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SURVEYOR MISSION OPERATIONS SYSTEM

SPACE FLIGHT OPERATIONS

MEMORANDUM

SURVEYOR VII

PD 602-74 1 March 1968

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SPACE FLIGHT OPERATIONS MEMORANDUM
SURVEYOR VII

I. INTRODUCTION

This report describes the space flight operations for Surveyor Mission G through the second lunar day. Highlights of the mission only are presented with emphasis on Mission Operations System performance having significance for future missions. Detailed information on the mission and spacecraft performance may be obtained from documents listed as references and in the bibliography at the end of this report.

Surveyor Project objectives are as follows:

1) To accomplish successful soft landings on the Moon as demonstrated by spacecraft performance subsequent to landing.
2) To provide basic data in support of Apollo.
3) To perform operations on the lunar surface which will contribute new scientific knowledge about the Moon and provide further information in support of Apollo.

The specific objectives applicable to Mission G were:

1) Perform a soft landing on the Moon.
2) Obtain post-landing television pictures of the lunar surface.
3) Determine the relative abundance of the chemical elements in the lunar soil by operation of the alpha scattering instrument (ASI).
4) Manipulate the lunar material with the soil mechanics/surface sampler (SM/SS) in view of the television camera.
5) Obtain touchdown dynamics data.
6) Obtain thermal and radar reflectivity data on the lunar surface.

A successful soft landing on the Moon was accomplished by Surveyor VII near the crater Tycho after a nominal flight involving a single midcourse correction maneuver. Following touchdown, the spacecraft was successfully operated throughout the lunar day and all planned scientific and engineering activities were carried out except for the alpha scattering experiment which was curtailed by failure of the instrument to initially deploy and by high temperatures near lunar noon.

Of particular importance was the landing site which afforded the opportunity for acquiring data from, and evaluating the properties of the lunar surface in an area differing superficially from the mare regions investigated during prior missions. In addition, the spacecraft incorporated the largest complement of scientific experiments flown on Surveyor missions. These included a survey TV camera, an alpha scattering instrument, a surface sampler, a magnetic bar experiment and special viewing mirrors.

A unique engineering feasibility test was conducted in support of the Apollo program. The test involved directing laser beams at the spacecraft from six astronomical stations within the U.S. while simultaneously viewing the Earth with the spacecraft TV camera. Of the attempts made, positive results were obtained twice.

II. MISSION SUMMARY

The transit phase of Mission G was conducted from launch on January 7, 1968 (GMT Day 007) through touchdown on January 10, 1968 (Day 010). Lunar operations commenced at touchdown and continued until January 26 at 14:12 GMT when all Surveyor VII first lunar day operations were ended, and the spacecraft was shut down for the remainder of the lunar night. The spacecraft was revived during the second lunar day on the first attempt at 19:00 GMT on 12 February 1968 (Day 043). Operations were limited due to problems in the electrical power system. Second lunar day operations were terminated at 06:48 GMT on February 21, 1968 (Day 052) when spacecraft revival attempts were discontinued after the spacecraft signal was lost approximately six hours earlier.

A. Transit Phase

The Surveyor VII spacecraft was launched from Pad 36A, Cape Kennedy, after a smooth countdown to T-90 M, at which time the built-in hold of one hour was extended for an additional 35 minutes in order to provide more optimum down-range tracking coverage. Liftoff was accomplished by the Atlas at 06:30:00.545 GMT on Day 007, on a launch azimuth of 102.914 degrees. The Atlas/Centaur launch vehicle performed with a high degree or reliability throughout its flight period and all mark events occurred very close to the predicted times.

Injection of the spacecraft occurred at 07:04:15 GMT with a trajectory that would have provided, with no midcourse correction, a total miss of approximately 77 km (48 miles) from the prelaunch target aiming point of 4.95° south latitude and 3.88° east longitude in the central area of Hipparchus. Normal preprogrammed spacecraft events (i.e., high power, landing legs extended, omni antennas extended, electrical disconnect from Centaur, automatic solar panel stepping, A/SPP roll axis stepping, and automatic Sun acquisition) occurred normally and in the proper order.

