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Seasat Final Report

Volume III: Ground Systems

Edited by
E. Pounder

June 15, 1980

National Aeronautics and
Space Administration

Jet Propulsion Laboratory
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PREFACE

The Seasat satellite was launched at 01:12:44 GMT on 27 June 1978 from the Western Test Range at Vandenberg Air Force Base, Lompoc, California. The spacecraft was injected into Earth orbit to demonstrate techniques for global monitoring of the dynamics of the air-sea interface and to explore operational applications. To achieve these objectives, a payload of sensors emphasizing all-weather, active and passive microwave capabilities was carried on the satellite. The mission was prematurely terminated on 10 October 1978 after 106 days of operation by a catastrophic failure in the satellite power subsystem.

Major mission accomplishments were:

(1) Demonstration of the orbital techniques required to support the mission and sensor operations.

(2) Demonstration of the simultaneous operation of all sensors for periods of time significant to global monitoring.

(3) The collection of an important data set for sensor evaluation and scientific use.

The early mission termination precluded:

(1) Demonstration of the planned operational features of the end-to-end data system.

(2) Collection of a global data set to meet overall geodetic and seasonal objectives and plans.

This report, in four volumes, includes results of the sensor evaluations and some preliminary scientific results from the initial experiment team activities. Scientific and applications studies will continue through FY 80, and will be included in the final version of this report.

ABSTRACT

The Seasat Project was a feasibility demonstration of the use of orbital remote sensing for global ocean observation. The satellite was launched in June of 1978 and was operated successfully until October 1978. At that time, a massive electrical failure occurred in the power system, terminating the mission prematurely.

Volume III of the Final Report treats the Ground Systems used during the mission life. Included are descriptions of the Operating Organization, the System Elements, and the testing program. Next, there is a discussion of the various phases of the mission: Launch and Orbit Insertion, Cruise, and Calibration. A special section is included on the Orbit Maneuver activities. Finally, operations during the satellite failure are reviewed and summarized.

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SECTION I

INTRODUCTION

Information contained in this volume, compiled by the Seasat Mission Control Team, is the final report for the Project Operations System. The mission was planned in phases, which were first documented by the Mission Control Team in the Space Flight Operations Plan.* Because of the spacecraft power failure, the mission was terminated while the satellite was still in the calibration phase, just prior to the planned observational phase. The observational phase was planned to start 115 days after launch, and would have continued through the remainder of the scheduled 1-year mission.

The following major topics are discussed in this volume:

(1) Pre-Launch Phase.

(2) Launch and Orbit Insertion Phase.

(3) Orbital Cruise Phase.

(4) Calibration Phase.

(5) Orbit Maneuvers.

(6) Satellite Failure Report.

Not discussed here is the Seasat Data Utilization Project (SDUP). After the satellite failure, this project was set up to complete the post-flight sensor analysis and produce the final sensor and geophysical data records. The SDUP activity is still in progress at this writing and will be reported separately when complete.

Other activities of this project are documented in separate volumes of this series:

Volume I	Program Summary
Volume II	Flight Systems
Volume IV	Attitude Determination

Abbreviations and acronyms used in this volume are defined in the appendix.

*Seasat-A Space Flight Operations Plan, JPL internal document 622-42, 15 May 1978.

SECTION II

PRE-LAUNCH PHASE

A. GENERAL

This section describes the Project Operations System (POS) activities as they pertain to the pre-launch phase. This section includes the description of functional organizations and their requirements, the design of mission operations, the implementation of the Seasat ground data system, and the POS test and training exercises conducted to support launch readiness.

The pre-launch phase included vehicle erection, mating, and checkout procedures at the Air Force Western Test Range (AFWTR) located at Vandenberg Air Force Base, California. This phase was the final stage of pre-launch preparations for most POS elements. Individual subsystems of the POS had by that time completed their scheduled implementation, and were prepared to execute the mission. The following paragraphs describe the POS organization, the Ground Data System (GDS) implementation, and the POS test and training activities as they pertained to requirements, schedules, and accomplishments.

B. PROJECT OPERATIONS SYSTEM ORGANIZATION

The POS organization was composed of five major systems (Figure 2-1), directed by a manager who was responsible to the project manager for the direct of mission operations. The manager was responsible for the conduct of the mission, which included mission operations planning, development, preparation, and execution. The specific POS responsibilities were:

(1) Establishment of the functional requirements for and the overall functional design of the GDS required for the conduct of mission operations.

(2) Placement of requirements on all supporting elements of the POS by preparation of the Support Instrumentation Requirements Document (SIRD).

(3) Design, development, and test of mission-dependent computer programs and special purpose hardware required for mission operations.

(4) Integration of the GDS elements.

(5) Preparation and execution of the project operations test and training plan.

(6) Establishment of the mission operations organization and interfaces with other supporting organizations.

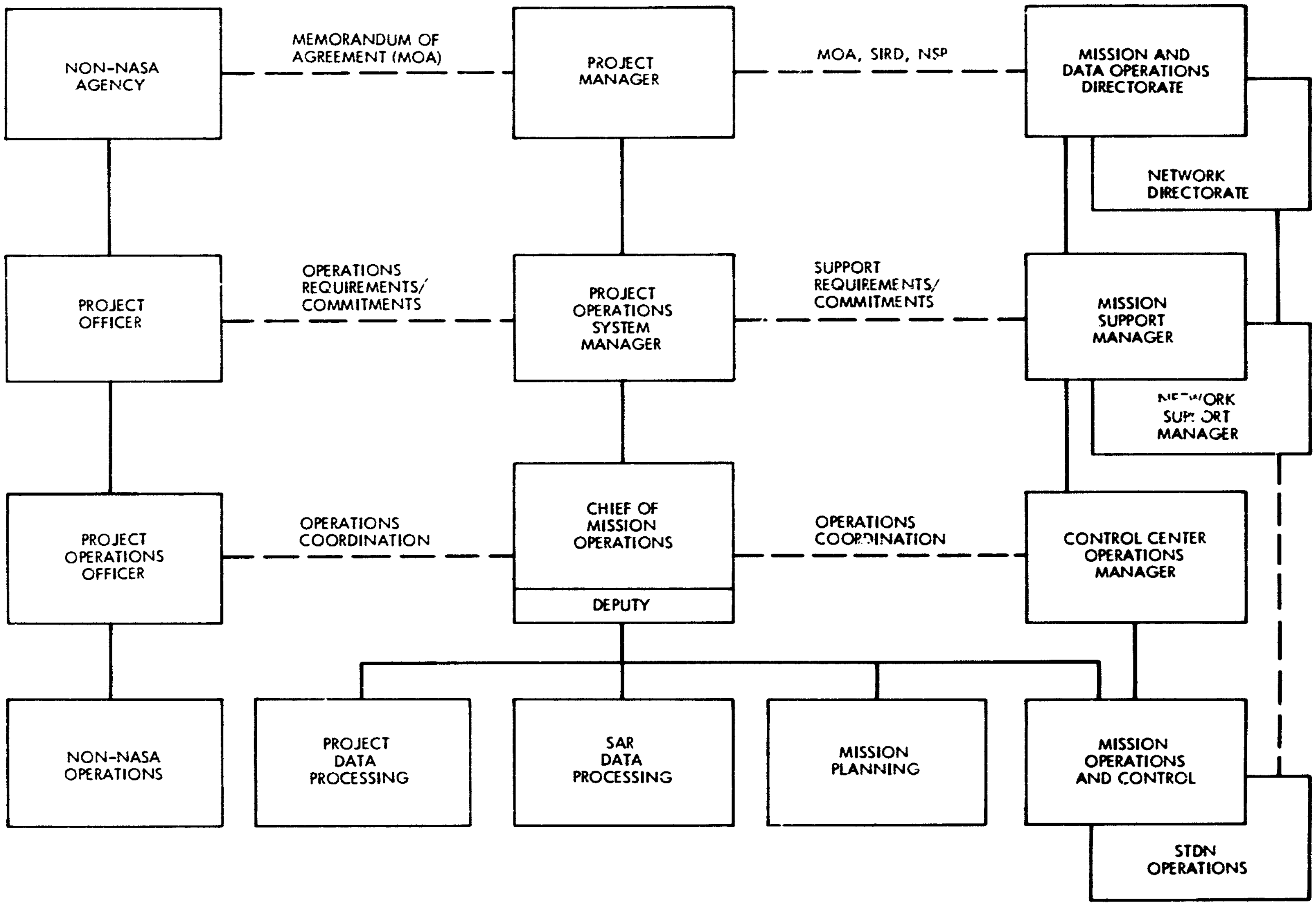


Figure 2-1. Project Operations System Interface Organization

(7) Conducting of the satellite and Mission Operations System (MOS) compatibility test.

(8) Planning and direction of mission operations.

1. Chief of Mission Operations

The Chief of Mission Operations (CMO) was responsible to the POS manager, and had operational responsibilities for mission management and the conduct of mission operations. CMO responsibilities were to:

(1) Direct the POS organization.

(2) Conduct mission operations according to mission plans and any guidelines and constraints specified by the project manager.

(3) Coordinate and direct analysis and planning activities of the POS.

(4) Specify mission operations plans, policies, and instructions to the Mission Control Team (MCT) for execution.

2. Mission Teams

a. Mission Operations Teams. The mission operations teams consisted of 11 elements representing the use of committed flight support resources as provided by the Jet Propulsion Laboratory (JPL), Goddard Space Flight Center (GSFC), Lockheed Missiles and Space Company (LMSC), and non-NASA agencies. Each of the mission operations teams (Figure 2-2) performed both planning and operational functions and interfaced with the MCT. The MCT, composed of the deputy CMO and Assistant Chiefs of Mission Operations (ACMO), was delegated certain responsibilities by the CMO.

Because of the locations of the various mission operations teams, the CMO and deputy CMO rotated between JPL and GSFC to effect mission control and to direct activities carried out by the mission operations teams.

b. Mission Control Team. The function of the MCT was to coordinate and control the activities of the mission operations teams in their execution of mission operations. During the primary mission, the MCT was staffed 24 h a day, 7 days a week by an ACMO. The on-duty ACMO was collocated with the Satellite Performance and Analysis Team (SPAT) and the Project Operations Control Center (POCC) Operations Support Team (POST) in the POCC. The essential activities coordinated by the MCT were ground support scheduling, command management support, tape recorder management, maneuver operations management, clock control, real-time pass activities, and discrepancy and status reporting.

c. Mission Planning Team. The basic function of the Mission Planning Team (MPT) was to generate a Command Request Profile (CRP) that reflected the

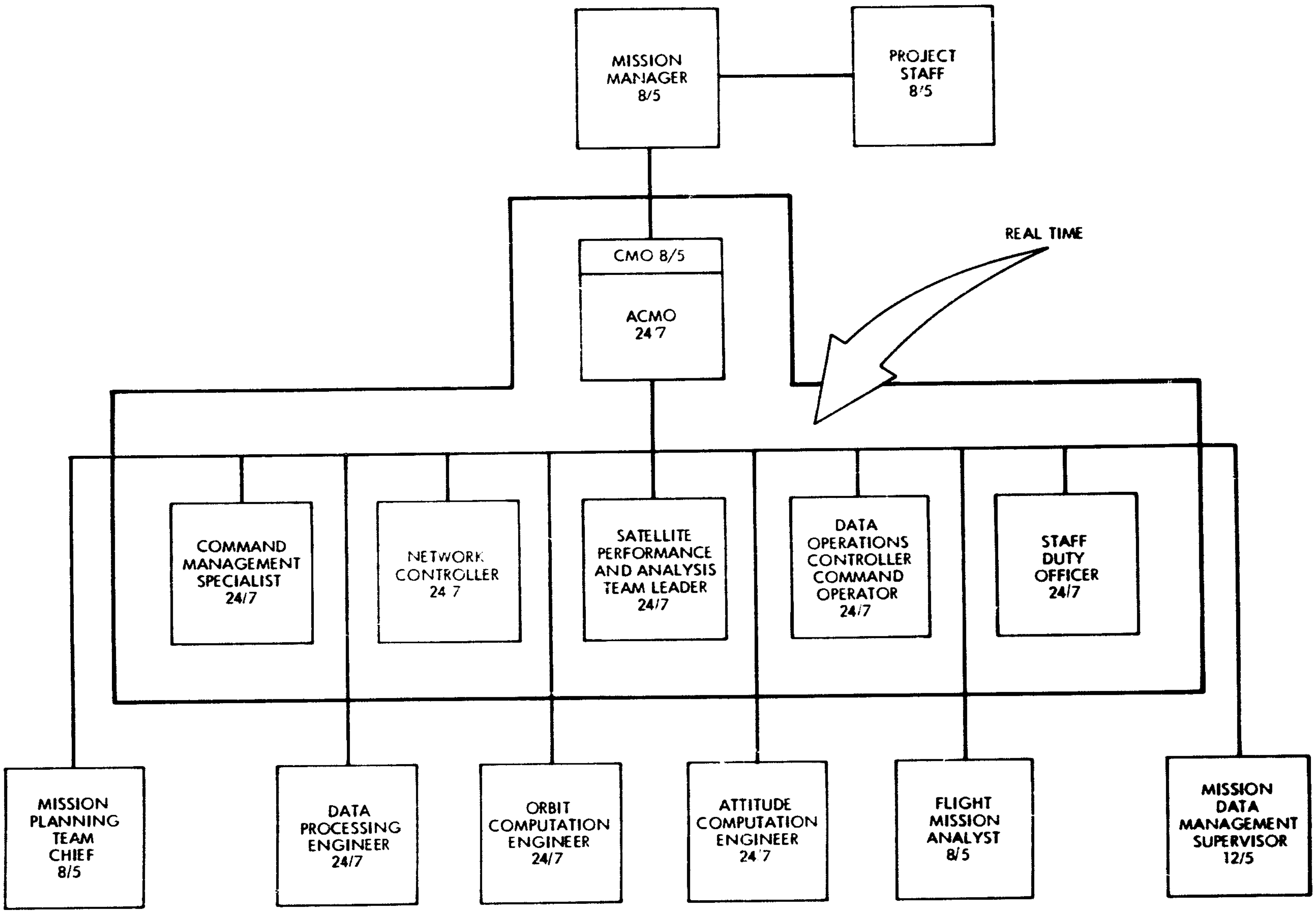


Figure 2-2. Mission Operations Organization

desires of the project and experimentors. The CRP was relayed to Seasat project operations elements at GSFC, where it was developed into satellite command loads.

The MPT was located at JPL and used JPL computers. A CRP contained time-ordered sequences of requested stored program commands and appropriate comments. The comments consisted of orbit-related events, recommended real-time commands, and other information useful for interpretation of the CRP.

The planning cycle to develop the CRP comprised a 4-week period, and inputs were received from the experiment teams, SPAT, MCT, POCC, Spaceflight Tracking and Data Network (STDN), and project management. The MPT performed CRP constraint checks to ensure that satellite subsystem constraints were not violated. The MPT was responsible for performing trend analysis and for monitoring the satellite status with data obtained from JPL's Project Data Processing System (PDPS). The MPT maintained up-to-date orbit information, recommended maneuver days, and specified the desired orbital elements. The MPT also designed sensor sequences to accommodate targets of opportunity.

d. Satellite Performance Analysis Team. The SPAT consisted of a lead monitor analyst and two satellite subsystem analysts. The basic functions of the SPAT were to provide the technical coordination for operation of the satellite system, monitor the performance of the system, and provide the data analysis required to provide information relative to satellite system status and performance. Specific responsibilities of the SPAT were to validate mission profiles, command loads, and real-time commands prior to transmission to the satellite or before input to the Command Management System (CMS). The SPAT was responsible for the definition of all GSFC-generated command loads for maneuvers, sensor targets of opportunity, and satellite configuration. In real time, the SPAT evaluated satellite system performance and status. In addition to performance monitoring, the SPAT provided data analysis of real-time data for trends and anomalous behavior in the satellite system and sensors. The SPAT prepared an inflight performance estimate report conforming with these performance and trend data.

e. Orbit Determination. The orbit determination support function for Seasat was directed by the orbit computation engineer, and was grouped into the following categories:

(1) Launch and early orbit support.

(2) Operational orbit support.

(3) Definitive orbit support.

(4) Observational tracking data support.

The launch and early orbit support function consisted of on-line computing support during the launch trajectory phase and the early phase of the achieved orbit. The time duration of the early orbit determination phase was dependent on station distribution and availability of observational tracking data. The primary objective of the operational orbit support function was to furnish predicted orbit-related information to designated participants throughout the Seasat project. Some of the participants receiving the predicted orbit-related information were the POCC, Attitude Determination System (ADS), Information Processing Division (IPD), STDN, and JPL. The objective of the definitive orbital operations support function was to provide definitive orbital-related information to other recipients. The objectives of the observational tracking data support function were to:

(1) Receive, store, retrieve, and pre-process S-band and quick-look laser data.

(2) Receive and pre-process the full-rate laser data and distribute it to the National Space Science Data Center (NSSDC) and designated recipients.

f. Flight Maneuver Operations Center Team. The basic functions of the Flight Maneuver Operations Center (FMOC) team were to plan and evaluate orbit maneuvers executed to meet mission and project requirements. The FMOC team was located at GSFC, was headed by a GSFC flight mission analyst, and used computers located in the GSFC Mission Operations Computing Facility (MOCF).

g. Attitude Determination Team. The basic functions of the Attitude Determination (AD) team were real-time yaw attitude computation, quick-look attitude determination using whole-orbit playback data, and definitive attitude determination on all data received from IPD with turnaround in time to meet the total 6-day Project Data Package (PDP) commitment. The AD team leader was the attitude computation engineer.

Quick-look and real-time data processing were performed as requested by the project. A complete orbit set of attitude data results were written on disk packs for access by the LMSC simulator software. These complete orbit data were also used to compile disk files for the LMSC power profile software.

h. Information Processing Division. The basic function of the IPD was to process satellite playback telemetry data and to prepare a PDP for use at JPL. The IPD is located at GSFC, and the team leader was the data processing engineer. The specific responsibilities of the IPD were to pre-process playback telemetry data, maintain accountability, and provide quick-look data as requested by the project. IPD assembled attitude, orbit, and command data for the PDP and for GSFC user organizations.

i. Command Management Facility (CMF). The basic function of the CMF was to accept (via the POCC) CRPs from the MPT located at JPL, and to generate the resulting command memory loads with a corresponding English descriptive memory load map and a Mission Sequence of Events (MSOE). The memory loads, map, and MSOE were transmitted to the POCC. The CMF team leader was the command management specialist. CMF provided the project an interface to edit all inputs of CRPs. With the inputs from the Seasat scheduler, CMF determined memory loads in size, time span, remaining capacity of satellite memory, and capacity of the station-to-uplink system.

j. POCC Operations Support Team. The POST was staffed by contractor personnel and responded to technical direction and requirements provided by the GSFC Seasat Control Center Operations Manager (CCOM). The team leader was the data operations controller located in the POCC. The basic function of the POCC was to serve as the facility in which project personnel monitored and controlled the operations of the Seasat spacecraft. The POCC was staffed around the clock by the GSFC POST, the JPL MCT, and the LMSC SPAT teams. The basic function of the POST was to provide the POCC operations support and equipment maintenance required to enable the MCT and SPAT to monitor and control the spacecraft.

The POCC scheduler generated the weekly STDN support request using project-provided generic requirements and special activity support requirements. The Seasat scheduler also scheduled non-NASA supporting stations, including the Fleet Numerical Oceanographic Center (FNOC), as required by the project.

k. Network Operations. The basic function of the STDNs was to provide station coverage from among the 12 committed stations on each orbit during normal operations following launch. The network controller was the STDN team leader. The stations were responsible for providing real-time telemetry and command data interfaces via NASCOM to the POCC during each orbital pass, recording playback data as scheduled, performing station delay measurements for satellite time correlations, and taking ranging and tracking data as scheduled.

l. Experiment Data Processing. The experiment data processing required to generate the Sensor Data Record (SDR) in the Mission Control and Computing Center (MCCC) was the responsibility of the MCCC Data Management Team (MDMT). This team was led by the mission data management supervisor. The MDMT was a multi-mission records processing team jointly funded by the Voyager and Seasat flight projects.

3. Non-NASA Agencies

a. Fleet Numerical Oceanographic Center. The United States Navy's FNOC located at Monterey, California, is the primary Navy center for computer analysis and prediction of both oceanographical and meteorological parameters. The team leader was the FNOC staff duty officer. The FNOC participated in the Seasat project as a result of a Memorandum of Agreement (MOA) between the Department of Defense (DOD) and NASA. According to that MOA, FNOC provided a near-real-time user data demonstration system. FNOC received data from the Fairbanks, Alaska (ULA) STDN station within 6 hours from the time the data were recorded by the spacecraft. FNOC processed these data and determined their engineering unit values. Figure 2-3 shows the data flow path for the receipt of world-wide data.

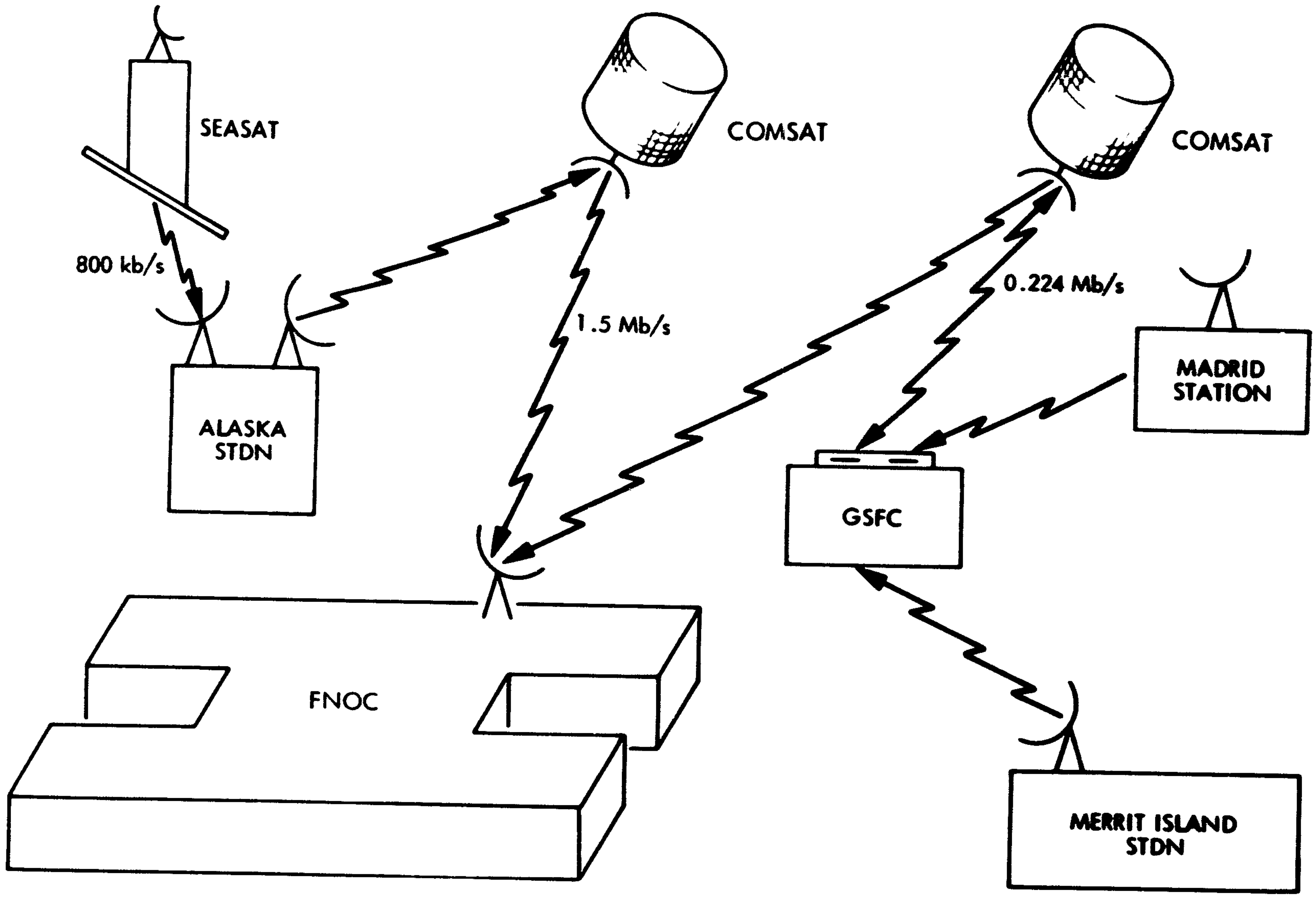


Figure 2-3. Data Transmit Paths for Seasat

b. Shoe Cove Tracking Station (Canada). This station received both low-rate telemetry and the Synthetic Aperture Radar (SAR) telemetry data links. The facility was primarily interested in receiving SAR data; therefore, only selected low-rate telemetry parameters were detected, synchronized, and processed. The SAR data were received and processed using the same type equipment used by the STDN. A voice line was used for coordination between the POCC and the station during real-time passes and reporting from the station.

Station control information, such as pass schedules, orbital elements, and SAR demodulation control statements, was provided via telex from GSFC to the Canadian Center for Remote Sensing (CCRS) at Ottawa and Prince Albert, where station predictions were generated.

c. Oakhanger Tracking Station (England). This station received both low-rate telemetry and SAR telemetry data links. The station was receiving and processing SAR data and 25-kb/s real-time data in cooperation with the European Space Agency (ESA). A voice line was used for real-time pass coordination between the POCC and the station. Selected telemetry parameters, which had been detected, were also reported by voice.

Station control information, such as pass schedules, orbital elements, and SAR demodulation control statements, was provided from GSFC to Oakhanger via telex where station predictions were generated.

d. Tromso Tracking Station (Norway). Station support was scheduled to start in mid-October 1978. Initially, the station would receive low-rate (25 kb/s) data only. Interface with Seasat operations was to have been minimized because of the passive receive-only telemetry mode of operation. Orbital elements for predict generation at the station were to be provided from GSFC via telex. The station was required to provide the CMO with biweekly status reports, indicating actual Seasat tracking activity.

C. GROUND DATA SYSTEM IMPLEMENTATION

The Ground Data System (GDS) elements implemented to support the Seasat Mission Data System (MDS) are shown in Figure 2-4. For a more in-depth review of each GDS element and specific interfaces, refer to the Space Flight Operations Plan.*

All GDS elements necessary for supporting real-time mission operations were brought to a support readiness condition prior to launch. The telemetry housekeeping tape (quick-look) generation system readiness was late, so with operational confidence being low, the AFWTR and NASA Kennedy Space Center (KSC)/ Western Launch Operations Division (WLOD) facilities were requested to provide early orbital support. Difficulties in the launch real-time satellite data link

*Seasat-A Space Flight Operations Plan, JPL internal document 622-42, 15 May 1978.

from the Agena second-burn coverage prompted a late request to have the United States Air Force (USAF) provide backup record-only launch support from the Indian Ocean S-band station at Mahe.

Several GDS elements necessary for non-real-time data support of the Seasat mission were not ready for launch. These elements were:

(1) IPD.

(2) NASA Ground Communications System (NASCOM) (224 kb/s STDN station Merritt Island (MIL) to GSFC to FNOC).

(3) FNOC.

(4) Laser deployments (MOBLAS 5-8).

(5) STDN station Oakhanger, United Kingdom (UKO).

(6) Shoe Cove/CCRS.

These implementation problems are discussed in the following paragraphs, along with GDS elements requirements, implementation schedules, and accomplishments. A GDS lien list is provided at the end of this section.

1. Mission Planning Subsystem

The primary functions of the Seasat Mission Planning Subsystem (MPS) were to:

(1) Provide Command Request Profiles to the Mission Control Team at GSFC.

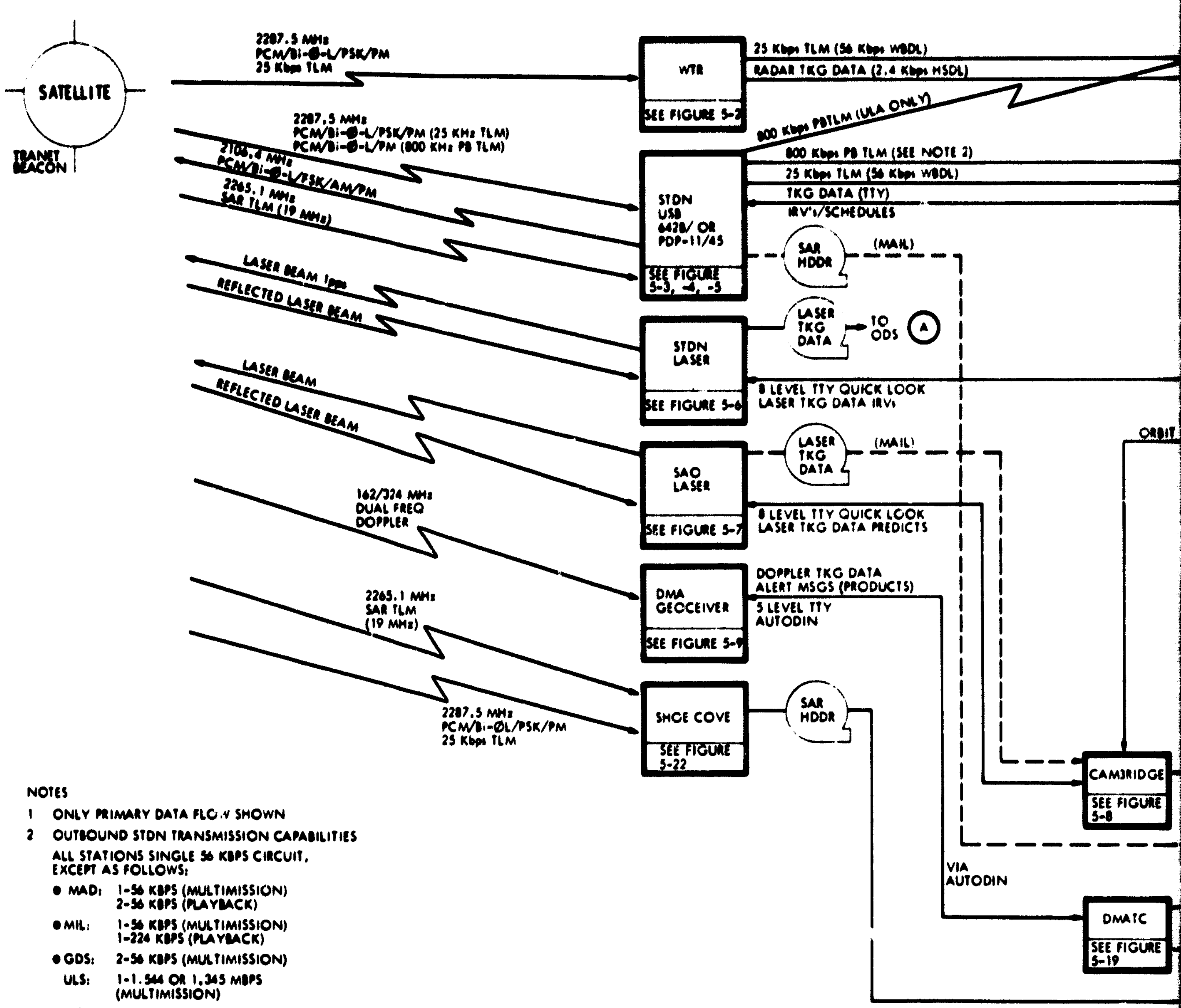
(2) Develop maneuver and orbit maintenance strategies and to specify maneuver execution periods and desired results.

(3) Provide planning products to experiment and data processing groups.

(4) Monitor long-term satellite performance to establish sensor operating constraints.

The first three functional capabilities were developed, tested, brought to full operational status, and successfully used throughout the Seasat mission. The fourth function, long-term performance monitoring, was never successfully demonstrated, partly because of lengthy delays in the availability of processed data and partly because of the lack of availability of a SPAT representative to the MPS. To the extent that this fourth function existed, it was performed within the SPAT at GSFC.

a. Sequencing. The sequencing elements of the MPS involved developing and transmitting the CRP to GSFC, which included the use of several information interfaces and two major software sets operating on the 1108 computer systems.



NOTES

1 ONLY PRIMARY DATA FLOW SHOWN

2 OUTBOUND STDN TRANSMISSION CAPABILITIES
ALL STATIONS SINGLE 56 KBPS CIRCUIT, EXCEPT AS FOLLOWS:

- ● MAD: 1-56 KBPS (MULTIMISSION)
  2-56 KBPS (PLAYBACK)
- ● MIL: 1-56 KBPS (MULTIMISSION)
  1-224 KBPS (PLAYBACK)
- ● GDS: 2-56 KBPS (MULTIMISSION)
- ULS: 1-1.544 OR 1.345 MBPS (MULTIMISSION)
- ● NOT FULLY COORDINATED OR COMMITTED

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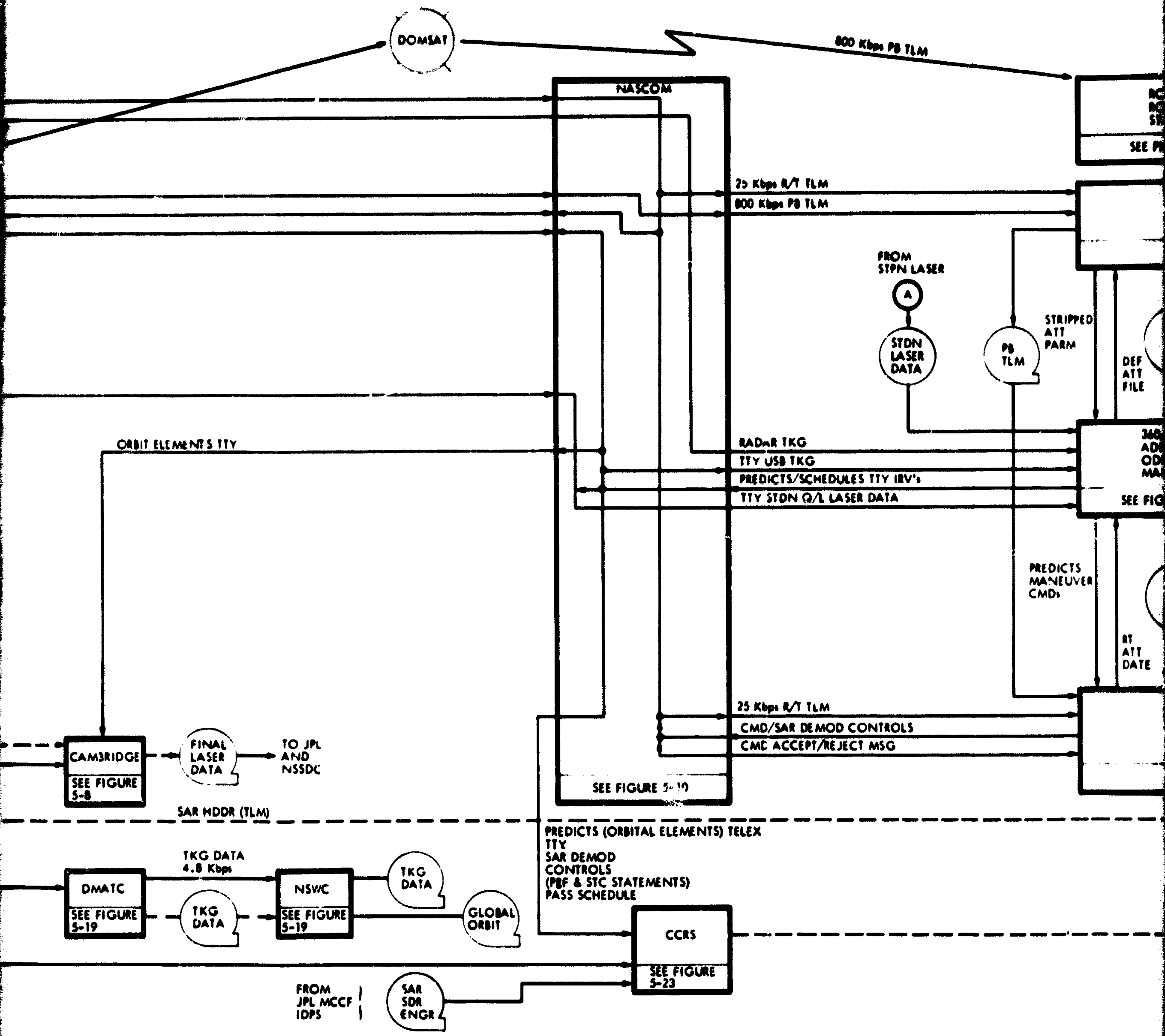

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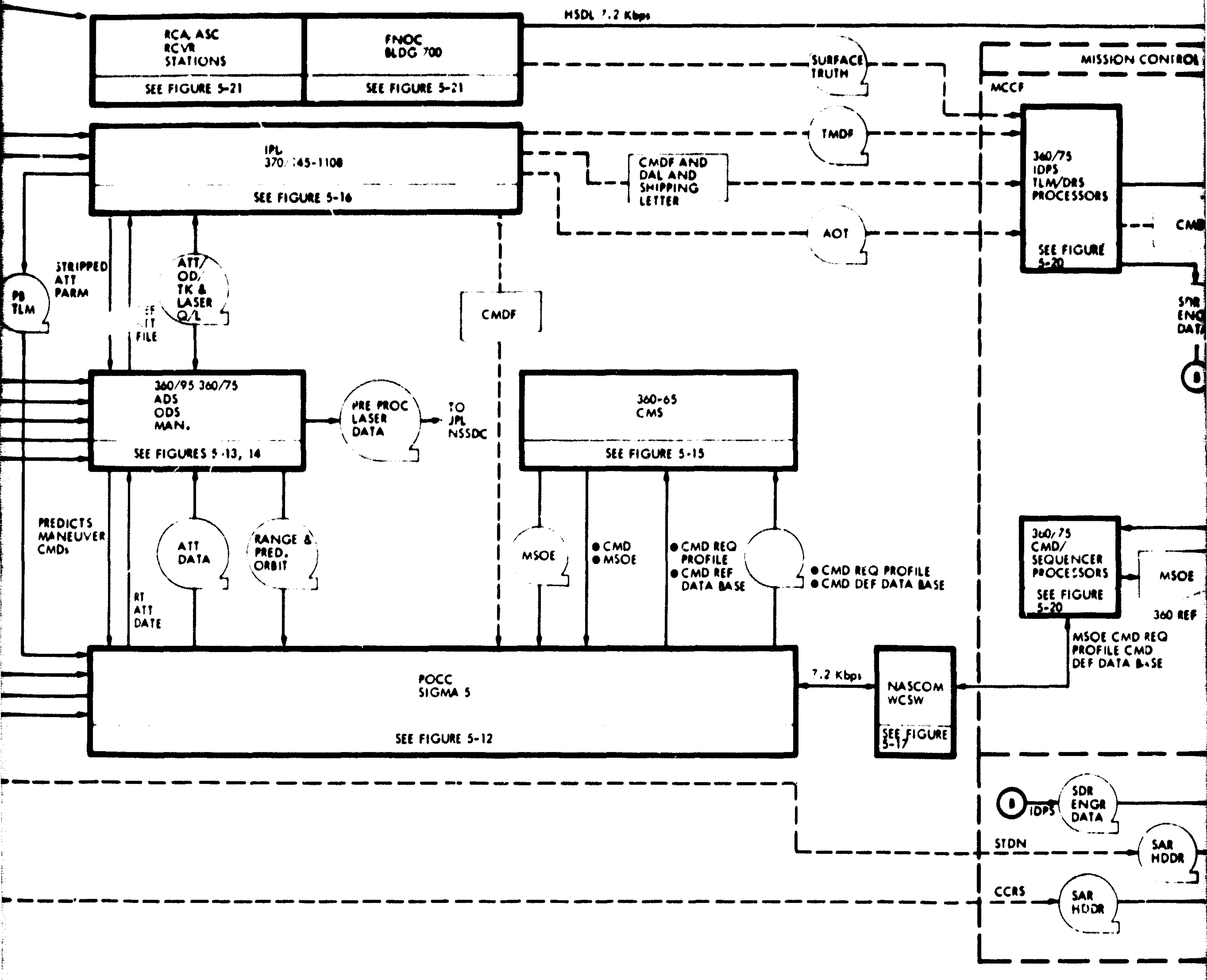

