit also performed well during the mission, considering it is routed over HF radio paths and is subject to poor propagation conditions. During the April–May 1966 testing period, however, one test with the Johannesburg station was cancelled because of an HSDL outage of approximately 6 hours. This particular outage was due to an equipment failure at Pretoria, which was further complicated by loss of voice communications with Pretoria.

The HSDL were anticipated to be even more reliable for the *Surveyor II* mission with the operational usage of NASCOM modems (modulator-demodulator). Both modems (NASCOM and Hallicrafters) were to be used for *Surveyor II* inasmuch as the Johannesburg station was not scheduled to receive NASCOM modems.

d. Wideband data link. The microwave link between the Goldstone DSCC and the SFOF generated numerous line-level discrepancies during the April–May testing period. After many discussions between JPL and Western Union, extreme emphasis was placed on obtaining proper equalization on those circuits, and it thereafter evidenced almost 100% reliability during the *Surveyor I* mission.

Table 88. Commands transmitted by prime tracking stations

Pass No.	Date (1966 GMT)	Event	Commands transmitted[a]		
			DSS 51	DSS 11	DSS 42
1	May 30, 31	Midcourse commands sent by DSS 11	77	84	3
2	May 31, June 1		10	8	26
3	June 1, 2	Soft landing, 06:17:37 GMT (June 2)	11	56	590
4	June 3		30	4,833	6
5	June 3, 4		60	1,080	680
6	June 4, 5		5	4,372	988
7	June 5, 6		20	7,876	300
8	June 6, 7	Lunar noon, 06:17 GMT (June 7)	1,656	9,345	67
9	June 7, 8		30	3,158	18
10	June 8, 9		20	4,000	15
11	June 9, 10		15	12,000	17
12	June 10, 11		22	10,100	71
13	June 11, 12		237	10,611	35
14	June 13		64	7,614	444
15	June 14, 15	Start lunar night, 15:12 GMT (June 14)	25	5,000	109
16	June 15, 16		73	96	30
17	June 16	Spacecraft power turned off by DSS 11, 20:31:00 GMT (June 16)	80	100	NA
		Station total	2,435	80,333	3,399
		Grand total	86,167		

[a]Of 86,167 commands transmitted, only one (sequence 0316) was rejected by the spacecraft.

Table 89. DSIF tracking passes

Pass No.	11	14	42	51	61	71	72
0			X	[X[a]		X	[X
1	X	X	X	X]	X		X]
2	X	X	X	X	X		
3	X	X	X	X			
4	X		X	X			
5	X		X	X			
6	X		X	X			
7	X		X	X			
8	X		X	X			
9	X		X	X			
10	X		X	X			
11	X		X	X			X
12	X		X	X	X		
13	X		X	X			X
14	X		X	X	X		
15	X		X	X			
16	X		X	X			
17	X			X			
Totals	17	3	17	17	4	1	3

[a] [ ] Indicates one continuous pass.

Table 90. *Surveyor I* communications circuit performance analysis

Station	Total outage, min	Mean outage duration, min	Reliability, %	Total number of circuits
	TTY circuit performance			
DSS 51	168	56	91.3	4
DSS 42	27	13.5	97.9	4
DSS 11	0	—	100.0	4
AFETR (AO)	5	5	99.7	3
	Voice circuit performance			
DSS 51	66	16.5	86.3	1
DSS 42	0	—	100.0	1
DSS 11	0	—	100.0	1
AFETR (AO)	0	—	100.0	3
	High-speed data circuit performance			
DSS 51	49	12.3	89.8	1
DSS 42	0	—	100.0	1
DSS 11	0	—	100.0	1
AFETR (AO)	0	—	100.0	1

3. *DSN/SFOF.*

a. Communications. The SFOF communications system adequately provided for transferring all types of information required for space flight operations within the SFOF. The system included all voice communication capabilities within the SFOF, as well as closed-circuit television and the distribution of teletype, high-speed data, and data received over the microwave channels to designated areas or users throughout the SFOF. In general, the communications system operated well within the expected reliability parameters; however, there were some potential problem areas and these are discussed in the following paragraphs.

Voice audio patch panel. During the April–May testing period, numerous voice-line patching errors occurred at the audio patch panel. This panel was completely saturated during multistation support and the design of the panel contributed to patching errors, even by the most qualified operators. As a result, a new audio patch panel was designed for subsequent missions.

High-speed data modems. One of the two Hallicrafters high-speed data (HSD) receiver modems (modem 1A) was considerably less reliable than the others during the mission. Modifications to the circuitry alleviated this problem before the *Surveyor II* mission. Both Hallicrafters and NASCOM modems were to be utilized for *Surveyor II* to increase performance reliability. Hallicrafters modems must remain in the system inasmuch as DSS 51 is not scheduled to receive NASCOM modems.

Telemetry processing station circuits. During the *Surveyor I* mission, there were only six HSD lines from the Communications Center to the telemetry processing station (TPS). This was totally inadequate for multimission support. Work was initiated to install additional lines.

b. Data processing. The data processing system (DPS) configuration for *Surveyor I* consisted of a TPS, two strings of IBM 7044/7094 computers, and the input/output (I/O) or display system.

During the *Surveyor* mission, the DPS successfully processed high-speed telemetry data, command confirmation data, and tracking data. The *Surveyor* Project was the first flight project supported by the SFOF DPS which had a telemetry bit rate of 4400 bits/s.

Telemetry processing station. The TPS configuration for *Surveyor I* consisted primarily of a PDP-4 and PDP-7 computer and both successfully processed all HSD from the overseas DSS stations, as well as the Goldstone data received over the microwave link. This processing included recording all HSD on FR-1400 recorders, decommutating the data, transferring the data to the IBM 7044/7094 computers for further processing, generating a digital tape for near-real time processing or backup, and supplying digital-to-analog converters with signals to drive analog recorders in the SPAA.

Utilization of the dual-string configuration during multiple DSS tracking periods permitted a data quality comparison to be made in real time between two stations. The *Surveyor* Project was the first that had this capability. In addition, the PCM telemetry data decommutation was accomplished by a combination of both hardware and software for the first time and this permitted the TPS to automatically recognize telemetry data mode changes.

The IBM 7044 computers successfully processed all HSD received from the TPS and all TTY data received from the Communications Center, as well as those requests and data parameters received from the I/O devices in the user or operations areas. The IBM 7094 computers, serving as the high-speed arithmetic or analysis computers, ran successfully for all user programs required

during the mission. During the transit phase of the mission, operations were conducted on a dual mode 2 configuration and for the most part, a single mode 3/mode 4 configuration was used during the lunar phase.

Some problem areas or system "bugs" were known to exist in both IBM 7044/7094 computer strings prior to launch. Having this foreknowledge made it possible to work around the system discrepancies during mission operation, and investigation was made of the problem areas in an effort to correct them for future missions.

Card reader problem. The card reader, which was normally used to transmit variable data parameters from the user areas through the IBM 7044 computer to the analysis programs in the IBM 7094 computer, did not function properly. The problems experienced with the card reader could have been operator procedural errors, equipment failures, software discrepancies, or a combination of the three. The hardware problems were corrected, all software was fully checked out, and the operators were thoroughly instructed on the procedures for operating the card reader.

Direct data channel errors. The direct data channel (DDC) was the mechanism by which the IBM 7044 and 7094 computers communicated with each other. Among the problems encountered here some were definitely software problems, and some in all probability were hardware deficiencies. Others that were termed DDC errors were actually normal system operation. A number of software changes were implemented to facilitate problem correction.

Nonshare problem. Nonshared is the term applied when the computers are operating in a mode 2 configuration and the IBM 7044 and 7094 are not able to communicate with each other. This causes the 7094 to become inoperative until communication with the 7044 is restored or the mode 2 configuration is broken. Here again the software was modified to facilitate problem correction.

Subchannel problem. At times it appeared that TTY data received on subchannel 11 from the Communications Center were not processed. Numerous tests with both IBM diagnostic and *Surveyor* Project 7044 programs failed to isolate the problem. Subchannel 12 was used during the mission and performed flawlessly.

Input/output system. The I/O system provided the means for entering data control parameters into the IBM 7044/7094 strings and also displaying computed data in the technical areas via the various display devices. With the exception of the card-reader anomalies discussed earlier, this system performed adequately.

c. Displays. The display system provided the means to visually communicate technical and operational information between and within the technical, control, and operational areas of the SFOF during *Surveyor I* operational periods. This system did not include the printers and plotters driven by and displaying the output of the data processing system. Generally, all display devices functioned satisfactorily to support the *Surveyor I* mission.

d. Facilities. The facilities designated within the SFOF to support the *Surveyor I* mission performed adequately. The facilities and support provided by the SFOF were as follows:

(1) Space was provided in mission-dependent and mission-independent areas. Mission Control Room No. 1 and Mission Support Area No. 1, which included the Spacecraft Performance Analysis Area and the Space Science Analysis Area, were devoted exclusively to *Surveyor I* mission support. Flight Path Analysis Area No. 1 was a shared area; however, the *Surveyor I* mission had its exclusive use during the flight. Common user areas supporting the mission included DSIF Net Control, the data processing area, and the Communications Center.

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

(3) SFOF internal communications support consisted of the operational voice communications system (voice nets), closed-circuit television, and internal teletype distribution.

(4) Other support functions included operation of display devices, data distribution in the facility, supervision of access control, and building housekeeping functions.

VII. *Surveyor II* Mission Synopsis

A. Introduction

The *Surveyor II* mission T&DS consisted of those activities, agencies and organizations associated with the preparation, testing, and support of pre-launch, launch and flight operations.

For *Surveyor* missions the T&DS performs tracking, in-flight control and data acquisition functions. To accomplish this task, the facility configuration included the launch facilities and tracking capabilities of the: (1) AFETR, (2) GSFC, (3) MSFN, (4) DSN, (5) SFOF at JPL, Pasadena, Calif., and (6) GCF for transmitting the acquired tracking and telemetry data to the required organs within the T&DS.

B. Mission Synopsis

The *Surveyor II* mission was conducted during the period from September 20 (day 263) through September 22, 1966 (day 265). The final countdown of the *Atlas/Centaur* launch vehicle proceeded smoothly and as scheduled, until the count was recycled at 12:01:00 GMT[12] to $T-5$ min. At this point several recycles were required because of difficulties with the *Atlas* boil-off and liquid oxygen (LOX) topping valves.

The count was resumed at approximately 12:26:00 GMT to attempt a launch prior to launch window closing at 12:32:00 GMT. Liftoff was accomplished at 12:31:59.824 GMT with a launch azimuth of 114.361 deg (closing azimuth for direct ascent trajectory was 115 deg). Following liftoff, the *Atlas/Centaur Surveyor* vehicle followed a direct-ascent trajectory through roll, pitch-over, booster burnout and jettison, *Centaur* insulation panels and shroud ejection, *Atlas* sustainer burnout, and *Centaur* separation from the *Atlas*. Then after a short coast, *Centaur* ignition was accomplished and the spacecraft was boosted on a direct-ascent trajectory to the prescribed point of injection.

Performance of the *Atlas/Centaur* appeared normal throughout the powered flight phase and all *mark* events occurred close to predicted times. A synopsis of *Surveyor II* events is contained in Table 91. Injection (*mark* 8) was accomplished at 12:43:26.1 GMT, and resulted in a spacecraft trajectory which would have provided, with no midcourse correction, a total miss distance of 88.2 mi from the targeted landing site. The spacecraft transmitter high power was turned on, and the spacecraft landing gears legs and omnidirectional antennas were extended by command from the *Centaur* flight programmer. Until separation, spacecraft telemetry was transmitted to ground receivers via the *Centaur* telemetry link. Following spacecraft/launch vehicle separation, at 12:44:32 GMT, the *Centaur* executed a retro maneuver designed to remove itself approximately 240 km from the *Surveyor II* spacecraft, to prevent the affixed Canopus sensor from locking onto reflected light from the *Centaur* stage shell. All spacecraft programmed flight events (*mark* 9, 10 and 11) were successfully accomplished and close to nominal times. Separation (*mark* 13) of the spacecraft from the *Centaur* was successfully accomplished at 12:44:32.6 GMT. Sun Lock was obtained at 12:48:15 GMT.

Table 91. *Surveyor II* mission synopsis of events

Date and event	PDT[a]	Time from launch
Day 263, September 20, 1966		
Launch	05:31:59:824	0
Injection	05:43:26	1 min 27 s
Separation, Centaur/Atlas	05:44:32	12 min 33 s
Automatic sun acquisition completed	05:49:45	17 min 45 s
Automatic solar panel deployment completed	05:54:59	23 min
Spacecraft visibility at Johannesburg begun	05:56:59	25 min
Initial DSS acquisition (two-way lock) confirmed	06:05:59	34 min
First ground sequence initiated	06:16:33	45 min
Canopus verification initiated	11:37:34	06 h 06 min
Canopus acquisition completed	12:09:38	06 h 38 min
First premidcourse attitude *maneuver initiated*	21:44:00	16 h 11 min 53 s
Midcourse thrust executed[b]	21:59:59	16 h 29 min
Day 264, September 21, 1966		
Went to auxiliary battery mode	4:41:16	23 h 09 min 16 s
Upper deployment of planar array, first attempt	19:45	38 h 13 min
Upper deployment of planar array, second attempt	19:51	38 h 19 min
Day 265, September 22, 1966		
Estimated battery power precludes soft landing	21:27	39 h 55 min 17 s
Helium tank depressurized	2:13:15	44 h 41 min 15 s
Retro engine firing sequence initiated	2:34:17	45 h 02 min 17 s
Emergency altitude marking radar signal generated	2:34:17	45 h 02 min 17 s
Retro engine ignition	2:34:50	45 h 02 min 50 s
Mission terminated	2:35	45 h 03 min

[a]PDT = Pacific daylight time — add 7 h for determining Greenwich Meantime (GMT).

[b]During and after midcourse, several unsuccessful efforts were made to ignite vernier engine No. 3.

[12]All times mentioned are GMT unless otherwise noted.

First DSN spacecraft acquisition was obtained by DSS-72 at 12:48:50 GMT. DSS 51 acquired one-way lock at approximately 12:57:00 GMT and two-way lock at approximately 13:05:47 GMT. When the DSN was ready for commanding, initial spacecraft operations were commenced at 13:16:33 GMT and completed in the standard manner at 13:39:24 GMT with the exception that Manual Lock-on (Command 0716) was recommended and executed rather than Cruise mode on (Command 0704) based on star sensor telemetry.

The standard sequence of events was deviated from by direction of Mission Control at 16:38:38 GMT when the spacecraft bit rate was reduced from 1100 to 137.5 bits/s and spacecraft command capability was transferred to DSS 72 rather than DSS 51 in order that additional tracking data could be obtained for better orbit determination. All computations were completed by 18:01 GMT. Spacecraft control returned to DSS 51 at approximately 17:50 GMT and the bit rate was returned to 1100 bits/s at 18:01:26 GMT.

Due to the large launch azimuth (114.361 deg), a 40-min outage of data and command capabilities was predicted between DSS 51 and DSS 11 visibility periods.

In order to assure continuous data and command capabilities, the Standard Sequence of events was deviated from by transferring once again to DSS 72 and reducing the spacecraft bit rate from 1100 to 17.2 bits/s at 21:47:54 GMT to match the DSS 72 capabilities. Spacecraft control transferred to DSS 11 at 23:05:00 GMT and bit rate increased to 1100 bits/s at 23:11:54 GMT. Figure 73 shows DSS 11 with its 85-ft antenna located at Goldstone, California.

The Star Verification and Acquisition sequence was initiated at 18:33:01 GMT. Star Map was initiated at 18:37:34 GMT and completed at 19:11:57 GMT after some 957 degrees of roll. During the Star Mapping sequence, five stars (Canopus, Shaula, Ras Alhaque, Menkalinan and Theta Ophiuchi) were tenatively identified as well as the earth and the moon. Some difficulty was experienced in readily identifying the celestial bodies due to earth and moon shine reflections entering the star sensor.

Telemetry data indicated an apparent decrease in sensitivity of receiver B and on day 264 (September 21, 1966) a special receiver B threshold test was recommended and performed at 01:23:50 GMT. This test consisted of reducing the radiate power from DSS 11 in 2-dB steps to determine receiver B threshold as indicated on telemetry. The results of this test strongly indicated that receiver B had not degraded by 20 dB but that possibly the telemetry sensor was erroneous. Further checks were planned after midcourse to clarify these findings.

Coast Phase I was standard with one gyro drift check performed at 19:26:24 on day 263; and one gyro speed check performed on day 264 at 03:07:42 GMT; as well as four low power interrogations at 18:09:31 GMT and 23:40:31 GMT on day 263, and 02:54:44 GMT, 04:14:00 GMT, on day 264. The spacecraft bit rate was left at 1100 bits/s rather than 550 bits/s as sufficient margin was available through midcourse.

Midcourse maneuver was set for execution at 05:00:00 GMT on day 264. A plus roll of 75.3 deg and a plus yaw of 110.5 deg with a thrust duration of 9.825 s was required. Midcourse preparation was initiated at 04:14:00 GMT of day 264 with a low power engineering interrogation. The spacecraft was reconfigured to the high power and 4400 bits/s condition. The first midcourse maneuver was executed at 04:44:00 GMT and a plus roll of 75.3 deg was verified by telemetry. The second maneuver was executed at 04:48:06 GMT and a plus yaw of 110.5 deg was verified from telemetry. Vernier pressurization and unlocking vernier engine No. 1 was accomplished at 04:53:38 and verified by telemetry. Midcourse velocity correction was loaded at 04:54:47 GMT and verified by telemetry. Thrust execution was accomplished at 05:00:02 GMT on day 264 at which time the spacecraft attitude became unstable. Emergency Velocity Correction was commanded at 05:00:13 GMT, some 1.2 s after a thrust period of 9.8 s as verified by telemetry. At this time the standard sequence of events was nullified. In order to attempt spacecraft stabilization, Rate Mode On (Command 0701) was executed at 05:03:49 GMT. However, as expected, the spacecraft spin rate was not reducing at a significant rate to stabilize, and attitude jets were inhibited (Command 0707) at 05:14:29 GMT in order to maintain at least half the gas.

Telemetry indications obtained during vernier thrust period strongly indicated that vernier engine No. 3 did not have ignition and was the probable cause of the spacecraft instability. It was recommended to mission control, after analysis, that the vernier engines be fired for 2 s in order to attempt partial stabilization if engine No. 3 fired. At 07:28:24 GMT the vernier engines were thrusted, but engine No. 3 again did not fire. Mission

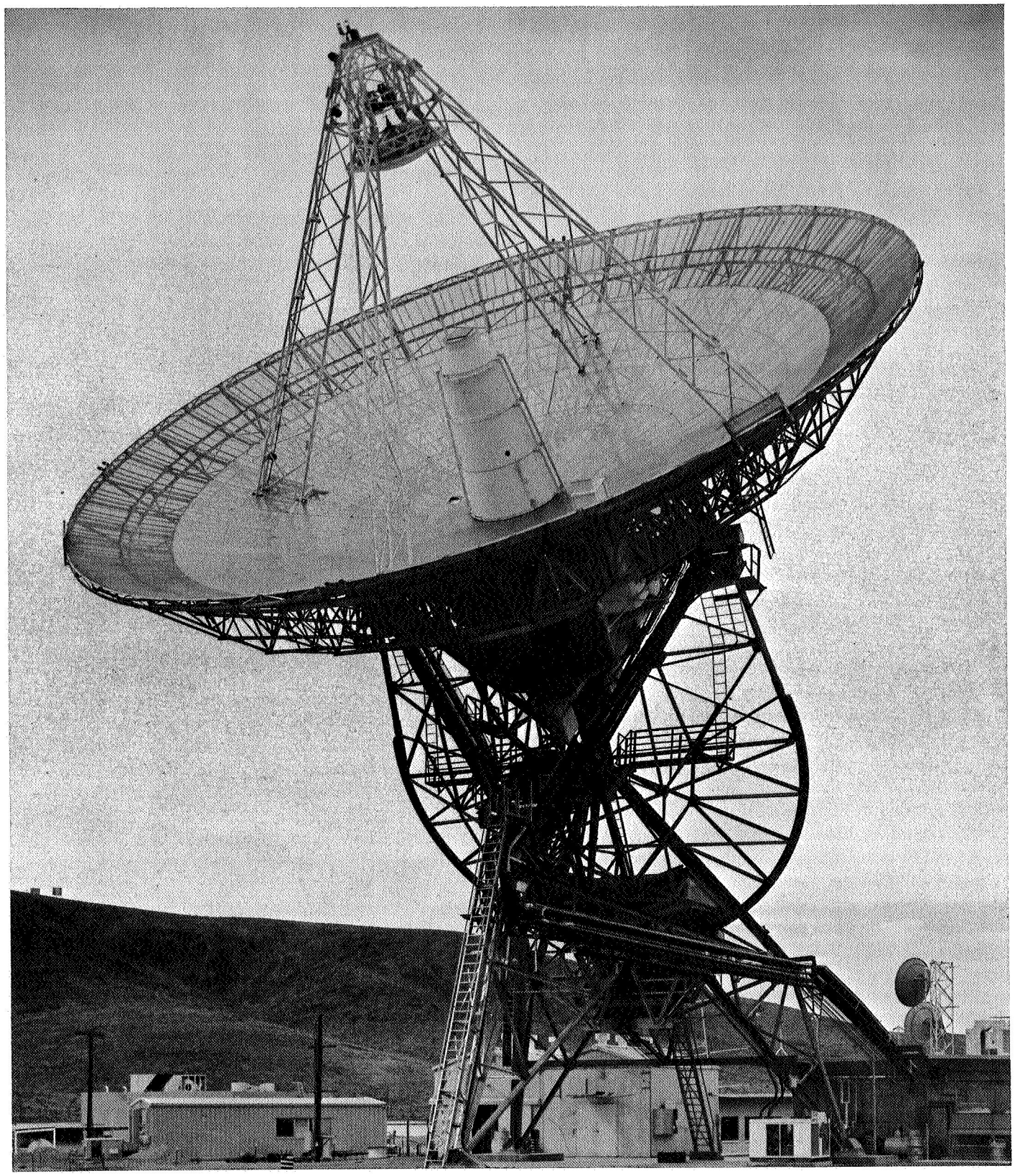


Fig. 73. Goldstone DSS 11 Pioneer tracking site, California

Control directed a repeat of the 2-s vernier engine firing and at 07:50:03 GMT the vernier engines were fired again for 2 s and once again engine No. 3 did not fire. Mission Control directed that no more attempts be made to fire the engines for the next 8 h in order that failure analysis could be started by design specialists. During the next 8 h the flight control power was cycled to conserve main battery energy. Auxiliary battery was commanded (Command 0317) on at 11:41:09 GMT and removed at approximately 22:27 GMT.

An analysis was accomplished in real time to formulate a plan to correct the existing problem. The following vernier engine test sequence was formulated and implemented for that purpose.

(1) Pulse fire the vernier engines five separate times with a firing of 0.2-s duration and separated by a 5-min interval between thrusts.

(2) Spacecraft to be in low power, 137.5 bits/s and Mode 1; for other times, utilize coast mode data.

(3) After completion of (1) thrust vernier engines for 2 s with spacecraft at high power and 1100 bits/s.

Step (1) was initiated at 19:44:00 GMT and completed at 21:16:00 GMT. However, due to communication problems with DSS 51 and problems in the priority activation of DSS 61, the initiation of step (3) was delayed until 23:28:08 GMT, and completion at 23:40:17 GMT was experienced with no positive indication that vernier engine No. 3 had ignition. Mission Control was convened at 23:45 GMT and it was recommended to: (a) step planar array for solar panel illumination in order to obtain spacecraft orientation, and (b) if possible fire vernier engines at high thrust rather than at low thrust. It was agreed by Mission Control that recommendation (a) should be accomplished and that a high thrust engine sequence should be generated. In addition, it was directed by Mission Control that the vernier engine test sequence be performed on an hourly basis. The 2-s vernier engine test firings were performed at 01:28:11 GMT, 02:39:14 GMT, 03:47:56 GMT and 04:55:26 GMT on day 265.

The vernier engines were fired in high thrust at 05:43:19 GMT with no indications of vernier engine No. 3 firing. Mission Control at 07:30:00 GMT directed the execution of five more 0.2-s vernier thrusts spaced 1 min apart followed by a high vernier thrust. The vernier engines were fired in low thrust at 07:44:59, 07:45:51, 07:47:14, 07:48:18 and 07:49:22 GMT. High thrust was executed at 08:05:12 GMT and still no indication of vernier engine No. 3 firing.

Mission Control directed that at 08:34:00 the following spacecraft operations be performed as the soft landing objectives definitely could not be met:

(1) Dump helium.

(2) Turn on RADVS with battery transfer logic disabled and utilizing the main battery only.

(3) Fire the retro rocket.

Thus helium was dumped at 09:13:16 GMT. At 09:19:57 GMT, RADVS was turned on but Mission Control directed early turnoff at 09:30:09. Complete engineering data was not obtained. The main retro ignition signal was sent (Command 0730) at 09:34:17 GMT. Ignition was verified from telemetry, but the signal and data were lost at 09:35:00 GMT prior to end of burn. The spacecraft was never re-acquired by the DSN. Continuous receiver search for the spacecraft was initiated, but without results. The TDS support for the *Surveyor II* mission was subsequently terminated.

A profile summary of *Surveyor II*, significant events, from launch to mission termination is given in Table 92.

Figure 74 shows the *Surveyor II* mission flight sequence in the direct ascent trajectory.

Table 92. *Surveyor II* mission profile summary

Event	GMT day:h:min:s	Station control and pass number[a]					Time of transfer[b] GMT h:min
		72	61	51	11	42	
Lift off	263:12:31:59.824						
Injection	263:12:43:26.1						

[a]See Table 104 for more detailed information.
[b]Time of DSS transfer is defined herein as two-way lock.

Table 92 (contd)

Event	GMT day:h:min:s	Station control and pass number[a]					Time of transfer[b] GMT h:min
		72	61	51	11	42	
Separation	263:12:44:32.6						
Sun acquisition and solar panel deployed	263:12:50:31						
DSS 72 acquisition	263:12:48:50						
DSS 51 acquisition	263:12:57:10				1		
Initial spacecraft operation completed	263:13:39:24				↓		13:04:58
Engineering interrogation completed							
(Low power — 1100 bits/s)	263:13:41:19						
Bit rate reduction							16:53:38
1100 to 137.5 bits/s	263:16:38:38	1					17:45:01
137.5 to 1100 bits/s	263:18:01:26				1		
Star acquisition	263:19:11:57				↓		
Gyro drift check completed	263:21:35:22						
(Duration — 2h, 09min, 22s)							
Engineering interrogation completed							
(Low power — 1100 bits/s)	263:18:24:35						
Manual lock-on (sun and star)	263:21:39:23						
Bit rate reduction							
1100 to 17.2 bits/s	263:21:47:54				↓		22:01:40
Bit rate increase		1					23:05:00
17.2 to 1100 bits/s	263:23:11:54				1		
Engineering interrogation completed					↓		
(Low power — 1100 bits/s)	263:23:47:46						
Modulation interrupt (4 times)	264:01:23:50						
Engineering interrogation completed							
(Low power — 1100 bits/s)	264:03:05:41						
Gyro check completed	264:03:13:07						
Engineering interrogation completed							
(Low power — 1100 bits/s)	264:04:18:10						
Transmitter B high power on	264:04:36:43						
Bit rate increase (1100 to 4400 bits/s)	264:04:37:36						
Pre-midcourse sun and roll initiated	264:04:44:00						
Pre-midcourse yaw initiated	264:04:48:06						
Midcourse preparation completed	264:04:54:47						
Midcourse thrust execution	264:05:00:02						
Nonstandard sequence							
Rate lock mode on	264:05:03:49						
Inhibit gas jet amperage	264:05:14:29						
Bit rate reduction (1100 to 550 bits/s)	264:05:19:23						
Transmitter B high power off	264:05:23:02						
Bit rate reduction (550 to 137.5 bits/s)	264:05:29:20						
Low power interrogation completed	264:05:48:43				↓		
Transmitter B high power on	264:07:18:28					1	05:51:00
Bit rate increase (137.5 to 1100 bits/s)	264:07:21:08					↓	
Nonstandard vernier test initiated	264:07:22:20						
Bit rate reduction (1100 to 550 bits/s)	264:07:29:53						
Bit rate reduction (550 to 137.5 bits/s)	264:07:34:04						
Transmitter B high power off	264:07:34:47						
Nonstandard interrogation concluded	264:07:58:55						
Interlock flight control power off	264:10:19:43						
Engineering interrogation completed (low power)	264:10:38:23					↓	
Auxiliary battery mode on	264:11:41:09					1	
Engineering interrogation completed						↓	
(Low power — 137.5 bits/s)	264:12:04:28						

Table 92 (contd)

Event	GMT day:h:min:s	Station control and pass number[a]					Time of transfer[b] GMT h:min
		72	61	51	11	42	
Nonstandard sequence completed	264:12:15:00			2			
Engineering interrogation completed (Low power — 137.5 bits/s)	264:13:41:25			↓			
Nonstandard high power interrogation completed	264:15:49:00						15:00:00
Nonstandard vernier test sequence completed	264:19:48:00						
Nonstandard vernier test sequence completed	264:20:08:00						
Nonstandard vernier test sequence completed	264:20:37:00						
Nonstandard vernier test sequence completed	264:20:56:00						
Nonstandard vernier test sequence completed	264:21:16:00			↓			22:05:00
Restore main battery mode	264:22:42:50		2				23:11:44
Transmitter B high power on	264:23:19:58						
Bit rate increase (17.2/137.5 to 4400 bits/s)	264:23:22:17				2		
Nonstandard vernier test initiated	264:23:23:35				↓		
Bit rate reduction (4400 to 1100 bits/s)	264:23:28:08						
Midcourse thrust execution	264:23:33:32						
Bit rate reduction (1100 to 137.5 bits/s)	264:23:40:42						
Transmitter B high power off	264:23:43:31						
Nonstandard vernier test sequence completed	265:01:01:12						
Nonstandard vernier test sequence completed	265:01:06:16						
Nonstandard vernier test sequence completed	265:01:15:11						
Nonstandard vernier test sequence completed	265:01:20:20						
Transmitter B high power on	265:01:21:36						
Bit rate increase (137.5 to 1100 bits/s)	265:01:24:22						
Nonstandard vernier test sequence completed	265:01:29:09						
Bit rate reduction (1100 to 137.5 bits/s)	265:01:29:38						
Engineering interrogation completed	265:01:44:36						
Nonstandard vernier test sequence completed	265:02:01:58						
Nonstandard vernier test sequence completed	265:02:08:40						
Nonstandard vernier test sequence completed	265:02:14:01						
Nonstandard vernier test sequence completed	265:02:20:07						
Nonstandard vernier test sequence completed	265:02:51:10						
Nonstandard vernier test sequence completed	265:03:17:56						
Nonstandard vernier test sequence completed	265:03:24:23						
Nonstandard vernier test sequence completed	265:03:29:36						
Nonstandard vernier test sequence completed	265:03:29:36						
Nonstandard vernier test sequence completed	265:03:35:02						
Nonstandard vernier test sequence completed	265:03:39:31						
Transmitter B high power on	265:03:43:46						
Nonstandard vernier test sequence completed	265:03:51:34						
Nonstandard vernier test sequence completed	265:04:17:56						
Nonstandard vernier test sequence completed	265:04:24:12						
Nonstandard vernier test sequence completed	265:04:30:21						
Nonstandard vernier test sequence completed	265:04:34:38						
Nonstandard vernier test sequence completed	265:05:30:18						
Transmitter B high power on	265:05:32:53						
Nonstandard retro engine test completed	265:05:48:51				↓		
Nonstandard retro sequence initiated	265:06:30:29					2	06:05:00
Solar panel stepping initiated	265:06:45:00					↓	
Retro-eject thrust	265:08:05:00						
Helium dumped	265:09:16:00						
Vernier ignition programmer latch set	265:09:34:27.55						
Retroignition	265:09:34:28:65						
Signal lost	265:09:35:00					↓	

CHARACTERISTIC AC-7
LUNAR INJECTION PARAMETERS

(FOR REFERENCE TRAJECTORY OF FOLLOWING CONDITIONS ONLY, ACTUAL AC-7 CONDITIONS VARIABLE):

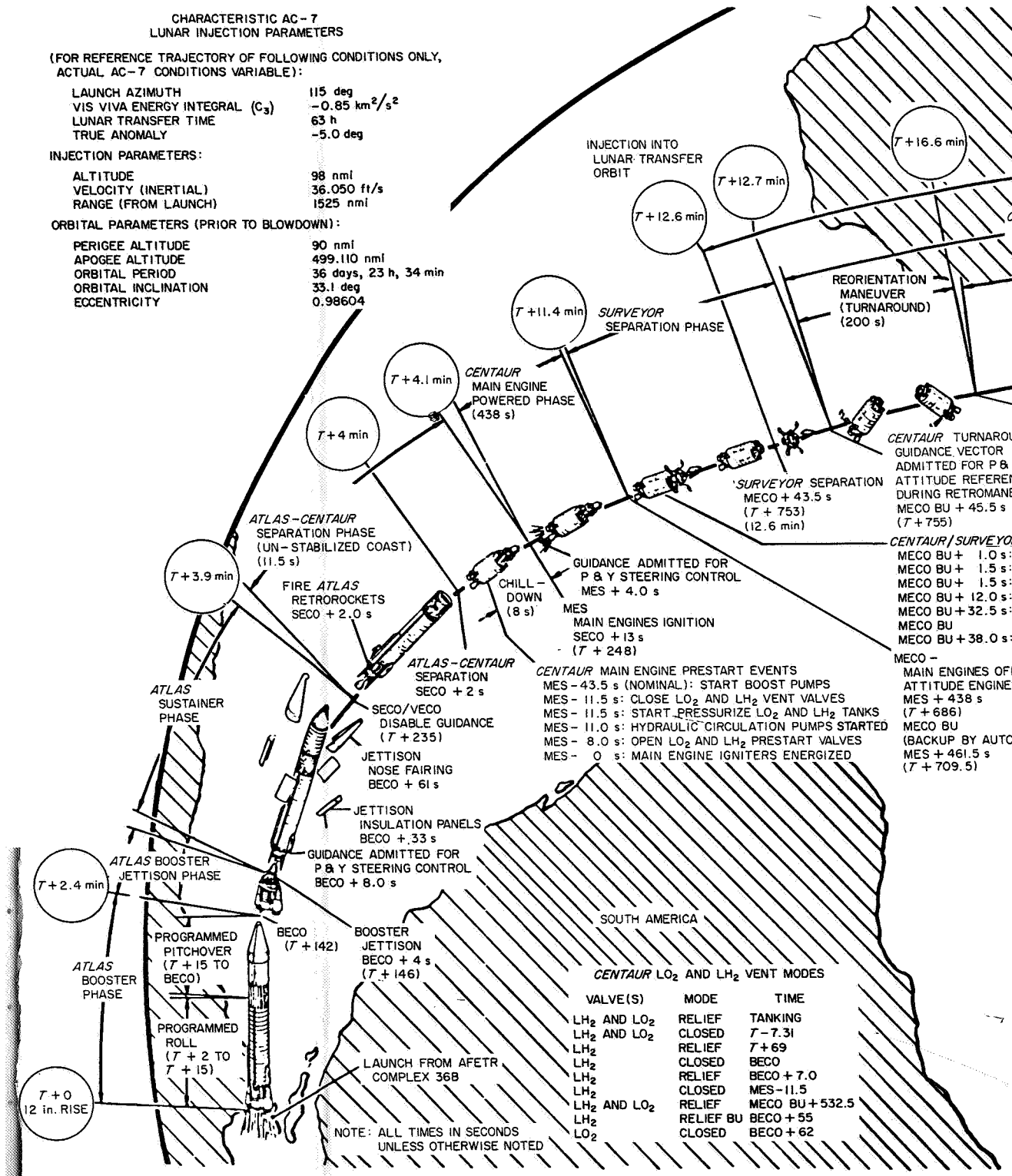
LAUNCH AZIMUTH	115 deg
VIS VIVA ENERGY INTEGRAL (C_3)	-0.85 km^2/s^2
LUNAR TRANSFER TIME	63 h
TRUE ANOMALY	-5.0 deg

INJECTION PARAMETERS:

ALTITUDE	98 nmi
VELOCITY (INERTIAL)	36.050 ft/s
RANGE (FROM LAUNCH)	1525 nmi

ORBITAL PARAMETERS (PRIOR TO BLOWDOWN):

PERIGEE ALTITUDE	90 nmi
APOGEE ALTITUDE	499.110 nmi
ORBITAL PERIOD	36 days, 23 h, 34 min
ORBITAL INCLINATION	33.1 deg
ECCENTRICITY	0.98604



CENTAUR LO_2 AND LH_2 VENT MODES

VALVE(S)	MODE	TIME
LH_2 AND LO_2	RELIEF	TANKING
LH_2 AND LO_2	CLOSED	T − 7.31
LH_2	RELIEF	T + 69
LH_2	CLOSED	BECO
LH_2	RELIEF	BECO + 7.0
LH_2	CLOSED	MES − 11.5
LH_2 AND LO_2	RELIEF	MECO BU + 532.5
LH_2	RELIEF BU	BECO + 55
LO_2	CLOSED	BECO + 62

NOTE: ALL TIMES IN SECONDS UNLESS OTHERWISE NOTED

AC-7 VEHICLE CONFIGURATION

ATLAS 194D

TANK
- STUB "D" WITH CYLINDRICAL FORWARD SECTION,
- SLOSH BAFFLES IN LO_2 TANK

ATLAS-CENTAUR SEPARATION
- EIGHT RETROROCKETS ON FUEL TANK (STA 1130)

MA-5 PROPULSION SYSTEM
- TWO 165K BOOSTER ENGINES,
- ONE 57K SUSTAINER ENGINE,
- TWO 1K VERNIER ENGINES,
- BAFFLED INJECTORS-BOOSTER ENGINES,
- HYPERGOLIC START-ALL ENGINES

PU MANOMETER SYSTEM

PROPELLANT LOADING
- FIVE LO_2 POINT SENSORS,
- FOUR FUEL POINT SENSORS

HYDRAULIC SYSTEM
- BOOSTER SUBSYSTEM,
- SUSTAINER/VERNIER SUBSYSTEM

PNEUMATIC SYSTEM
- EIGHT HELIUM STORAGE BOTTLES
- PROGRAMMED PRESSURIZATION OF LO_2 TANK

FLIGHT CONTROL SYSTEM
- SMRD DISPLACEMENT AND RATE GYROS,
- RATE GYRO PACKAGE MOUNTED AT STATION 600,
- SERVO AMPLIFIER
- PROGRAMMER SIGNALS
  - CYCLE LH_2 VENT VALVES
  - JETTISON *CENTAUR* INSUL PANELS AND NOSE FAIRING
  - PRE-SECO START OF *CENTAUR* BOOST PUMPS,
  - SIMULTANEOUS *ATLAS* SECO/VECO,
  - SEPARATE *ATLAS-CENTAUR*
- SECO SIGNAL CONTROLLED BY EITHER:
  - ENGINE PROPELLANT DEPLETION SWITCH (PRIME)
  - OR GUIDANCE DISCRETE (BACKUP No. 1)
  - OR RP-1 LIQUID LEVEL SENSOR (ALTERNATE PRIME)
- *CENTAUR* GUIDANCE CLOSED-LOOP TO *ATLAS*

ELECTRICAL SYSTEM
- ONE 28-V MAIN VEHICLE BATTERY (MANUALLY ACTIVATED),
- TWO 28-V RSC BATTERIES (MANUALLY ACTIVATED),
- ONE 28-V TLM BATTERY (REMOTELY ACTIVATED)

TELEMETRY-SUBSYSTEM No. 1

ANTENNAS
- TWO DUAL RSC-TLM ANTENNAS,
- RSC RING COUPLER, AND TLM TEE COUPLER

RANGE SAFETY COMMAND SYSTEM
- DUAL RECEIVERS
- TWO POWER SOURCES
- ONE ARMING DEVICE
- ONE DESTRUCT UNIT

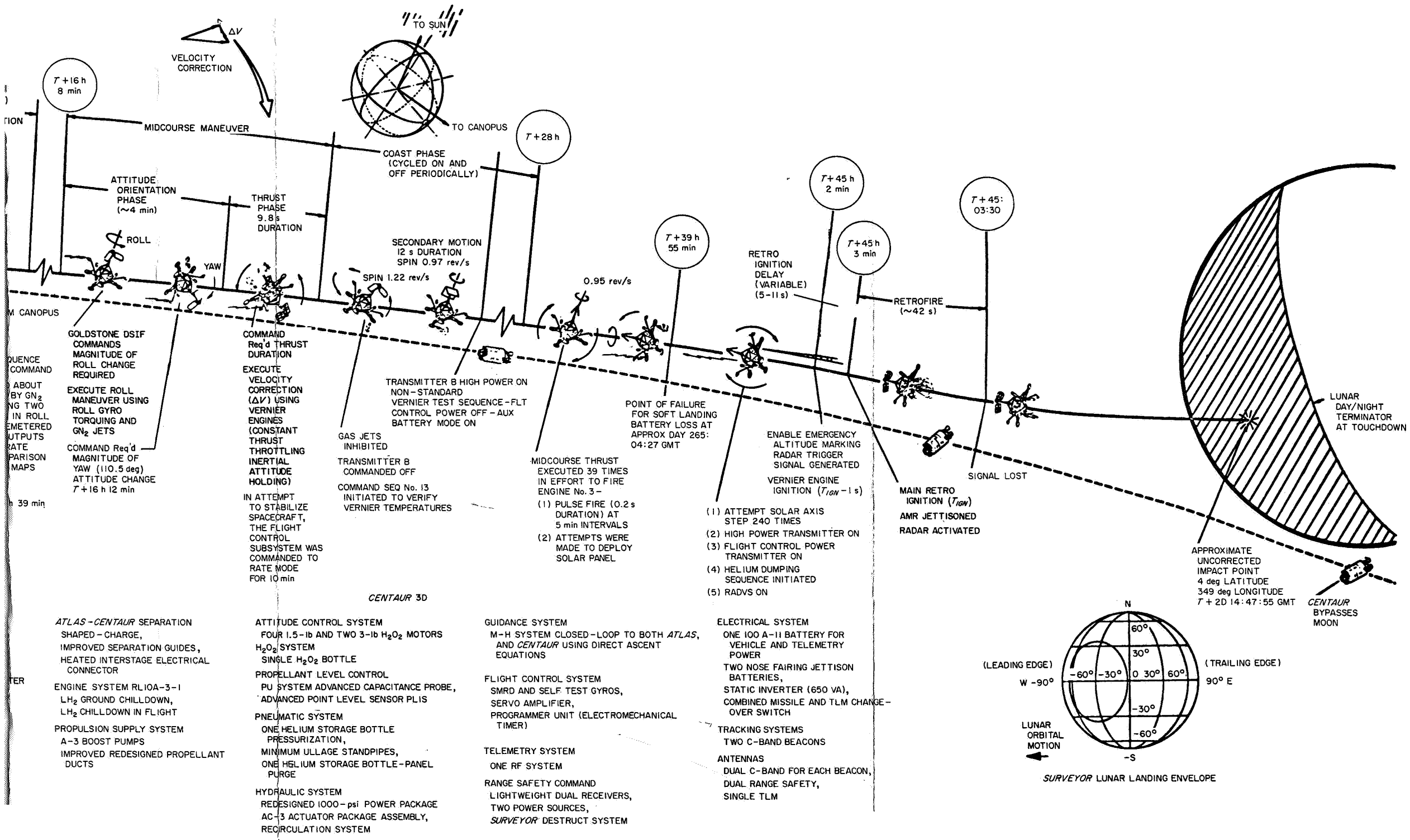
TANK
- 0.014 GUAGE 301 CRES,
- SMALL LO_2 TANK,
- LIGHTWEIGHT THRUST BARREL

FORWARD BULKHEAD AND PAYLOAD ADAPTER
- *SURVEYOR* FORWARD BULKHEAD ARRANGEMENT,
- *SURVEYOR*-TYPE ADAPTER

NOSE FAIRING
- *SURVEYOR*-TYPE JETTISONABLE
- REDESIGNED VENT STACK

INSULATION PANELS-LIGHTWEIGHT JETTISONABLE

INTERSTAGE ADAPTER
- *SURVEYOR*-TYPE



SURVEYOR LUNAR LANDING ENVELOPE

CENTAUR 3D

ATLAS-CENTAUR SEPARATION
- SHAPED-CHARGE,
- IMPROVED SEPARATION GUIDES,
- HEATED INTERSTAGE ELECTRICAL CONNECTOR

ENGINE SYSTEM RL10A-3-1
- LH_2 GROUND CHILLDOWN,
- LH_2 CHILLDOWN IN FLIGHT

PROPULSION SUPPLY SYSTEM
- A-3 BOOST PUMPS
- IMPROVED REDESIGNED PROPELLANT DUCTS

ATTITUDE CONTROL SYSTEM
- FOUR 1.5-lb AND TWO 3-lb H_2O_2 MOTORS

H_2O_2 SYSTEM
- SINGLE H_2O_2 BOTTLE

PROPELLANT LEVEL CONTROL
- PU SYSTEM ADVANCED CAPACITANCE PROBE,
- ADVANCED POINT LEVEL SENSOR PLIS

PNEUMATIC SYSTEM
- ONE HELIUM STORAGE BOTTLE PRESSURIZATION,
- MINIMUM ULLAGE STANDPIPES,
- ONE HELIUM STORAGE BOTTLE-PANEL PURGE

HYDRAULIC SYSTEM
- REDESIGNED 1000-psi POWER PACKAGE
- AC-3 ACTUATOR PACKAGE ASSEMBLY,
- RECIRCULATION SYSTEM

GUIDANCE SYSTEM
- M-H SYSTEM CLOSED-LOOP TO BOTH *ATLAS*, AND *CENTAUR* USING DIRECT ASCENT EQUATIONS

FLIGHT CONTROL SYSTEM
- SMRD AND SELF TEST GYROS,
- SERVO AMPLIFIER,
- PROGRAMMER UNIT (ELECTROMECHANICAL TIMER)

TELEMETRY SYSTEM
- ONE RF SYSTEM

RANGE SAFETY COMMAND
- LIGHTWEIGHT DUAL RECEIVERS,
- TWO POWER SOURCES,
- *SURVEYOR* DESTRUCT SYSTEM

ELECTRICAL SYSTEM
- ONE 100 A-11 BATTERY FOR VEHICLE AND TELEMETRY POWER
- TWO NOSE FAIRING JETTISON BATTERIES,
- STATIC INVERTER (650 VA),
- COMBINED MISSILE AND TLM CHANGE-OVER SWITCH

TRACKING SYSTEMS
- TWO C-BAND BEACONS

ANTENNAS
- DUAL C-BAND FOR EACH BEACON,
- DUAL RANGE SAFETY,
- SINGLE TLM

SURVEYOR SPACECRAFT - II CONFIGURAT

A-21 (ENGINEERING TEST MODEL)

STRUCTURE
- THIN-WALLED TUBULAR TRUSS SPACEFRAME OF 7075-T6 ALUMINUM ALLOY (POLISHED)
- FOLDABLE LANDING LEGS (3), EACH WITH SHOCK ABSORBER AND FOOT PAD
- CRUSHABLE LANDING BLOCKS (3)
- DEPLOYABLE OMNI ANTENNA BOOMS (2)
- ANTENNA/SOLAR PANEL MAST AND POSITIONER
- THERMAL CONTROLLED COMPARTMENTS A AND B

PROPULSION
- MAIN RETROROCKET (SOLID PROPELLANT):
  - 36-in. D SPHERICAL CASE, SEMI-IMBEDDED NOZZLE, JETTISONED AFTER BURNOUT
  - THRUST (FIXED): 8800 lb (MEAN)
  - PROPELLANT (COMPOSITE TYPE): PBAA (FUEL), AMMONIUM PERCHLORATE (OXIDIZER)
- VERNIER SYSTEM (LIQUID PROPELLANT):
  - THREE THRUST CHAMBERS (ONE GIMBALLED, TWO FIXED), RESTARTABLE, THROTTLEABLE
  - THRUST (VARIABLE): 30- TO 104-lb/CHAMBER
  - PROPELLANTS (HYPERGOLIC): MMH HYDRATE (FUEL), N_2O_2/NO (OXIDIZER)
  - SIX PROP. TANKS, POSITIVE EXPULSION BLADDERS
  - ONE HELIUM SUPPLY BOTTLE (1290 $in.^3$)

FLIGHT CONTROL
- INERTIAL REFERENCE UNIT (IRU): RATE GYROS (P, Y, R), LONG, ACCELEROMETER, INERTIA SWITCH
- OPTICAL SENSORS: ACQUISITION, PRIMARY AND SECONDARY SUN SENSORS, CANOPUS STAR SENSOR
- RADAR SENSORS: ALTITUDE MARKER RADAR (AMR), RADAR ALTIMETER AND DOPPLER VELOCITY SENSOR (RADVS) - 4-BEAM
- FLIGHT CONTROL ELECTRONICS: CONTROL CIRCUITS, DIGITAL PROGRAMMER, AC/DC POWER CONVERSION
- GN_2 P, Y, R ATTITUDE JETS, SUPPLY BOTTLE (412 $in.^3$)

ELECTRICAL POWER
- SUPPLY:
  - 3200 W-H, 22-V MAIN BATT (RECHARGEABLE)
  - 900 W-H, 22-V AUX BATT (NON-RECHARGEABLE)
  - 792-CELL, 89-W (NOMINAL) OUTPUT SOLAR PANEL
- POWER MANAGEMENT:
  - CENTRAL POWER CONTROL UNIT
  - AUXILIARY BATTERY CONTROL UNIT*

TELECOMMUNICATIONS (S-BAND)
- REDUNDANT (2) RECEIVER/TRANSPONDERS
- REDUNDANT (2) TRANSMITTERS
- DUAL OMNI-DIRECTIONAL ANTENNAS
- SINGLE DIRECTIONAL HI-GAIN PLANAR ARRAY ANTENNA, EARTH TRACKING

COMMAND
COMMAN
REDUNI DECOI
EIGHT
RECEIV
SIGNAL
CENTR
ENGR S
AUXILI
SIGNAL
LOW R

TELEVIS
TV CAME
VARIAB APER ELEVA INSER

TELEVIS
TV CAM
FIXED ALIGN FRAM

THERMAL
PASSIVE
SUPER MYLA PROP. ELEC
RADIAT ON C
THERM SURFA
ACTIVE
HEATE PROP
THERM COMP

ENGINEER
ADDED
ALL ITE

SCIENTIF
(NONE)

NOTES:
BU =
PU =
RSC =
TLM =

Fig. 74. Survey

3

SURVEYOR SPACECRAFT – II CONFIGURATION

A-21 (ENGINEERING TEST MODEL)

STRUCTURE

- THIN-WALLED TUBULAR TRUSS SPACEFRAME OF 7075-T6 ALUMINUM ALLOY (POLISHED)
- FOLDABLE LANDING LEGS (3), EACH WITH SHOCK ABSORBER AND FOOT PAD
- CRUSHABLE LANDING BLOCKS (3)
- DEPLOYABLE OMNI ANTENNA BOOMS (2)
- ANTENNA/SOLAR PANEL MAST AND POSITIONER
- THERMAL CONTROLLED COMPARTMENTS A AND B

PROPULSION

- MAIN RETROROCKET (SOLID PROPELLANT):
  - 36-in. D SPHERICAL CASE, SEMI-IMBEDDED NOZZLE, JETTISONED AFTER BURNOUT
  - THRUST (FIXED): 8800 lb (MEAN)
  - PROPELLANT (COMPOSITE TYPE): PBAA (FUEL), AMMONIUM PERCHLORATE (OXIDIZER)
- VERNIER SYSTEM (LIQUID PROPELLANT):
  - THREE THRUST CHAMBERS (ONE GIMBALLED, TWO FIXED), RESTARTABLE, THROTTLEABLE
  - THRUST (VARIABLE): 30- TO 104-lb/CHAMBER
  - PROPELLANTS (HYPERGOLIC): MMH HYDRATE (FUEL), N_2O_2/NO (OXIDIZER)
  - SIX PROP. TANKS, POSITIVE EXPULSION BLADDERS
  - ONE HELIUM SUPPLY BOTTLE (1290 $in.^3$)

FLIGHT CONTROL

- INERTIAL REFERENCE UNIT (IRU): RATE GYROS (P, Y, R), LONG, ACCELEROMETER, INERTIA SWITCH
- OPTICAL SENSORS: ACQUISITION, PRIMARY AND SECONDARY SUN SENSORS, CANOPUS STAR SENSOR
- RADAR SENSORS: ALTITUDE MARKER RADAR (AMR), RADAR ALTIMETER AND DOPPLER VELOCITY SENSOR (RADVS)-4-BEAM
- FLIGHT CONTROL ELECTRONICS: CONTROL CIRCUITS, DIGITAL PROGRAMMER, AC/DC POWER CONVERSION
- GN_2 P, Y, R ATTITUDE JETS, SUPPLY BOTTLE (412 $in.^3$)

ELECTRICAL POWER

- SUPPLY:
  - 3200 W-H, 22-V MAIN BATT (RECHARGEABLE)
  - 900 W-H, 22-V AUX BATT (NON-RECHARGEABLE)
  - 792-CELL, 89-W (NOMINAL) OUTPUT SOLAR PANEL
- POWER MANAGEMENT:
  - CENTRAL POWER CONTROL UNIT
  - AUXILIARY BATTERY CONTROL UNIT*

TELECOMMUNICATIONS (S-BAND)

- REDUNDANT (2) RECEIVER/TRANSPONDERS
- REDUNDANT (2) TRANSMITTERS
- DUAL OMNI-DIRECTIONAL ANTENNAS
- SINGLE DIRECTIONAL HI-GAIN PLANAR ARRAY ANTENNA, EARTH TRACKING

COMMAND DECODING AND SIGNAL PROCESSING

- COMMAND DECODING:
  - REDUNDANT (2) CENTRAL COMMAND DECODERS
  - EIGHT SUBSYSTEM DECODERS
  - RECEIVER-DECODER SELECTOR
- SIGNAL PROCESSING:
  - CENTRAL SIGNAL PROCESSOR
  - ENGR SIGNAL PROCESSOR
  - AUXILIARY ENGR SIGNAL PROCESSOR*
  - SIGNAL PROCESSOR AUXILIARY
  - LOW RATE DATA AUXILIARY

TELEVISION

- TV CAMERA No. 3 (POST-LANDING SURVEY):*
  - VARIABLE FOCAL LENGTH, FOCUS, AND APERTURE SETTINGS, AZIMUTH AND ELEVATION SCANNING, COLOR FILTER INSERTIONS, 600 LINES/FRAME
- TELEVISION AUXILIARY UNIT
- TV CAMERA No. 4 (PRE-LANDING APPROACH):
  - FIXED FOCAL LENGTH, FOCUS, AND ALIGNMENT (AFT LOOKING), 600 LINES/FRAME

THERMAL CONTROL

- PASSIVE PROVISIONS:
  - SUPERINSULATION (CRUMPLED ALUMINIZED MYLAR SHEETS) ON MAIN RETRO, SELECTED PROP. TANKS, COMPARTMENTS A AND B ELECTRICAL WIRING
  - RADIATOR SURFACE (VYCOR GLASS MIRRORS) ON COMPARTMENTS A AND B
  - THERMAL ISOLATION MOUNTS, THERMAL PAINT, SURFACE BUFFING, PLATING, ETC.
- ACTIVE PROVISIONS:
  - HEATERS IN COMPARTMENTS A AND B, GYROS, PROP TANKS AND LINES
  - THERMAL SWITCHES: COMPARTMENT A (9) AND COMPARTMENT B (6)

ENGINEERING PAYLOAD (*SURVEYOR* ANALYSIS)

- ADDED ENGINEERING INSTRUMENTATION SENSORS
- ALL ITEMS DESIGNATED WITH *

SCIENTIFIC PAYLOAD (LUNAR EXPLORATION)

- (NONE)

NOTES:

- BU = BACKUP
- PU = PROPELLANT UTILIZATION
- RSC = RANGE SAFETY COMMAND
- TLM = TELEMETRY

Fig. 74. *Surveyor II* mission flight sequence

VIII. *Surveyor II* T & DS Mission Requirements

A. General

In general the T&DS requirements for *Surveyor II* mission were the same as for the *Surveyor I* mission. Only the differences in requirements between the two missions are discussed in their related categories.