DSS 51 tracked the spacecraft one-way for approximately 4 minutes during the launch pass and was able to verify normal spacecraft status shortly after injection. DSS 42 was designated as the initial acquisition station and reported two-way lock accomplished at 07:27:26 GMT. Prior to acquisition, good spacecraft telemetry data from the MSFN station at Carnavon, Australia, was received for approximately 14 minutes. Initial spacecraft commanding was initiated at 07:31 GMT and was completed as planned after verification of normal spacecraft status.

The star verification and acquisition sequence was initiated at 14:20 GMT with DSS 61 commanding the roll maneuver. During the roll maneuver, the automatic star lockon signal was observed to not function properly. Consequently, during the second roll, the spacecraft was stopped with Canopus within the sensor field of view and a manual lockon was commanded. This problem was similar to that experienced during the early missions when sensor saturation prevented generation of the automatic star lockon signal.

The accuracy of the injection, along with nominal spacecraft performance, permitted selection of an in-flight aiming point in the prime landing site area near the crater Tycho. It was expected that two midcourse corrections would be required to meet the small miss tolerance allowed in this area. Preparation of the spacecraft for the first midcourse correction was initiated at 22:46 GMT, Day 007 with an engineering interrogation. The spacecraft was configured in high power and 4400 bps at 23:02 GMT. The premidcourse correction maneuvers of a negative 3° roll and a positive 117° yaw were successfully executed by 23:25 GMT. The velocity correction of 11.08 m/sec, involving a burn time of 11.3 seconds, was executed at 23:28 GMT. Telemetry and doppler shift data verified that the velocity correction was performed as commanded. Following midcourse thrust, a reverse yaw maneuver was commanded at 23:34 GMT. The single yaw maneuver was also sufficient to bring Canopus within the star sensor field of view, making a post-midcourse roll maneuver unnecessary. Star lockon was again manually commanded, the spacecraft was configured for Coast Phase II and returned to 1100 bps in low power.

Post-midcourse tracking data indicated a very accurate correction with a miss of approximately 3 km from the target point. Consequently, the planned second midcourse maneuver was not required.

Coast Phase II was very nominal; all temperatures remained within operational or transit survival limits and spacecraft performance was very satisfactory. Thirteen gyro drift checks were performed during the total transit phase. The final gyro drift rates observed during the terminal phase of the mission were: roll: 0.65 deg/hr; pitch: 0.2 deg/hr; and yaw: 0.0 deg/hr.

Terminal descent operations were initiated by DSS 11 at 23:54:48 GMT, Day 009, with accomplishment of the preterminal maneuver engineering interrogation. The terminal maneuvers were commanded and the spacecraft successfully performed a positive roll of 80.5°, a positive yaw of 96.1° and a final negative roll of 16.50°. Compensation for gyro drift was not included in these attitude maneuvers due to the small net error involved; however, an attempt was made to initiate the rotations at limit cycle nulls. The touchdown strain gages were activated after the received carrier power was reported to be well within the touchdown strain gage turn-on criterion. A retro sequence delay quantity of 2.775 seconds was loaded and verified. AMR power was commanded on and verified at 00:57:32 and thrust phase power was turned on at 00:58:33 GMT. The AMR was enabled at 01:00:33 GMT and the emergency AMR signal was commanded at 01:02:12 GMT. AMR mark was received at 01:02:10.6 GMT; the automatic portion of the descent sequence was performed by the spacecraft in a nominal manner. Continuous telemetry and good touchdown strain gage data were received during the touchdown phase, indicating a successful soft landing had occurred at 01:05:37 GMT on Day 010 (January 10). The landing site was subsequently determined to be 40.89° south latitude and 11.44° west longitude, approximately 1.69 km from the aiming point.

B. First Lunar Day Operations

The post-landing power shutdown was commanded immediately after touchdown and the post-landing engineering assessment was shortened in order to initiate 200-line TV operations as quickly as possible. The first picture was commanded at 01:46:50 GMT. In this mode, a total of 14 200-line frames were commanded and received, all of good quality, and the camera was commanded off at 02:11 GMT. A/SPP stepping for 600-line TV (positioning the solar panel toward the Sun and the planar array toward the Earth) was completed in less than one hour. The first 600-line TV sequence began at 03:41 GMT, and continued for one and one-half hours. Very good pictures were received which revealed a rough, rocky, uneven lunar highland area, quite different from the mare areas in which previous Surveyors had landed.