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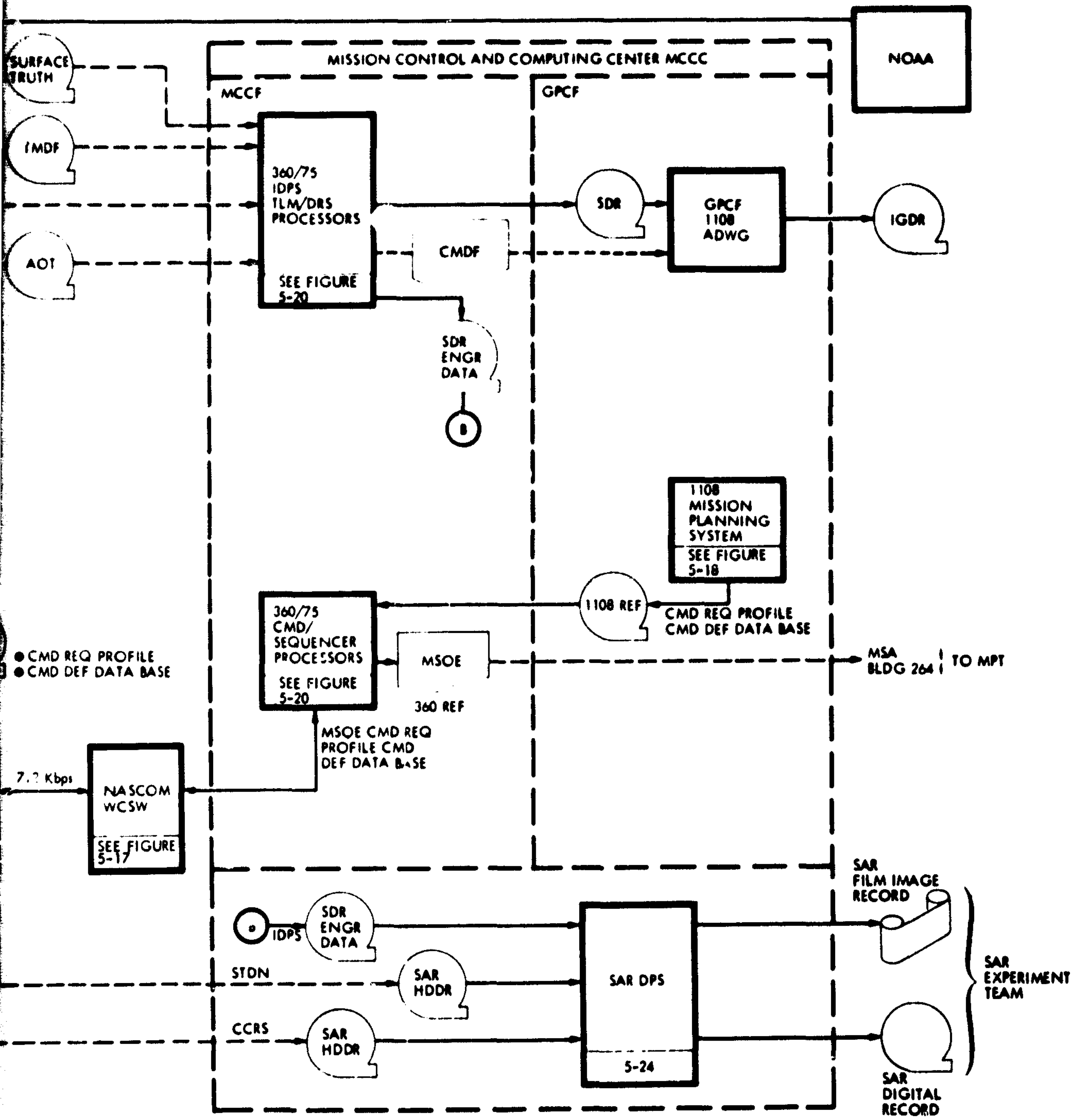

Figure 2-4. Seasat Ground Data System Overview

4

The information interfaces were between the MPS and the SPAT sensor experiment representatives, the sensor engineering assessment managers, and the orbit determination group in Code 570 at GSFC. One of the software sets was the operational version of the Satellite Mission Design Program (SAMDPO) developed by the Mission Design Section at JPL from a predecessor program (SAMDP2.0) used in the original Seasat mission design. The other software set was the mission planning software set developed as a Seasat-peculiar item by Alta Vista Technical Services under contract to the Mission Design Section at JPL. Functional flow through the MPS (Figure 2-5) involved the collection of orbital elements from GSFC Code 570 to drive SAMDPO, engineering constraints and requirements from SPAT, and sensor sequencing requirements from both the experiment representatives and the sensor managers for engineering assessment. The SAMDPO output, together with the other inputs, served as the input to the mission planning software set which resolved orbital event-related times to GMT command times, expanded macro requests (satellite group commands), resolved time conflicts between commands, and flagged satellite command restraint violations. This was an iterative process with two levels of project review prior to final output. The first review was at the input level, where the project office reviewed the sensor inputs and engineering constraints for completeness and appropriateness. The second review was a detailed command review by the Seasat Project Office and other interested personnel. The final output was a CRP nominally covering a 7-day period written on an MCCC system 360-compatible tape for formatting and transmission via high-speed data line to the POCC Sigma 5 computer system at GSFC.

The pacing item in the sequencing development activity was the data interface with CMS. Preliminary agreement was reached by October 1976 to the degree required to permit CMS design to begin. Several changes and remaining uncertainties, notably the addition of the Global Positioning System (GPS), lack of precise knowledge of the information available from Code 570, and uncertainties in STDN station scheduling, led to delays in the final specification of the MPS/CMS interface. The GPS was subsequently removed from the satellite when it was determined that the required orbital data could be generated with sufficient accuracy in SAMDPO, and a division of responsibility between MPS and MCT was developed for tape management, which circumvented the station scheduling problems, so that the requirements for MPS and CMS could be established with the required firmness by June 1977. At this point coding of Mission Planning Software System (MPSS) Version 0.1 could be completed. Three test tapes were delivered to CMS for testing, resulting in the identification of several changes required on both sides of the interface. The MPS changes were accomplished in the next two months. The high-speed data line capability, originally scheduled for mid-November 1977, was delayed several months, so that data exchange between MPS and CMS continued through tape deliveries. Mission Planning Software System Version 0.2 was successfully acceptance-tested and placed under change control on 31 January 1978. With the completion of sensor hardware delivery and installation at LMSC, the sensor representatives began developing more detailed plans for the sensors, requiring additional modifications to the software, but in the meantime software version 0.2 was delivered and installed as Mission Operations Software System (MOSS) Version 1.0 on 16 May 1978. The launch version (MOSS 1.1) was delivered and installed on 22 June 1978.

The SAMDPO software was developed as a separate program from its predecessor beginning in spring 1977. The basic requirement for the program was to

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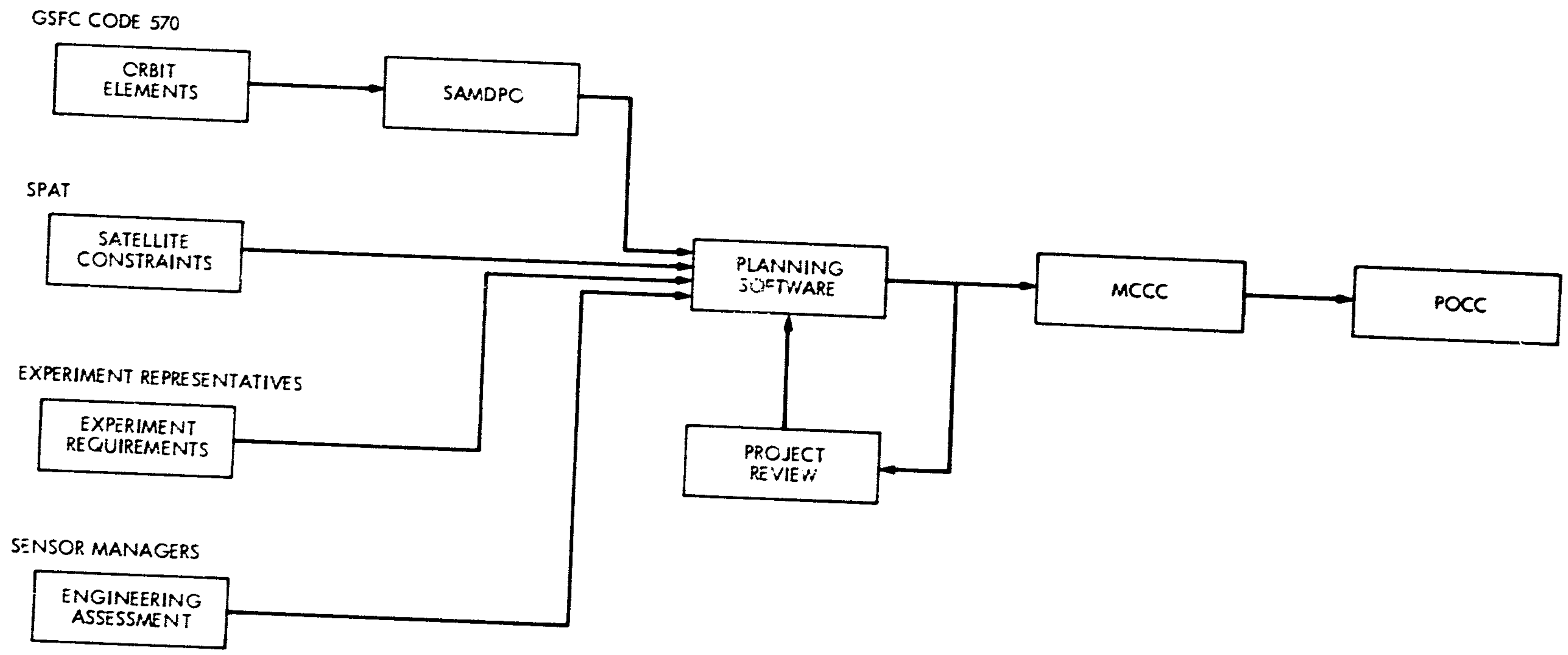

Figure 2-5. Sequencing Functional Flow

create a time-ordered set of orbit-related events for use as command triggers or operational information by the planning software or operational personnel (Table 2-1).

A development version of the program was running by late summer 1977, although some of the requested orbital events had not yet been implemented. The development version output file was complete enough to permit end-to-end testing of the MPS software from September to December 1977. SAMDPO was internally tested and certified for use on 12 February 1978. Integrated testing with the planning software, however, indicated that the certified version still did not have the full operational capability required. Several of the orbital events required were computationally incorrect, others were intermittent, and still others had not yet been implemented. Refinement of the operations concept also had yielded new requirements for SAMDPO outputs. Throughout the next 2 months, emphasis was placed on improving the internal accuracy of SAMDPO and revising its subroutines to reflect improvements already incorporated in a companion version of SAMDPO 3.0. Considerable effort was expended on increasing computational efficiency, as SAMDPO had the longest running time of all of the MPS software.

By May 1978, there was considerable concern that an operational version of the program would not be available for launch. Accordingly, the list of requirements yet to be validated was examined and priorities assigned. All mandatory items were incorporated first and installed in an operational mission-built version of the program on 25 May 1978. Work continued on the non-mandatory requirements. As each was brought on line in the development version, it was tested against the mission-built version and validated by the planning software. MOSS 1.1, installed 22 June 1978, contained the updated version of SAMDPO. There still remained some items to be implemented in SAMDPO at launch, and these items were worked on throughout July and August 1978. During September 1978 work on the new version of SAMDPO was temporarily halted because of resource limitations. By the time of the satellite power subsystem failure on 10 October 1978, the new version was complete and awaiting integrated testing and validation prior to installation on the operational system in MOSS 1.3.

Three types of tests for various versions of SAMDPO were accomplished throughout the program:

(1) Internal tests were conducted against previous versions of the program or against standard test runs on related programs (SAMDP2.0 and SAMDP3.0).

(2) External tests compared the output of SAMDPO for standard test runs on the GSFC Code 570 software.

(3) Integrated tests were run using the SAMDPO output file as the driver for the mission planning software.

Special input checking routines had been incorporated in the planning software to identify missing or inconsistent entries in the SAMDPO output file, such as event start without an associated event end, non-consecutive revolution numbers, etc. Integrated testing was conducted on an as-developed basis rather than as-delivered, so that not only the existing MOSS version of SAMDPO but also the latest developmental version was always available for operational use. This