All basic objectives remained the same for the *Surveyor II* mission as for the *Surveyor I* mission. (See Section I-G for detailed mission objectives.) However, certain flight objectives peculiar to the *Surveyor II* mission were as follows.

1. Primary objectives. The primary objectives were to:

(1) Accomplish a soft landing on the moon at a site east of the *Surveyor I* landing point.

(2) Demonstrate the capability of the spacecraft to soft land on the moon with an oblique approach angle not greater than approximately 25 deg.

(3) Obtain post-landing television pictures and touchdown dynamics, radar reflectivity, and thermal data of the lunar surface.

2. Secondary objective. The secondary objective was to demonstrate the capability of DSSs 61 and 72 to support future *Surveyor* missions.

B. Air Force Eastern Test Range

The AFETR and MSFN were required to support the *Surveyor II* mission in the near earth phase of flight. The primary purpose for requiring tracking and data acquisition support during the near-earth phase of flight was to obtain early indications that the flight was either nominal or non-standard in order to maximize the probability of DSIF acquisition and to provide information for the conduct of subsequent space flight operations.

There were six major kinds of information needed for determining the standard or non-standard status of the *Surveyor II* flight during the near-earth phase. These six types of information were:

(1) Launch vehicle performance as indicated by the launch vehicle telemetered data which is transmitted to Cape Kennedy in real-time.

(2) The AFETR/RTCS calculations of:

(a) Orbital elements and injection conditions (both post-MECO, preretro and postretro)

(b) DSIF predicts based on the orbits in (a)

(c) Mappings of the orbital elements in (a) to lunar encounter

(3) The real-time reporting of space vehicle *mark* events

(4) Tracking station acquisition times and station reports of any anomalies encountered

(5) Spacecraft performance as indicated by the spacecraft telemetered data which is transmitted to Cape Kennedy in real-time

(6) Spacecraft performance as indicated by the real-time voice reporting of ten spacecraft parameters.

Emphasizing the importance of near-earth tracking is the case of the last two *Atlas/Centaur* flights prior to the *Surveyor II* mission. During the AC-8 flight, it was the RTCS orbital calculations combined with the launch vehicle telemetered data which led to the quick evaluation of the non-standard condition of the flight, and thus enabled the AFETR and DSN stations to quickly reconfigure and acquire the earth-orbiting vehicles. The lack of sufficient near-earth tracking and data acquisition support of *Surveyor I* greatly hindered early evaluation of the status of the flight. Station acquisition times provided the only information regarding the nominal flight until DSS 51 and DSS 72 acquired the spacecraft.

In recognition of the importance of near-earth tracking and data acquisition support, the *Surveyor* Project placed requirements for support by the AFETR and the MSFN. A brief summary of these requirements follows.

1. Class I metric data coverage requirements. Class I metric data coverage requires:

(1) Continuous coverage from launch to *Centaur* MECO plus 30 s

(2) Any continuous 60 s between MECO and *Centaur* retro start

(3) Any continuous 60 s after *Centaur* retro end

2. Class I VHF telemetry data coverage requirements. Class I VHF telemetry data coverage requires:

(1) Continuous coverage from launch to spacecraft separation plus 5 s

(2) Continuous coverage from spacecraft separation −5 s to the end of *Centaur* lateral thrust

3. Class I S-band telemetry data coverage requirements. Class I S-band telemetry requires continuous coverage from spacecraft high-power *ON* to DSIF rise +2 min.

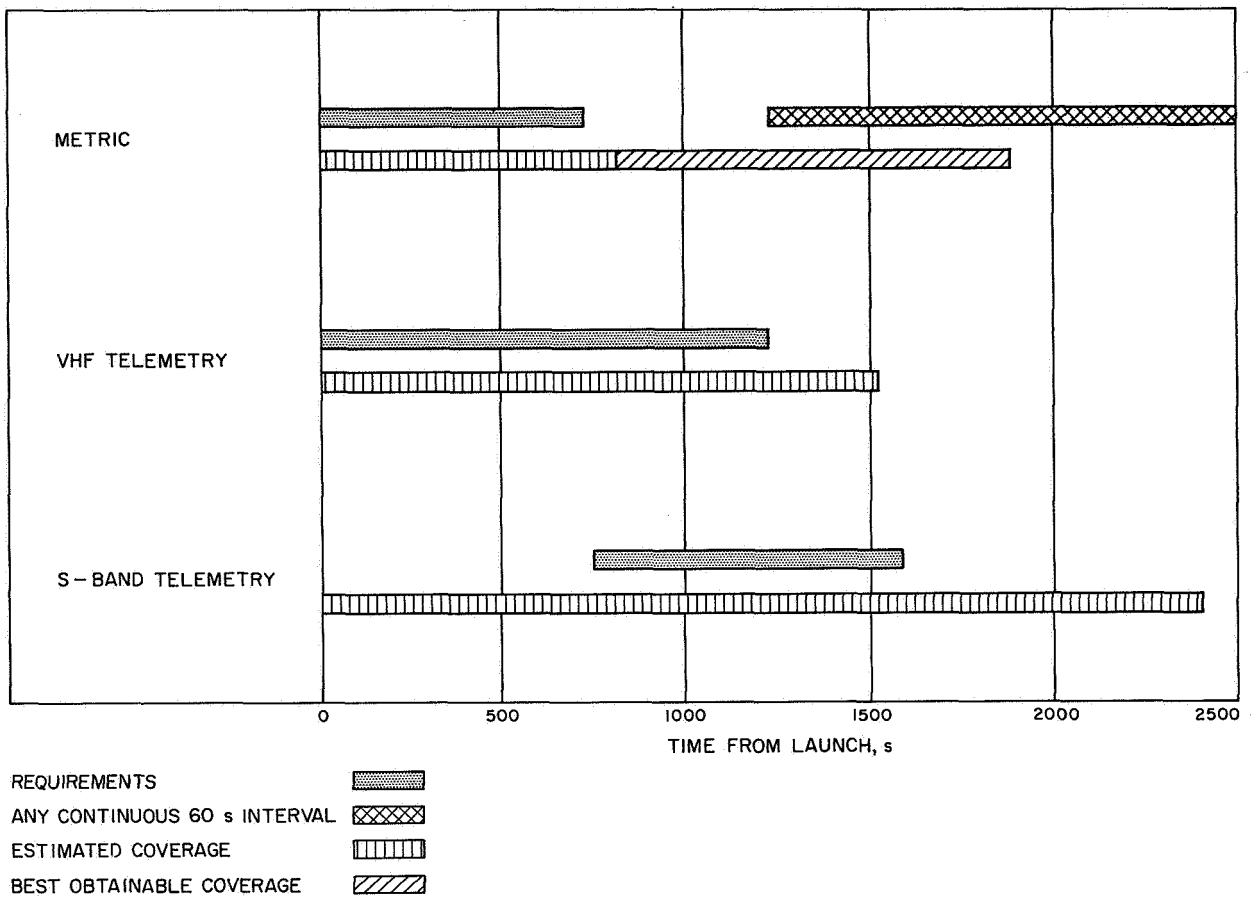


Fig. 75. *Surveyor II* AFETR requirement summary

Further requirements are given below. Figure 75 shows the *Surveyor II* AFETR support requirement coverage.

4. Tracking (metric)

a. Requirements. The metric requirements for the *Surveyor II* mission were the same as those for *Surveyor I*. The AFETR did not anticipate any problems in meeting the class I metric data, except for the requirement for 60 s of continuous track between MECO and start of retro, when the launch vehicle would be in an area downrange from the Antigua station.

The tracking stations which were planned to provide the post-MECO, preretro metric data requirements were Antigua and Trinidad. The Ascension Island and Pretoria tracking stations were planned to provide the postretro metric data requirements. The RTCS was planned to provide the orbital calculations which were required. (See Section IX-A-1 for further station details.)

b. RIS. Additional range instrumentation ships were to be strategically located to support the requirement of providing metric data for 60 s between MECO and start of retroignition. The result of not providing for this requirement was quite severe, as it reduced the launch window considerably. The AFETR was unable to produce adequate RIS support to meet this requirement.

5. VHF telemetry. The class I requirements for VHF telemetry for the *Surveyor II* mission were the same as those for the *Surveyor I* mission, except that the class I VHF coverage interval for the *Centaur* link had been relaxed. It had previously required VHF coverage from $T - 5$ min to the end of the *Centaur* retro maneuver, that is, continuous coverage from before liftoff until well into the Ascension view period. This requirement had been relaxed and was from $T - 5$ min to completion of lateral thrust, which takes place at approximately 818 s, on the average.

The AFETR was required to meet the class I VHF telemetry requirement on the following basis. VHF telemetry was to be obtained from the launch area, from Grand Bahama Island, Antigua Island, Ascension Island,

Trinidad, Pretoria, and two telemetry ships, the *Sword Knot* and the *Coastal Crusader.* The two telemetry ships were to be located to give prime emphasis to the S-band separation area, and would not be positioned under the same ground rules that were used for the *Surveyor I* mission, in which tradeoffs were made between class I S-band and class I VHF coverages. The VHF coverage required by the two telemetry ships was to be greater than that committed on the *Surveyor I* mission since LeRC had indicated that they could accept a lower signal-to-noise level on the tapes. The AFETR normally commits FM-FM telemetry tapes with a signal-to-noise ratio of 15 dB unless the range user allows them to use a lower ratio. However, LeRC stated that a 12-dB signal-to-noise ratio provided usable data. The additional 3 dB would increase the slant range by approximately the square root of 2. This, coupled with the relaxed coverage interval was to aid the AFETR in meeting the class I requirements.

6. S-band. The requirements for the *Surveyor II* mission S-band telemetry reception were identical to those for the *Surveyor I* mission. (See Section III-B-3 for details.)

The AFETR was to provide support from the Cape area, Grand Bahama Island, Antigua, Trinidad, the telemetry ships *Coastal Crusader* and *Sword Knot*, Ascension Island, and Pretoria. The ships were to be positioned in such a manner as to provide redundant coverage with Antigua during the critical separation and injection phases of flight.

One ship had not completed its acceptance testing. However, it had supported the previous *Surveyor* launch, as well as other S-band activities, and was expected to complete its testing prior to the *Surveyor II* mission. The 30-ft TAA-3 antennas at Antigua and Ascension Island were still on an engineering test basis. They had provided data for the *Surveyor I* mission, as well as *Lunar Orbiter* and *Pioneer.* In addition, a backup capability existed at both Antigua and Ascension, in the form of small 3-ft broadband antennas. The only problem area that existed was that the *Sword Knot* had an oscillation problem in its antenna servo system. It was headed toward port, and was expected to be repaired and back on station in time to support the *Surveyor II* mission.

7. Computer requirements. The requirements on the RTCS were identical with the requirements for *Surveyor I* mission, with the addition of processing the DSIF data. That is, a requirement existed for providing DSIF data to the AFETR RTCS to be incorporated with their data in meeting the requirements for certain orbits, mapping to lunar encounter, miss parameters, etc. However, the processing of this DSIF data was to be on an engineering test basis only. The AFETR processed DSIF data previously on an engineering test basis for *Lunar Orbiter.*

The RTCS was committed to providing the support requested for the *Surveyor II* mission.

8. Communications—real-time data delivery requirements

a. Metric data. The real-time data delivery requirements for the *Surveyor II* mission were identical with the requirements that existed for the *Surveyor I* mission. As stated previously, the metric data was to be derived from radars in the Cape area, Grand Bahama Island, Grand Turk, Antigua, Trinidad, Ascension Island, and Pretoria. High-density data was to be brought up the subcable from the up-range radars through Antigua and sent to the RTCS for orbital computation and range safety predicts. One change in data source from the *Surveyor I* mission was that low-density data from Antigua would be supplied directly to building AO. Previously, all the data was brought up at high density, and went to the Mission Control Center where it was held in abeyance. Nevertheless, one point every 6 s was selected and forwarded to building AO. During the *Surveyor II* mission, this low-density data would come directly from the site and not pass through the MCC.

b. VHF telemetry data. The requirements for real-time VHF telemetry data were identical with the requirements levied on the AFETR for the *Surveyor I* mission.

The real time VHF telemetry data were to be received by antenna in the Cape area, Grand Bahama Island, and Antigua Island. Pretoria did not have the capability to retransmit the complete VHF data link in real time but was to retransmit spacecraft data on a VHF link. However, the class I requirement interval extended only through the Antigua view.

c. S-band data requirements. The requirement for the reception and real-time retransmission of spacecraft S-band data was identical with the requirement for the *Surveyor I* mission.

The data sources for this S-band data were to be the antennas in the Cape area, Grand Bahama Island, Antigua, Ascension Island, and the telemetry ships *Coastal Crusader* and *Sword Knot.*

When the spacecraft switched to high-power *on*, the data source would either be Antigua Island, the telemetry

ships, or Ascension Island. These data were to be transmitted via HF from the ships or Antigua Island either directly to the Cape, if propagation conditions permitted, or to Antigua Island, where it was to be relayed uprange via sub-cable to Tel-2. At Tel-2, it would be transmitted to building AO for processing and/or transmission back to SFOF.

C. Goddard Space Flight Center

The GSFC/MSFN T&DS requirements for the *Surveyor II* mission were essentially the same as those enjoined by the *Surveyor I* mission.

1. Tracking (metric). MSFN Support was planned in accordance with the Support Instrumentation Requirements Document (SIRD) received at the GSFC which established requirements for the support of *Surveyor* missions. The requirements for range safety support were documented by letter from the Range Safety Branch through the Goddard Network Support Office. The requirements for metric support were the same as requested for the *Surveyor I* mission. Essentially, this was C-band radar track from Bermuda, Grand Canary, and Carnarvon.

The only site that was committed to support the *Surveyor II* mission was Bermuda. Carnarvon was not committed because the radar was down for overhaul during the month of September 1966. Grand Canary was not committed for two reasons: (1) the GSFC could not reformat the radar data because of commitments to other programs, and (2) the phasing modification necessary to make this radar compatible with other tracking radars was not scheduled.

2. VHF telemetry. The MSFN was to receive, record, and perform real-time readout of *mark* events during the view periods of the following stations: Bermuda, Grand Canary, Kano, and Tananarive.

Bermuda, Grand Canary, Kano, and Tananarive were to provide telemetry coverage on certain days at certain launch azimuths, as shown in Table 93 and Fig. 76. The MSFN was also to provide backup AFETR safety support by displaying certain parameters at Bermuda of the *Atlas* telemetry link.

3. Computer requirements. The computers at Goddard were to receive real time tracking data from the AFETR. These data would be used to generate acquisition messages for Grand Canary and Kano. However, due to the early rise time, the message might not arrive prior to acquisition. The Bermuda radar was to send high-speed and low-speed radar data to the RTCS at the AFETR. The RTCS then was to generate pointing data for Grand Canary and Kano telemetry sites in real time.

D. Deep Space Network

The DSN had requirements to meet in performing T&DA functions for the *Surveyor II* mission. Various changes, from the *Surveyor I* mission, in DSN T&DS requirements are enumerated below.

1. Deep space instrumentation facility. At least three prime DSIF stations were required to support the *Surveyor II* mission. These were located approximately 180 deg apart girdling the earth. The prime stations committed (see Section IX-A-3-a) were to perform T&DA functions and supply numerous data, as described below.[13]

a. Tracking. Tracking data, consisting of antenna pointing angles and doppler (radial velocity) data, was to be supplied in near real-time via TTY to the SFOF and post-flight in the form of punched paper tape. Two-way and three-way doppler data were required full time during the lunar flight, and also during lunar operations at Project request. The two-way doppler requirement implied a similar requirement for transmit capability at the prime stations.

b. Telemetry. Spacecraft telemetry data were to be received and recorded on magnetic tape. Baseband telemetry data were to be supplied to the mission-dependent command and data handling console for decommutation and real time readout. The DSIF also was to perform pre-communication processing of the decommutated data, using an on-site data processing computer. The data were then to be transmitted to the SFOF in near real-time, using high-speed data modems.

c. Commands. Command transmission was another function required of the DSIF. The transmission of approximately 250 commands to the spacecraft was required during the nominal sequence from launch to touchdown. This command requirement placed a second critical requirement for two-way communication with the spacecraft. Confirmation of the commands sent was to be processed by the OSDP computer and transmitted by TTY to the SFOF. The OSDP computer was also to be used to verify command tapes punched on-site from TTY instructions received from the SFOF.

[13]For tracking data accuracy requirements see Table 8.

Table 93. MSFN estimated telemetry coverage for September 20, 1966

Launch azimuth	AOS		Decommutator lock		Decommutator unlock		LOS		Valid data
	GET[a]	Azimuth, deg	GET[a]	Azimuth, deg	GET[a]	Azimuth, deg	GET[a]	Azimuth, deg	
Grand Canary									
84	15:20	247	15:30	241	22:50	136	22:50	136	07:20
87	15:00	246	15:20	240	22:20	143	22:20	143	07:00
90	15:00	241	15:10	241	22:00	151	22:00	151	06:50
93	14:40	242	15:00	237	21:30	162	21:30	162	06:30
96	14:40	240	15:00	236	21:00	170	21:00	170	06:00
99	15:00	235	15:10	232	20:40	177	20:40	177	05:30
102	15:00	234	15:30	228	20:00	185	20:00	185	04:30
105	15:20	230	15:50	224	19:10	193	19:10	193	03:20
108	16:00	223	16:20	219	18:10	202	18:10	202	02:50
111									
114									
Kano									
84	18:20	281	18:30	279	28:10	146	28:10	146	09:10
87	18:00	278	18:10	277	27:40	158	27:40	158	09:30
90	18:00	273	18:00	273	27:00	175	27:00	175	09:00
93	17:40	270	17:50	269	25:40	201	25:40	201	07:40
96	17:40	268	18:00	265	24:20	218	24:20	218	06:20
99	19:20	256	19:20	256	22:40	232	22:40	232	03:20
102									
105									
108									
111									
114									

[a]Ground elapsed time.

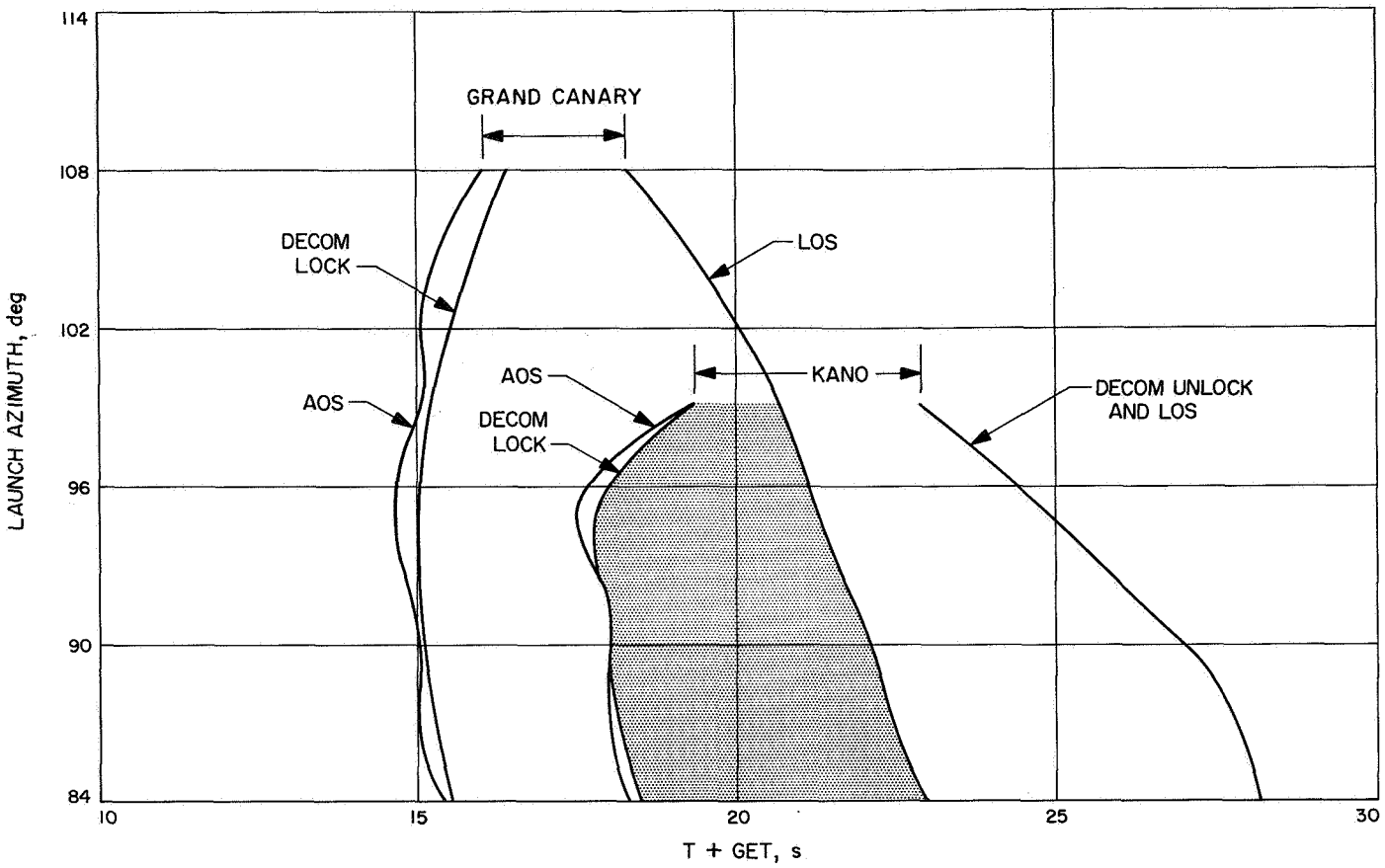


Fig. 76. MSFN estimated telemetry coverage for September 20, 1966

d. Video. Video data were to be received and recorded on magnetic tape. These data were to be sent to the CDC, and, at DSS 11 only, to the TVGDHS for photographic recording. In addition, video data from DSS 11 was to be sent in real time to the SFOF for magnetic and photographic recording by the TVGDHS.

e. Additional requirements. In addition to the above technical support, the DSIF had requirements to provide the following:

(1) Facilities support for mission-dependent equipment, including space for CDCs at all prime stations and for the TVGDHS at Pioneer (DSS 11).

(2) Maintenance and operation of all mission-independent equipment.

(3) Maintenance and operation of some mission-dependent equipment by negotiation with the *Surveyor* Project. For example, DSIF operators were trained for maintenance and operation of the CDC. A similar agreement was to be negotiated for the TVGDHS at DSS 11.

(4) Logistic and spares support for mission-dependent equipment.

(5) At lunar landing, two receivers were to be used for different functions. One was to provide a signal to the CDC, the other to the TVGDHS. Signals for the latter system were a prime Project requirement at that stage of the mission. This mode of operation increased the requirements for receiver reliability at Pioneer station.

2. Ground Communications Facility/NASCOM. The GCF transmitted tracking, telemetry, and command data from the DSIF to the SFOF, and control and command functions to the various T&DS stations. It also transmitted simulated tracking data to all stations during tests. The GCF was also required to transmit video data and baseband telemetry from Goldstone Pioneer (DSS 11) to the SFOF.

The types and number of lines required were:

(1) Voice: one line, to be shared between the DSIF and the Project for administrative and control functions.

(2) Teletype: four lines to all prime sites for tracking data, telemetry, commands, and administrative traffic.

(3) High-speed data: one line from each site to the SFOF for telemetry data transmission in real time.

(4) Wideband microwave to DSS 11: two 6-MHz lines for video to the SFOF, and one duplex 96-kHz line.

For the *Surveyor II* mission, DSS 72 was required to have a full complement of communications links, including an HSDL capable of transmitting up to 1200 bits per second. The NASCOM system of high-speed data modems (modulator-demodulator) had been implemented at DSS 11, 42, 61, 71, and 72 for transmission of *Surveyor* data to the SFOF.

Additional circuits between the SFOF and Cape Kennedy were required because DSS 71 was to be utilized for the *Surveyor II* mission. A special additional voice line was to connect the Mission Director, located at building AO at Cape Kennedy, and the Assistant Mission Director, located in the SFOF.

The NASCOM circuits were required to be available to support *Surveyor II* as follows:

(1) Circuit requirements for *Surveyor* operational readiness test (ORT) C-5.0, phase I, from September 12, 23:00 GMT, to September 14, 06:30 GMT:

Station	Circuits	Activation times
AFETR (AO)	2 voice, 1 HSDL	12/05:51 to 13/14:11
	1 voice, 3 TTY	13/01:31 to 13/14:11
DSS 51	1 voice, 4 TTY, 1 HSDL	13/04:11 to 13/23:41
DSS 42	1 voice, 4 TTY, 1 HSDL	13/09:26 to 14/06:30
DSS 72	1 voice, 4 TTY, 1 HSDL	13/09:26 to 14/06:30

(2) Circuit requirements for *Surveyor* ORT C-5.0, phase II, final, from September 15 to 16, GMT:

Station	Circuits	Activation time
DSS 42	1 voice, 4 TTY, 1 HSDL	15/17:51 to 16/08:35

(3) Circuit requirements for DSS 71, which was scheduled for launch operations only:

Circuits	Approximate time
1 voice, 2 TTY, 1 HSDL	*L* minus 4 h to *L* plus 1 h

(4) Special NASCOM coverage was required for mission events at the following approximate times:

Launch	*L* minus 4 h to *L* plus 8 h
Midcourse	*L* plus 11 h to *L* plus 18 h, 30 min
Lunar touchdown	*L* plus 57 h to *L* plus 65 h

(5) The AFETR status voice net was requested to be bridged to one or more of the DSSs and interested officials.

(6) Special radio propagation forecasts were requested on all communication paths to those stations scheduled to track during critical mission periods. Normal radio propagation forecasts were to suffice during the cruise periods. Distribution was to be identical to that for the *Surveyor I* mission.

(7) Postlaunch communications requirements were to be forwarded to NASCOM as soon as possible after normal liftoff.

3. *DSN/SFOF.*

a. Communications. Some changes were required in the DSN Intracommunications System (ICS) to meet support requirements for the *Surveyor II* mission. The major elements of the ICS are the OVCS, CCTV, and internal teletype distribution throughout the SFOF. Changes in the CCTV were required because of area reconfigurations, and a number of minor last-minute changes were made on the OVCS buttons. All changes were completed before launch. Communications support requirements for *Surveyor II* included operation of display devices, data distribution in the SFOF, supervision of access control, and facility housekeeping functions.

The SFOF/Goldstone DSCC microwave system had to be reworked, primarily in the video area. There had been operational patching problems on all lines, but these were corrected.

b. Displays. The requirements for displays for the *Surveyor II* mission were the same as for *Surveyor I.*

c. Data processing. A significant operational change that was accomplished after the *Surveyor I* mission was the increase in the number of high-speed data circuits between the Communications Center and the TPS from 6 to 17. This increase, in addition to expanded TPS switching capability, very definitely increased the overall operational efficiency of the TPS. All elements of the TPS configuration for *Surveyor* were checked out and considered to be in a state of operational readiness to support *Surveyor II.*

The following functions were required to be performed by the data processing equipment in the SFOF:

(1) Computation of acquisition predictions for the DSIF in the form of antenna-pointing angles and receiver and transmitter frequencies.

(2) Orbit determination.

(3) Midcourse maneuver computation and analysis.

(4) On-line telemetry processing.

(5) Command tape generation.

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

d. Facilities. Space was required in both mission-dependent and mission-independent areas. Mission Control Room No. 1 and Mission Support Area No. 1, which included the Spacecraft Performance Analysis Area and the Space Science Analysis Area, were devoted exclusively to *Surveyor* support. Flight Path Analysis Area No. 1 was a shared area, but was devoted exclusively to *Surveyor* during flight operations. Common user areas supporting *Surveyor* include DSIF Net Control, the data processing area, and the Communications Center. Figure 77 diagrams the general data flow within the SFOF.

IX. *Surveyor II* T&DS Flight Preparation

Tracking and data acquisition is an essential part of any space flight activity. The following pages summarize the tracking and data system preparation for the *Surveyor II* flight.

A. Configuration

1. Air Force Eastern Test Range. The AFETR was configured in such a way as to provide supporting functions to the near-earth phase of the *Surveyor II* mission. Table 94 shows the AFETR prelaunch configuration.

The radars that were planned for commitment to the support of the *Surveyor II* mission were those at the Cape area: 1.18 at Cape Kennedy, 19.18 on Merritt Island, and 0.16 Patrick Air Force Base; and 3.18 (later changed to radar 3.16) on Grand Bahama Island, 7.18 on Grand Turk, 40.43 on Trinidad, 91.18 on Antigua Island, 12.18 on Ascension Island, and 13.16 at Pretoria. In addition to these prime radars, backup support was planned at Grand Bahama Island and Ascension Island.

The key facilities for meeting the three types of data requirements are examined in this section and their coverage capabilities discussed. Key locations are

(1) Antigua: The AFETR station at Antigua had one FPQ-6 radar capable of tracking the *Centaur* C-band transponder. Antigua station rise occurred during the powered phase of the flight.

(2) Trinidad: The AFETR station at Trinidad had an FPS-41 radar capable of skin-tracking objects at 427 MHz. Since Trinidad is about 400 nmi due south of Antigua its rise also occurred before main-engine cutoff on those azimuths for which it had any view.

(3) Ascension Island and Pretoria: The AFETR stations at Ascension Island and Pretoria were to be used to meet the class I requirement for 60 s of continuous data after the *Centaur* retroignition maneuver. At Ascension there were two C-band radars, an FPS-16 and a TPQ-18 (a transportable version of the FPQ-6). Pretoria had an MPS-25 C-band radar, which was a trailer-mounted version of the FPS-16.

(4) RIS *Sword Knot,* RIS *Coastal Crusader*: The range instrumentation ships *Sword Knot* and *Coastal*

Table 94. AFETR prelaunch configuration, *Surveyor II*

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

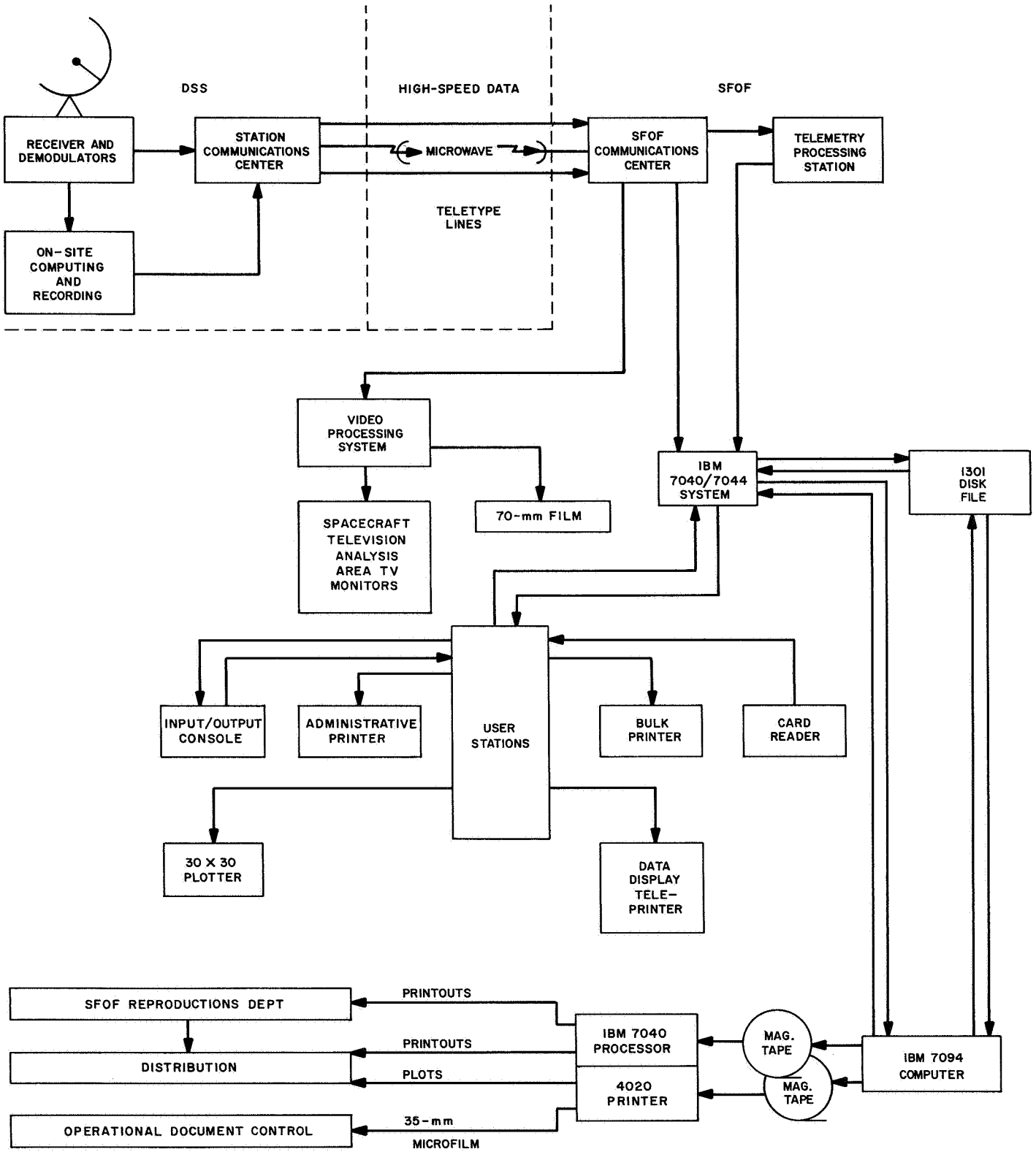


Fig. 77. Generalized data flow, *Surveyor II* space flight operations

Crusader each have two telemetry antennas. The TAA-1 antenna of the *Sword Knot* and the TAA-1B antenna of the *Coastal Crusader* were to be used for VHF telemetry coverage. Without going into an azimuth-by-azimuth and a day-by-day listing, it can be stated that the planned positions of these ships arranged for their view periods to begin approximately at main engine cutoff and continue past the Ascension station rise. The *Twin Falls* was not committed to support the *Surveyor II* mission as it was not in a state of readiness. Figure 78 shows the preliminary instrumentation coverage commitment for the *Surveyor II* mission support.

a. Tracking. The AFETR tracks the C-band beacon of the *Centaur* stage to provide metric data required during intervals of time before and after spacecraft separation. These data are then used to provide DSN inflight predict information.

The lack of metric ship support precluded the AFETR from meeting the class I requirements for most of the launch period and over the launch azimuths required by the *Surveyor* Project for the September launch opportunity.

The primary purpose for requiring tracking and data acquisition support during the near-earth phase of a flight is to obtain early indications that the flight is either nominal or nonstandard in order to maximize the probability of DSIF acquisition and to provide information for the conduct of subsequent space flight operations.

Table 95 gives a summary of the AFETR instrumentation support for *Surveyor II* mission.

b. VHF telemetry. Nine AFETR stations and three MSFN stations were to provide VHF telemetry support for Mission II. Five of these stations: Tel-2 (Cape Kennedy), Grand Bahama Island, Eleuthera Island, Grand Turk, and Bermuda were expected to provide uprange support from launch to *Centaur* main engine cutoff. Since the key interval for telemetry coverage extends from main engine cutoff to the end of *Centaur* lateral thrust, only the remaining stations are discussed here.

Antigua. Antigua had two telemetry antennas, a TLM-18 and a TAA-3A. The TLM-18 antenna was expected to provide *Centaur* VHF telemetry coverage. It was considered possible to receive good VHF telemetry data down to a 0 deg elevation angle. Consequently the TLM-18 view periods were expected to exceed commitments.

Antigua was the last downrange station which could retransmit VHF telemetry data in real time. Since Antigua was the only station viewing main engine cutoff (on some azimuths) having this real-time retransmission capability, it was the only station which could provide guidance telemetry data for use in the RTCS orbital calculations. Consequently, a postlaunch failure of the Antigua VHF telemetry transmission system, together with a loss of Antigua radar track, would have meant that no pre-retrofire orbital calculations could be made after main engine cutoff. Such a dual failure did occur during Mission I.

In addition to the important role Antigua had in providing telemetry support after main engine cutoff, it also had an important role during the period before main engine cutoff. After the Grand Bahama Island station had set, Antigua was the only station viewing the last part of the *Centaur* powered flight.

Ascension and Pretoria. The AFETR stations at Ascension and Pretoria each possessed a TLM-18 antenna for VHF telemetry coverage. The Ascension station rise occurred after the start of the *Centaur* retrofire maneuver. Pretoria rise will occur within 5–6 min of Ascension rise. Both Ascension and Pretoria set times occurred long after DSIF acquisition whether initial acquisition was by DSS 72 or DSS 51. Consequently, these stations were to provide very good coverage of the *Centaur* retrofire maneuver.

c. S-band telemetry. Seven AFETR stations were to provide S-band telemetry support for the *Surveyor II* mission: Tel-2 (Cape Kennedy), Grand Bahama Island, Antigua, Ascension, Pretoria, *Sword Knot,* and *Coastal Crusader.*

The Tel-2 station had a 3-ft S-band antenna, Grand Bahama was to use the right-hand polarization of its TAA-2 antenna, Antigua used a TAA-3A antenna, Ascension also had a TAA-3A antenna and a 3-ft S-band parabola mounted on its TLM-18 antenna, Pretoria had a 3-ft S-band parabola mounted on its log periodic antenna, and both the *Sword Knot* and *Coastal Crusader* had 24-ft TAA5-24 antennas, for the *Surveyor II* mission.

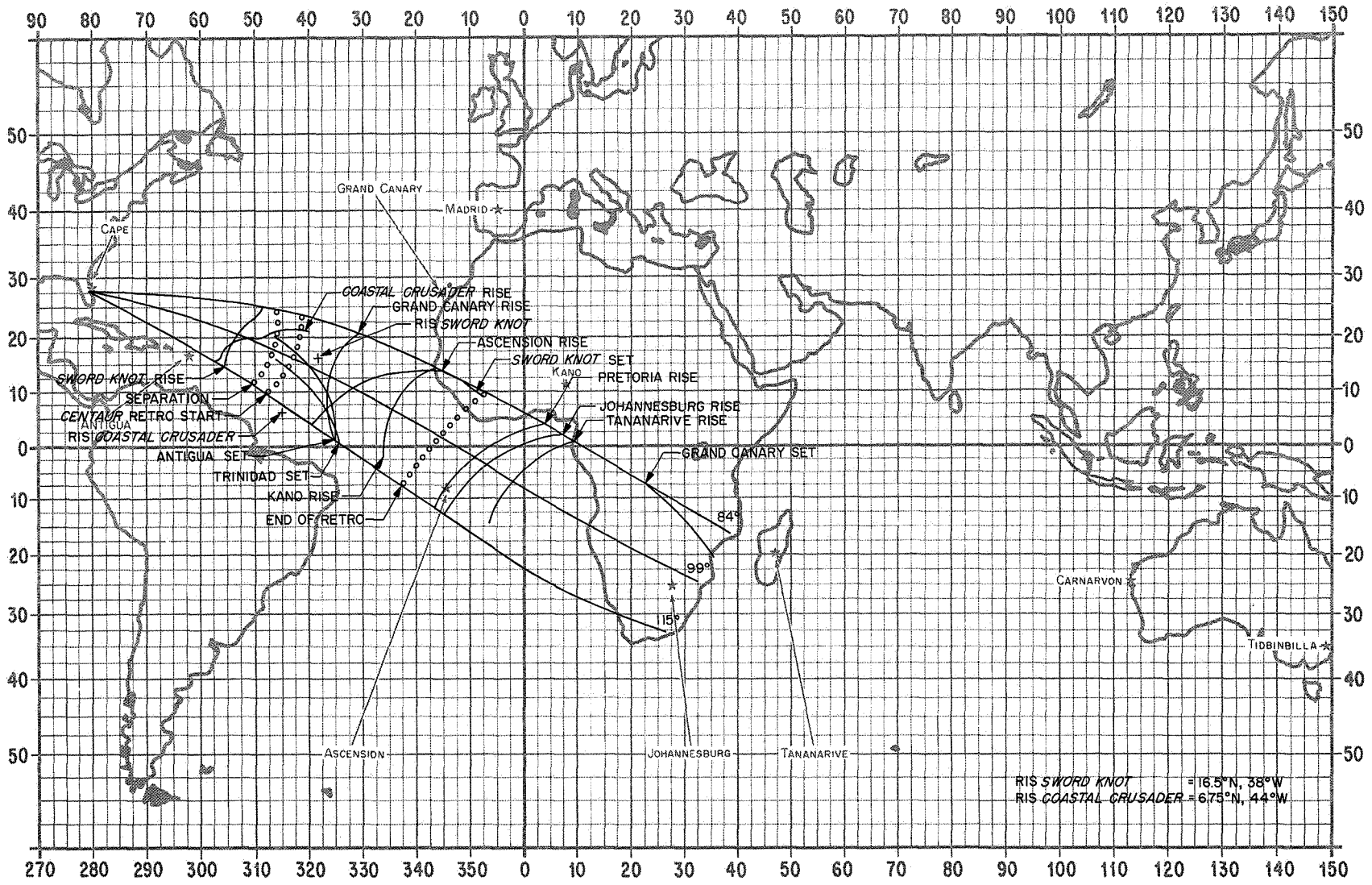


Fig. 78. Preliminary instrumentation coverage, *Surveyor II*

Table 95. Summary of AFETR instrumentation support, *Surveyor II*

Summary of range instrumentation[a]		Cape Kennedy AFS	Patrick AFB	Merritt Island	Grand Bahama Island	Eleuthera Island	Grand Turk	Antigua Island	Atlantic Ocean area	Ascension Island	Pretoria	Bermuda	RIS	Trinidad
Radar pulse and continuous wave														
S-band pulse		1												
X-band pulse		2												
L-band pulse														1
C-band pulse		1	1	1	2		1	1		2	1	1	1	
AZUSA[b]														
MISTRAM[b]														
UDOP[b]														
Telemetry														
	Tel 2	Tel 3												
Antennas	3				2	2	2	2		3	2		2	
Receivers	11				8	4	4	9		6-8	5		2	
Combiners	2				2			1		1	1			
S/S—CF recorders	4				2	1	1	3		2-3				
Tape recorders	6				2	1	1	2		3	2		2	
Oscillographs	1-25							2		2	0-1		2-3	
DW recorders	1-40										4		4	
TDM decommutator	1							2-3		2	1		1	
Other support														
MILS									X	X				
FCA		X												
Communications														
Radio, point-to-point		X						X		X				
Radio, air-to-ground		X												
Subcable		X			X		X	X						
Timing		X	X	X	X	X	X	X		X	X		X	X
Range safety														
Command/control		X			X		X	X						
Supervisory/control														
ASCO														

Type	No.	Type	No.	Type	No.
Impact prediction computer	1	Wire screen	1	Plotting Board	10
Tel ELSSE	3	TV skyscreen	3		
Optics					
16 mm cine	26	70 mm sequence	4	Cinetheodolite	4
35 mm cine	7	IGOR	3	Ribbon frame camera	6
16 mm H/S		ROTI	3	Ballistic camera	
35 mm H/S					
Aircraft					
STARS (as required)					

[a]See *Glossary* for explanation of abbreviations.