Lunar operations were conducted in accordance with the Lunar Operations Plan as refined by the daily lunar operations planning meetings. A major problem, requiring revision to the LOP, was experienced on Day 010 when the alpha scattering instrument would not deploy from the background position to the lunar surface as commanded. A special analysis and test effort was performed to overcome a mechanical failure in the deployment mechanism, and the instrument was finally deployed on Day 012, using the SM/SS to push the instrument to the lunar surface. The SM/SS was subsequently used to reposition the ASI two additional times, providing data samples from three separate locations.

In general, spacecraft temperatures were higher than expected, and necessitated frequent cooldown periods with consequent delays to science activities. However, by judicious scheduling of lunar activities and close power/thermal management of the spacecraft, essentially all lunar objectives were accomplished. Total data acquisition included 20,993 video frames, 65 hours and 44 minutes of alpha scattering data and 36 hours and 21 minutes of surface sampler operations.

Following sunset at the spacecraft at 06:24 GMT on Day 023, first lunar day operations were continued for an additional 79 hours, 48 minutes until final shutdown at 14:12 GMT, Day 026.

C. Second Lunar Day Operations

The first revival attempt on the second lunar day was initiated by DSS 61 approximately 130 hours after sunrise at 19:00 GMT, Day 043 (February 12). The spacecraft responded immediately, terminating a shutdown period of 17 days, 5 hours. An engineering assessment revealed a major power subsystem anomaly, however, which placed the spacecraft in a marginal survival category for the remainder of the lunar day and greatly limited operations. Other anomalies were:

1) Landing leg No. 1 was collapsed, giving the spacecraft an 8-degree tilt away from the Earth.
2) TV in 600-line mode was inoperable. Tests indicated a failure in the camera 600-line horizontal sweep circuit.
3) Alpha scattering instrument proton system inoperable.

Scheduled science operations were limited to two abbreviated activity periods on Days 044 and 045. The TV camera was operable in the 200-line mode, however, and approximately 39 video frames of good quality were received. These included pictures of new, nearby surface areas revealed by the spacecraft tilt. Surface sampler operations were limited to a brief but successful test of the extension stepping capability of the instrument.

Due to the critical condition which developed in the battery, a decision was made to forego TV and SM/SS activities and preserve the spacecraft in favor of the alpha scattering experiment which was given first scientific priority. ASI temperatures were above operating limits at this time due to the lunar noon. The spacecraft was successfully "nursed" through the next two days and power management techniques succeeded in producing a limited improvement in battery performance. Further degradation could not be prevented, however, and the battery lost its remaining capability on Day 048. Solar panel current was sufficient to support alpha scattering operations, however, and more than 20 hours of good alpha system data were successfully obtained.

Power management and operational experiments, accompanied by increasing loss of lock, continued until the carrier was lost for the final time at 00:24 GMT, Day 052 (February 21). This preceded the predicted lunar sunset time by approximately 21-1/2 hours. Efforts to revive the spacecraft were continued until 06:48 GMT, February 21, when all search activities were terminated.

III. MISSION OPERATIONS SYSTEM

The Mission Operations System (MOS), including both mission-independent and mission-dependent elements, is described in general terms in TM 33-264, Surveyor Mission Operations System (Ref. 5). The MOS configuration employed on

Mission G was essentially the same as for Mission F with the exception of the following significant changes which were implemented between Missions F and G:

1) A new operational "W" computer string was created in the SFOF by reconfiguring the 7044W and 7094V computers.
2) Two new communications circuits via earth satellite were used from Ascension Island. These consisted of a telemetry data circuit to the SFOF via GSFC and a teletype circuit to Cape Kennedy for transmission of downrange metric data.
3) The 1219 computer facility in the SFOF was equipped with three separate CRT display outputs for use in the SFOF via CCTV. Each CRT display format could be selected from remote control boxes located in the Operations area, Mission Control area, SPAA and SSAA.

Other system changes are noted in appropriate sections which follow.

In general, the overall performance of the MOS was good, and proved capable of responding to all operational demands of the mission. Certain elements, at times, displayed problems which resulted in reduced performance. None of the problems, however, caused any significant degradation in the conduct of the mission. Individual problems are discussed in the sections which follow.