Table 2-1. Orbit Events Output by SAMDPO

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
.
 A DDD/HHMM.SS              DESCRIPTION---------------------------------------->
 A                          DESCRIPTION---------------------------------------->
 O DDD/HHMM.SS REVN-STA ALT ALD=KKK=NNN.N KM
 O DDD/HHMM.SS REVN-STA ALT ALU=KKK=NNN.N KM
 O DDD/HHMM.SS REVN-STA AOS ACQ SIGNAL        ELV=DDD MAX=DDD AZM=DDD
 O DDD/HHMM.SS REVN-STA AZM AZM=DDD DEG
 O DDD/HHMM.SS REVN-STA ELV ELV=DDD DEG
 O DDD/HHMM.SS REVN-STA LOS LOSS SIGNAL       ELV=DDD         AZM=DDD
 O DDD/HHMM.SS REVN-    ODA DAY ENTRY
 O DDD/HHMM.SS REVN-    OIE ICE ENTRY
 O DDD/HHMM.SS REVN-    OLE LAND ENTRY
 O DDD/HHMM.SS REVN-    ONI NIGHT ENTRY
 O DDD/HHMM.SS REVN-    ORB EAST LON=DDD.DDDDD B=DD.DD DEG
 O DDD/HHMM.SS REVN-    OSE SEA ENTRY
 O DDD/HHMM.SS REVN-    SOC START SUN OCC
 O DDD/HHMM.SS REVN-    XOC EXIT SUN OCC
```

incremental approach to testing permitted early use of each validated program improvement, and also permitted considerable insight into the effect of individual changes on the balance of the program.

b. Orbit Maintenance. Pre-launch planning called for early adjustment of the Seasat orbit so that a stable orbit optimized for sensor data acquisition could be achieved within 30 days of launch. The orbit selected was a 3-day near-repeat orbit in which the ground trace laid down in 43 revolutions (revs) would be displaced 18.5 km (10 nm) to the east during the next 43 revs. After 5 months of operation in this orbit, the complete equator would have been crossed every 18.5 km, setting up a uniform sensor sampling grid. During this period, maneuvers to maintain the 18.5-km spacing were to be performed as required. It was also planned to interrupt the grid buildup when an exact overflight of the Bermuda STDN station could be achieved to perform an exact 3 day repeat experiment over Bermuda, then return to the 18.5-km grid buildup. During the second 6 months of the mission, it was intended that a different grid buildup would be used to provide a different global sampling characteristic.

The MPS responsibilities lay in the areas of development of maneuver strategy, the specification of post-maneuver orbital elements required, and the selection of maneuver days. The maneuver modeling, thruster calibration, command generation, and maneuver execution were all responsibilities of the Maneuver Operations Planning Team (MOPT) at GSFC. MPS support in the pre-launch training and operational readiness testing activities was given on an as-needed basis. By launch, the complete maneuver area had achieved a high state of readiness. Detailed orbit maneuver information is contained in Section VI.

c. Planning Products. Several planning products and planning aids were produced by the MPS during the pre-launch and flight activities. These aids included orbit calculators, ascending node tables, computer plots, map overlays, tabular listings of events of interest, computed products, and special analyses. Planning product users ranged from MCT to experiment team members to data users outside of the project framework. The products could generally be classified as operational aids, data acquisition aids, or informational aids. Their classification generally denotes both their source within the MPS and also their ultimate use.

The operational aids were generally produced by the Mission Planning Software System as a by-product of the process of preparing the CRP. The principal users were the members of the MCT at GSFC, the intent being to provide the MCT with the information required to aid in STDN station scheduling and real-time command generation. The two routinely produced operational aids were a tape recorder management aid (TRPLAN) and a SAR real-time command aid (SARPLN). The TRPLAN listed all of the potential tape recorder playback sites for each tape load and flagged the time available for playback. By using TRPLAN, the ACMOs were able to select primary and secondary dump sites for the satellite tape recorders. In this manner, tape recorder read-in management was decoupled from the tape recorder read-out management, which was dependent on knowledge in advance of station scheduling. Although decoupling did simplify the activity, both in the MPS and MCT, it did depend on using a fixed-length read-in, which resulted in a loss of efficiency in the use of prime tape dump stations. This loss seriously impacted the data recovery and assembly at GSFC. Investigations into the possibility of changing the read-in algorithm to increase efficiency of usage, specifically of the STDN station Fairbanks (ULA), indicated that no simple algorithm could be developed that did not depend on some knowledge of station scheduling further in advance than the network schedulers normally worked. The only alternative to this loss of efficiency would have been to place the responsibility for both read-in and read-out tape management with the MCT at GSFC. This was rejected as imposing too great an additional load on the MCT.

SARPLN was intended as an aid to the MCT if targets of opportunity were identified and requested by the project without sufficient time to exercise the MPS planning capability. SARPLN identified the beginning and end of every possible SAR pass within a given time span, and also included such pertinent information as satellite eclipse times and station elevations. This information, together with the SAR group commands residing in the CMS and the table of Sensitivity Time Control (STC) and Pulse Repetition Frequency (PRF) commands as a function of satellite altitude, provided the MCT with the capability to hand-generate any requested SAR pass.

The data acquisition aids were those produced by the MPS generally using the SAMDP3 program for use by the experiment teams to determine opportunities for acquiring data at specific locations. Chief among these aids was the SEATRAK™ satellite tracking calculator and its associated tables of predicted ascending and descending node locations and times. The calculator is a set of polar projection Earth maps with overlays which provide satellite and sensor swath geometry and timing information. It is similar to the orbit calculators often used by previous programs for providing approximate information for Earth orbiters. To use the calculator, it is necessary to have some known orbital position and time. This was provided by compiling the set of node positions and times with the calculators. These were updated each time the essential characteristics of the expected orbit changed; that is, updates were issued after the decision to delay orbit adjust and after the design of the actual orbit adjust maneuvers was complete. An additional update was scheduled for distribution on completion of the exact 3-day repeat experiment over Bermuda. The calculators proved accurate enough that they were used by experiment teams, notably the SAR and SASS teams, to produce command requests.

Specially produced computer plots and map overlays were also generated in response to specific requests. These also were generated using the SAMDP3 program. The primary users were those interested in special experiments such as the Gulf of Alaska Seasat Experiment (GOASEX).

Information aids were provided from a number of MPS sources to a variety of interested parties. A human-readable version of the CRP, desigated TYMLYN, was produced each week for the use of all parties who required detailed information on planned science activities. A special SAR request listing was prepared weekly to indicate the beginning and end of all requested SAR information. Another SAR listing maintained a running accounting of cumulative on-times in the previous 24-h period for the use of the SAR and satellite electrical power personnel. Special analyses and information tabulations were provided in response to special requests from those associated with the project.

In addition to the planning products, there were also user requests for products that would aid in the processing of received satellite data. Special SAMDP3 runs were made to provide satellite geometry data to the SAR data processing group to use as inputs in the SAR processing.

2. POCC Implementation

a. Hardware and Software

Requirements As described in the SIRD, project-unique requirements were to:

(1) Generate a Command Master Data File (CMDF) of all commands, including time of occurrence, initiated from the control center.

(2) Monitor and correct the spacecraft on-board GMT clock.

(3) Compute and compare solar array tracking angle and yaw angle in real time using satellite-predicted orbit, sun ephemeris, and telemetry readouts.

(4) Format and transmit STC and PRF settings to the STDN SAR data formatter control unit.

(5) Establish JPL/POCC hard-link for transmission of mission planning command data.

Implementation of Requirements. All major requirements were resolved using established documents such as the Support Instrumentation Requirements Document (SIRD), NASA Support Plan (NSP), etc.. Details of requirements were resolved by GSFC and JPL engineering personnel. When requirements crossed GSFC organizational elements and interagency boundaries, Interface Control Documents (ICDs) were established with appropriate signatures. The POCC was directly responsible for six of these documents; two were initiated from JPL as a joint effort. The POCC also established a sensor processing agreement, which determined and defined all POCC quick-look requirements for monitoring the performance of the five on-board sensors. This agreement was approved by the six agencies.

Concurrent with the Seasat software development, a new Mission Operations Room (MOR), office facilities, and a three-computer switching system (for adequate computer back-up support) were developed. Although this was not a direct requirement for Seasat, the Multi-Satellite Operations Control Center (MSOCC) II was established to provide a dedicated MOR for Seasat personnel and the scheduled availability of three Sigma 5 computer systems for support.

Software and hardware designs were implemented on or ahead of schedule. Firming of software requirements occurred in March 1977 at a Univac/GSFC/JPL critical Software Design Review (SDR). The most difficult task, which remained essentially on schedule, was the General Electric (GE) switching system hardware integration, which occurred during on-going AE and OSO spacecraft operations.

This was accomplished with minimum impact to either on-site operations or Seasat development. This effort also included the first use of 4800-bit NASCOM transmission blocks, hardware block polynomial decoders, solid-state switching with microprocessor control, color configuration cathode ray tube (CRT) display with light-pen CRT switching, and color satellite system command display with light-pen command execution. The two most difficult new (not generic) software tasks were to design, integrate, test, and maintain schedules for the JPL interface for command input and the universal time correction and correlation requirements. Although the end-products were satisfactory, these two elements consumed so much time because they were new, that it was difficult to plan, test, and generate. The block telemetry scanning radiometer (SR) format also created a new data base and generated a software design philosphy which to some extent did impede development, but proved to be a better way of processing data.

Testing. In addition to the contractor (Univac and GE) obligation of module, system, and regression testing, a test team was formed. This team consisted of JPL, Univac, and GSFC operations and engineering personnel whose purpose was to test all software deliveries before they were used in operations. The test program objective was to generate and test a new software delivery approximately every 2 weeks. A new delivery would contain new requirements (which were minimum), enhancements, discrepancy corrections, and additional scheduled capabilities. This test effort began on Friday and progressed through the weekend, and the system was generally made available on Monday. The method of joint and weekend testing proved to be successful, although exhausting to all participants.

Another important testing event was the spacecraft/POCC compatibility test. A spacecraft test plan was co-authored by GSFC and JPL, written for both engineering and mission-oriented objectives, and approved as a joint LMSC, GSFC, and JPL effort. The test, which required approximately 18 h, was very successful, even though the timelines and all operations objectives were not met.

Subsequent to spacecraft launch, other mission operation tests were performed with engineering support. A software user guide was prepared and delivered with the controlled software system tapes, according to GSFC document OCD-2X-038-1, and a formal enhancement and discrepancy system was established from a GSFC Operating Control Directive (OCD). The software user guide was used as the principal training aid along with 2 weeks of formal spacecraft operations and maintenance and operations (M&O) training, on-the-job training (OJT), and one-on-one training. After launch, a 6-month, 3-man follow-on Univac support contract was in effect to continue necessary maintenance of the Seasat software system.

Schedule. All items related to POCC development were milestoned and presented to various GSFC, NASA headquarters, and JPL elements. This material was last presented at the October 1977 review at JPL and the 30-day and 7-day prelaunch reviews at GSFC. It also included such things as concerns, contingencies, capabilities, and status summaries.

b. Operations and Maintenance Support

Requirements. POCC operations requirements are documented in the SIRD, NSP, JPL Space Flight Operations Plan (SFOP), GSFC Mission Operations Plan (MOP), GSFC Network Operations Support Plan (NOSP), etc.. Table 2-2 provides a summary

Table 2-2. Seasat POCC Operations Support Team Responsibilities (O&M Contractor Support)

Post personnel will:

(1) Maintain the POCC equipment.

(2) Operate the POCC computers.

(3) Coordinate, control, and monitor POCC equipment configurations and data flow:

(a) POCC $\xleftrightarrow{\text{TLM/CMD/SAR}}$ STDN

(b) POCC $\xleftrightarrow{\text{CRP/MSOE}}$ JPL

(c) POCC $\xleftrightarrow{\text{CRP/MSOE}}$ CMF

(d) POCC $\xleftrightarrow{\text{TLM}}$ ADS

(4) Coordinate scheduling of STDN support.

(5) Schedule and coordinate transmission and retransmission of playback.

(6) Provide verbal briefings and direction to the STDN during pre-pass, pass, and post-pass operations.

(7) Transmit real-time commands and command memory loads to the spacecraft under the direction of the project.

(8) Generate and transmit SAR demodulation control data to ULA, MIL, and GDS stations via data link, and to non-STDN stations via telex.

(9) Process microsecond time-tagged real-time telemetry data for computation of spacecraft clock time offsets. Distribute time offsets to the project MCT, IPD, CMF, ADS, FNOC, and others, if required.

(10) Participate in the pre-launch checkout of the POCC and its external interfaces, including participation in training exercises and simulations.

(11) Maintain accountability for POCC/project operations support information and data (e.g., support schedules, scheduling aids, ephemeris tapes, predicted slant range tapes, memory load tapes, etc.).

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of the operations and maintenance (O&M) support provided by the POCC Operations Support Team (POST), and Figure 2-6 shows the many POCC operational and data interfaces required to support the Seasat mission.

Implementation to Meet Requirements. POCC O&M support was provided by contractor personnel under the direction of the GSFC control center operations manager. O&M personnel also assisted with hardware and software implementation and engineering tests, under the direction of the GSFC control center operations manager and systems manager.

POCC O&M implementation consisted of forming and training the POST to support Seasat operations, and developing operational procedures. Staff buildup began in September 1977, when an individual with 12 years of control center operations experience was assigned as the Seasat operations coordinator. Other positions were filled as the workload increased, with all key positions filled by January 1978. To start out with experienced operations personnel, two data operations controllers from the Orbiting Solar Observatory (OSO) POCC and two from the Atmosphere Explorer (AE) POCC were assigned to Seasat. Replacements were assigned and trained for OSO and AE before this action was taken. Seasat command operator positions were filled in a similar manner.

The Seasat operations coordinator worked with the POCC manager to develop approximately 20 OCDs that specified the operational procedures to be used by the POST for the Seasat mission. These directives covered the operational interfaces with the many organizations shown in Figure 2-6 and with internal POCC operating procedures. Development of these procedures was a time-consuming, but very beneficial task.

Tables 2-3 and 2-4 summarize the formal (classroom) and informal training received by the POST personnel. Training was provided by personnel from GSFC, JPL, LMSC, Univac, GE, and RCA.

Testing. The POST participated in a great deal of testing, much of which was also useful for training purposes. POST personnel assisted the control center systems manager (CCSM) with engineering tests between the POCC and the organizations shown in Figure 2-6.

One major undertaking of the POST was the conduct of pre-launch POCC/STDN data flow tests and the evaluation of the results of these tests. A detailed test plan was prepared by the POST that outlined the tests to be performed, their purposes, the forms to be used for recording test results, and also identified the personnel responsible for supporting the tests. Eighty POCC/STDN data flow tests of 60 to 90 min each were conducted between 28 March 1978 and the launch date. Most of these tests were successfully completed with all stations by early May. Tables 2-5 and 2-6 summarize the testing status as of 11 May. Early data flow tests showed missing or incorrect time-tagging of the telemetry data by the STDN because special equipment modifications to provide microsecond resolution time-tagging for the Seasat mission had not yet been installed at the stations.

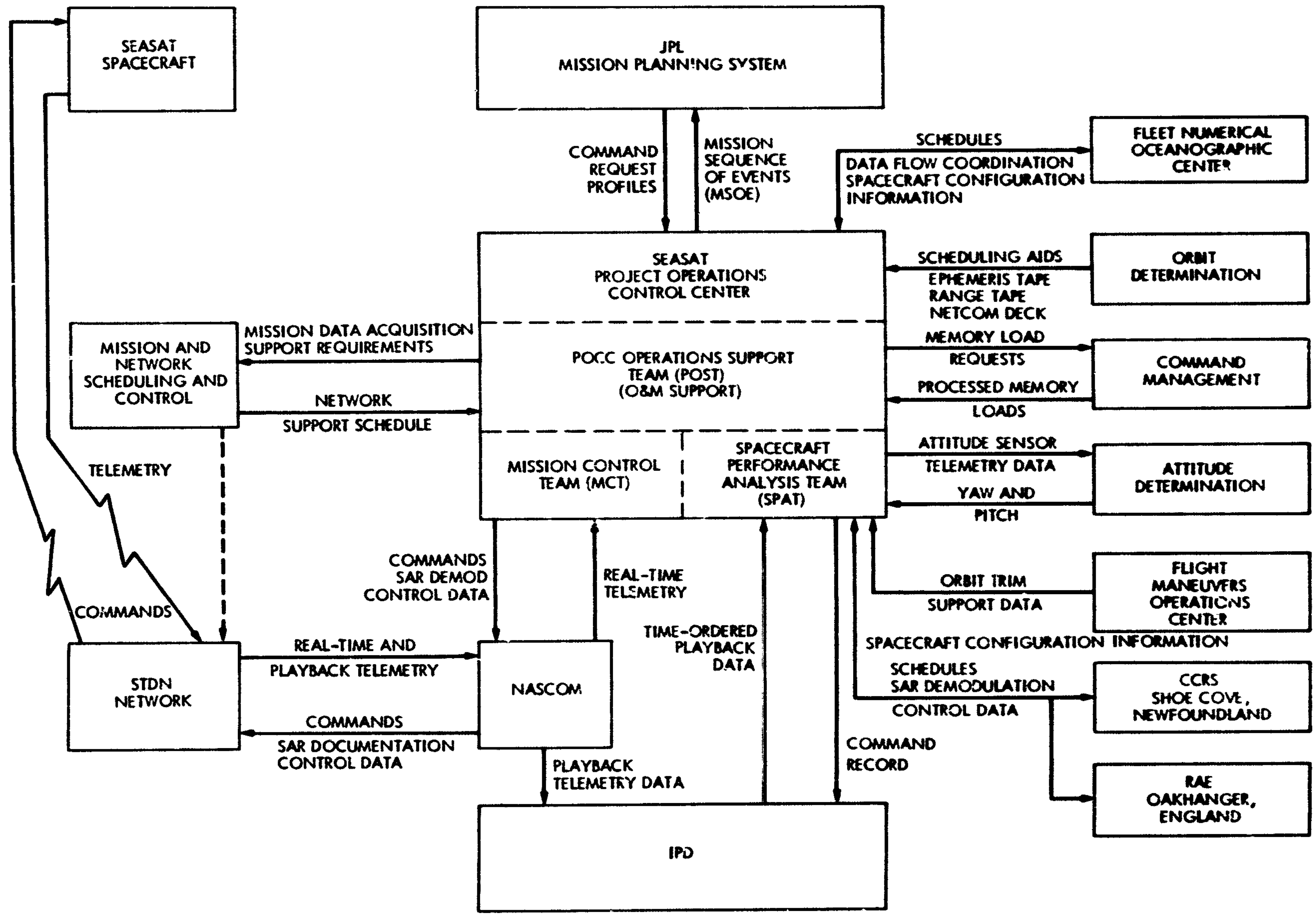


Figure 2-6. Seasat Project Operations Control Center Interfaces

Table 2-3. Formal Classroom Training

Formal Training Completed 3/17/78

(1) Spacecraft Training Completed 1/19/78

General overview presentation . . . . 10/12/77 (1 day)

Detailed training classes . . . . 1/10/78 to 1/19/78 (8 days)

(2) Software Operations Classes Completed 12/22/77

Classes . . . . 12/12/77 to 12/22/77 (9 days)

(3) Hardware Maintenance Training Completed 3/17/78

New Hardware

General Purpose Console (GPC) . . . . 11/28/77 to 12/2/77 (5 days)
GPC/GE electronic switcher system . . . . 2/13/78 to 2/24/78 (10 days)
Simulator/line test unit (PDP 11/34). . . . . 2/28/78 to 3/3/78 (7 days)

Existing Hardware . . . . 3/6/78 to 3/17/78 (10 days)

Signa 5 systems overview
KYBD/CRTs
Controller multiplexers for driving KYBD/CRTs and GPCs
Stripchart recorders
Data products line printers

Table 2-4. Informal Training

Informal Training Completed . . . . 6/23/78 (last simulation with STDN)

(1) Operations Training

POCC personnel who attended formal software and spacecraft training class provide OJT to remaining POCC personnel.

POCC personnel regularly supported:

Engineering tests Intra/inter-team tests Data flow tests Simulations	Primarily from January 1978 to launch

Test and simulation support resulted in:

Refinement of OPS procedures
Familiarization with the POCC system
Familiarization with external interfaces, including the STDN configuration and project data formats

(2) Hardware Training

Maintenance personnel assisted with hardware installation, checkout, and maintenance.

Table 2-5. DDPS Phase I, Program 2, POCC/STDN Data Flow Test Summary (Total of 55 Tests, Period 3/28/78 to 5/11/78)

		Test Function Checked											
Sta	No. of Tests	A	B	C	D	E	SCE 1	SCE 2	DDPS Format-ting	Time-Tag Accuracy	Pre/Post Pass Equipment Delays	Time Cali-bration	SAR Demodulation I/F
ACN	6	S	S	S	S	S	S	S	S	S	S	-	N/A
ACO	6	S	S	S	S	S	S	S	S	S	S	-	N/A
BDA	0	No 56-kb/s link until October 1978											
ETC	1	S	S	*	*	*	S	S	S	S	S	-	N/A
GDS	6	S	S	S	**	S	S	S	S	S	S	-	****
GWM	6	S	S	S	S	S	S	S	S	S	S	-	N/A
HAW	5	S	S	S	***	***	S	S	S	S	S	-	N/A
MAD	6	S	S	S	S	S	S	S	S	S	S	S	N/A
MIL	9	S	S	S	S	S	S	S	S	S	S	S	S
ORR	5	S	S	S	S	S	S	S	S	S	S	-	N/A
QUI	0	No 56-kb/s link											
ULA	5	S	S	S	S	S	S	S	S	S	S	S	S

Test Legend:

A - PRT (DDPS/SCE) with simulator data
B - RT pass, simulator data, SCE 1, pre- and post-pass equipment delay measurements of 00123 and 00456
C - RT pass, actual spacecraft data (from analog tape); SCE 2, make journal tape for test E, pre- and post-pass equipment delays of 00100
D - Post-pass playback of RT pass from analog tape using tape time track
E - Post-pass playback of RT data from journal tape (from test C to simulate POCC missing data from a time correlation pass)
S - Successful
* Tests C&D analog tape had many dropouts. No time to run E
** Bad time tags
*** Unsuccessful in receiving good data for D&E
****Test May 22-26

Table 2-6. DDPS Phase I, Program 2, POCC/STDN Data Flow Test Summary (Period 5/2/78 to 5/11/78)

		Test Function Checked												
Sta	No. of Tests	U1	U2	U3	U4	U5	U6	U7	SCE 1	SCE 2	DDPS Format-ting	Time-Tag Accuracy	Pre/Post Pass Equipment Delays	SAR Demodulation I/F
ULA	5	S	S	S	*	S	N/A	**	S	S	S	S	S	S

Test Legend:

U1 - PRT (DDPS/SCE) with simulator
U2 - RT pass, simulator data, SCE 1, pre- and post-pass equipment delay measurements of 00123 and 00456
U3 - RT pass, actual spacecraft data (from analog tape); SCE 2, pre- and post-pass equipment delays of 00100
U4 - Post-pass playback of RT pass (25 kb/s) from analog tape using tape time
U5 - RT pass with 25-kb/s RT and 800-kb/s dump using actual spacecraft data from analog tape
U6 - 800-kb/s dump past pass playback from analog tape using tape time (TELOPS/FNOC only)
U7 - RT (25-kb/s) data, via 56-kb/s link (simulates unavailability of 1.544-Mb/s link)
S - Successful
* Bad time tags
**No change to test

The POST also participated in the POS test and training plan activities described in Section II-D of this report. GSFC POCC Operational Readiness and Performance Assurance (ORPA) meetings were held regularly from 26 January 1978 through the end of the mission. Representatives attended from all groups with responsibilities in the POCC. The ORPA POCC deficiency and enhancement request system was used to track software and hardware problems and enhancement requests.

Schedules. POST support was provided on a schedule that was compatible with project requirements.

3. Command Management System

a. Requirements. The CMS at GSFC was responsible for the management of memory commanding for the Seasat mission. The CMS received mission planning information from JPL through the POCC, and translated it into memory loads that were transmitted to the POCC for subsequent loading on the Seasat onboard memories.

Specifically, the requirements for the CMS were to:

(1) Provide an interface to accept and edit all inputs of stored command requests.

(2) Merge all current, pending, and automatic command requests into a single GMT-ordered list.

(3) Determine memory loads in size, time span, and loadability.

(4) Fabricate spacecraft commands from the command requests into acceptable spacecraft memory load format for transmission to the POCC.

(5) Check for constraint violations.

(6) Provide with each memory load an English command/orbital event description in a GMT-ordered list.

The CMS was developed for the IBM S/360-65 computer at GSFC with an IBM S/360-95 as backup.

b. Implementation. The CMS software system was developed by Computer Sciences Corporation under the direction of GSFC Code 514. Figure 2-7 shows the data interfaces and processing steps involved.

No significant problems were encountered in the development and implementation of the Seasat CMS. Processing specifications were provided in the project's SIRD; data interfaces were defined in the ICDs, and operational considerations were coordinated in planning meetings held both at JPL and GSFC.

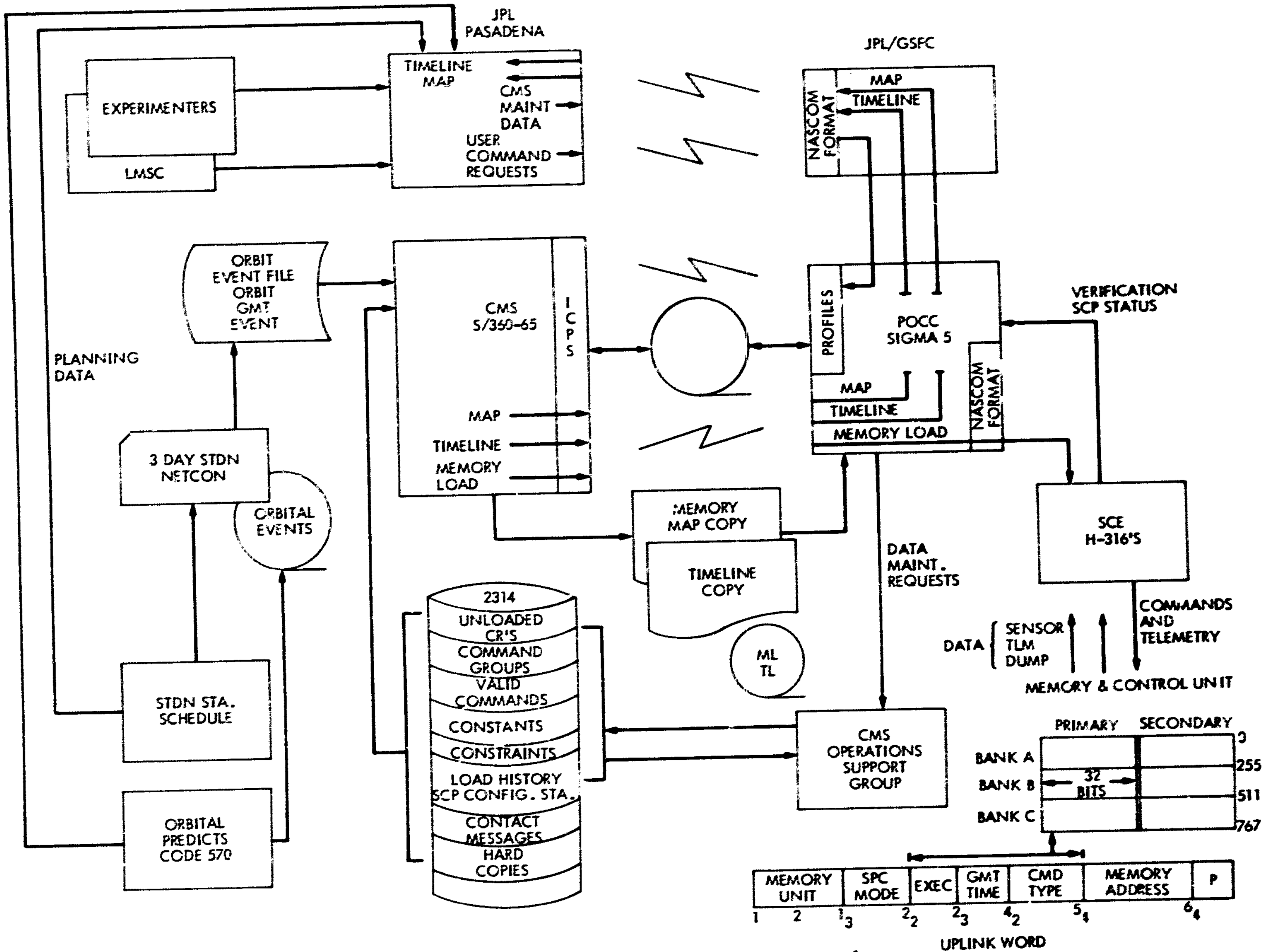


Figure 2-7. CMS Interfaces and Processing

c. Testing. Seasat CMS proof tests were conducted at two levels: software acceptance tests and system operational tests. Software acceptance testing was conducted by the CMS operations contractors, Computer Sciences Technicolor Associates (CSTA), and consisted of verifying and demonstrating the basic CMS functions, i.e., project requirements. These tests were successfully conducted between February and May 1978.

The CMS also supported a series of operational simulation tests conducted by the JPL MCT. These tests, conducted between March and June 1978, exercised CMS capabilities and interfaces using planned mission sequences and timelines. All tests were successfully completed, and the CMS-generated products (loads, maps, and MSOEs) were delivered according to test schedules.

Two minor problems were identified during system tests. These problems were the occasional failures of the CMS/POCC computer-to-computer (electrical) interface and extraneous print characters contained in the command load English descriptor. The transmission problems were not resolved, but presented no operational impact because of a backup tape interface capability. The extraneous print problem was corrected after launch by a minor software patch.

d. Schedule. The Seasat CMS software was delivered in four phases evolving from a skeleton system in April 1977 to a final (full capabilities) system in March 1978. All deliveries were essentially on schedule, and the CMS was considered ready for mission support by 28 March.

As previously stated, a software patch was delivered after launch (August 1978); however, the problem was considered to have no impact on mission operations, and the fix was delayed until after early mission activities.

4. Orbit Determination System

a. Requirements. The responsibilities of the orbital operations personnel were to:

(1) Provide launch and early orbit determination.

(2) Provide operational orbit support.

(a) Provide predicted operational orbit computations with an accuracy of 20 km (11 nm) to project-designated recipients at the end of a 1-week period.

(b) Provide orbital elements to FNOC, JPL, Smithsonian Astrophysical Observatory (SAO), Oakhanger, Shoe Cove, and the user community.

(3) Provide definitive orbit computations with an accuracy of 50 m (164 ft) along-track, 30 m (98 ft) cross-track, and 30 m radial to project-designated recipients.

(4) Process, format, and distribute S-band and laser tracking data.

(5) Provide scheduling aids to project-designated recipients.

b. Implementation. In resolving the above requirements. SIRD and MOP documents were used. ICDs were also established: (1) between Orbit Determinations and the POCC, and (2) between Orbit determinations and the IPD and JPL. In establishing these ICDs, a joint effort was made by the parties involved.

Orbital computations were performed on the IBM 360 computer complex using the existing orbit determination system for other spacecraft. The programming changes required in the system were for generation of range tape required by the project to compute the clock offset.

To meet the previously mentioned accuracies of 50 m, 30 m, and 30 m, the support system used the appropriate force modeling, representation, station geodetics, and physical and environmental parameters. A close working relationship between the orbital operations support group and the networks was maintained to secure the appropriate distribution and amount of observational tracking data. The definitive orbital ephemerides were provided to IPD and Attitude Determination in the form of magnetic tape and in the time frame to meet the 6-day project package data delivery.

Strict procedures were established for quality control on computations of this particular function. Processing of this definitive orbit determination data required the use of the IBM 360 computer on a daily basis for approximately 1.5 h, but, because of the fine individual efforts, this had little impact on other projects.

c. Testing

(1) Observational tracking data from the existing spacecraft (Landsat-1 and GEOS-3) were processed to demonstrate that accuracies of 50 m, 30 m, and 30 m in orbit computation could be achieved. However, this placed the following requirements on the project:

(a) Project to provide 14 passes a day (one each orbit and at least one each station) of S-band Doppler data to orbit operations.

(b) Project to provide seven passes a day, well geographically distributed, of S-band range data to orbit operations.

(2) Predicted range tapes to be provided to the POCC to determine if the tape was properly formatted.

(3) Predicted definitive orbit data to be provided to IPD and JPL.

(4) Telety,· orbital elements to be provided to JPL, FNOC, UKO, and SNF. No testing was required to transmit the orbital elements to SAO and Sunnyvale, as these interfaces were already in use for other spacecraft.

d. Schedules. All schedules were met on time.

5. Attitude Determination System (ADS)

a. Requirements. The ADS support by GSFC consisted of determination of three primary functions under the direction of the attitude computations analyst. For this mission, there were three distinct attitude determination functions: real time, quick-look, and definitive. In satisfying all three requirements, telemetry data from the two Ithaco infrared horizon sensors and the four Adcole sun sensors were the primary method for determining attitude.

The specific requirements were:

(1) Real Time. For each station contact to compute yaw from the satellite sun sensor data, to extract, calibrate, and display pitch and roll, and to compute solar panel tracking error data.

(2) Quick-Look Attitude Determination. To compute whole orbit yaw data as accurately as possible and provide to the satellite analysis team: (a) nine orbits (maximum 30 percent) during the first 2 weeks after launch, and (b) two to four orbits for each orbit maneuver or adjust, with a turnaround time requirement of "near-real time."

(3) Definitive Attitude Determination. To provide continuous pitch, roll, and yaw attitude to 0.17 deg (3 sigma) for each axis, to be generated daily and to span the same satellite data day as the contents of the PMDF.

The Definitive Attitude File (DAF) contained time-tagged attitude data points at a frequency high enough to cause less than 0.02-deg linear interpolation error per axis, but within the period range of 5 to 60 s. The DAF was to be generated in time to meet the overall 6-day project data package.

(4) A secondary ADS requirement was to support the LMSC attitude simulator software programs. These requirements were to obtain the results of whole orbit yaw attitude data in engineering units and run on a general purpose IBM 360 computer.

b. Implementation. Real-time attitude determination was defined as the on-line processing and displaying of attitude parameters as the real-time data were being received from the tracking station. Attitude determination in real time was performed only in the Seasat POCC on the Sigma 5 computer, upon option, using all real-time data received throughout all phases of the mission. In computing attitude, the POCC used only real-time data that had been transmitted from the tracking station using a high-speed data link through NASCOM (Figure 2-8). The POCC stripped and calibrated real-time pitch and roll data directly from the spacecraft, and optionally adjusted each observation by a fixed bias. Following this judgment, the pitch and roll angles were displayed on a CRT display. The yaw angle was computed only when sun sensor data were available, as follows.

Solar ephemeris and predicted spacecraft ephemeris, from an orbit EPHEM tape, was used weekly to generate and store the predicted sun unit vector in the orbital coordinate system on the hour for 1 week. These stored data and the telemetered sun sensor and scanner data were used to compute yaw in the Geocentric Inertial Coordinate (GIC) system at selected intervals upon request. Because this computation was performed asynchronously with the real-time processing, it was done using available cycle time and, consequently, computed and displayed a yaw attitude approximately every 30 s. Out-of-limit conditions for pitch, roll, and yaw were also flagged and displayed on the CRT. The observed minus predicted solar panel tracking angle error were also computed and displayed in real time. It used as input the same stored sun information in the orbit coordinate system as was used for yaw computations, in addition to the solar panel tracking angle from telemetry. The computation of this value was also done in an asynchronous mode using available cycle time. There was no accuracy requirement or commitment for real-time processing of pitch, roll, yaw, and solar panel tracking angles.

Quick-look attitude determination was the processing of whole orbit (playback tape recorder) telemetry data for attitude solutions on an as-soon-as-possible basis (nominally 6 h after receipt at GSFC). Quick-look data were processed using the definitive attitude determination system on one of the IBM S/360-75 (C1), -75 (C2), and -95 (backup) computers, configured as illustrated in Figure 2-9. The processing was done during the first 2 to 4 weeks of the mission to support the attitude control system and orbit adjustment, and subsequently to support orbit trim maneuvers that were expected to occur once a month throughout the mission. During this period, up to four playback passes (100 min each) of selected data a day were sent directly from the station to the IPD. The IPD reversed the telemetry bit stream to chronologically order the data and send it to the POCC via a hand-carried magnetic tape (illustrated by the dashed lines in Figure 2-8). The tape was played through the POCC software between real-time contacts where the attitude-related information was stripped and sent via a 9.6-kb/s analog data link (ADL) to the quick-look processing area. There the data were stored on disks and accessed by the definitive attitude determination software to compute pitch, roll, and yaw when valid sun sensor data were available.

Hard copy plots of pitch, roll, and yaw were hand-carried to the POCC for each playback pass processed, and an attitude results data set was generated on a sharable disk for access by the LMSC parameter estimation program. These programs were used to trim the spacecraft control parameters to maintain the spacecraft attitude within its specified control limits. The attitude plots were also used by the POCC to determine when the switch from gyro control to wheel control could take place following the orbit adjustment and orbit trim maneuvers. A detailed attitude data flow diagram is provided in Figure 2-10.

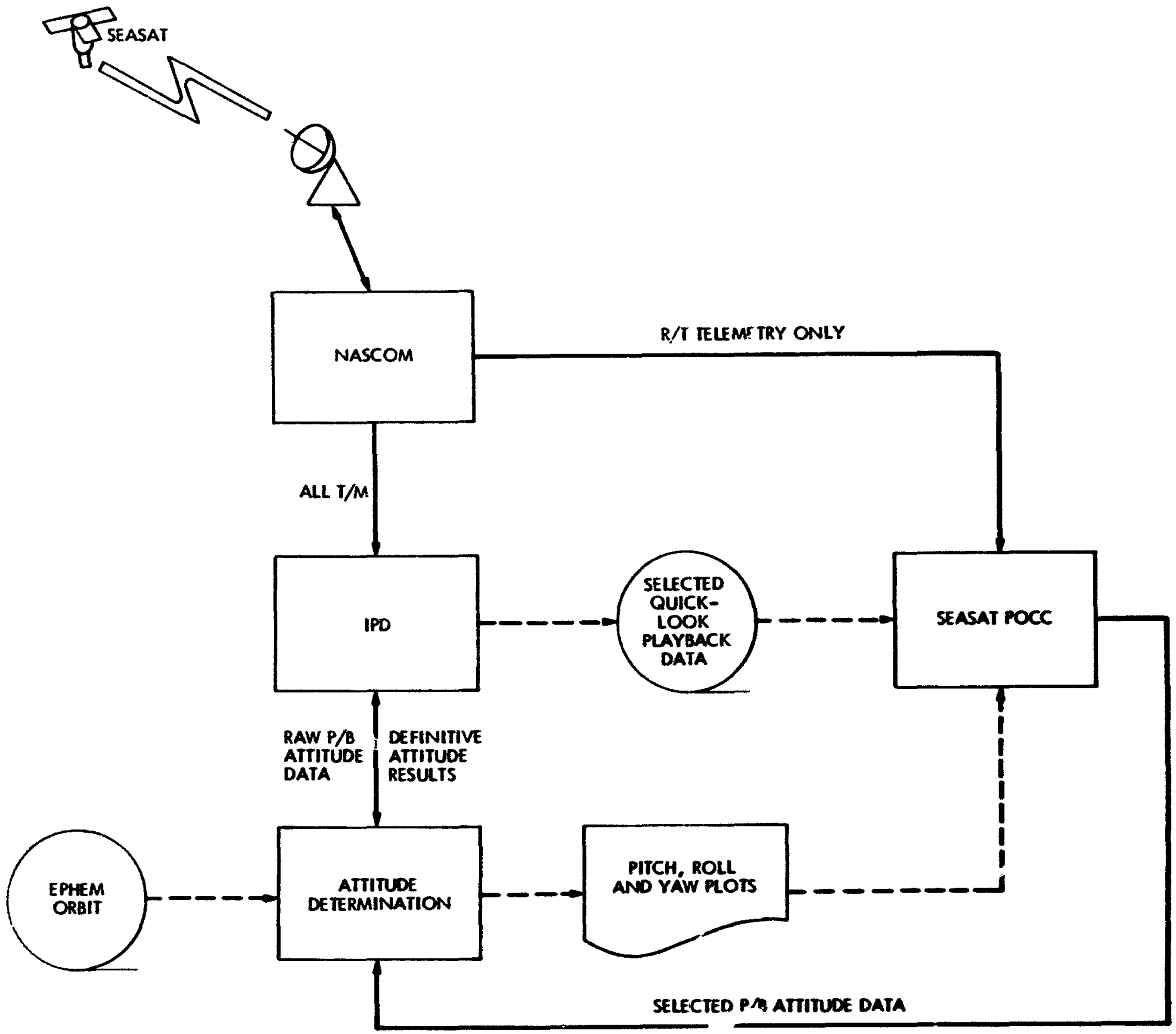


Figure 2-8. GSFC Attitude Determination Data Functional Flow Diagram

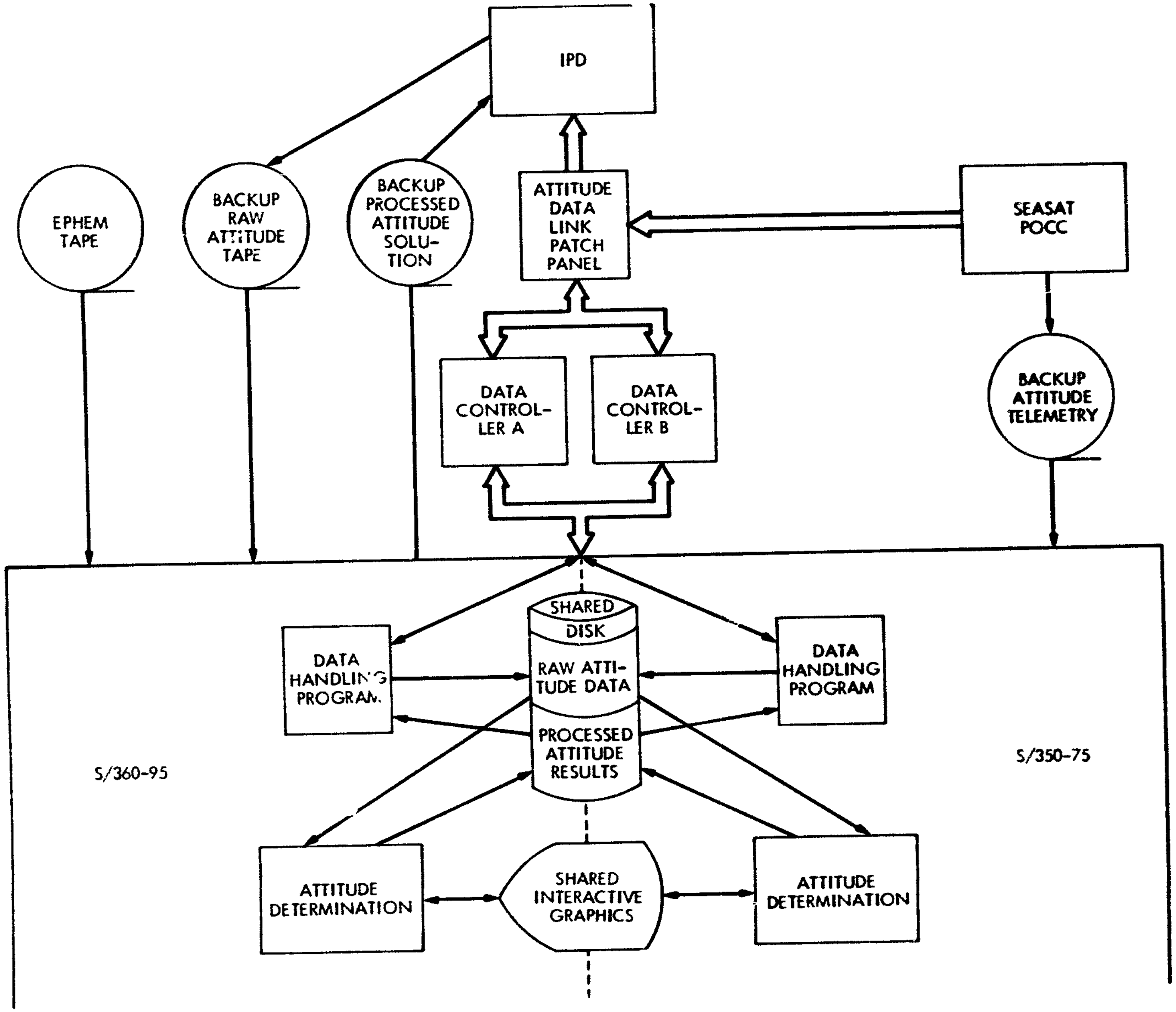


Figure 2-9. Attitude Computation Hardware Configuration

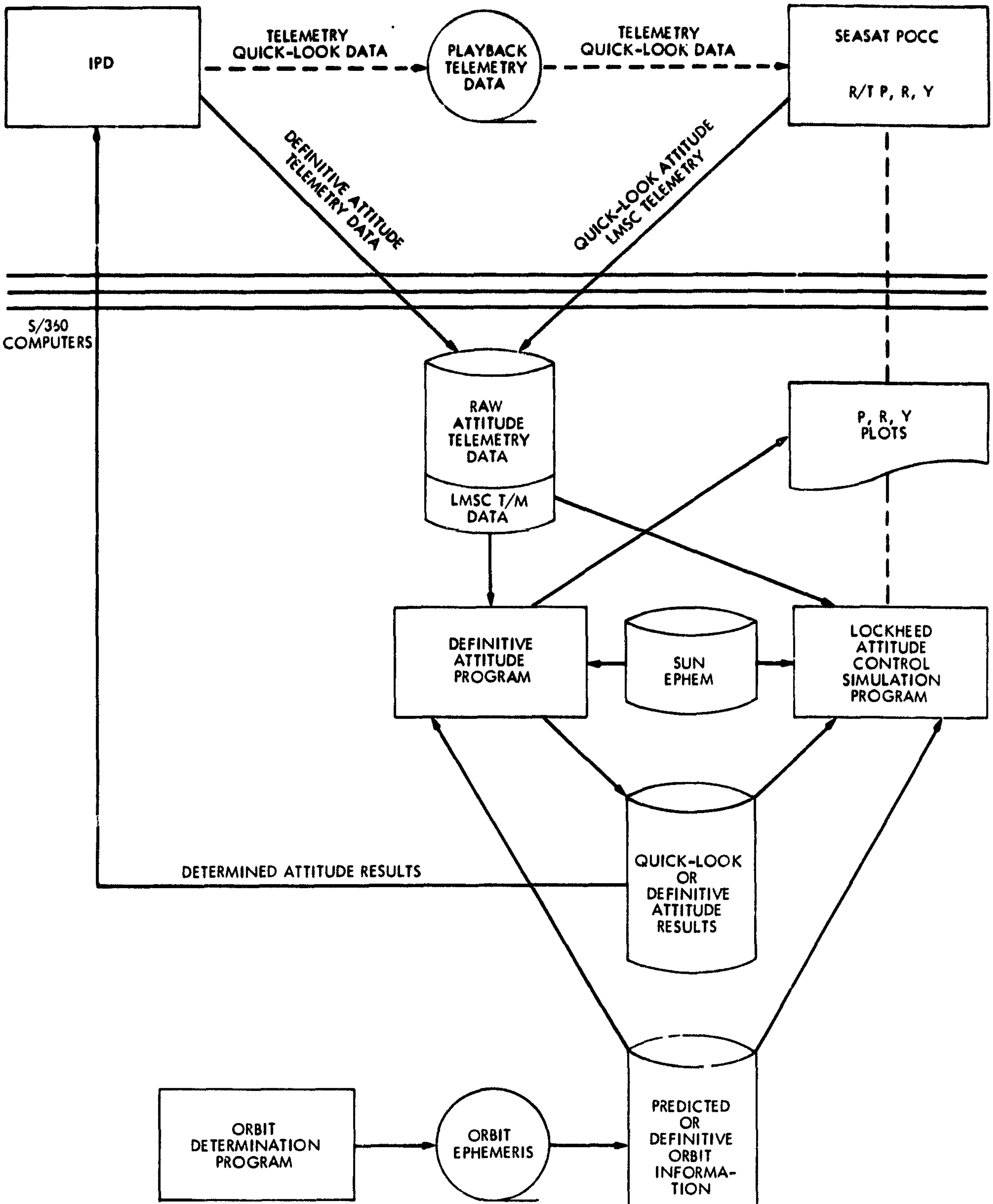


Figure 2-10. GSFC Attitude Data Flow Detail

Definitive attitude determination was defined as after-the-fact processing of attitude telemetry data using a determined (definitive, as opposed to predicted) orbit ephemeris to produce a continuous time history of the spacecraft attitude. For the Seasat mission, definitive attitude processing was accomplished using the IBM S/360-95 computer with the -75 C1 serving as a backup (Figures 2-9 and 2-10). The definitive attitude determination activity was initiated immediately following the spacecraft universal time corrected (UTC) correlation update and was continued for the duration of the mission. All playback and real-time data received at the tracking station were tranmsitted by hard line through NASCOM to the IPD. The IPD then checked the data, created a time history of the telemetry data, and packaged it in 24-h blocks. These data began at 0000 h of spacecraft clock time, which was maintained to within 200 μs of UTC, and ended at 2400 h of spacecraft clock time.

These 24-h blocks minus and plus one orbit of data (100 min, for yaw interpolation only) was sent daily to the definitive attitude processing area. There the data were validated and adjusted for timing, oblateness, and horizon radiance errors. The data were then processed using the sun and definitive orbit ephemerides to compute pitch and roll angles for all times that there were valid telemetry information and yaw angle when valid sun sensor data were available.

Yaw attitude results for all other times were provided by an attitude interpolation and extrapolation algorithm developed by JPL personnel, which was backed up by an algorithm that filled in data with a constant value for yaw. JPL had complete responsibility for providing the values of all parameters that characterized the yaw interpolation algorithm. Attitude data during small telemetry gaps (whose length was dependent on spacecraft attitude rates) were filled in by interpolation with the attitude data smoothing algorithms.

The raw telemetry data package received from the IPD covered 0000 to 2400 h of spacecraft clock time, and the attitude results for the spacecraft were packaged to cover the corresponding UTC. These results were included in the IPD 6-day project data package. A timeline for Seasat definitive attitude data processing is presented in Figure 2-11. Telemetry data and definitive orbit data were normally received in the attitude processing area 2 to 3 days after the data were received at the ground station. Attitude results were usually returned to IPD within 1 to 2 days after the receipt of both the orbit and telemetry data. Any additional data received for a given collection day after the initial data had been processed were treated as a separate entity and were output as an entity.

The goal of the attitude determination processing was 0.17 deg (3σ) for pitch, roll, and yaw. Definitive attitude results were not required during spacecraft orbit adjust periods or when the satellite was being maneuvered to non-nominal attitudes (pitch, roll, or yaw angles greater than 10 deg in magnitude).

Because the satellite hardware operated in a backup mode of attitude control and the configuration changed throughout most of the mission, an estimate of the actual accuracy achieved is not possible.

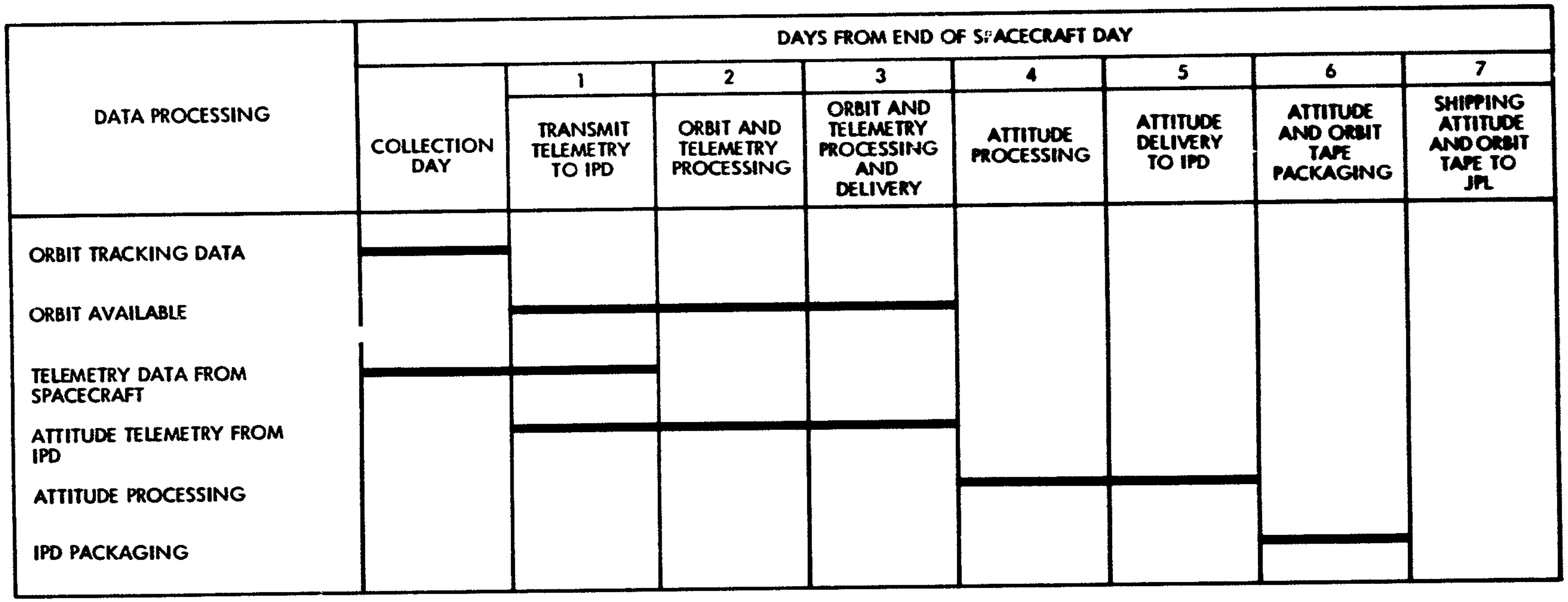


Figure 2-11. Nominal Seasat Data Processing Timeline

c. Tests and Interface Checks. A complete end-to-end attitude test of the ADS was not possible without having actual satellite data available in a flight configuration. Therefore, simulated data streams were generated and their output followed and verified throughout the system. Table 2-7 contains a summary of the tests conducted by the ADS to verify the system. When a problem was encountered, a correction was made and a retest was performed. Additionally, retesting was performed for each new delivery of software within the system.

Table 2-7. Tests and Interface Checks

Real-Time Attitude

Simulated telemetry tape to exercise and compare known results.

(1) Pitch and roll stripping and conversion.

(2) Sun angle stripping, conversion, and calculation.

(3) Check yaw computation.

(4) Check for solar panel tracking angle.

Quick-Look Attitude

(1) Simulated and real telemetry tapes run through POCC software to strip out attitude-related data and send through ADL to MAPS.

(2) Hand-compare dumps of data input and output from POCC and received at ADS.

(3) Compare attitude raw data and results between POCC and MAPS.

(4) Exercise MAPS with attitude data simulator.

(5) Check out backup attitude telemetry data tape.

Definitive Attitude

(1) Check for proper data stripping from IPD for MAPS by hand-using simulated and real telemetry tapes and dumps.

(2) Use dummy attitude results tape for early check of MAPS/IPD/JPL interface.

(3) Exercise MAPS with attitude data simulator to exercise MAPS and MAPS/IPD/JPL interface.

(4) Check out backup attitude telemetry and results magnetic tape to ensure that it is the same as that which comes across link.

d. Schedule. The schedule for the ADS is shown in Figure 2-12. The schedule was implemented as planned or changed as indicated in the notes at the bottom of the figure.

6. Flight Maneuver Operations Center

a. Requirements. The primary responsibility of the GSFC Flight Maneuver Operations Center (FMOC) was to aid the JPL MCT in the prediction, planning, and evaluation of Seasat orbit maneuvers. Specifically, the requirements were to:

(1) Evaluate the post-injection orbit and plan maneuvers to remove injection errors.

(2) Perform the post-maneuver analysis required to calibrate the onboard thruster system.

(3) Provide maneuver requirements predictions based on an analysis of the ground trace history.

(4) Design maneuver events (thrust magnitude and times) to achieve the desired target parameters.

b. Implementation. No major problems were encountered in FMOC implementation (Figure 2-13). Considerable pre-launch coordination was conducted in planning meetings attended by mission personnel from JPL, GSFC, and LMSC. Maneuver interfaces were defined, and a timeline was developed for maneuver planning, execution, and evaluation. The FMOC software developed for Seasat comprised an evolutionary maneuver model augmented with Seasat-peculiar physical and performance data. Vehicle information was provided by LMSC, and software development was performed under contract to GSFC by Computer Sciences Corporation.

c. Testing. FMOC system acceptance tests (functional proof tests) were successfully conducted between November 1977 and February 1978. The FMOC also participated in four maneuver simulations between April and June 1978. Each of these simulations assumed a set of current as opposed to desired orbit conditions. The maneuvers were then designed, executed, and evaluated according to the mission procedures and timeline. The simulations proved to be beneficial, and maneuver responsibilities and interfaces were well defined.

d. Schedule. System development, test, and integration progressed according to schedule and the FMOC was ready for mission support by 1 May 1978.

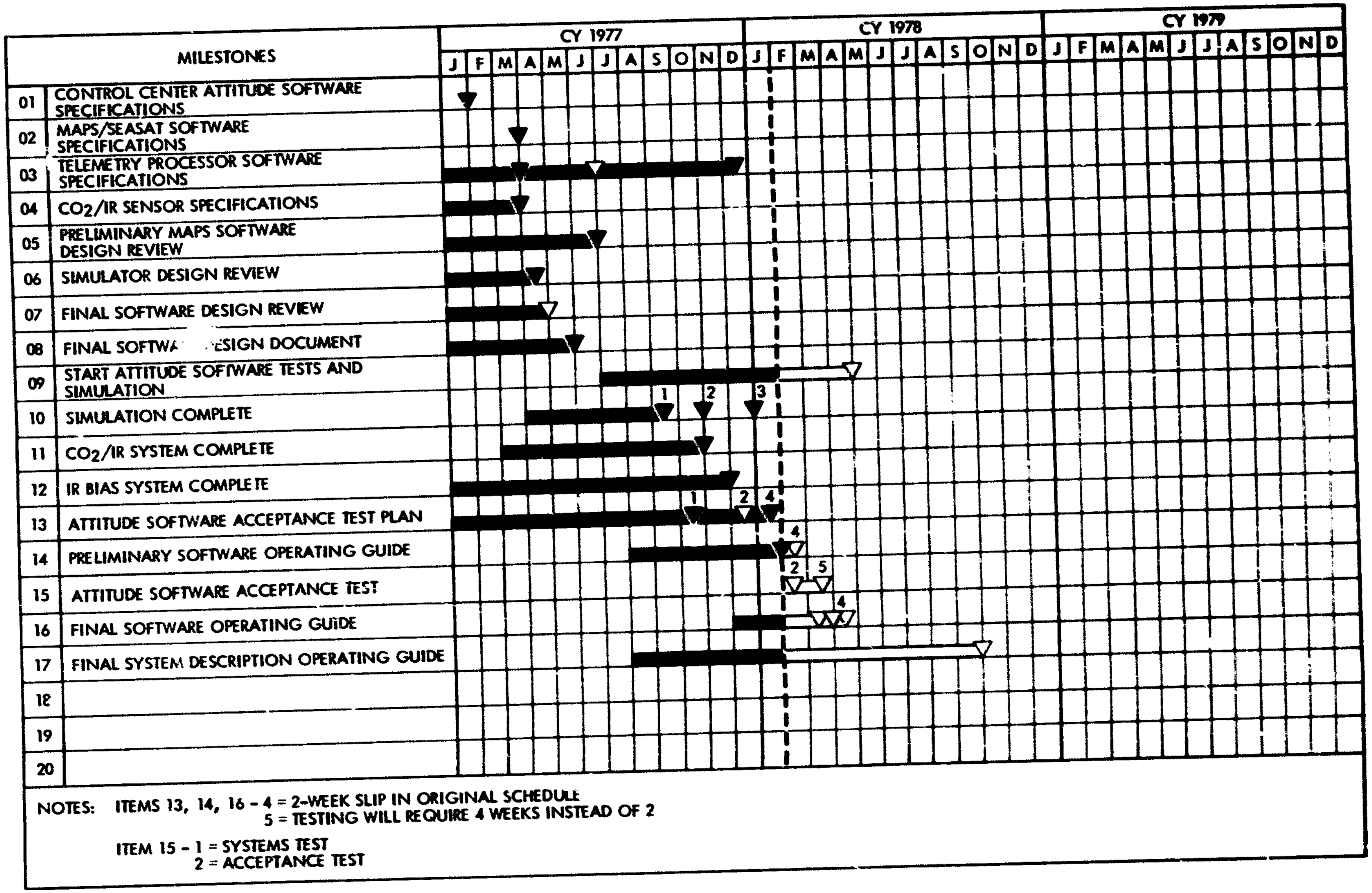


Figure 2-12. Seasat Attitude Support Milestone Schedule

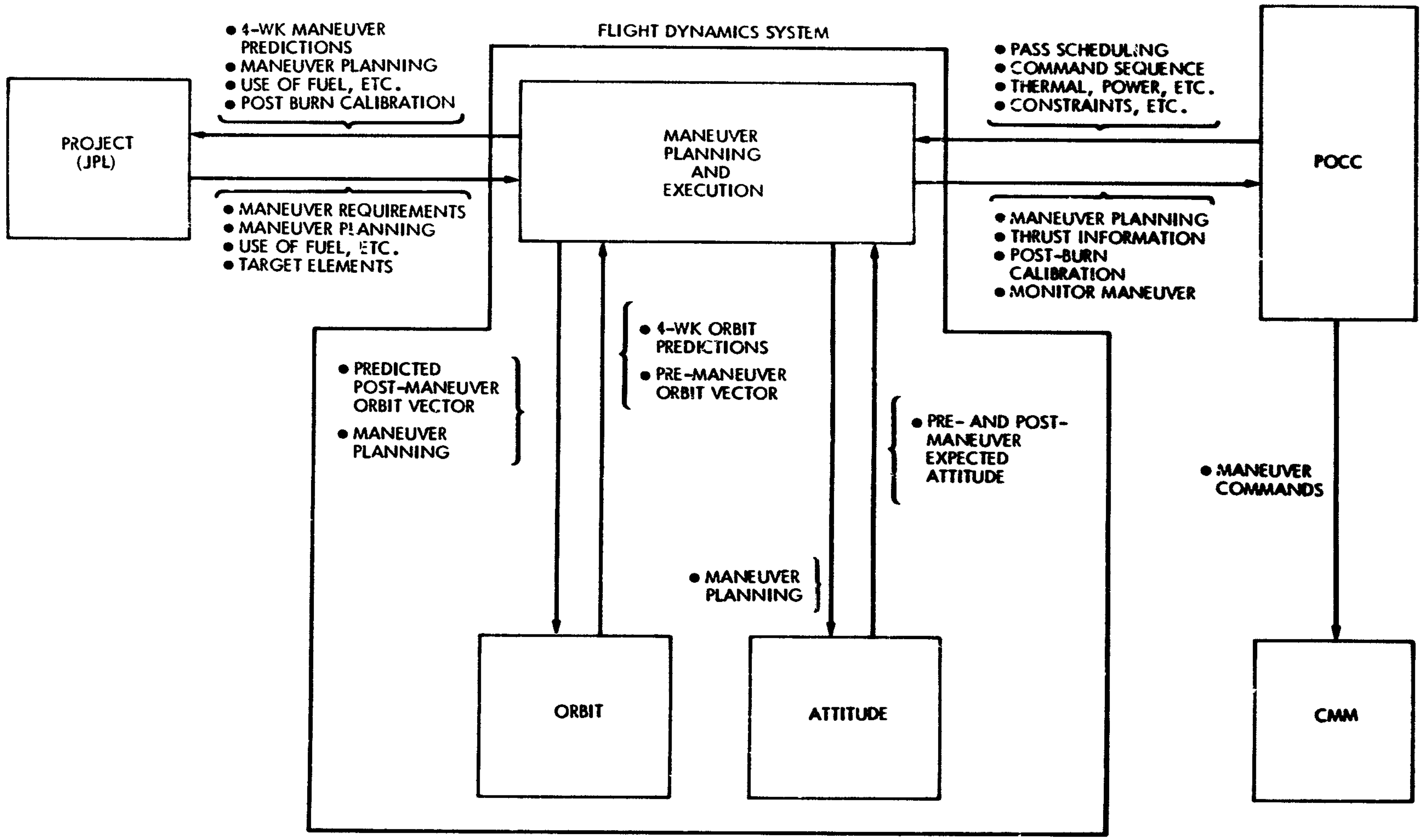


Figure 2-13. FMOC Implementation Plan

7. Telemetry On-Line Processing System/IPD

a. Requirements. Specific requirements for the Telemetry On-Line Processing System (TELOPS) and the IPD were to:

(1) Reverse the reversed playback telemetry data.

(2) Remove overlap from the playback data.

(3) Process data on a 1-day (24-h) basis.

(4) Generate Project Master Data File (PMDF).

(5) Generate Data Accountability Log (DAL).

(6) Strip attitude parameters from the PMDF and transmit to the attitude computation center.

(7) Strip housekeeping data from PMDF for use by the POCC.

(8) Receive attitude (ATT), orbit (ORB), and command (CMD) data from the respective organizations at the GSFC for inclusion in the Project Data Package (PDP).

(9) Concatenate ATT and ORB data on a single tape.

(a) Ensure that the attitude/orbit (A/O) tape contained an ATT and ORB file.

(b) Tape check the A/O tape and generate a shipping letter.

(10) Assemble and forward the PDP containing PMDF, ORB, ATT, and CMD data to JPL.

(11) Ensure that tapes shipped to other users were copies of tapes shipped to JPL.

(12) Archive only PMDF (playback telemetry data).

(13) Ensure quick turnaround of quick-look data (one to two revolutions a day for the first 2 weeks after launch, then about once a month during orbit trim maneuvers and during low power periods). IPD to provide data to the POCC within 4 to 6 h of receipt at TELOPS.

There was no requirement to process real-time data.

b. Implementation. The overall playback data flow for Seasat is shown in Figure 2-14. Data were nominally processed in the production mode and, during launch and spacecraft critical periods, in the quick-look mode for the POCC. The

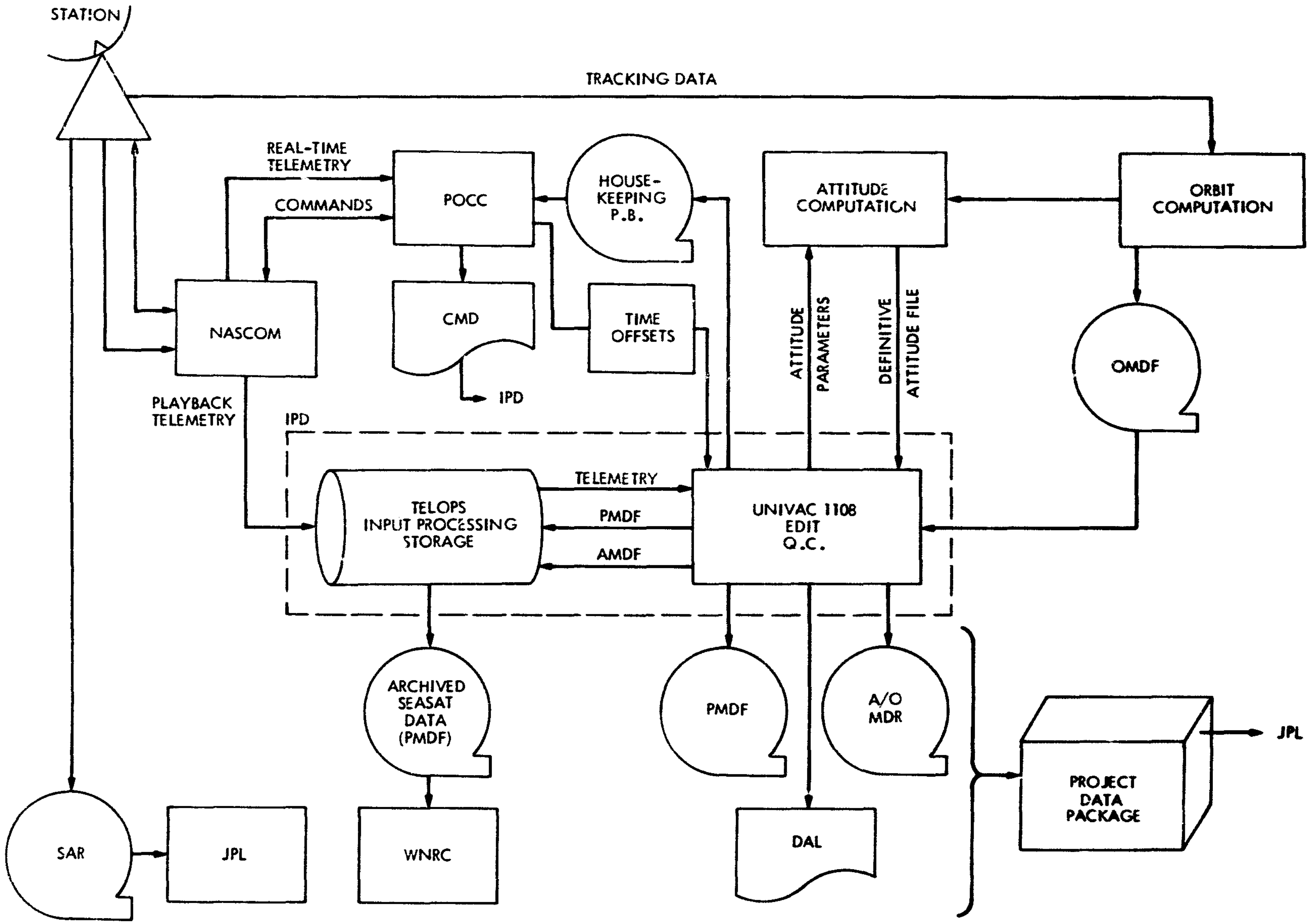


Figure 2-14. Overall Playback Data Flow

quick-look mode was the rapid turnaround of data processed through the production cycle and provided to the POCC on a magnetic tape.

Production data processing used Seasat telemetry data acquired at the STDNs. IPD provided the project with the complete coverage telemetry after receiving and processing the data from the STDNs.

An A/O tape was also generated for each day of data processed. Attitude data were received from ADS through the data communications link between the Univac 1108 and IBM 360 computers. Orbit data were received by IPD on digital magnetic tape from the operational orbit support branch. Attitude data occupied the first file of A/O tape, and the orbit data occupied the second file. A computer printout containing spacecraft command data was also provided to IPD by the Seasat POCC. These three sets of data were packaged and shipped to JPL for additional processing by the Seasat Project.

The Input Processor (IP) in the TELOPS environment was the IBM 370 computer. The IP received the telemetry data through NASCOM, appended transmission quality flags to each pass message, reversed the playback data, and performed data quality checks. These data were then stored in a mass storage system in the order the data were recorded from the spacecraft.

The operations team in this area consisted of four people. They provided 24-h, 7-day-a-week coverage. Four 6250 b/in. capability tape drives were added to the existing system, primarily due to the high rate Seasat telemetry, though not exclusively for Seasat.

A spacecraft-unique software routine was developed for processing Seasat data. The telemetry data were edited by the Telemetry Data Processing System (TDPS), a program on the Univac 1108 computer. The TDPS edited the playback data from the TELOPS mass storage system.

Prior to launch, two tape drives with 6250-b/in. capabilities were added to the existing system. This, again was not exclusively for Seasat, but because of the high-rate Seasat telemetry data. There were no special software developments for the Seasat mission.

c. Testing. The major problem in testing the system was the lack of actual spacecraft data. Various interfaces were tested using the only available 34-min data, which were recorded during the compatibility test. The following is a list of the interfaces that were checked:

(1) IPD/Network

(a) 56 kb/s.

(b) 112 kb/s.

(c) 224 kb/s.

(d) 1.344 Mb/s.

(2) IPD/POCC.

(a) High-speed keying (HSK) tape to POCC.

(b) Command listing from POCC.

(c) Time offsets from POCC.

(3) IPD/Attitude.

(a) Raw ATT to MSC&AD.

(b) Definitive ATT from MSC&AD.

(4) IPD/Orbit: 24-h orbit tape from OSCD.

(5) IPD/JPL.

(a) PMDF.

(b) DAL.

(c) A/O tape.

(d) Command listing.

d. Schedules. Although most of the schedules were slipped, every item was completed by 26 May 1978 as mentioned in the launch review.

8. NASA Communications Network

The NASCOM provides all NASA mission control and network control centers with real-time operational communications to launch sites and remote tracking, data acquisition, and command stations. These communications are for pre-mission spacecraft launch checkout, mission and network simulations, operational support of launch, and Earth-orbital phases of missions.

The NASCOM is an operational global communications system of diversely routed voice, low-speed data (teletype), and high-speed and wideband data communications channels, with switch and technical control facilities linking approximately 100 terminal stations. The NASCOM circuits are full-period channels, leased from various domestic and foreign common carriers on a worldwide basis. A variety of telegraph, voice, data (analog and digital, with a range of digital data rates), and television (TV) services are provided. For mission-unique requirements, temporary circuits are sometimes used to meet short-term requirements.

a. Requirements. The mission-unique requirements were to:

(1) Upgrade the 56-kb/s data circuits to the stations.

(2) Provide a 1.544-Mb/s data circuit between ULA, FNOC, and GSFC.

(3) Supply multiple 56-kb/s data circuits between MAD-GSFC.

(4) Supply a 224-kb/s data circuit between MIL-GSFC and GSFC-FNOC.

(5) Supply a new 3760 computerized message switcher at GSFC, block error decoders (BEDs) at JPL and FNOC, and new contractor Earth stations at MIL and GSFC to support the 224-kb/s data circuits. These requirements are shown in Figure 2-15.

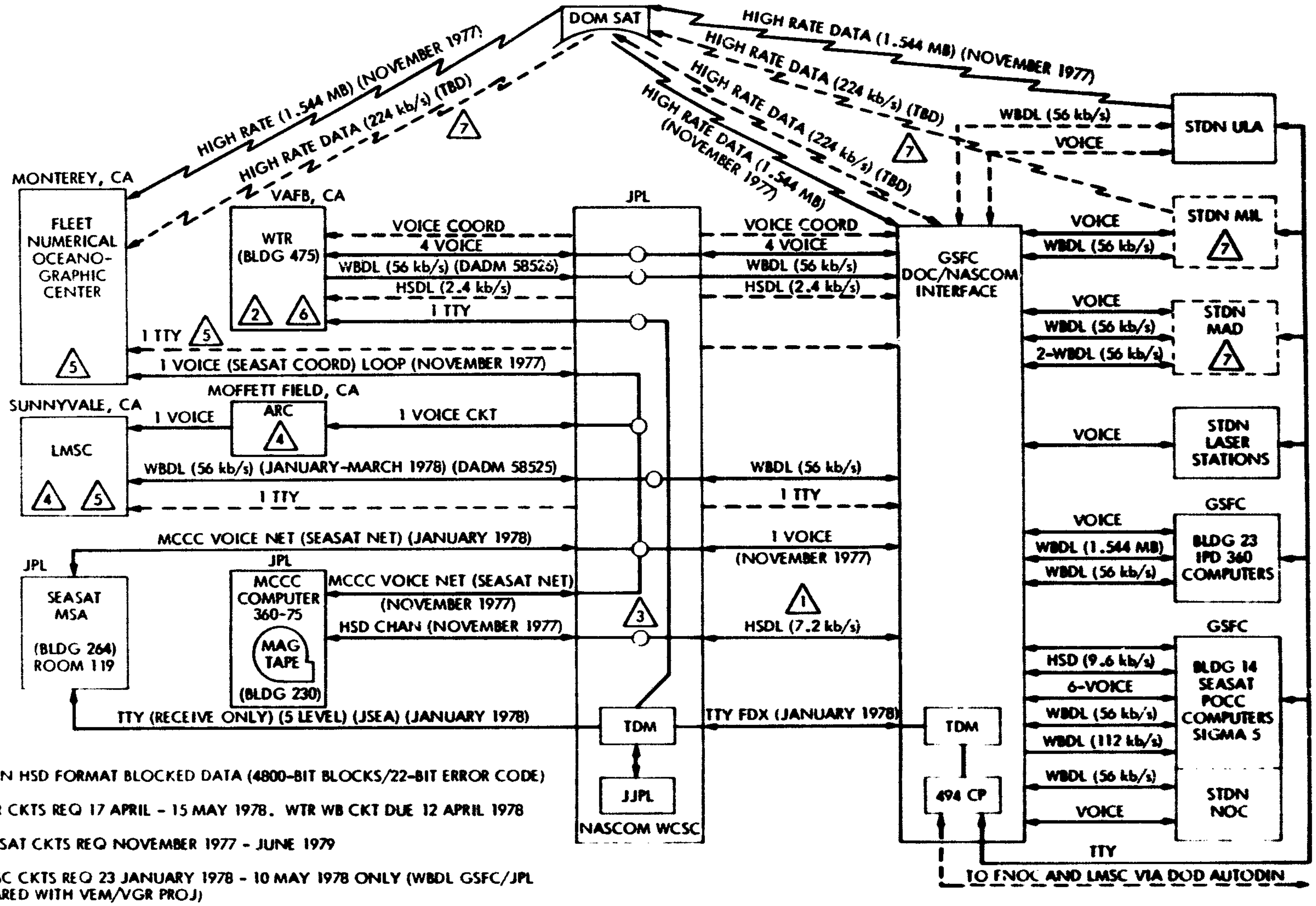
b. Implementation. The requirements were implemented on schedule, as follows:

(1) A simplex 1.544-Mb/s wideband data service was provided from ULA with a simultaneous transmit capability to FNOC and to GSFC. This system was used to transmit the 800-kb/s playback telemetry data to FNOC and to GSFC IPD/TELOPS and the 25-kb/s real-time telemetry data to the Seasat POCC at GSFC.

(2) The Department of Defense (DoD) recuired the FNOC to receive spacecraft playback data that was downlinked at a station other than ULA. This was accomplished, when scheduling permitted, by using a 224-kb/s service between MIL and GSFC, and another 224-kb/s service between GSFC and FNOC. This playback data transmission was speed-reduced to fit the circuit, and the data blocks were message-switched at GSFC to FNOC. Two 56-kb/s wideband data circuits were linked together from MAD to GSFC to provide a 112-kb/s capability. The playback data transmission was also speed-reduced to fit the circuit, and the data blocks were message-switched at GSFC and transmitted to FNOC over the 224-kb/s wideband data circuit.

(3) An existing 7.2-kb/s circuit was used to transmit spacecraft command-related data from the JPL Mission Support Area (MSA) to the Seasat POCC at GSFC. These data were retransmitted to the GFSC CMS on a local GSFC 9.6-kb/s circuit for the production of a Mission Sequence of Events (MSOE). The MSOE was transmitted by a 9.6-kb/s circuit to the Seasat POCC for subsequent retransmission to the JPL MSA via a 7.2-kb/s circuit.

(4) The spacecraft checkout tests at LMSC were supported by a 56-kb/s wideband circuit (full duplex) routed via JPL to GSFC. This circuit was used to transmit commands from the Seasat POCC at GSFC to the Seasat spacecraft, and to transmit spacecraft data to the POCC. A voice circuit was also provided for coordination purposes. Playback data (800 kb/s) were transmitted at a reduced rate from LMSC to the GSFC IPD/TELOPS.



NOTES:

1. STDN HSD FORMAT BLOCKED DATA (4800-BIT BLOCKS/22-BIT ERROR CODE)
2. WTR CKTS REQ 17 APRIL - 15 MAY 1978. WTR WB CKT DUE 12 APRIL 1978
3. SEASAT CKTS REQ NOVEMBER 1977 - JUNE 1979
4. LMSC CKTS REQ 23 JANUARY 1978 - 10 MAY 1978 ONLY (WBDL GSFC/JPL SHARED WITH VEM/VGR PROJ)
5. TTY ADMIN MSG TO FNOC AND LMSC VIA GSRM/DOD REFILE
6. 1-VOICE COORD, HSDL (2.4 kb/s) AND 4-VOICE CKTS - PROJ MGR COORD LOOP, DATA COORD LOOP, LAUNCH STATUS LOOP, SPAT COORD LOOP DUE MARCH 1978
7. DOD SUPPORT APPROVED BY NASA MIL/GSFC, GSFC/FNOC 224 kb/s WB CKT AND 2-56 kb/s MAD-GSFC WB CKTS DUE DATE (TBD)

Figure 2-15. Seasat Communications Support Requirements Via NASCOM

(5) A simplex 50-kb/s wideband circuit routed via JPL to GSFC was provided to transmit spacecraft and Agena data from the Space and Missile Test Center (SAMTEC) Western Test Range to the Seasat POCC at GSFC. Existing high-speed data, voice, and teletype circuits were used to provide the necessary launch support.

(6) The wideband systems digital facilities were implemented in a variety of ways, depending on locations, overseas considerations, and the carriers concerned. Overseas channels were implemented via communication satellite systems that included Earth stations of the foreign and domestic Intelsat. Foreign end-segments were implemented using terrestrial and domestic satellite facilities of the Bell System and other specialized communication carriers.

c. Tests. Three types of tests are usually performed on NASCOM equipment. The supporting contractors from whom NASA leases the circuits are responsible for conducting tests before NASA acceptance. These test data are then reverified to the extent necessary by NASCOM engineers. Operational testing is then performed in conjunction with the POCC and STDN testing program to ensure that configurations and equipment performed with actual data as required.

d. Schedule. The schedule is shown in Figures 2-16 and 2-17.

9. Space Flight Tracking and Data Network

GSFC Networks Directorate support to the Seasat Program began in calendar year (CY) 1973 during Phase A studies for a Seasat mission as part of NASA's Earth and Ocean Applications Program. Support continued through an implementation period from approximately November 1975 to April 1978, and was concluded in the fourth quarter of 1978. Support ended as a result of a spacecraft power system failure approximately 3-1/2 months after launch. Included in the following paragraphs are descriptions of STDN support throughout the three periods, emphasizing new and applied capabilities developed for Seasat mission support.

a. Study Phase. The network input to this phase of the program consisted of providing STDN cost estimates and expected capabilities, station locations, antenna characteristics, communications performance data, etc., to the project organization preparing trade-off studies, and ultimately the Mission Specification document. Following contract award (fourth quarter of CY 75), fact-finding activities were supported to ensure that the satellite systems would be compatible with the STDN, for conventional tracking, telemetry, and command functions and for design of the SAR telemetry and ground support systems (which required significant development work).

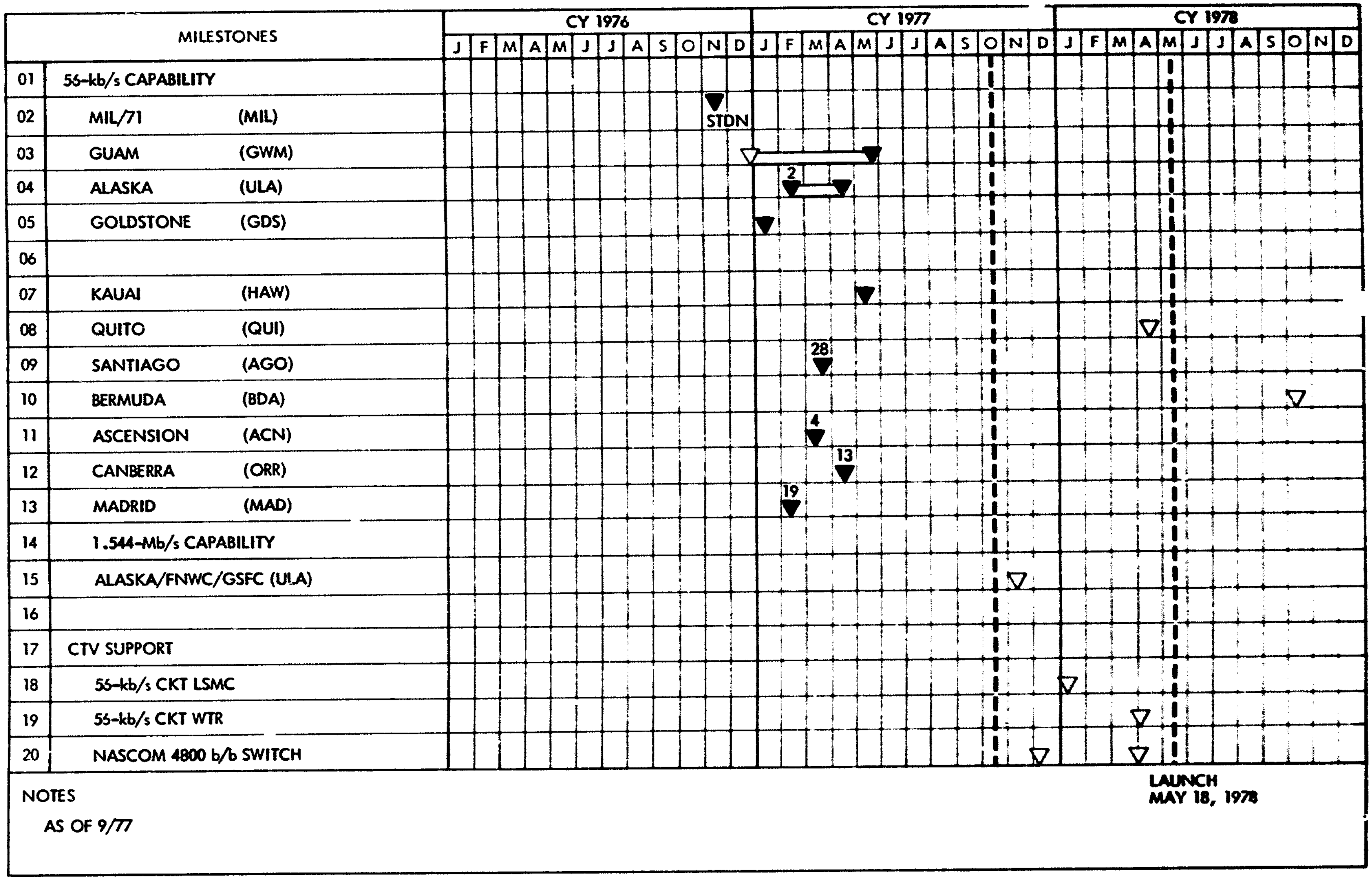


Figure 2-16. NASCOM Wideband Support

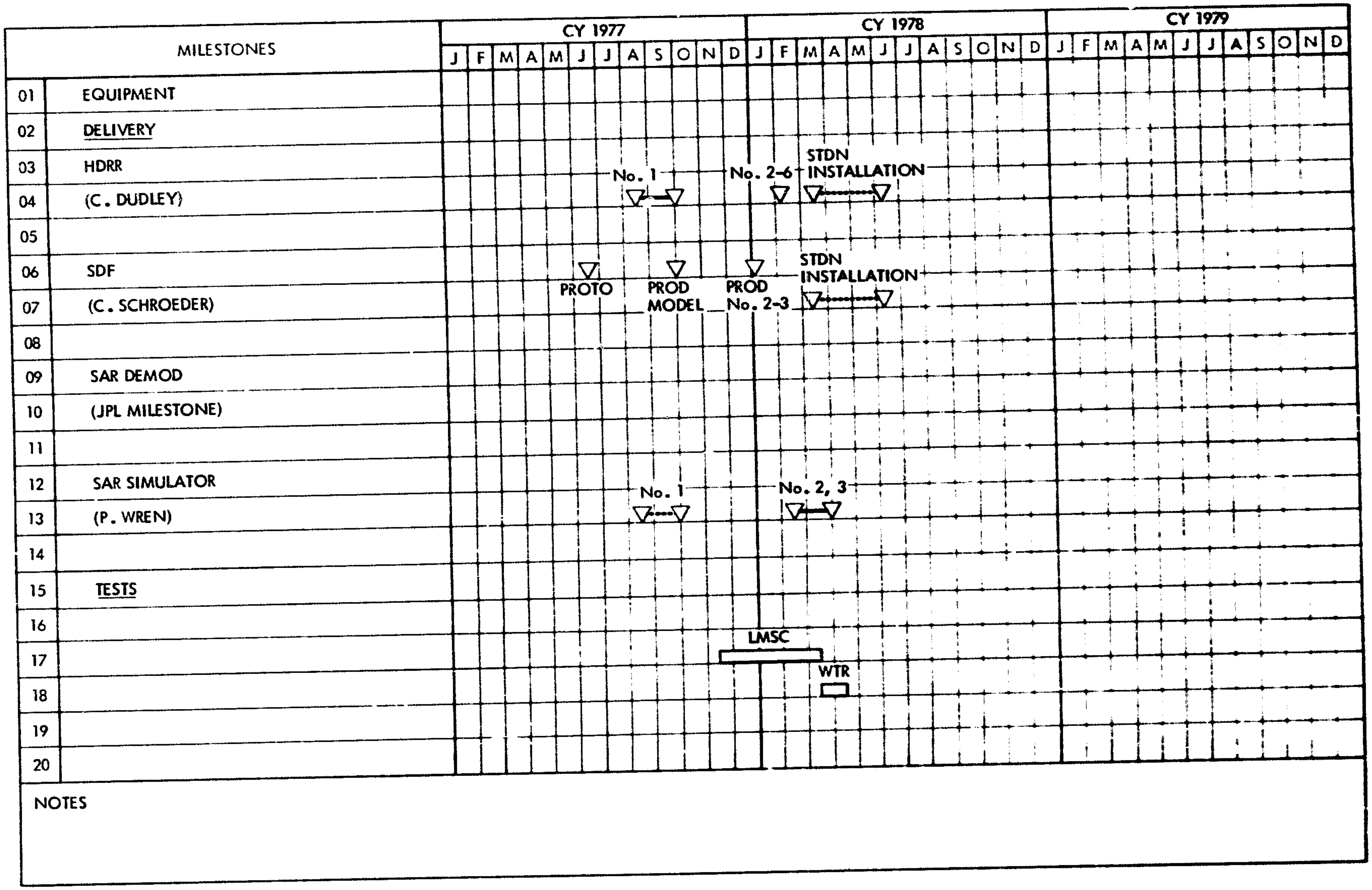


Figure 2-17. SAR Support Implementation Schedule

b. <u>Implementation Phase</u>. STDN support during the implementation phase is described in the following paragraphs on a data and support system basis.

<u>Command System</u>. During the period from the fourth quarter of CY 75 to the second quarter of CY 76, the project determined that the "standard" command detector unit (14-kHz subcarrier, PCM/FSK-AM/PM), also planned to be flown on the SAGE and ISEE missions, was confirmed to be compatible by design, and was selected by the project to be flown on the Seasat mission. Design link calculations were confirmed by the network to be compatible. The STDN implementation for providing command system support and pre-launch test support periods are shown in Figure 2-18.

The only command system implementation problem disclosed by pre-mission testing systems review was a demonstrated inability of station SAR telemetry control equipment to account for the time-of-day crossover for pass loads containing equipment settings for acquisition of signal (AOS) during 1 day of the year and loss of signal (LOS) on a succeeding day of the year. A one-wire modification to the SAR station equipment (which, incidentally, removed time regression error compensation circuits in a pass load) corrected the problem.

The STDN command software was initially developed in August 1977 with anticipated use during a planned October 1977 spacecraft/network radio frequency (RF) compatibility test. The test slipped to November 1977 and had to be aborted because of spacecraft system problems. Tables 2-8 and 2-9 are listings of software support instructions (SSI) issued during the Seasat support period.

Table 2-8. STDN Software Support Instructions (SSI) Issued During Seasat Support Period

SSI	TTY Date/Time Month Year	MSFTP 2 Simulator TESOC 557 S		MSFTP-3 Decomm TESOC 590 MD		MSFTP-3 TESOC 557 MD		MSFTP-3 TESOC 557.1 MD		481DF (A) TESOC 557 DG		481DF (A) TESOC 2004.1 SC	
		Level	Errata	Level	Errata	Level	Errata	Level	Errata	Level	Errata	Level	Errata
061	23/2320Z Aug 1978							(B) Mil. only					
062	10/1520Z Sep 1978												
063	08/1056Z Sep 1978												
064	24/0026Z Oct 1978												
065	28/0451Z Oct 1978			(B)		(A)		(B)					

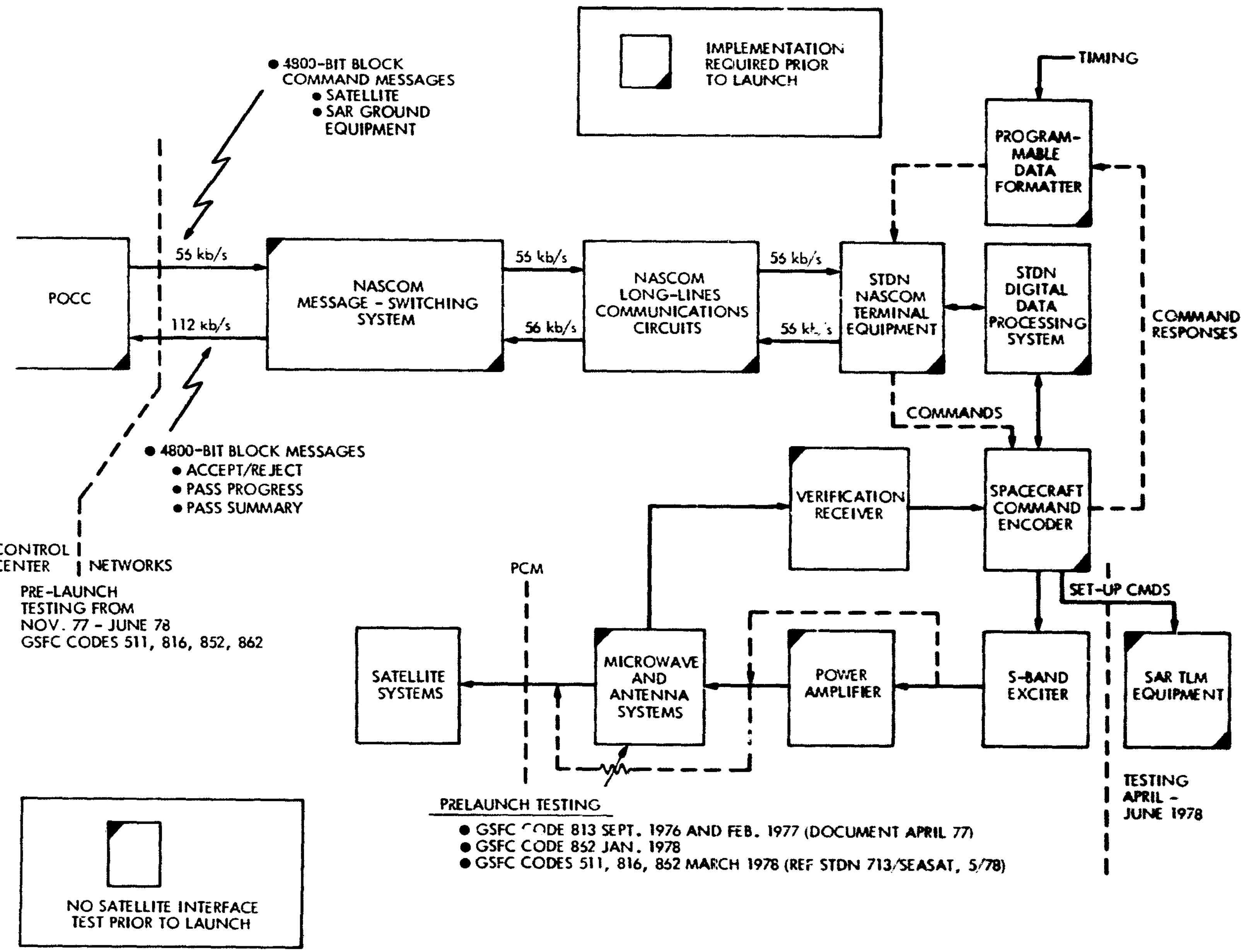


Figure 2-18. STDN Command System Support for Seasat

Table 2-9. STDN Telemetry Processing Software Support Instructions (SSI) Issued During Seasat Support Period

SSI	TTY Date/Time Month Year (GCEN)	Digital Data Processing System									
		Program 2		Program 3							
		642 SIC 9999-(L) SCAN 6-700.1		642 (CP) SIC 9999-(L)CP SCAN 6-703		PDP-11 SIC 9999-(L)DP SCAN 11-703		PDP-11 SIC 9999-(L)TP SCAN 11-703		PDP-11 SIC 9999-(L)FP SCAN 11-703	
		Level	Errata	Level	Errata	Level	Errata	Level	Errata	Level	Errata
050	10/2303Z Jan 78	-	-	-	-	-	-	-	-	-	-
051	20/1811Z Jan 78	-	-	-	-	-	-	-	-	-	-
052	08/1930Z Feb 78	-	-	-	-	-	-	-	-	-	-
053	23/2155Z Feb 78	ϕ-DD (Testing Only)	ϕ14-ϕ19	-	-	-	-	-	-	-	-
054	06/2313Z Apr 78	ϕ-DD (Testing Only)	14-19, 22, 23, 99	-	-	-	-	-	-	-	-
055	07/1955Z Apr 78	ϕ-DD (Testing Only)	14-19, 22, 23, 99	-	-	-	-	-	-	-	-
056	19/1520Z Apr 78	ϕ-DD (Testing Only) (HCCM Ops Spt) ϕ-DE (Seasat Test Spt)	14-19, 22, 23, 99 -	-	-	-	-	-	-	-	-
057	02/1841Z May 78	ϕ-DD (HCCM Ops Spt) ϕ-DE (Seasat Test Spt)	14-19, 22, 23, 99 -	-	-	-	-	-	-	-	-
058	11/1525Z May 78	ϕ-DD (HCCM Ops Spt) ϕ-DE (Seasat Test Spt)	14-19, 22, 23, 99 001 (Centaur)	-	-	-	-	-	-	-	-

Table 2-9. STDN Telemetry Processing Software Support Instructions (SSI) Issued During Seasat Support Period (Continuation 1)

SSI	TTY Date/Time Month Year (GCEN)	Digital Data Processing System: Program 2: 642 SIC 9999-(L) SCAN 6-700.1 Level	Errata	Program 3: 642 (CP) SIC 9999-(L)CP SCAN 6-703 Level	Errata	PDP-11 SIC 9999-(L)DP SCAN 11-703 Level	Errata	PDP-11 SIC 9999-(L)TP SCAN 11-703 Level	Errata	PDP-11 SIC 9999-(L)FP SCAN 11-703 Level	Errata
059	18/0626 May 78	ϕ-DD	14-19, 22, 23, 99								
		(HCMM Ops Spt)									
		ϕ-DE	001								
		(Seasat Test Spt)									
060	26/1115Z May 78	ϕ-DD	14-19, 22, 23, 99								
		(HCMM Ops Spt)		ϕ	None	ϕ6	None				
		ϕ-DE	001	(Seasat ULA Test Spt)							
		(Seasat Test Spt)									
061	02/0117Z May 78	ϕ-DD	14-19, 22, 23 99								
		(HCMM Ops Spt)		ϕ	None	ϕ6	None				
		ϕ-DE	001	(Seasat ULA Test Spt)							
		(Seasat Test Spt)									
062	08/0407Z Jun 78	ϕ-DE	1-6	ϕ	None	ϕ6	None				
		(Seasat Test Spt)		(Seasat ULA Test Spt)							
063	12/0115Z Jul 78	ϕ-DE	1-7 MIL: 1-7,9	ϕ	None	06DP	04	06TP	13, 80, 81	06FP	00
		(Seasat Ops Spt)		← Seasat Test Spt →							
064	25/2216Z Jul 78	ϕ-DE	1-7 MIL: 1-7,9	ϕ	None	06DP	04	06TP	13, 80, 81	06FP	00
		(Seasat Ops Spt)		← Seasat Test Spt →							

Table 2-9. STDN Telemetry Processing Software Support Instructions (SSI) Issued During Seasat Support Period (Continuation 2)

SSI	TTY Date/Time Month Year (GCEN)	Digital Data Processing System: Program 2: 642 SIC 9999-(L) SCAN 6-700.1		Program 3: 642 (CP) SIC 9999-(L)CP SCAN 6-703		PDP-11 SIC 9999-(L)DP SCAN 11-703		PDP-11 SIC 9999-(L)TP SCAN 11-703		PDP-11 SIC 9999-(L)FP SCAN 11-703	
		Level	Errata	Level	Errata	Level	Errata	Level	Errata	Level	Errata
065	12/0258Z Aug 78	ϕ-DE	1-7 MIL ETC: 1-7,9	ϕ	None	06DP	04	06TP	13, 80, 81	06FP	00
		(Seasat Ops Spt)		← Seasat Ops Spt →							
	12/0258Z Aug 78			1-CP	None	* 07DP	-	* 07DP	-	07DP	-
				← Seasat Eng & Data Flow Test Spt →							
066	24/0001Z Aug 78	ϕ-DE	1-7 MIL ETC: 1-7,9	1CP	Manual Patch for Nimbus	* 07DP	-	* 07DP	-	07DP	-
			Errata 9 is for 224 KBS COMM1/F			*		*			
067	24/1445Z Aug 78	ϕ-DE	1-7 MIL ETC: 1-7,9	1CP	Manual Patch for Nimbus	07DP	-	07TP	-	07FP	-
			Errata 9 is for 224 KBS COMM1/F			*		*		*	
068	02/1043Z Sep 78	ϕ-DE	1-7,9	1CP	32-34	07DP *	-	07TP *	-	07FP *	-

*Although identified as level 7 in SSI's 65-69, the program was actually a debugged and reissued level 6