[b]Trajectory measuring systems.

d. Real-Time Computer System. The RTCS had the capability, providing the data was available, of

(1) Computing an interrange vector (IRV) for use by the downrange stations (including DSS 72) to generate their own acquisition information.

(2) Computing orbital elements and injection conditions (both single-station and multi-station solutions).

(3) Computing an I-matrix of associated statistics for the above orbits.

(4) Computing predicts for the Deep Space Stations.

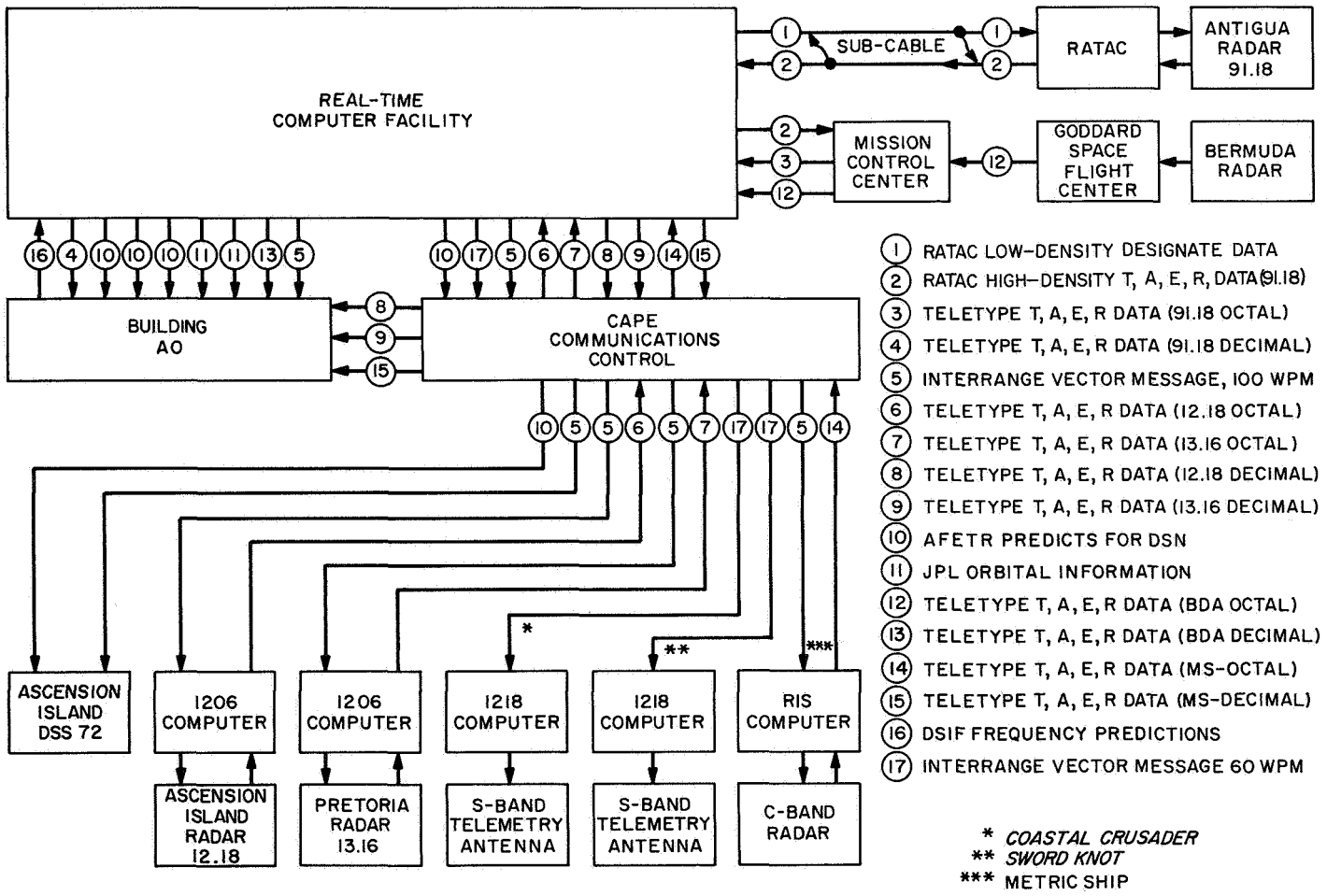
(5) Mapping to lunar encounter.

(6) Performing orbital calculations using DSIF data.

All of these capabilities were intended to be exercised on the *Surveyor II* mission. However, the lunar mapping and processing of DSIF data capabilities were to be on an engineering basis.

These capabilities of the RTCS would allow for an early evaluation of the state of the mission to be made. These capabilities were not to be used to plot a precise landing place on the moon. For that purpose considerable effort and expense have been undergone to develop the mission operation system and SFOF capabilities. However, it cannot be overemphasized that the capabilities of the RTCS were to significantly aid in the early evaluation of the mission, which in turn would provide an important input to the conduct of the space flight operations.

Figure 79 shows the real-time data flow of the RTCS configuration for the *Surveyor II* mission.



RATAC: RADAR TRAJECTORY ACQUISITION

Fig. 79. RTCS configuration for real-time data flow, *Surveyor II*

2. Goddard Space Flight Center. The MSFN was configured to support the *Surveyor II* mission by performing the following functions:

(1) Tracking the *Centaur* beacon (C-band) for approximately 3.5 h.

(2) Receiving and recording telemetry, linked to *Centaur*, from acquisition at Bermuda to loss of signal at Kano, Nigeria.

(3) Providing real-time confirmation of certain *mark* events (see Table 108).

(4) Providing real-time reformatting of Carnarvon radar data from the hexadecimal system to the 38-character octal format and retransmitting these data to the RTCS at AFETR.

(5) 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 supported the *Surveyor II* mission with the tracking facilities and equipment listed in Table 96. However, GSFC did not support the operational readiness test (ORT) before launch. Table 97 shows the MSFN overall instrumentation configuration.

a. Tracking. The acquisition aids at Bermuda, Grand Canary, and Kano were required to track the launch vehicle and to provide RF inputs to the telemetry receivers. Performance recorders were to be used to record automatic gain control and angle errors for postmission analysis. The acquisition aids were required to provide telemetry RF inputs from acquisition of signal at Bermuda through loss of signal at Kano. Telemetry coverage for decommutation, receive, and record was required from Bermuda, Canary Island, and Kano. *Mark* event readouts were required from all stations in real time or in as near real time as was possible when the vehicle was in view of each station. Telemetry coverage was to extend from acquisition of signal at Bermuda through loss of signal at Kano.

Table 96. GSFC support configuration, *Surveyor II*

Location	Acquisition aid	VHF telemetry	C-band radar	SCAMA	Radar high-speed data	Real-time readouts
Bermuda	X	X	X	X	X	X
Grand Canary	X	X		X		X
Kano	X	X		X		X
Carnarvon				X		
GSFC					X	
Cape Kennedy				X	X	

The C-band radars at Bermuda and Carnarvon were to provide radar beacon tracking, magnetic tape recording at a minimum of 10 points/s and real-time data transmission to GSFC and AFETR. Bermuda was to track the *Centaur* vehicle in conjunction with AFETR radars during the powered flight phase of the mission, and transmit in real-time, high speed data to GSFC and to the RTCS at AFETR. Bermuda was also to transmit real-time, low speed radar data to GSFC.

Carnarvon was to track the *Centaur* vehicle from acquisition of signal, occurring at approximately $T - 44$ min, to loss of signal. Vehicle view time was expected to be about 3.0 h or until C-band beacon radiation expired at approximately $T - 3.5$ h. Carnarvon was also to transmit real-time, low speed radar data to GSFC from acquisition of signal to loss of signal. This data had to be reformatted and retransmitted to the RTCS at AFETR for approximately 15 min after *Centaur/Surveyor* separation.

b. VHF telemetry. The MSFN stations at Bermuda and Grand Canary were in the process of developing S-band capability. However, any S-band coverage made by them was to be on an internal MSFN training basis only. A general discussion of individual station capabilities follows.

Grand Canary and Kano. These MSFN stations had quad-helix antennas for providing *Centaur* VHF telemetry coverage. The view periods for these stations tended to be somewhat similar to those of Ascension and Pretoria with the following exception: the location of these MSFN stations and their slant range capability would generally prevent their viewing the more southerly launch azimuths from about 111 and 115 deg.

The only potential problem (besides the view-period constraint) of these stations was, again, one of acquisition. Inflight predicts were to be supplied to Grand Canary and Kano by either the RTCS or the GSFC computers at Greenbelt, Maryland.

c. Computer. Computer support was to be provided by the GSFC data operations branch during the prelaunch, launch, and orbital phases of the mission. Ground communications to all participating stations were required by

Table 97. MSFN overall instrumentation configuration, *Surveyor II*

Stations \ Systems[a]	C-band radar	S-band radar	Spandar[b]	Telemetry R and R	Telemetry RT display	Telemetry data	High-speed telemetry data	*Gemini* LDS	RSDP SUM	*Gemini* LV telemetry	*Gemini* LV command	DCS	DRUL	DRED	RF command	Voice	Teletype	HS radar data	Flight-controller, manned	AC *aid*	TM receiver antenna	FC, AG	AG remoting
MCC-H					X	X			X			X				X	X	X	X			X	X
MCC-K				X		X	X	X		X	X	X		X		X	X	X		X	X		
MILA	X																						
Cape Kennedy	X	X		X						X	X		X		X								
Patrick AFB	X																						
Grand Bahama Island	X	X		X		X	X						X		X					X	X		X
Grand Turk	X	X		X		X	X						X		X					X			X
Bermuda	X	X		X			X						X		X	X	X	X		X	X		X
Grand Canary	X	X		X	X	X			X			X			X	X	X		X	X		X	
Kano				X												X	X			X			X
Tananarive				X												X	X			X			X
Pretoria	X																						
Carnarvon	X	X		X	X	X			X			X			X	X	X		X	X		X	
Canton Island																X	X			X			X
Hawaii	X	X		X	X	X			X			X			X	X	X		X	X		X	
Guaymas		X		X	X	X			X							X	X		X	X		X	
California	X	X		X												X	X			X			X
Texas		X		X		X	X					X	X		X	X	X	X		X			
White Sands	X															X	X			X			
Eglin	X															X	X			X			
Antigua Island	X			X		X	X						X		X					X	X		X
Ascension Island	X			X																X	X		X
Coastal Sentry				X	X	X			X			X			X	X	X		X	X		X	
Rose Knot				X	X	X			X			X			X	X	X		X	X		X	
US Navy Range Tracker Wheeling	X			X																X			X
Aircraft				X																			X
Wallops Island			X																	X			

[a]See *Glossary* for explanation of abbreviation.

[b]Analog-to-synchro converter.

existing NASCOM and DOD network facility voice and teletype circuits.

All data associated with the *Surveyor II* mission were to be identified, annotated, packaged, labeled, and transmitted in accordance with MSFN procedures.

Network support preparations were to include forecasting and scheduling network activities, including simulations, by network control group procedures. Simulations were to be conducted in accordance with the Network Operations Plan. Any special instructions or deviations from Network Operations Plan procedures were to be transmitted by the network controllers.

3. Deep Space Network. The DSN is the NASA facility for the two-way precision communication system designed to communicate with, and to permit the control of, the *Surveyor II* spacecraft after it had travelled approximately 10,000 mi from earth. The DSN was required to perform four basic functions in support of the *Surveyor II* mission: (1) tracking and locating the spacecraft: measuring its distance, velocity, and position, and providing the data necessary for orbit determination, (2) data acquisition: gathering telemetry data from the spacecraft, (3) command, and (4) control: sending instructions from the ground to guide the spacecraft in its flight to the moon, telling the spacecraft when to perform required maneuvers and when to turn on the instruments for performing certain operations, and determining trajectories from analysis of telemetry data from the DSIF and standard sequence of events. The main elements of the DSN are

(1) The DSIF with space communication and tracking stations located around the world. For *Surveyors I* and *II*, the three primary Deep Space Stations were DSS 11 (Pioneer) at Goldstone, California; DSS 51, Johannesburg, Republic of South Africa; and DSS 42, Tidbinbilla, near Canberra, Australia. The DSIF, through precision radio tracking and communication, obtained angular data (position) and doppler data (velocity) on the spacecraft from the tracking stations, as well as provided command control (uplink) and data reception (downlink) from the spacecraft. The DSS 71 at Cape Kennedy supported the spacecraft final checkout before launch and verified telemetry and tracking compatibility between the DSN and the flight spacecraft during the prelaunch and first flight phase of a space flight mission.

(2) The GCF. The GCF is that part of the DSN which provides communications between all parts of the DSN through telephone, teletype, submarine cables, and high speed and wideband microwave links.

(3) The SFOF. The control center (from *Surveyor* launch through mission completion) for DSIF tracking and data-acquisition activities, spacecraft trajectory and orbit determinations, generation of commands transmitted to the spacecraft, and analysis and interpretation of the data received. It is equipped with control consoles, status and operation displays, computers, and data processing and communication equipment. The SFOF provides communication by telephone and teletype throughout DSN, and internal communication at JPL by telephones, voice intercom units, public address systems, and closed-circuit television and other types of visual displays.

a. The DSIF. At the DSIF: (1) The following Deep Space Stations, all of which have 85-ft antennas, gave prime tracking station coverage to support the *Surveyor II* mission:

DSS 11 Pioneer, Goldstone DSCC

DSS 42 Tidbinbilla

DSS 51 Johannesburg

Figure 80 shows the deep space instrumentation facility located at Johannesburg, South Africa, with its 85-ft antenna.

(2) DSS 72, Ascension Island was required to provide first pass tracking and telemetry data, only.

(3) In addition to the support given by the prime stations, the following assisting coverage was provided.

(a) DSS 71, Cape Kennedy. Coverage was required to support RF compatibility tests between *Surveyor II*, located on the launch pad, and DSS 71. These tests were completed before launch. At the time of launch, DSS 71 was to receive telemetry data from $L - 5$ min to loss of signal. These data were to be sent to the SFOF for engineering evaluation, but the station was not committed to provide project support for this phase of Mission II.

(b) DSS 61, Robledo, Spain. Because of commitments to other projects, DSS 61 was not available to track *Surveyor II* except on an emergency backup basis. Some coverage might have been available during lunar operations, when it did not interfere with other project commitments.

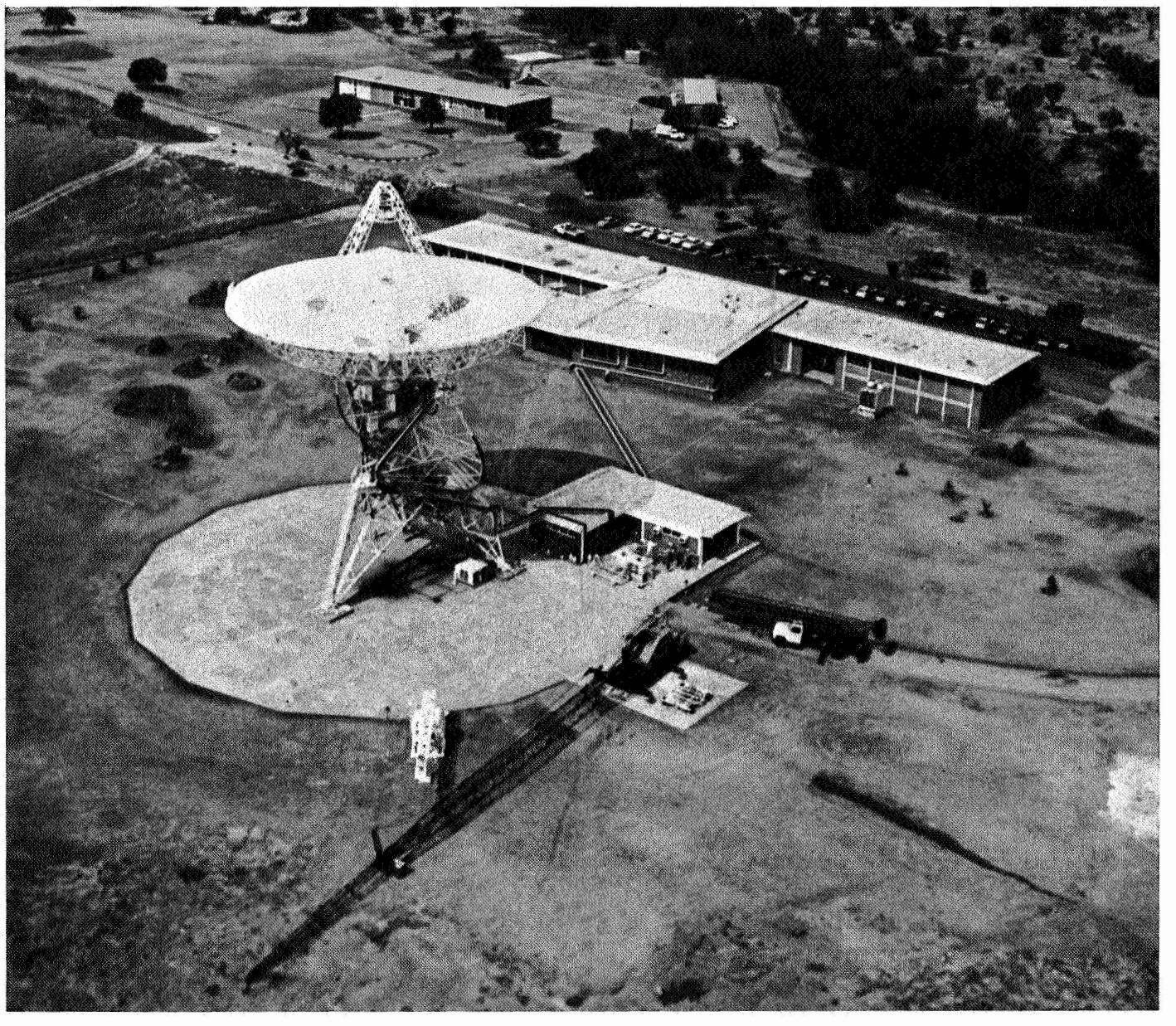


Fig. 80. Aerial view of DSS 51, Johannesburg

(c) DSS 14, Mars Station, Goldstone. The DSS intended as a backup to DSS 11 (Pioneer) data recording, during midcourse and terminal descent, was the Mars station with the 210-ft antenna. However, this station was still being implemented with the required instrumentation and all participation in *Surveyor II* mission was to be carried out on a best-effort basis.

The Deep Space Stations are shown on page 216 with their locations and instrumentation configurations in support of *Surveyor II* (see Table 98).

Table 98. DSS support configuration, *Surveyor II*

DSS	Location	Designation	Configurations
11	Goldstone, Calif. (Pioneer site)	Prime	GSDS
42	Tidbinbilla, Australia	Prime	GSDS
51	Johannesburg, South Africa	Prime	L/S
71	Cape Kennedy, Florida	Prelaunch and launch support	—
61	Robledo, Spain	Training	GSDS
72	Ascension Island	Backup	GSDS

The DSIF operates on S-band frequencies in support of *Surveyor* missions. Figure 81 shows the DSIF configuration for *Surveyor* and associated S-band *Surveyor* block diagram.

b. DSN communications system. NASCOM high-speed data modems (modulator-demodulator) were implemented at DSS 11, 42, 61, 71, and 72. Hallicrafters modems were still in use at DSS 51. Tests demonstrated that the modems at all sites were operational.

DSN Ground Communications Facility. Figure 82 shows the *Surveyor II* mission circuit configuration for the Ground Communications Facility (GCF). The launch circuit requirements are shown in Figs. 83 through 87.

DSN Intracommunications System. In accordance with general operating policies, the Intracommunications System (ICS) configuration for the *Surveyor II* mission was established prior to the last operational readiness test on September 12, 1966, and elements of the systems configuration were frozen until after the landing maneuver.

Special coverage. It was not planned to supply special maintenance coverage for Western Union microwave circuits to Goldstone DSCC for *Surveyor II*. However, negotiations progressed between the DSN and the Project to obtain this special coverage.

DSN interface. This interface was supplied by the DSN to provide real-time transmission of downrange spacecraft telemetry data from building AO at the AFETR to the SFOF, and remained unchanged for *Surveyor II*.

The DSN provided an interface for downrange telemetry from both VHF and S-band sources. The nominal switchover time was after *S-band high-power-on* was commanded and the spacecraft responded. The interface with the Project was at the input to the command and data handling console (CDC) in building AO. The output of the CDC was then interfaced with the Ground Communications Facility for transmission to the SFOF. It was also possible to go directly from the range data output to the GCF, bypassing the CDC.

c. Space Flight Operations Facility. The overall assessment was that the SFOF was in readiness to support *Surveyor II* as it was scheduled. Both SFOF equipment and mission-independent personnel were in a condition of flight readiness. The minor problems associated with the data processing system were cleared prior to launch. The confidence factor ran even higher for the *Surveyor II* mission than it was for *Surveyor I*. This was due, primarily, to two reasons. First, the SFOF had supported both *Pioneer* and *Lunar Orbiter* missions in a very satisfactory manner along with the *Surveyor I* mission. Second, the changes made for the *Surveyor II* mission, even though minor, undoubtedly increased the overall effectiveness of the SFOF.

The DSN provided facilities and operating functions for data processing, display, and distribution, and for the mission control functions performed within the SFOF. For *Surveyor II*, the main changes were the reconfiguration of the Space Science Analysis Area (SSAA), and the moving of the mission advisors area to the second floor.

Figure 88 gives a block diagram of the Space Flight Operations Facility and the associated DSN Ground Communications Facility for the *Surveyor II* mission.

SFOF data processing system. The data processing system was required to perform the same functions for the *Surveyor II* mission as for *Surveyor I*, and the DPS checkout plan was essentially the same. Among the modifications for the *Surveyor II* mission were the following:

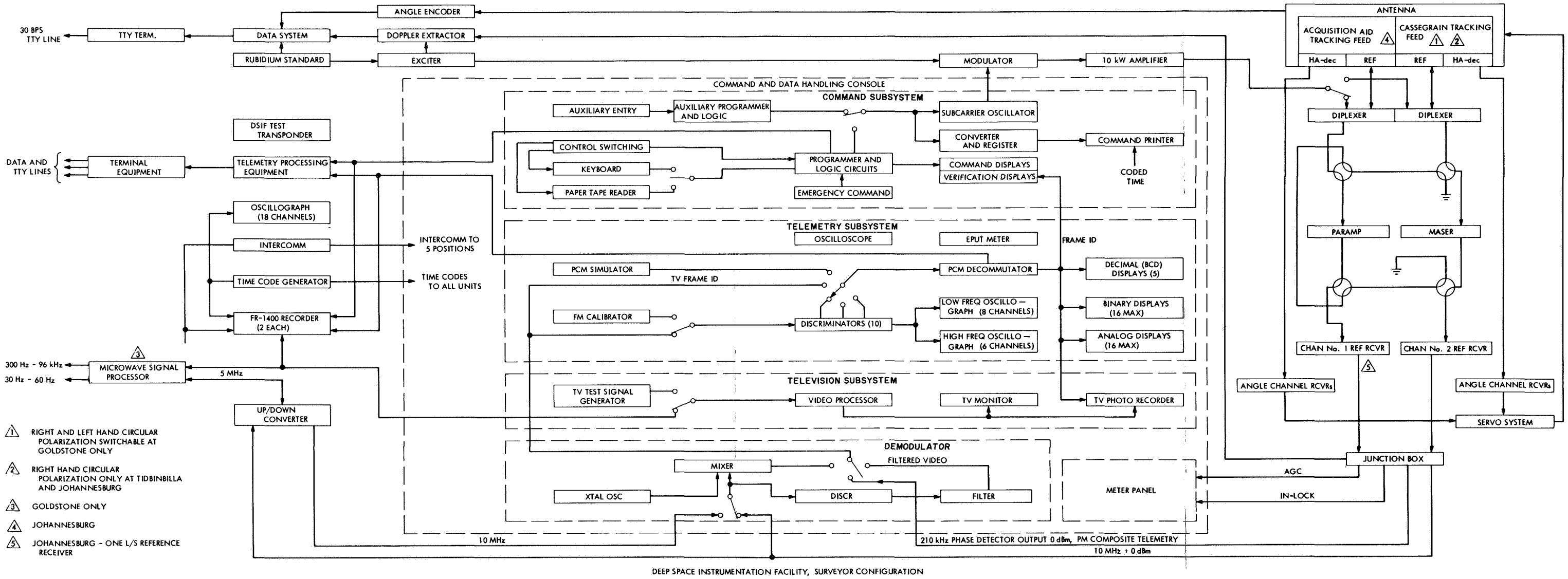


Fig. 81. S-band station block diagram, *Surveyor* missions

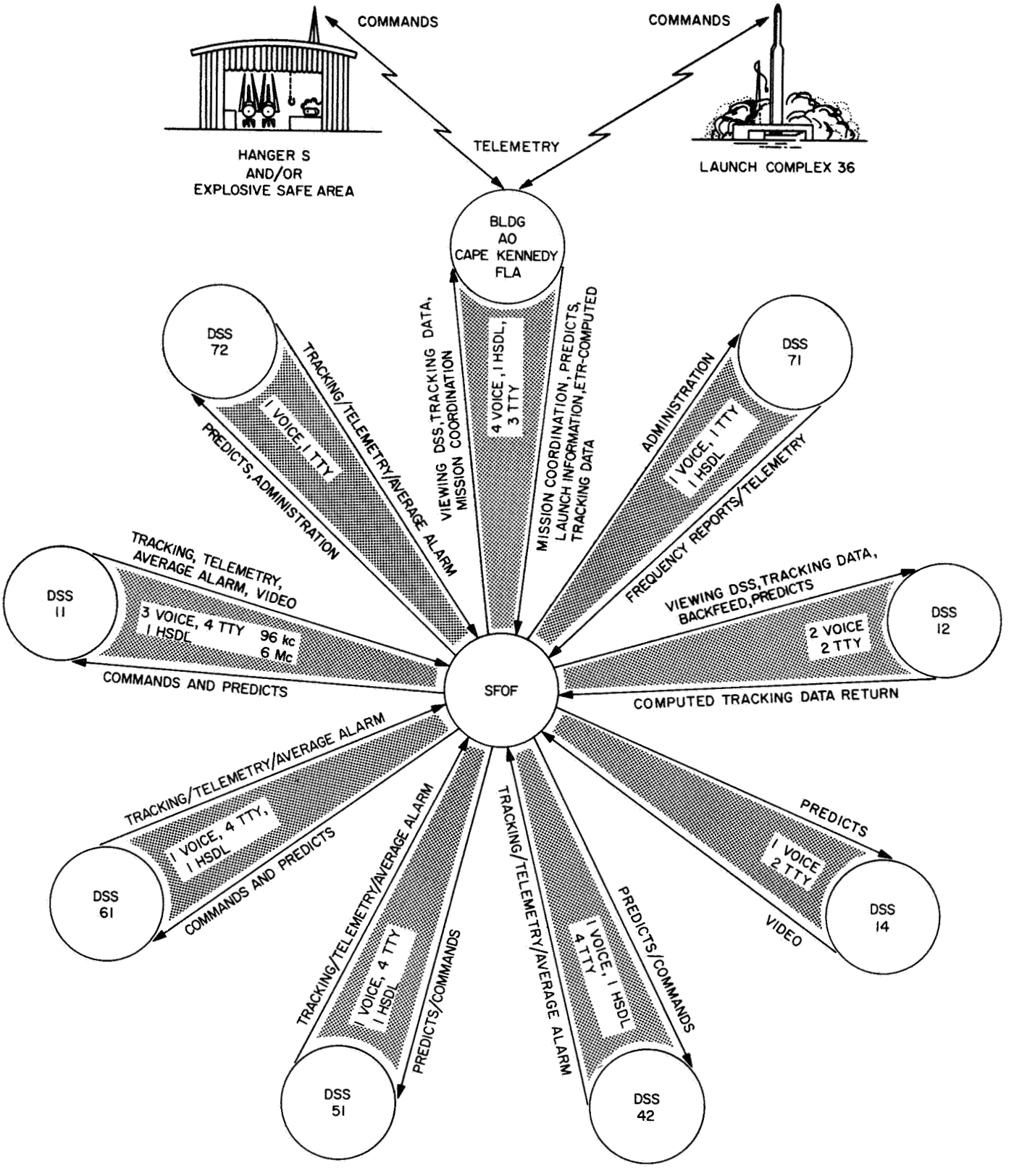
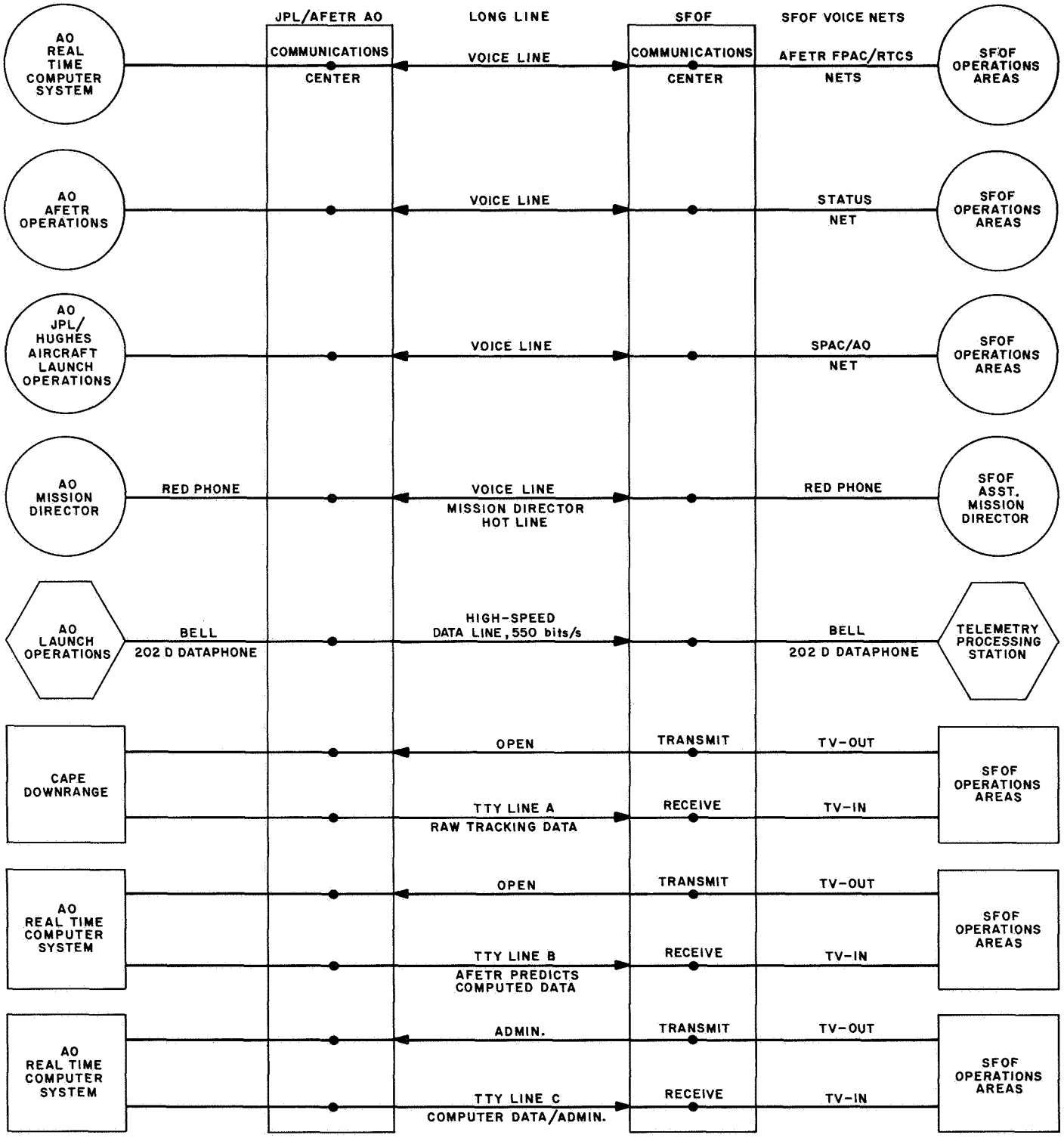
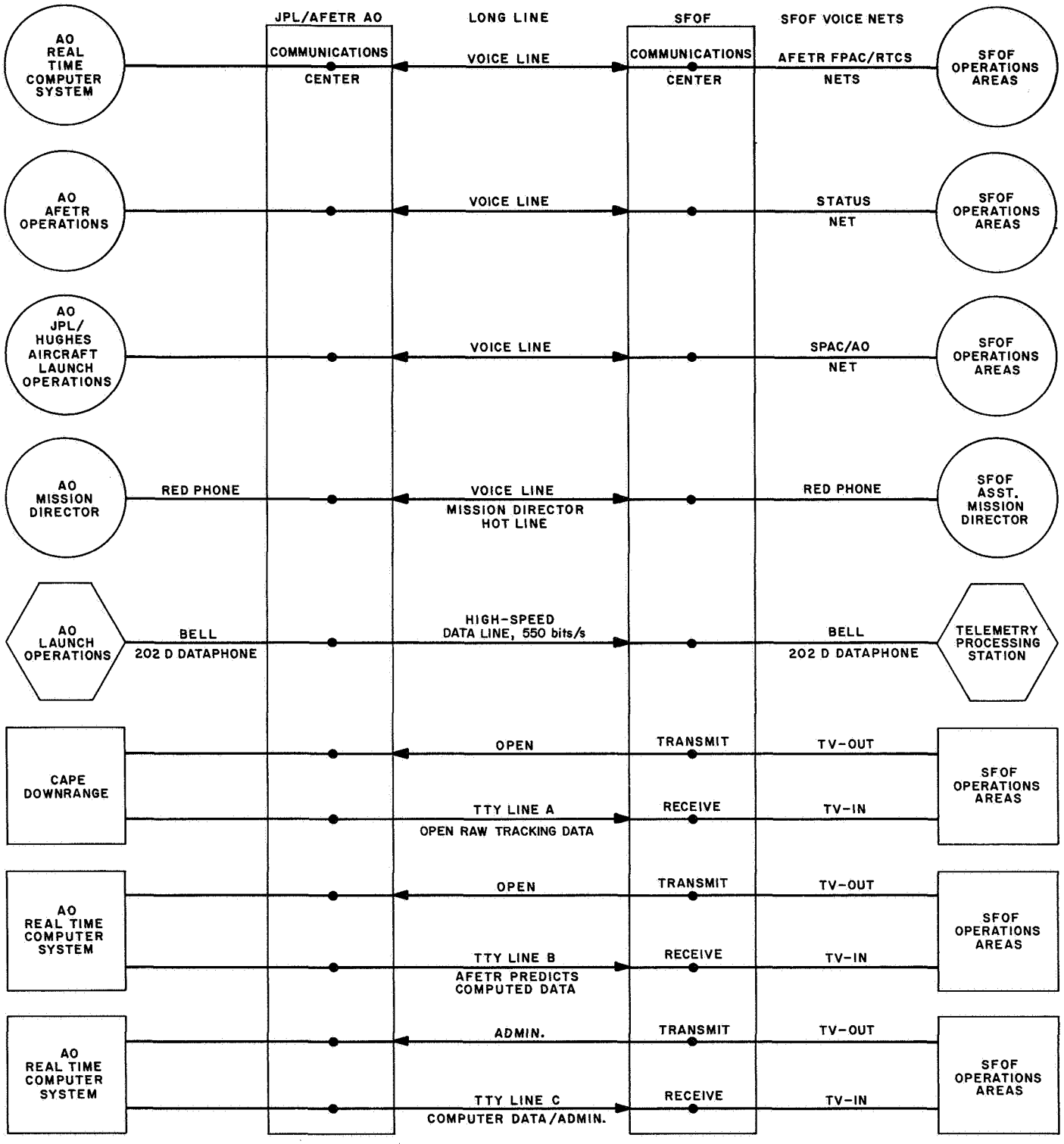


Fig. 82. DSN Ground Communications Facility circuit configuration, *Surveyor II* mission



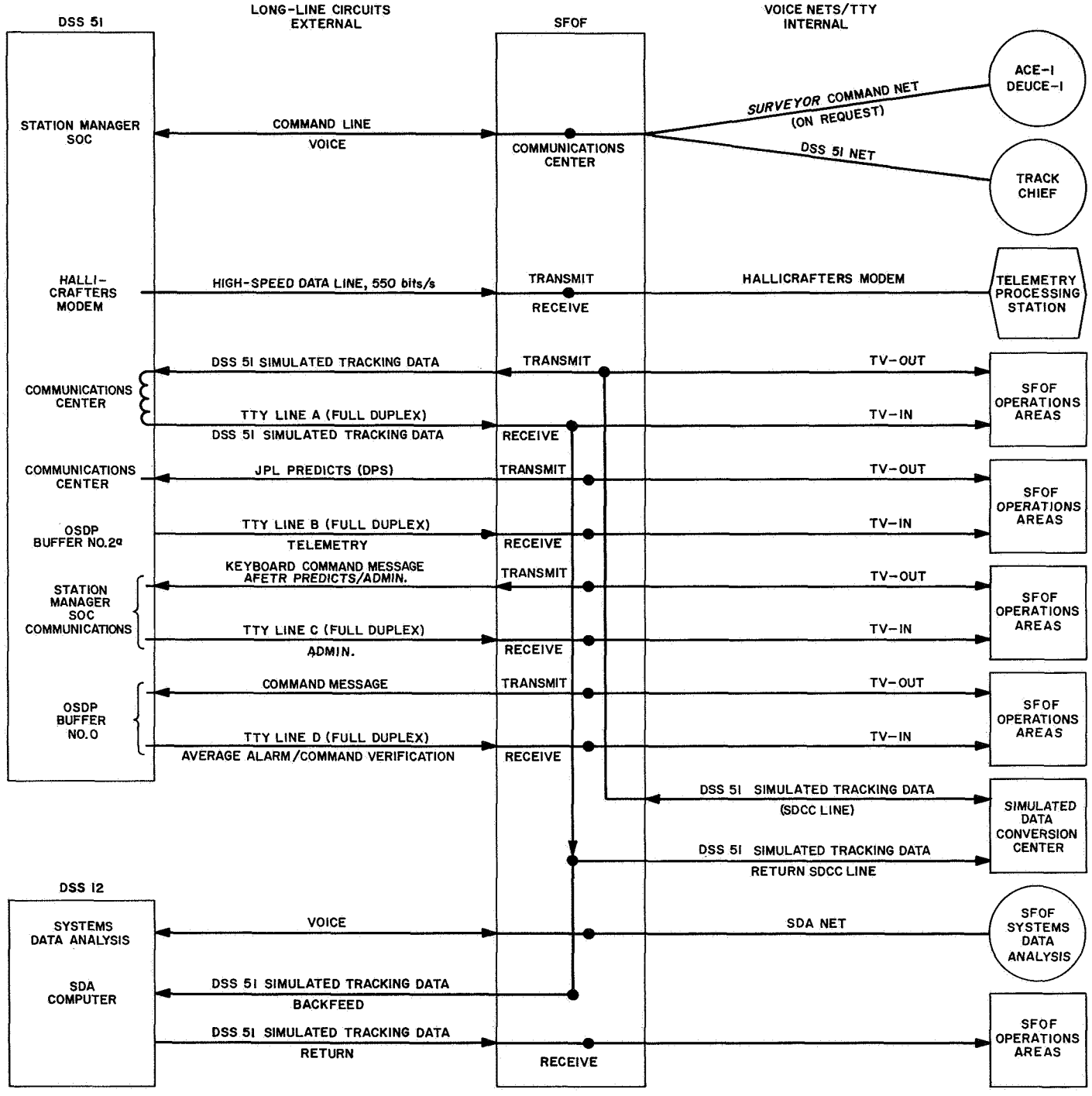
AO BUILDING AO, AFETR, CAPE KENNEDY, FLA.
FPAC FLIGHT PATH ANALYSIS AND COMMAND
SPAC SPACECRAFT PERFORMANCE ANALYSIS AND COMMAND

Fig. 83. *Surveyor II* mission SFOF/AFETR circuit configuration



AO BUILDING AO, AFETR, CAPE KENNEDY, FLA.
FPAC FLIGHT PATH ANALYSIS AND COMMAND
SPAC SPACECRAFT PERFORMANCE ANALYSIS AND COMMAND

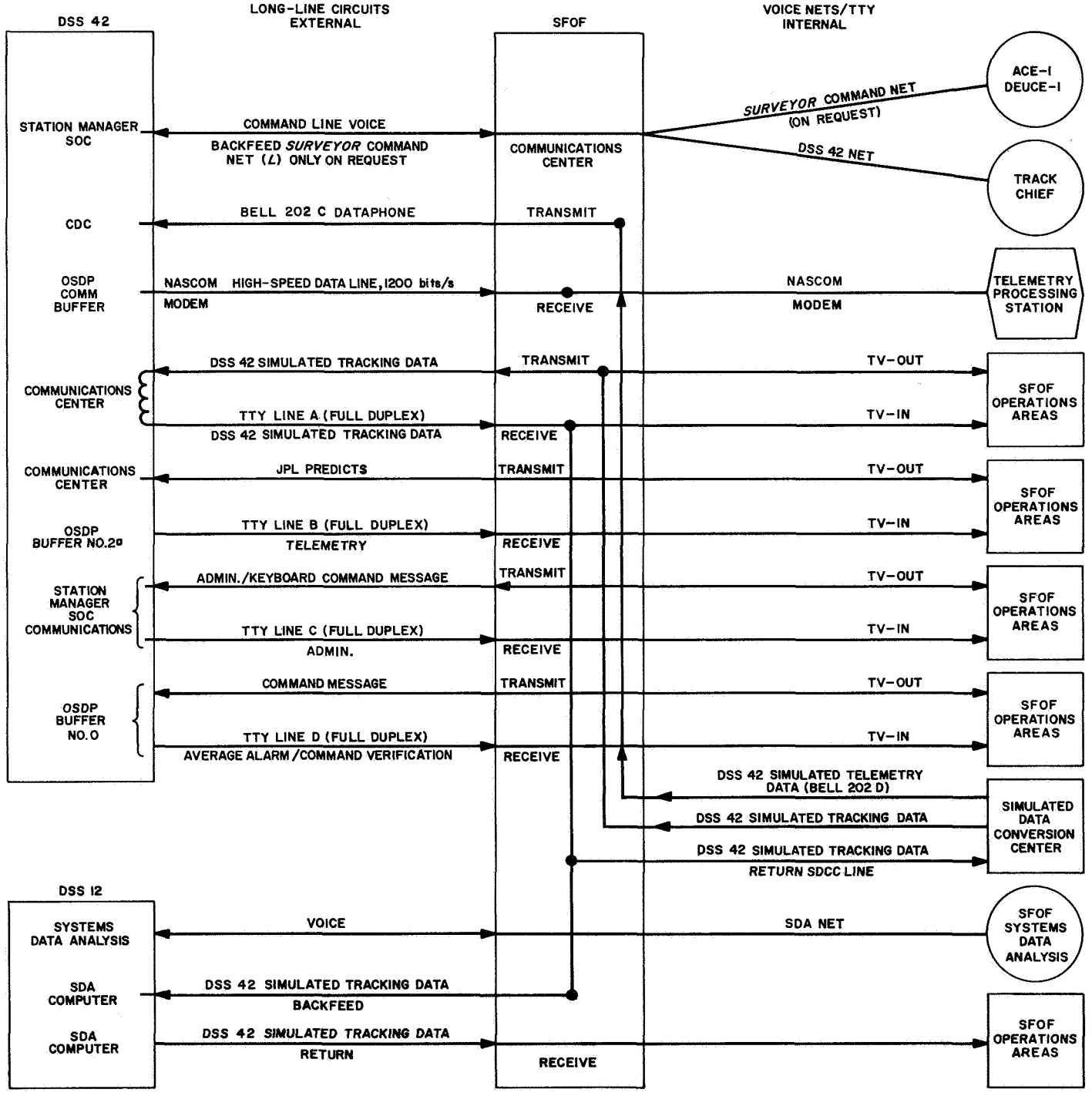
Fig. 84. *Surveyor II* mission initial SFOF/DSS 72 circuits—ORT and launch configuration



[a] OSDP BUFFER NO.1 COMMAND CONFIRMATION DATA REPERFORATED AT STATION AND TRANSMITTED TO SFOF ON TTY B CIRCUIT AT END OF STATION PASS

ACE-I SPACE FLIGHT OPERATIONS DIRECTOR FOR *SURVEYOR*
DEUCE-I ASST. FLIGHT OPERATIONS DIRECTOR FOR *SURVEYOR*
OSDP ON-SITE DATA PROCESSING
SOC *SURVEYOR* OPERATIONS CHIEF

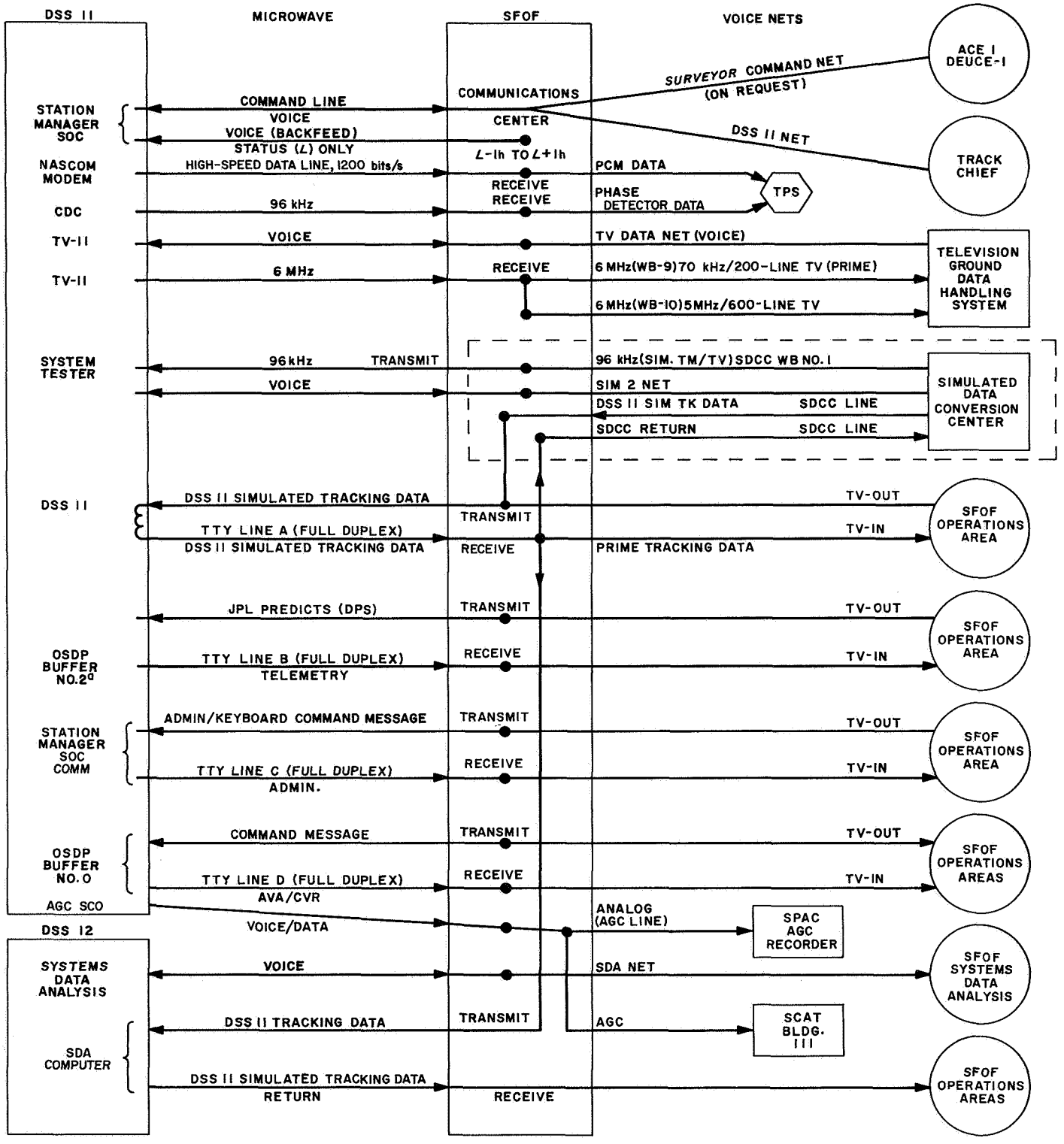
Fig. 85. *Surveyor II* mission initial SFOF/DSS 51 circuits—ORT and launch configuration



a OSDP BUFFER NO.1 COMMAND CONFIRMATION DATA REPERFORATED AND TRANSMITTED ON TTY B CIRCUIT OF SFOF AT END OF STATION PASS

ACE-I SPACE FLIGHT OPERATIONS DIRECTOR FOR *SURVEYOR*
DEUCE-I ASST. SPACE FLIGHT OPERATIONS DIRECTOR FOR *SURVEYOR*
CDC COMMAND AND DATA HANDLING CONSOLE
OSDP ON-SITE DATA PROCESSING SYSTEM
SOC *SURVEYOR* OPERATIONS CHIEF

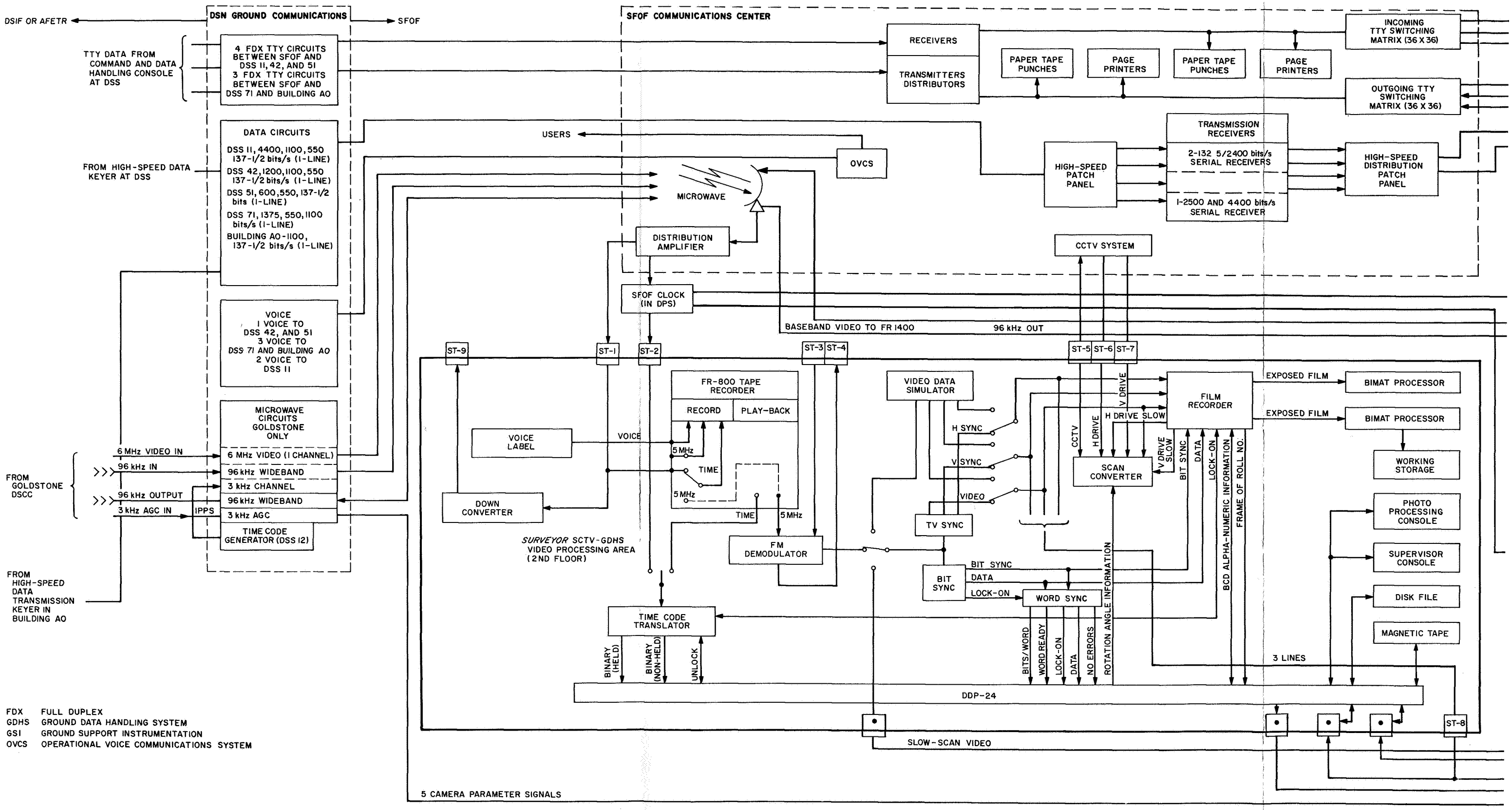
Fig. 86. *Surveyor II* mission initial SFOF/DSS 42 circuits—ORT and launch configuration



a OSDP BUFFER NO.1 COMMAND CONFIRMATION DATA REPERFORATED AT STATION AND TRANSMITTED TO SFOF ON TTY B CIRCUIT AT END OF PASS.