IV. MISSION OPERATIONS

Within the context of the philosophy stated in the Introduction to this report, the following paragraphs covering the major elements of Mission Operations emphasize the performance of each operational group and supporting organization and describe highlights which are significant to future space missions. Responsibilities, organization, and functions of the operational groups are described in the Space Flight Operations System Design Specifications (Ref. 6) and the Surveyor-SFOF Detailed Operating Procedures (Ref. 7). The governing operational plan for Mission G is contained in the Space Flight Operations Plan, EPD-180, dated 14 December 1967, and the Lunar Operations Plan, EPD-486-MG, dated 22 December 1967.

A. Mission Control

The Mission Control function for Mission G was manned by personnel with prior mission experience and was conducted in accordance with established procedures. Mission Control performance was satisfactory and reflected a capability to cope with nonstandard situations. Mission Control remained active during the entire period of spacecraft activity, although at a reduced manning level beginning shortly after touchdown. Several significant problem areas were encountered which required Mission Control resolution:

1) Failure of the alpha scattering instrument deployment mechanism to move the instrument from the background position to the lunar surface resulted in considerable analysis and special tests with the surface sampler to determine the procedure subsequently employed to successfully accomplish the deployment.
2) The combination of higher-than-expected temperatures and the time required to complete the alpha scattering instrument deployment caused a much greater scheduling problem during lunar operations than had been experienced on previous missions. A greater planning effort and tighter control over implementation of the lunar activities was required in order to accomplish the numerous planned experiments.
3) DPS problems were encountered during the critical periods just prior to launch and touchdown. In both cases, the third computer string was brought up and utilized to alleviate the immediate problem. In all cases, the action taken proved to be effective and timely and resulted in minimum loss of operational capability.
4) The laser experiment required extensive planning and coordination with the participating agencies during the mission because of the delay in receipt of the experiment requirement.

The 1219 CRT displays proved to be a great aid to mission control personnel in monitoring the spacecraft status.

During lunar operations, several unsuccessful attempts were made to revive Surveyors V and VI. These attempts were made with Surveyor VII in standby.

B. Spacecraft Performance Analysis and Command

The operational and analysis positions in the SPAC group were staffed by basically the same HAC and JPL personnel utilized in prior Surveyor missions.

Significant differences in SPAC operations between Mission G and previous Surveyor missions were the addition of three TV monitors, driven by the 1219 computer which provided a display of selected telemetry data in real time at various SPAC specialist positions.

The SPAC team supporting Mission G performed well, contributing significantly to the overall smoothness and success of the mission. All spacecraft operations during transit were conducted in accordance with the planned sequence of events except for the execution of a manual star lock-on which became necessary due to the lack of an automatic star lock-on signal. Lunar spacecraft operations were conducted in accordance with normal procedures. Occasional dropouts of the command uplink were experienced and were suspected to be the result of multipath reflections from the terrain surrounding the spacecraft. Since only one receiver was usually affected at a time, the good receiver was selected during command periods.

C. Flight Path Analysis and Command

The FPAC function for Mission G was manned by essentially the same JPL and Hughes personnel who participated in Mission F.

In general, all FPAC computer program runs were completed in time to meet mission requirements. Most hardware/software system problems were handled expeditiously and caused minimal delay. The card read error problems experienced on Mission F were expected and caused no significant delay until the terminal phase, at which time it was necessary to switch telemetry data to another computer. Predicts generated at launch were lost from the buffers of both computer strings when they were restarted in order to reestablish the proper CP interface. This necessitated regeneration of the T-5 predicts, but caused only a few minutes delay in their transmittal to DSS 42 and 51. No spacecraft acquisition problem resulted from this delay.

Since procedures used during past missions to predict S/C center frequencies by biasing the preflight measurement data had not proved effective, these procedures were abandoned in favor of using the preflight temperature/frequency curves unaltered.

From the time of two-way acquisition by DSS 42 until approximately retro ignition minus 40 minutes and except during star acquisition, the DSN tracked Surveyor VII in the two-way mode and, with minor exceptions, returned high-quality, two-way doppler data. The only significant losses of good two-way data occurred during the first passes over DSS 51 and DSS 11. DSS 51 lost approximately 1/2 hour of good two-way doppler at the start of its first pass due to a faulty frequency shifter unit, and DSS 11 lost 30 minutes of doppler resolver data during the midcourse maneuver due to a misadjusted potentiometer in the doppler resolver counter.

All participating stations were equipped with doppler resolvers which resulted in a reduction in the standard deviation of the doppler data (60-second samples) from a preresolver level of approximately 0.008 cps to about 0.002 cps. Unfortunately, this did not produce a significant decrease in the corresponding orbit determination uncertainties because the Surveyor Project was not equipped with the computer programs necessary to take advantage of the data improvement.