Table 2-9. STDN Telemetry Processing Software Support Instructions (SSI) Issued During Seasat Support Period (Continuation 3)

SSI	TTY Date/Time Month Year (GCEN)	Digital Data Processing System									
		Program 2		Program 3							
		642 SIC 9999-(L) SCAN 6-700.1		642 (CP) SIC 9999-(L)CP SCAN 5-703		PDP-11 SIC 9999-(L)DP SCAN 11-703		PDP-11 SIC 9999-(L)TP SCAN 11-703		PDP-11 SIC 9999-(L)FP SCAN 11-703	
		Level	Errata	Level	Errata	Level	Errata	Level	Errata	Level	Errata
069	05/1752Z Sep 78	ϕ-DE	1-7,9	1CP	32, 33, 34 Manual Patch for Nimbus	07DP *	-	07TP *	-	07FP *	-
070	08/0050Z Sep 78	ϕ-DE	1-7,9	1CP	32, 33, 34 Manual Patch for Nimbus	06DP	-	06TP	24-29	06FP	-
071	29/0038Z Sep 78	ϕ-DE	1-7,9, 11, 12, 17, 18, 19, 21, 24 (-10 Head B Test Gos)	1CP	32-34	06DP	-	06TP	24-29	06TP	
072	14/0013Z Oct 78	ϕ-DE	1-7, 9, 11, 12, 17, 18, 19, 21, 24 (-10 Head B Test Gos)	1CP	32-34	06DP	-	06TP	24-29	06FP	-

*Although identified as level 7 in SSI's 65-69, the program was actually a debugged and reissued level 6

Table 2-9. STDN Telemetry Processing Software Support Instructions (SSI) Issued During Seasat Support Period (Continuation 4)

SSI	TTY Date/Time Month Year (GCEN)	Digital Data Processing System									
		Program 2		Program 3							
		642 SIC 9999-(L) SCAN 6-700.1		642 (CP) SIC 9999-(L)CP SCAN 6-703		PDP-11 SIC 9999-(L)DP SCAN 11-703		PDP-11 SIC 9999-(L)TP SCAN 11-703		PDP-11 SIC 9999-(L)FP SCAN 11-703	
		Level	Errata	Level	Errata	Level	Errata	Level	Errata	Level	Errata
073	01/1856Z Nov 78	ϕ-DE	1-7, 9-12, 17-19, 21, 24, 32 (35 still tape test)	1CP	32-34	06DP	-	06TP	24-29	06FP	-
074	10/0355Z Nov 78	ϕ-DE	1-7, 9-12, 17-19, 21, 23, 24, 32, 35 Delta Patch	1CP	32-34	06DP	-	06TP	24-29	06FB	-
075	07/1000Z Dec 78	ϕ-DE	1-7, 9-12, 17-19, 21, 23, 24, 32, 33, 35, 39 Delta LV Manual Patch	1CP	32-34	06DP	-	06TP	24-29	06FP	-

10. LMSC Programs Developed for Seasat

a. Power Program

Development. The power program for the Seasat mission was initially developed during the proposal phase to be used as a design tool for determining solar array panel requirements. The program was modified after the Critical Design Review (CDR) to more accurately calculate power availability based on intra-revolution integration and K1/K2 status monitoring. Modifications continued throughout Seasat's lifetime and beyond. The program was used extensively for in-flight operations support.

Background. The initial version of the program used routines developed for orbit average power, shadowing effects, beta angle calculations, and solar ephemeris used on other programs. This version also included degradation effects from Palo Alto Laboratories.

The orbit average power calculation was replaced by an integration routine (and improved battery modeling) based on work performed by the central power group.

Checkout and Implementation. The power program was initially checked by comparison with other analytical techniques. In-flight calibration was performed and run on GSFC 360-75 computers for flight support.

Purpose. The purpose of the power program was to provide solar array design analysis and to provide in-flight power system capability.

Results. Flight experience has shown that the program was accurate to better than 51 percent (telemetry data uncertainty).

b. Computer Programs for Attitude Control System Trim

Development. These programs were developed before launch to be applied on activation of the Orbital Attitude Control System (OACS), using full orbit data from onboard recorders. Subsequent trim updates were scheduled once each month, if necessary.

Background. The perturbation method for parameter estimation was used successfully on these programs and adapted to the Seasat configuration and requirements. Newly developed improvements were derived from recent works on estimation applications.

Implementation. The programs were implemented on GSFC computers and were tested using simulated flight data.

Purpose. These programs were required for trim adjustment of control system parameters not accurately known before on-orbit observation, such as residual magnetic momenta and electromagnetic torque compensation gains.

Results. Flight results demonstrated the pointing accuracy improvement from errors of about 6 deg before trim to about 1 deg after trim.

11. Air Force Western Test Range

The Seasat launch vehicle integration and launch support activities were supported by the Space and Missiles System Organization (SAMSO) using the 6595th Space Test Group (STG) and the Space and Missile Test Center (SAMTEC) at Vandenberg Air Force Base (VAFB) and the Kennedy Space Center/Western Launch Operations Division (KSC/WLOD). The project requirements at VAFB were directed through the 6595th STG with Air Force Western Test Range (AFWTR) implementation and operations responsibility conducted by the SAMTEC organization. The project support facilities and the satellite command and telemetry data handling and processing resources were provided through KSC/WLOD.

a. Ground Data System Requirements. The Ground Data System (GDS) requirements for Seasat support at AFWTR were identified in the Program Requirements Document (PRD) and are listed below:

(1) Command. 2106.4 MHz PCM/PSK, AM/PM data link from the LMSC System Test Data System (STDS) Test Van 1 to the Agena vehicle at Space Launch Complex (SLC-3W), pre-launch.

(2) Telemetry.

(a) Link 43 at 2243.5 MHz with 19 subcarriers.

(b) Link 87 at 2287.5 MHz, PCM/Bi-ϕ-L/[illegible]X/PM with 25 KHz on a 1.6-MHz subcarrier.

(c) Link 87 at 2287.5 MHz, PCM/Bi-ϕ-L/PM with 800 kHz on 1.6-MHz subcarrier.

(d) Real-time Link 87, frame-synchronized 25-kb/s formatted for wideband transmission to POCC at GSFC.

(e) Link 43 required for pre-launch through launch vehicle separation.

(f) Link 87 required for pre-launch through ascent phase, including Agena first and second burns.

(3) Tracking.

(a) Radar skin tracking with data processing to produce position and velocity state vectors with transmission to GSFC.

(b) Launch vehicle guidance computation with satellite position and velocity guidance state vectors at separation provided to LMSC trajectory at Sunnyvale, California.

(4) NASCOM Communications.

(a) 50 kb/s wideband data circuit for real-time telemetry from KSC/WLOD to POCC at GSFC. (56 kb/s was required, but carrier could not implement in time; therefore, 50 kb/s was accepted.)

(b) 2.4 kb/s high-speed data circuit for radar tracking data from VAFB tracking data processor to Goddard Real-Time System (GRTS) at GSFC.

(c) One voice circuit for each of the following:

Radar tracking data coordination.

Range countdown.

Mission operation circuit, VAFB to POCC.

Mission directors circuit, VAFB to POCC.

Telemetry coordination, KSC/WLOD to POCC.

SPAT analysis, KSC/WLOD to POCC.

Mission advisors, VAFB to JPL/GSFC/LMSC at Sunnyvale.

Satellite manager to satellite analyst.

ARIA data coordination at KSC/WLOD.

(5) Teletype.

(a) One standard GSFC to KSC/WLOD administrative.

(b) One state vector information VAFB to ETR via DoD circuit with NASCOM extension hardwired at ETR/GSFC to GRTS room at GSFC.

b. Launch Test Working Group. The Launch Test Working Group (LTWG) was convened in early 1977 to function as the forum for placing requirements, monitoring the status of implementation, and resolving problems. A subgroup of the LTWG was the Range Requirements Working Group (RRWG), whose purpose was to interact on GDS requirements and agree on the needed range configuration to meet stated requirements. The actual support configuration used for Seasat is shown in Figure 2-19. The details of the GDS requirements stated above were defined in the WTR Operations Requirement document generated by the 6595th STG. The actual implementation was responded to in the WTR Operations Directive generated by SAMTEC. The RRWG activities began in October 1977 (approximately 8 months before launch) at the insistence of GDS engineering, as AFWTR normally would not begin this type of activity until 6 weeks before launch.

c. Ground Data System Testing. By February 1978, an agreed-upon GDS test plan had been published that established prerequisites that had to be completed before an end-to-end ground data system test could be conducted to demonstrate GDS readiness to support both satellite system checkout activities and POS tests and training activities. Because SAMTEC considered their capabilities to be standard and multimission, the range did not include any operational test and training in their activities. Agreement was reached so that appropriate range resources would support satellite test and POS training activities.

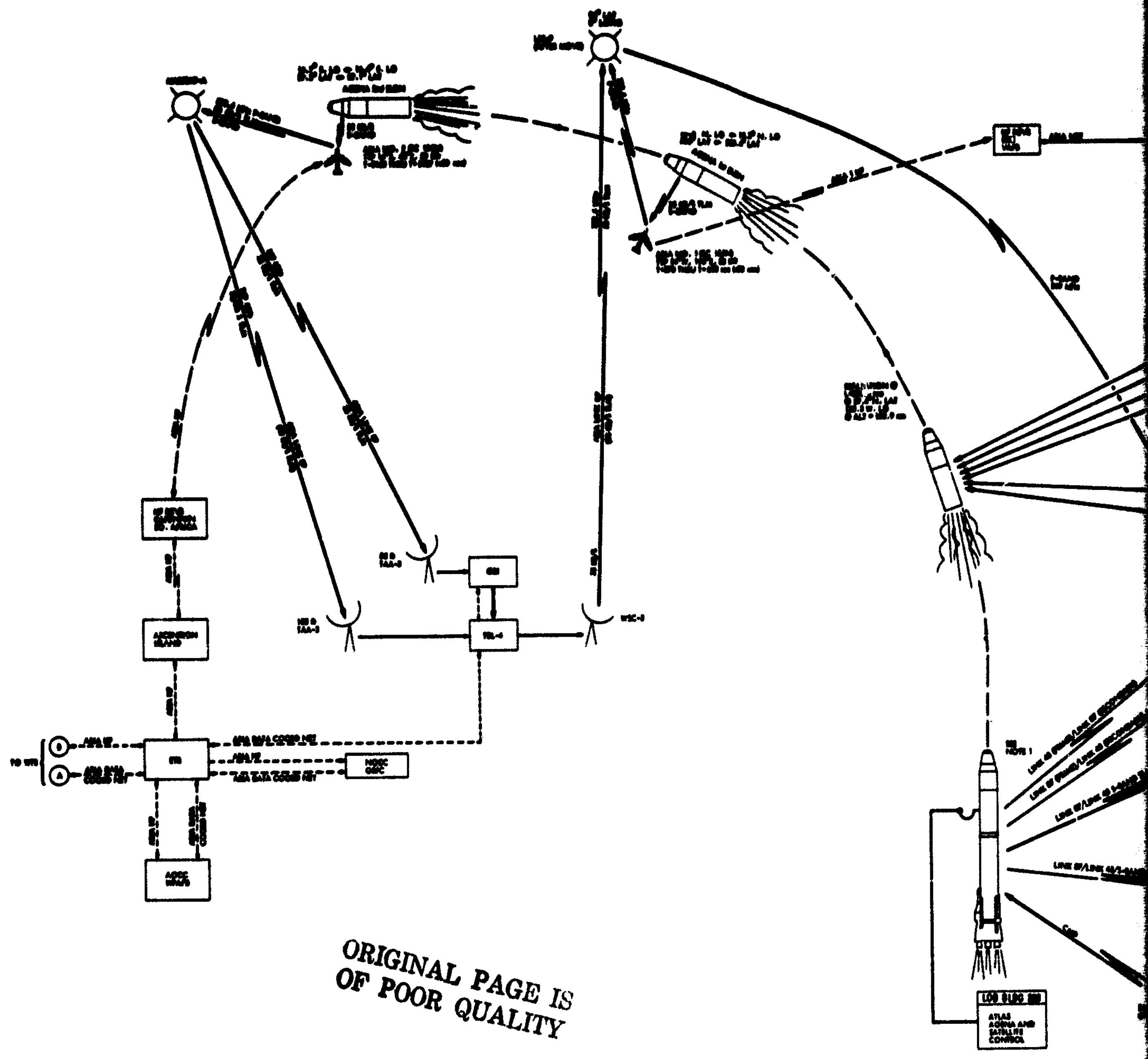
The established milestone dates were: (1) GDS demonstration test date was 20 March 1978, and (2) combined POS test date was 5 April 1978. Both of these dates were slipped approximately 2 weeks because of the failure of NASCOM to implement the 50-kb/s wideband circuit by 1 March 1978, as required (actually available 31 March), nonavailability of the ARIA aircraft Marisat A satellite, and the delayed shipment of the Seasat satellite to VAFB.

The GDS represented a very complex system with many organizational interfaces. This complexity was not fully understood by all participants and resulted in not being able to achieve a successful demonstration of the two-satellite relay of 25-kb/s telemetry data in the time allocated. After four attempted system tests and several link tests, a decision was made to request the USAF Satellite Test Center at Sunnyvale to bring up the Indian Ocean Air Force Station at Mahe to record the telemetry downlink during the Agena second burn as a backup to the ARIA aircraft. This was done successfully.

The KSC/WLOD support was excellent at all levels of requested support. Their flexibility and competence were key contributions to the successful support of the Seasat mission.

12. Shoe Cove, Newfoundland Station Support

The Government of C nada has established an interdepartmental organization for the study of remote s sing systems. The program, designated Sursat for Surveillance Satellite, organized to examine a broad spectrum of remote-sensing systems with the objective of selecting a system or group of systems that are optimized to Canadian requirements. The Canadian involvement in the Seasat mission was directed at acquiring a working knowledge of a spaceborne SAR. The following paragraphs outline the Canadian ground station implementation used for Seasat data acquisition at the Shoe Cove Satellite Receiving Station (SCSRS) located near St. John's, Newfoundland.



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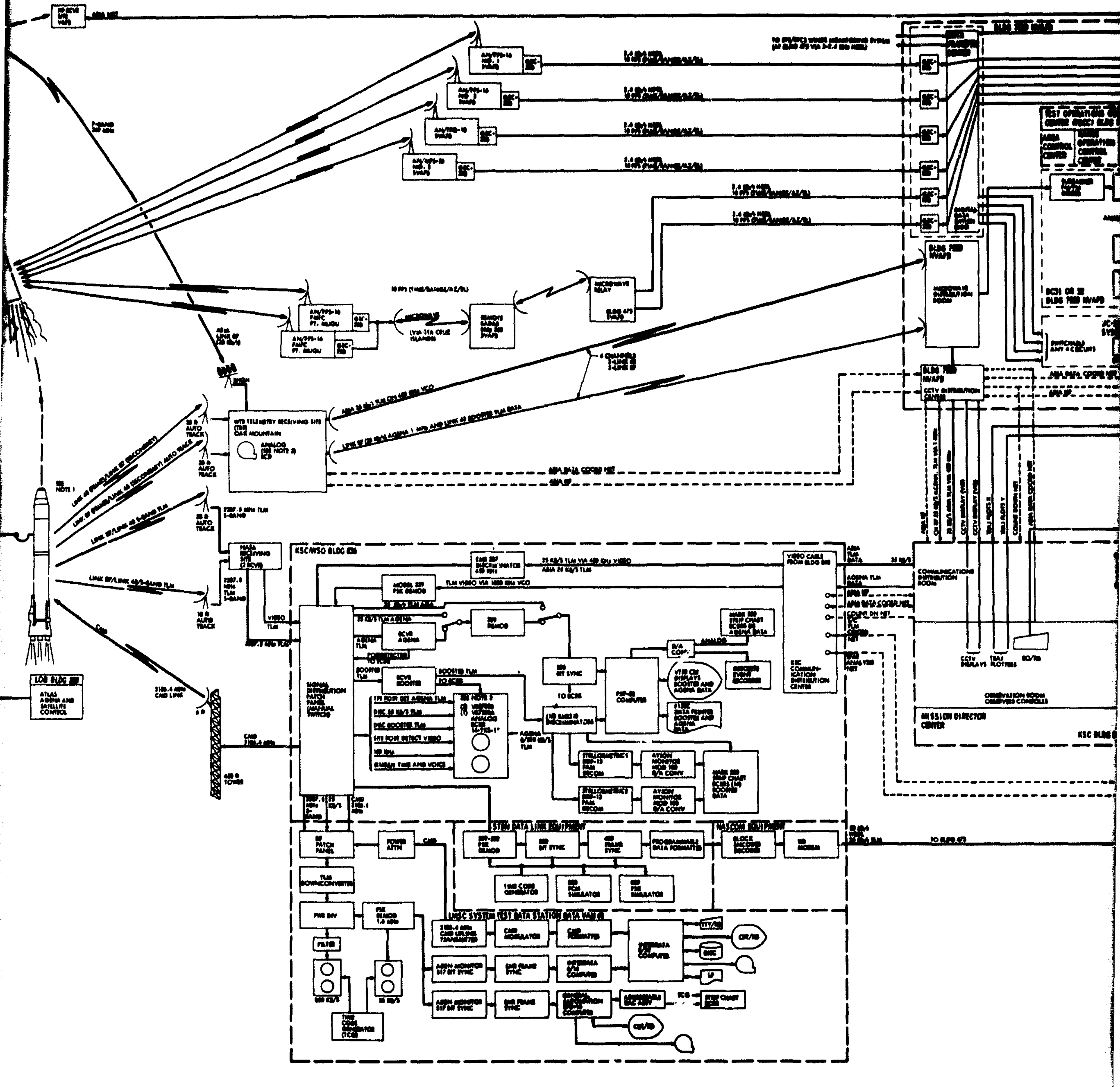

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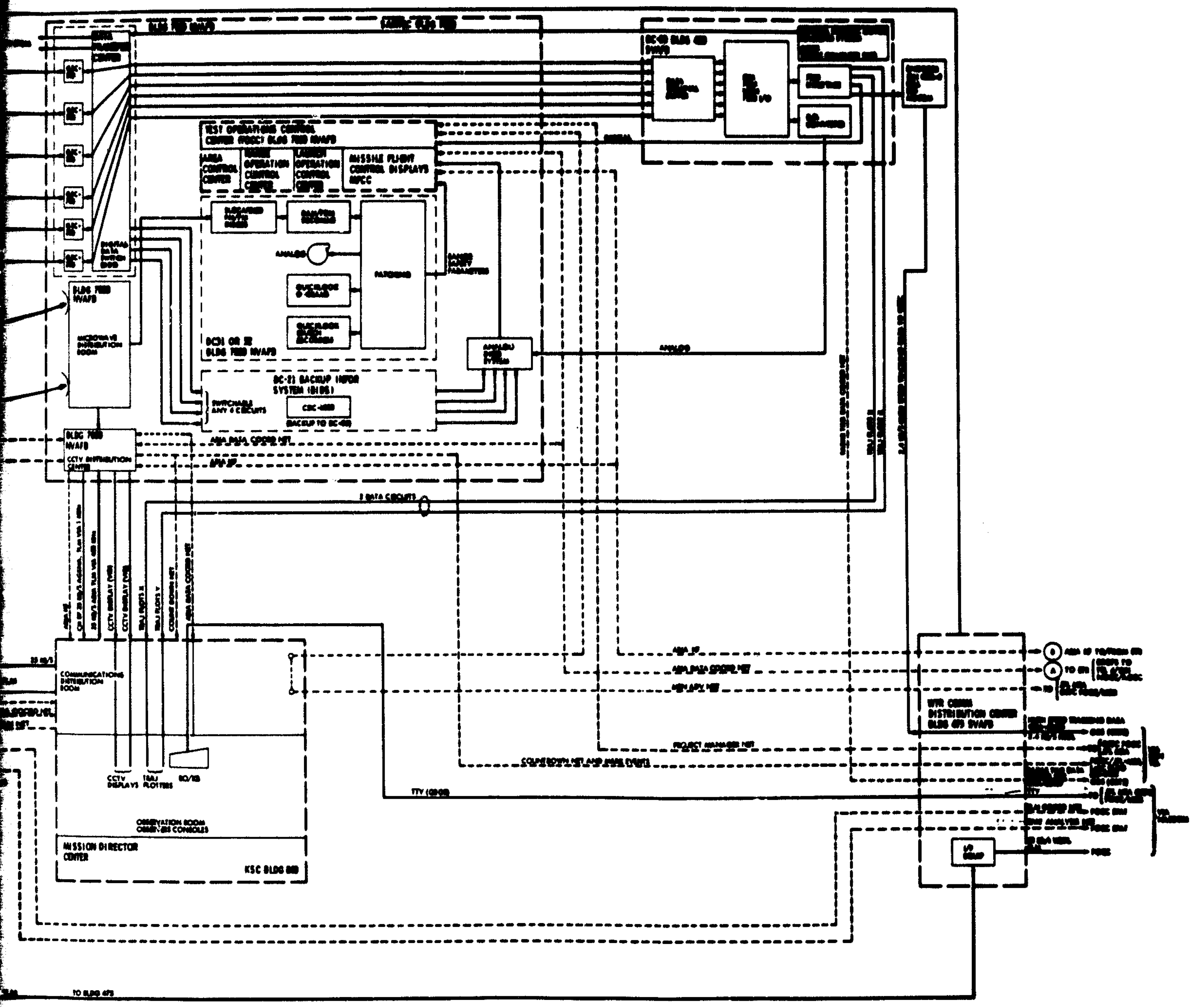

Figure 2-19. Seasat WTR Support GDS Configuration

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a. Requirements. The primary requirements of the SCSRS were to acquire and record SAR data for later processing by various experimentors. The specific station requirements are outlined below.

S-Band and Data Links

(1) SAR Data Link. The Seasat wideband analog data link was unique in that it required specifically designed demodulators. Because the link required a 400-MHz intermediate frequency (IF) input to a NASA STDN Multifunction Receiver (MFR), the SCSRS was modified accordingly. The Shoe Cove Landsat/NOAA acquisition system uses a 285- to 410-MHz IF for S-band; thus the front end of the downlink was modified. To do this, a separate S-band signal was split off the antenna monopulse sum channel, immediately following the parametric amplifier (Figure 2-20) to permit the SAR data link to operate independently of the tracking system. Because the existing Shoe Cove RF system is equipped for unified S-band (USB) reception, and because the USB link is used for monopulse tracking, the tracking functions of an all-up MFR were not required. Therefore, a unique Seasat receiver was specified, providing the wideband AM detection functions required by the SAR coherent demodulator.

(2) Seasat Telemetry Data Link. The station was required to monitor several SAR engineering parameters during active SAR periods. To accomplish this, it was elected to monitor and record the complete low-rate telemetry (LRT) data stream carried on a 1.6-MHz subcarrier of the USB data link, so that a series of experiments using the low-rate sensors could be initiated.

Digital Recording Subsystem. The station was required to record high-density digital tapes of SAR data. Because it was necessary for the station to be compatible with other stations, a SAR digitizer and high data rate recorder (HDRR) were selected that were identical to those used by the NASA STDN stations. The equipment was designed by the Applied Physics Laboratory (APL) of Johns Hopkins University.

A minor modification of the APL system was required to permit playback of the HDRR tapes for the recording of analog signal film. This was a result of last-minute detail changes required by system interface requirements for the optical recorder system.

Analog Recording System. The SCSRS system was required to record SAR data in analog form both photographically and magnetically. The photographic recorder recorded raw signals on film for subsequent optical processing. The magnetic recorder provided a reduced resolution image, which served as a backup for either the optical or digital recorder systems or both. Magnetic analog recording was originally intended to provide a method to acquire SAR data early in the program. This requirement decreased in importance when the spacecraft launch was delayed beyond May 1978.

The film recorder recorded full bandwidth SAR signals, representing a complete radar swath of 100 km (54 nm). The signal film was shipped to Ottawa, where it was developed and optically processed by a Defense Research Establishment, Ottawa (DREO) laboratory.

The magnetic analog recorder recorded a 12-MHz wide portion of the radar spectrum. The offset video signal was bandpass-filtered and frequency-translated to form two low-pass signals, each band-limited to 6 MHz. The two signals were recorded on a two-channel video recorder. On playback, the two low-pass signals were again frequency-translated, then combined to form a bandpass representation of the original offset video.

b. Implementation

Antenna RF System. The existing SCSRS antenna system was used to provide the front end for the Seasat system. The existing Landsat USB link was also used for both LRT acquisition and the antenna tracking loop.

The antenna system comprised a 10-m prime focus parabolic reflector equipped with a single-channel monopulse feed. The feed operated at both 2200 and 2300 MHz and 1650 to 1750 MHz with optimization for the 2200- to 2300-MHz band. Antenna gain was 21 dB at 2250 MHz. The feed is shown schematically in Figure 2-20. The monopulse system at 2250 MHz comprised a 30-dB parametric amplifier fed from the sum channel antenna and a 30-dB transistor amplifier fed from the difference channel. The sum channel was then split by a power divider. One of the sum channels and one of the difference channels were combined in a 13-dB coupler to produce the amplitude modulation (AM) signal. This AM signal was then amplified by a 15-dB transistor amplifier before being applied by cable to the Landsat down-converter. The remaining sum channel was cabled to the Seasat down-converter.

The Landsat down-converter operated with a local oscillator frequency of approximately 1918 MHz to produce a down-converted output at 285 to 385 MHz. This signal was then cabled through a multiplier to a Microdyne Model 1100 LS receiver. This receiver was tuned to 369 MHz to provide reception for the USB data link, and also provided an AM envelope detector for use with the antenna tracking loop.

The Seasat down-converter operated with a local oscillator frequency of 1800 MHz to produce an IF frequency of 400 to 500 MHz suitable for use with the Seasat receiver. Because this data link was taken from the sum channel ahead of the tracking loop coupler, tracking AM was not present to cause interference with the operation of the MFR or Seasat receiver. The Seasat receiver output several signals to the SAR coherent demodulator, which was designed and constructed by APL.

Digital Data Acquisition System. SAR data were demodulated by the SAR coherent demodulator. This device output SAR data and control signals to the digital data acquisition system. The digital system was identical to that of the NASA STDN systems designed and constructed by APL, except for one or two minor differences caused by Shoe Cove unique interface requirements.

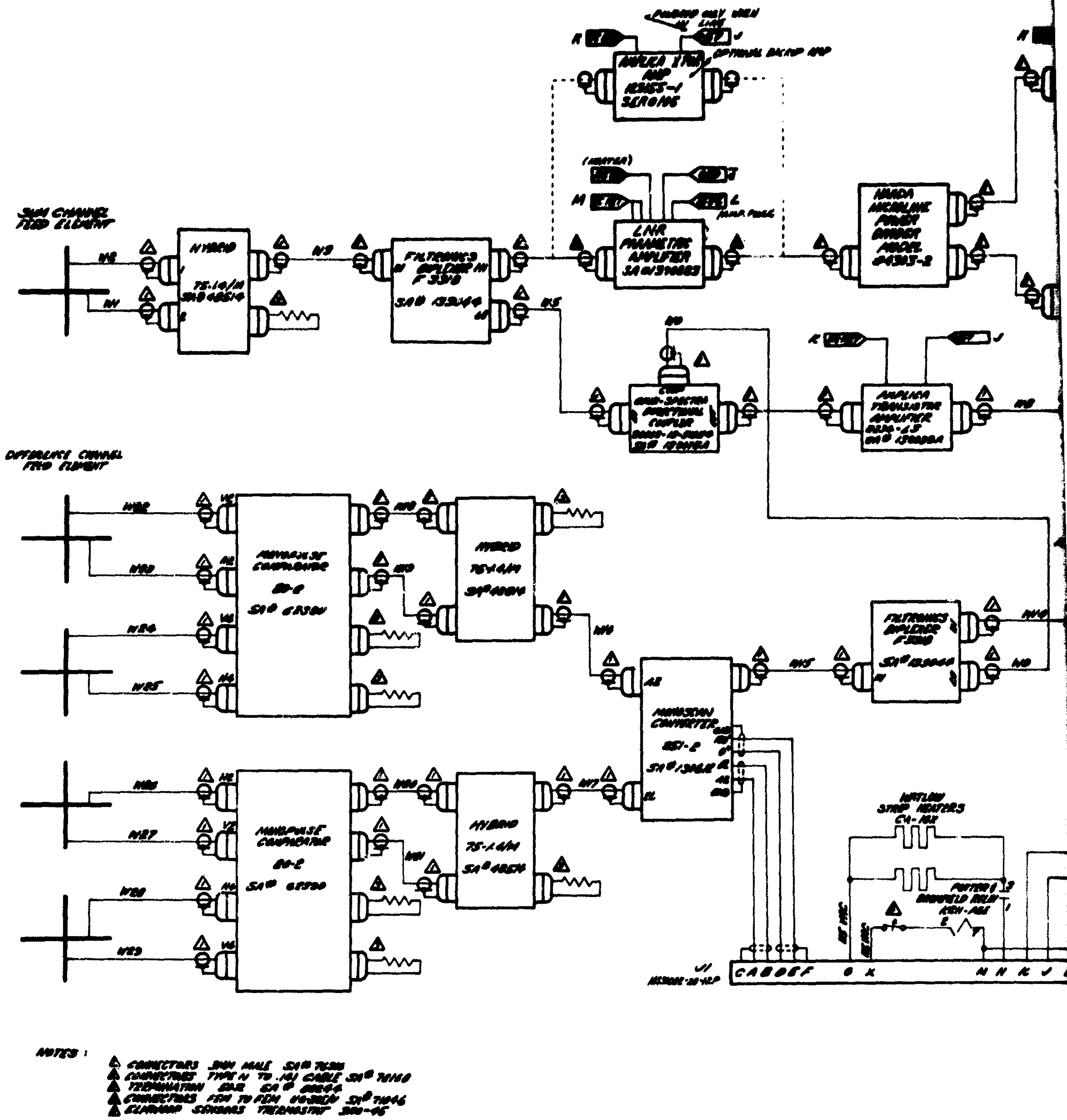
SUM CHANNEL FEED ELEMENT
DIFFERENCE CHANNEL FEED ELEMENT
HYBRID
LNR PARAMETRIC AMPLIFIER
NOTES :

Figure 2-2

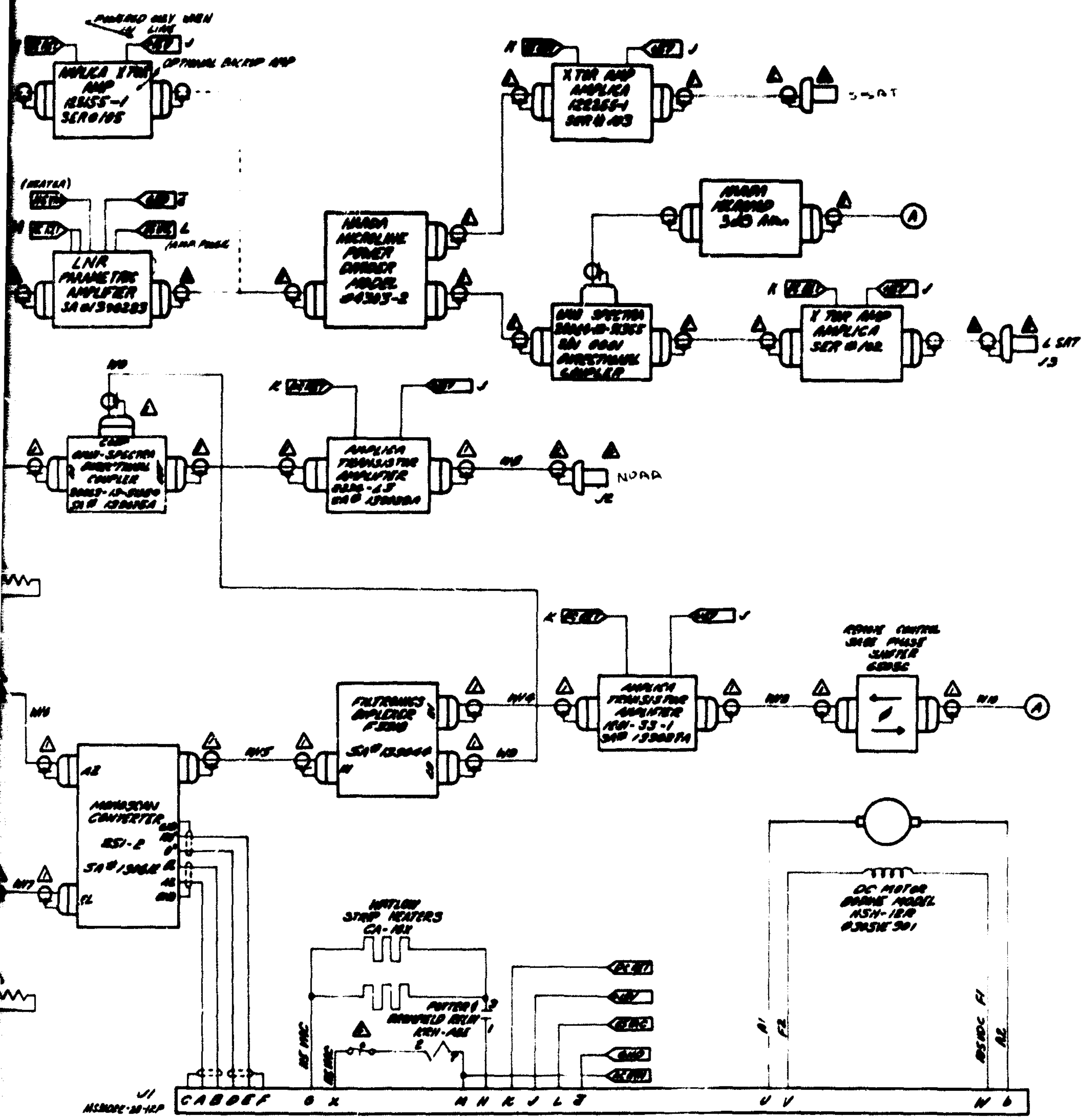

Figure 2-20. Antenna Feed System Schematic Diagram

Data were digitized up to 5-bit samples at a peak sampling rate of 45 MHz. These data were buffered and stored on magnetic tape at an average rate of 117 Mb/s. The tape recorder used was a Martin Marietta 42-track HDDR, identical in design to that of the NASA STDN units. SCSS used the recorder in a 39-track recording configuration, recorded with the vernier speed control set to 100 percent. Therefore, all tapes recorded at SNF were fully compatible with the NASA formats.

The APL equipment was included at the SAR signal simulator for system test purposes. The availability of this equipment permitted playback of the digital tapes for use in making photographic film recordings of the SAR signal. The simulator was equipped with a video regenerator designed to convert digitized SAR data back to the previous analog form. The regenerator also provided for the extraction and display of various data items, which were multiplexed in the recorded digital data system. Also, the regenerator provided control signals to the optical signal recorder for PRF rate and coherent trigger synchronization.

Optical Film Recorder. A twin-transport optical film recorder was provided as an intermediate step in the generation of optically processed SAR images. The recorder was part of a system under development by DREO and the Communications Research Center. The recorder development work was jointly undertaken by these agencies as part of the Seasat program.

The recorder was manufactured by CIR, a Toronto company, and consisted of two independent film transport and CRT assemblies, with each transport capable of recording one-half swath of the SAR radar echo in real time. Therefore, it was possible to record the full 100-km (54 nm) radar swath in real time. The recorder accepted the offset video, coherent trigger, and PRF rate signals, together with the time code, from the SAR unique system. These signals were then used to control the recorder operation. The recorders operated to produce two 25-cm (5 in.) wide signal films. Processing of the film latent image took place in Ottawa. The film was then optically processed to generate the SAR imagery.

Digital SAR Processing. Part of the Sursat program involved the development of a digital image processor. This project, conducted by McDonald Dettwiler & Associates in Vancouver, involved production of a software digital image processor capable of transforming a digitized signal record into an image.

To implement the ground station acquisition part of the system, the existing Landsat computer system was modified to provide two 6250-b/in. computer compatible tape (CCT) drives, each capable of operating at 125 in./s or 6.25 Mb/s. To produce a CCT of the digitized SAR data, the HDRR was operated at 1/32nd real time, or 3.66 Mb/s. The serial data stream was format-synchronized, buffered in a large (196-kbyte) buffered memory, then output from the memory to the CCT. Tapes produced by this system were processed in Ottawa.

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Low-Rate Telemetry System (LRTS). The low data rate data stream was acquired by the USB receiver. The received baseband signal was passed to a 1.6-MHz subcarrier demodulator, where the original split-phase modulation was reconstructed. This signal was then synchronized and interfaced to the Landsat computer system for recording and processing. The bit/frame synchronizer and the processor interface were constructed as a single unit for installation in the computer main frame, which proved to be a satisfactory arrangement. The computer system implemented the monitoring of the required SAR engineering parameters. Monitored parameters were displayed on an interactive CRT, and were hard-copy logged to a line printer. The status of each monitored parameter was displayed on a special-purpose indicator panel. All data received on the LRT data link were recorded on a CCT. This enabled Canadian users to obtain real-time LRT sensor data that will be used in future experiments.

c. Test Plan. The test plan outlines the tests used to verify the performance of the various system components. The general test plan followed was to use the pre-shipment factory acceptance tests as the basis for integration testing. Following installation of an item, the acceptance test procedure was repeated as necessary to ensure that integration itself had not caused a problem

HDRR Acceptance Tests. The HDRR was tested by Martin Marietta, according to their test plan, on 16 May 1978. These tests were not witnessed by a Canadian government representative because of time constraints. However, the unit was delivered to APL for integration with the SAR-unique formatter/simulator. Because of the warranty conditions applicable to the equipment, it was not necessary to witness the acceptance tests.

System Integration of HDRR/SAR Unique Rack. The SAR unique rack, comprising the SAR coherent demodulator, SAR data formatter, and SAR signal simulator, was manufactured, assembled, and tested at APL. The APL engineering team was contracted to accept responsibility for integration of a Tau Tron bit error rate tester and a Hewlett-Packard oscilloscope. The latter units were supplied by CCRS directly to APL.

The SAR coherent demodulator used for this phase of system integration was a brassboard prototype. This unit was used to provide SNF with the capability to receive and process the SAR data ahead of scheduled delivery of a production unit.

Acceptance tests for the complete SAR-unique/HDRR subsystem were conducted at the APL facilities during August 1978. The equipment was then shipped to SNF where it was installed and again tested by an APL engineering team.

The subsystem was then integrated to the SCSRS antenna/RF system for final checkout. On completion of this work in early September 1978, SNF began recording digitized SAR data on a regular basis.

LRTS Integration. The LRTS was delivered in late July 1978. It was installed and tested in the SCSRS system computer using recorded low rate telemetry data. Testing consisted of recording the CCT data from the LRT data tape, followed by image dumping of statistically selected parts of the CCT. Tape dumps were then examined for format validity and data content validity.

The system was tested for varying input signal-to-noise ratios to ensure that all performance specifications were met. As SCSRS was not equipped with any form of signal simulator for the LRT data link, testing was confined to the use of actual satellite telemetry.

Analog Recorder. The analog recorder was delivered, installed, and tested by a team of engineers from DREO. Testing consisted of demonstrating that the recorder spectrum conditioning circuits were functioning properly. As it was not possible to play back recorded data at that time, no other testing could be undertaken.

Optical Recorder. A brassboard prototype of an optical signal recorder was constructed by DREO personnel and delivered and installed by their staff in late July. Testing of this device relied on the availability of actual SAR data, as there was no method to simulate or replay recorded data. Testing consisted of recording a test film from the SAR data link, then shipping the film to Ottawa for development and processing. This proved to be a cumbersome method of handling signal film, but was the only available procedure to resolve the problem because the primary effort in recorder and processor development was centered in Ottawa.

c. Schedule. Although there was no specific commitment as to when the Shoe Cove station would begin support of the Seasat mission, a goal was established to have the station fully implemented and tested by launch time. Actual tracking operations began approximately 45 days after launch.

13. Oakhanger, England (UKO) Station Support

a. Requirements. Requirements of the Oakhanger station were to:

(1) Track Seasat on all visible passes above 5 deg subsequent to launch with minimum data loss.

(2) Collect and record all telemetry information on the 2287.5 MHz carrier and give real-time outputs of eight SAR-related telemetry units.

(3) Receive SAR data on 2265.1 MHz when scheduled and record the digitized data on magnetic tape.

(4) Provide a real-time feedback to GSFC on SAR telemetry units over a voice link during supports.

b. Implementation. The following items were implemented to meet Seasat support equirements:

(1) The servo system was upgraded to give 10-deg/s maximum azimuth velocity.

(2) A program track was developed for element processing, tracking, and acquisition.

(3) Telemetry equipment was installed (EMR 728 PSK demodulator, EMR 2721 signal converter, EMR 2731 frame synchronizer). A Prime 300 computer was installed for telemetry formatting and recording with a real-time readout.

(4) A telemetry program was developed for the Prime 300 computer to format and control the EMR units.

(5) A down-converter was installed for SAR reception with a 465.1-MHz IF output and 50-MHz bandwidth.

(6) An MFR was installed.

(7) A cleanroom was built to house the HDDR.

(8) An analog recorder (Ampex FR1800) was installed for direct telemetry recordings and to facilitate non-real-time CCT production.

c. Tests. The following tests were completed during preparation for mission support:

(1) Azimuth and elevation servo tests were performed using Landsat after initial performance checks proved successful.

(2) Program track tests and element processing using Landsat signals and data.

(3) SAR system receive tests using total loop check capability of SAR ground equipment.

(4) Telemetry tests using simulated data from an EMR data simulator unit.

(5) Telemetry program tests using simulated data.

(6) Crew training using total system and Landsat.

d. Schedule. Although there was no specific commitment as to when UKO would begin support of Seasat, a goal was established to have the station fully implemented and tested by launch time. Actual tracking operations began approximately 30 days after launch.

14. Fleet Numerical Oceanographic Center

a. Background Information. Fleet Numerical Oceanographic Center (FNOC) at Monterey, California, has been developing a satellite data processing capability to provide a remote sensing data base for use in the Navy's weather forecasting operation. In line with this interest, FNOC planned to use Seasat data in the Satellite Data Processor. Concurrently, NASA planned to demonstrate the near-real-time use of Seasat data by commercial as well as scientific users.

As a result of these two interests, an agreement was negotiated between NASA and DoD, where FNOC agreed to conduct a real-time user data demonstration in support of the Seasat Project. The demonstration was to show that Seasat data and related FNOC products could be provided to DoD and industrial and scientific users in a timely manner. In addition, FNOC was to be a source for "surface truth" products for the verification of Seasat-generated data products.

The Memorandum of Agreement (MOA) for a real-time user demonstration for the Seasat Project* contained a description of the responsibilities of the Seasat Project and FNOC with respect to the planned demonstration. Included in the described responsibilities was the requirement for JPL to provide algorithms, flow charts, software consulting services, and test data as required by FNOC to permit their integration of the geophysical software with the real-time data processing facility provided by FNOC.

This transfer of technological information and data between the Seasat Project and FNOC evolved into four interfaces areas:

(1) The real-time operational data interface.

(2) The Instrument Data Processing System (IDPS) interface.

(3) The geophysical algorithm development interface.

(4) The Auxiliary Data Record (ADR) interface.

The real-time operational data interface was handled as part of the GDS engineering functions under the cognizance of the Seasat Operations Manager and is not addressed here. The other three interfaces were handled as part of the system engineering function under the cognizance of the Seasat Information Processing Manager and are discussed in the following paragraphs.

b. Technical Approach. Although the transfer requirements, responsibilities, and content varied for each of the interface areas, a common technical approach was used. The basic transfer unit for the transmission of information and data between the Seasat Project and FNOC was defined as a "data package," which consisted of telemetered spacecraft data, written material, computer cards, and any other matter that was passed between the two agencies. Each data package was forwarded by the transmitting agency to the receiving agency through a letter

*Project Plan for Seasat-A 1978 Mission, JPL internal document 622-3, Appendix B, May 1978 of transmittal. To provide for an efficient mechanization of the process, single technical points of contact were established within each agency. Each identical point of contact was responsible for ensuring that the data packages were prepared for transmittal and were transferred (or received).