ACE-I SPACE FLIGHT OPERATIONS DIRECTOR FOR *SURVEYOR*
DEUCE-I ASST. SPACE FLIGHT OPERATIONS DIRECTOR FOR *SURVEYOR*
AVA AVERAGE ALARM
CVR COMMAND VERIFICATION
SCAT SPACECRAFT ANALYSIS TEAM
SOC *SURVEYOR* OPERATIONS CHIEF
SPAC SPACECRAFT PERFORMANCE ANALYSIS AND COMMAND

Fig. 87. *Surveyor II* mission initial SFOF/DSS 11 circuits—ORT and launch configuration



FDX FULL DUPLEX
GDHS GROUND DATA HANDLING SYSTEM
GSI GROUND SUPPORT INSTRUMENTATION
OVCS OPERATIONAL VOICE COMMUNICATIONS SYSTEM

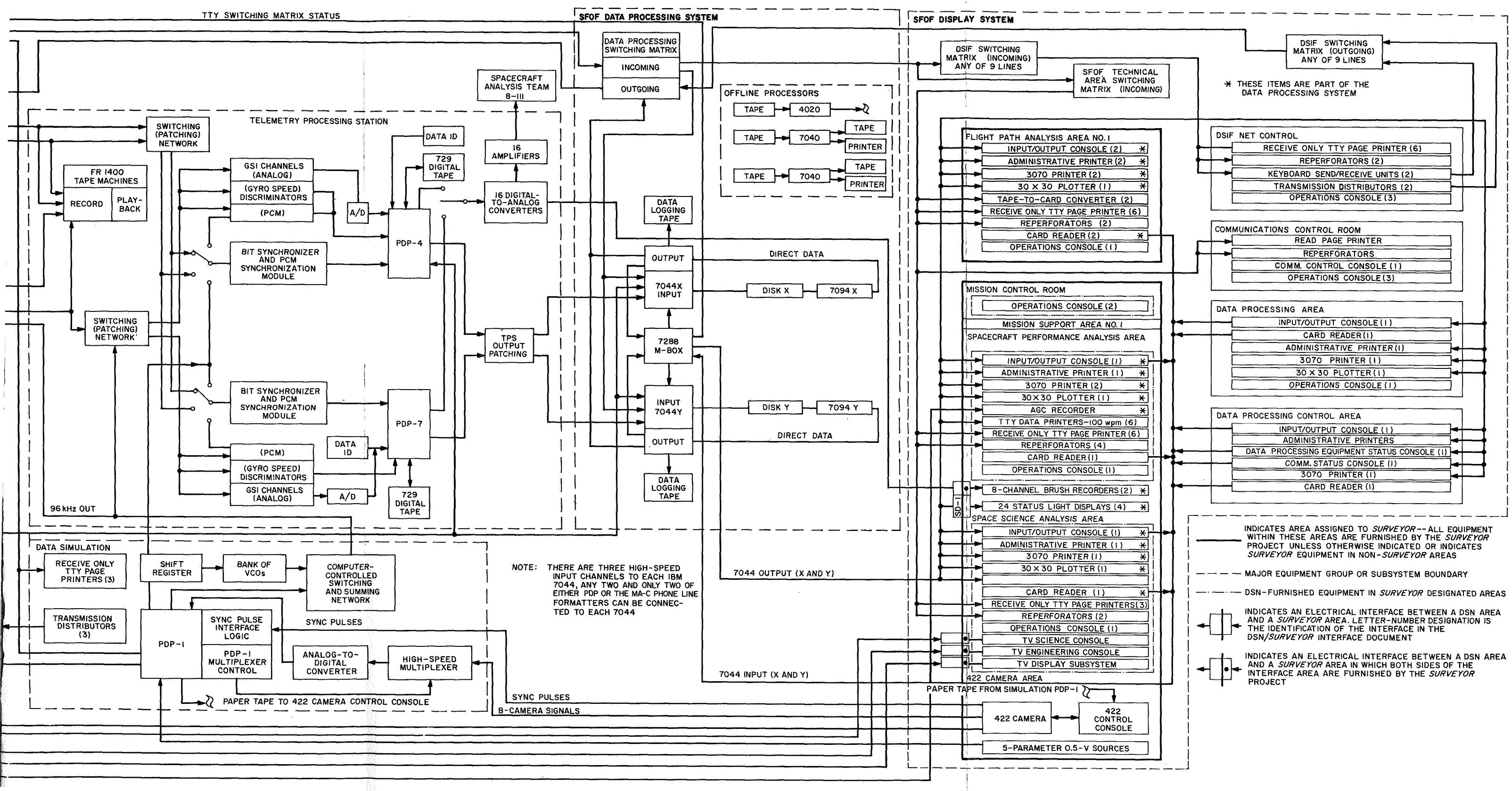


Fig. 88. Block diagram of the Space Flight Operations Facility and DSN Ground Communications Facility

(1) Telemetry processing station: The most significant change made in the TPS for the *Surveyor II* mission was the replacement of the PDP-4 (programmed digital processor) computer with a PDP-7. Formal acceptance of the PDP-7 had been accomplished by the *Surveyor* Project, and this configuration (dual PDP-7s) performed very satisfactorily throughout the testing cycle.

(2) Analysis computers: The IBM 7044/7094 computer-string performance during the tests conducted indicated that these systems were ready to support the mission as it was scheduled. Minor problems with these systems, however, were experienced. The most significant of these appeared to be a syncing problem in the 7288 (Data Comm Channel), which resulted in the loss of some data to the 7044 computer. Another problem was with the TTY output channels to the 100-wpm TTY printers in the Spacecraft Performance Analysis Area. Both of these problems were cleared by routine maintenance.

Surveyor II mission computer operations personnel were not considered to be as fully qualified as those for *Surveyor I*. The turnover rate, coupled with the very difficult task of hiring experienced computer operators, necessitated a rigorous and continual training program. It was expected that *Surveyor II* would be supported by a very competent team of operators by launch date, however.

(3) Input/output system: The most significant change to the I/O system configuration for *Surveyor II* was in the SSAA which was to be driven by the TPS. All *Surveyor II* tests were supported, with no major anomalies noted. The card reader problems experienced during the *Surveyor I* mission were investigated and found to be due to improper installation of modifications on the readers by the manufacturer. These, of course, were rectified, and satisfactory performance was expected.

SFOF facilities support. The areas in the SFOF that were used for operations flight path analysis and mission support for *Surveyor II* were the same as those for *Surveyor I*, and had essentially the same display configurations. Relatively few changes were made in support configurations, as indicated in the following:

(1) Technical areas: The technical areas in the SFOF that were committed in support of the *Surveyor II* mission were the same as those committed for *Surveyor I*. The mission advisors area was moved to the second floor of the SFOF. All areas were essentially configured the same as for *Surveyor I*.

(2) Physical facilities: All elements that fall under this classification were considered ready to support *Surveyor II*. The physical facilities included the power system, the air-conditioning system, elevator, etc.

(3) SFOF functions/services: Access control service was modified for the *Surveyor II* mission. The most significant change was that personnel holding mission-independent badges would have access to any place in the SFOF where they had business. Mission-dependent or Project badges were restricted to certain areas and these areas were designated on the badge. Another change was that technical area assistants were not available for the *Surveyor II* mission. The Support Chief maintained a minimum number of operational aides who, upon request and if available, were used for specific tasks in the technical areas.

B. Tests

To insure the successful launch and flight of the *Surveyor II* mission a great deal of preparation and compatibility testing was needed to determine the Missions Operational Readiness status. Thus, operational readiness tests were performed in an endeavor to assure a mission success. (For test classification and objectives, see Section IV-B, Tests.)

1. AFETR. The operational and test facilities of the AFETR are in a constant state of testing. The preparation and testing for launch support of the *Surveyor II* mission was successfully accomplished by Sept. 16, 1966.

There was, however, a certain amount of apprehension concerning AFETR and MSFN simulation testing. Premission activities were planned to include two ORT simulations, which subsequently had to be cancelled. Two ORT simulations were planned for September 7 and September 13, 1966, but conflicts with other programs forced cancellation of these simulations. Finally, on September 16, 1966, a simulation was held with MSFN and AFETR participating.

a. Metric. Originally it was understood that the AFETR would supply a three-range instrumentation ship support for the *Surveyor II* mission. Later it became known that

the RIS *Twin Falls* was not operationally ready until the middle of October 1966 and hence was unavailable for the September 20 launch date. This was due to the engineering and test scheduling. The ship proceeded with category III testing.

The AFETR indicated metric coverage could be expected from the Antigua and Trinidad radars. However, due to the RIS abridgment, metric requirements could only be met within restricted launch azimuths.

b. RTCS. The RTCS also took place in ORT simulations with measured success. All segments of the RTCS proved ready to support the Sept. 20, 1966 launch window.

2. *GSFC.* Various ORT simulations were scheduled for MSFN on September 7 and 13, 1966 and subsequently cancelled. A simulation ORT was scheduled for September 16 on a non-interference basis. Although coordination problems arose the simulation was accomplished with all stations reporting readiness.

Mission scheduling for the September 20 launch date presented no program conflicts. All tracking sites reported a green condition with the exception of the Bermuda FPS-16 radar which went red as a result of an elevation data problem. This problem was cleared and Bermuda reported it was in a state of readiness to support *Surveyor II.*

The ORT simulations continued on September 16. Prior to picking up the count at $T - 140$ min, the Bermuda station was released from other program tracking to support the test, and the Grand Canary station reported availability for test activities. Communications with the Mission Control Center at MCC-K were not established until $T - 90$ min due to uncertainty as to the location and lines that needed connection. The count proceeded as planned with a launch azimuth of 102 deg for the September 20 launch opportunity. The MSFN station at Kano advised that they would not see the 102-deg launch azimuth. However, Kano supported the simulations by utilizing the view periods and event times for a 99-deg launch azimuth.

a. Radar data. At $T - 30$ MCC-K stated they could not simultaneously send AFETR radar data to GSFC computers for *Surveyor II* simulations and support other programs in progress.

During the $T - 5$ min hold it was decided that the AFETR would record the radar data and replay it for GSFC computers when the other program tracking and activities were concluded.

b. Computer. Two problems occurred during the plus count. One, no acquistion messages were generated from GSFC computers to sites. This was due to a data operations branch decision not to transmit data to avoid mixing the stations up on their in-progress tracking. The second problem was in regard to the inability of GSFC computers to use Trinidad radar during the simulation. This problem occurred because the mission planner failed to notify computer personnel that the Trinidad data was available and had to be used for some launch azimuths to generate acquisition messages for Grand Canary and Kano. The simulations were then brought to a conclusion on September 16.

The simulations were reported as satisfactory but not smooth. All wrinkles, however, were successfully ironed out by the launch date.

3. *DSN.* The DSN had responsibility to prepare for the *Surveyor II* flight by various testing. The following information is given regarding that preparation.

a. CDC/DSIF Compatibility. The DSS 71 at Cape Kennedy was equipped with a CDC in the period between *Surveyor I* and *II* missions. A DSIF compatibility test was conducted in mid-August which established RF compatibility. The testing was proven out by DSS 71 performance during prelaunch, launch and liftoff.

Various CDC operations were conducted at 5 DSIF stations for the *Surveyor II* mission, although only the three prime stations were committed for command, *Surveyor* TDA data, and TV operations. The prime stations were Goldstone (DSS 11), Canberra–Tidbinbilla (DSS 42), and Johannesburg (DSS 51). The CDCs at Madrid (DSS 61) and Ascension Island (DSS 72) were also readied and activated, primarily for a backup role. DSS 72 was committed for two-way lock and did have two-way lock with the spacecraft for 45 min. The Goldstone station was activated for *Surveyor* in the summer of 1964; Canberra and Johannesburg in spring of 1965; Madrid and Ascension Island during early 1966.

The following major tasks were accomplished at each station (after installation of the equipment concerned) insuring equipment readiness for the *Surveyor II* mission:

(1) CDC Unit, Subsystem, and System tests to confirm proper operation of the complete CDC equipment.

(2) CDC/DSIF Compatibility Tests to confirm functional and engineering compatibility between the CDC, and the DSIF receiver, transmitter, computer, recorders, and timing system. Figure 89 shows the sequence of tests for the *Surveyor II* mission.

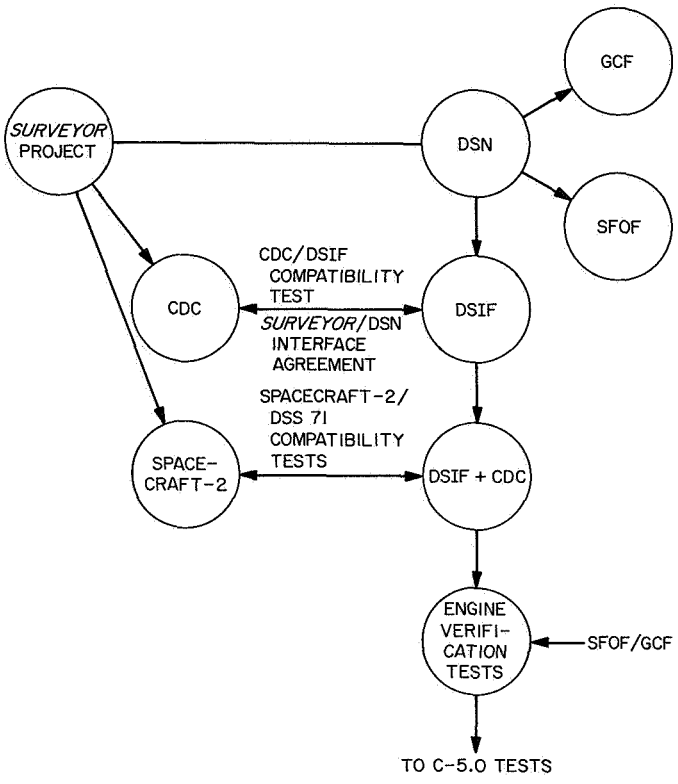


Fig. 89. *Surveyor II* mission test sequence

b. Spacecraft-2 MOS compatibility. The Mission Operations System (MOS) testing was accomplished in two areas; (1) spacecraft-2 Tel-2 Compatibility Test and (2) spacecraft-2 DSS 71 Compatibility Test. The following information is given for furthering an understanding of MOS compatibility testing for the *Surveyor II* mission. Figure 90 gives a simplified block diagram of the spacecraft-2 MOS test configuration at AFETR.

Spacecraft-2 Tel-2 compatibility test. The primary objective of this portion of the spacecraft-2 MOS Compatibility Test was to demonstrate the ability of a typical range receiver facility, represented by Tel-2, to receive, detect and transmit to building AO, the *Surveyor* spacecraft-2 telemetry data received via the *Centaur* VHF and spacecraft S-Band RF links.

A secondary objective was to measure certain Tel-2 receiver and telemetry subsystem parameters, and to collate these with error rate measurements at the STEA-CDC to determine the degree to which the telemetry data recovery equipment approached expected performance.

The test objectives were met on a non-interference basis and required no special test configurations or procedures. The test was essentially a functional compatibility test for the purpose of demonstrating the ability of the STEA-CDC decommutator to acquire lock with the serial PCM obtained from either the *Centaur* or spacecraft-2 RF links via the Tel-2 VHF or S-band receivers respectively. The signal to the decommutator was switched between the Tel-2 receiver output (after discrimination of the PCM from the subcarrier) and the reconstructed TDM-1 decommutator PCM output. At Tel-2, receiver and telemetry system performance parameters were recorded and a tape recording made of the telemetry subcarrier in the Mission A format specified in Program Requirements Document (PRD) 3400. At the STEA in building AO, a computer dump of the spacecraft telemetry was made for each input configuration in lieu of an error rate measurement.

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

S-band link telemetry. The same comments that appear in the above paragraph apply here except that the telemetry was received via the *Surveyor* spacecraft S-band RF link and the Tel-2 S-band receiver.

All spacecraft-2 Tel-2 test objectives having been met indicated the testing was successful. The STEA-CDC demonstrated the ability to synchronize with the spacecraft-2 and telemetry received from both the *Centaur* VHF link and the spacecraft S-band link.

Spacecraft-2 DSS 71 compatibility test. The primary objective of this portion of the spacecraft-2 MOS Compatibility test was to demonstrate the ability of a typical DSIF station, represented by DSS 71, to acquire a command configuration with the spacecraft-2 spacecraft. This involved measuring those spacecraft and ground RF systems parameters that related to the command link. Such parameters include transmitter and receiver frequencies,

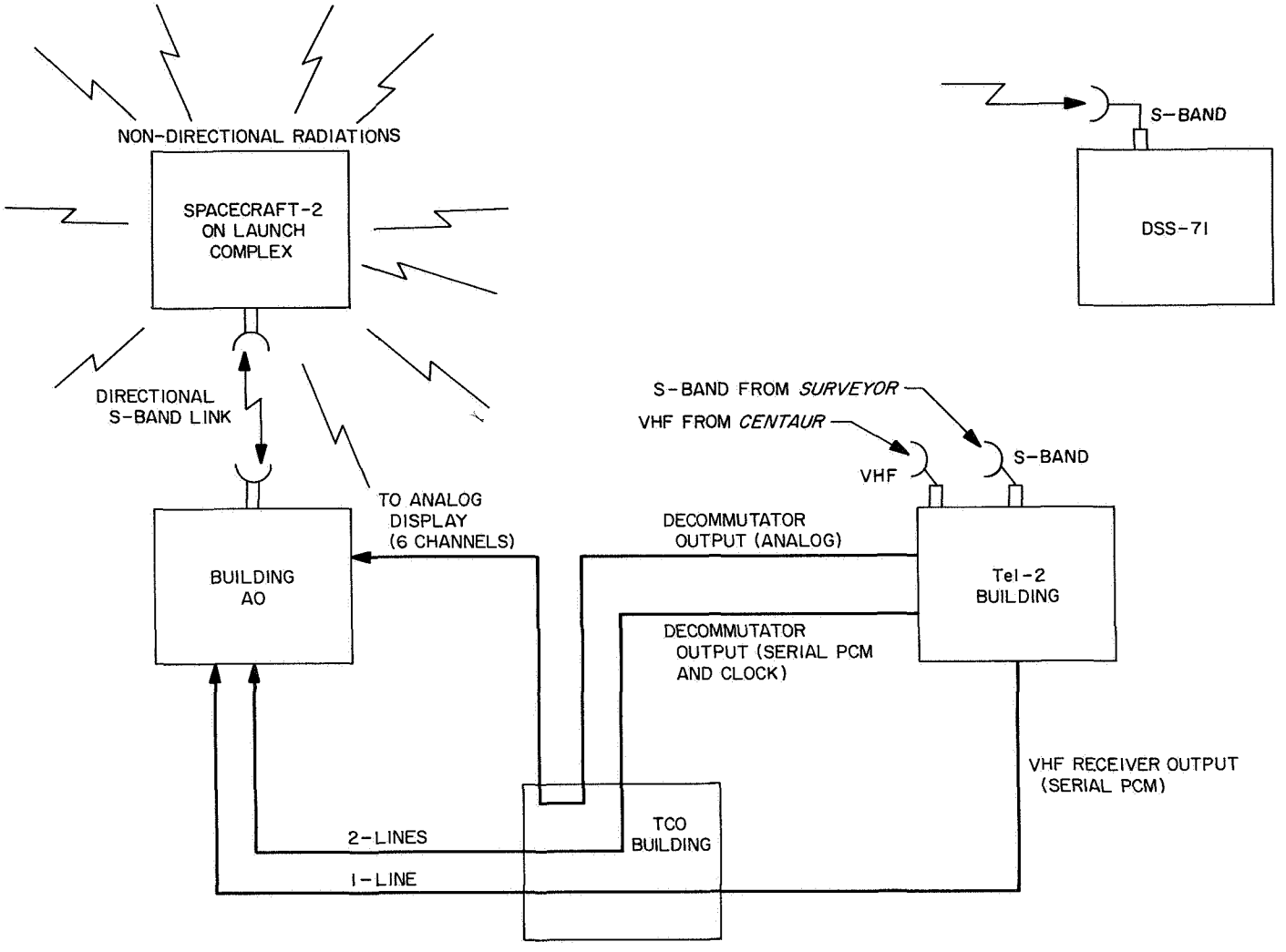


Fig. 90. Simplified block diagram spacecraft-2/mission operations system test configuration AFETR tests

receiver thresholds, and receiver acquisition and tracking ranges.

A secondary objective of this test was to obtain measurements of the spacecraft-2 telemetry modulation parameters to verify the numbers given in Ref. 2, thereby gaining further confidence in the telemetry subsystem's performance predictions which are based on these numbers.

During this test on August 10 to 12, 1966, the spacecraft-2 spacecraft was encapsulated in the shroud and mounted on the AC-7 launch vehicle on pad 36 and the entire assemblage was then enclosed by the service tower. The directional RF link between the service tower and building AO was operational. DSS 71, being within the beamwidth, thus communicated with the spacecraft through this link.

During the entire test, RF link fluctuations of at least ± 1 dB were observed at all times, with ± 2 dB variations not uncommon.

The DSS 71 configuration during this test was as shown in Fig. 91. The variable attenuators between the antenna and the transmitter and receiver were for performing threshold tests of the spacecraft and DSS 71 receivers. The printer was used to print out an apparent biased doppler frequency during the NBVCXO frequency drift test. The spectrum analyzer provided a means of observing the spectral content of the wide-band voltage controlled auxiliary oscillator (WBVCXO) during the WBFM test. The wave analyzer and rms voltmeter (part of the

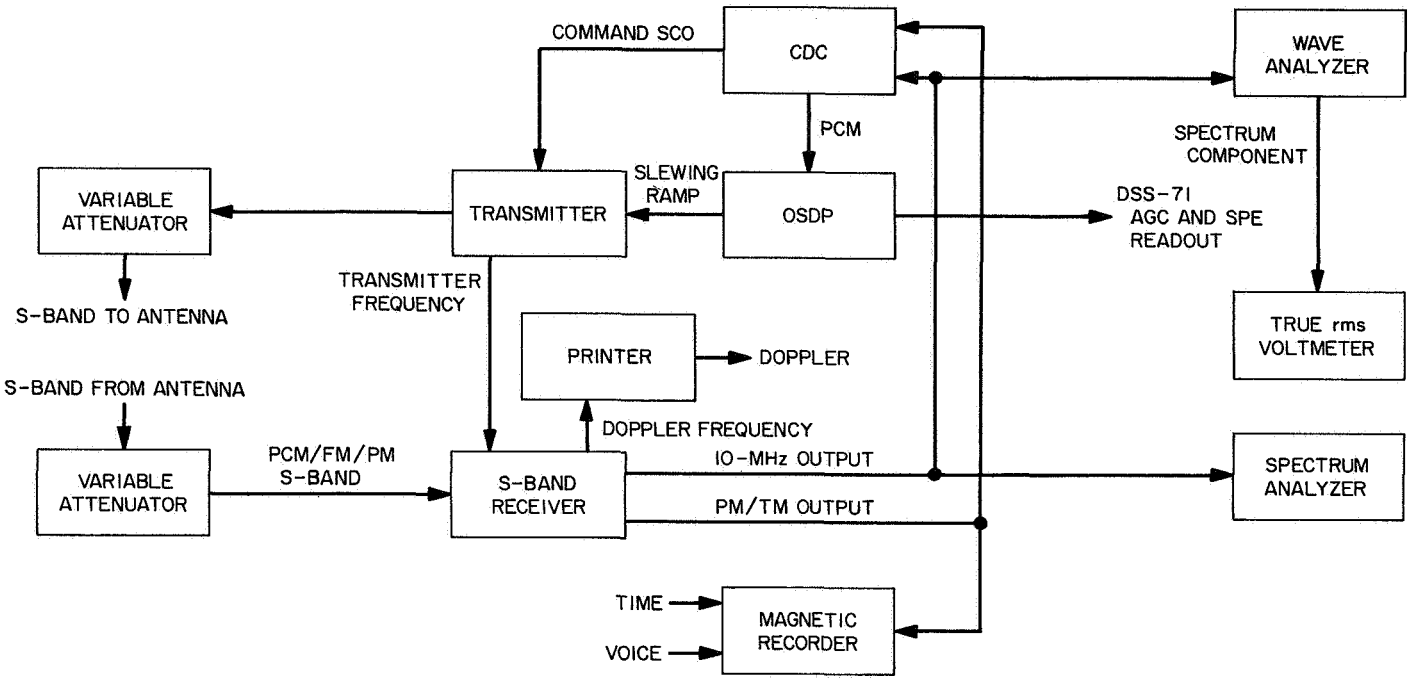


Fig. 91. DSS 71 test configuration

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 including a special one to obtain sample telemetry data during the telemetry error rate test. The use of the OSDP to control the DSS 71 transmitter frequency was devised by the station personnel. This technique was especially useful during the phase-lock tuning range test and the automatic phase control (APC) and AFC acquisition frequencies tests. The computer was programmed to slew the transmitter frequency linearly in time at a prescribed rate. In the phase lock mode tests, the desired spacecraft reaction resulted in loss of down-link lock which automatically stopped the computer from further tuning the transmitter. In the AFC mode tests, the STEA telemetry engineer reported the occurrence of the desired spacecraft response and the computer was stopped manually.

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

With insignificant exceptions, the spacecraft-2 spacecraft and DSS 71 systems met, or exceeded, specifications or requirements of the mission in all areas tested.

c. Spacecraft-2 DSIF compatibility. Spacecraft/DSIF compatibility tests were conducted at DSS 71 during August 11 and 12, 1966. The A-string WBVCXO was found to be 120 kHz low at S-band. Depending on the direction and magnitude of the thermal drift, the program of the WBVCXO could appear beyond the training range and bandwidth of the DSIF receiver. This would affect the 600-line TV operation and WBFM data modes.

In both cases, a bias was obtained on the output signals when the A-string WBVCXO was used. In other respects, spacecraft-2 was found to be compatible with the DSIF.

d. Facility tests (DSS class-A internal). These tests were scheduled and conducted by each Station Manager and involved only the individual station. (There was no long line or SFOF participation.) The A tests utilized the standard Sequence of Events and were employed by the station as a countdown exercise. There are two A test phases, as follows: those that prepare the station for B tests, and those that are designed to train for C tests. Both A test phases developed the ability of personnel to use the proper procedures and hardware within a given time constraint. All prime and training stations completed a full sequence of A tests. The stations continually perform significant sequences in the A tests for practice, station countdown, and training new people.

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

f. B-1.6 DSS 72/SFOF test. This test was conducted in one 5-h session. The DSS 72/SFOF Configuration was exercised by tracking and telemetry data corresponding to those portions of the flight sequence appropriate to the station's visibility period. This test was used to verify the DSS 72/SFOF capability to:

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

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

(3) Process tracking data.

The command capability portion of this test was deleted since the station could not perform a full command test and would not be required to command during the *Surveyor II* mission. The successful completion of the test demonstrated the station capability to support later C-1 Tests.

g. SFOF/DSS 72 integration (class C-1.5) test. The objective of this test was to train DSS 72 personnel and exercise the SFOF/DSS 72 interface in the execution of spacecraft acquisition as a backup to DSS 51 within the constraints of geographical location and station equipment. Because AFETR support was withdrawn from the test and also because of problems with simulation data, the objectives of this test were not fully realized. DSS 72 performance was judged adequate to support future tests and *Surveyor II*.

h. SFOF/DSN/AFETR integration (class C-3.0) tests. The objective of this test was to exercise the total Space Flight Operations System in a simulated mission, emphasizing the sequential/simultaneous interactions between the SFOF, all DSS stations, and the AFETR.

Two of these tests were conducted. According to planning, each test was to be about thirty hours in duration and was to be conducted in two phases. The first test phase consisted of an 18-h mission period from prelaunch through the midcourse maneuver. The second test phase consisted of the 12-h mission period beginning about touchdown minus 5½ h through lunar operations.

Phase II of the first test was accomplished in a manner that met all the test objectives; however, various problems caused phase II of this test to fall short of test objectives. As a result of these problems, the pre-test countdown between the SFOF and DSS 11, and the conduct of the pre-launch portion of the test, was unsuccessful. A commercial power failure at the SFOF eventually caused the pre-lunar part of phase II to be cancelled. Lunar operational tests were performed and SPAC objectives were met.

Phase I of the second C-3.0 test was accomplished with most objectives achieved. However, the computation of the midcourse maneuver was faulty and considerable time delay resulted. The test was halted for nearly an hour to permit computation of the midcourse in non-real time. One result was that Optional Sequence 24 (earth picture TV sequence) was not performed. Phase II of this test, which was to be lunar operation without terminal descent, was cancelled by the SFOD.

i. SFOF/DSS/AFETR operational readiness (class C-5.0) test. The objective of this test was to provide a final preflight verification and demonstration of the adequacy of personnel proficiency and ground equipment capability to meet the requirements of the mission. This test was similar to the C-3.0 test; the same test profile and participation requirements were applied.

One C-5.0 test was scheduled and performed. Phase II of this test had been extended to include approximately nine hours of lunar optional sequence testing. However, the lunar optional portion of the test was subsequently cancelled by the SFOD. Also prior to the test, requirements for an earth picture after midcourse was cancelled. In general, the objectives of this test were achieved for the support of *Surveyor II* mission.

Table 99 gives a complete summary of tests conducted prior to the *Surveyor II* mission launch.

j. Engineering verification tests. Engineering verification tests were conducted in September 1966 at DSSs 11, 12, 14, 51, 71, and 72. These tests confirmed that the participating stations were in the functional configuration specified for the *Surveyor II* mission. Results of the Engineering tests are given in Table 100.

Table 99. Summary of tests conducted prior to *Surveyor II* mission launch

	August				September			
	Week of							
	7	14	21	28	5	12	19	26
1. B-1.6 SFOF/DSS 72 compatibility test (5-h test)			▲					
2. C-1.5 SFOF/DSS 72 integration test (15-h test)				▲				
3. C-3.0 SFOF/DSS/AFETR integration test, 32 h over two dates (twice)					▲▲	▲▲		
4. C-5.0 SFOF/DSS/AFETR operational readiness (32 h over two dates)							▲▲[a]	

[a]Scheduled, but subsequently cancelled

Table 100. Engineering verification test results

Test: receiver thresholds

A Maser on Receiver 1

B Paramp, SCM

C Paramp on Receiver 2

D Paramp, SAA

Station	Unit	Expected, °K	Actual, °K	
DSS 11	A	55 ±10	45.6	
	B			
	C	270 ±50	310.0	
	D			
DSS 42	A	55 ±10	40.0	
	B			
	C	270 ±50	250.0	
	D			
DSS 61	A			
	B	N/A		
	C			
	D			
DSS 51	A	55 ±10	43.7	44.5
	B			
	C	320 ±50	305.0	370.0
	D			
DSS 72	A			
	B	270 ±50	251.8	
	C			
	D	270 ±50	290.5	
DSS 71	A	217.5 ±300	201.6	
	B			
	C	210.0	185.6	
	D			
DSS 14	A	28 ±5	30.1	
	B			
	C			
	D			

Table 100 (contd)

Test: receiver thresholds

A Receiver 1 12 Hz Maser

B Receiver 1 152 Hz Maser

C Receiver 2 12 Hz Paramp

D Receiver 2 152 Hz Paramp

Station	Unit	Expected, dBmW		Actual, dBmW	
DSS 11	A	$-170.8\ ^{+1.4}_{-1.2}$		−173.0	
	B	$-159.8\ ^{+1.4}_{-1.2}$		−166.0	
	C	$-163.9\ ^{+1.4}_{-1.2}$		−165.0	
	D	$-152.9\ ^{+1.4}_{-1.2}$		−156.0	
DSS 42	A	$-170.8\ ^{+1.4}_{-1.2}$		−172.5	
	B	$-159.8\ ^{+1.4}_{-1.2}$		−163.5	
	C	$-163.9\ ^{+1.4}_{-1.2}$		−165.0	
	D	$-152.9\ ^{+1.4}_{-1.2}$		−156.0	
DSS 61	A				
	B	N/A			
	C				
	D				
DSS 51	A	$-170.0\ ^{+1.4}_{-1.2}$	$-159.0\ ^{+1.4}_{-1.2}$	−171.5	−160.5
	B	$-163.9\ ^{+1.4}_{-1.2}$	$-152.9\ ^{+1.4}_{-1.2}$	−161.5	−152.5
	C	-170.0 ± 1		−171.0	
	D	-162.0 ± 1		−160.5	
DSS 72					
Receiver No. 1					
Paramp (SCM)					
12 Hz	A	−163.9		−167.0	
152 Hz	B	−152.9		−155.0	
Receiver No. 2					
Paramp (SAA)					
12 Hz	C	−162.9		−166.0	
152 Hz	D	−151.9		−154.0	
DSS 71	A	−158.0		−149.0	
	B	−148.0		−140.0	
	C	−158.0		−148.0	
	D	−148.0		−139.0	
DSS 14	A	-170.8 ± 1.4		−172.0	
	B	-159.8 ± 1.4		−164.0	
	C	(500 Hz) -166.0 ± 2 (200 Hz) -160.0 ± 2		−167.0 −163.0	
	D	(700 Hz) -155.0 ± 2		−156.0	

Table 100 (contd)

Test: signal levels for normal tracking performance on maser

A Maximum Receiver 1 (Saturation)
B Maximum Receiver 2 (Saturation)
C Minimum Receiver 1 HA
D Minimum Receiver 1 Dec

Station	Unit	Expected, dBmW	Actual, dBmW
DSS 11	A	> -90	-70
	B	> -90	
	C	$-161\ ^{+0}_{-3}$	-162
	D	$-161\ ^{+0}_{-3}$	
DSS 42	A	> -90	-70
	B		
	C	$-161\ ^{+0}_{-3}$	-162
	D		
DSS 61	A		
	B	N/A	
	C		
	D		
DSS 51	A	> -85	-84
	B	> -85	-94
	C	-160 ± 1	-158
	D	-160 ± 1	-158
DSS 72	A	> -90	-81
	B		
	C	$-161\ ^{+0}_{-3}$	-165
	D		
DSS 71	A	> -90	-61
	B		
	C		
	D		
DSS 14	A		
	B		
	C		
	D		

Table 100 (contd)

Test: receiver VCO frequencies for ±6 V

A Receiver 1
B Receiver 2
C Receiver (Spare)
D —

Station	Unit	Expected		Actual	
		Frequency, MHz	Variation, Hz	Frequency, MHz	Variation, Hz
DSS 11	A	23.385417	±900	23.385446	+959 −845
	B	23.385417	±900	23.385454	+940 −849
	C	23.385417	±900	23.385477	+860 −954
	D				
DSS 42	A	23.385417	±900	23.385363	+880 −840
	B	23.385417	±900	23.385307	+881 −885
	C	23.385417	±900	23.385409	+921 −919
	D				
DSS 61	A	N/A			
	B				
	C				
	D				
DSS 51	A	23.593750	±900	23.593744	−1087 +1031
	B	23.593750	±900	23.593747	−920 +930
	C	23.593750	±900	20.788950	+1541 −1182
	D	23.593750	±900	29.786624	+1587 −1345
DSS 72	A	23.385417	±2400	23.385376	+2454 −2333
	B	23.385417	±900	23.385420	+913 −869
	C	23.385417	±2400	23.385418	+2416 −2354
	D	23.385417	±900	23.385406	+891 −873
DSS 71	A	23.385417	±900	23.385392	+836 −835
	B	23.385417	±900	23.385419	+848 −858
	C				
	D				
DSS 14	A	23.385417	±2300	23.385417 +2454 −2555	
	B	23.385417	±2300	23.385417 +2483 −2437	
	C				
	D				

Table 100 (contd)

Test: exciter VCO frequencies for ±6 V

A Prime exciter

B Spare exciter

C —

D —

Station	Unit	Expected		Actual	
		Frequency, MHz	Variation, Hz	Frequency, MHz	Variation, Hz
DSS 11	A	22.013672	±900	22.013645	+904 −961
	B			22.013697	+924 −875
	C				
	D				
DSS 42	A	22.013672	±900	22.013673	+813 −820
	B			22.013667	+858 −853
	C				
	D				
DSS 61	A	N/A			
	B				
	C				
	D				
DSS 51	A	22.013672	±900	22.013670	+596 −587
	B			22.013725	+821 −819
	C				
	D				
DSS 72	A	22.013672	±900	22.013760	+900 −963
	B			22.013768	+850 −925
	C				
	D				
DSS 71	A	22.013672	±900	22.013643	+975 −958
	B			22.013616	+873 −866
	C				
	D				
DSS 14	A	N/A		N/A	
	B				
	C				
	D				

Table 100 (contd)

Test: angle snap-ons at −100 dBmW

A SCM low speed 0.05 Hz BW +0.1 deg offset

B SCM low speed 0.05 Hz BW −0.1 deg offset

C SAA high speed 0.2 Hz BW +1.0 deg offset

D SAA high speed 0.2 Hz BW −1.0 deg offset

Station	Unit	Expected, deg	Actual, deg	
			HA-Az	Dec E1
DSS 11	A	35 ±5%, 5.0 ±0.5 s, 14.0 ±2.0 s	46%	35%, 3.4 s, 1.3 s
	B	35 ±5%, 5.0 ±0.5 s, 14.0 ±2.0 s		
	C	35 ±5%, 1.5 ±0.2 s, 4.0 ±0.5 s	40%, 3.0 s, 4 s	52%, 2.0 s, 4.2 s
	D	35 ±5%, 1.5 ±0.2 s, 4.0 ±0.5 s		
DSS 42	A	35 ±5%, 5.0 ±0.5 s, 14.0 ±2.0 s	30%, 5.5 s, 13.0 s	30%, 5.0 s, 14.0 s
	B	35 ±5%, 5.0 ±0.5 s, 14.0 ±2.0 s	25%, 5.5 s, 14.0 s	30%, 5.0 s, 13.0 s
	C	35 ±5%, 1.5 ±0.2 s, 4.0 ±0.5 s	40%, 1.9 s, 3.4 s	35%, 1.5 s, 2.8 s
	D	35 ±5%, 1.5 ±0.2 s, 4.0 ±0.5 s	45%, 2.0 s, 3.7 s	45%, 1.3 s, 2.7 s
	A	N/A		
	B			
	C			
	D			
DSS 51	A	35 ±5%, 5.0 ±0.5 s, 14.0 ±2.0 s		
	B	35 ±5%, 5.0 ±0.5 s, 14.0 ±2.0 s	37%, 5.1 s, 14.5 s	35%, 4.6 s, 14.2 s[a]
	C	35 ±5%, 1.5 ±0.2 s, 4.0 ±0.5 s		
	D	35 ±5%, 1.5 ±0.2 s, 4.0 ±0.5 s	55%, 1.5 s, 3.8 s	50%, 1.8 s, 3.4 s[a]
DSS 72	A	40 ±5%, 0.2 ±0.05 s, 1.1 ±0.1 s	36%, 0.4 s, 5.7 s	55%, 0.2 s, 1.2 s
	B	40 ±5%, 0.2 ±0.05 s, 1.1 ±0.1 s	37%, 0.4 s, 3.5 s	55%, 0.4 s, 1.0 s
	C	40 ±5%, 1.3 ±0.1 s, 5.0 ±0.2 s	30%, 2.0 s, 4.0 s	40%, 2.0 s, 4.3 s
	D	40 ±5%, 1.3 ±0.1 s, 5.0 ±0.2 s	30%, 1.8 s, 5.3 s	40%, 2.1 s, 4.5 s
DSS 71	A	N/A		
	B			
	C			
	D			
DSS 14	A	N/A		
	B			
	C			
	D			

[a]Average of + and − offsets.

Table 100 (contd)

Test: measure boresight alignment

A $|HA| + |Dec|$

B —

C —

D —

Station	Unit	Expected, deg	Actual, deg
DSS 11	A B C D	0.03 ±0.02	0.022
DSS 42	A B C D	0.03 ±0.02	0.037
DSS 61	A B C D	N/A	
DSS 51	A B C D	0.03 ±0.02	0.03
DSS 72	A B C D	0.10 ±0.02	0.110 SAA, 0.012 SCM
DSS 71	A B C D	N/A	
DSS 14	A B C D	N/A	

Table 100 (contd)

Test: measure boresight angle—SCM

A HA—90 dBmW low speed 0.1 Hz

B Dec—90 dBmW low speed 0.1 Hz

C HA—130 dBmW low speed 0.025 Hz

D Dec—130 dBmW low speed 0.025 Hz

Station	Unit	Expected, deg	Actual, deg
DSS 11	A	0.000	0.010
	B	0.004	0.006
	C	0.000	0.060
	D	0.004	0.070
DSS 42	A	59.058	59.062
	B	30.536	30.529
	C	59.042	59.062
	D	30.532	30.530
DSS 61	A	N/A	
	B		
	C		
	D		
DSS 51	A	315.248	
	B	048.298	
	C	315.242	
	D	048.298	
DSS 72	A		315.980
	B		001.248
	C		315.980
	D		001.248
DSS 71	A	N/A	
	B		
	C		
	D		
DSS 14	A	N/A	
	B		
	C		
	D		

Table 100 (contd)

Test: measure boresight angle—SAA

A HA—100 dBmW high speed 0.2 Hz
B Dec—100 dBmW high speed 0.2 Hz
C HA—130 dBmW high speed 0.2 Hz
D Dec—130 dBmW high speed 0.2 Hz

Station	Unit	Expected, deg	Angle, deg
DSS 11	A	N/A	
	B		
	C		
	D		
DSS 42	A	50.962	59.935
	B	34.962	35.019
	C	59.944	59.914
	D	35.014	35.059
DSS 61	A	N/A	
	B		
	C		
	D		
DSS 51	A	061.868	
	B	043.932	
	C	061.906	
	D	043.924	
DSS 72	A		316.214
	B		359.764
	C		316.241
	D		359.845
DSS 71	A	N/A	
	B		
	C		
	D		
DSS 14	A	N/A	
	B		
	C		
	D		

Table 100 (contd)

Test: boresight angle change

A SCM, −90 to −130 dBmW

B —

C SAA, −100 to −130 dBmW

D —

Station	Unit	Expected, deg	Actual, deg	
			HA	Dec
DSS 11	A	< 0.01		
	B			
	C	< 0.1		
	D			
DSS 42	A	< 0.01	0.000	0.001
	B			
	C	< 0.1	0.021	0.040
	D			
DSS 61	A			
	B	N/A		
	C			
	D			
DSS 51	A	< 0.01		
	B			
	C	< 0.1		
	D			
DSS 72	A		00	00
	B			
	C		0.027	0.081
	D			
DSS 71	A			
	B	N/A		
	C			
	D			
DSS 14	A			
	B	N/A		
	C			
	D			

Table 100 (contd)

Test: receiver angle errors, paramp on SAA
offset ±2 deg signal level −110 dBmW
A Polarization 0 deg
B Polarization 90 deg
C Polarization 180 deg
D Polarization 270 deg

Station	Unit	Expected, mV	Actual, mV		
			+2 deg	Average	−2 deg
DSS 11	A	−210 ±70	−270	260	165
	B		−168	168	210
	C	+210 ±70	−270	260	165
	D		−165	165	210
DSS 42	A	−210 ±5			
	B				
	C	+210 ±15			
	D				
DSS 61	A				
	B	N/A			
	C				
	D				
DSS 51	A	−210 ±70			
	B				
	C	+210 ±70			
	D				
DSS 72	A	−210 ±5	420		
	B		410		
	C	+210 ±15	420		
	D		410		
DSS 71	A				
	B	N/A			
	C				
	D				
DSS 14	A				
	B	N/A			
	C				
	D				

Table 100 (contd)

Test: receiver angle errors, maser on SCM
offset ±0.1 deg signal level −110 dBmW
A Polarization 0 deg
B Polarization 90 deg
C Polarization 180 deg
D Polarization 270 deg

Station	Unit	Expected, mV	Actual, mV			
			HA		Dec	
			+	−	+	−
DSS 11	A	−200 ±50	260	260	165	168
	B		168	168	210	210
	C	+200 ±50	260	260	165	165
	D		165	165	210	210
DSS 42	A	−200 ±50	195	200	170	185
	B		165	175	210	220
	C	+200 ±50	200	205	170	185
	D		165	170	210	220
DSS 61	A	N/A				
	B					
	C					
	D					
DSS 51	A	−200 ±50	0.38	0.36	0.41	0.37
	B		0.37	0.34	0.37	0.38
	C	+200 ±50	0.37	0.36	0.43	0.37
	D		0.37	0.34	0.37	0.37
DSS 72	A	N/A				
	B					
	C					
	D					
DSS 71	A	N/A				
	B					
	C					
	D					
DSS 14	A	N/A				
	B					
	C					
	D					

Table 100 (contd)

Test: doppler counter test			
Station	**Unit**	**Expected, Hz**	**Actual, Hz**
DSS 11	A B C D	600,000,000 ±1	600,000,000
DSS 42	A B C D	1,200,000,000 ±1	1,200,000,000
DSS 61	A B C D	N/A	
DSS 51	A B C D	105,583,710 ±1	105,583,001
DSS 72	A B C D	600,000,000 ±1	600,000,001
DSS 71	A B C D	N/A	
DSS 14	A B C D	N/A	

Table 100 (contd)

Test: doppler jitter tests
P-P DPE
A Receiver 1
B —
C Receiver 2
D —

Station	Unit	Expected (P-P), deg	Actual (P-P), deg
DSS 11	A	30	10
	B		
	C		14
	D		
DSS 42	A	30	14
	B		
	C		
	D		
DSS 61	A		
	B	N/A	
	C		
	D		
DSS 51	A	30	15
	B		
	C		
	D		
DSS 72	A	30	26
	B		32
	C		
	D		
DSS 71	A	30	34.8
	B		
	C	30	36.43
	D		
DSS 14	A		
	B	N/A	
	C		
	D		

Table 100 (contd)

Test: modulation and phase detector sensitivities

A Modulation voltage for 10-dB carrier suppression

B —

C TLM phase detector voltage for 5-dB carrier suppression

D FR-1400 input for above condition

Station	Unit	Expected, Vrms	Actual, Vrms
DSS 11	A	$0.39\ ^{+0.03}_{-0.00}$	0.38
	B		
	C	0.224 ±0.05	0.254
	D	2.2 ±0.5	2.46
DSS 42	A	$0.39\ ^{+0.03}_{-0.00}$	0.385
	B		
	C	0.224 ±0.05	0.225
	D	2.2 ±0.5	2.3
DSS 61	A	N/A	
	B		
	C		
	D		
DSS 51	A	N/A	
	B		
	C		
	D		
DSS 72	A	$0.39\ ^{+0.03}_{-0.00}$	0.41
	B		
	C	0.224 ±0.050	0.282
	D	2.2 ±0.5	2.0
DSS 71	A	$0.39\ ^{+0.03}_{-0.00}$	0.387
	B		
	C	0.224 ±0.050	0.195
	D	2.2 ±0.5	0.175
DSS 14	A	N/A	
	B		
	C		
	D		

X. *Surveyor II* T&DS Flight Support

A. General

During the near-earth flight phase of the mission, various information sources were monitored in order to obtain an early evaluation of the status of the mission which, in turn, aided in the initial acquisition by the deep space stations of the spacecraft and provided useful information for the conduct of subsequent spaceflight operations. Consequently, this section is limited to summarizing those activities directly related to T&DS flight support.