In order to minimize the OD uncertainties for an expected second midcourse maneuver, it was decided to perform the first maneuver at L+17 hours. This necessitated some changes to the nominal ODPX Program profile prior to midcourse. The final maneuver execution time of 16.41 hours after injection was chosen to allow:

1) Sufficient tracking time to accurately determine the initial trajectory.
2) Sufficient tracking time to provide required accuracy in the event a second midcourse was required.
3) Performance of the correction during the Goldstone view period.

The required velocity component in the critical plane, to correct miss, was 11.05 m/sec. The noncritical direction component was 0.8 m/sec and was selected to minimize the maneuver timing error. The resulting total delta velocity was 11.08 m/sec.

Post midcourse tracking indicated that the orbits were converging on a landing site approximately 3 km from the target point in an acceptable region well within the area of Lunar Orbiter high resolution coverage. Consequently, a second midcourse maneuver was not performed.

The best estimate of the uncorrected, unbraked impact point is in the central area of Hipparchus at selenographic coordinates 6.05° south latitude and 5.39° east longitude. This is approximately 77 km (48 miles) from the prelaunch target aiming point of 4.95° south latitude and 3.88° east longitude.

The soft touchdown aiming point at the time of the midcourse maneuver was 40.87° south latitude and 11.37° west longitude. A comparison of Lunar Orbiter photographs with Surveyor VII photographs reveals the landing site to be 40.89° south latitude and 11.44° west longitude, a miss distance of 1.69 km.

D. Space Science Analysis and Command

The science payload operations for Mission G consisted of operating the television camera, the alpha scattering instrument, and the soil mechanics/surface sampler. Since the payload was a combination of instruments which had been flown and operated successfully on prior missions, there were no significant changes in SSAC operations other than to combine previous types of efforts to meet daily objectives. Each instrument support group was manned by the same experienced personnel who supported their respective instruments during prior missions.

The performance of SSAC personnel in support of mission objectives was highly proficient in all respects. Except for restrictions on instrument operation around lunar noon due to high instrument temperatures, operations were conducted on a round-the-clock basis. More TV was obtained by the overseas stations than for previous missions due to greater requirements for TV support of SM/SS activities during Goldstone visibility. All daily operational objectives were accomplished with a few minor exceptions. Interfaces with Mission Control, Project Scientist Representatives, SPAC and DSIF were smooth and effective. Total data acquired during the first lunar day amounted to 20,993 video frames, 65 hours 44 minutes of alpha scattering data and 36 hours 21 minutes of surface sampler operation.

The television camera performed in a flawless manner although there were a few minor deviations in performance. Technical performance of the ASI during the first lunar day was excellent except for failure of the deployment mechanism. This failure did not affect operating characteristics of the instrument and was eventually overcome by the use of the surface sampler. Because deployment failure and excessive temperatures tended to restrict operations to periods less than desired, the instrument was operated at temperatures in excess of specifications. All commands to the surface sampler were correctly decoded and the mechanism operated perfectly in all respects.

E. Television Ground Data Handling System

The system used for Mission G was the same as the configuration employed during Mission F.

Operations in the TV-1 area were comparatively smooth and trouble-free during the entire lunar day. Real-time spacecraft signals received via the microwave link from DSS 11 were of excellent quality with the exception of a portion of one view period when microwave channel switching problems occurred. The lost data was recovered on the following day from the DSS 11 FR 900 recording.

When possible, minor equipment failures within the TV-1 area were corrected in real time and TV data losses were held to a minimum. Among these failures were:

1) The main clutch spring in Film Transport No. 1 broke but was rebuilt and installed by JPL machinists with minimum loss of film data transfer.

2) The video data simulator used during countdown calibrations failed to operate in the framing mode. The TV-11 simulator was employed as a backup and countdown calibration schedules were met.

3) Normal wear to photo processing equipment gear trains and drive belts required replacement in real time during operations but did not affect photo product delivery schedules.