c. IDPS Interface. The IDPS was a part of the Seasat Project Data Processing System (PDPS) located at JPL. While FNOC had no direct interface with the IDPS in its planned implementation for the Seasat mission, the information and knowledge acquired by JPL personnel as a result of the development of the IDPS was of interest. As such, the IDPS interface related to the transfer of documents, computer program material, and ancillary information that was of benefit to FNOC in the implementation of an IDPS-type capability for the Real-Time User Data Demonstration System (RTUDDS) at FNOC.

Support for the RTUDDS in the IDPS interface area was of an indirect nature only. As such, Seasat support was limited to the effort required to prepare data packages for transmittal. No documentation or computer software was developed in the IDPS interface area whose requirements were based on the needs of the RTUDDS. As information of interest to FNOC became available as a result of normal IDPS development activities, a data package was constructed for transmission to FNOC.

Information transmitted for the IDPS interface consisted of the following elements:

Data Elements	Form	Completeness
Related documentation	Documents, IOMs	As available
Annotated program listings	Assembly/Fortran	As available
Test/verification data	Magnetic tape hardcopy	As available

"Completeness," as used above, defines the extent to which a given element was comprehensive. For example, related documentation might not be available for each program element or routine. The precise format of the information transferred as a data package was specified in the letter of transmittal. The primary information transferred consisted of the IDPS location processor routines, pertinent data tapes (A/O and PMDF), and channel tabulation hardcopy.

d. Geophysical Algorithm Development Interface. JPL was assigned the responsibility for coordinating the development of the algorithms and programs required for geophysical conversion. These algorithms and programs were primarily supplied by the sensor implementation managers and the experiment teams. The algorithms and programs were developed on the Algorithm Development Facility (ADF), an element of the PDPS at JPL.

As these algorithms and programs were developed, various data elements were transmitted to FNOC. These data elements contained information that ranged from the specification sheets for each algorithm to the actual debugged and validated software. Data elements were provided for each of the scientific instruments on board the spacecraft with the exception of the SAR. FNOC used the algorithms and programs for producing the geophysical software before use in the RTUDDS.

Information transmitted for the geophysical algorithm development interface consisted of the following elements:

Data Elements	Form	Completeness
Related documentation	Documents, IOMs, diagrams, specification sheets	As available
Software products	Annotated program listings, magnetic tape cards	As requested and available
Test data	Test reports, test decks	As requested and available

As planned by FNOC, the RTUDDS implementation would only process altimeter data to the "sensor file" level and would not process visual and infrared radiometer (VIRR) data. FNOC planned to process both Scanning Multichannel Microwave Radiometer (SMMR) and Seasat Scatterometer System (SASS) data to the "geophysical file" level.

e. Auxiliary Data Records Interface. As an operational weather center, FNOC produced a number of standard data products that were a source for surface truth data. This group of data products were designated as Auxiliary Data Records (ADRs) by the Seasat Project.

The interface functions consisted of making arrangements for having FNOC make the data products available to the Seasat Project. The information transmitted by FNOC for the ADRs interface consisted of the following elements:

Data Elements	Form	Completeness
FNOC field data	Magnetic tape	As requested
FNOC spot data	Magnetic tape	As requested
Operational plots	Hardcopy	As available
Spectral Ocean Wave Model (SOWM) products	Hardcopy	As requested

f. Future FNOC-Type Interfaces. It is appropriate to analyze the FNOC interface as a historical learning process. Most of the problems encountered were somewhat predictable and were more management-related than technically related.

Although the Seasat Project and FNOC had a signed MOA with respect to the RTUDDS, there was some confusion in the interpretation of the document. Not surprisingly, each tended to interpret the MOA in the manner most favorable to the particular point they were attempting to accomplish.

From the interface function perspective, the most significant problem was a disparity between the Seasat Project and FNOC with respect to the schedule for algorithm development. As viewed by the project, FNOC was processing satellite data in support of a project experiment. Therefore, the time frame for accomplishing the experiment was related to the project algorithm development plans. However, FNOC had made non-Seasat Project-related commitments to provide the satellite data to other DoD agencies. As viewed by FNOC, they had a requirement to have available at launch a capability to support their other commitments. If this difference in needs had been identified at the time the MOA was generated, perhaps it could have been better resolved than after the fact. As it was, concurrent geophysical algorithm implementation at JPL and at FNOC was attempted.

The second significant item was the projected requirement to verify FNOC's software implementation. As viewed by the Seasat Project, when FNOC distributed data to industrial users that was identified as Seasat data, then the project wanted to verify the data prior to distribution. To accomplish this, it was felt that it would be necessary to certify FNOC's implementation. It should be noted that concurrent algorithm implementation tended to increase the difficulty of resolving this item. As the satellite aborted the mission before the completion of algorithm implementation, the item was resolved by default.

From a technical viewpoint, the interface function seemed to work well. It was aided by having a single point of contact, especially at JPL. Although a technological transfer of geophysical algorithms is possible, concurrent development activities increases the difficulty. In general, the transfer of ADRs from FNOC to JPL presented few problems except from a schedule coordination point of view.

15. Project Data Processing Subsystem (PDPS)

The PDPS comprised the IDPS, Master Sensor Data Record (MSDR), and the ADF used by the experiment teams to develop algorithms for converting telemetry data to geophysical units (e.g., wind fields, temperatures, altitudes, wave heights, etc.). The PDPS was created primarily to receive the Project Data Package (PDP) from GSFC on a daily basis after launch. It was also responsible for the GSFC/JPL/NASCOM link used by the Mission Planning Subsystem (MPS) to transmit sequence profiles to GSFC and the resulting command lists back to JPL. This function was independent of the IDPS, but was implemented and operated by essentially the same personnel.

a. Requirements

IDPS. Requirements of the IDPS were to receive the daily PDP from GSFC and to perform a somewhat standardized set of data processing activities. The daily PDP consisted of eight Project Master Data File (PMDF) magnetic tapes, each containing a 3-h block of telemetry data and one attitude/orbit (A/O) magnetic tape containing a 24-h orbit file. The primary output product was the MSDR, which was a magnetic tape consisting of data records for each satellite sensor and for the engineering data. The output record for any sensor consisted of telemetry data that were decommutated, time-tagged, converted to engineering units, and Earth-located. The Earth location processor used the A/O tape to calculate the latitude and longitude of the boresight intercept of each sensor's antenna with the Earth's surface at a set of times unique to each sensor.

Other magnetic tape data products included the Sensor Data Records (SDRs) for individual sensors or for the engineering data. Paper products included performance summaries, channel tabulations, and channel plots. These products were intended for use early in the mission during the engineering assessment of individual sensor and spacecraft bus performance. The functional requirements for the IDPS are outlined in the IDPS Functional Specification, JPL internal document 622-14.

MPS/NASCOM Link. The requirements for the GSFC/JPL full-duplex NASCOM link used by the MPS were specified by the Seasat Ground Data System Engineer (GDSE). Three types of records generated at JPL by the Mission Planning Team (MPT) were transmitted to GSFC:

(1) A command dictionary that defined the name and bit pattern of each spacecraft command.

(2) Definitions of groups of commands in a given sequence that could be identified by a group name.

(3) Mission sequence, which used individual commands and group commands, but which lacked the specific transmission or execution times dependent on the STDN scheduling.

The record transmitted to JPL by GSFC was the resultant command list, which included times dependent on the STDN scheduling.

b. Implementation

IDPS. The IDPS was implemented on the Mission Control and Computing Center (MCCC) institutional Data Records System (DRS), which used two IBM-360-75 computers. The MCCC DRS provided the existing development and operations environment used by the Seasat Project. All of the software developed was unique to, and funded by, the Seasat Project. The MCCC DRS was operated by the Data Management Team (DMT), a multimission activity. The Seasat Project funded its part of the DMT.

MPS/NASCOM Link. The MPS/NASCOM link was implemented on the MCCC real-time system, which used a single IBM 360-75 computer (not one of the two DRS machines). This link used an existing design currently supporting another project. Link operations were provided by the MCCC institutional operations and scheduling staff.

c. Testing

IDPS. Some data flow tests to provide a PDP for processing were the only planned formal tests involving the IDPS. These tests were made, although several individual PMDF and A/O tapes were received and used for format and structure tests. The IDPS did use satellite data tapes recorded during pre-launch testing at LMSC. The LMSC tapes and a JPL-developed simulation capability provided the only testing of the IDPS before launch.

Because of this inadequate testing, it was anticipated that many problems would be encountered in the IDPS software when actual data became available after launch. This, in fact, was the case. At the time of the anomaly, the IDPS was on its sixth software revision, and five more revisions were delivered to operations after that time. Most of these 11 revisions were only minor corrections; at least two, however, were major revisions that included both significant additional capability as well as corrections.

MPS/NASCOM Link. The MPS/NASCOM link was tested extensively by the MCCC institutional personnel in conjunction with GSFC personnel. The data transmitted to GSFC were generated by the MPT at JPL using the same programs developed for flight operations. The command list was generated at GSFC using flight operations software. This command list was then transmitted to JPL to test the other half of the full-duplex link.

d. Schedule.

IDPS. The scheduled date of 15 February 1978 for a GDS test of the PDP interface between GSFC and the IDPS and the scheduled date for launch readiness were the only significant milestones. Both of these dates were met.

MPS/NASCOM Link. The scheduled date of 15 November 1977 for a GDS test of the link and the scheduled date for launch readiness were the only two significant milestones. The readiness date for the GDS was slipped by about 4 months. The link was ready for support to the satellite launch activities.

e. Data Turnaround Time. The planned pre-launch time estimate of sensor data record availability to the sensor evaluation task groups for geophysical algorithm development and to the sensor managers for engineering performance evaluation was 12 days after data acquisition by the STDN site. This 12 days was allocated as follows:

(1) STDN handling: 1 day.

(2) IPD processing: 6 days.

(3) Shipment to JPL: 1 day.

(4) IDPS processing: 4 days.

The day for STDN handling was intended to permit all on-site data processing, formatting, and transmission over NASCOM lines to GSFC. Also to be included in this day was the time for retransmission to GSFC of data not considered acceptable by the quality criteria, but recoverable at the receiving site from either the analog magnetic tape prior to telemetry frame synchronization or from the digital magnetic tape used to drive the NASCOM lines. Once received at GSFC by TELOPS, the IPD data system used to terminate the NASCOM telemetry transmissions, the data were organized into pre-edit files corresponding to the original satellite-to-STDN site transmission. At this point the data, in the form of pre-edit files, was made available to the Telemetry Processing System (TPS) in IPD for its 6 days of data handling.

The IPD/TPS processing task consisted of organizing the pre-edit files into chronological order and extracting data on a 24-h GMT day basis. The engineering data from the 24-h GMT day file was sent to the ADF, where the satellite attitude error history was created and provided to IPD. Also provided to IPD were the GMT daily orbit file from the Orbit Determination Facility and the actual satellite UTC clock offset from the POCC. When all of these data were available, the 24-h GMT daily telemetry file was written on magnetic tape as the PMDF. The attitude history file, UTC clock offset, and the orbit file were written on the A/O magnetic tape. These tapes were individually checked and prepared for shipment to JPL.

One day was allotted for shipment. The plan called for morning deliveries of data to the Baltimore airport by the GSFC transportation department. The information concerning flight number and waybill number were to be telephoned to JPL for vendor pickup to be arranged. The data would then be delivered in the evening of the day shipped. The data packages were received by the Mission Control Center Operations (MCCO) data library expediting service.

The 4 days at JPL included 1 day for the MCCO library personnel to unpack the data packages, inventory the contents, acknowledge receipt, enter the data tapes in the MCCO library, and inform the DMT of the availability of the data. The DMT used the remaining 3 days for processing, analysis, and record keeping functions. The processing consisted of a two-step activity with an analysis period after each step. The first step was a simple tape dump similar to the GFSC/IPD tape check process. This dump program provided the initial quality control screening for tapes with such commonly noted problems as read errors, time-tag errors, and data gaps. The second step was the processing of the data to the daily MSDR, which constituted the Seasat Project's archival data base for additional geophysical processing and data evaluation. The DMT was responsible for keeping records of all tapes processed.

This 12-day processing cycle to data availability in MSDR form was not met. The 1 day for STDN handling to prepare a GMT day's data for IPD was typically over a week and frequently several weeks. There were several problems, the primary one being the inability of the STDN and NASCOM lines to handle, on a consistent basis, the large volume of data received from the satellite. The unexpectedly large number of retransmissions of data from the STDN sites to GSFC competed with the primary transmissions and caused severe loading and scheduling problems. One other, not so obvious, problem was caused by the requirement for data transmission to IPD on a complete GMT day basis. The data were sent to TELOPS on a satellite tape recorder dump basis of 3- to 4-h duration. To provide a sufficient data time span to extract one complete GMT day, as many as 8 to 10 consecutive satellite tape recorder dumps had to be received successfully by TELOPS.

In general, most of the data were received successfully within a day or so, but could not be used because of one or more bad transmissions and the difficulties of obtaining data. A number of workarounds and plans were implemented to alleviate this situation. The inability to consistently and successfully obtain data from the STDN sites to GSFC was one of the most severe data handling problems faced by the Seasat Project. The TELOPS processor was a new system brought on-line by IPD shortly before the Seasat launch. The TPS was the existing IPD processor containing the Seasat applications software. These two systems both required considerable reprogramming effort as actual experience was gained in the handling of flight data. The performance of these systems, while marginal to poor initially, became satisfactory as problems were isolated and corrected.

The shipment of data generally required only 1 day. The only serious problem was the inconsistency by the GSFC transportation department in notifying the MCCO library expediting service or the JPL transportation department of a shipment in progress. This usually caused a delay of at least 1 extra day to coordinate the pickup of the data for delivery to JPL. The longest delay was 2 weeks for a single tape when JPL was not informed of the shipment by GSFC.

The processing to the MSDR by the DMT at JPL using the IDPS was never held to the 4-day schedule. The data deliveries to JPL in the early days of the mission were very sporadic, non-chronological, and uncertain. The received data were processed immediately by both the DMT and by the development programmers in the IDPS. The data deliveries from GSFC were so slow overall that the IDPS software problems were isolated and corrected without impacting data delivery for additional geophysical processing. Some of the data received early in the mission were reprocessed several times with continuously upgraded software. The IDPS program basically reached their form about the time of the satellite failure. The complete history of the MSDR deliveries to IDPS during the mission is plotted on Figure 2-21.

Shortly after the failure, all of the PMDF tapes at JPL were returned to GSFC for removal of a time regression introduced as an artifact by the IPD processing. Also, a problem in the attitude history file generation was detected that required the reprocessing of a number of A/O tapes.

A/O tapes were corrected by March 1979. The set of PMDF and A/O tapes was finally complete at JPL and processed to the MSDR level by the DMT by the end of April 1979.

D. POS TEST AND TRAINING

The objective of the POS test and training plan was to systematically develop and demonstrate the readiness of the POS (hardware, software, personnel, and procedures) to support Seasat launch and mission operations. To achieve this objective, a phased program was used that included classroom training, simulation exercises, satellite system test support, and operational demonstrations. Each of these activities is discussed in the following paragraphs. A POS test chronology is given in Table 2-10.

1. Classroom Training

Between October 1977 and May 1978, five lecture sessions were presented to Seasat teams at GSFC. These sessions lasted from 1 to 10 days each and covered detailed descriptions of the mission profile, operations organization, ground data system, satellite vehicle, and science payload. JPL Mission Planning and Mission Control Teams, LMSC, Univac, and science sensor representatives presented 180 h of instruction. Training manuals were assembled from classroom materials and were retained for reference in the control center.

2. Simulation Exercises

Simulation exercises were conducted in three phases: (1) intra-team; (2) inter-team; and (3) combined POS. Each phase was designed to accommodate the development schedule for team procedures and GDS capabilities. A chronology of team exercises and GDS readiness dates is given in the following paragraphs.

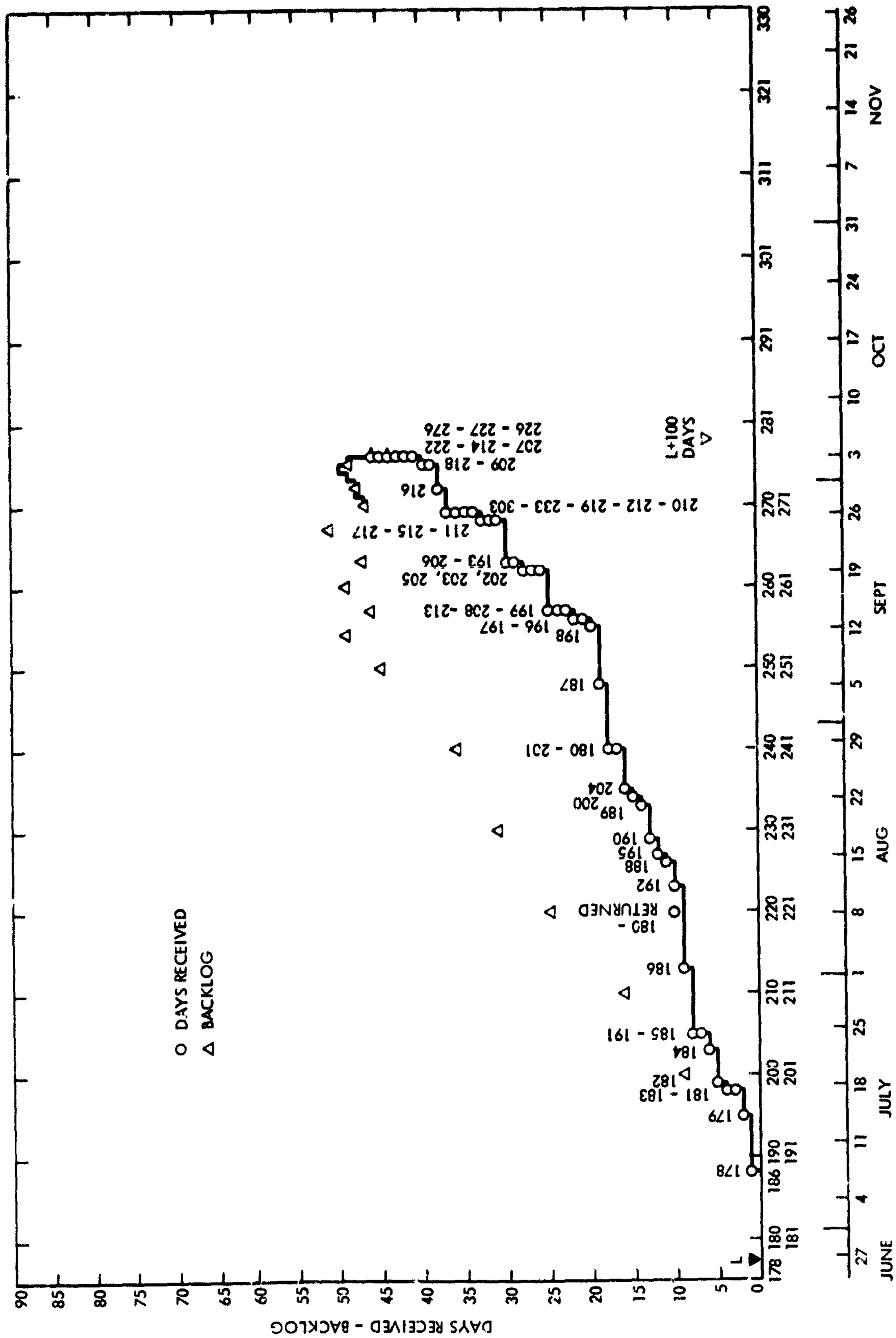


Figure 2-21. PMDF Delivery Schedule

Table 2-10. POS Test Chronology

Date	Event
1977	
12/15	POCC Version 4 (test version), Operational
12/16	Intra-Team: Telemetry Command
1978	
1/6	Intra-Team: Tape Recorder Operation
1/27	Intra-Team: SAR Operation
2/1	Orbit Determination System, Operational
2/15	POCC Version 5, Operational
2/17	Intra-Team: Launch and Early Orbit
2/22-24	Intra-Team: Orbit Adjust (three parts)
2/27	POCC Version 6, Operational
2/28	Intra-Team: Sensor Activation
3/16	Inter-Team: Launch and Early Orbit Attitude Determination System, Operational Command Management System, Operational Information Processing Division, Operational
3/20	POCC Version 7, Operational Network (Program II), Operational
3/23	Inter-Team: Launch and Early Orbit (retest)
3/24	Inter-Team: Orbit Adjust
3/27	MCCC (JPL), Operational
3/31	Inter-Team: Sensor Activation

C-2

Table 2-10. POS Test Chronology (Continuation 1)

Date	Event
4/3	POCC Version 8, Operational
4/6	Inter-Team: Launch and Early Orbit (retest)
4/12	Combined POS: Launch and Early Orbit
4/15	Flight Maneuver Analysis, Operational
4/20	Inter-Team: Attitude Trim (two parts)
4/24	POCC Version 9, Operational
5/9	Combined POS: SAR Targets of Opportunity
5/15	POCC Version 10 (launch version), Operational
5/16	Combined POS: Launch and Early Orbit
5/18	Combined POS: Orbit Adjust (four parts)

a. Intra-Team Exercises. These exercises emphasized real-time operations procedures and POCC capabilities. Between 16 December 1977 and 28 February 1978, nine exercises totaling 28 h were supported by MCT, SPAT, and POST. Of the eight test categories performed, only one was determined to be unsuccessful by the test supervisor. The test failure was attributed to spacecraft simulator problems. These problems were corrected, and a retest on 28 February was successful.

b. Inter-Team Exercises. These exercises expanded simulation participation to include non-real-time planning and analysis functions. Although the test categories and control center procedures used for intra-team testing remained essentially unchanged, data and procedural interfaces were exercised with the Mission Planning, Command Management, Orbit Determination, Attitude Determination, and Maneuver Analysis Teams. Seven tests, totaling 32 h, were conducted between 16 March and 27 April 1978. The launch and early orbit exercise was conducted three times, primarily because of data flow problems with the Simulation Operations Control Center (SOCC). The other three test categories were considered functionally successful, although all test reports indicated problems with the processing and distribution of satellite playback data.

c. <u>Combined POS Exercises</u>. For these exercises, the operations teams and end-to-end ground system were joined in a series of mission event simulations. Network support was provided by the MAD, MIL, Greenbelt, and ULA tracking stations. Four exercises totaling 30 h of real-time operations were conducted, including a launch and early orbit simulation supported by the Western Test Range (WTR) launch operations complex. All tests were considered successful. As in inter-team testing, however, satellite playback data processing was identified as a problem area.

3. Satellite System Test Support

As part of the POS training program, the MCT and SPAT conducted satellite system test activities. In February 1978, the LMSC Lead Monitor Analysts participated in the baseline simulated flight test at LMSC. The POCC was also configured for listen-only support of the thermal/vacuum and flight readiness (countdown) tests during April and May. During these three tests, more than 50 h of spacecraft data were analyzed and stored on history tapes for subsequent processing and display validation.

In March 1978, a satellite compatibility test was conducted using the STDN Compatibility Test Van (CTV) located at the LMSC Seasat facility in Sunnyvale. The test was conducted in two parts on 11 and 13 March. Part I consisted of a satellite/POCC (end-to-end) test. The test successfully demonstrated the compatibility of tracking, telemetry, and command interfaces between the satellite and the POS. Compatibility test results are documented in Part II of the Ground Data System Test Report.

4. Operational Demonstrations

As previously stated, the primary objective of the test and training plan was to demonstrate operational proficiency before the Seasat launch. Accordingly, three operational demonstrations were performed in May and June 1978. A mission planning and mission control exercise conducted during the week of 8 May demonstrated the capability to transfer and validate command data consistent with the mission profile. Reaction procedures for satellite and GDS anomalies were demonstrated in four exercises during the week of 15 May. The Mission Dress Rehearsal/Operational Readiness Test (MDR/ORT), conducted during the last 7 days before launch, was the final demonstration. The MDR/ORT was conducted in the final mission configuration and verified the readiness of the POS to perform the functional sequences that comprised the Seasat mission.

E. CONFIGURATION CONTROL

Beginning in February 1978, the hardware, software, and operational procedures comprising the Seasat POS were systematically placed under configuration control. Changes to the requirements or design of interactive POS elements were subject to approval by a Change Control Board consisting of the Project Operations Manager, JPL MCCC Manager, GSFC Mission Operations System Manager, and the

Chief of Mission Operations. The purpose of this board was to ensure that the integrated POS was maintained at an operational level adequate to support personnel training, launch, and flight operations.

Three levels of control criteria were employed:

(1) Configuration control.

(2) Modified configuration control.

(3) Configuration freeze.

Criteria definitions and their applicability to Seasat POS development and flight operations activities are shown in Tables 2-11 and 2-12.

Table 2-11. Configuration Control Definitions

Control Level	Definition
Configuration control	Changes limited to those that allowed accomplishment of mission requirements, as scheduled
Modified configuration control	Same as above, but required operations concurrence and system demonstration after modification
Configuration freeze	No system modifications; configuration broken only to restore from system failure. System demonstration required after restoration

Table 2-12. Configuration Control Schedule

System	Configuration Control	Modification Control	Configuration Freeze
POCC NASCOM	Integration delivery to L - 30 days	L - 30 days to L - 5 hours	L - 5 hours to L + 3 revolutions
	L + 17 days to end of mission	L + 3 revolutions to L + 17 days	
STDN	Integration delivery to L - 30 days	L - 30 days to pre-launch interface	Pre-launch interface to L + 3 revolutions
	L + 17 days to end of mission	L + 3 revolutions to L + 17 days	
MPS CMS ADS ODS FMOC IPD PDPS	Integration delivery to L - 30 days	L - 30 days to L + 17 days	
	L + 17 days to end of mission		

SECTION III

LAUNCH AND ORBIT INSERTION PHASES

A. INTRODUCTION

This section discusses the launch and orbit insertion phases of the Seasat mission. The launch phase is defined as that time period from liftoff to Agena second burn cutoff, and the orbit insertion phase as that from second burn cutoff to momentum wheel attitude control capture (12 to 25 h).

B. GROUND SYSTEM LAUNCH CONFIGURATION

1. Western Test Range

The WTR ground data system configuration is shown in Figure 2-19. All prelaunch direct control of the Atlas launch booster, Agena, and Seasat satellite was accomplished from the launch operations building (LOB) at Space Launch Complex-3 West (SLC-3W). During the initial boost phase after launch, both the WTR telemetry receiving station and NASA telemetry (TLM) antenna tracked the launch vehicle until loss of signal occurred. Two Advanced Range Instrumentation Aircraft (ARIA) were used to receive and transmit telemetry data during the first and second burns of the Agena propulsion system.

Radiometric data tracking of the launch vehicle was accomplished using the WTR radar tracking network.

2. Spacecraft Tracking and Data Network

The detailed STDN configurations are defined in GSFC document STDN-601/Seasat, Network Operations Support Plan (NOSP).

Six stations (MAD, ULA, GDS, HAW, ORR, and ACN) were used for launch support. MAD, ULA, and HAW were under configuration freeze (configuration broken only to correct failures; demonstration after restoration) and unavailability of their support was declared as launch hold criteria. GDS, ORR, and ACN were under configuration control (meet scheduled support).

The pre-pass checkout of these stations began four hours before liftoff and was completed in the order of ACN, ORR, HAW, GDS, ULA, and MAD. There were no launch vehicle requirements from the STDN stations; however, all stations provided normal spacecraft tracking support.

3. Project Operations Control Center

The POCC for Seasat was a part of the Multi-Satellite Control Center II (MSOCC II) complex. MSOCC II supported two other satellites besides Seasat and contained three identical Sigma 5 computers.

From launch minus 4 h to launch plus 8 h, one of the other two Sigma computers provided a hot backup to the Sigma 5 computer used for Seasat operations. This backup computer was loaded with the Seasat operating system and data base. In case of problems, the computer switching could have been made in approximately 1 min.

The software required to support the Sigma 5 computer system consisted of a Xerox real-time batch monitor (RBM) operating system and Seasat applications programs designated SEAC. The SEAC software provided the control center personnel the capabilities to monitor and command the activities of the spacecraft subsystems and sensors. The SEAC software was grouped into the following categories:

(1) Control Subsystem, which provided the functions required to service other programs.

(2) Telemetry Subsystem, which provided the capability to receive two inputs of data concurrently. One input could be recorded, processed, and displayed; the other input could be recorded and processed later.

(3) Command Subsystem, which provided for command generation from keyboards and a general-purpose console, transmission of commands to the tracking station, verification of the results of the commands, and the creation of the Command Master Data Record (CMDR).

(4) Display Subsystem, which provided capabilities for the display of commands and telemetry on CRT displays, line printers, and strip chart recorders.

Version 10.003 of the SEAC software was used to support the spacecraft launch. This system tape was produced on 12 June 1978, and was under configuration control. Liens against this software are summarized as follows:

Type	Written	Open
Discrepancy reports	107	15
Enhancement reports	31	11

The most significant discrepancy was the requirement for patches for Scanning Multichannel Microwave Radiometer (SMMR) special processing (square root routine for calculating standard deviation-produced negative numbers). This problem was solved by creating another system tape with these patches. This tape was used, as required, for SMMR special processing. This decision had no impact on launch support. These patches were later incorporated in system tape 10.004, created on 3 July 1978.

4. Orbit Determination Operations

The Orbit Computational Engineer from the Operations Support Computing Division was responsible for pre-launch and post-launch orbital computations, orbit determination, tracking data dissemination, and all other related support activities.

During launch, high-speed data in the form of position and velocity vectors in an Earth-fixed coordinate frame were received at GSFC by the Goddard Real-Time System (GRTS) from the launch support function at WTR. These high-speed data were used to drive the displays in the operations control viewing area. These data were available to GRTS at GSFC until the time of WTR loss of signal (LOS) during the first burn of the Agena stage.

The GRTS was used to perform orbital computations based on S-band tracking data from the STDN sites. The S-band tracking data were transmitted by teletype data links from the participating STDN stations by the GSFC NASCOM message switching system and then directly to the IBM 360-75 computer complex in near-real time. The orbital parameters and other pertinent data from these computations were made available to designated recipients in the operations areas.

C. SEQUENCE OF EVENTS (PLANNED VERSUS ACTUAL)

The Seasat satellite was launched from AFWTR by an Atlas/Agena launch vehicle at 01:12:44 GMT on 27 June 1978. The plotboards driven at GSFC indicated near-nominal vehicle performance. The vehicle was tracked by the AFWTR tracking network and by the ARIA 1 aircraft through the Agena first burn shutdown and by the ARIA 2 aircraft during the Agena second burn. Tables 3-1 through 3-4 list the planned versus actual events.

D. LAUNCH SITE ACTIVITIES

The AFWTR launch activities sequence in support of Seasat data requirements are listed in Table 3-5 and shown in Figure 3-1. All elements of the launch ground data system functioned properly except the ARIA Indian Ocean/Marisat/AFETR/LES-9 real-time telemetry satellite data link. As had been experienced in all GDS testing, excessive bit errors ($>50 \times 10^{-4}$) received at the WTR Telemetry Receiving Station (TRS) through the link were responsible for only a limited amount of data being received. Radio frequency interference (RFI) and modulation products were the most likely candidates to explain the experienced problems. However, the data link coordination control did not allow expedient fault isolation of the problems. The Air Force Indian Ocean Station (AFIOS) did record the Agena second burn events. With quick turnaround (launch plus 5 min), it successfully retransmitted the telemetry data to VAFB/TRS and to KSC/WLOD Telemetry Processing Station (TPS), where the data were processed and analyzed by the LMSC data van and JPL and LMSC analysts. All data received at the KSC/WLOD TPS were also successfully transmitted to the POCC Sigma 5 computer at GSFC.

Table 3-1. Launch Phase Programmed Events

No.	Event	Time Relative to Liftoff,s Planned	Time Relative to Liftoff,s Actual	Comments
1	Booster engine cutoff	130	130	WTR coverage
2	Booster engine jettison	133	133	WTR coverage
3	Shroud jettison	208	208	WTR/ARIA 1 coverage
4	Sustainer engine cutoff	285	285	WTR/ARIA 1 coverage
5	Start CTU clocks	290	290	WTR/ARIA 1 coverage
6	VECO enable	300	300	WTR/ARIA 1 coverage
7	VECO	304	304	WTR/ARIA 1 coverage
8	Separation	309	309	WTR/ARIA 1 coverage
9	First burn start	386	386	WTR/ARIA 1 coverage
10	First burn shutdown	617	617	ARIA 1 coverage
11	Second burn start	3436	3442	ARIA 2 coverage
12	Second burn shutdown	3442	3442	ARIA 2 coverage. ARIA 2 reported time for this event was in error. ARIA 2 data as processed in POCC were unusable

E. MISSION OPERATIONS ACTIVITIES

The POCC for the GSFC support of the Seasat mission was the Seasat Operations Control Center (Seasat OCC) located in building 14 at GSFC. The POCC was the focal point of project-unique operations, planning, and monitoring.

During the launch, the mission control function was performed in the Mission Control Room (MCR). The following personnel were present in the MCR:

(1) Project Operations Manager.

(2) Mission Support Manager.

Table 3-2. Orbit Insertion Phase Programmed Events

No.	Event	Time Relative to Liftoff,s		Comments
		Planned	Actual	
1	Oxidizer dump start	3445	3445	ARIA 2 coverage
2	Orbit antenna 1 deploy	4551	4551	MAD coverage
3	Fuel dump start	5107	5107	
4	Solar arrays deploy	5640	5640	ULA/GDS coverage
5	Deploy SAR data link antenna	6199	6199	HAW coverage
6	Deploy SASS antennas 1,3	6209	6209	HAW coverage
7	Deploy SASS antennas 2,4	6234	6234	HAW coverage
8	SAR antenna 90 deg pitchout	6409	6409	HAW coverage

(3) Ground Data Systems Engineer.

(4) Launch Coordinator.

The following personnel were not required to be present in the MCR, but were in constant communications with the Mission Support Manager:

(1) Orbit Computations Engineer.

(2) Attitude Determination Engineer.

(3) Network Operations Director.

In the Seasat POCC, the following personnel were present:

(1) Chief of Mission Operations.

(2) Two Assistant Chiefs of Mission Operations.

Table 3-3. Orbit Insertion Phase Non-Programmed Events

No.	Event	STDN and Rev Number Planned	Actual	Comments
1	Solar array rotation	HAW 1	ACN 1	S/C receiver not locked on HAW uplink
2	SAR antenna 90 deg rotate	ORR 1	ULA 2	ORR. Negative acquisition
3	SAR antenna extended	MAD 2	HAW 2	
4	SAR antenna extend motor shutoff	ULA 2	HAW 2	
5	CTU B off	MAD 2	ULA 5	
6	Tranet amplifiers on	MAD 2	MIL 4	
7	Converter 3 on, 1 off	HAW 2	GWM 9	Sequence not correct
8	Clock preset	ULA 3	AGO 5	
9	Start PMW	ULA 3	ULA 4	
10	Start RRW	GWM 4	GWM 4	
11	Successful wheel capture	MAD 16	ACN 16	Four attempts were made earlier, but were unsuccessful

(3) Two SPAT Teams.

(4) SPAT Leader.

(5) SPAT Lead Monitor Analyst.

Other LMSC experts were required to be in the Launch Support Room, and were in communications with the Lead Monitor Analyst.

Table 3-4. Activities Planned But Not Carried Out
(See Systems Performance)

No.	Event	Planned Time	Comments
1	Switch transmitters	ULA 1	
2	Ranging	MAD 1	5 min, 00 s, ranging
		HAW 1	1 min, 20 s, ranging
		ACN 1	4 min, 00 s, ranging
		MAD 2	1 min, 00 s, ranging
		ULA 2	1 min, 00 s, ranging
		HAW 2	1 min, 00 s, ranging
		ORR 2	4 min, 00 s, ranging
		ACN 2	10 min, 00 s, ranging
		GWM 4	5 min, 00 s, ranging

1. Telephone Communications

Telephone communications were established for the Seasat mission to provide for effective control, liasion, coordination, and data collection. It was the responsibility of the Assistant Chief of Mission Operations (ACMO) to be aware of all activities and the status of the other teams. The ACMO received periodic reports from:

(1) Mission Support Manager.

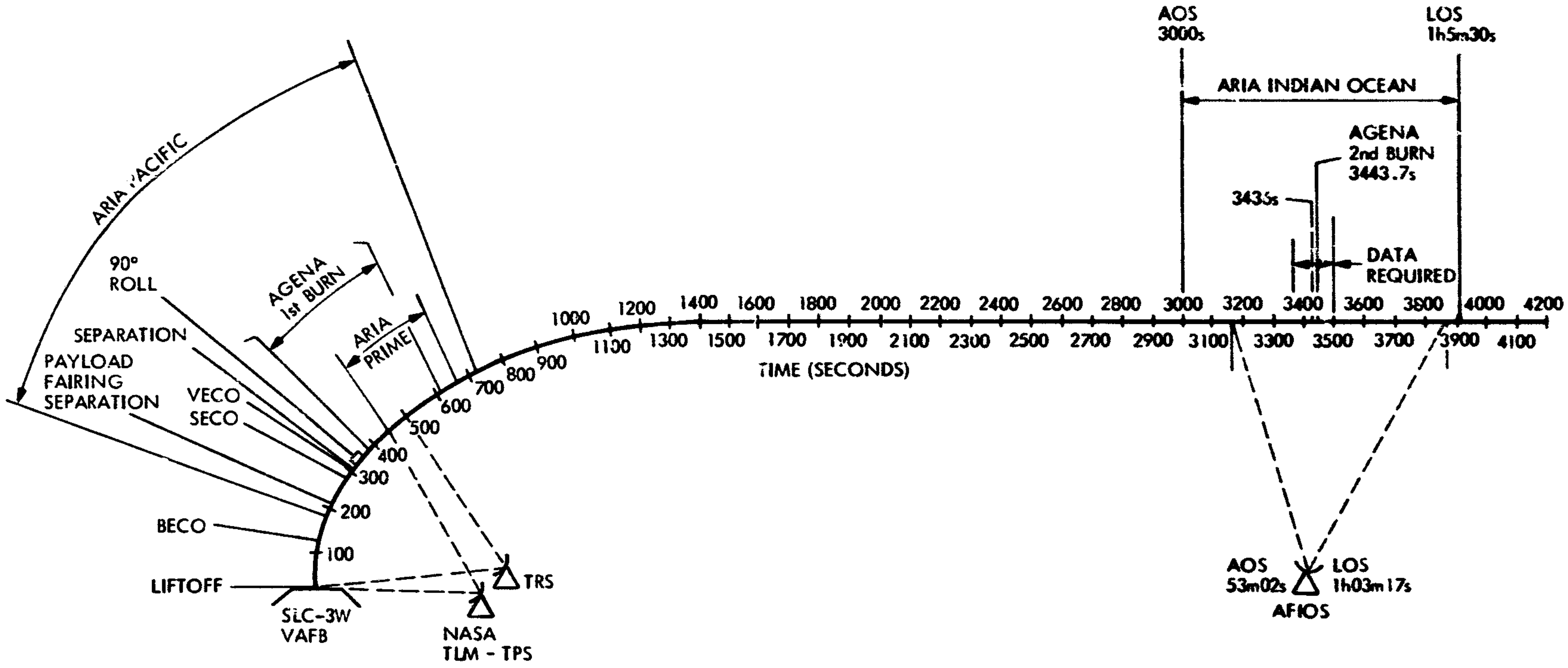
(2) Control Center Operations Manager.

(3) Network Operations Manager.

(4) SPAT Lead Monitor Analyst.

Table 3-5. Launch Activities Supporting Seasat Data Requirements

No.	Event/Item	Time
1	High-speed simulated data flow and IRV validation	L - 100 min
2	ARIA (IO)/GSFC validation (BERTS and simulation tape)	L - 90 min
3	Agena final readiness (Task 5)	L - 65 min
4	T - 60 min jimsphere balloon release (6) (contingency)	L - 60 min
5	ARIA (PAC)/TRS revalidation (BERTS)	L - 40 min
6	LOX tanking (Task 6)	L - 35 min
7	Satellite vehicle open loop radiation	L - 30 min
8	ARIA (PAC) configuration for mission support	
9	Terminal count (Task 7), telemetry flight recorder on	L - 13 min
10	Range green	L - 3 min
11	Liftoff	L - 0 min
12	Transmit real-time high-speed data to GSFC	
13	ARIA (PAC) Tacsat carrier on	L + 60 s
14	ARIA (PAC) AOS	L + 180 s
15	ARIA (PAC)/ROS report 3 mark events (GMT time with event readouts)	L + 616.5 s
16	ARIA (PAC)/ROS report 1 mark event	L + 636.5 s
17	ARIA (PAC) LOS	L + 720 s
18	Transmit IRV to LMSC and GSFC	L + 800 s
19	ARIA (IO)/TRS data flow (BERTS)	L + 1200 s
20	ARIA (IO)/TRS data flow (BERTS)	L + 2100 s



TIME	DATA USER	PRIME	BACKUP
PL TO T-30M	VAN POCC	TPS TRS	TRS TPS
T-30 TO L+450s	VAN POCC	TRS TRS	TPS/ARIA (PAC) W/GAP (260s)
L+450s TO L+720s	VAN POCC	ARIA (PAC) ARIA (PAC)	TRS (TO 490s) TRS (TO 490s)
L+720s TO L+3000s	VAN POCC	NONE	
L+3000s TO L+3930s	VAN POCC	ARIA (IO) ARIA (IO)	AFIOS AFIOS

Figure 3-1. Seasat Launch Support Profile

2. Displays

Pre-launch and real-time launch data pertaining to the mission were displayed on illuminated screens at the front of the Operations Control Area (OPSCON). The operations center branch was responsible for the implementation and operation of these displays:

(1) Launch count.

(2) Launch events and orbital elements.

(3) Flight path angle versus velocity ratio.

(4) Subsatellite plot.

(5) Countdown clock.

(6) Tracking and telemetry schedule.

(7) Acquisition elevation angles and mark events.

(8) Picture screen.

F. SYSTEMS PERFORMANCE

At launch, the powered flight trajectory of Seasat produced an injection orbit that was within specifications, although somewhat off the nominal values (Table 3-6). Figure 3-2 shows LMSC Monte Carlo-modeled distributions for the orbit parameters of interest. The ΔV required to correct the launch orbit was 6.3 m/s compared to a nominal value of 4.4 m/s and a 99 percent probability level of 11 m/s.

G. GROUND SYSTEM PERFORMANCE

Information available at GSFC indicated that the WTR and the ARIA deployed over the Pacific Ocean (overlapping with WTR) acquired Seasat launch telemetry (25 kb/s) in accordance with the pre-flight planned timeline. The data were transmitted in near-real time to the LMSC computer van at WTR and the POCC at GSFC.

The second ARIA supporting this phase of the mission, deployed over the Indian Ocean, acquired the spacecraft telemetry downlink only intermittently, providing no usable telemetry data to either WTR or the POCC. The Air Force Satellite Control Facility (AFSCF) Indian Ocean Station, however, provided nearly redundant coverage to the ARIA and did acquire the satellite telemetry data through the second burn, recording these data on magnetic tape. The data were played back to WTR after loss of signal (end of view period).

The STDN Madrid 26-m station performed successful initial acquisition and provided real-time spacecraft 25-kb/s telemetry data to the GSFC POCC, but was unable to successfully acquire the uplink. As a result of this, no ranging or

Table 3-6. Achieved Injection Conditions

Parameter	Value		Cumulative Probability Level, %	Pre-Launch Specification
Semi-major axis, km	Mean	7170.271	50.45	7150-7186
	Nominal	7168.7	30.93	
	Actual	7162.770	0.89	
Eccentricity	Mean	0.001560	54.84	0.0-0.0052
	Nominal	0.0008	15.75	
	Actual	0.000667	9.99	
Inclination, deg	Mean	108.09	51.80	107.5-108.5
	Nominal	108.00	20.10	
	Actual	108.023	27.07	
Argument of perigee, deg	Mean	71.7	61.82	0-360
	Nominal	90.4	87.68	
	Actual	254.0	99.86	

commanding could be performed. Madrid reported using a real-time interrange vector (IRV) generated by GSFC and reported the following predict angle differences (relative to on-track angles) by voice report:

Initial acquisition: [illegible] deg X,Y angles

Loss of signal: 5 deg X angle, 2 deg Y angle

Alaska was the next station, following the Madrid view period, which was scheduled to track, acquire telemetry data, and transmit commands issued from the POCC computer. A critical command in the sequence was the switch from the ascent omni antenna on the side of the Agena tank to the on-orbit antenna. Alaska failed to detect the Seasat downlink. A post-launch analysis of 9-m antenna angle data showed that the station used the real-time acquisition message (GSFC had requested the pre-flight nominal be used) containing time and angle errors outside the capability of the 9-m antenna system to effect a main-beam intercept. The following were found to be Alaska acquisition problems:

(1) Real-time acquisition data were less accurate than pre-flight nominals.

(2) GSFC Network Support Team passed predict message day time group and sequence number to station instead of predict type and epoch (needed for computer designation).

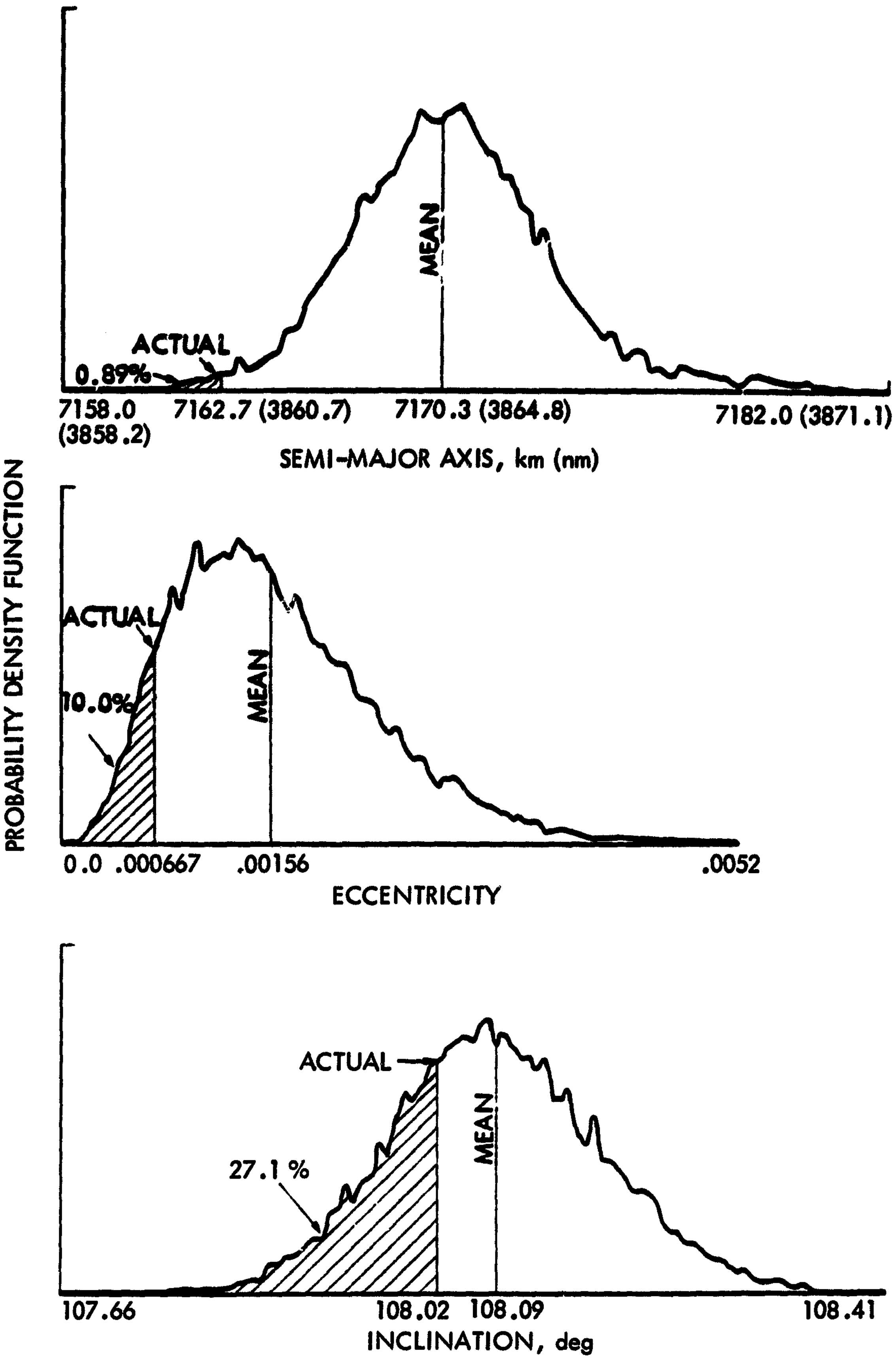


Figure 3-2. Monte Carlo Distribution of Injection Conditions

(3) Alaska inadvertently chose an intercept point too close to the terrain.

(4) Alaska stayed in manual antenna mode instead of initiating program track mode at predicted acquisition of signal (AOS) time plus 30 s (standard procedure).

During the first five passes, all stations except Ascension Island (ACN) had problems in acquiring the uplink to the spacecraft. The ACN personnel were trained to initiate "search out" at the exciter control when uplink sweep intercepted ground uplink channel frequency at a zero SPE. This may explain why ACN was able to maintain uplink lock and uplink commands, while other stations were apparently dropping spacecraft receiver lock on previous and subsequent passes.

Other stations showed improvements in their ability to acquire and maintain lock in the spacecraft receiver by adopting the following changes:

(1) Lowering the mod index from 0.98 to 0.85.

(2) Slowing the sweep rate.

(3) Using medium loop bandwidth.

These procedures were implemented during rev 5.

The POCC computer system functioned well during the launch and early orbits. There were only two occasions when the Sigma 5 was rebooted. Erroneous readings, which indicated that the computer's real-time telemetry processor was in a failed condition, required the reboots.

SECTION IV

ORBITAL CRUISE PHASE

A. INTRODUCTION

The Orbital Cruise Phase, defined as being between the Launch and Orbit Insertion Phase and the Calibration Phase, had a designated time period of 2 weeks, starting with the first available STDN ground station contact. In fact, there was some overlap between the Launch and Orbit Insertion Phase and the Orbital Cruise Phase, where satellite subsystems and total system assessment and analysis were scheduled to have been performed. The overlap period spanned revs 001 through 005, when the satellite clock was first set and data taking began. This followed the successful deployment of the data antennas, sensor elements, and other satellite appendages.

Initially, primary assessment emphasis was given to the Power, Attitude, and Data Systems, followed by the Thermal System and, finally, the Propulsion System during orbit maneuvers. After sufficient analyses of orbital tracking data had been completed, a precision orbit determination was made and the resultant maneuver recommendations generated. However, because of Attitude Control System (ACS) problems, the recommendation was not to perform a maneuver during this time period. With the orbit being established, extensive Attitude Control System analysis was performed along with the planned sensor engineering assessment.

The sensor assessment was conducted, as planned, in three phases: (1) early sensor turn-on; (2) sensor quiet period; and (3) all sensors on. At the end of the Orbital Cruise Phase, all sensors were on and the transition to the Calibration Phase was effected. Figure 4-1 shows the ascent-to-orbit sequence.

B. SEQUENCE OF EVENTS

Two sequences are shown for the planned Orbital Cruise Phase in Figure 4-2 and Table 4-1. These are the Early Science Mission Sequence and the Planned Mission Sequence, respectively. Table 4-2 lists the Actual Mission Sequence.

C. MISSION OPERATIONS SYSTEM ACTIVITIES

The MOS activities for this phase were conducted from a "baseline" sequence of events (SOE) that was developed specifically for Pre-Launch, Launch, Orbit Insertion, and Orbital Cruise Phases by the Mission Control Team (MCT). This third sequence was developed from the information obtained from the two sequences of events listed in the previous paragraph. The MCT 15-day sequence is a document containing the detailed planned operations activities for the Orbital Cruise Phase. As this detailed SOE is a complete pre-definition of the time period, it is impossible because of its size to include it in this report.

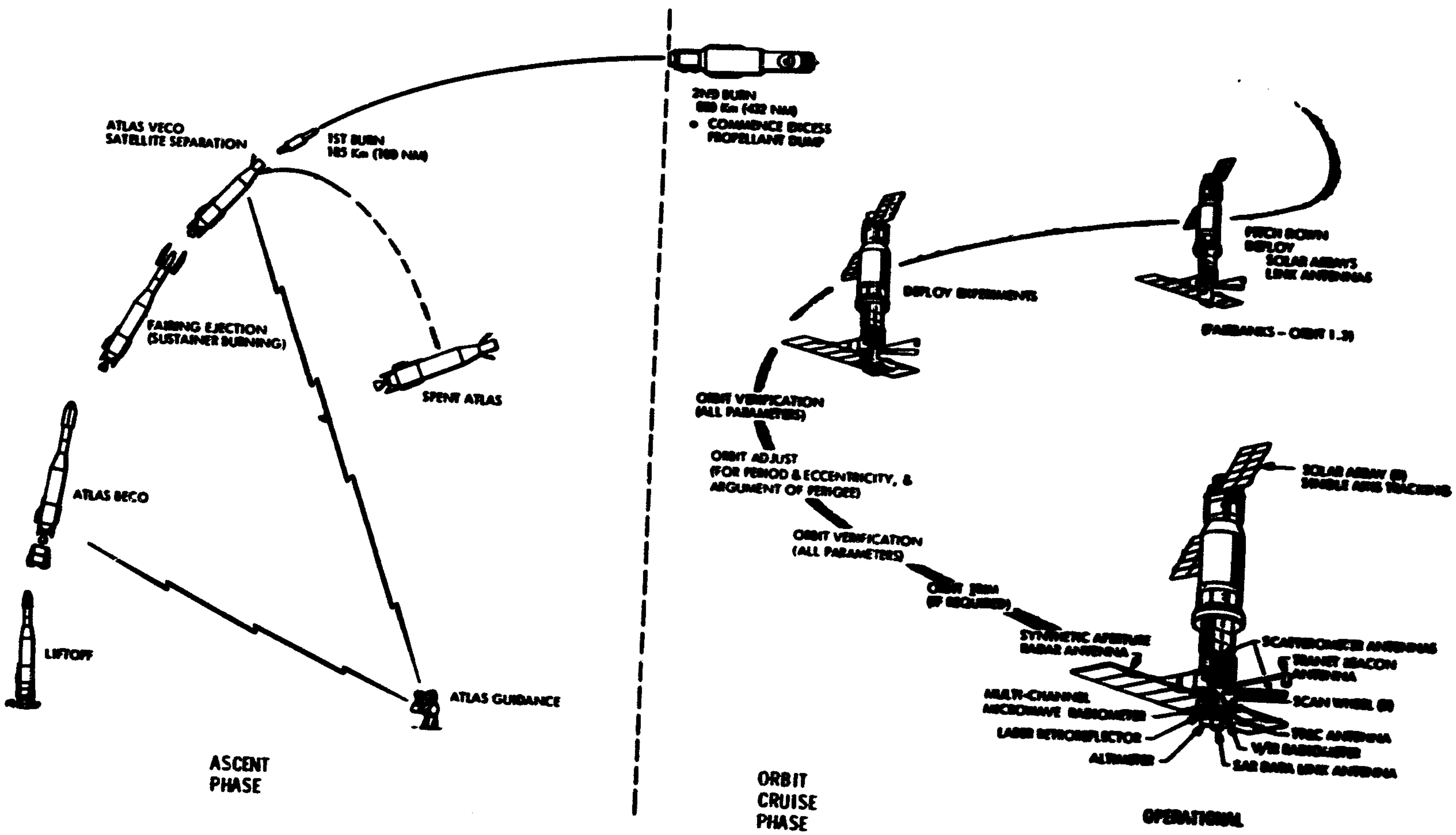


Figure 4-1. Ascent-to-Orbit Sequence

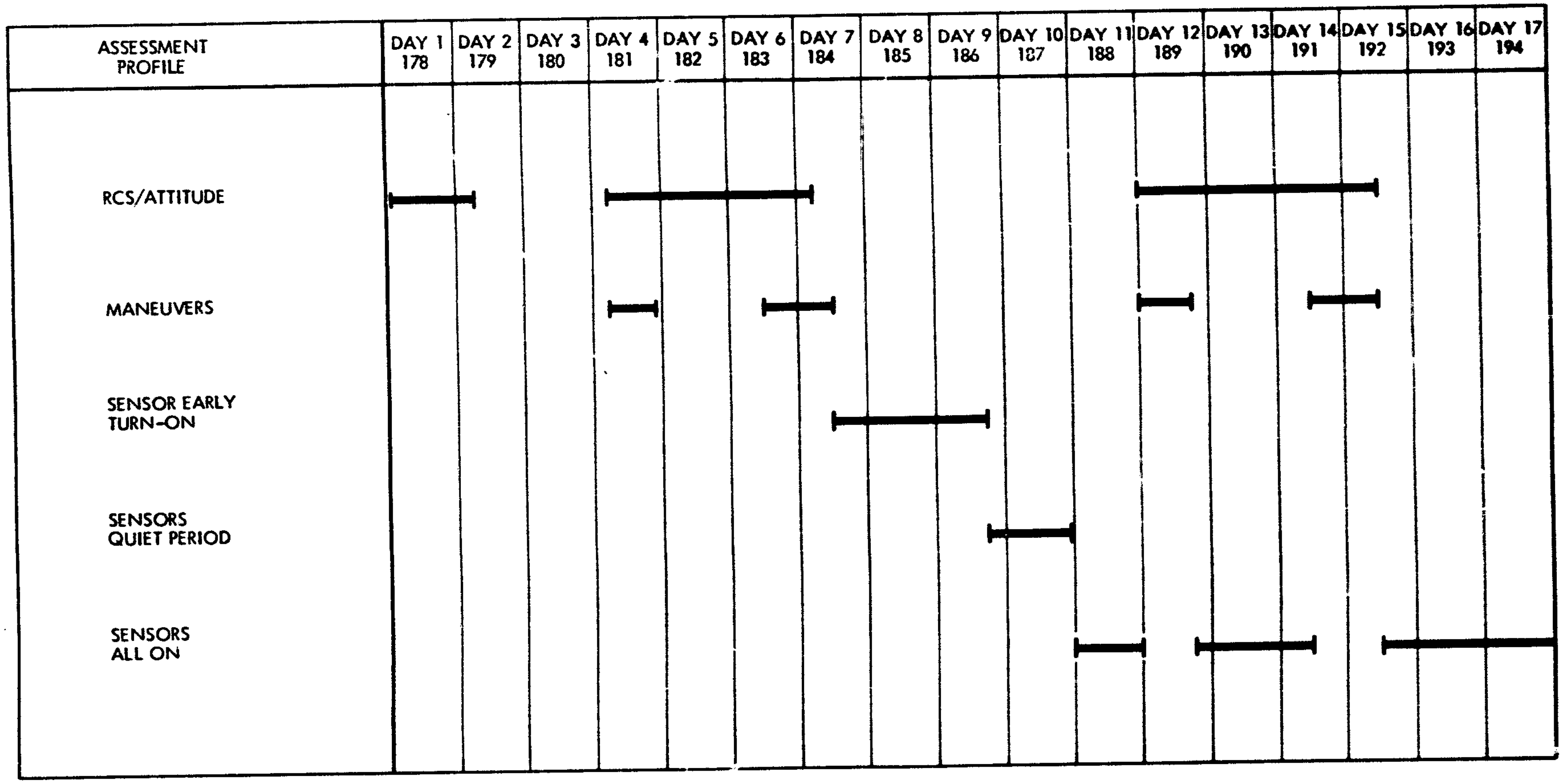


Figure 4-2. Early Science Mission Sequence

Table 4-1. Planned Mission Sequence

Date	Day	Rev	GMT	Event
06/26/78	177			F-1 day preparations. Countdown start
06/27/78	178		01:05:00	Liftoff
		0001		Deploy antennas and solar array
		0001 to 0002		Deploy SAR antennas
		0003		Set clock and release. Power. Zero SMMR. Power subsystem checkout. ACS checkout and analysis. First Orbit Determination (OD)
06/28/78	179	0016		Transfer from Reaction Control System (RCS) to OACS
		0021		Begin processing of full-rev data for ACS
		0023		Post-injection orbit solution
		0025		Load attitude trim commands
			18:00:00	Maneuver meeting (cal. burn No. 1)
			22:00:00	Maneuver load to CMS
06/29/78	180	0029 to		All day: ACS evaluation
		0042	14:00:00	Review maneuver load
			17:00:00	Orbit solution
			20:00:00	Orbit Adjust Maneuver Program (OAMP) run
06/30/78	181	0043	00:00:00	Begin maneuver period. Execute cal. burn No. 1
			12:00:00	End maneuver period
			14:00:00	Manuever meeting (Orbit Adjust (OA) maneuver No. 1)

Table 4-1. Planned Mission Sequence (Continuation 1)

Date	Day	Rev	GMT	Event
06/30/78	181	0043	17:00:00	Orbit solution
			20:00:00	OAMP run
			22:00:00	Maneuver load to CMS
07/01/78	182	0057 to 0071	15:00:00	Post-maneuver orbit solution
			18:00:00	Final OAMP run
			20:00:00	Review and adjust maneuver load
			22:00:00	Adjusted maneuver to CMS
07/02/78	183	0078	09:00:00	Begin maneuver period. Execute OA maneuver No. 1
07/03/78	184	0092	12:00:00	End of maneuver period.
		0094		Altimeter (ALT) early turn-on No. 1 (HAW)
		0096		ALT early turn-on No. 2 (ORR)
		0098	12:00:00	ALT early turn-on No. 3 (MIL)
		0099		SAR early turn-on No. 1 (MIL)
07/04/78	185	0100		SAR turn-on No. 2 (GDS)
		0102		SMRR turn-on No. 1 (MAD). ALT early turn-on No. 4 (HAW)
		0103		SAR turn-on No. 3 (ULA)
				VIRR turn-on No. 1 (ORR)
		0104		SMRR turn-on No. 2 (GWM)
		0105		SAR turn-on No. 4 (MIL)
		0106		SAR turn-on No. 5 (ULA)
		0109		SMMR turn-on No. 3 (HAW)

Table 4-1. Planned Mission Sequence (Continuation 2)

Date	Day	Rev	GMT	Event
07/05/78	186	0115 to 0128		
07/06/78	187	0130		ALT on. Begin quiet time (ULA)
		0133		VIRR on. Begin quiet time (AGO)
		0136		SMMR on. Begin quiet time (ULA)
		0139		SASS on. Begin quiet time (MAD)
		0141		SASS HVPS on, Mode 1 (MIL RTC)
			14:00:00	Select cal. burn No. 2 sequence
			22:00:00	Cal. burn No. 2 load to CMS
07/07/78	188	0143	00:00:00	SASS operating, Mode 1. ALT on, Track 1 (GDS)
		0144		VIRR to operate (GDS)
		0145		SMMR on (ULA)
		0150		Begin normal SAR operation
			16:00:00	Approve maneuver load
			17:00:00	Orbit solution
			20:00:00	OAMP run
07/08/78	189	0158 to	00:00:00	Begin maneuver period. Execute cal. burn No. 2
		0171	12:00:00	End of maneuver period. ALT on, Track 1. SASS on, Mode 1. VIRR on. SMMR on. SAR normal operations
			14:00:00	Select OA maneuver No. 2 sequence
			22:00:00	Maneuver load to CMS

Table 4-1. Planned Mission Sequence (Continuation 3)

Date	Day	Rev	GMT	Event
07/09/78	190	0172 to 0185		Sensors on. Satellite quiet day
			15:00:00	Post-maneuver solution
			18:00:00	Final OAMP run
			21:00:00	Predicted post-maneuver ephemeris
07/10/78	191	0186 to 0199	09:00:00	Begin maneuver period
07/11/78	192	0200 to 0214	12:00:00	Execute OA maneuver No. 2. End of maneuver period. ALT on, Track 1. SASS on, Mode 1. VIRR on. SMMR on. SAR normal ops. Satellite quiet day.

Table 4-2. Actual Mission Sequence

Date	Day	Rev	GMT	Event
06/27/78	178	0009	17:26:30	Converter No. 1 off (GWM)
06/28/78	179	0016	03:31:00	Attempt wheel capture. Unsuccessful (MAD)
		0017	05:01:00	Attempt wheel capture. Unsuccessful (ACN)
		0019	09:52:30	Clock fine adjust (AGO)
		0027	22:57:30	Adjust RRW bias (MIL)
06/29/78	180	0030	03:00:00	Attempt wheel capture. Unsuccessful (MAD)
			03:26:00	Back to RCS (HAW)
		0042	23:41:00	Stopped PMW. Reset RRW. Magnetic desaturation off (MIL)
06/30/78	181	0044	02:30:00	Disable Right Scan Wheel Assembly (RSWA) output
		0051	15:50:00	High Mode Reaction Control Cluster (HMRCC) heater off (HAW)
		0055	21:36:00	PMW to on (ULA)
			21:48:00	Send first clock offset and first clock adjust command (AGO)
		0056	23:08:00	Clock adjust command. Normalized clock to microseconds (MIL)
07/01/78	182	0060	03:41:00	Transfer to OACS (HAW)
			05:08:00	Back to RCS (ACN)
		0061	05:37:19	Right signal processor to off (ULA)
			06:43:30	PMW to off (ACN)

Table 4-2. Actual Mission Sequence (Continuation 1)

Date	Day	Rev	GMT	Event
		0067	17:51:00	Control Logic Assembly (CLA) power supply No. 1 to off (ACN)
		0070	21:17:00	ALT heater bus rapid cycling noted (AGO)
07/02/78	183	0072	00:17:00	PMW to on (GDS)
			00:17:01	CLA power to Magnetic Control Assembly (MCA) off (GDS)
		0074	03:09:00	Transfer to OACS (hyd. desaturation) (MAD)
		0075	05:23:00	Transfer back to RCS (HAW)
			06:15:00	PMW stop (ACN)
07/04/78	185	0102	04:14:11	ALT fourth turn-on (HAW)
			04:29:27	ALT turned off (HAW)
		0103	05:27:00	Rerun of SMMR early turn-on No. 1 (MAD)
			05:31:00	SMMR turned off (MAD)
			05:43:13	SAR early turn-on No. 3 (ULA)
			05:53:53	SAR turned off (ULA)
			06:16:48	VIRR first turn-on (ORR)
			06:22:26	VIRR electronics off (ORR)
		0104	07:41:35	SMMR early turn-on No. 2 (GWM)
			07:50:40	SMMR turned off (GWM)
		0105	08:44:36	SAR early turn-on No. 4 (MIL)
			08:53:30	SAR turned off (MIL)

Table 4-2. Actual Mission Sequence (Continuation 2)

Date	Day	Rev	GMT	Event
07/04/78	185	0107	12:05:29	SAR early turn-on No. 5 (GDS)
			12:24:29	SAR turned off (ULA)
		0108	15:22:40	SMMR early turn-on No. 3 (HAW)
			15:34:25	SMMR turned off (HAW)
07/05/78	186	0114	00:23:00	CLA power on (GDS)
			00:23:01	Left signal processor off (GDS)
			00:23:31	CLA power supply No. 2 off (GDS)
			00:25:00	PMW started (GDS)
		0116	04:45:00	Transfer to OACS; wheel capture (ACN)
		0124	17:14:00	Magnetic desaturation (MAD)
07/06/78	187	0130	03:09:39	ALT fifth turn-on (GDS)
		0133	08:21:17	ALT turned off (GWM)
			09:09:09	VIRR second turn-on (AGO)
		0136	12:57:02	VIRR electronics off (ULA)
		0136	12:59:02	SMMR turn-on No. 4 (ULA)
		0139	18:17:03	SMMR turned off (MAD)
			18:19:18	SASS enabled (MAD)
		0141	21:43:59	SASS turn-on No. 1 (MIL)
07/07/78	188	0143	01:03:11	SMMR turn-on No. 5 (MIL)
		0144	02:41:49	VIRR final turn-on (HAW)
		0145	04:17:11	ALT final turn-on (ULA)
		0153	18:02:00	Connect solar array panels 9 and 10 (ACN)

Table 4-2. Actual Mission Sequence (Continuation 3)

Date	Day	Rev	GMT	Event
07/08/78	189	0159	03:24:00	CLA power on (MAD)
			03:24:05	CLA power supply No. 2 off (MAD)
		0160	05:09:00	Left Scan Wheel Assembly (LSWA) processor off (MAD)
07/10/78	191	0199	23:01:00	Switched from orbit adjust to orbit normal mode (MIL)

The MCT SOE was a major product generated solely by the MCT before launch, and it served well as the baseline operations activities plan in most areas. The MCT SOE started at launch minus 4.5 h and ran through launch plus 15 days. It contained all of the pre-launch procedures to activate the WTR, STDN, and its attendant NASCOM facilities, data flow tests, and operational status checks throughout the GDS before launch and subsequent orbits.

The exceptions to this plan are discussed on a day-to-day basis in the following paragraphs. The Attitude Control System was the major exception and significantly impacted the SOE, resulting in a cancellation of all orbit adjust and trim maneuvers until a later date. SOE integrity was maintained for sensor activation and, generally, for tape recorder management. Tape recorder management by the MCT in real time proved to be more complex than estimated. The primary reason for this was caused by holding specific attitude data onboard the satellite until the GDS could verify its capture had been accomplished. This occurred twice. What had been anticipated as a hold of several hours resulted in a tape recorder hold of days while the desired attitude data worked its way through the GDS and was validated by analysis.

The MCT SOE was designed to merge into the first Mission Planning SOE (MSOE) starting on day 191 (10 July 1978). This schedule demanded timely execution of the science or sensor turn-on operation activities, as planned. The sensor engineering assessment phases were as follows:

(1) Early turn-on, with each sensor being individually turned on, assessed, and then turned off.

(2) Sensor quiet period, in which all sensors were activated individually and remained on for mutual evaluation and for assessment of RF interference.

(3) All sensors on for operational assessment.

The SASS was an exception to this activation process, as the SASS sensor team specified a single turn-on cycle. It was the last sensor to be activated, and it remained on until the mission terminated.

With the orbit maneuvers postponed, it would seem to have diminished the total number of activities to be performed. The additional requirement to establish an operational OACS mode placed stringent demands on the time available because of the cancellation of the planned orbit maneuvers. All major objectives, except the orbit maneuvers and the limited attitude control performance, were successfully completed, and the phaseover to the MSOE at the conclusion of the Orbital Cruise Phase was accomplished as planned.

D. MISSION PLANNING TEAM OPERATIONS

1. Mission Planning Software

Subsequent to launch, satellite problems and the modification of sensor operations required some additional revisions to the mission planning software. Key among these was the satellite thermostat malfunction, which required the development of the SAR operating philosophy in response to both power shortages and increased experimentor interest in acquisition of SAR data for spot targets rather than limited continuous swaths. The latter increased the SAR planning activity to the point where it was the dominant planning activity, requiring both iterative computer runs and considerable manual intervention. Program modifications to accommodate these changes were made in parallel with normal flight planning and were incorporated into a third mission build version of the software (MOSS 1.2) on 1 October 1978. At the time of the Seasat power failure, which terminated the mission on 10 October 1978, development was underway on a machine-to-machine interface with the SAR target identification and selection software.

Several problems occurred in the use of the mission planning software set during the mission. The problem mentioned above, where either a change in operating characteristics of the satellite or a change in operating philosophy occurred, is an obvious one in which the actual requirements upon the operating system were not adequately enveloped by the imposed requirements. It was, however, recognized prior to launch that such an occurrence was not only possible, but quite likely, and the software was designed so that individual programs could be changed or added without impacting the balance of the software through the use of standardized input/output intermediate files. This was an anticipated problem, and was one of implementation rather than wholesale modification.

A second, and more subtle, problem not fully anticipated was the requirement for a high degree of manual intervention and human decision in the operation of the software. Before launch, it was felt that once operational, the software could be run in what would essentially be a batch mode with output review and iteration. Therefore, the input and review functions could be separated to a high degree from the running of the software. In actual practice, however, the inherent flexibility of the software and the large number of decision points encountered in progressing through the routines (Figure 4-3) required that the operator not only be fully acquainted with the inputs and the actual science requirements on a day-to-day basis, but also that he perform a review function on the intermediate files as the run progressed. This effectively precluded the use of data assistants in the operation and required that sequencing engineers run the programs.