The deep space phase of T&DS Support for the *Surveyor II* mission is also herein discussed, emphasizing the role of the DSN.

The prime functions of telemetry recovery and command generation were accomplished by the DSN stations. As stated, the DSN stations utilized in a prime capacity were Goldstone, California (DSS 11); Johannesburg, South Africa (DSS 51); and Canberra–Tidbinbilla, Australia (DSS 42). In addition, Ascension Island (DSS 72) was committed for a two-way lock during their first pass. Madrid, Spain (DSS 61) was activated on a priority basis in real time because of bad communications that existed between DSS 51 and the SFOF in Pasadena during visibility at DSS 51. The CDC equipment at DSS 61 and DSS 72 was on-line in a passive backup role during their mission visibility periods.

Table 101 gives a history of the *Surveyor II* mission milestones.

B. Countdown

During the countdown, a number of problems occurred with some of the T&DS facilities supporting the mission. Utilizing the launch-hold criteria, it was concluded that none of these problems constituted a hold, and consequently, the Mission Director was so advised. However, it should be noted that all of these problems had cleared up by launch. There were two apparent problems with the launch vehicle: (1) an indication of low temperature in the *Centaur* H_2O_2 system; and (2) the *Atlas* LOX boil-off valve failed to close; this caused 33 min of unscheduled hold plus 3 min of recycle time. These delays resulted in the launch occurring just 9.2 s before the close of the Sept. 20 window. Table 103 gives a summary of T&DS countdown problems.

The countdown began on Sept. 20 with the planned window opening to occur at 11:56 GMT at a launch azimuth of 95 deg. It was also planned to absorb the 10-min difference between this window and the Sept. 20 window by adding 10 min to the 60-min built-in hold at $T - 90$ min.

The planned window length for this day was 36 min. This window allowed for 60 s of post-MECO tracking by Antigua with elevation angles $\geqq$ ½ deg and at least 30 s of post-MECO tracking with elevation angles $\geqq 2$ deg. It also provided adequate VHF and S-band telemetry coverage of the near-earth flight.

Table 102 summarizes the T&DS facilities problems during the countdown. The Mission Director was advised

Table 101. *Surveyor II* mission milestones

Event	Date	Time	
		PDT[a]	Time after launch
Launch	Sept. 20, 1966	5:31:59	0
Injection		5:43:26	11 min 27 s
Separation		5:44:32	12 min 33 s
Automatic sun acquisition completed		5:48:14	16 min 15 s
Automatic solar panel deployment completed		5:54:59	23 min
Spacecraft visibility at Johannesburg begins		5:56:59	25 min
Initial DSIF acquisition (2 way-lock) confirmed		6:05:59	34 min
First ground command sequence initiated		6:16:33	45 min
Canopus verification initiated		11:37:34	6 h 6 min
Canopus acquisition completed		12:09:38	6 h 38 min
First premidcourse attitude maneuver initiated		21:44:00	16 h 12 min 1 s
Midcourse thrust executed		21:59:59	16 h 28 min

[a]Pacific daylight time — add 7 h for determining GMT.

that none of these problems constituted a hold condition. The referenced table shows that all of these problems had cleared up by launch minus 7 min.

Table 102. T&DS countdown problems summary

GMT	T — time, min	Problem
0731	T — 180	RF propagation to *Sword Knot* fair (some electrical activity)
0857	T — 94	One voice circuit to DSS 72 down
0901	T — 90	Starting 70-min built-in-hold
0911	T — 90	Bermuda radar down
0915	T — 90	Elevation encoder problem with Bermuda radar; estimated operational by 0940 GMT
0917	T — 90	Bermuda radar up
0919	T — 90	Voice circuit to DSS 72 up
0953	T — 90	One TTY circuit to DSS 72 down
1011	T — 90	Resuming count (end of built-in-hold)
1029	T — 72	DSS 72 TTY circuit up
1046	T — 55	Trinidad radar down—coherent memory filter problem—no estimate
1105	T — 36	Trinidad radar GO
1108	T — 33	RF propagation fade—*Coastal Crusader* HF direct and relay paths both out
1115	T — 26	Relay path from *Coastal Crusader* through Antigua now good
1120	T — 21	HF direct and relay paths from *Crusader* both out again
1136	T — 5	Starting 15-min built-in-hold
1137	T — 5	One TTY circuit to DSS 42 down
1138	T — 5	Data paths with *Crusader* now good. Prime paths established as HF direct from Ascension and both ships
1140	T — 5	DSS 42 TTY circuits all up
1150	T — 5	High-speed data line from DSS 72 marginal
1151	T — 5	Hold extended for *Centaur* H_2O_2 low temperature indication
1158	T — 5	Resuming count
1159	T — 5	One TTY circuit to DSS 42 down
1201	T — 1 min, 55 s	Hold and recycle to T — 5. *Atlas* LOX boil-off valve did not close
1204	T — 5	DSS 72 circuits are all up
1212	T — 5	Heavy storm descended on Canberra area—might lose DSS 42
1219	T — 5	*Atlas* LOX boil-off valve OK—must replenish LOX supply
1221	T — 5	DSS 51 voice circuit down
1225	T — 5	DSN and MSFN GO
1227	T — 5	Resumed count. LOX still not up to flight level
1229	T — 2 min, 35 s	*Atlas* LOX topping secured
1230	T — 90 s	Range clear to launch
1232	T — 0	Liftoff at 12:31:59.824 GMT; azimuth, 114.361 deg

During the holds for launch vehicle problems, discussions were held with LeRC–*Centaur* Project. Both vehicle problems cleared up, but there was concern that the liquid oxygen supply on board, which had dropped below the acceptable level, could be replenished before the window closed. It was decided to pick up the count at the last possible minute and continue to tank with the hope that the level would be acceptable by the close of the window. This hope was realized and the launch occurred just 9.2 s short of the window closing.

C. Liftoff to DSIF Acquisition

The *Surveyor II* mission spacecraft was launched on a direct ascent lunar intercept trajectory at 12:31:59.824 GMT on September 20, 1966, at a launch azimuth of 114.361 deg. DSS 11 (Goldstone-Pioneer), DSS 42 (Canberra, Australia), DSS 51 (Johannesburg, South Africa) were designated as the prime tracking stations for *Surveyor II* with DSS 72 (Ascension Island) as backup. These stations provided continuous tracking data coverage from shortly after injection until loss of signal occurred at approximately 09:35 GMT on September 22, 1966.

During the flight, the occurrence of mark events was reported in real time by the AFETR and MSFN, followed later with a report of the times at which they occurred. The small deviations of the mark times from nominal were discussed but were judged to be well within the 3-σ dispersions. The *Centaur* burn time was about 3.4 s longer than expected; however, similarly longer *Centaur* burn times had been experienced on previous flights. Consequently, the powered flight trajectory was considered to be quite nominal.

Launch vehicle telemetry was retransmitted in real time from all stations down to Antigua until the spacecraft switched to high power, at which time the spacecraft S-band data were sent up the sub-cable in real time and the real-time retransmission of launch vehicle data ceased. The launch vehicle real-time data were displayed in the telemetry laboratory in building AE, while the spacecraft data were displayed in building AO and retransmitted to the SFOF. A real-time analysis of the launch vehicle data was reported and monitored over a net available in building AO. A commentary on the range safety plots was also reported in real time. After the loss of real-time launch vehicle data, a discussion was held with the telemetry analyst in building AE. This discussion, together with the other real-time commentaries indicated a nominal powered flight of the space vehicle. The normality of the powered flight was confirmed by the

real-time reports of nominal acquisition times by each tracking station.

Four min after MECO, the RTCS had computed the first orbit based on Antigua radar data. This orbit, although considered a *fair* fit, further corroborated a nominal powered flight and injection into a lunar transfer orbit had occurred. A mapping of this orbit to lunar encounter was next made by the RTCS. This mapping of the *fair* fit orbit indicated a **B**-vector miss of 4849 km and a radius of closest approach of 2435 km.

For the remainder of the near-earth flight phase, the evaluation of the status of the flight was dependent upon the RTCS orbital calculations, reports of spacecraft performance, and tracking stations acquisition times and performance. The RTCS computed six orbits, five transfer orbits and one *Centaur* postretro orbit, using different data sources. After the first orbit based on Antigua data, the RTCS computed an orbit based on real-time *Centaur* guidance data. The next orbit was a recursive solution using Antigua data, which improved the first orbit. Next was a multistation solution using Antigua C-band data and Trinidad skin-track data. These last two orbits were computed on the RTCS B computer while computer A was attempting to process the Ascension Island and Pretoria post-retro data. However, the Ascension Island and Pretoria data were difficult to process because of the many data points which were *off-track*.[14]

Although DSS 51 had acquired the spacecraft in one-way within 17 s of its predicted rise and good two-way data from DSS 51 was being transmitted about 10 min later, the RTCS delayed processing the DSS 51 data until it had finished computing the postretro orbit. The reason for this delay was based on two information sources which indicated a slight possibility that the *Centaur/Surveyor* separation had not been normal. These sources were the Trinidad tracking reports and the intermittent tracking data from Ascension Island and Pretoria. The Trinidad radar is capable of tracking more than one object. When it was reported that this radar did not see separation, there was some concern. The intermittent data from Ascension and Pretoria was thought to have possibly been by a tumbling vehicle. However, it was later learned that the Trinidad aspect angle may have prevented it from observing separation. Furthermore, NRT voice reports on the *Centaur* roll, pitch, and yaw rate gyros confirmed a stable vehicle had been observed at Ascension Island. Thus, the concern about a poor separation proved to be false.

[14]The intermittent tracking by Ascension Island and Pretoria was attributed to a *weak beacon.*

The postretro orbit, which was finally computed, represented a *poor* fit of the data. An orbit was then computed using the DSS 51 HA/Dec and doppler data. The velocity residuals on this orbit were on the order of 0.005 ft/s.

With the exception of the orbit based on the guidance telemetry data, all of the orbits calculated by the RTCS were mapped to lunar encounter. All of the RTCS orbits and mappings are summarized in Table 103. For purposes of comparison, two orbits by the Mission Operations System (MOS) are listed in this table. These orbits are the MOS orbit based on the Antigua data and the best MOS pre-midcourse orbit computed after the mission. It should also be noted that Table 104 shows the *poor* fit postretro orbit of the *Centaur* mapped to a radius-of-closest approach of 5052 km and a B-plane miss of 8106 km. However, the uncertainties about this orbit prevented a firm conclusion being drawn about the *Centaur* orbit. Such conclusions must await the post-flight processing of the guidance telemetry data recorded at Ascension Island and Pretoria.

Figure 92 shows the *Surveyor II* earth track provided by the various stations involved.

D. DSIF Acquisition to Midcourse Maneuver

All of the DSIF prime and engineering practice stations reported *go* status during the countdown. All measured station parameters were within nominal performance specifications, and communications circuits were up. Launch occurred at 12:31:59, 824 GMT on a launch azimuth of 114.361 deg.

Predictions indicated *Surveyor II* rise at DSS 51 at 12:55:00 GMT, September 20, 1966. DSS 51 reported good one-way data at 12:55:17, autotrack on the SCM (antenna main beam) at 13:00:07, and good two-way data at 13:05:07; thus, DSS 51 required 10 min from spacecraft rise to get good two-way data. Had the acquisition been optimum, DSS 51 could have been in good data, two-way lock at approximately 12:58, or about 3 min after spacecraft rise. By way of comparison, DSS 51 reported good data and two-way lock less than 4 min after spacecraft rise in the *Surveyor I* mission.

This delay of about 6 min from an optimum acquisition was due partly to a hardware problem (the SCM monitor-receiver was initially saturated by high signal strength) and partly to a procedural problem at DSS 51 precipitated by the hardware problem.

Table 103. RTCS orbits and encounter parameters

Orbit No.	Epoch 9/20/66, GMT	Data source	Orbital elements					
			Eccentricity	*Inclination,*[a] deg	C_3,[b] km^2/s^2	LAN,[c] deg	APF,[d] deg	True anomaly (TA), deg
1	12:43:44.7	Antigua 91. 8 radar	0.9816531	33.42406	−1.11	340.2712	135.51074	16.072
2	12:43:30.0	*Centaur* guidance data	0.9837955	33.40954	−0.98	340.3491	135.61014	14.633
3	12:47:48.0	Antigua data recursive solution	0.9826815	33.42760	−1.05	340.2667	135.79814	36.707
4	12:46:03.9	Antigua and Trinidad radars	0.9835357	33.48421	−1.00	340.2100	135.78328	28.265
6	12:43:29.8	DSS 61 HA/Dec and doppler	0.9835590	33.43489	−1.00	340.2584	135.68269	14.539
5[e]	13:01:18.0	Ascension 12.18 and Pretoria 13.16 radars	0.9785863	33.45231	−1.30	340.2969	135.73180	79.677

Premidcourse encounter conditions

No.	Injection epoch, 9/20/66, GMT	Encounter epoch, 9/23/66, GMT	Time of flight	B,[f] km	RCA,[g] km	B • TQ,[h] km	B • RQ,[i] km	B • TT,[j] km	B • RT,[k] km	LAT,[l] deg	LON,[m] deg
1	12:43:44.7	5:14:09.3	2:16:30:24.6	4849.0525	2434.8664	4471.9895	−1875.7319	4697.4317	−1203.0983	11.617893	92.109330
3	12:47:48.0	4:09:14.2	2:15:21:26.2	2099.0335	582.36382	1815.8081	−1052.9874	1946.2466	−786.17160	15.387094	9.0443203
4	12:46:04.0	3:36:43.0	2:14:50:39.0	1368.5010	263.97458	1331.5226	−315.97852	1362.5589	−127.39056	2.5676573	355.02471
6	12:43:29.8	3:21:45.1	2:14:38:15.2	1342.9242	256.94610	1331.0906	−177.88501	1342.8975	8.4698698	−0.12938482	354.88423
—[n]	12:43:13.67	3:19:53.434	2:14:36:39.8	1134.48	—	—	—	1131.39	−83.60	1.744	350.366
—[o]	12:43:13.67	3:19:54.426	2:14:36:40.8	1333.9162	—	1321.7977	−179.38803	1333.9064	5.1242575	−0.051930781	354.70985
5[e]	13:01:18.0	7:47:55.5	2:18:46:37.5	8105.8635	5052.4335	6875.7939	−4292.8407	7456.1152	−3179.8379	20.923352	79.733587

[a] Inclination of the orbital plane to the equatorial plane.
[b] C_3, twice the energy per unit mass.
[c] Longitude of the ascending node (LAN).
[d] Argument of pericenter (APF).
[e] *Centaur* postretro orbit; data sets include many *off-track* points.
[f] B, magnitude of the impact parameter.
[g] RCA, *magnitude* of the closest approach vector.
[h] B • TQ, projection of the impact parameter B upon the vector T.
[i] B • RQ, projection of the impact parameter B upon the vector R.
[j] B • TT, projection of the impact parameter B upon the vector T.
[k] B • RT, projection of the impact parameter B upon the vector R.
[l] Probe selenocentric latitude (LAT).
[m] Probe selenocentric east longitude (LON).
[n] MOS/FPAC check orbit using Antigua data (6-s sample rate).
[o] Best MOS/FPAC premidcourse orbit (computed after mission).

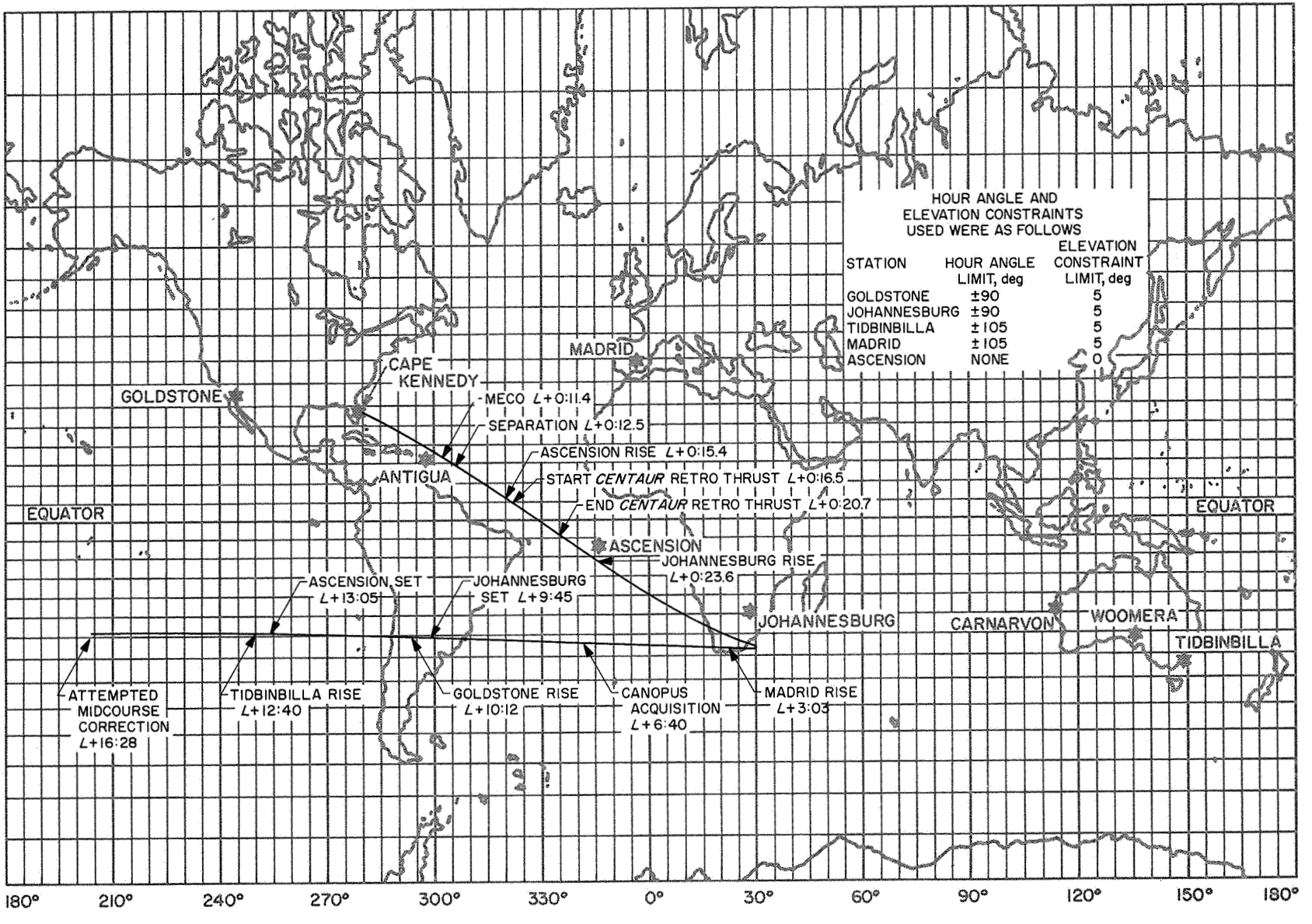


Fig. 92. *Surveyor II* earth track

The spacecraft was initially tracked by DSS 71 which had been in one-way lock since 12:00. Later as stated above, DSS 51 acquired the spacecraft at 12:55:17 but experienced difficulty transferring from the SAA antenna to the SCM. The station utilized the monitor receiver spectrum analyzer output to obtain a more accurate response.

Ascension Island, DSS 72, acquired spacecraft control at 16:50, but returned it to DSS 51 at 17:45 to conduct threshold and bit-error tests in the CDC area. At 22:00, due to a spacecraft visibility gap between DSS 51 set and DSS 11 rise, control of the spacecraft was returned to DSS 72, and the station had to prepare for acquisition in real time.

At 23:05, after Pioneer DSS 11 rise, spacecraft control was transferred there. Echo, DSS 12, and Mars, DSS 14, stood by as backup for transmitting and receiving, respectively. The station conducted power level tests by decreasing power from 10 kW in 2-db increments and recorded the resulting power levels. Spacecraft receiver B threshold was reached at 47 W. Three station transmitter shutdowns occurred during the pass, but in each instance power was returned immediately.

E. Midcourse Maneuver to Mission Termination

The midcourse maneuver was performed at 05:00 on September 21 and data from DSS 11, DSS 14, and DSS 42 quickly indicated that the spacecraft was tumbling. Telemetry indicated that vernier engine No. 3 had not fired. At 05:51, the spacecraft was transferred to DSS 42, which had earlier experienced difficulty in obtaining lock due to an angle error in predict set 25. The station attempted to start vernier engine No. 3 by performing two 2-s vernier engine thrusting sequences. However, both attempts failed.

Johannesburg, DSS 51, took control of the spacecraft at 15:00 to begin the station's second pass. Throughout the pass the station had lock difficulties due to spacecraft tumbling, but, with the exception of a few short periods, lock was maintained. Due to communication difficulties, the spacecraft command was transferred to Robledo, DSS 61, which then acquired and set up for command within 15 min.

Pioneer, DSS 11, acquired at 23:09. Because telemetry indicated oxidizer flow, the vernier engine malfunction was analyzed as a stuck fuel flow regulator valve. As a result of this analysis, a decision was made to pulse fire the vernier engines in an attempt to free the stuck valve. This action was conducted by DSS 11 which hourly performed a sequence of five vernier engine burns of 0.2-s duration followed by a single burn of 2.0-s duration. Vernier engine No. 3 still did not ignite.

The spacecraft was transferred to Tidbinbilla, DSS 42, at 06:05 on September 22, and the station performed several command sequences. These included a solar panel stepping sequence and a 20-s vernier engine burn. The final command sequence performed was: (1) dump helium and calibrate the transducer, (2) turn on the RADVS power to verify operation at low-battery voltage, and (3) fire the main retro engine. The last command was calculated to impart a 10-g load on the spacecraft in an attempt to free the stuck valve. However, after the firing, all spacecraft signals abruptly terminated. At 09:56 on September 22, 1966, DSS 42 terminated spacecraft search and the *Surveyor II* mission was concluded.

F. Summary of DSIF Station Operations

The summary of the DSIF station operations is presented in Table 104. Refer to preceding Table 83 for the Ground mode indicator. Section V-H describes the various columnar heads. The only major differences are that: (1) Table 104 has no TV-pictures-received column, (2) DSS 12 (not listed in Table 83 but present in this Table 104) is Echo at Goldstone, Calif., and (3) not as many ground modes are listed.

G. Space Flight Operations Facility

1. Communications. For the *Surveyor II* mission, the DSN Intracommunications System (ICS) provided the capability of receiving, switching, and distributing, to designated areas or users within the SFOF, all types of information required for space flight operations. The system included all voice communications capabilities within the SFOF, CCTV, TTY, HSD, and data received over the microwave channels.

In general, the ICS operated well within the expected reliability parameters. No failure/problem reports (FPRs) related to the *Surveyor II* mission were filed against the communications system during the period September 19–22, 1966. There were five FPRs filed against communications for the period September 13–19, but none of these affected the mission. Most were communications patching errors at the SFOF and Goldstone communications facilities. Nine comm trouble tickets on SFOF communications equipment were generated during the *Surveyor II* mission.

Table 104. Summary of DSIF station operations

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time			
Launch							
71	263 263	12:31:59 12:35:07	1 Total	00:03:07 00:03:07	120.0 125.0 130.0		Station was in one-way lock from day 263 at 12:00. *Surveyor II* launch occurred at 12:31:59.8.
Launch Pass							
72	263 264	12:48:50 01:41:13	1 2 3 Total	00:06:22 01:54:46 10:33:35 12:34:43	095.0 142.7 151.5		Prior to track: Recorder A reproduce heads failed; optical boresight calibrations Station was in one-way lock from day 263 at 12:00. *Surveyor II* launch occurred at trajectory-and-acquisition computer program, to generate predicts with the interrange vector from AFETR. Station was released from track on day 263 from 20:34 to 21:19 and conducted threshold and bit error tests in CDC area. Accuracy of doppler counter hundred's digit was questionable. Timing circuit was suspected of malfunctioning. Spacecraft was transferred to DSS 51 on day 263 at 17:45, and to DSS 11 at 23:05.
51	263 263	12:55:07 22:20:07	1 2 4 5 Total	00:09:46 07:16:30 00:43:17 01:14:55 09:24:28	090.0 120.7 138.5	85	Hour angle cast brake jammed due to loose coupling pin. Brake unit was replaced. While tracking on SAA at slow rates, antenna seemed to oscillate. As a result spacecraft was not in main beam and SCM lockup was made difficult. Station utilized spectrum analyzer output from Microwave Subsystem monitor receiver for more accurate response. Digital printer printed incorrect figures in 100-Hz frequency column during 10-s printouts. Spacecraft was transferred to DSS 72 on day 263 at 16:50 and 22:00.
Pass No. 1							
11	263 264	22:50:40 06:00:20	1 2 3 Total	00:07:50 06:37:00 00:23:37 07:08:27	118.8 130.5 148.0	71	On day 263 at 23:21:40 and day 264 at 02:54:46, transmitter collector flow interlock caused transmitter to turn off briefly. Spacecraft was reacquired two-way after transmitter was reset. On day 264 from 01:37 to 02:06, power level test was conducted. Power was reduced in 2-dB increments and resulting power level recorded. Range covered was from 10 kW to 47 W at which point Receiver B threshold was reached. On day 264 at 02:05:50, during power level reduction sequence, technician on antenna lost balance as result of antenna tilt, accidentally tripped antenna power switch. Power was immediately restored and spacecraft was again reacquired two-way.

[a]Ground mode: refer to Table 83.

Table 104 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, −dBmW (max, avg, min.)	Total commands sent	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time			
Pass No. 1 (contd)							
11 (contd)							Midcourse maneuver thrust execution occurred at 05:00. At 05:01, reports indicated that the spacecraft was tumbling. Nonstandard commands were begun in an effort to stop the tumble. Tumble rate was calculated at 1 revolution/s. Telemetry indicated that Vernier engine No. 3 had not ignited. Spacecraft was transferred to DSS 42 at 05:51.
12	263 264						Station was on active standby with transmitter power during DSS 11 Pass 1.
14	263 264	22:49:32 06:06:20	1 3	00:06:59 07:05:54	127.0 132.2 137.5		After midcourse maneuver, station reported spacecraft was tumbling at a rate of 1 revolution/s. Station provided backup receiver and recording facilities.
42	264 264	02:33:22 15:48:54	2 3 Total	09:09:00 04:06:32 13:15:32	117.0 129.3 158.0	86	On day 264 at 02:30, during initial acquisition, both receivers were switched to the SCM/paramp configuration in an attempt to verify low signal level. When no signal was received, station returned to SCM/maser configuration. Lock was not obtained for first 30 min of track due to apparent angle errors in predict set 25. By searching around indicated predicts in both axes, station was finally able to obtain lock. However, signal was too weak for SAA. Errors were approximately +0.8 deg dec, and −0.4 deg HA. At 05:00, during midcourse maneuver, AGC on Sanborn chart recorder indicated 1-s cyclic variations of approximately 12 to 15 dB. Doppler readout cycled plus and minus 20 Hz during a 25-s period. At 07:28 and 07:49:58, commands were sent for 2-s vernier engine-thrusting sequences. In both attempts, engine No. 3 failed to fire. At 08:07, an estimate was made that 30 h of low power operation remained in the battery power supply. Spacecraft was transferred to DSS 51 at 15:00. During post-track calibrations, antenna declination brake seized. An estimate of 4-h down time was made.
Pass No. 2							
51	264 264	11:08:51 23:09:00	1 2 3 Total	00:12:02 07:05:02 04:42:39 11:59:43	120.0 140.0 150.0	101	On day 264 at 12:15, receiver dropped lock due to frequency variation of approximately 200 Hz. At acquisition, Receiver No. 2 was unable to lock due to spacecraft tumble. Receiver No. 1 was in marginal phase lock, even in 152-Hz loop bandwidth position. Net Control authorized modification to increase tracking loop bandwidth to 300 Hz.

[a]Ground mode: refer to Table 83.

Table 104 (contd)

DSS No.	Time from acquisition to end of track, GMT		Tracking		Ground received signal level, — dBmW (max, avg, min.)	Total commands sent	Significant events, equipment failures and anomalies
	Day of year	Time	Ground mode[a]	Total time			
Pass No. 2 (contd)							
51 (contd)							Modification began at 13:10 and was completed at 13:40. After modification, phase lock was possible although frequent glitches and occasional complete losses of lock occurred. Receiver No. 1 was used for telemetry reception. Since telemetry confirmed oxidizer flow, analysis was made that a stuck fuel flow regulator valve might be cause of vernier engine No. 3 failure. Based on this possibility, a decision was made at 18:20 to pulse fire vernier engines in an attempt to shake valve loose. Spacecraft was transferred to DSS 61 at 22:05.
61	264 264	20:47:30 22:55:50	2 3 Total	00:49:20 01:19:00 02:08:20		3	Due to communication difficulties with DSS 51, DSS 61 was directed to track spacecraft. Station responded within 15 min.
11	264 265	23:09:00 06:49:30	1 2 Total	00:45:15 06:53:18 07:38:33	135.0 143.1 155.0	753	Vernier Test: Command sequences were transmitted in hourly cycles. Sequences consisted of five vernier engine burns of 0.2-s duration followed by one vernier engine burn of 2.0-s duration. Telemetry contained no indication of vernier engine No. 3 firing. Spacecraft was transferred to DSS 42 on day 265 at 06:05.
14	264 265	23:04:57 06:46:30	3 Total	07:41:33 07:41:33	116.0 137.7 141.7		Station reported following spacecraft tumbling rates (in rpm): 57.4 on day 264 at 23:20, 60.1 at 23:41, 60.1 on day 265 at 00:37, 66.1 at 01:35, 70.9 at 02:49, 70.6 at 03:00, 85.6 at 04:15, and 91.0 at 06:17.
42	265 265	02:36:05 09:56:00	1 2 3 Total	00:16:00 03:30:00 03:28:55 07:14:55	122.0 134.7 160.0	443	Station reported following spacecraft tumbling rates (in rpm): 92 on day 265 at 07:53, 138 at 08:07, 146 at 09:21, and 116 at 09:35. The following command sequences were transmitted: At 06:42, solar panel stepping command was completed with negative results; at 08:05, a 20-s vernier engine burn was commanded; and the final sequence (consisting of dumping helium to calibrate the transducer, turning on the RADVS power to verify operation at low-battery voltage, and firing main retro engine) was accomplished at 09:34. Firing of the retro engine was calculated to impart a 10-g load on spacecraft. Spacecraft signal terminated after retro engine was fired. At 09:35:00 all relevant traces on CEC recorder ceased abruptly. There was no gradual decrease in signal or increase in angle error channels. Station began search with Receiver No. 1 on SCM and Receiver No. 2 on SAA. At 09:56, upon notification from Net Control, station terminated spacecraft search. *Surveyor* Mission B was concluded.
				Total commands sent		1,542	

[a]Ground mode: refer to Table 83.

None of the nine was of a critical nature and repair or replacement was accomplished on eight of the trouble tickets in real time. However, there were some problem areas. These are discussed in the following paragraphs.

a. Voice audio patch panel. During the *Surveyor I* mission testing period, a considerable number of voice-line patching errors occurred at the audio patch panel. This problem lessened greatly during the *Surveyor II* mission, with only minor audio patching errors evident during testing and the mission. A new audio patch panel design was completed, to be available for *Surveyor III.* This was considered one of the weakest systems supporting the *Surveyor* mission.

b. SFOF communications status display. The communications status display during operational readiness tests (ORTs) and during mission flight proved inadequate to support multi-missions. This made it difficult, at times, to present in all areas the true status of all communications circuits, since the CCTV displays were too small to show all DSSs and circuits. Special emphasis was given to improve this situation for later missions.

c. Communications telemetry processing station circuits. The 6 tie-lines available for *Surveyor I* proved to be inadequate, and created critical problems during the mission. In preparation for the *Surveyor II* mission, these circuits were increased to 18. However, because of patching constraints within the communications telemetry processing station (TPS), continual changing of modems and clock data lines was necessary. An attempt was made to resolve the TPS line-patching constraints by adding new patching capability in the TPS to allow each DSS/HSD line and modem to be used without the need for patching.

d. High-speed data modems.

Hallicrafters/JPL modems. Modem 1A, one of the two Hallicrafters receiver modems (modulator-demodulator), was again considerably less reliable during testing than the other, as was the case during the *Surveyor I* mission. Modifications to the circuitry were accomplished after *Surveyor I* to alleviate the problem, but this receiver continued to give problems during ORTs and was not used during the mission. Hallicrafters modem receiver 1B was used exclusively for DSS 51 HSD. Its reliability was considered high during the *Surveyor II* mission and much superior to that evinced during the *Surveyor I* mission.

NASCOM modems. The use of NASCOM modems in the *Surveyor II* mission proved to be highly successful, with fewer line outages and higher quality of data from all stations. Minor procedural problems were evident during tests, especially in the use of the regeneration mode and bit-rate changes at NASCOM en route switching centers. NASCOM assisted in clarifying appropriate procedures.

e. Wideband communications system. During ORTs, considerable distortion and line-level problems developed between DSS 11 video (TV-11) and the *Surveyor* TVGDHS at the SFOF (TV-1). Extensive line testing of the microwave systems identified these as:

(1) A Collins microwave alignment problem at Goldstone DSCC.

(2) A line amplifier problem at the SFOF communications terminal.

(3) A wideband line isolation problem in the SFOF TVGDHS terminal.

Problems (1) and (2) were partly or wholly resolved through alignment and maintenance. However, the 6-MHz wideband line isolation problem was controlled, but not totally resolved. Action was taken to isolate the TVGDHS equipment from the 6-MHz wideband lines.

f. Network video interface. A temporary color-television sync generator was again installed to provide commercial television networks with a common sync signal the morning before launch. As before, there was much concern because the configuration was modified so close to launch time. Eventually, one of the networks may provide the communications center with a permanent sync generator. The internal sync operated without fault during tests and launch. To ensure adequate time to check out the commercial TV/SFOF sync interface on later missions, the Public Information Office was encouraged to coordinate with the commercial network much earlier.

g. SFOF/Goldstone DSCC microwave system. The microwave circuits developed numerous line-level and patching discrepancies during the August–September 1966 testing periods. However, after JPL communications engineers and Western Union personnel had succeeded in obtaining proper equalization on these circuits, most of the problems disappeared during the mission. Most patching problems experienced during testing involved patching of mission nonstandard simulated data through station tracking and video systems and return, to the SFOF.

During the mission, when simulations were removed and actual spacecraft data were being processed, almost no

patching errors were noted. Special maintenance support was not provided except for approximately 8 h during the DSS 11 midcourse pass. Arrangements had already been made with Western Union, however, to provide special maintenance support during the critical lunar touchdown phase had the mission progressed that far. Action was taken to increase the Goldstone microwave system TTY circuits to a total of 13, as insufficient circuits were available during the *Surveyor II* mission for SFOF multi-mission support.

2. *Data processing system.* The SFOF data processing system (DPS) provided the data processing and data display capability to reduce and analyze the spacecraft engineering and DSS tracking data and to execute mission control. The DPS configuration for *Surveyor II* consisted of two PDP-7 computers in the telemetry processing station (TPS), two strings of IBM 7044/7094 computers in the central computing complex (CCC), and a subset of the input/output (I/O) system. Figure 93 gives the general configuration of the SFOF data processing system that supported the *Surveyor II* mission.

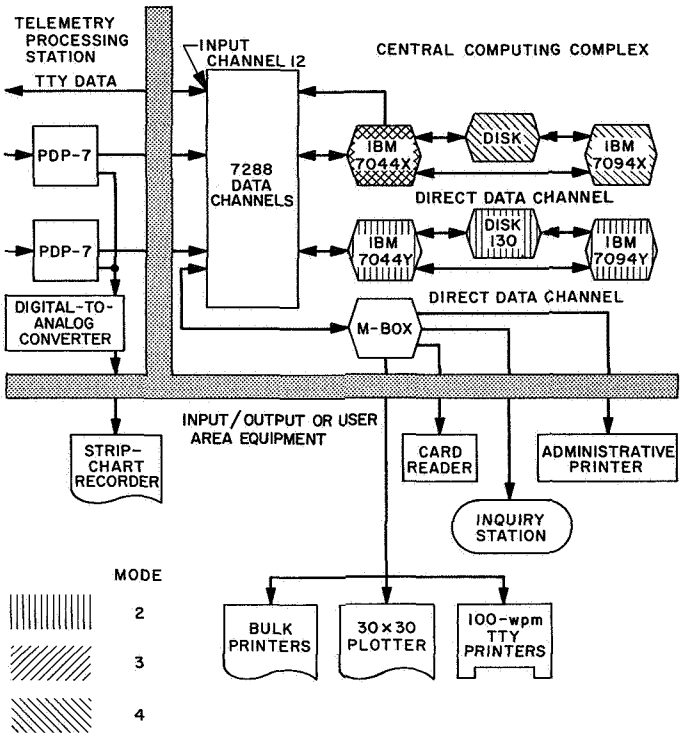


Fig. 93. General configuration of SFOF data processing system

The DPS performed the following support functions for the *Surveyor II* mission:

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

(2) Orbit determinations.

(3) Midcourse maneuver computations and analysis.

(4) On-line telemetry processing.

(5) Command tape generation.

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

a. Telemetry processing station. The TPS configuration for *Surveyor II* comprised two PDP-7 computers, which were used extensively to process high-speed telemetry data. This processing consisted of decommutating the data, transferring the data to the IBM 7044 computers via the 7288 data channels, generating a digital tape for near-real time processing, and supplying digital-to-analog converters with discrete data parameters to drive analog recorders in various SFOF areas.

Review of all documented failures and problems revealed that relatively few anomalies were experienced during the *Surveyor II* mission. The most significant of these were two PDP-7 problems that occurred when the telemetry modes were changed. From all indications, the computer appeared to be functioning properly; however, it was not supplying data to the 7288 data channels. The problem was quickly resolved by switching the second PDP-7 as the prime processor. Intensive investigation was initiated to determine whether this was a hardware or a software problem. Extensive tests were also conducted. However, the results were inconclusive.

b. Central computing complex. The IBM 7044/7094 computer-string dual configuration successfully processed all HSD received from the TPS and all TTY data received from the Communications Center, as well as all I/O requests from the user areas. A dual mode 2 string was utilized by the Project until 00:00 GMT on September 22, 1966.

The most significant problems experienced were three internal restarts on the IBM 7044 computers. These were a result of two typewriter failures and a parity error between the 7044 and 7094 computers. Other anomalies were three 729 tape unit failures and an M-box failure. The M-box failure was experienced during the prelaunch countdown and was found to be due to a defective wire. At 00:00 GMT on September 22, the Project released the

Y-string to the DSN to repair the on-line printer on the 7094 computer. It should be noted that at this time the T&DS was no longer receiving telemetry data, and therefore this problem had no effect on the mission.

All of the problems experienced in the CCC were quite easily circumvented and had very little or no effect on the success of the mission. All problems were a result of normal equipment attrition, and additional measures to prevent such occurrences were not planned.

c. Input/output system. The I/O system provided the capability for entering data control parameters into the IBM 7044/7094 computers and also for displaying computed data in the user areas via the various display devices. This system performed quite adequately, with only a few reported problems.

The most significant problem occurred just after the midcourse maneuver when the I/O console in the Spacecraft Performance Analysis Area began malfunctioning. The Project made a decision to temporarily transfer the SPAA computer control to the Space Science Analysis Area until the problem could be rectified. The failure was subsequently isolated to a fuse in the −10 V power supply of the I/O console. SPAA support reverted to the SPAA console after a total down time of 35 min.

d. Failure/problem reporting system. The primary purpose of the DSN FPR system was to provide a controlled closed-loop system for reporting and correcting operational failures or problems that occurred throughout the DSN in order to ensure that the DSN was properly prepared to support subsequent flight operations. A secondary purpose of the FPR system was to serve as a source of information for determining the operational effectiveness of the DSN during actual *Surveyor II* flight operations.

A total of 230 FPRs were written during *Surveyor II* testing and flight operations, with 25 of these being initiated during the countdown or actual flight. An itemized listing of all FPRs is given in Table 105. The 25 failures or problems experienced during the mission had no serious effect on the mission, and the majority of these were corrected in near-real time. The more significant problem areas are summarized in Table 106.

Table 105. *Surveyor II* mission failure/problem reports

Suspected system or agency	Total number of FPRs	FPRs written during flight
Communications	13	–
Data processing	122	21
Support	8	–
DSIF	26	2
Engineering	2	–
Project operations	47	2
Project hardware	12	–
Totals	230	25

XI. *Surveyor II* T&DS Performance Evaluation

The T&DS support for the *Surveyor II* mission was considered excellent; all requirements were met and most were exceeded. Some minor problems were experienced during operations but without effect on required coverages. Events reported within this section contributed valuable information in supporting later lunar missions.

A. Air Force Eastern Test Range

The near-earth flight phase of the *Surveyor II* mission was quite nominal in that all events occurred within the tolerance of nominal times. There was one apparent

Table 106. DPS most significant problem areas for *Surveyor II* mission

Problem	Cause	Corrective action planned	Effect on mission
TPS: PDP-7	Miswiring	Isolate and correct	Very little; some real-time telemetry data were lost
CCC: internal restarts	Miscellaneous minor failures	None	Very little if any
CCC: 729 tape drives	Routine wear and tear	None	Very little if any
CCC: M-box	Defective wire	None	None
CCC: IBM 7094-Y on-line printer	Motor	None	None
I/O: SPAA I/O console	Fuse	None	35 min down time
Support: Eidophor projector	High-voltage rectifier	None	None

indication that the separation of the *Centaur* and the spacecraft might not be normal. However, subsequent information proved that this indication was false.

The AFETR and MSFN support of the launch and near-earth flight phase of the mission was excellent and exceeded their committed support. Special mention must be made of the Cape Kennedy real-time computer system, which provided the most important and timely tools in making an early evaluation of the status of the flight.

The T&DA functions were carried out to a high degree of efficiency as well. A complete evaluation of AFETR radar coverage, estimated coverage, intermittent track, and possible rough track is shown in Fig. 94.

1. Tracking (metric) data. The AFETR tracked the C-band beacon of the *Centaur* stage to provide metric data. These data were required during intervals of time before and after separation of the spacecraft for use in calculating the *Centaur* orbit, which was used as a close approximation of the post-separation spacecraft orbit. The *Centaur* orbit calculations were used to provide DSN acquisition information (inflight predicts).

The lack of a metric range instrumentation ship to augment the downrange land-based radars was recognized by both *Surveyor* Project and AFETR as detrimental. The resulting restriction in the launch window was such that a scrub would have resulted if any hold had been required over that actually experienced. The fact that the Project elected to launch without metric RIS support is not to be considered a precedent for future launches.

The AFETR stations 1 (Cape Kennedy/Patrick AFB), 3 (Grand Bahama Island), 7 (Grank Turk), 12 (Ascension Island), 13 (Pretoria), 91 (Antigua Island), and 40 (Trinidad) radar, provided continuous coverage to 938 s after launch (T + 938 s). The Trinidad radar (40.43) operated in the expected skin track mode. Because spacecraft separation occurred near the end of the Trinidad

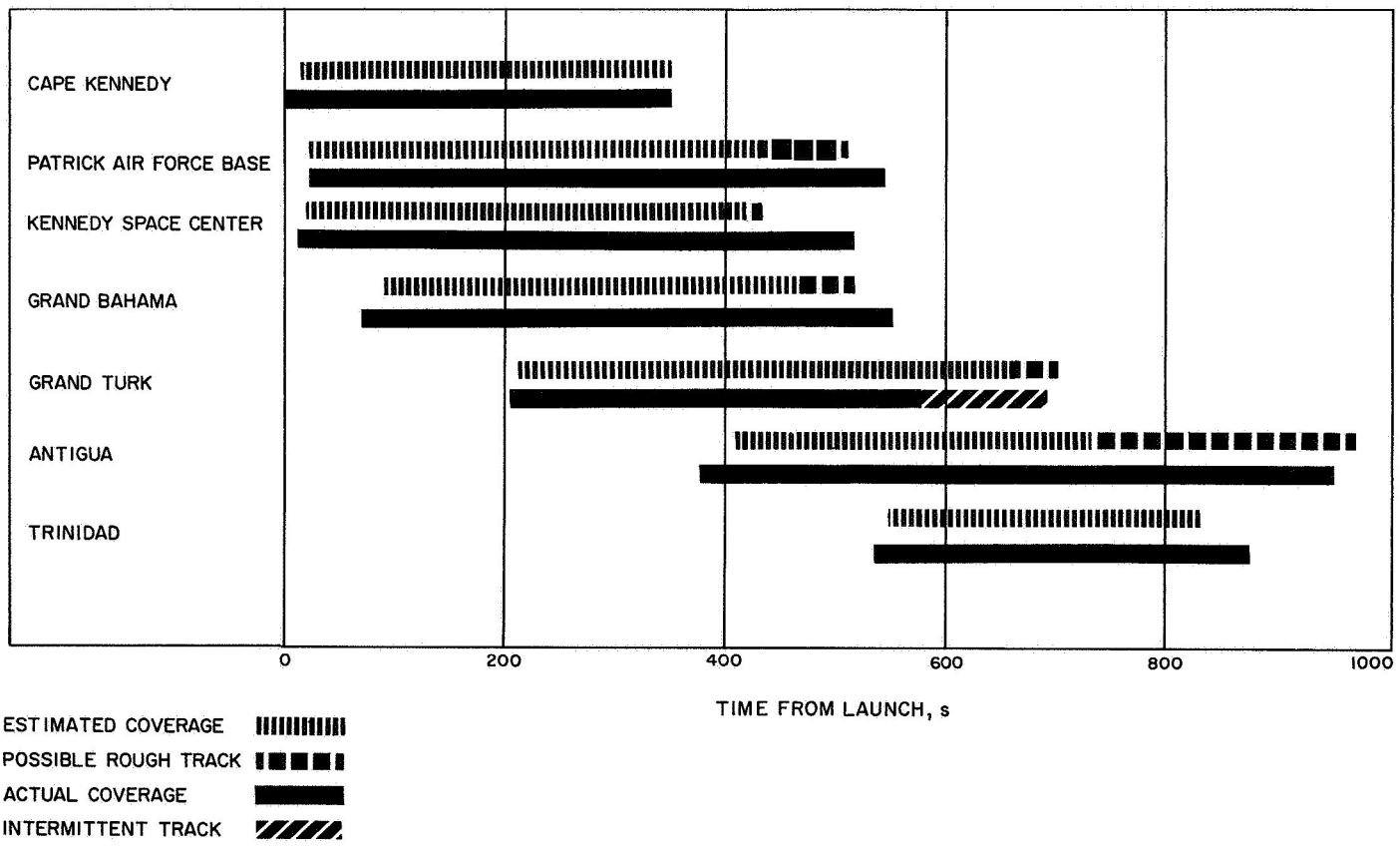


Fig. 94. *Surveyor II* AFETR radar summary

track, and in view of separation rates between the spacecraft and *Centaur*, separation distance was not great enough to be observed with radar in the 1-MHz flow-recording transmitter mode. Rough track was made by Grand Turk (7.18) as radar approached the LOS point. At this time the AFETR had no indication of occurrence-of-balance point shift. Downrange radars at Ascension Island (12.18) and Pretoria (13.6) had intermittent track due to the lobing beacon caused by vehicle instability. Radar estimated and actual coverages are shown in Figs. 95 and 96. Class I requirements were met and exceeded.