During the first lunar day, TV-1 recovered a total of 20,993 video frames via microwave from TV-11 and from FR 800 tapes recorded overseas. From these, the following photo products were produced:

Mosaics:	648 negatives, 1134 prints
Photo Enlargement:	5619 prints
Strip Contact Prints:	560 rolls
Master Positive:	80 rolls
PIO Dupe:	80 rolls
EDR:	80 rolls
CDC Film:	59 rolls

Video tapes recorded at TV-1:

HW 7600 Analog Recorder:	90 each
FR 1400 Analog Recorder:	26 each
FR 700 Video Recorder:	68 each

F. Data Processing System

The IBM 7044/7094 Redesign Software System, modified to process both Mariner IV and Surveyor VII data, was utilized in the DPS during Mission G. Teletype traffic, other than Surveyor, was not removed from the Communications Processor during the critical periods as had been done on Missions E and F. Manning of the DPS was adequate and the performance of all personnel was skillful and proficient.

Significant differences from prior missions were:

1) The IBM 7044W and IBM 7094V were reconfigured as a Mode 2 string and CCTV monitors were installed.
2) Computer program MTGS was modified to increase the accuracy in some of the constants.
3) Coordination procedures were modified in order to speed up the initiation of predict transmissions.
4) NASCOM end-of-message marks and new headers were generated by the IBM 7044 every 15 minutes or every 5400 teletype characters, whichever occurred sooner.

The following problems deserving special attention were encountered:

1) At liftoff, the interface between 7044X and the CP failed, causing incomplete words to be received by the 7044. The computer programs were loaded on the Y-string as expeditiously as possible and operations continued on the Y-string.
2) During the midcourse maneuver, TPS Station No. 2 faulted, causing a momentary loss of data until the program was restarted. PDP-7 No. 3 was replaced by PDP-7 No. 1 but the faults recurred to the extent that Station No. 2 operations were significantly curtailed during lunar operations.
3) During the terminal phase, the 7044W queue list could not be cleared. The 7094 also indicated disk transmission errors. The telemetry processing was switched to the Y-string. This resulted in ODP program card read problems. The 7044X was then made available and was used to process telemetry data during the terminal descent.

4) Communication Processor computer changes induced interface problems between the CP and the 7044, necessitating several restarts of the 7044.

5) The ODP program did not run successfully when telemetry data was being processed by the same string. It is suspected that the problem may be due to a card read problem in the 7044/7094 program.

6) The organizational interfaces between mission dependent and mission independent personnel in the SFOF computer operations became extremely awkward and drawn-out at times. These interfaces should be better defined and well understood.

G. Space Flight Operations Facility

The overall performance of the maintenance and operations personnel and equipment in the SFOF in supporting Mission G was satisfactory. Staffing for the mission was adequate, and no manning problems were experienced in any of the operation and support areas.

Major changes in the facility between Missions F and G were:

1) The 7044W and 7094V computers were reconfigured into a new operational W-string.

2) The new SFOF computer-driven display system was used and a number of interesting and useful displays were developed to support real-time operations.

A significant problem in the interface between the CP and 7044X occurred shortly before liftoff. As discussed in paragraph F, the Y-string was brought up as a replacement for the X-string. The net result was a 15-minute loss of the CP /7044 at a critical time during the countdown.

Another significant problem occurred on January 18, 1968 when a circuit breaker controlling the diesel power unit was switched off in error. This resulted in a shutdown of some communications equipment in the SFOF, and caused a 25-minute delay in providing data to the project.

H. Deep Space Instrumentation Facility

The DSIF provided essentially continuous support to Surveyor Mission G during all spacecraft operating periods. Prime station support was provided by DSS 11, 42 and 61. DSS 51 provided additional support during all three of its transit-phase view periods. Initial two-way acquisition and commanding of the spacecraft was performed by DSS 42. DSS 71 supported the pre-launch S/C-DSIF RF compatibility tests, and, during the launch phase, was the prime source of real-time AFETR telemetry transmission to the SFOF. DSS 14 provided transit phase and lunar operations support using the 210-foot antenna.

During lunar operations there were instances of loss of uplink lock and consequent loss of command capability. In each case, the uplink was reacquired and commanding proceeded normally. This occurred at DSS 11, DSS 61, and DSS 42 on different occasions. The DSIF participated fully in investigating these problems but no evidence of ground equipment malfunctions could be found.

During pre-launch preparations, there was momentary concern over the readiness of the TV Ground Data Handling System at Goldstone (TV-11) for mission support. The main problems were due to extended mission support provided to SC-5 and SC-6 during December, the tight schedule, and the amount of testing required prior to Mission G. With the help and cooperation of TV-1 personnel, all tests were completed and TV-11 performed efficiently and reliably throughout the first lunar day.