2. ***VHF telemetry.*** Starting during the countdown, the AFETR continuously received and recorded *Atlas* telemetry (229.9-MHz link) and *Atlas/Centaur* telemetry (225.7-MHz link) until shortly after spacecraft separation. Thereafter, *Centaur* telemetry was recorded, as station coverage permitted, until completion of the *Centaur* retromaneuver.

Continuous VHF telemetry data signal was received from liftoff through station 13 LOS at $T + 3805$ s. In addition to the coverage by land stations 1, 3, 91, 12, and 13, coverage of the gap between Antigua and Ascension Island was made by RIS *Sword Knot*, RIS *Coastal Crusader*, and one range telemetry aircraft. VHF telemetry estimated and actual coverages are shown in Fig. 97. Class I, II, and III requirements were met.

3. ***S-band telemetry.*** The AFETR received and recorded *Surveyor* S-band (2295-MHz) telemetry after the spacecraft transmitter high power was turned on and until 15 min after injection.

The S-band telemetry resources planned to meet this requirement were the two RIS, one range telemetry aircraft, and the 30-ft S-band (TAA-3A) antenna systems located at Antigua and Ascension Island.

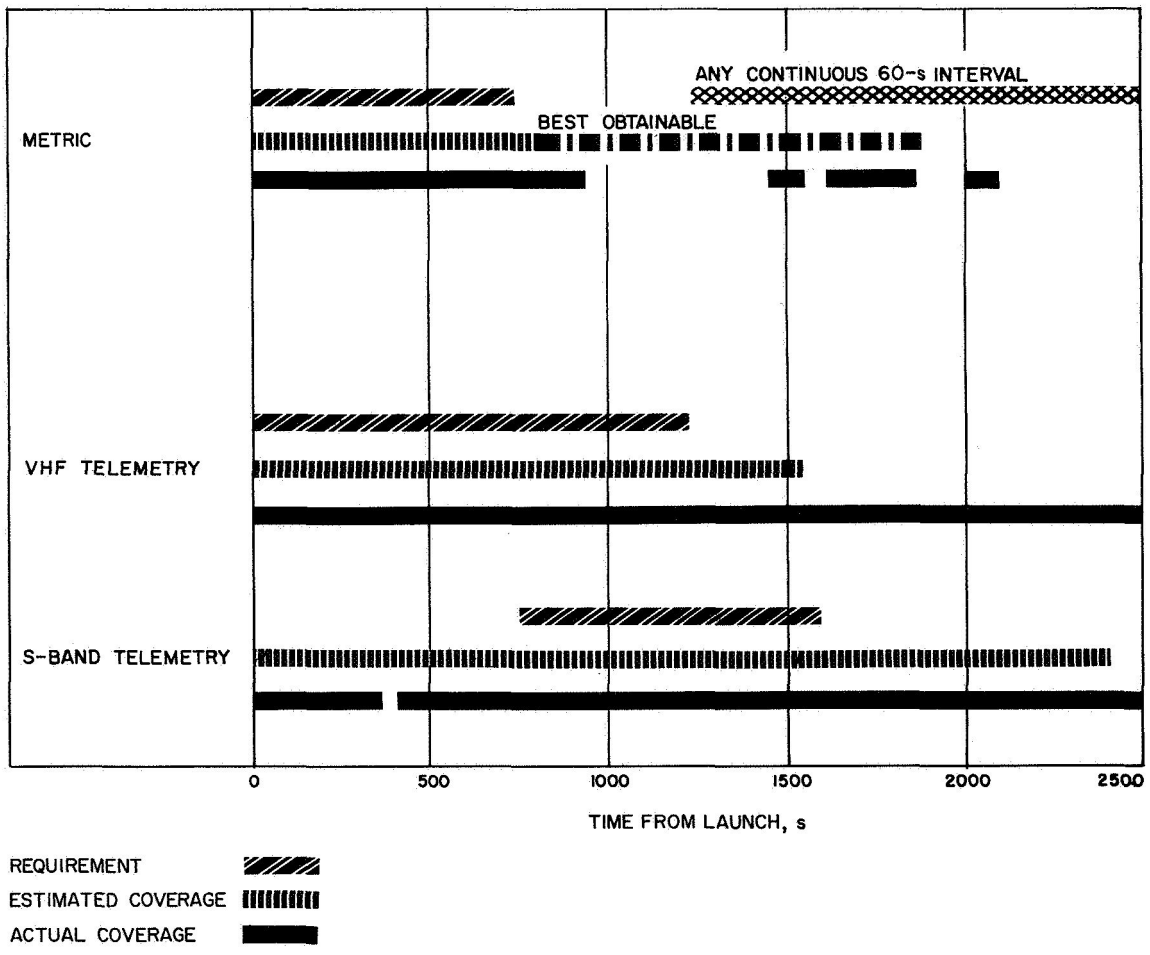


Fig. 95. *Surveyor II* AFETR support/requirement coverage

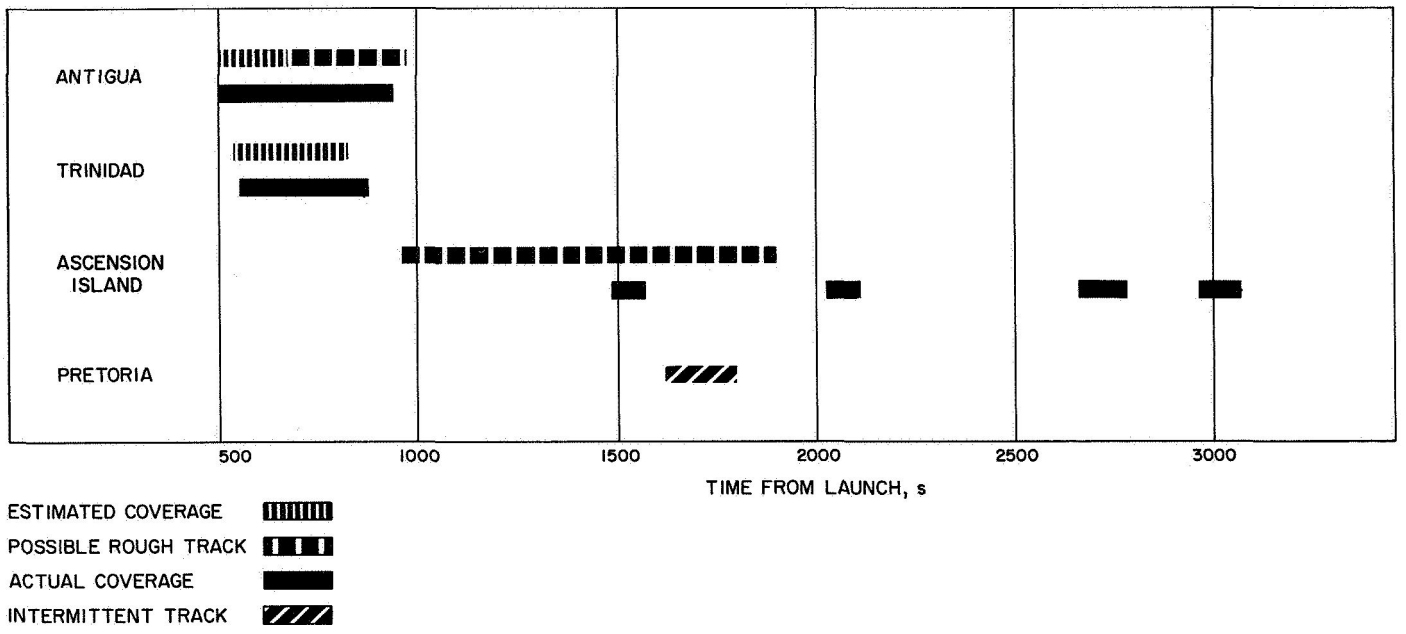


Fig. 96. *Surveyor II* AFETR radar coverage

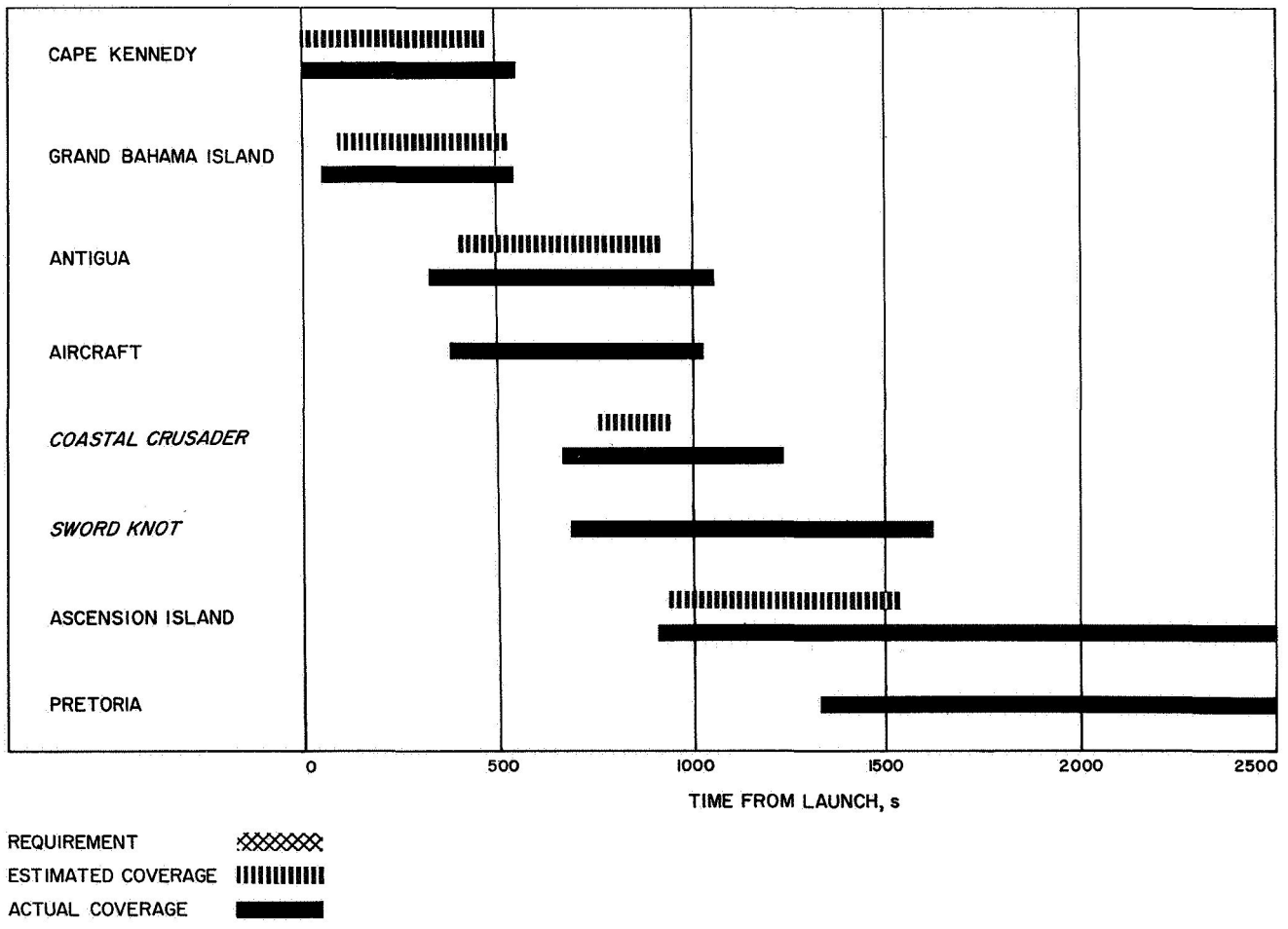


Fig. 97. *Surveyor II* AFETR VHF telemetry coverage

All the primary S-band systems were used on a limited commitment basis because they were still under engineering control.

Confidence ran fairly high in these systems because the *Sword Knot* had successfully provided S-band coverage for *Centaur A/C-8* launch, and the *Coastal Crusader* had provided S-band support for the *Pioneer* and *Lunar Orbiter* missions. The range telemetry aircraft, however, had not previously supported a live S-band mission.

A 3-ft S-band antenna, with its associated downconverter and receiver, was in place at Ascension Island. This system provided the S-band data from Ascension Island for the previous *Centaur* launch and was used to back up the TAA-3A antenna system. A similar backup system was provided at Antigua. In addition, the telemetry aircraft covered the early interval after turn-on of *Surveyor II* transmitter high power.

With the exception of a 10-s gap after T + 380 s, AFETR stations, ships, and aircraft obtained continuous S-band telemetry coverage from liftoff through station 12 LOS at T + 2675 s. Station 12 experienced a dropout between 1742 and 1790; however, station 13 filled this interval. The S-band telemetry estimated and actual coverages are shown in Fig. 98. Class I, II, and III requirements were met.

4. Real-time computer system. The required real-time computer system services were met in a routine manner by the existing facilities of the RTCS. Delays were experienced as shown in Table 107. The RTCS ran two solutions for pre-retrofire IRV, SOPM, and these orbited elements: one from Antigua (91.18) data only, and one from 91.18 and 40.43 data. Computation of post-retrofire data was delayed because of rough radar data from stations 12 and 13. The RTCS was required to compute IRV, SOPM, and orbital elements based on UVW data received from the *Centaur* guidance link, and provided by the Kennedy Space Center to the AFETR RTCS. The UVW data contained errors, causing a delay in awaiting corrected data. Some differences between planned and actual times were the result of a range user agreement at the RTCS to alter the planned schedule.

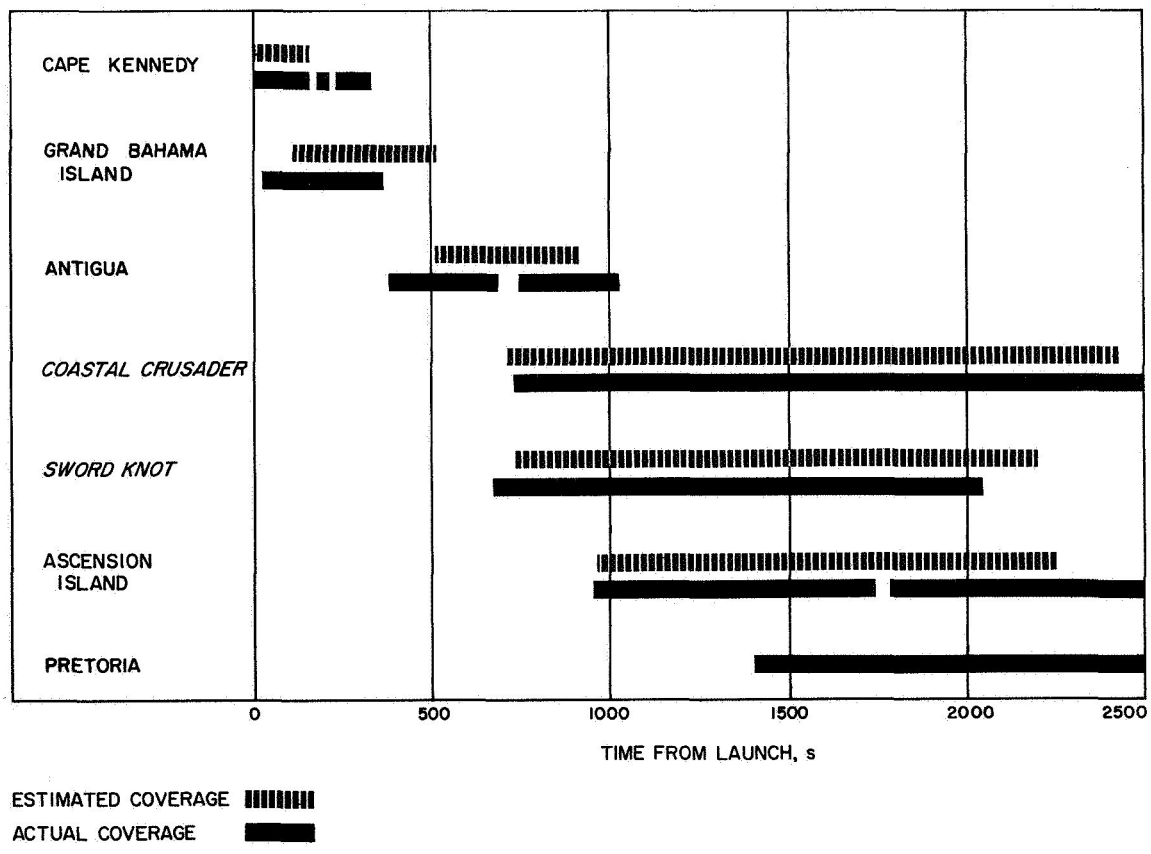


Fig. 98. *Surveyor II* AFETR S-band telemetry coverage

Table 107. *Surveyor II* AFETR RTCS computation and transmission

Nominal T+, s	Actual T+, s	Item
4	8	Liftoff message
16	15	Pre-retro IRV, SOPM, and orbital elements (non-recursive)
21	20	Lock angles for Grand Canary and Kano
21	21	AFETR predicts to 72, 51, 61
	23	Replay Kano lock angles
34	41	Pre-retrofire moon map (non-recursive)
41	57	IRV, SOPM, and orbital elements
67	73	Pre-retrofire IRV, SOPM, and orbital elements (recursive, based on 91.18 data)
79	77	Pre-retrofire I-matrix (91.18 data)
93	81	Pre-retrofire moon map (recursive, based on 91.18 data)
	116	Pre-retrofire IRV, SOPM, and orbital elements (recursive, based on 91.18 and 40.43 data)
	119	Pre-retrofire moon map (recursive, based on 91.18 and 40.43 data)
	125	Pre-retrofire I-matrix (91.18 and 40.43 data)
51	164	Post-retrofire IRV, SOPM, and orbital elements (recursive, based on 13.16 data)
120	171	Pre-retrofire IRV, SOPM, and orbital elements (based on 91.18 and DSS 51 data)
56	174	Post-retrofire moon map (recursive)
126	180	Pre-retrofire predicts (based on 91.18 and DSS 51 data)
146	182	Pre-retrofire moon map (based on 91.18 and DSS 51 data)
135	187	Pre-retrofire I-matrix (based on 91.18 and DSS 51 data)
82	190	Post-retrofire I-matrix

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

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

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

The AFETR provided and operated RF, teletype, telephone, and other communications systems as planned. A difficulty was experienced in using the missile operations paging system (MOPS) due to noise and crosstalk. The AFETR communications system is running tests and making improvements. Commercial power failed at $T + 60$ s, and a Cape-wide loss was experienced for approximately 5 s. The power loss did not cause any significant problems for the AFETR because most facilities were operating from critical or generator power. Four or five optical items were lost or had short runs because of power failure.

Because of erroneous instructions, the AFETR did not provide RF propagation forecasts as required. This was corrected about 2 h prior to launch.

B. Goddard Space Flight Center

The MSFN, managed by the GSFC, well supported the *Surveyor II* mission. Tracking of the *Centaur* beacon (C-band) was continued for approximately 3½ h. Telemetry of the *Centaur* links was received and recorded from Bermuda AOS until LOS at Kano. Real-time confirmation was provided of certain *mark* events, as shown in Table 108. GSFC reformatted Carnarvon radar data at the GSFC from the Carnarvon hexidecimal system to the

Table 108. *Surveyor II mark* events

Event	*Mark* No.	Mission time (predicted)[a]	Mission time (actual)	GMT (actual) (Sept. 20, 1966)
Liftoff to acquisition by Deep Space Instrumentation Facility				
Liftoff (2-in. rise)		*L*[b] + 00 h, 00 min, 00.00 s	*L* + 00 h, 00 min, 00.00 s	12:31:59.824
Initiate roll program		*L* + 00 h, 00 min, 02 s		
Terminate roll, initiate pitch program		*L* + 00 h, 00 min, 15 s		
Mach 1			*L* + 00 h, 00 min, 58 s	12:32:58
Max aerodynamic loading			*L* + 00 h, 01 min, 15.7 s	12:33:15.5
Booster engine cutoff (BECO)	1	*L* + 00 h, 02 min, 22.72 s	*L* + 00 h, 02 min, 22.2 s	12:34:22.0
Jettison booster package	2	*L* + 00 h, 02 min, 25.82 s	*L* + 00 h, 02 min, 25.3 s	12:34:25.1
Admit guidance steering		*L* + 00 h, 02 min, 31 s		
Jettison *Centaur* insulation panels	3		*L* + 00 h, 02 min, 56.0 s	12:34:55.8
Jettison nose fairing	4		*L* + 00 h, 03 min, 22.9 s	12:35:22.7
Start *Centaur* boost pumps		*L* + 00 h, 03 min, 36 s		
Sustainer engine cutoff (SECO)	5	*L* + 00 h, 03 min, 55.35 s	*L* + 00 h, 03 min, 55.1 s	12:35:54.9
Atlas/Centaur separation	6		*L* + 00 h, 03 min, 57.0 s	12:35:56.8
Centaur main engine ignition (MEIG)	7	*L* + 00 h, 04 min, 06.85 s	*L* + 00 h, 04 min, 06.6 s	12:36:06.4
Centaur main engine cutoff (MECO)	8	*L* + 00 h, 11 min, 23.44 s	*L* + 00 h, 11 min, 26.3 s	12:43:26.1
Vehicle destruct system safed by ground command			*L* + 00 h, 11 min, 36.2 s	12:43:36.0
Extend *Surveyor* landing legs command	9	*L* + 00 h, 11 min, 50.85 s	*L* + 00 h, 11 min, 51 s	12:43:51
Extend Surveyor antennas command	10	*L* + 00 h, 12 min, 01.35 s	*L* + 00 h, 12 min, 01 s	12:44:01
Surveyor transmitter high power on command	11	*L* + 00 h, 12 min, 21.85 s	*L* + 00 h, 12 min, 21 s	12:44:21
Surveyor/Centaur electrical disconnect	12	*L* + 00 h, 12 min, 27.30 s	*L* + 00 h, 12 min, 27 s	12:44:27
Surveyor/Centaur separation	13	*L* + 00 h, 12 min, 32.85 s	*L* + 00 h, 12 min, 32.6 s	12:44:32.4
Solar panel unlocked and start stepping			*L* + 00 h, 12 min, 34 s	12:44:34
Start *Centaur* 180 deg turn	14	*L* + 00 h, 12 min, 37.85 s	*L* + 00 h, 12 min, 38 s	12:44:37
Start *Centaur* lateral thrust	15	*L* + 00 h, 13 min, 17.85 s	*L* + 00 h, 13 min, 18 s	12:45:17
Start sun acquisition roll			*L* + 00 h, 13 min, 18 s	12:45:18
Cutoff *Centaur* lateral thrust	16	*L* + 00 h, 13 min, 37.85 s	*L* + 00 h, 13 min, 38 s	12:45:37
Primary sun sensor lock-on			*L* + 00 h, 16 min, 13 s	12:48:13
Start *Centaur* retro (blowdown tanks)	17	*L* + 00 h, 16 min, 32.85 s	*L* + 00 h, 16 min, 33 s	12:48:32
Solar axis locked; start roll axis stepping			*L* + 00 h, 18 min, 34 s	12:50:34
Cutoff *Centaur* retro and power off	18, 19	*L* + 00 h, 20 min, 42.85 s	*L* + 00 h, 20 min, 43 s	12:52:42
Roll axis locked in transit position			*L* + 00 h, 22 min, 46 s	12:54:46
Initial DSIF acquisition (two-way lock) completed			*L* + 00 h, 32 min, 58 s	13:04:58

[a]The predicted values were computed postflight utilizing actual launch azimuth, tanked propellant weights, and atmospheric data that depend on day and time of liftoff.

[b]*L* = time at launch.

Table 108 (contd)

DSIF acquisition to star acquisition		
Initial commanded spacecraft operations		
1. Command transmitter from high to low power	L + 00 h, 44 min, 33 s	13:16:33
2. Command off accelerometer amplifiers, solar panel deployment logic, and strain gage power	L + 00 h, 46 min, 45 s	13:18:45
3. Command rock solar panel back and forth to seat locking pin	L + 00 h, 48 min, 16 s	13:20:16
4. Command rock roll axis back and forth to seat locking pin	L + 00 h, 49 min, 44 s	13:21:44

38-character octal format and retransmitted these data to the RTCS at the AFETR. The NASCOM support system was provided for all NASA elements for simulations and launch, and extended this communications support as necessary to interface with the combined worldwide network. The GSFC supported the *Surveyor II* mission with the equipment and the signaling, conferencing, and monitoring arrangement shown in Table 109.

1. Tracking. The MSFN station at Bermuda provided C-band radar coverage and back-up range safety support. Bermuda initiated such radar beacon tracking, magnetic tape recording (at a minimum of 10 points/s), and real-time data transmission to GSFC and the AFETR.

Bermuda, Grand Canary, and Kano were equipped with acquisition aids to track the vehicle and provide RF inputs to the telemetry receivers. Performance recorders were used to record AGC and angle errors for postmission analysis. The acquisition aids provided telemetry RF inputs from AOS at Bermuda to LOS at Kano. All MSFN acquisition aid systems performed their required functions.

2. VHF telemetry. Bermuda, Grand Canary Island, and Kano were also equipped to decommutate, receive, and record telemetry. Capability for coverage was provided from Bermuda AOS to LOS at Kano. *Mark* event readouts (Table 108) were required from all stations in real time, or in as near real time as possible, when the vehicle was in view of a station.

MSFN telemetry support was well performed. There were no equipment failures or discrepancies during the operation. Bermuda was required to confirm *mark* events 6 through 11 on the *Centaur* link.

Grand Canary was required to confirm *mark* events 17 through 19. *Mark* event 17 was not confirmed because the event occurred prior to Grand Canary acquisition of signal, while *mark* events 18 and 19 were confirmed as required.

Kano was required to confirm *mark* events 17 through 19 on the *Centaur* link. None of these *mark* events was confirmed.

3. Data handling. Data were provided by MSFN stations at Bermuda, Grand Canary, Kano, and Carnarvon in accordance with the requirements of the Network Operations Plan.

4. Ground communications. Existing NASCOM and Department of Defense (DOD) Network facility voice

Table 109. *Surveyor II* GSFC network configuration

Location	Acquisition	Telemetry	C-band radar	SCAMA	Telemetry	Radar high-speed data	Real-time readouts
Bermuda	X	X	X	X	X	X	X
Grand Canary	X	X		X	X		X
Kano	X	X		X	X		X
Carnarvon				X	X		
GSFC						X	
Cape Kennedy				X	X	X	

and teletype circuits provided ground communications to all participating stations.

5. Computer support. The GSFC Data Operations Branch provided computer support during the pre-launch, launch, and orbital phases of the mission.

C. Deep Space Network

The DSN supported *Surveyor* missions with the integrated facilities of the DSIF, the GCF, and the DSN facilities in the SFOF.

The overall data quality provided by the DSN was considered very good. From the time of two-way acquisition by DSS 51 until the midcourse maneuver, the DSN tracked *Surveyor II* in the two-way mode with only very minor exceptions, and returned high quality two-way doppler data throughout this period. Particularly noteworthy in the pre-midcourse phase is that DSS 72 took approximately 2 h of good two-way doppler data (for the first time), which had great importance in that it allowed an independent confirmation of the validity of the DSS 51 two-way doppler data, and allowed the Orbit Determination Group to produce an accurate estimation of the pre-midcourse orbit with far more statistical confidence than if they had had only DSS 51 data to work with. Furthermore, DSS 72 was able to fill the view period gap between DSS 51 and DSS 11 on the first pass with two-way data. The DSN tracked the spacecraft in the two-way mode from midcourse until LOS, and returned data apparently as good as any obtained; however, a refined assessment of the data quality during the post-midcourse phase is severely hampered by the varying spacecraft tumble rates after midcourse.

1. Deep Space Instrumentation Facility. The following Deep Space Stations, all having 85-ft antennas, were committed as prime stations for the support of the *Surveyor II* mission:

(1) DSS 11, Pioneer, Goldstone DSCC, Barstow, Calif.

(2) DSS 42, Tidbinbilla, Australia (near Canberra).

(3) DSS 51, Johannesburg, S. Africa.

(4) DSS 72, Ascension Island (used for the first pass).

These prime stations were committed to provide tracking coverage on a 24-h/day basis, from launch to lunar landing, and for the first lunar day and night. For succeeding lunar days and nights, the commitment was for 24-h/earth-day coverage during the first three and the last two earth days, and for a 10-h/earth day in between.

In addition to the basic support provided by prime stations, the following facilities support was provided for the *Surveyor II* mission:

(1) DSS 71, Cape Kennedy, provided facilities for spacecraft/DSIF compatibility testing, and also received telemetry after liftoff for engineering evaluation of the newly installed command and data handling console equipment.

(2) DSS 61, Robledo, Madrid DSCC, provided emergency telemetry and command coverage during the second pass, when communication problems with DSS 51 were encountered. Figure 99 shows DSS 61, the Robledo, Spain tracking site.

(3) DSS 12, Echo, Goldstone DSCC, provided a backup transmitter capability during midcourse maneuver.

(4) DSS 14, Mars, Goldstone DSCC, provided backup telemetry coverage using the 210-ft antenna during both Goldstone passes. The Mars station assisted with accurate measurement of spacecraft tumbling rates during the second pass.

a. RF tracking performance. Tracking data, consisting of antenna pointing angles and doppler (radial velocity) data, were supplied in near real time via teletype to the SFOF and in postflight data packages in the form of punched paper tape. Two-way and three-way doppler data were supplied full time during the lunar flight. The two-way doppler function implied a transmit capability at the prime stations.

Spacecraft center frequencies. In order that spacecraft predictions may be generated and supplied to the DSN tracking stations for purposes of spacecraft acquisition, aided track, and station-to-station transfers of the spacecraft, it is essential that the spacecraft transmitter (one-way) center frequency and spacecraft transponder (two-way) center frequency be accurately known. The nominal values for these frequencies are 2295.000000 MHz (at carrier level) for the transmitter center frequency and 22.013670 MHz (at station VCO level) for the transponder center frequency. Normally, these frequencies are

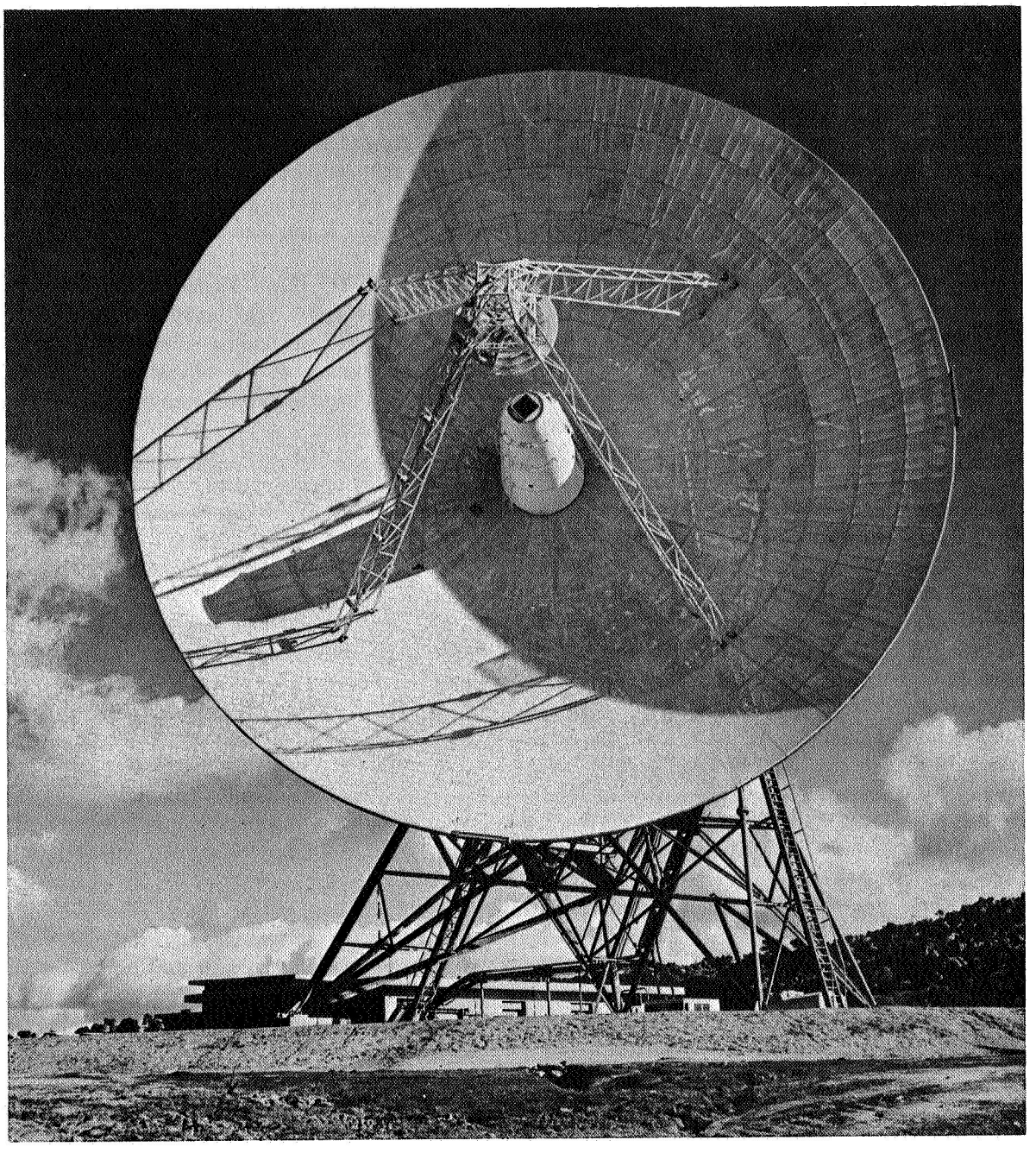


Fig. 99. DSS 61, Robledo, Spain, tracking site

measured months before the mission for use in the Preflight Predictions Document, and then they are measured several times in the last 10 h of the countdown for use in real-time predictions. The one-way center frequency and two-way center frequency that were used in the Preflight Predictions Document were 2294.998680 MHz and 22.013656 MHz, respectively, which were abstracted from the preflight data supplied by Hughes Aircraft Company for an estimated launch temperature of 90°F. During the last 90 min before launch, the sequence of events called for frequency measurements to be made and transmitted to JPL at $T - 40$ min and $T - 20$ min, however, reports were received at $T - 75$ min, $T - 60$ min, $T - 48$ min, $T - 20$ min, and $T - 10$ min, and both the $T - 40$ min and $T - 20$ min reports were incomplete (they lacked the one-way frequency). This

deviation from the sequence of events caused a considerable amount of confusion on the part of the spacecraft performance and command (SPAC) advisors and the systems data analysis (SDA) group, and the net result was that probably the most accurate frequency measurements were not used in the acquisition predictions. Because only one measurement of the one-way frequency (2295.001694 MHz) was made in the last 40 min before launch, there was no problem of choice, and furthermore, this value was in fair agreement with preflight data. However, both the $T - 40$ min and $T - 20$ min two-way frequency measurements showed a large variation from preflight data (so far unexplained), whereas the $T - 10$ min report was fairly close to the preflight data. The SPAC advisors recommended the $T - 20$ min value for use in the acquisition predictions (22.013637 MHz), which was done, whereas the $T - 10$ min report (22.013708 MHz) seems to be the far more reasonable measurement when compared to preflight data, and should probably have been used in the acquisition predicts. After initial acquisition at DSS 51, preflight frequency and temperature data were used exclusively in the predictions. From 1 h after launch ($L + 1$ h) to $L + 10$ h the frequencies used were 2294.998680 MHz and 22.013656 MHz (90°F), and from $L + 10$ h on, the frequencies used were 2294.994962 MHz and 22.013575 MHz (100°F).

Spacecraft predictions. Spacecraft predictions, which are composed of such time-tagged station observables as pointing angles, one-way doppler, two-way doppler, and best-lock ground transmitter frequency, are more or less routinely provided to the DSN tracking stations to ensure the success of spacecraft acquisitions, aided track, and station handovers of the spacecraft. However, during the launch phase, the provision of accurate predictions to DSS 51 and other tracking stations becomes a critical matter because of the crucial need for early acquisition and command of the spacecraft. For first two-way acquisition at DSS 51, there are three distinct sets of predictions available:

(1) Preflight Predictions Document.

(2) $L - 5$ min predictions based on actual launch azimuth.

(3) AFETR predictions based on actual postinjection tracking data.

Although both the preflight predictions and the $L - 5$ min predictions are generated before launch, the $L - 5$ min predictions have two important advantages over the preflight predictions in that they are based on updated frequency information and they are generated for the exact actual launch azimuth. Because of these two factors, the $L - 5$ min predictions were generated and sent to DSS 51 and DSS 72, with the advisement that they be used instead of the Preflight Predictions Document. DSS 72 did not receive the $L - 5$ min predict set in time and was able to acquire the spacecraft one way with relative ease using the Preflight Predictions Document. At about $L + 20$ min, predictions from AFETR based on actual postinjection tracking data were received at JPL; they very closely matched the $L - 5$ min predictions, thereby verifying the accuracy of the acquisition predicts at DSS 51. DSS 51 was therefore instructed to use and did use the $L - 5$ min prediction set for its initial acquisition. From this time until LOS, predictions were generated and transmitted to the DSN stations on a routine basis with the occurrence of only one minor problem. DSS 42 required 35 min to lock up the spacecraft in a good data, three-way mode on the spacecraft's first pass, and then reported that its angle deviations from predicts were 0.8 deg in declination and 0.4 deg in hour angle, both sizable errors compared to the antenna beam width of 0.3 deg. This error in pointing angle predictions (but not doppler quantities) was caused by an outdated set of antenna angle correction coefficients for DSS 42 in the predict program.

Initial two-way acquisition at DSS 41. Predictions indicated the *Surveyor* Mission B rise at DSS 51 at 12:55:00 GMT, September 20, 1966. DSS 51 reported good one-way data at 12:55:17, auto-track on the S-band cassegrain monopulse (SCM) (antenna main beam) at 13:00:07, and good two-way data at 13:05:07; thus, DSS 51 required 10 min from spacecraft rise to get good two-way data. Had the acquisition been optimum, DSS 51 could have been in a good-data, two-way lock at approximately 12:58, or about 3 min after spacecraft rise. By way of comparison, DSS 51 reported a good-data, two-way lock less than 4 min after spacecraft rise in the *Surveyor I* mission.

This delay of about 6 min from an optimum acquisition was due partly to a hardware problem (the SCM monitor-receiver was initially saturated by high signal strength), and partly to a procedural problem at DSS 51 precipitated by the hardware problem.

Near-real-time tracking data monitor. All two-way tracking data taken during the *Surveyor II* mission were

Table 110. Summary of DSS tracking data used in *Surveyor II* pre-midcourse orbit computations

Orbit identification	DSS	Data type	Start data time, mo/day–GMT	End data time, mo/day–GMT	No. of points	Std deviation[a]	Root mean square[a]	Mean error[a]	Data sample rate, s
AFETR Pre-retrofire check orbit	91 (AFETR)	Az	9/20–12:43:30	9/20–12:44:30	10	0.0063	0.0063	−0.0000	6
		El	9/20–12:43:30	9/20–12:44:30	10	0.0184	0.0184	0.0000	6
		R[b]	9/20–12:43:30	9/20–12:44:30	8	0.0013	0.0013	−0.0000	6
PROR X	51	CC3[c]	9/20–13:06:22	9/20–13:39:22	180	0.0606	0.0606	0.0000	10
		HA[d]	9/20–13:06:27	9/20–13:39:27	179	0.0221	0.0221	−0.0002	10
		Dec	9/20–13:06:27	9/20–13:39:27	179	0.0105	0.0105	0.0008	10
ICEV X	51	CC3	9/20–13:06:22	9/20–14:31:32	244	0.0542	0.0542	0.0005	10 and 60
		HA	9/20–13:06:27	9/20–14:32:02	246	0.0197	0.0197	0.0005	10 and 60
		Dec	9/20–13:06:27	9/20–14:32:02	246	0.0110	0.0115	0.0030	10 and 60
PREL XA	51	CC3	9/20–13:06:22	9/20–13:42:42	200	0.0597	0.0597	0.0002	10
		HA	9/20–13:06:27	9/20–13:42:47	199	0.0218	0.0219	0.0010	10
		Dec	9/20–13:06:27	9/20–13:42:47	199	0.0110	0.0111	0.0010	10
		CC3	9/20–13:44:32	9/20–15:41:32	104	0.0109	0.0109	0.0000	60
		HA	9/20–13:44:02	9/20–15:42:02	112	0.0064	0.0064	−0.0005	60
		Dec	9/20–13:44:02	9/20–15:42:02	111	0.0060	0.0134	0.0120	60
DACO YC	72	CC3	9/20–17:05:32	9/20–17:44:47	89	0.2040	0.2130	−0.0620	10
	51	CC3	9/20–13:06:22	9/20–18:25:32	386	0.0438	0.0454	−0.0110	10 and 60
	91	R	9/20–12:43:24	9/20–12:47:24	30	0.1030	0.1140	−0.0480	6
DACO YD	51	CC3	9/20–13:06:22	9/20–20:22:32	446	0.0408	0.0408	−0.0002	10 and 60
DACO YE	51	CC3	9/20–13:06:22	9/20–20:40:32	464	0.0401	0.0401	−0.0003	10 and 60
		HA	9/20–13:13:07	9/20–20:45:02	540	0.0154	0.0205	0.0130	10 and 60
		Dec	9/20–13:13:07	9/20–20:45:02	540	0.0101	0.0115	0.0050	10 and 60
DACO XE	51	CC3	9/20–13:06:22	9/20–13:42:42	200	0.0594	0.0594	−0.0002	10
		CC3	9/20–13:44:32	9/20–19:53:22	221	0.0121	0.0122	0.0004	60
	72	CC3	9/20–17:07:32	9/20–17:29:47	85	0.0437	0.0439	−0.0040	10
DACO 1.5	72	CC3	9/20–17:07:32	9/20–22:58:27	300	0.0414	0.0415	−0.0021	10
	51	CC3	9/20–13:06:22	9/20–13:42:42	200	0.0594	0.0594	−0.0006	10
		CC3	9/20–13:44:32	9/20–21:54:32	314	0.0085	0.0086	0.0008	60
LAPM XA	72	CC3	9/20–17:07:32	9/20–22:58:17	305	0.0409	0.0409	0.0004	10
	11	CC3	9/20–23:08:32	9/20–23:49:32	30	0.0042	0.0042	0.0004	60
LAPM YA	51	CC3	9/20–13:06:22	9/20–21:54:32	529	0.0373	0.0373	−0.0000	10 and 60
	11	CC3	9/20–23:08:32	9/21–00:23:32	59	0.0042	0.0064	0.0048	60
LAPM YB	72	CC3	9/20–17:05:32	9/20–22:58:27	303	0.0464	0.0474	−0.0095	10
	11	CC3	9/20–23:08:32	9/21–00:56:32	86	0.0045	0.0112	0.0100	60
	51	CC3	9/20–13:06:22	9/20–21:54:32	529	0.0374	0.0374	−0.0003	10 and 60
Pre-midcourse Cleanup XC	72	CC3	9/20–17:07:32	9/20–22:58:12	309	0.0406	0.0406	0.0004	10
	11	CC3	9/20–23:08:32	9/21–04:39:32	261	0.0062	0.0068	0.0020	60
		CC3	9/21–04:40:57	9/21–04:43:37	15	0.0212	0.0229	−0.0080	10
	51	CC3	9/20–13:06:22	9/20–13:42:42	202	0.0594	0.0594	0.0013	10
		CC3	9/20–13:44:32	9/20–21:54:32	327	0.0094	0.0094	−0.0009	60

[a]CC3 in Hz; HA, dec, az and el in deg; R in km.

[b]R = R-station-to-probe slant range.

[c]CC3 = two-way doppler.

[d]HA = local hour angle.

computer monitored in near-real time and no significant problem areas in the data were uncovered.

RF tracking performance. The DSIF stations provided continuous angular and doppler tracking data of the *Surveyor II* spacecraft from initial acquisition (one-way) by DSS 72 at 12:52:51 GMT, September 20, 1966 until *Surveyor II* LOS at 09:35:00, September 22, 1966. In general, the overall quality of the tracking data taken during the *Surveyor II* mission was excellent. Data types used (before midcourse) in the Orbit Determination Program (ODP) were angular data taken during the first pass over DSS 51 and two-way doppler data taken during the first passes over DSS 72, DSS 51, and DSS 11. A summary of the data used in the ODP, together with data statistics, is given in Table 110. The relative quality of 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 similar 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 presented in detail in Section VI-C.

In general, DSIF station operations during the *Surveyor II* mission were effectively implemented. This is best judged by the fact that the DSN was able to provide high quality data to the Orbit Determination Group such that they were able to meet orbital accuracy requirements for the midcourse maneuver. From the time of first two-way acquisition of the spacecraft over DSS 51 until LOS, the spacecraft was almost continuously in two-way lock, station transfers were rapid and efficiently executed, and a minimum of good data was lost.

1. Pre-midcourse phase, angular tracking: In general, doppler data yield far greater accuracy in the determination of a spacecraft orbit than do angle data, and were therefore used almost exclusively in the orbit determination process during most of the *Surveyor II* mission. The one exception was the launch phase, when little doppler data were available and a quick determination of the orbit necessitated the use of both doppler and angle data. Angle data from DSS 51 were used in the ODP during the premidcourse phase of the *Surveyor II* mission. To improve the quality of the angle data used in the orbit determination program, the data were first corrected for antenna optical pointing error (OPE). (The OPE is determined by having the DSS 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 II* mission inflight orbit computations are given in Table 111.

Experience gained in past missions has shown that the OPE correction coefficients do not remove all systematic pointing errors. This is reasonable because the RF and optical axes of the antenna are not necessarily the same. That is, the RF axis is a function of the position of the quadripod feed, whereas the optical axis is not. Thus, if there is a quadripod deflection (due to thermal effect and/or gravitational loading) at some given instant of time, the optical error and the RF error would not be the same. Furthermore, the optical refraction and the RF refraction are not the same because of 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, the latter because the antenna null pattern does not have the same slope at all polarization angles.

The first-pass angular data from DSS 51 show fairly constant biases of +0.015 deg in hour angle and

Table 111. Antenna correction coefficients for DSS 51[a]

Coefficient	Correction	Coefficient	Correction
A_{00}	−2.823094562E − 02	B_{00}	1.529098827E − 02
A_{01}	5.353777033E − 05	B_{01}	3.410829831E − 04
A_{02}	−3.082597437E − 05	B_{02}	−4.336071801E − 06
A_{03}	−6.626461141E − 07	B_{03}	6.109815447E − 07
A_{10}	−3.171398689E − 04	B_{10}	−1.559484352E − 04
A_{11}	9.542137245E − 06	B_{11}	−2.032267916E − 06
A_{12}	−3.367726933E − 07	B_{12}	5.779247847E − 08
A_{13}	−8.201321554E − 09	B_{13}	−2.831355530E − 10
A_{20}	1.589100967E − 06	B_{20}	−1.186130483E − 05
A_{21}	1.835756063E − 07	B_{21}	−5.239010283E − 08
A_{22}	3.851291638E − 09	B_{22}	−2.152496155E − 10
A_{23}	−8.191144217E − 11	B_{23}	−4.436567279E − 11
A_{30}	4.599327736E − 08	B_{30}	−2.298149026E − 08
A_{31}	3.344301616E − 09	B_{31}	8.193320409E − 10
A_{32}	1.386713245E − 10	B_{32}	−1.910069905E − 11
A_{33}	1.816077278E − 12	B_{33}	−7.276751867E − 13

[a]*These corrections are useful for elevations greater than 15 deg, and declinations between N 30 and S 35 deg.*

+0.005 deg in declination angle. Attention should be drawn to the fact that these errors represent a very significant improvement in the light of experience gathered from previous missions in connection with DSS 51 angular data quality. For instance, during the *Surveyor I* mission, the similar bias figures were −0.060 deg in hour angle and −0.050 deg in declination angle. An investigation was made to determine if a slight change in the techniques used to generate the correction coefficients led to an improvement in their accuracy. Angular residuals for the first pass over DSS 51 can be seen in Figs. 100–104. The first-pass angular data from DSS 72 show biases of approximately +0.040 deg in azimuth angle and −0.050 deg in elevation angle. No angular correction coefficients have yet been generated for DSS 72, one of the reasons for this being that the weather at DSS 72 seldom permits optical star tracks to be made. Angular residuals for the first pass over DSS 72 can be seen in Figs. 105–107. The angular data from DSS 72 were not used in any inflight orbits.