Various operational, equipment and interface problems were experienced during the mission; however, none caused a serious loss of data or had any significant effect on the overall mission.

The following is a summary of the major activities of each station during the mission.

1. DSS 11 - Goldstone (Pioneer) California. DSS 11 tracked Surveyor VII for three passes during the transit phase, commanding the critical midcourse and terminal maneuvers. After the touchdown pass, DSS 11 continued tracking during the remainder of the lunar day and into the lunar night, compiling a total of 16 passes. During the first pass on Day 007-008, the midcourse maneuver was commanded with nominal performance except for star lock-on which was performed manually due to sensor saturation. The terminal descent sequence was successfully

commanded on the third pass with nominal spacecraft response. A modified post-landing sequence was accomplished and the first 200-line television frame was received within 45 minutes after touchdown. A/SPP positioning was accomplished after 14 200-line frames were received, and the remainder of the third pass was devoted to 600-line TV and engineering interrogations. Station activity on subsequent passes emphasized surface sampler (SM/SS) operations and television pictures. The surface sampler was utilized to deploy the alpha scattering instrument after the normal deployment mechanism failed, and to move the instrument to two other locations on the lunar surface. Alpha scattering data was acquired and engineering interrogations were performed throughout the lunar operational period. In addition, the station participated in the laser experiments and an RF multipath experiment. Several unsuccessful attempts were made to revive other Surveyor spacecraft when SC-7 was in standby.

Several operational and equipment problems were encountered; however, none resulted in any serious effect on the mission.

2. <u>DSS 14 - Goldstone (Mars), California</u>. DSS 14 with its 210-foot antenna provided transit phase support during all three passes. Provision had been made to allow the DSS 11 CDC to utilize the DSS 14 receiver output, if necessary. Project-furnished equipment was installed to permit predetection recording. At midcourse and touchdown, the baseband telemetry receiver output was transmitted to the SFOF via the microwave link. Good data was received from DSS 14 during all three tracking periods.

3. <u>DSS 42 - Tidbinbilla, (Canberra) Australia</u>. During the transit phase of the mission, DSS 42 had three tracking periods and performed the initial two-way acquisition and spacecraft commanding. Good PCM data was received from Carnarvon prior to DSS 42 first view. This data was processed and transmitted to the SFOF for approximately 14 minutes before switching to DSS 42 data after acquisition. After touchdown, DSS 42 continued to track for 16 passes during the lunar day and into the lunar night. During the lunar passes, the station was quite active with extensive TV operations, alpha scattering data acquisitions, A/SPP positioning, RF and signal processing experiments, engineering interrogations, and power/thermal management activities.

Although several operational and equipment problems were encountered, none had any significant effect on the mission.

4. DSS 51 - Johannesburg, South Africa. DSS 51 acquired on the launch pass after injection and tracked the spacecraft for approximately 4 minutes during a very short view period. Although communications were poor, the station was able to verify that the spacecraft status was nominal and that automatic solar panel deployment was taking place. During the three succeeding transit phase passes, DSS 51 tracked both two-way and three-way, monitored the star acquisition performed by DSS 61, and performed engineering interrogations and gyro drift checks. Some decoder switching was observed during the third pass. Except for the loss of approximately 30 minutes of two-way data during the first pass due to a faulty frequency shifter unit, no significant equipment or operational problems were encountered which adversely affected the mission.

5. DSS 61 - Madrid, Spain. DSS 61 tracked for three passes during the transit phase and for 16 passes during the lunar phase. Star acquisition was performed on the first transit pass. During the roll maneuver, automatic star lock-on did not function properly and it was necessary to perform a manual lock-on. Except for the star acquisition sequence, commanding from DSS 61 was minimal during the transit passes. However, the station was in view during midcourse and touchdown and these events were monitored until the end of the view. Activities during the lunar day and night consisted of extensive television, alpha scattering accumulations, engineering interrogations, A/SPP positioning and power/thermal management. Sunset at the spacecraft occurred earlier than anticipated during DSS 61 view, and an exceptional job was turned in by this station in obtaining shadow progression and solar corona TV sequences. During one pass, a period of high winds caused noise spikes in the RF system and forced a change in bit rate from 1100 bps to 550 bps for both telemetry and alpha scattering data. The immediate source of this problem was not determined. Several other operational and equipment problems were encountered; however, none had any significant effect on the mission.