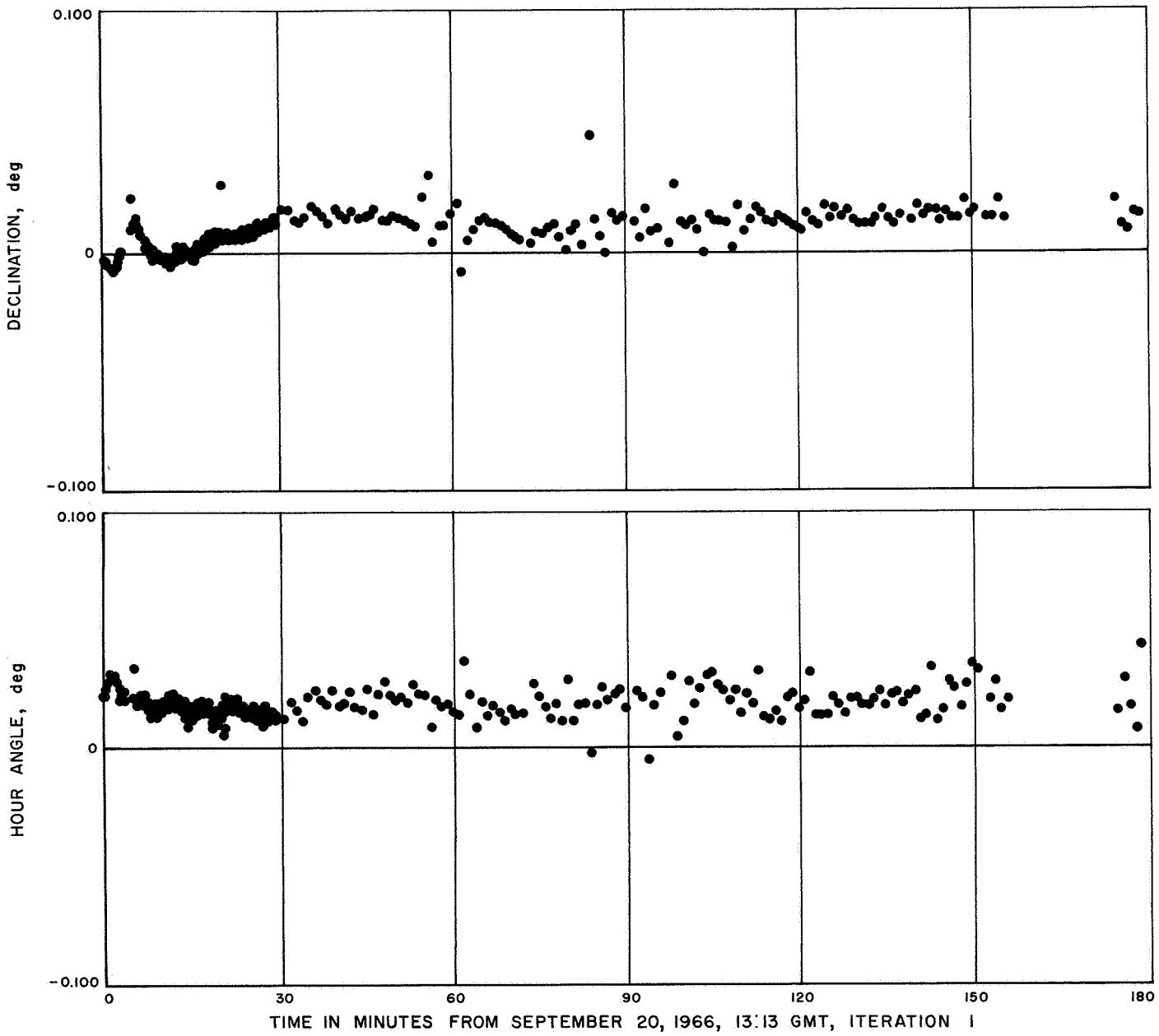


Fig. 100. DSS 51 hour angle and declination residuals, first pass; start 13:13 GMT

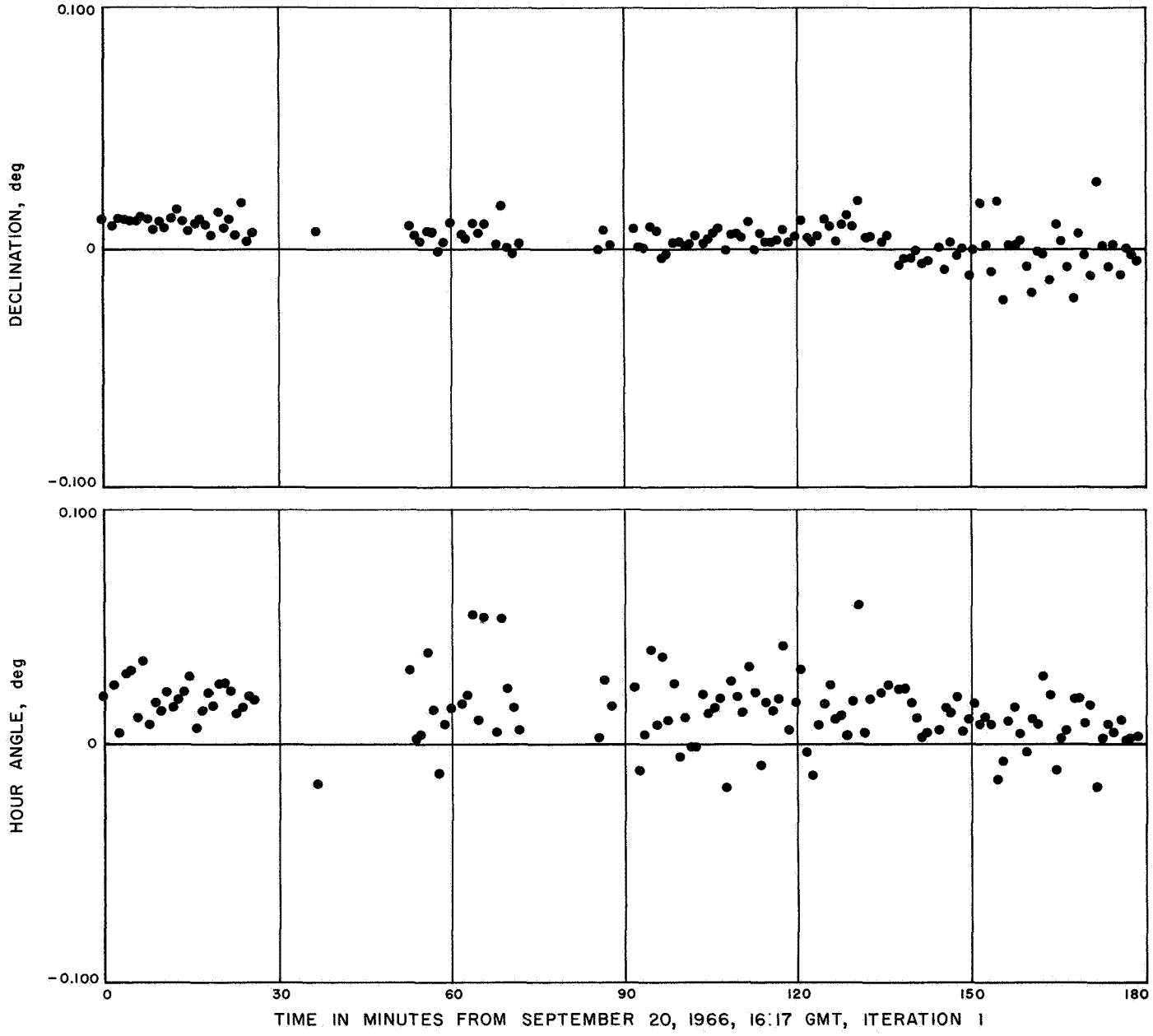


Fig. 101. DSS 51 hour angle and declination residuals, first pass; start 16:17 GMT

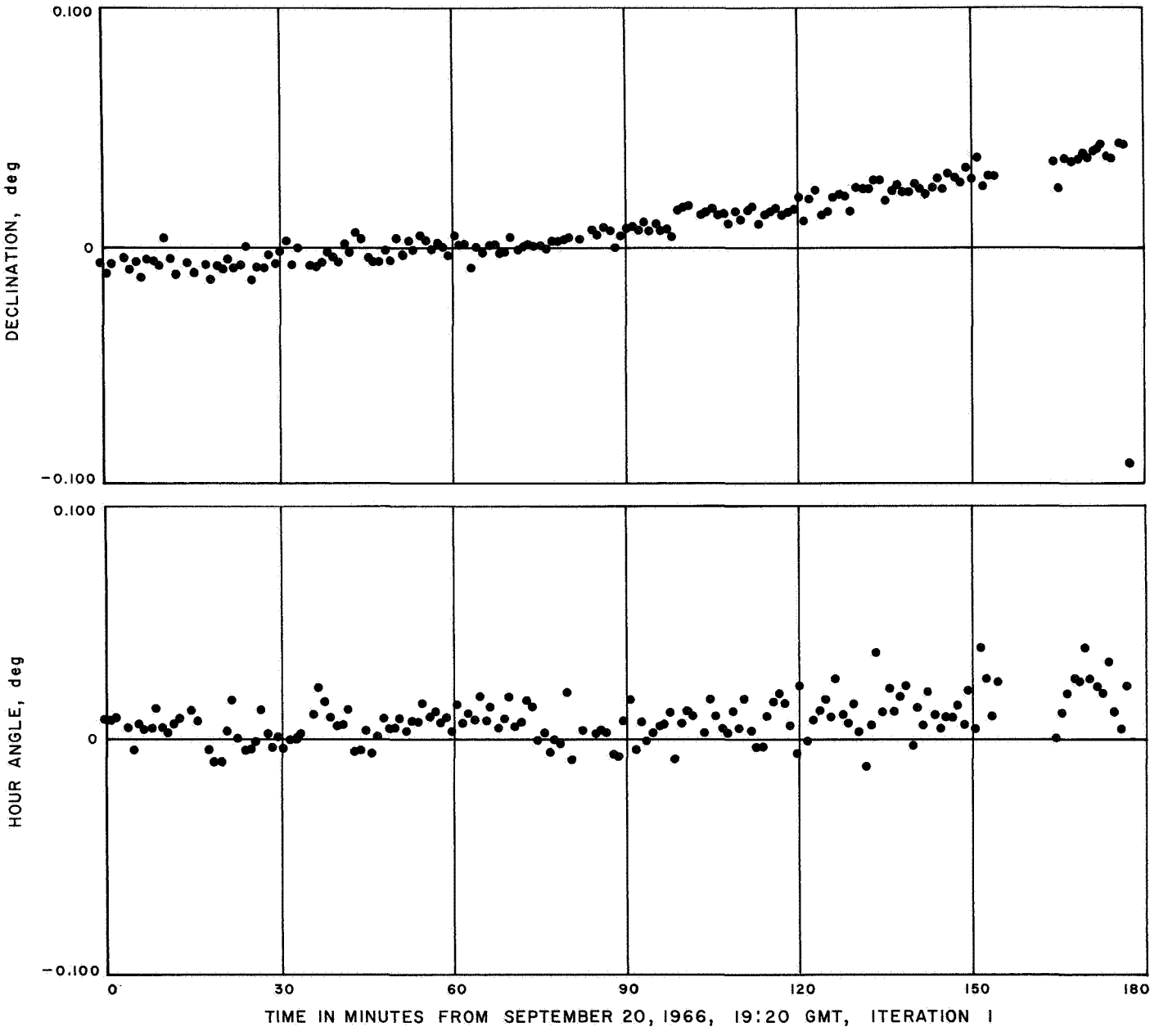


Fig. 102. DSS 51 hour angle and declination residuals, first pass; start 19:20 GMT

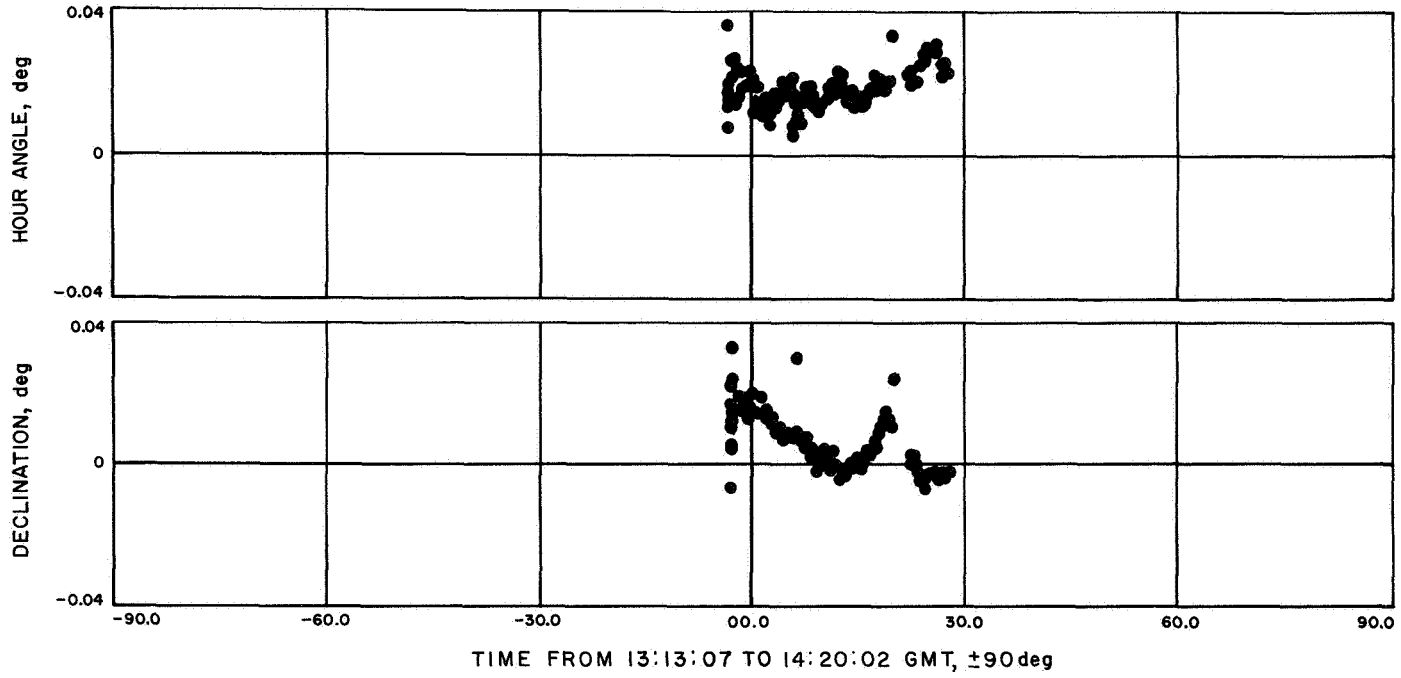


Fig. 103. DSS 51 residuals vs local hour angle, first pass; start 13:13 GMT

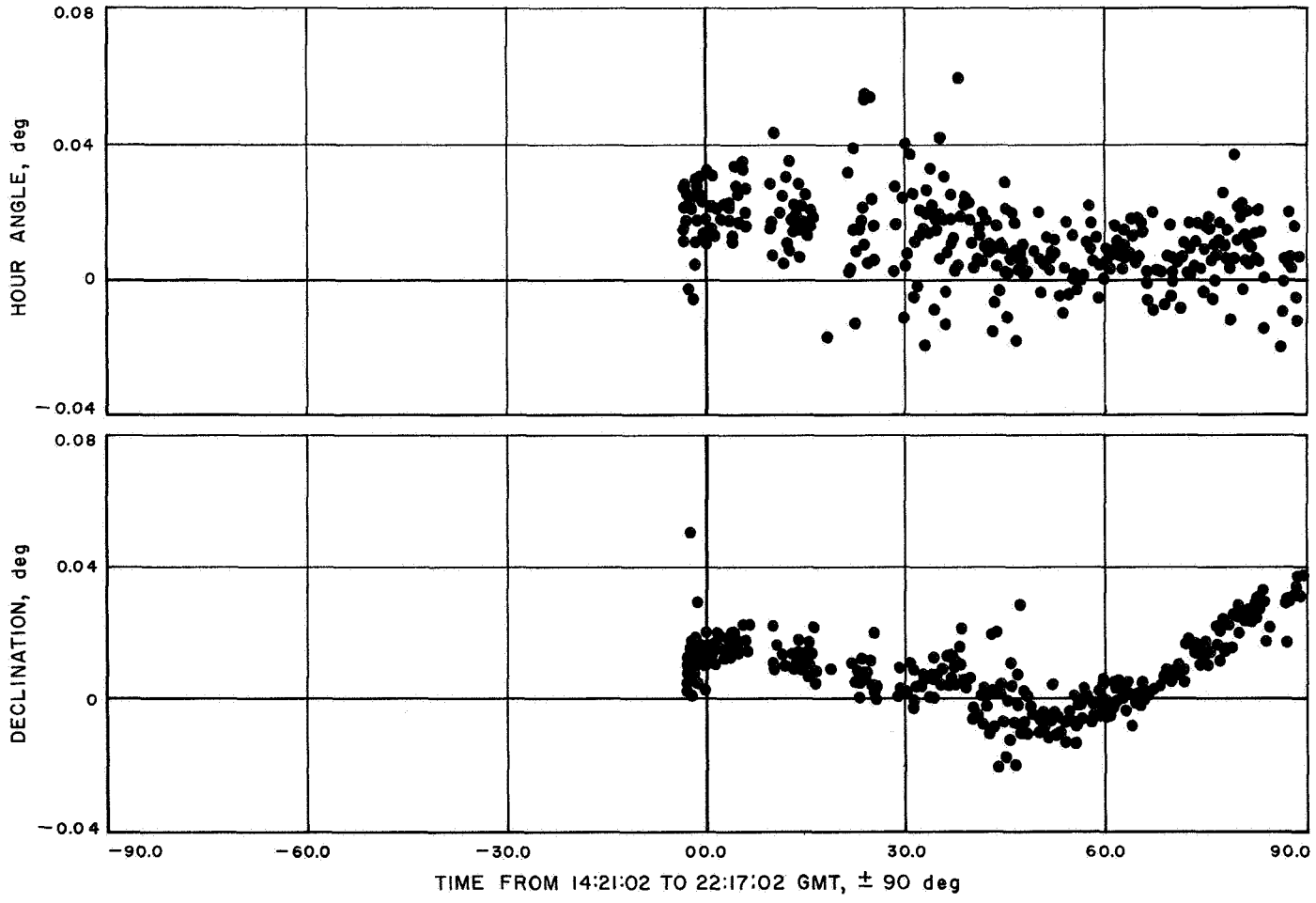


Fig. 104. DSS 51 residuals vs local hour angle, first pass; start 14:21 GMT

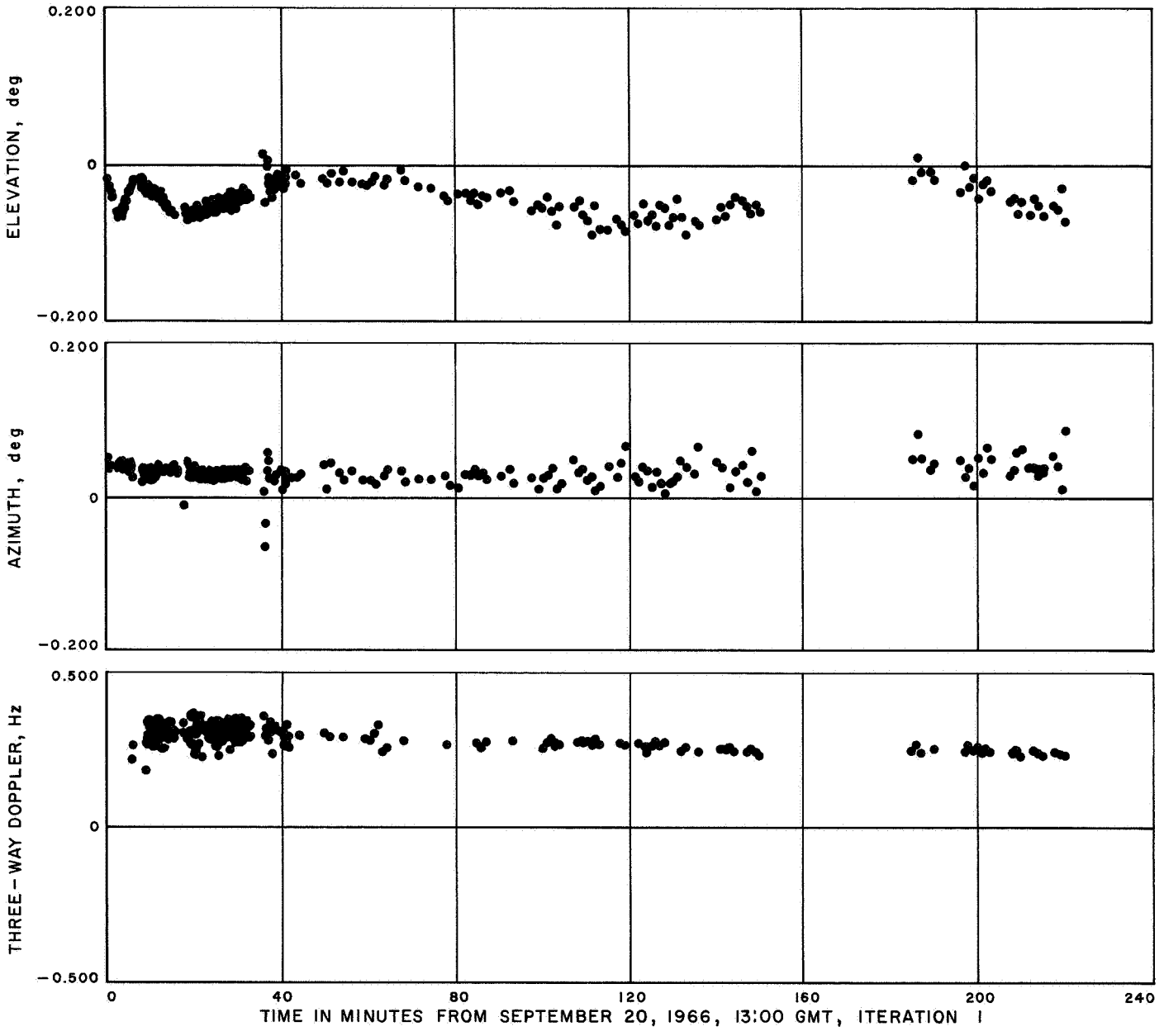


Fig. 105. DSS 72 three-way doppler, azimuth, and elevation residuals, first pass, start 13:00 GMT

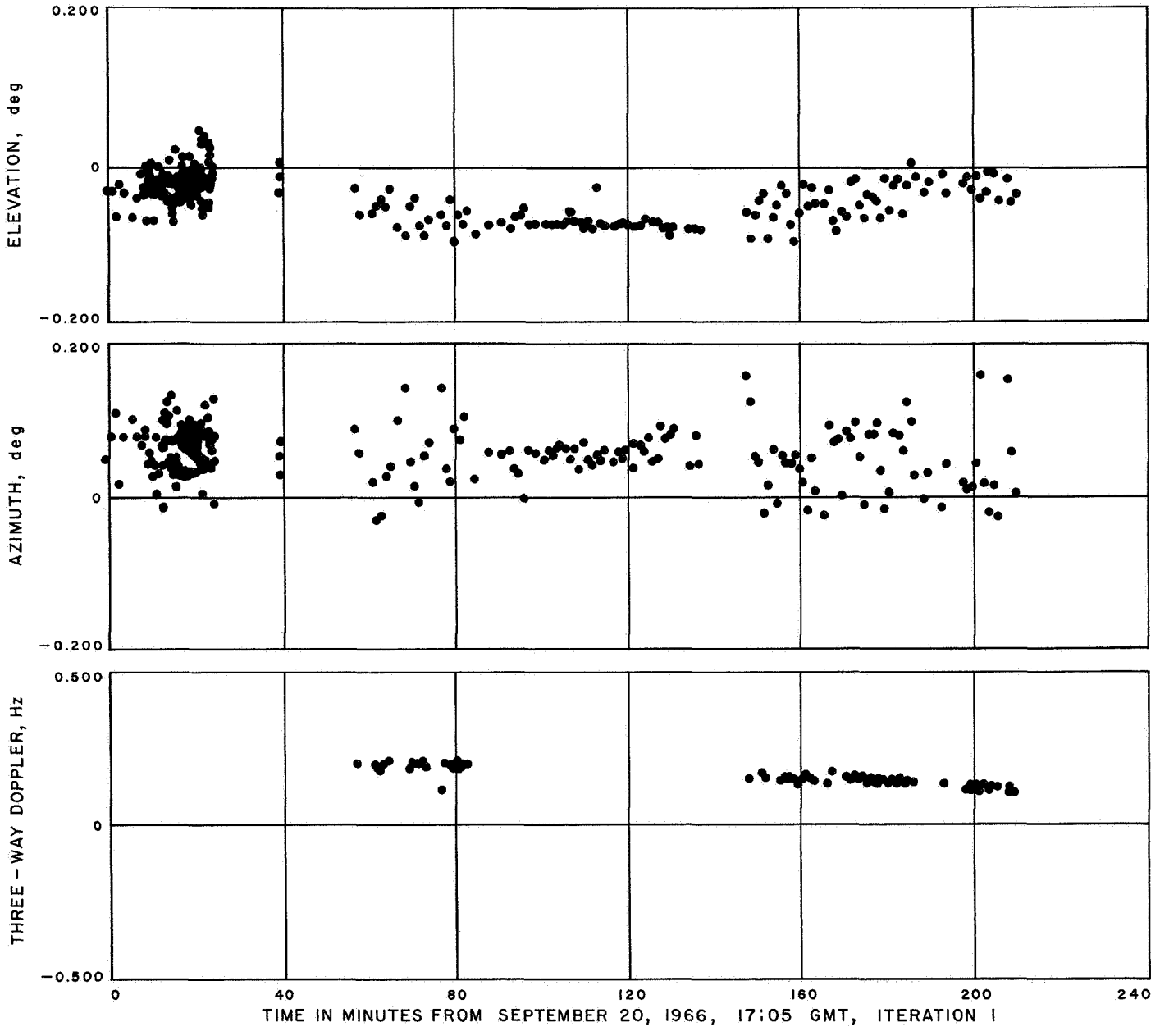


Fig. 106. DSS 72 three-way doppler, azimuth, and elevation residuals, first pass, start 17:05 GMT

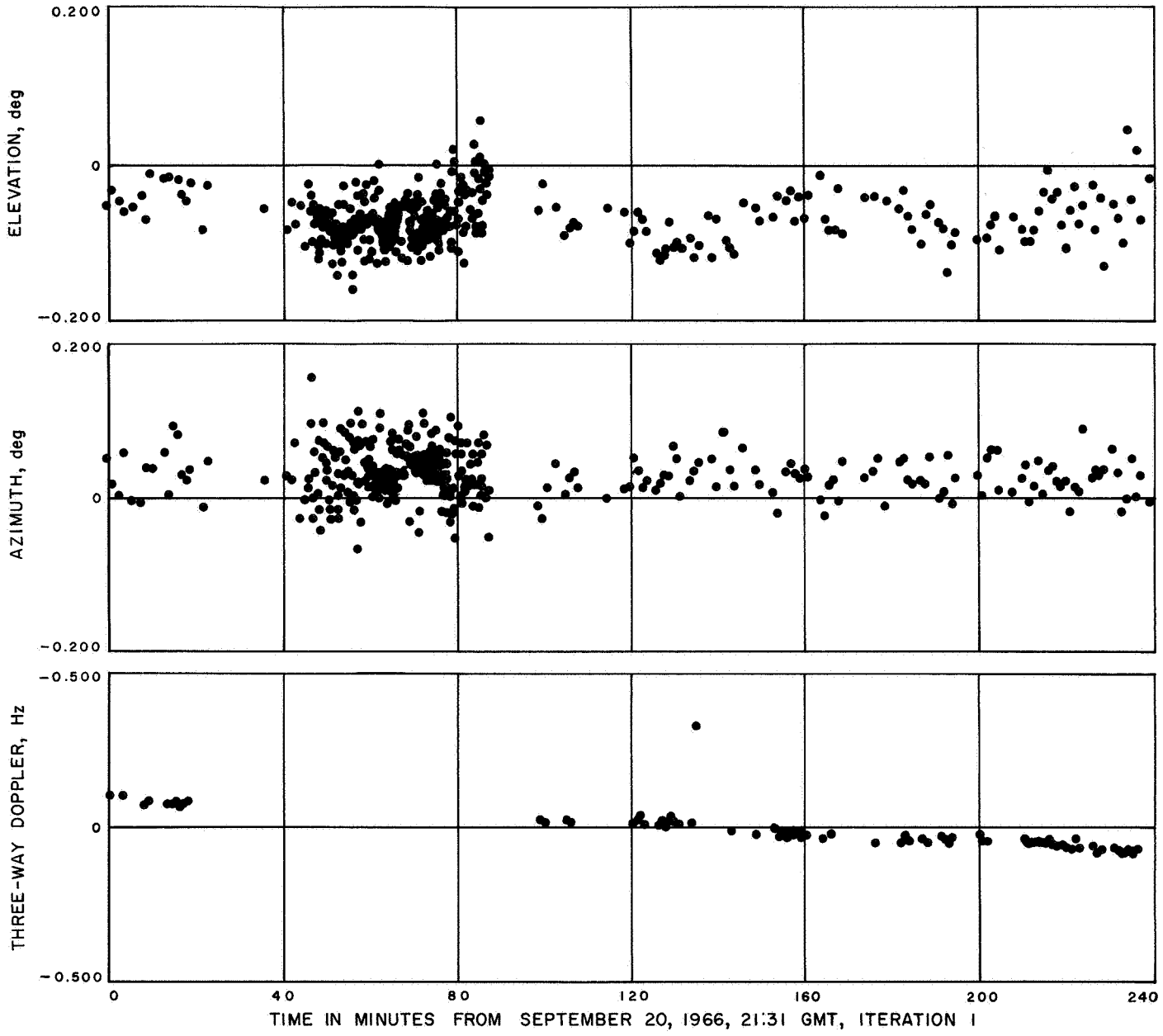


Fig. 107. DSS 72 three-way doppler, azimuth, and elevation residuals, first pass, start 21:31 GMT

2. Pre-midcourse phase, doppler tracking: DSS 51, the first station to see the spacecraft in the two-way mode after injection, began taking good two-way, 10-s-count doppler data at 13:05:07 GMT, September 20, 1966. DSS 51 switched to 60-s-count data at 13:42:47, and continued in the two-way mode until 22:00:02, with the exception of two short time blocks between 16:51:02 and 17:44:02 when DSS 72 was in the two-way mode, and between 18:34:02 and 19:07:02 when the spacecraft was in the one-way mode during Canopus acquisition. The doppler data taken during the first pass at DSS 51 were quite good, showing a standard deviation of approximately 0.060 Hz for 10-s-count data and 0.009 Hz for 60-s-count data. The doppler residuals for this pass at DSS 51 can be seen in Figs. 108–110. Of particular note in this pre-midcourse phase was the fact that DSS 72 took two-way doppler data for the first time, which had great importance in that it allowed an independent confirmation of the validity of the DSS 51 two-way doppler data (DACO YC) very early in the mission, and thus

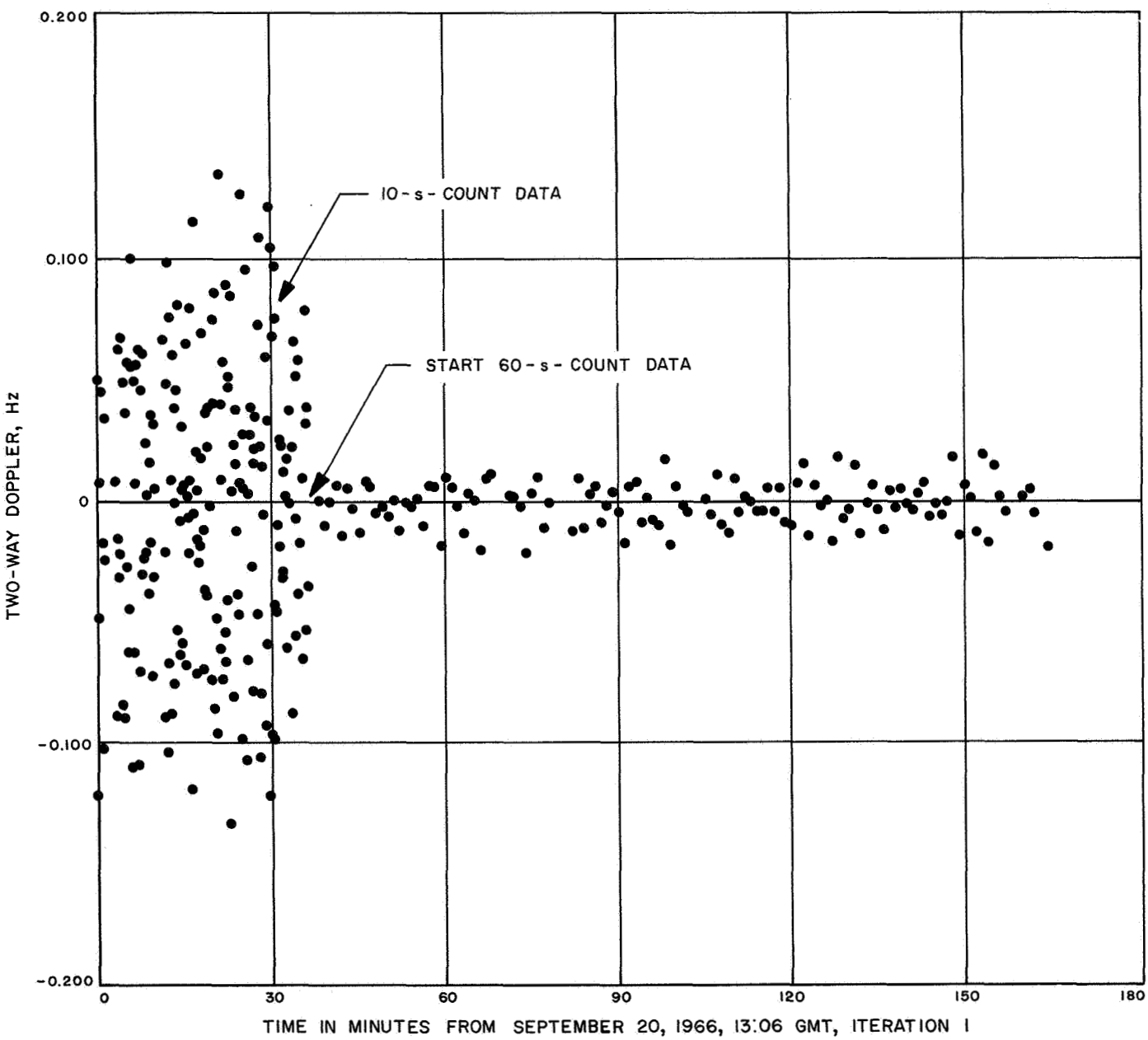


Fig. 108. DSS 51 two-way doppler residuals, first pass, start 13:06 GMT

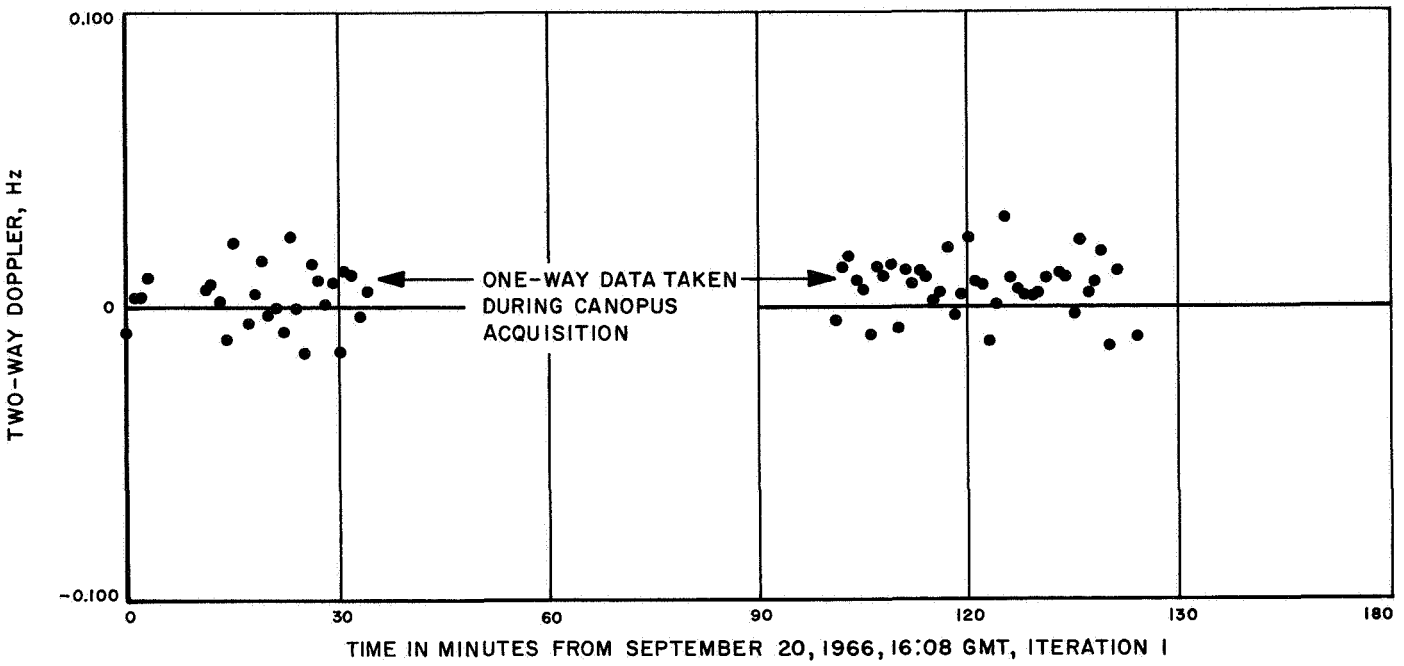


Fig. 109. DSS 51 two-way doppler residuals, first pass, start 16:06 GMT

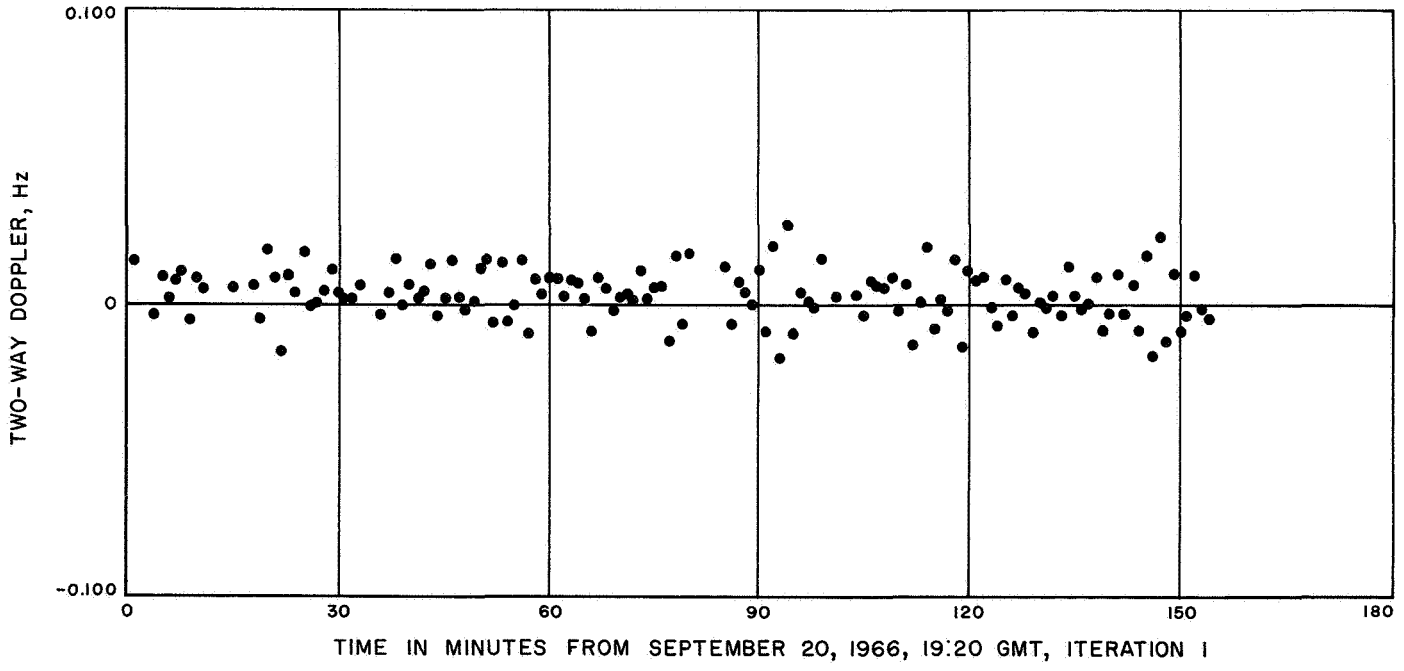


Fig. 110. DSS 51 two-way doppler residuals, first pass, start 19:20 GMT

allowed the Orbit Determination Group to produce an accurate estimation of the pre-midcourse orbit with far more statistical confidence than if they had had only DSS 51 data to work with. DSS 72 was in the two-way mode from approximately 17:03:02 GMT, September 20, 1966, to 17:46:52, and from 22:02:02 to 23:05:42; during the second period DSS 72 was able to fill with two-way doppler data the view period gap between DSS 51 and DSS 11, which existed on the first pass. The two-way, 10-s-count doppler data taken at DSS 72 during the first pass had a standard deviation of approximately 0.040 Hz, and can be viewed in Figs. 111 and 112. During the rest of its first pass, DSS 72 took three-way doppler data with DSS 51, and this can be seen in Figs. 105–107. The three-way data taken at DSS 72 during the first pass showed a bias of about 0.200 Hz, which compares very favorably with a similar bias of about 10 Hz for the first-pass three-way doppler data taken at DSS 72 during the *Surveyor I* mission. DSS 11 began taking good two-way doppler data at 23:16:02, September 20, 1966 and continued until the time of midcourse maneuver at 05:00:00, September 21, 1966. These data had very little noise, showing a standard deviation of 0.005 Hz; however, a slightly higher than usual bias of approximately 0.016 Hz was encountered. These residuals can be viewed in Figs. 113–115. DSS 42 took approximately 2 h of three-way doppler data with DSS 11 before the midcourse maneuver, and these data can be seen in Fig. 116. These data were quite good for three-way data, having a standard deviation of approximately 0.007 Hz and a bias of 0.016 Hz.

3. Midcourse maneuver: A midcourse maneuver was programmed for 05:00:00 GMT, September 21, 1966, but was aborted because one engine failed to ignite. The results of this abortive maneuver and the subsequent tumble induced in the spacecraft can be seen in the 1-s,

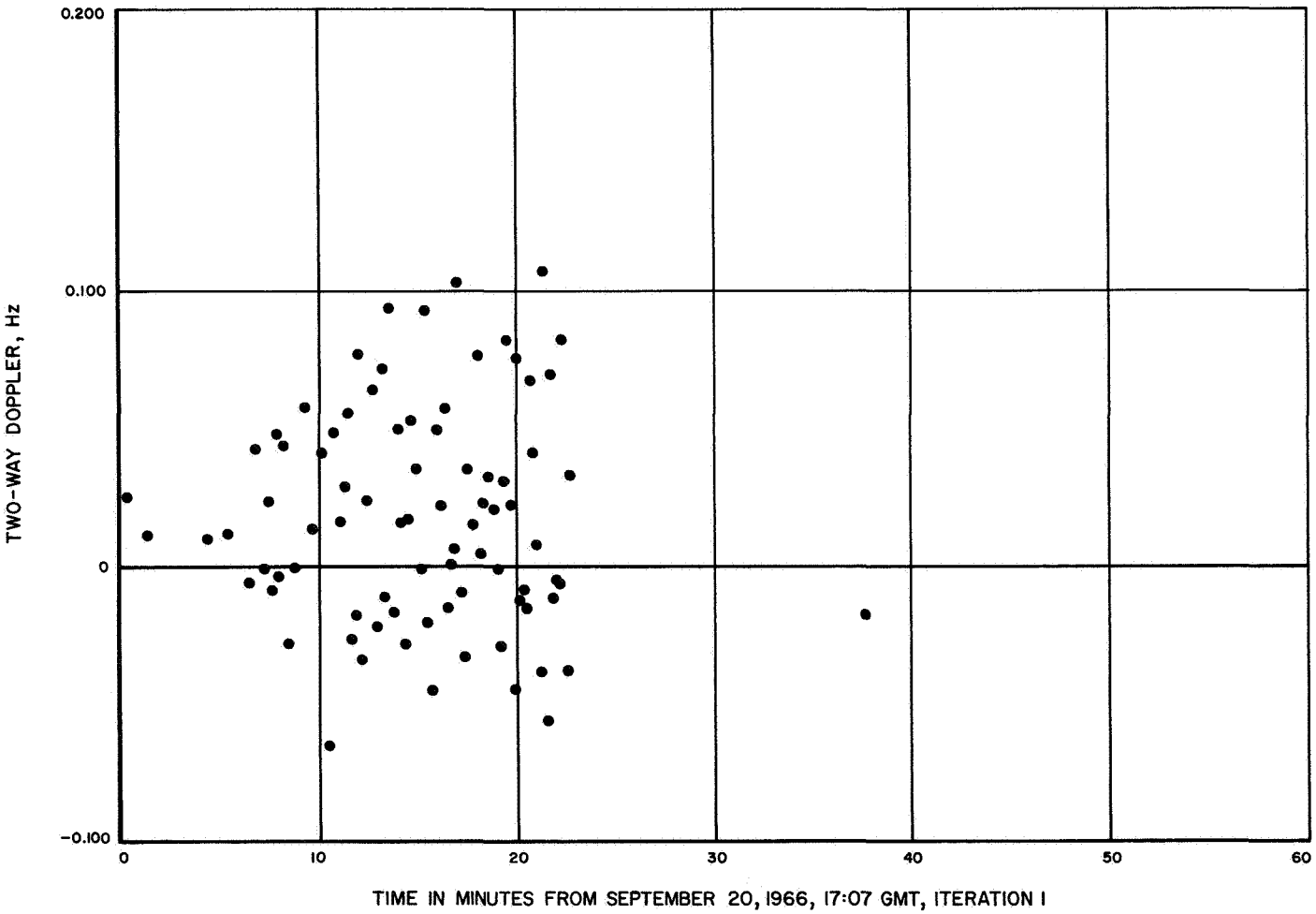


Fig. 111. DSS 72 two-way doppler residuals, first pass, start 17:07 GMT

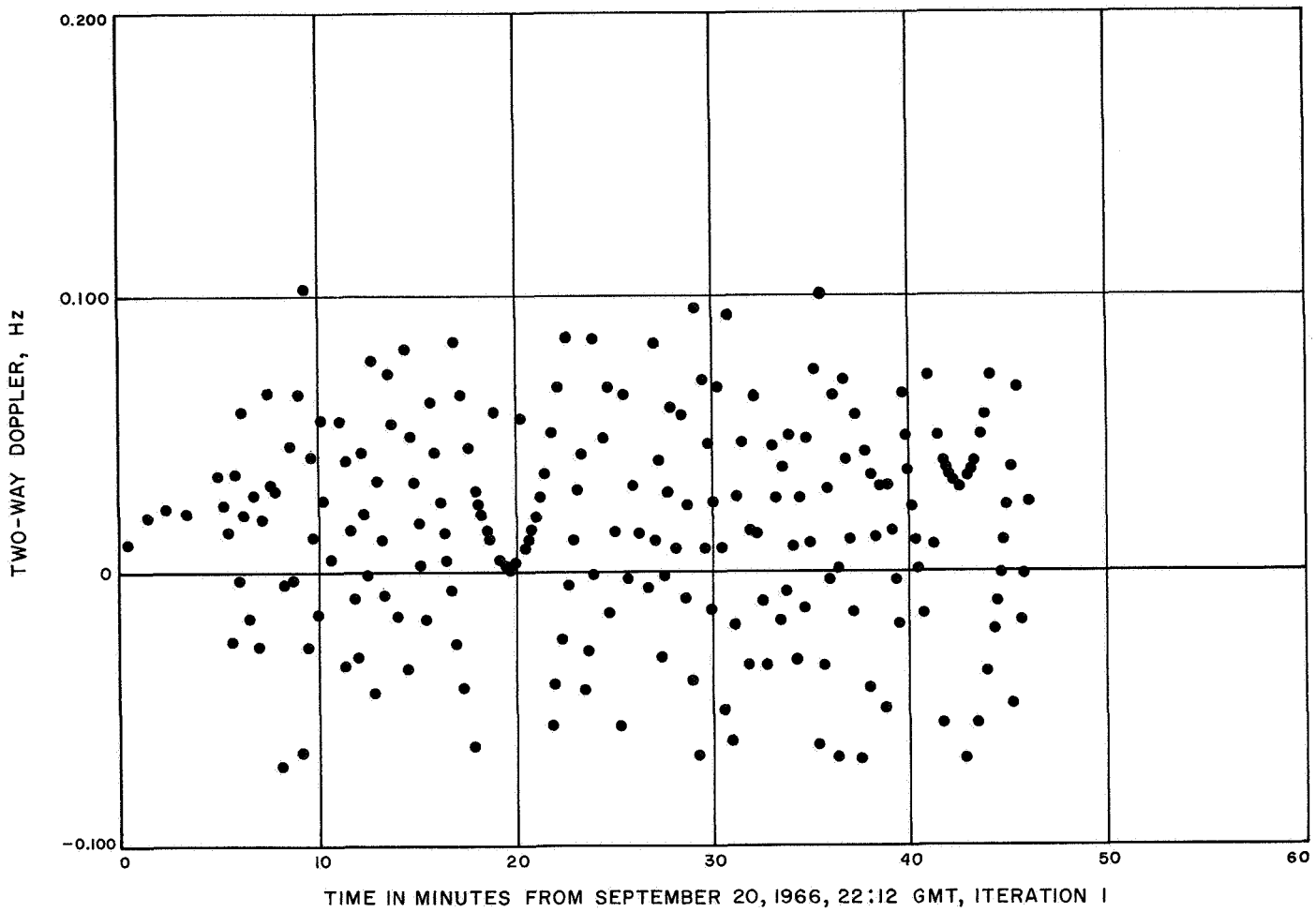


Fig. 112. DSS 72 two-way doppler residuals, first pass, start 22:12 GMT

three-way doppler data taken at DSS 42 during the burn period and immediately thereafter, as presented in Fig. 117.