6. DSS 71 - Cape Kennedy, Florida. DSS 71 support for the mission consisted of providing PCM data to the SFOF during the spacecraft prelaunch countdown and up through the end of the near-Earth phase. Source of the data was Building AO until T-5 minutes and Tel-4 thereafter until approximately L+40 minutes. Data in both cases was processed by the CDC and the TCP computer and transmitted to the SFOF via HSDL and TTY. This data path worked quite well and good data was received at the SFOF during all times that good data was received

at Cape Kennedy. During countdown and launch, until spacecraft visibility was lost, the station antenna was optically aligned with the spacecraft and the receiver was locked to the spacecraft signal as a backup to the Tel-4 data source.

I. Tracking and Data System Near-Earth Phase Support

The Tracking and Data System (TDS) Near-Earth Phase Network (NEPN) included selected resources of the AFETR, the MSFN, the DSN, and NASCOM. Coverage was provided for Atlas/Centaur tracking data (metric), Atlas/Centaur telemetry (VHF), Surveyor telemetry (VHF and S-band), and real-time orbit computation. The TDS support for the mission was considered good and the minor problems experienced had no significant effect on the overall support. All requirements were met and, in most cases, exceeded. An option was exercised to extend the 60-minute hold at T-90 minutes by an additional 35 minutes, thus ensuring near-optimum tracking coverage by downrange stations.

Tracking data acquisition during the near-Earth phase was good, and all Class I requirements were met. The mainland stations, GBI, Grand Turk, and Antigua provided continuous coverage from liftoff to L+808 seconds. Ascension covered the interval from L+1286 to L+1592 seconds, and the RIS Twin Falls and Pretoria provided coverage from L+1670 to L+2342 seconds. A short dropout occurred as predicted during the Grand Turk interval.

Atlas/Centaur telemetry coverage via VHF was greater than predicted and all requirements were met or exceeded. Continuous and substantially redundant VHF telemetry was received beginning with the countdown, through Antigua LOS at L+826 seconds, and from L+1225 to L+3261 seconds. All Mark Events except 19 and 23 were received and read out by AFETR and MSFN stations.

Spacecraft S-band telemetry was received continuously from liftoff to L+760 seconds by Tel-4, GBI and Antigua. With the exception of a short gap between Ascension and the RIS Twin Falls, these two stations, Pretoria, and the RIS Sword Knot provided continuous coverage from L+1225 to L+3709 seconds.

All requirements for real-time transmission of Surveyor telemetry data to the SFOF were met. As planned, data via VHF was provided from liftoff to spacecraft high-power on, and thereafter via S-band.

The Real Time Computer System (RTCS) provided all required support. A total of eight orbits were computed by the RTCS, including a parking orbit using

Antigua data, a second and third parking orbit using Centaur guidance telemetry data, a theoretical transfer orbit using Antigua data plus nominal second burn data, two actual pre-retro transfer orbits from Pretoria data, a post-retro orbit using Carnarvon data and a spacecraft orbit from DSS 42 data. From these, IRV, orbital elements, MSFN look angles, DSN predicts, moon-mapping and injection matrices were provided.

J. Ground Communications

In general, the NASCOM Network provided excellent support throughout the mission. Communications Processor operations proved reliable during critical mission phases. During lunar operations, the Goddard CP experienced a number of failures but these did not cause serious loss of data. Hardwire teletype circuits were available in the event of a CP failure during critical periods, but were not needed during the mission.

Two new earth satellite communications circuits were made available to the AFETR Ascension Island station to provide improved downrange communications reliability. One satellite circuit consisted of a dataphone circuit from AFETR Station 12 to JPL via GSFC. Good data was received in the TPS via this circuit; however, the data was not processed because of the high-quality data received via the normal Tel-4/DSS 71 path. A second satellite circuit was used to transmit downrange metric teletype data from Ascension to Cape Kennedy. This circuit also provided good data. The Goldstone microwave circuits, including the 6MHz video line, performed very well during the mission. Only one significant 6 MHz line problem occurred, causing loss of real-time data for part of one pass. All data was recovered at the end of the pass, and the prime data recorded at DSS 11 was not affected.

Special communications support linking all participating stations was provided for the laser experiment.

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