4. Post-midcourse phase: The DSN tracked the *Surveyor II* spacecraft from 05:00 GMT September 21, 1966, until LOS at approximately 09:35 September 22, 1966; however, the data are not readily amenable to analysis because of the varying tumble rates induced in the data as a result of the repeated spacecraft engine ignitions performed in an attempt to salvage the mission.

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

The DSIF provided continuous tracking and telemetry coverage from L + 17 min (DSS 72 rise) to end of mission at L + 45 h, 24 min. This was the first use of DSS 72 as a committed *Surveyor* station, and the two-way tracking data supplied were quite useful in the initial orbit calculations. This station was also used to fill a gap in station coverage between the first-pass set at DSS 51 and the first-pass rise at DSS 11. The gap had a duration of 31 min and was a result of launching late in the window. Because of the lower antenna gain (30-ft antenna) and higher system noise temperature (paramp instead of maser), it was necessary to reduce the spacecraft data rate to 17.2 bits/s to obtain usable telemetry data. This was done, and DSS 72 was able to obtain telemetry data during the gap period.

DSS 61 was designated a training station during the *Surveyor II* mission. The station was committed to provide tracking capability within a 1 to 1½-h call-up.

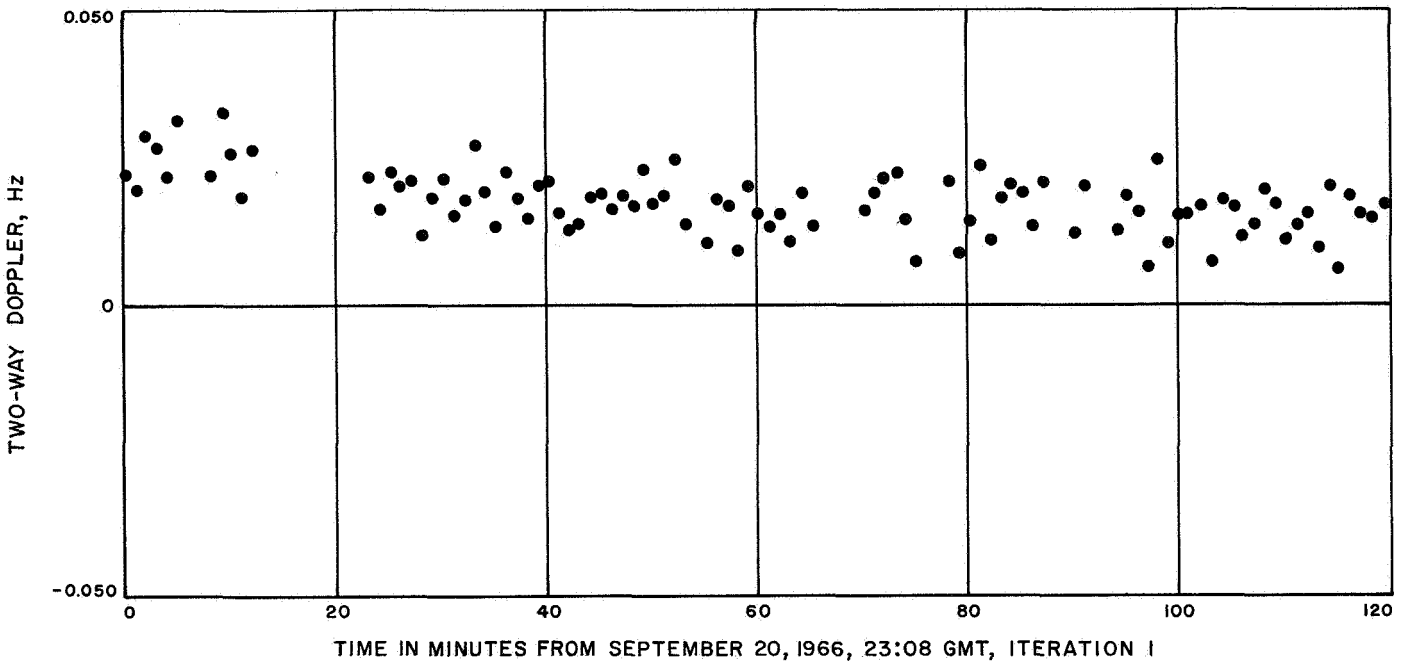


Fig. 113. DSS 11 two-way doppler residuals, first pass, start 23:08 GMT

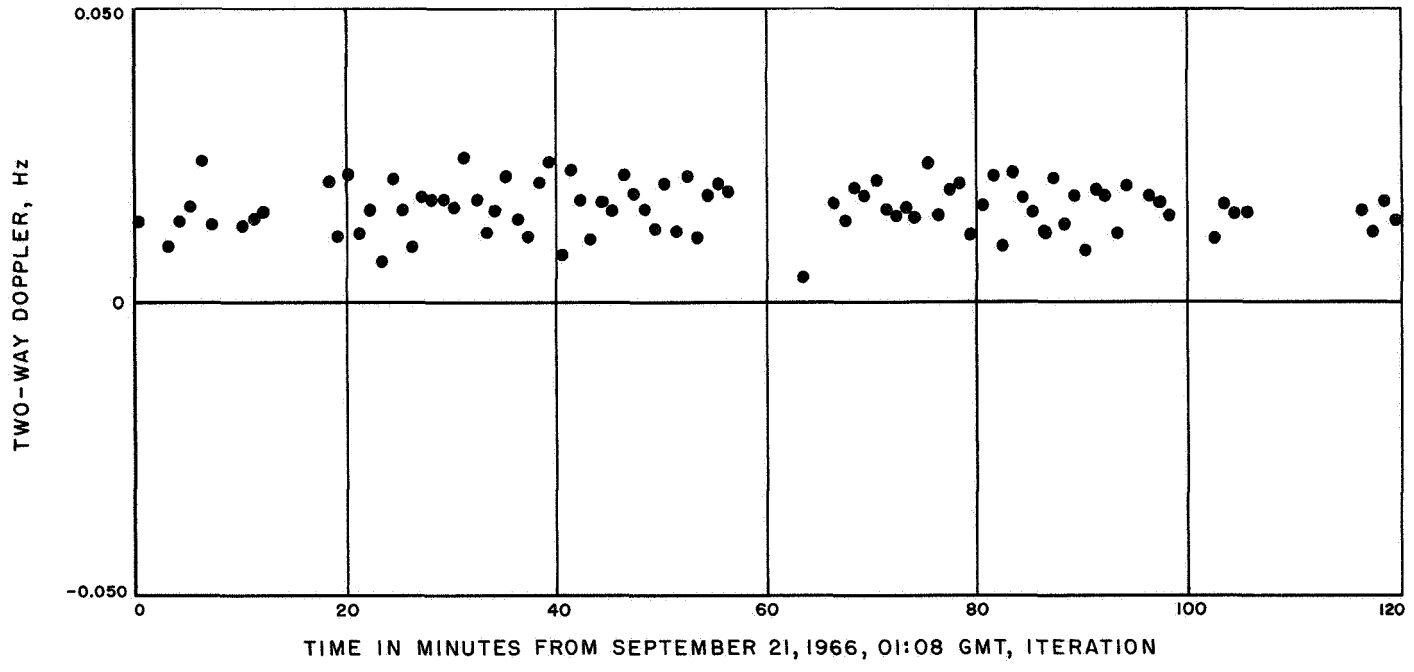


Fig. 114. DSS 11 two-way doppler residuals, first pass, start 01:08 GMT

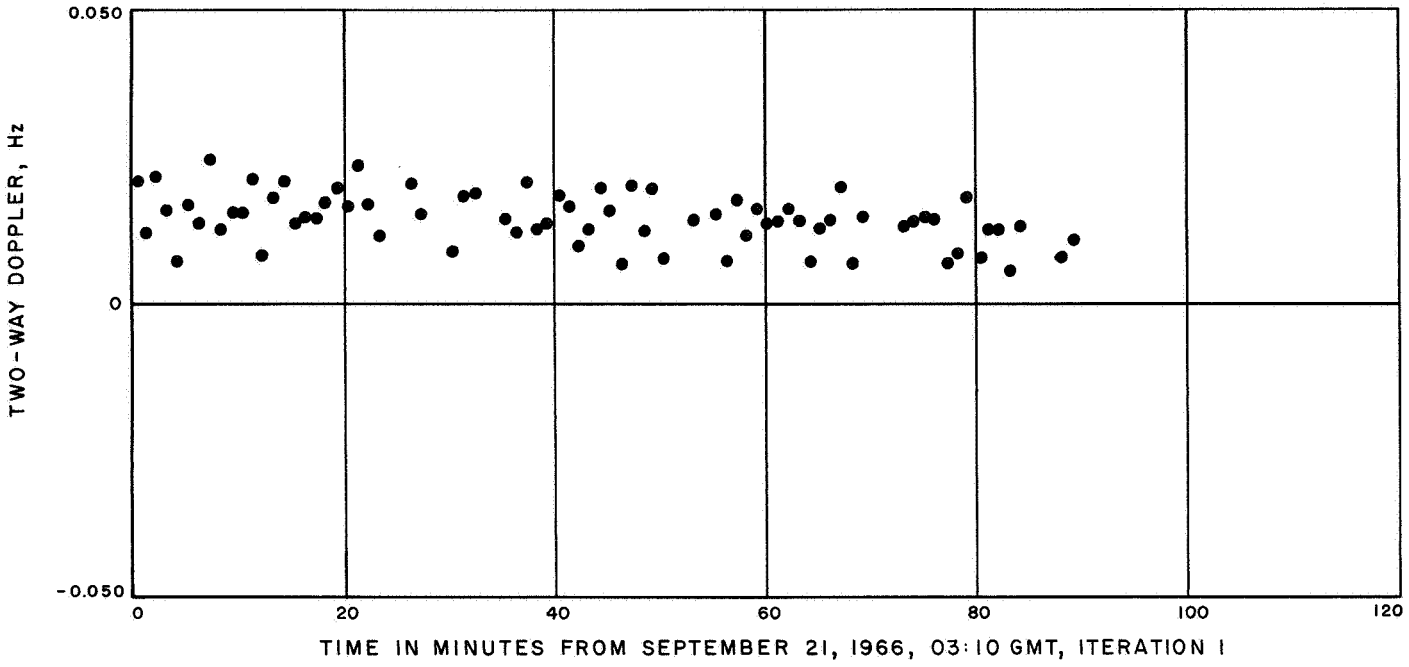


Fig. 115. DSS 11 two-way doppler residuals, first pass, start 03:10 GMT

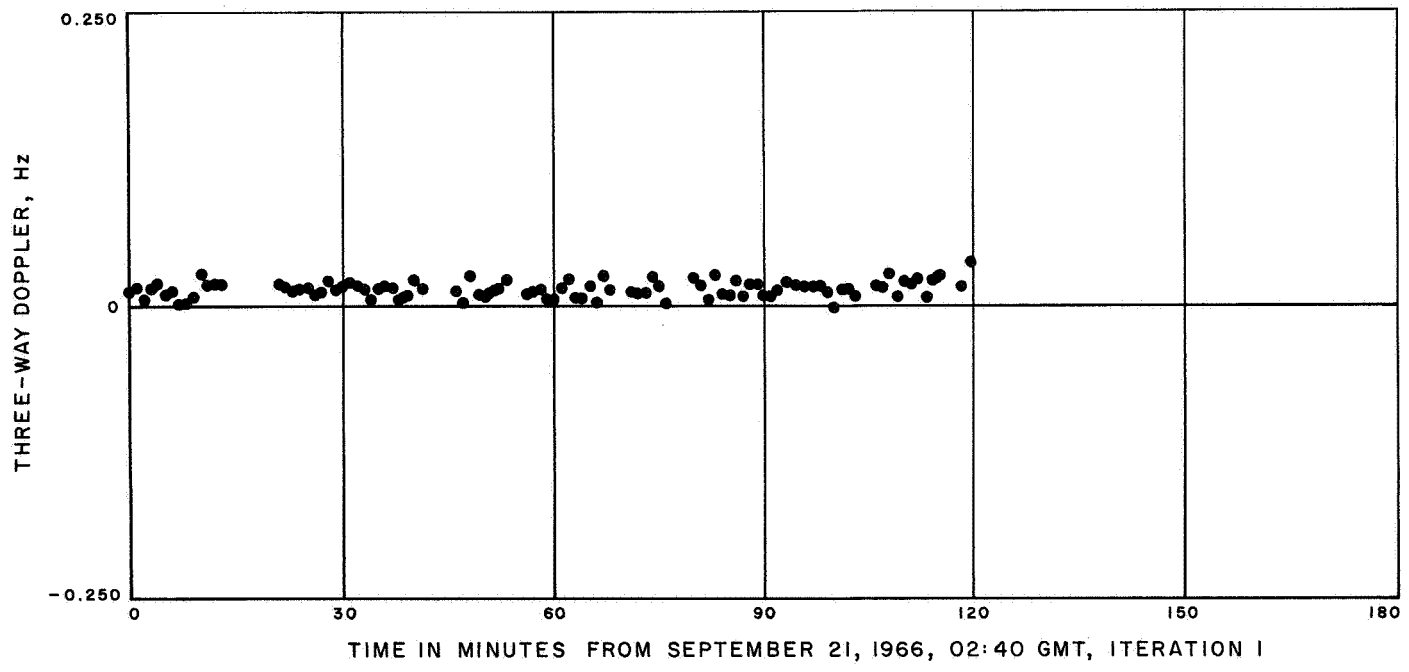


Fig. 116. DSS 42 three-way doppler residuals, first pass, start 02:40 GMT

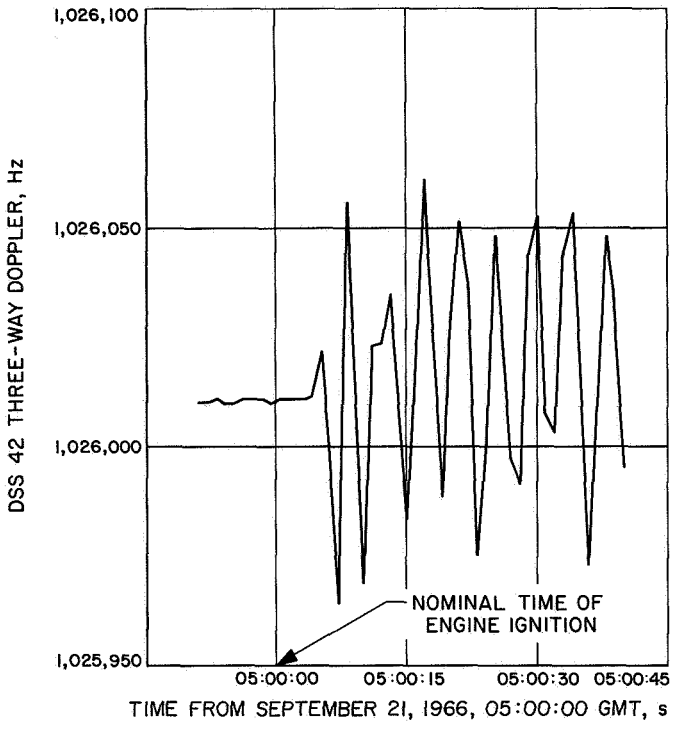


Fig. 117. Midcourse maneuver aborted

During the second pass at DSS 51 when communications were out, DSS 61 was called up. The station continued tracking during a *Pioneer* pass and reconfigured for *Surveyor* within minutes to provide tracking support. No high-speed data were obtained from DSS 61 during this pass because of a manning problem complicated by an OSDP hardware problem.

c. Backup support. During midcourse, DSS 12 was configured to provide X backup in the event the transmitter at DSS 11 failed. This support was in standby status, and procedures were available because they had been previously exercised between DSS 11 and DSS 12. The support, however, was not required.

DSS 14 provided recording backup during the midcourse period. This support was adequate.

Figure 118 gives a profile of DSIF mission activity. Individual station tracking periods are plotted along with hours from launch.

An evaluation of the DSIF tracking station performance under non-standard mission conditions was good. Low spacecraft signal values coupled with spacecraft frequency variations of 200 and 300 Hz at S-band resulted in difficult tracking.

The tracking loop bandwidths were modified to extend the bandwidth by a factor of two at DSS 51, and by a factor of four at DSS 42, during the second pass at each station.

d. DSIF equipment. The prime network of DSS 11, 42, 51, 71, and 72 entered the mission with all stations in the green condition, and all measured station parameters within nominal performance specifications.

The signal levels received at the stations are shown in Fig. 119. They compare favorably with the predicted value. Only the portion of the mission before the midcourse maneuver is shown. Because of spacecraft tumbling, the post-midcourse data is very inaccurate. A 2-dB discrepancy between DSS 11 signal levels and those of other stations (notably DSS 42) is apparent. This discrepancy is a result of the automatic gain control calibration method used and is consistent with results obtained in the *Surveyor I* mission. The 7-dB drop in signal level recorded by DSS 51 between 16:00 and 18:00 GMT is due to an increased carrier suppression of the 137.5-bits/s rate of 3 dB, and a 4-dB spacecraft antenna loss due to spacecraft orientation. Note that this occurred prior to star-track acquisition.

DSS 42 experienced some difficulty obtaining lock during its initial tracking period because of inaccurate angle pointing data in the received predicts. Because of its larger reflector (210 ft), DSS 14 received a signal 8 dB above the received signal level of other stations. Similarly, because of its smaller reflector (30 ft), DSS 72 received a signal at a level 10 dB less than the other stations. These levels were consistent during the respective station's tracking periods. The variations in the DSS 72 signal level data are due to the increased carrier suppression at 17.2 bits/s coupled with a loss of calibration accuracy at low signal levels.

DSS 61 was able to interrupt a *Pioneer* track, reconfigure for *Surveyor*, and be in two-way lock ready for commanding in approximately 13 min. This was accomplished with a few men in the middle of the night, and in spite of complicating hardware problems.

The significant anomalies together with their causes and effects are given in Table 112. In addition to those listed as significant, a number of minor perturbations

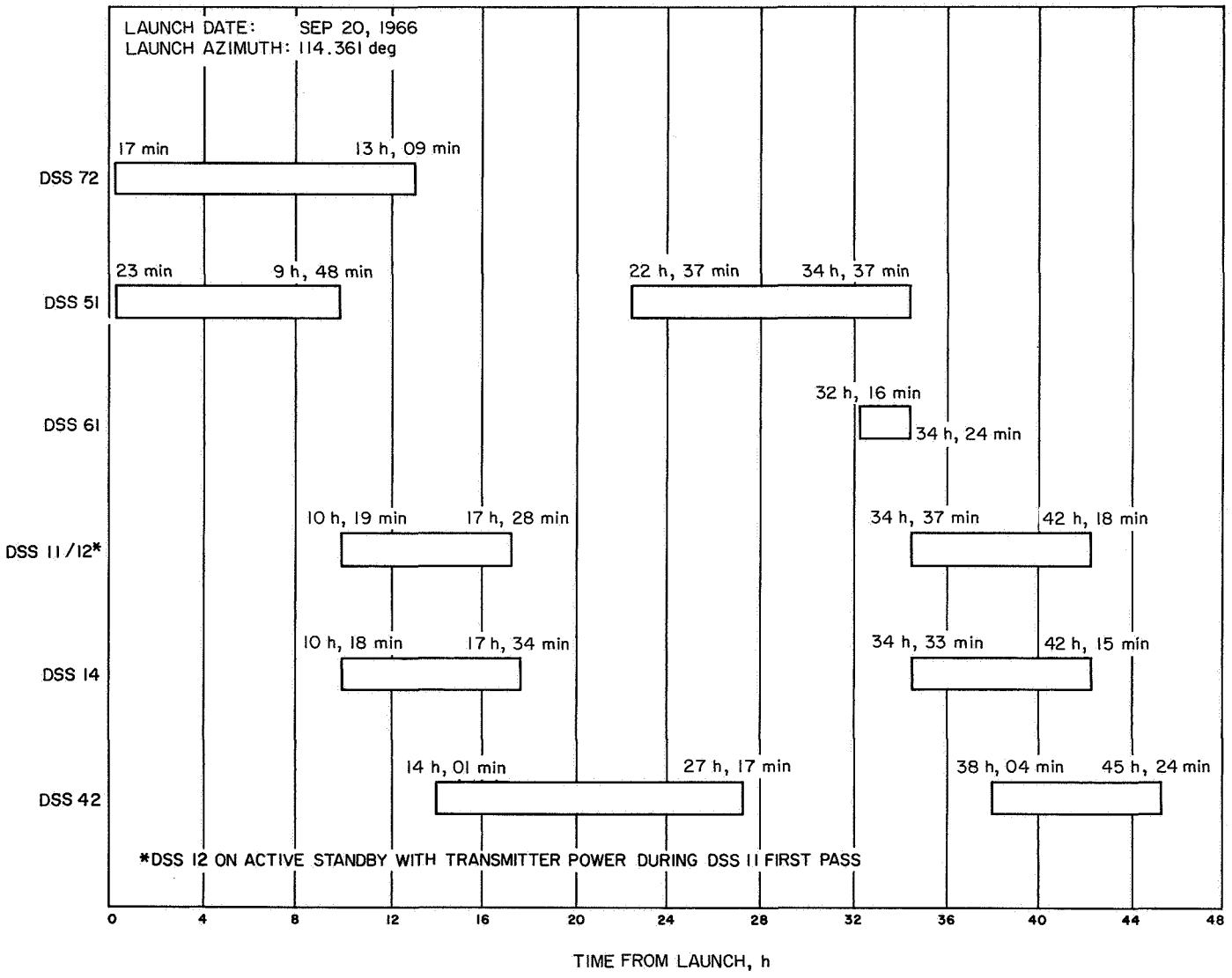


Fig. 118. DSIF station tracking periods

Table 112. Summary of DSIF anomalies, *Surveyor II* mission

DSS	Pass	Time (GMT)	Anomaly	Probable cause	Immediate action	Effect on the mission	Current action	Comments
42	Pre-*L*		FR-800 tape recorder did not meet anticipated performance	Equipment complexity	Reconfigured track assignments to accommodate lower performance	This problem affected only standardization of track assignments between stations; no data loss	The equipment problems will be resolved by the station personnel and the DSIF cognizant operating engineer	
51	1	13:00	Difficulty in transferring from SAA to SCM	Unbalance in SAA servo; poor tracking on low angle rates; wrong evaluation by SCM monitor receiver due to high signal level	Used spectrum analyzer for monitoring transfer	Delayed going to auto track by 3 min	Investigating	This seems to be primarily a systems engineering problem compounded by a nonrecurring short-term SAA servo drift
51	1	13:00	Difficulty in obtaining a transmitter turn-on (X_a) for nonstandard uplink acquisitions	Requirement was not anticipated	Determined required data in real time	Delayed going to two-way doppler by approx 7 min	Designing procedure to provide acquisition station with additional turn-on X_a frequencies and times to be used if unable to use the initial value	This action was required because DSS 51 was not ready for X_a turn-on at the anticipated time because of the equipment problems discussed in DSS 42
72	1	19:00	Difficulty in maintaining downlink lock while tuning SAA	Operator selected 12 Hz tracking bandwidth instead of 48 Hz	Tuned slowly	Delayed receipt of good two-way doppler by a total of 30 min		This was due to operator fatigue. He had been on duty for over 18 h. This long duty was required because of the short staff at DSS 72
72	1		TDH data-doppler counter 100s digit turned over slowly	Unknown	(Anomaly was not apparent at the station)	Very little	Investigating	This problem was not apparent at the station during the prelaunch countdown, the mission, and the posttrack calibrations
72	1	19:00	CDC required setup at 17.2 bits/s data rate	Station was instructed prior to launch that this bit rate would not be used	Station set up equipment in real time	None	Coordinating data rate requirements with *Surveyor* Project	The signal level received at DSS 72 was below the threshold for higher bit rates. The CDC personnel did a good job of implementing this capability in real time. This requirement was a result of an unanticipated 40-min gap between DSS 51 set and DSS 11 rise. DSS 72 was pressed into service in real time to cover this gap

Table 112 (contd)

DSS	Pass	Time (GMT)	Anomaly	Probable cause	Immediate action	Effect on the mission	Current action	Comments
11	1		Spacecraft AGC receiver B telemetry reading was suspect	Spacecraft telemetry system malfunction	Perform threshhold test on spacecraft receiver using DSS 11	None	None	DSIF assisted SPAC in evaluating a spacecraft anomaly by performing threshold test
11	1		Transmitter trip, twice	Collector flow interlock reacting to flow surges	Turn transmitter back on	Transmitter off for 30 s on two occasions	Flow regulator was repaired	Malfunctioning flow regulator
51	2		Could not maintain lock on tumbling spacecraft	Excessive doppler jitter	Widen tracking bandwidth from 152 Hz to approx 300 Hz	Station was able to continue tracking	Investigating	This problem required a modification of the receiver VCO to maintain the receiver ability to track the nonstandard spacecraft
51	2		Loss of telemetry threshold	Excessive bandwidth in telemetry channel of L/S receiver	None	Loss of telemetry data	Recommend S-band receiver	This problem was the result of discarding the suitcase receiver because of the nonstandard spacecraft and using the L/S receiver in its place. The L/S receiver was not designed with variable telemetry bandwidths; therefore, the telemetry bandwidth was much larger than required and telemetry threshold was lost
61	2	20:48	TDH punch jammed	Unknown	Punch replaced	Loss of tracking data	TFR 61-TDH-01-A004-037	
61	2	21:57	TDH data did not include carriage return	Defective card in punch feed system programmer. Comm buffer malfunction	Punch No. 2 was made prime in place of defective punch No. 1	Loss of tracking data	TFR 61-TDH-02-A008-038	
61	2		HSDL data had constant 1 bit in word "0" position	Commutator buffer malfunction	Attempted to change to backup OSDP computer	Loss of telemetry at SFOF for about 2 h. DSS 51 HS data was received continuously	Bad solder connection has been repaired	This problem was essentially a hardware problem. However, it was compounded by the lack of a TCP operator during this emergency *Surveyor* track
42	2		Could not track tumbling spacecraft	Excessive doppler jitter	Widen tracking bandwidth from 152 Hz to 300 Hz and then to 600 Hz	Station was able to continue tracking	Investigating	

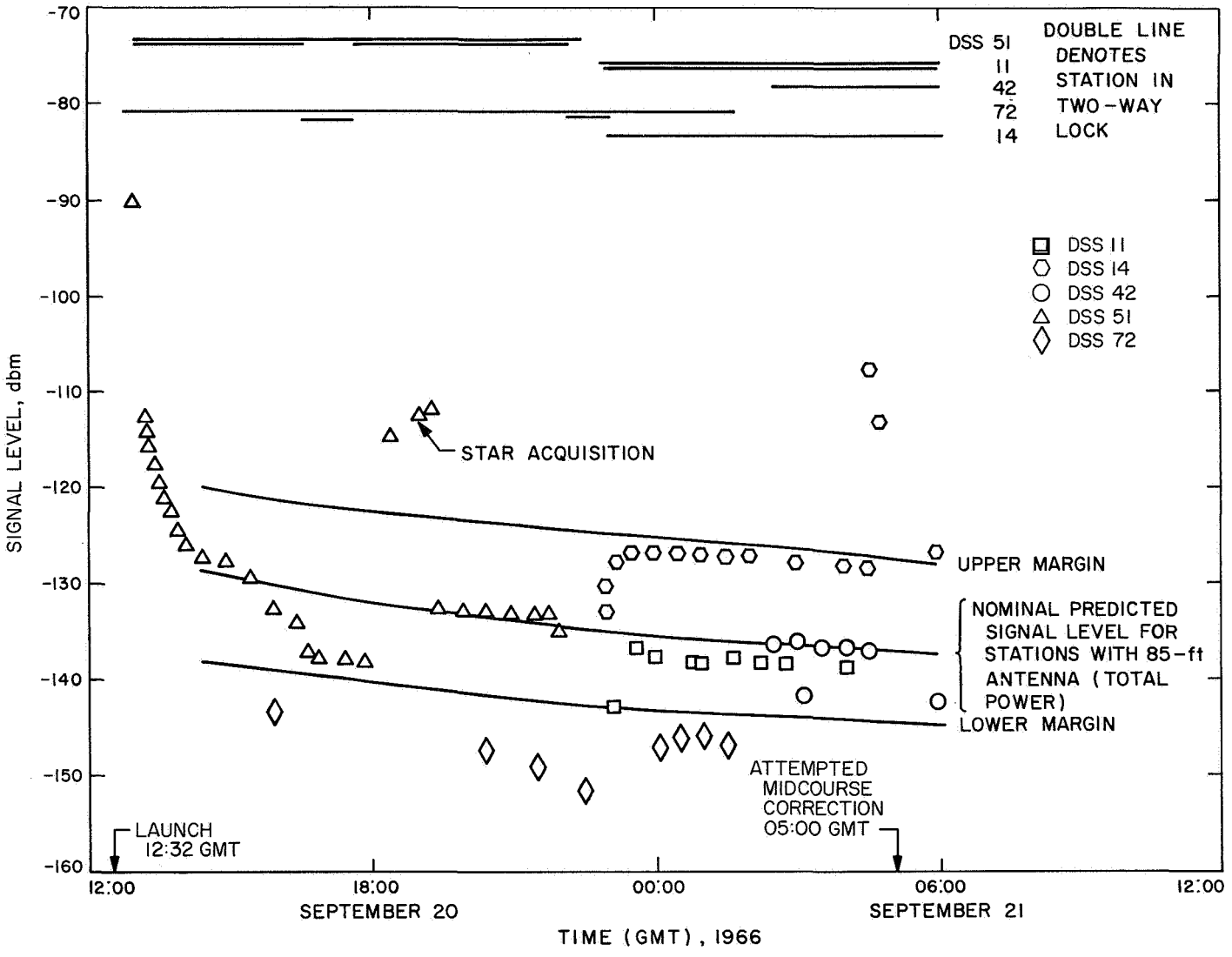


Fig. 119. DSIF received signal levels

were corrected by the station personnel without affecting the mission. They are not included in this tabulation.

The DSIF operated very well during this nonstandard mission. The stations provided unanticipated performance under difficult conditions. At least four of these conditions should be noted:

(1) DSS 72 covered the tracking gap between DSS 51 spacecraft set and DSS 11 spacecraft rise on the first pass.

(2) DSS 61 provided an emergency track during severe communication problems with DSS 51.

(3) DSS 11 performed spacecraft threshold test to aid in evaluating spacecraft anomaly.

(4) DSS 51 and DSS 42 modified their Goldstone Duplicate Standard (GSDS) receivers to real time in order to continue tracking the tumbling spacecraft.

Although the masers at all stations performed well during this mission, the pre-launch experience caused some concern about their reliability.

The low angle rate and high signal level performance of DSS 51 requires investigation and possibly some engineering action or replacement with a standard S-band system.

The capability of tracking a tumbling spacecraft was investigated and some engineering action taken.

Table 113. *Surveyor II* DSIF problem summary

Problem	Effect on mission	Cause	Solution
Test plans arrive at stations too late for stations to adequately man, schedule and prepare for test	Some effect on stations' preparation	Project late in submitting test plans	Insist project provide test plans to stations one week before test
Overloaded OVCS *Surveyor* Control Net	Communications slower than optimum	Too many SFOF facilities use this voice net	Better use of voice nets
During commanding periods DSIF Net Control has no voice line available unless Mission Control releases line to net	Delay in obtaining and passing data quickly to stations during commanding periods	Only one voice line available for shared use by DSIF Net Control and Mission Control	Obtain separate voice lines for Net Control and Mission Control
Changes to Tracking Instruction Manual made few weeks before launch as a result of new support requirements for stations	Minor	Project or Systems Engineering change request	No known solution
Spacecraft data from computer is available within SFOF that would help Track Advisor. Data not currently available to him	Minor	Data only available on a 110-wpm TTY printer	Provide a 100-wpm TTY printer at Track Advisor's position
If initial acquisition station does not acquire two-way at XA given in predicts, a new XA and related time is required	Could be serious if two-way acquisition cannot be achieved	Problem exists only if station does not achieve two-way acquisition on first try	Develop a procedure which will provide a series of XAs vs times

Table 113 gives a listing of problems encountered during the *Surveyor II* mission. Included are the cause, solution, and effect on the mission and preventative action recommended.

2. Ground Communications Facility/NASCOM. For the *Surveyor II* mission, the GCF transmitted tracking, telemetry, and command data from the DSIF to the SFOF and control and command functions from the SFOF to the DSIF by means of NASCOM facilities. It also transmitted simulated tracking data to the DSIF and video data and baseband telemetry from DSS 11, Goldstone DSCC, to the SFOF.

a. Voice lines. The NASCOM voice circuits provided to the *Surveyor II* mission performed nearly perfectly. Failures occurred in the circuits to the South African station (DSS 51) and the Ascension Island station (DSS 72).

The DSS 51 voice circuit performance was above average during the prelaunch phase. Just after launch, however, this circuit failed because of expected high-frequency propagation conditions. The "backdoor" circuit via Australia was also out during this same critical period. A commercial call was established to DSS 51 via the New York overseas operator, and voice operation was transferred to this temporary circuit. This circuit also failed from time to time, though at different time intervals from the NASCOM circuits. This additional capability was very helpful and was maintained for approximately two hours after launch. On Sept. 21, 1966, the same high-frequency radio propagation condition occurred during certain critical portions of the DSS 51 pass following the midcourse phase; activation of the commercial overseas operator circuit was again required for a period of approximately two hours.

The DSS 72 voice circuit was continually up and down, as were most of the other DSS 72 circuits during both premission tests and the mission, because of high-frequency radio propagation. NASCOM provided all possible support in attempting to restore DSS 51 circuits during the mission-critical phases of launch and spacecraft emergency following midcourse.

b. Teletype lines. The teletype circuits were also exceptionally reliable; the weakest circuits (DSS 51) showed approximately 97% reliability. The most serious problem associated with teletype circuits developed at the Goldstone DSCC, where the total number of teletype lines available in support of the *Surveyor II*, *Lunar Orbiter*, and *Pioneer* missions was inadequate. During launch and midcourse the system operated faultlessly. The lack of circuits to Goldstone was a constraint during the August–September 1966 testing periods. JPL communication engineers added one additional TTY circuit to the Goldstone microwave system, increasing the total to nine prior to the *Surveyor II* mission; this number, however, was still insufficient during SFOF multi-mission periods.

NASCOM provided two additional temporary TTY circuits from JPL to GSFC to assure sufficient lines during the launch phase of the mission. Tables 114 and 115 give an analysis of TTY circuit reliability.

c. High-speed data lines. This part of the communications system performed flawlessly during the mission, providing better quality HSD, with less downtime, than during the *Surveyor I* mission. Both NASCOM and Hallicrafters modems (modulator-demodulator) had to be used during the *Surveyor II* mission, inasmuch as the Johannesburg station (DSS 51) had no NASCOM modems.

During the August–September 1966 testing period, the Ascension Island station (DSS 72) was not able to support some scheduled *Surveyor* HSD tests because of a lack of communications circuits caused by a *Gemini* conflict. Also, poor propagation conditions affecting communication with Johannesburg and Ascension Island were responsible for some loss of data. Another malfunction was a NASCOM modem regenerator inserted in error at the NASCOM Canberra switching center during JPL data-phone HSD simulation transmission testing. During the mission, crossed lines at GSFC were also responsible for 10-min loss of data from AFETR, and a mispatch in the JPL Communications Center resulted in the loss of some data from Goldstone.

Table 114. *Surveyor II* mission communications circuit performance analysis, $L - 4$ h to $L + 4$ h

Station	Total outage, min	Mean outage duration, min	Reliability, %	Total number of circuits
	TTY circuit performance			
DSS 51	0	N/A	100.00	4 (1920)
DSS 42	39	19.5	97.89	4 (1920)
DSS 11	0	N/A	100.00	4 (1920)
AFETR (AO)	2	2.0	99.85	3 (1440)
DSS 72	242	17.3	94.84	4 (4695)
	Voice circuit performance			
DSS 51	25	12.5	94.79	1 (480)
DSS 42	0	N/A	100.00	1 (480)
DSS 11	0	N/A	100.00	1 (480)
AFETR (AO)	0	N/A	100.00	3 (1440)
DSS 72	35	17.5	96.95	1 (1150)
	HSD circuit performance			
DSS 51	0	N/A	100.00	1 (480)
DSS 42	0	N/A	100.00	1 (480)
DSS 11	0	N/A	100.00	1 (480)
AFETR (AO)	0	N/A	100.00	1 (480)
DSS 72	0	N/A	100.00	1 (1150)

Table 115. *Surveyor II* mission communication circuit performance analysis, midcourse, $L + 15$ h to end of mission

Station	Total outage, min	Mean outage duration, min	Reliability, %	Total number of circuits
	TTY circuit performance			
DSS 51	0	N/A	100.00	4 (1920)
DSS 42	39	19.5	97.89	4 (1920)
DSS 11	0	N/A	100.00	4 (1920)
AFETR (AO)	2	2.0	99.85	3 (1440)
DSS 72	242	17.3	94.84	4 (4695)
	Voice circuit performance			
DSS 51	25	12.5	94.79	1 (480)
DSS 42	0	N/A	100.00	1 (480)
DSS 11	0	N/A	100.00	1 (480)
AFETR (AO)	0	N/A	100.00	3 (1440)
DSS 72	35	17.5	96.95	1 (1150)
	HSD circuit performance			
DSS 51	0	N/A	100.00	1 (480)
DSS 42	0	N/A	100.00	1 (480)
DSS 11	0	N/A	100.00	1 (480)
AFETR (AO)	0	N/A	100.00	1 (480)
DSS 72	0	N/A	100.00	1 (1150)
	TTY circuit performance			
DSS 51	103	20.6	97.1	4 (3614)
DSS 42	83	27.6	98.6	4 (5990)
DSS 11	0	N/A	100.0	4 (3900)
DSS 61	0	N/A	100.0	3 (435)
	Voice circuit performance			
DSS 51	53	10.6	95.3	1 (1130)
DSS 42	0	N/A	100.0	1 (1230)
DSS 11	0	N/A	100.0	1 (975)
DSS 61	0	N/A	100.0	1 (85)
	HSD circuit performance			
DSS 51	0	N/A	100.0	1 (949)
DSS 42	0	N/A	100.0	1 (1230)
DSS 11	0	N/A	100.0	1 (975)
DSS 61	0	N/A	100.0	1 (85)

d. Wideband data link. The microwave link between the Goldstone DSCC and the SFOF performed with virtually 100% reliability for the *Surveyor II* mission.

3. *DSN/SFOF.*

a. Communications. The overall performance of the Intracommunications Systems, which supplied the operational voice communications system (voice nets), closed-circuit television, and teletype and high-speed data distribution within the SFOF, was generally satisfactory with the exception of the problems discussed in Section X-G. Some difficulties were experienced in message distribution between DSIF Net Control, Mission Control, and other areas of the SFOF. The main reason for this was that during the *Surveyor II* mission, SFOF facilities were shared with *Pioneer VI*, *Pioneer VII*, and *Lunar Orbiter*, and it soon became apparent that there were not enough TTY printers to serve all projects. Also, because technical area assistants were not available for the *Surveyor II* mission, individual controllers in DSIF Net Control were responsible for message distribution. Since the TTY machines and pneumatic tubes were located across the room from DSIF Net Control consoles, the controller had to leave the console to receive and distribute messages. There were times, unfortunately, when the controller was too busy to do this and messages were not distributed promptly. The *Surveyor* Net Control was completely overworked, and difficult to communicate on at critical times. The closed-circuit television selector system on the DSIF Net Control consoles was not configured properly for efficient use on the *Surveyor II* mission.

b. Data processing system. The data processing system processed high-speed telemetry data, command confirmation data, and tracking data for the *Surveyor II* mission, and performed in a nominal manner with only minor hardware problems that did not detract from mission support.

c. SFOF facilities support. During mission operations, the facilities of Mission Control Room No. 1 and Mission Support Area No. 1, which includes the SPAA and the SSAA, were devoted exclusively to *Surveyor II* mission support. Flight Path Analysis Area No. 1, which is normally a shared area, was reserved exclusively for *Surveyor II* during actual flight. These areas functioned well. In the common user areas, however, which were shared during the *Surveyor* mission by *Pioneer* and *Lunar Orbiter*, some conflict was experienced, particularly in DSIF Net Control. Background noise occasionally became excessive and interfered with communications, although all active controllers used headsets to keep the noise level down. Shared desks and work areas were not always properly cleared for changeover from one project to the next, which caused some confusion and the possibility of loss of valuable data. This has been a problem in other multi-mission operations, but was especially bad during the *Surveyor II* mission.

Glossary

A-21	2100-lb *Surveyor* spacecraft configuration, including 62-lb engineering payload
ACE-1	Space Flight Operations Director for *Surveyor*
A/C-6	*Atlas/Centaur-6*
A/C-8	*Atlas/Centaur-8*
AE	building at AFETR
AFC	automatic frequency control
AFETR	Air Force Eastern Test Range
AGC	automatic gain control
AGE	aerospace ground equipment
AIS	analog instrumentation subsystem
AMR	altitude marking radar
AN/FGC-60	digital data transmission equipment
AO	building AO (AFETR checkout facility)
AOS	acquisition of signal
APC	automatic phase control
ASCO	*Atlas* sustainer (engine) cutoff
A/SPP	antenna and solar panel positioner
AZUSA	short-baseline, continuous-wave, phase-comparison, single-station tracking system (operating at C-band and giving two direction cosines and slant range for determining space position and velocity)
BCD	binary coded decimal
BCR	battery charge regulator
BECO	booster engine cutoff
BUSS-1	Communications Chief
BW	bandwidth
C-band	radio frequency band in the 5- to 6-GHz region
CCR	closed-cycle (helium) refrigerator
CCTV	closed circuit TV
CC 3	command control two-way tracking mode
CDC	command and data-handling console
CEC	Consolidated Electrodynamics Corp. (recording oscillographs)
CKAFS	Cape Kennedy Air Force Station
comm	communications
CRT	composite readiness test
D/A	digital to analog
DACO	data consistency orbit
DDC	direct data channel
dec	declination
DIS	digital instrumentation system
DOD	Department of Defense
DOP	Detailed Operating Procedure
DPE	dynamic phase error
DPS	data processing system
DR	data requirements
DSCC	Deep Space Communications Complex
DSIF	Deep Space Instrumentation Facility
DSN	Deep Space Network
DSS	Deep Space Station
DSS 11	Pioneer Deep Space Station
DSS 12	Echo Deep Space Station
DSS 13	Venus Deep Space Station
DSS 14	Mars Deep Space Station
DSS 41	Woomera Deep Space Station
DSS 42	Tidbinbilla Deep Space Station
DSS 51	Johannesburg Deep Space Station
DSS 61	Robledo Deep Space Station
DSS 71	Cape Kennedy Deep Space Station
DT	digital tracker
DW	direct writing

ECA	Engineering Change Authorization
ECR	Engineering Change Request
ELSSE	electronic sky-screening equipment (range safety)
EP-3	energizing pressure 3 (battery pressure)
EPD	Engineering Planning Document
ETOOP-2	AFETR NASA Program Support Office
ETOT	AF Directorate of Program Support Office
ETV	engineering TV mode
FACT	flight acceptance compatibility test
FCA	frequency control analysis
FM	frequency modulation
FPAA	Flight Path Analysis Area
FPAC	Flight Path Analysis and Command
FPQ-6	precision missile tracking radar
FPS-16	fixed point station (a type of radar)
FPR	Failure/Problem Report
FR-800	Ampex video tape recorder
FR-1400	Ampex tape recorder
GCF	Ground Communications Facility
GD/C	General Dynamics/Convair
GET	ground elapsed time
GSDS	Goldstone duplicate standard
GSFC	Goddard Space Flight Center
HA	hour angle
HAC	Hughes Aircraft Company
HP	Hewlett-Packard (manufacturer)
HS	high speed
HSD	high-speed data
HSDL	high-speed data line
HSDS	high-speed data subsystem
HV	high voltage
IBM	International Business Machines
ICEV	injection conditions evaluation orbit
ICS	intracommunication system
IGOR	intercept ground optical recorder
IMP	interim monitoring program
I/O	input/output
IRIG	Interrange Instrumentation Group
IRV	interrange vector
ISI	Instrumentation Support Instruction
J	junction
JPL	Jet Propulsion Laboratory
KSC	Kennedy Space Center
LAPM	last pre-midcourse orbit
L-band	radio frequency band in the 390- to 1550-MHz region
LDS	launch data system
LeRC	Lewis Research Center
LHA	local hour angle
LOPO	Lunar Orbiter Project Office
LOS	loss of signal
LOX	liquid oxygen
L/S	L- to S-band
MC	midcourse
MCC	Mission Control Center
MCC-K	Mission Control Center, Cape Kennedy
MCR	Mission Control Room
MDE	mission-dependent equipment
MECO	main engine cutoff
MEIG	main engine ignition
MES	main engine start (*Centaur*)
MGC	manual gain control
MILS	missile impact location system
MISTRAM	missile trajectory measurement system
M&O	maintenance and operations
MOP	Mission Operations Plan

MOPS	missile operations paging system
MOS	Mission Operations System
MSFN	Manned Space Flight Network
MSFN stations	Bermuda, Grand Canary, Carnarvon, Kano, Tananarive
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications System
NBVCXO	narrow-band, voltage-controlled auxiliary oscillator
NOP	Network Operations Plan
N POM	*n*th post-midcourse orbit
NRT	near-real time
NSO	Network Support Office
NTSA	NASA Testing Support for *Atlas/Agena*
NTSC	NASA Testing Support for *Centaur*
OCR	optimum charge regulator
OD	operational directive
ODP	orbit determination program
OGO	*Orbiting Geophysical Observatory*
OMAS	operational miscellaneous audio system
OPAS	operational public address system
OPE	optical pointing error
OR	Operational Requirements
ORT	operational readiness test
OSDP	on-site data processing
OSRS	operational status recording subsystem
OSSA	Office of Space Science and Applications (NASA Headquarters)
OTCS	operational teletype communications system
OTDA	Office of Track and Data Acquisition (NASA Headquarters)
OVCS	operational voice communications system
OVRS	operational voice recording system
PAFB	Patrick Air Force Base
PAM	pulse amplitude modulation
PATE	programmed automatic tape evaluation
P-band	telemetry frequency band
PCM	pulse code modulation
PDC	Premission Documentation Change
PDP	programmed data processor
PM	phase modulation
POST	postflight analysis orbit
PRD	Program Requirements Document
PRCL	pre-midcourse cleanup orbit
PREL	preliminary midcourse orbit
PROR	predict orbit
PSP	program support plan
RADVS	radar altimeter and doppler velocity sensor
RATAC	radar target acquisition (system)
RFI	radio frequency interference
RIS	range instrumentation ship
RMS	retromotor simulator
RO	receive only (teletype machine)
ROTI	recording optical tracking instrument
RSC	range safety control
RTC	real-time computer
RTCS	Real-Time Computer System
SA	science analysis
SAA	S-band acquisition aid
S-band	ratio frequency band in the 1550- to 5200-MHz region
SCAMA	signaling, conferencing, and monitoring arrangement
SCD	S-band cassegrain diplexer
SCM	S-band cassegrain monopulse
SCO	subcarrier oscillator
SDA	system data analysis (group)

SDCC	Simulated Data Conversion Center
SDS-910 SDS-920	Scientific Data Systems computers
SECO	sustainer engine cutoff
seq	sequence
SFOD	Space Flight Operations Director
SFOF	Space Flight Operations Facility
SIRD	Support Instrumentation Requirements Document
SMAA	semimajor axis
SNR	signal-to-noise ratio
SOC	*Surveyor* Operations Chief
SOCP	*Surveyor* on-site computer programs
SOP	standing operating procedures
SOPM	standard orbital parameter message
SPAA	Spacecraft Performance Analysis Area
SPAC	Spacecraft Performance Analysis and Command (group)
SPE	static phase error
SS	steady state
S/S	signal strength
SSAA	Space Science Analysis Area
SSAC	Space Science Analysis and Command
SSD	Space Systems Division
STADAN	Space Tracking and Data Acquisition Network
STARS	surface-to-air recovery system
STEA	system test equipment assembly
T-21	prototype 2100-lb *Surveyor* spacecraft of A-21 configurations for system type-approval and mission-simulation tests
TAA-3A	30-ft antenna S-band system
TAER	time azimuth elevation rate
TCD	telemetry and command data
TCP	telemetry and command processor
TD-1	transmission distribution (machine No. 1)
T&DA	Tracking and Data Acquisition
TDH	tracking data handling
TDM	time division multiplex
T&DS	Tracking and Data System
Tel-2	telemetry building at AFETR
TFR	Trouble/Failure Report
THD	Tracking Handling Data system
TIM	Tracking Instruction Manual
TM	telemetry mode
TR	transformer-rectifier
trans	transmitter
TVGDHS	television ground data handling system
TVCS	television communications system
UDOP	ultra-high frequency doppler system
ULO	Unmanned Launch Operations
UWV	antenna microwave system
VCO	voltage-controlled oscillator
VECO	vernier engine cutoff
VR 1560	RCA video tape recorder
WB	wideband
WBCS	wide-band communications system
WBFM	wide-band frequency modulation
WBVCXO	wide-band, voltage-controlled, auxiliary oscillator
WTRJB	on-site trajectory-and-acquisition computer program
X	computer string X
X_A	ground transmitter VCO frequency setting for specific time
Y	computer string Y
7.18	Grand Turk radar
9.1	Antigua (original description for Antigua Station 91)
12	Ascension Island designation
91.18	radar on Antigua Station 91

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