A third problem encountered in operations involved a software error in the MCCC IBM 360 computer software which reblocked the CRP for high-speed data line (HSDL) transmission. Each command or comment in the CRP occupied a single card image, with nine card images grouped into a data record for the 1108 to 360 interface. The 360 blocked the CRP into six-card records compatible with the NASCOM HSDLs. A special X-card was included in the CRP to mark the transition between days, each day starting with a special card bearing processing information for the CMS designated as the stored program command (SPC) load card. When the SPC load card appeared as the first card in a nine-card image record, the 360 software would initialize. This was normal for the first day in the CRP, but if any SPC load card occurred in the first card image of subsequent records, the initialization caused the preceding six cards to be discarded by the system. After the initial discovery of this problem, an immediate workaround was effected by retransmitting individual days of CRP to avoid recurrence. Once the problem was understood, a special stand-alone program was written to determine the location of all SPC load cards in the CRP so that dummy comments could be inserted to ensure that the SPC load card did not occur as the first card in any record. The problem was finally corrected in the 360 development software about 30 days after the discovery of the problem. No notification was received that the change was effected in the operational system.

A fourth problem encountered resulted from the insertion of satellite commands into the command loads without processing them through the CMS. When relatively few of these commands were being inserted from the POCC, or when they were processed through the CMS, they could be checked effectively for timing violations, in the former case manually and in the latter automatically by the CMS computer. With the addition of approximately 100 heater cycling commands a week to the POCC-generated commands, manual checking was insufficient to locate all time conflicts. As a result, several times command coincidences occurred in the loads. The satellite was mechanized to execute the first command recognized for any given second and to ignore any others carrying the same GMT time. The command coincidences resulted in, among other things, failure to execute a heater bus on command and a SAR no-transmit command, both potentially dangerous to the satellite. For any similar mission in the future, the software must exist to check for constraints downstream of the last point at which unchecked commands are routinely inserted.

2. SAMDPO Software

Actual development and testing of SAMDPO continued throughout the lifetime of the Seasat mission. All problems encountered in the operation were worked out during the operation with the exception of an apparently intermittent problem in

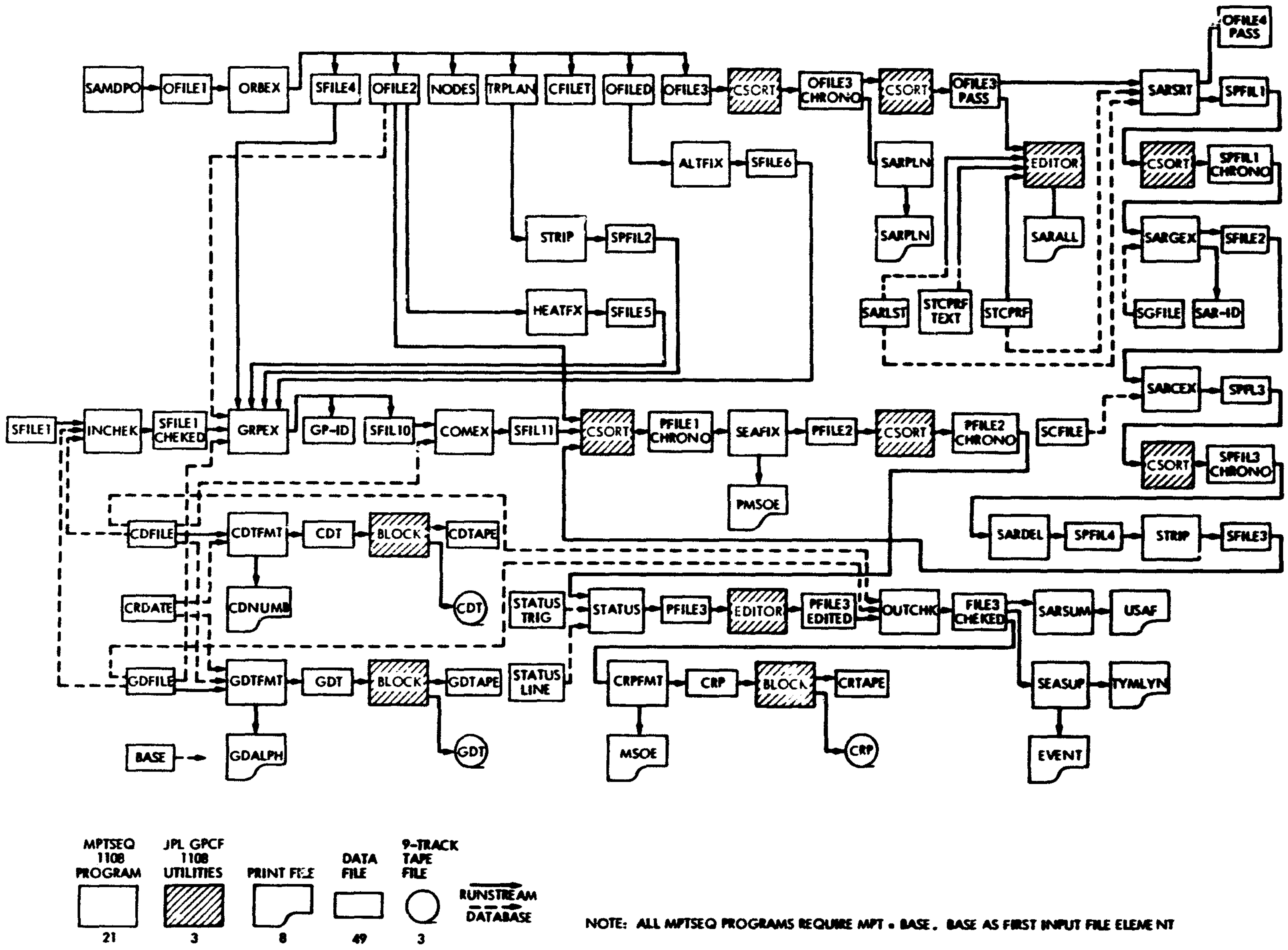


Figure 4-3. Mission Planning Team Sequence Software

the long-term orbit predicter, which resulted in miscalculations of the position of ascending nodes. The source of this problem was never located, but the problem could be avoided by checking the SAMDPO output against the tables of predicted ascending node positions generated by other software.

Flight experience showed that the orbital event predictions produced by SAMDPO matched extremely well with events observed during the flight. Originally, it was thought that the age of the ephemeris data used by SAMDPO might result in errors along the track which would be reflected in significant timing errors toward the end of the prediction span (roughly orbit epoch time plus 2 weeks). To guard against these errors, a time correction capability had been incorporated into the CMS so that more recent Code 570 inputs might be used to produce daily time corrections known as super time trims. Flight experience was such that the use of the super time trim was never required.

The one drawback to using SAMDPO as an operational program was the excessive running time required. Although converting the predecessor program used for mission design to an operational program was attractive from a programming standpoint, a totally new operational program designed specifically for the Seasat mission planning might have been more efficient in the long term. The operations plan called for the running of 4 weeks of predicts once each week. The size of SAMDPO and the number of calculations required each run were both so large that special operational procedures were required both to avoid excessive costs and to ensure that the required runs could be completed each week. Input decks were prepared and submitted each Friday afternoon with instructions to delay running them until after the files were dumped on the 1108 computer system each Friday night. Even so, with the program running on a near-dry system, run times were never shorter than 3 h although using the full capability of the 1108 computer system. If the program had to be run on weekend days in competition with batch and demand jobs on the system with higher priorities, run times of 15 h were not uncommon. For a program of this complexity and size, the total cost trade-off between developmental costs and operational costs should be made. This trade-off was not necessarily made in the case of SAMDPO.

The information interfaces generally worked well. Because of the relatively fluid nature of flight operations planning, the detailed mechanization of the information interfaces was left relatively unfrozen until just before launch, and then permitted to evolve into a comfortable working relationship. The primary early emphasis was on establishing a single point of contact for each information interface and developing the best possible understanding of the early orbit operations desired. As it turned out, the SMMR and VIRR low-rate sensors had only recommended turn-on and turn-off sequences, several operational constraints, and a limited set of assessment requirements. For the remainder of the mission, the goal of both sensors was to collect an uninterrupted set of all possible data.

The other two low-rate sensors did have an active interface with the MPS. The altimeter was represented for both science acquisition and engineering assessment by the Altimeter Sensor Manager of Wallops Flight Center. Engineering assessment requirements were identified and reviewed in an expeditious manner and presented no problems, as was also the case with altimeter group commands. A calibration algorithm was developed several months before launch and was implemented in the mission planning software. Altimeter science acquisition requirements were modified during flight in response to suspected altimeter problems and the thermal control thermostat failures. In each case, the nature of the sequencing changes had been anticipated before launch, and the appropriate command triggers and routines existed in the software. It remained only to negotiate the details of the changes and to implement them. As only command algorithms were at issue, no extended interaction was required, and the interface was effected entirely through black phone with datafax backup.

The SASS presented more of a problem, as the science requirements included approximately 300 sensor mode changes each week to accommodate specific coverage of selected targets. These changes were transmitted from the Langley Research Center to the MPS by datafax each week for the operational period several weeks ahead. The mode changes were then reviewed for consistency and manually inserted into a computer input file. Machine checking identified only syntax errors, not input errors. As a result, during the mission several mode changes at erroneous times slipped into the CRP. This should have been a machine-to-machine interface with manual review and override to eliminate errors.

The SAR group was the only sensor group with full-time representation at JPL. As a result, information flow between the SAR and the MPS occurred daily on a face-to-face basis, which was fortunate because, ultimately, the SAR planning became the largest single activity of the MPS. Before launch, each SAR member had identified SAR targets of interest and time periods for data acquisition over each target based on the pre-launch nominal orbit. With the delay in orbit adjust maneuvers because of the attitude control anomalies subsequent to launch, the pre-flight SAR planning was invalid. During the early portion of the flight mission, SAR experiment requests were hand-generated for a nominal six 10-min SAR passes each day, but the planning guidelines called for issuing the SAR transmit command at 10-deg elevation or station AOS, whichever was predicted to occur later. This meant that the information required across the interface between the SAR and the MPS was the revolution number and SAR ground station requested plus any special instructions for engineering assessment commands. As the minimum power period for the satellite approached, however, the SAR operating time was curtailed to conserve power. By this time, the first SAR processing of data had convinced the experiment team members that SAR passes much less than 10 min in duration were of value if they included specific targets of interest.

As a result, the normal mode of operation during the minimum power period became the acquisition of from two to eight SAR passes varying in duration from 2 to 6 min each day. The information passing across the interface at this point became the GMT time of turn-on and turn-off, the SAR ground station requested, and any special assessment commands. While capability to accommodate this form of input existed in the mission planning software, problems were encountered. Many targets of interest were at relatively low elevation angles within the SAR station passes. Errors in specifying the GMT times, which were due to differences in orbit solutions used in the target selection and CRP preparation processes resulted in requested SAR on and off times lying outside ground station view. The impact to the MPS was that these occurrences had to be flagged as planning violations, reviewed, manually adjusted, and rerun through the software. This added an iterative loop both in the software operation and across the information interface not envisioned before launch. The problem created became increasingly severe after the end of the minimum power period when as many as 12 SAR passes each day over specific targets of interest would be routinely requested. At the time of mission termination, effort was in process within the SAR experiment team to program the target selection algorithm in the 1108 computer system in terms of delta time with respect to time of ascending node. This program was intended to produce a computer file of SAR pass requests that could be accessed by the planning software so that the GMT times could be generated without ground station mask violations. There is every reason to believe that, had development of this machine-to-machine interface been completed and used, SAR planning would have been greatly simplified.

The information interface with SPAT never materialized as envisioned before launch. Originally, it was intended that one SPAT member would be located at JPL full-time to represent SPAT within the MPS. This representative was to be in daily contact with the main body of SPAT at GSFC to serve as a liason for passing planning information other than the MPS deliverables to GSFC and near-real-time performance information to the MPS. As a result of, first, the attitude control anomalies, then the heater thermostat failures, and finally the low power problem, the SPAT representative was required to remain at GSFC to assist in real-time data analysis and command through September 1978. The representative had spent about 3 weeks in residence at JPL at the time of the mission termination, most of which was devoted to the installation of the LMSC power prediction program on the 1108 computer system. During his stay at GSFC, MPS contact with SPAT was largely through black phone contacts with the representative. While this was adequate as a temporary measure, information flow between the MPS and GSFC would have been much improved if the SPAT representative had been available for involvement in the planning process on a daily basis. One of the most glaring Seasat deficiencies was the lack of any mechanism other than the SPAT representative's residence at JPL for returning performance and command information to JPL on a timely and rigorous basis. The LMSC daily status bulletins, initiated considerably after launch, were of considerable help in providing this information, but were irregular in delivery and were often incomplete.

E. SYSTEMS PERFORMANCE

1. Satellite Performance

This section provides a summary of spacecraft systems performance during the orbital cruise phase of the mission. Plans to produce a monthly satellite performance analysis report (described in JPL internal document 622-42, Seasat-A Spaceflight Operations Plan, May 1978) did not materialize because of early problems described here.

Wheel captures were attempted on revs 16 (MAD) and 17 (ACN), but large attitude errors forced a return to the Reaction Control System (RCS) in each instance.

In an attempt to minimize the attitude errors, the Roll Reaction Wheel (RRW) bias was changed on rev 27 (MIL), and wheel capture was again attempted on rev 30 (MAD). On rev 30 (HAW), the attitude errors again became excessive, and the satellite was returned to the RCS.

On rev 42 (MIL) the Pitch Momentum Wheel (PMW) and the RRW were stopped, and magnetic desaturation was turned off. The Right Scan Wheel Assembly (RSWA) output was inhibited on rev 45 (MAD). The High Mode Reaction Control Cluster (HMRCC) heater was turned off on rev 51 (HAW) for power conservation. On rev 55 (MIL), the PMW was turned on.

Another attempt was made to transfer to the Orbital Attitude Control System (OACS) on rev 60 (HAW), but again wheel capture was denied by excessive attitude errors, and the satellite was returned to the RCS on rev 60 (ACN). The right signal processor and the PMW were turned off on rev 61 (ULA/ACN), and Control Logic Assembly (CLA) power supply 2 was turned off on rev 67 (ACN).

Rapid cycling of the altimeter heater bus was observed on rev 70 (AGO) and again on rev 71 (MIL). The cyclic period was approximately 10 s. The appropriate LMSC subsystem engineers were alerted to this condition.

In preparation for another attempt to transfer to the OACS, the PMW was turned on, and CLA power to the Magnetic Control Assembly (MCA) was turned off on rev 72 (GDS). Transfer to the OACS in the hydrazine desaturation mode occurred on rev 74 (MAD). By rev 75 (HAW), the attitude errors had become excessive, and the satellite was transferred back to the RCS. PMW stop was executed on rev 75 (ACN), and the magnetic desaturation mode was inhibited on rev 76 (ULA).

A test was conducted on rev 88 (MAD/ORR) to gather more data on the attitude problem. The gyros were turned on during rev 86 (GDS) and permitted to stabilize for two orbits. The forward gyro started, and the Scan Wheel Assembly (SWA) pitch and roll was enabled. With the spacecraft on gyros, the left and right SWAs were alternately enabled for one revolution each. At the conclusion of this test, attitude subsystem efforts were suspended until rev 114 (GDS).

The sensor engineering assessment phase began on rev 94 (HAW), and ended on rev 145 (ULA). During this period, the sensors were individually cycled on and off at the direction of the applicable sensor representatives.

The initial turn-on for the altimeter was aborted when the station was unable to receive satellite data because of a ground equipment problem. Subsequently, the altimeter was turned on and off a total of five times, with final turn-on occurring on rev 145 (ULA).

The SAR was cycled on and off five times. During the first on period, the pulse repetition frequency (PRF) switch was set to position 4 to enable the ground equipment to lock on the data.

The first turn-on attempt for the SMMR occurred on rev 102 (MAD). The instrument was not in the proper mode to accept the turn-on sequence as formulated, and pass time expired before a new command sequence could be initiated to the spacecraft. The SMMR was subsequently turned on and off, without incident, a total of three times and was ultimately turned on during rev 136 (ULA).

VIRR on and off sequences were routinely accomplished twice during this phase. The final turn-on occurred on rev 144 (HAW).

With no preliminaries, the SASS was enabled on rev 139 (MAD), and was turned on during rev 141 (MIL). Figure 4-4 shows a timeline of the sensor on/off sequences during the engineering assessment phase.

Following the engineering assessment phase, power considerations required that solar array panels 9 and 10 be connected to the system. This was accomplished on rev 153 (ACN).

The sensor on/off sequence was interrupted by another attempt at wheel capture. CLA power on, left signal processor off, CLA power supply 2 off, and PMW start were all accomplished on rev 114 (GDS). The spacecraft was transferred to the OACS on rev 116 (ACN). Magnetic desaturation was initiated on rev 142 (MAD). With acceptable stability demonstrated, CLA power on and CLA power supply 2 off were sent on rev 159 (MAD). LSWA processor off was sent on rev 160 (MAD), and the vehicle was transferred from the orbit adjust to the orbit normal mode on rev 199 (MIL).

2. Ground System Performance

Ground system operations for this time period began with rev 6 and extended through rev 199 (days 178 to 192). This phase of the operations was the most active of the mission. Normally, this phase was planned to begin after rev 3, when the satellite clock was reset to current GMT. The clock was not set to GMT until rev 5 (AGO), completing the configuration of the data subsystem, and was the last planned step before the start of the Orbital Cruise Phase.

Scheduling for the Orbital Cruise Phase was performed and submitted according to the plan outlined in the Space Flight Operations Plan (SFOP). A total of 295 STDN passes were planned and scheduled. On an average, this was slightly over 22.5 passes each day, with the peak day being launch day with a total of 37 passes. By the time the Orbital Cruise Phase began with rev 6, 22 passes had been completed (refer to Section III). A total of 295 passes were scheduled and 289 were conducted as scheduled. The reasons for the loss of the six passes (approximately 2 percent) were as follows:

(1) Skylab. Two passes lost to critical Skylab coverage.

(2) Communications. Two passes lost because of a 3760 computer problem and a wide band data line (WBDL) problem.

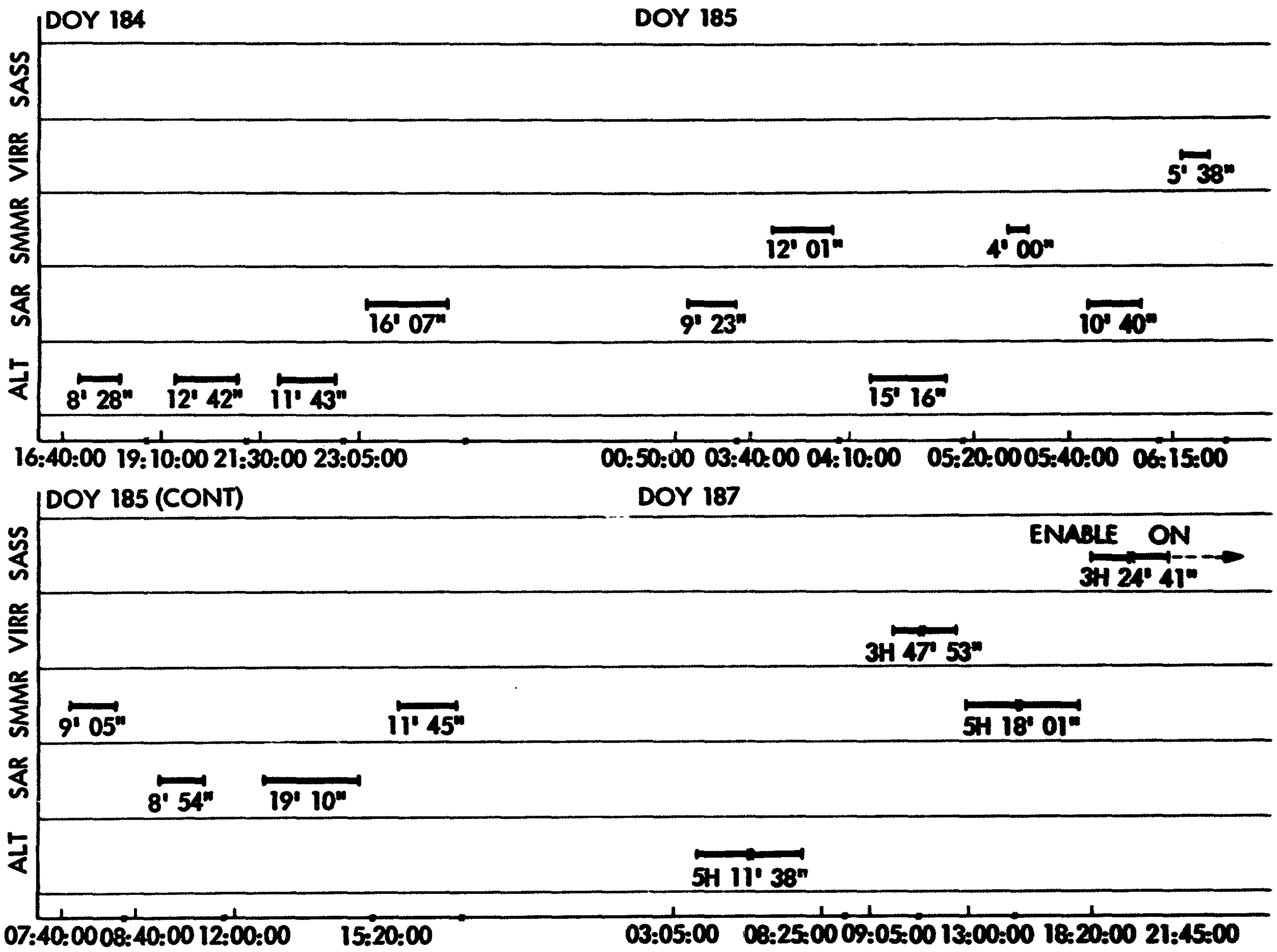


Figure 4-4. Sensor On/Off Sequence Timeline

(3) Spacecraft Command Encoder. One pass cancelled because of red Spacecraft Command Encoder (SCE).

(4) Sigma 5 Computer. One pass cancelled to give time to implement SEAC software Version 10.005.

The scheduling during this phase proceeded very well; however, this high activity had an adverse effect on securing enough Sigma 5 time to perform playback of TELOPS tapes to the Attitude Determination System (ADS), post-real-time analysis of TELOPS tapes, and other background processing required to support the mission in real time.

TELOPS/IPD was also specifically scheduled to provide the Seasat/POCC with quick-look playback tapes. These tapes and orbits were pre-defined to evaluate the characteristics of the ACS when the satellite was under the control of the OACS. Additionally, data were also to be processed, analyzed, and fitted to the predicted power usage curve, which had been generated by the LMSC power program.

As the LMSC attitude programs could only be completely tested by using actual satellite data, the early receipt of TELOPS tapes was vital to the verification of these programs. During these first days of the mission, documented records of the delivery of tapes from TELOPS were not maintained. Late delivery, coupled with the satellite ACS problems, had a severe impact on real-time failure analysis and the planned systems analysis of the attitude control and power systems.

The POCC Sigma 5 computer was responsible for the largest number of failures during this mission phase. During the 289 real-time passes performed, there were 109 various discrete failures or real-time data losses. The Sigma 5 was re-initialized during real-time passes 47 times. In addition to these single "reboots," eight additional "double reboots" were required. Finally, two complete system reloads were required during this phase.

Normally, the first action taken to correct a problem was to initiate a Sigma 5 reboot. Therefore, some of these re-initialization attempts to correct a problem were misdirected at the Sigma 5. Double reboot was the term used when the first re-initialization attempt did not clear the data processing problems and a second Sigma 5 initialization was required immediately after the first attempt.

At two different times, a complete system reload was performed. The characteristics of the Sigma 5 and SEAC software were such that reboots or failures occurred in groups over a period of time. Because of frequent reboots over a short period of time, a system reload would be performed. A system reload required about 1 h, and had to be carefully planned to re-establish the unique data processing subroutines (procedures) used by the MCT and SPAT to analyze the satellite data in real time. It appeared that perhaps the Sigma 5 core was becoming fragmented, impeding data processing. This problem was not specifically identified on the next SEAC software (Version 10.005), which was implemented on the last day of this phase (day 191).

One documented interface problem that continued and often resulted in a Sigma 5 reboot was the failure of CRT and keyboard devices. These interface failures, which were hardware failures at the CRT/Sigma 5 interface, did not normally affect the on-going data processing of the SEAC program, but were to clear the device and return it to an operational status after a reboot was required. Another Sigma 5 interface that failed on some occasions was the POCC Data Set Controllers (DSCs). There were two DSC failures in this phase. A DSC failure was difficult to distinguish from NASCOM data line failures. There were also five failures in the NASCOM segment of the ground system during this phase.

The ADS/Sigma 5 interface also precipitated numerous Sigma 5 reboots, although only one ADS failure was clearly recorded on a real-time pass log. This failure typically manifested itself at the conclusion of a Sigma 5-to-ADS transmission. During these transmissions, the Sigma 5 stripped out eight parameters from the TELOPS playback tapes, built data records, and transmitted these records to ADS through an HSDL. The Sigma's telemetry data processing following this task would not function properly (for real-time operations) unless it was re-initialized after a non-real-time ADS transmission. This interface problem was corrected by implementing ground system operating procedures in the Seasat POCC.

A second HSDL/Sigma 5 interface was the CMS/Sigma 5 interface. While this interface was not planned to be exercised extensively during this phase, the HSDL/CMS interface frequently failed throughout the life of the mission. The backup to the HSDL was hand delivery of the CMS tapes to the POCC. Because of the close proximity of the POCC and CMS facilities, the HSDL failure was not investigated in any depth.

The last category of direct Sigma 5 and POCC interfaces to be discussed is the Orbit Determination System (ODS) interface. Two problem areas reported in the ACMO's completed pass logs were range tapes and satellite tracking predicts at the STDN stations. The ranging tape was generated by ODS to be used by the Sigma 5 Timecal Program. The output of this program was used to determine the satellite clock offset from actual GMT. One documented range tape failure occurred in this phase. However, because of the turnaround time required to obtain a new tape from the ODS, only one failure created a significant problem in producing time offsets as planned every 24 h. A delay resulting from a range tape problem had a rippling effect through subsequent data processing by TELOPS and other users of this clock offset information.

There were two ODS (predict) problems in this phase: (1) the predicted AOS/LOS times on the predict sets being used by the STDN stations were in error by more than several seconds, and (2) the orbit numbers on the predicts used by the stations were offset by one orbit for several days. During the time when the AOS times were incorrect (from several seconds to approximately 1 min), the MCT was operating in a single tape recorder mode. Inaccurate predicts caused delayed acquisitions and missed opportunitites to perform tape recorder dumps over planned STDN stations. The orbit number errors required an excessive amount of additional bookkeeping to correct orbit numbers when this very valuable time was needed to perform real-time problem analysis in the POCC.

The second most significant category of failures was those originating at the STDN stations. A total of 42 discrete failures resulting in data losses occurred during this phase. The most common failure type was again software related, as over 50 percent of the failures were either SCE or Digital Data Processing System (DDPS) failures. The SCE failures, of which there were 13, generally occurred at random throughout the network. However, the DDPS failures, of which there were nine, were primarily concentrated at ULA and were DDPS program 3 failures.

Another category of failures was those where the station's receiver dropped lock because of a mode change on the satellite or because the initial receiver configuration was not compatible with the satellite downlink. Following launch, all STDN stations had difficulty in maintaining two-way lock and in commanding Seasat. With the stations' assistance, particularly MIL, an acquisition procedure was developed in real time that proved to be very successful. This new STDN procedure changed the nominal sweep rates and uplink mod/index levels as stated in the NOSP standard acquisition procedure. There were several data losses related to changing RF modes on the satellite; these were the 800-kb/s data playback mode and the ranging mode. Data losses because of switching to a 800-kb/s data playback mode diminished over a very short time period. This problem appeared to have been procedural, and was corrected by the STDN station operators. Five data losses occurred during this phase following ranging on/off commands and data losses continued to occur at random throughout the mission. This problem was not investigated in any depth by the Seasat Project to determine if these data losses were satellite- or station-related problems.

In summary, there was a discrete system failure for every 2.7 orbits. In addition, there were interface problems that spanned part or all of the Orbital Cruise Phase and were not relevant to an orbit-by-orbit accounting. No other data are at hand to compare with these failure points. While the failure rate seems to be much higher than in other mission periods, the total mission activity was also at its peak during this phase and more demands were placed on all elements of the ground system. Problems were not an unexpected factor in any case, and almost all were corrected quickly and expertly by the responsible personnel in the ground system, as had been expected before launch. In the areas where immediate solutions were available, procedural workarounds were quickly implemented. All major planned events were executed except the orbit maneuvers. The MCT was prepared to conduct these maneuvers, if required. The transition to the Calibration Phase from the Orbital Cruise Phase was completed as planned.

SECTION V

CALIBRATION PHASE

A. INTRODUCTION

This section discusses the mission operations activities during the Calibration Phase of the mission. The Calibration Phase is defined as the time period in which the required calibrations for the spacecraft sensors were performed. The primary purpose of this phase was to demonstrate the operational capabilities of the spacecraft and covered the time period of 30 to 90 days after initial checkout.

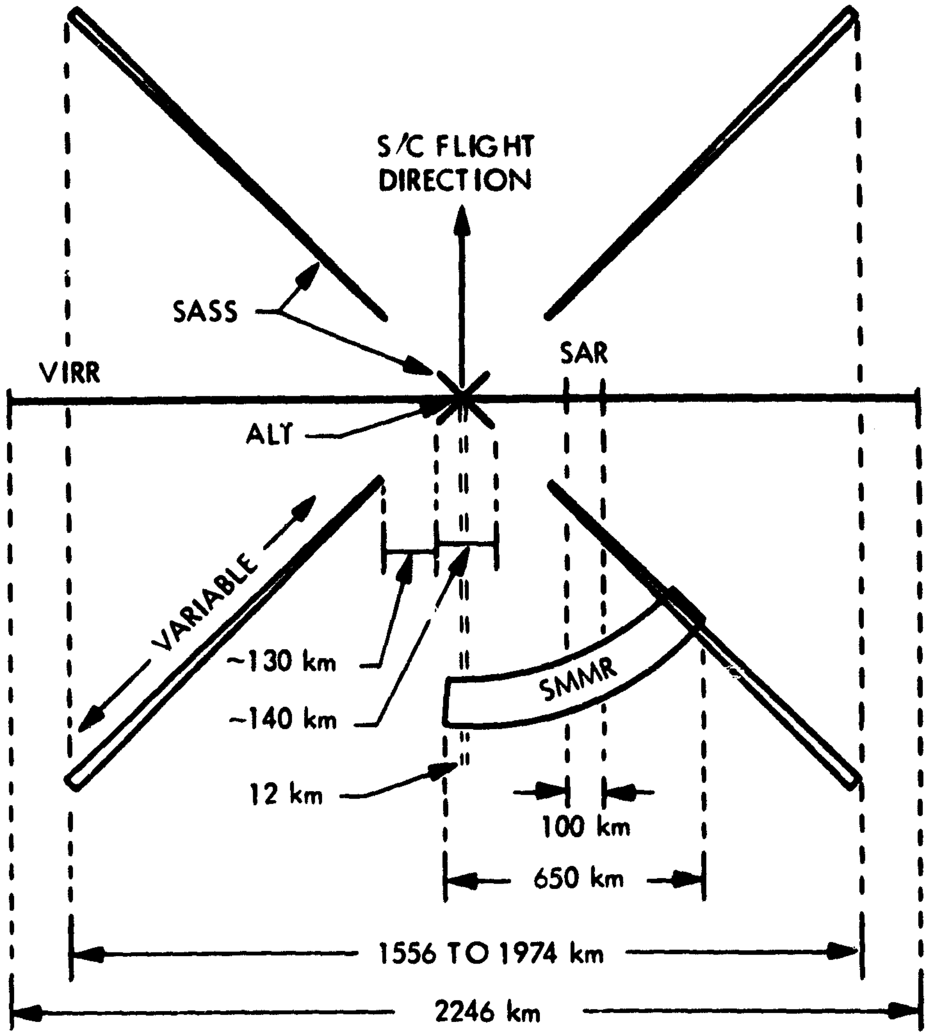
B. SEQUENCE OF EVENTS

The sequence of events for this phase of the mission was the standard Mission Sequence of Events (MSOE). As described in Section I, the MSOE was the final product of the Mission Planning Team (MPT). It was the responsibility of the Mission Control Team (MCT) to review, update if required, and implement the sequence as received from the MPT. Although the MCT maintained a very active interface with the MPT, the MCT had very little visibility with the other MPT interfaces. It was these interfaces that determined the science mission profile during the Calibration Phase. In summary, the MCT focused on the conduct of the mission while the MPT coordinated the calibration outputs.

C. SENSOR CALIBRATION

Five sensors were carried aboard the Seasat spacecraft. The Radar Altimeter, Scatterometer (SASS), and Synthetic Aperture Radar (SAR) were active radiators, and the Scanning Multichannel Microwave Radiometer (SMMR) and Visual and Infrared Radiometer (VIRR) were passive receivers. Each sensor had different coverage characteristics, depending on the pointing, field-of-view, and data handling requirements and, for the SASS, the Doppler velocity between the spacecraft and the ground points. The sensors were secured to the spacecraft so that changes in coverage occurred only as a result of changes in the spacecraft position or altitude. The only exception to this was the altimeter, which sensed conditions at the subsatellite point normal to the surface and independent of nominal spacecraft oscillations.

The swath for each sensor was defined by the ground cross-track area produced by the sensor's receiving field-of-view. The ground pattern and swath for each sensor is shown in Figure 5-1. The ground trace of each sensor swath is shown for one orbit on a Mercator projection in Figures 5-2 through 5-5. The calibration objectives for the sensors are described in the following paragraphs.



INSTRUMENT POINTING (DEGREES)

	CONE	CLOCK	FOV
ALT	0	0	1.5 CIRCULAR
SAR	20.5	90	±3 CONE
SASS	0-7, 19.5-55	45	±0.25 CROSS CONE
	"	135	"
	"	225	"
	"	315	"
SMMR	42	133-183	±2 CONE
VIRR	51.38	90,270	±0.15 CROSS CONE

Figure 5-1. Seasat Instrument Coverage

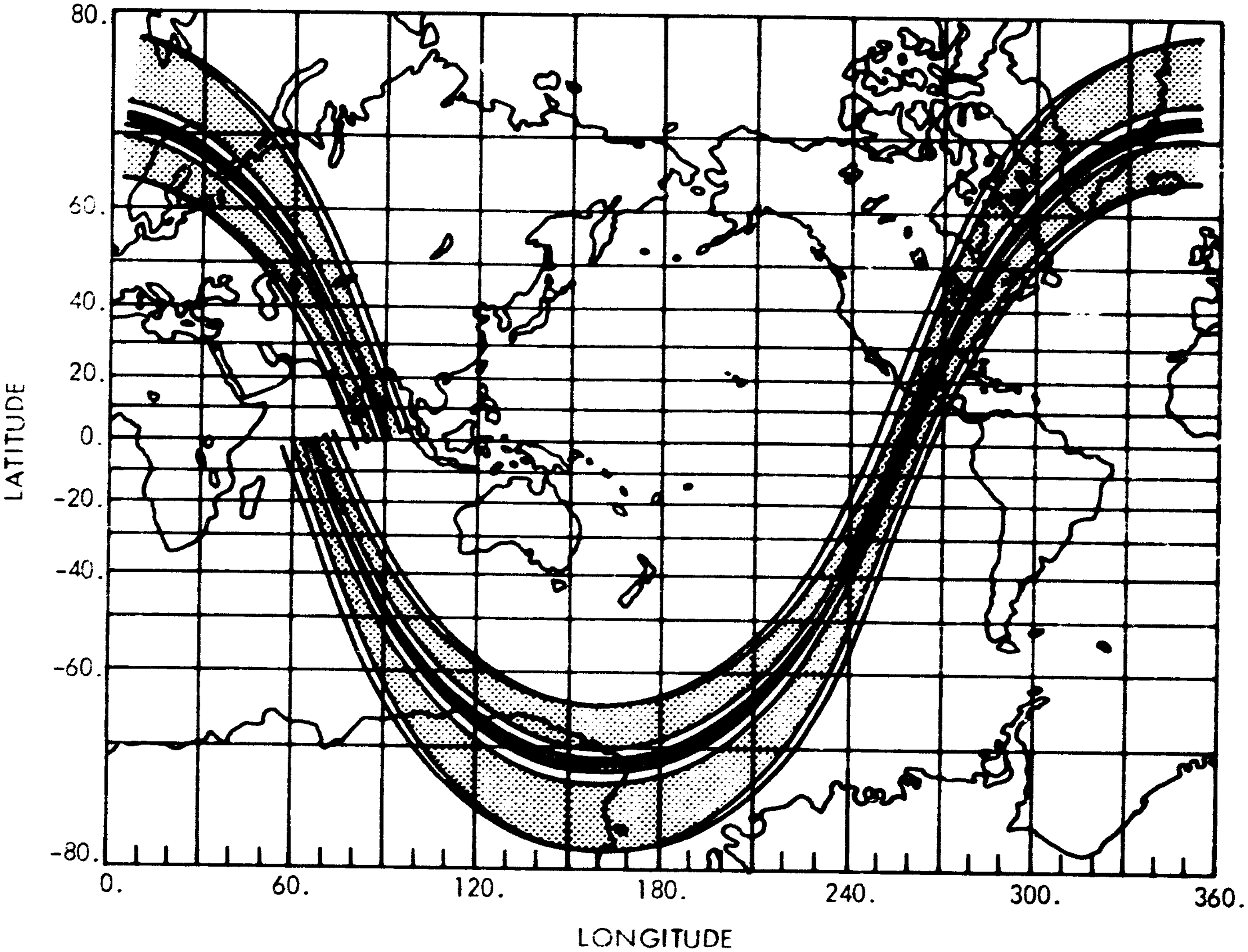


Figure 5-2. Seasat Mercator SASS Swath

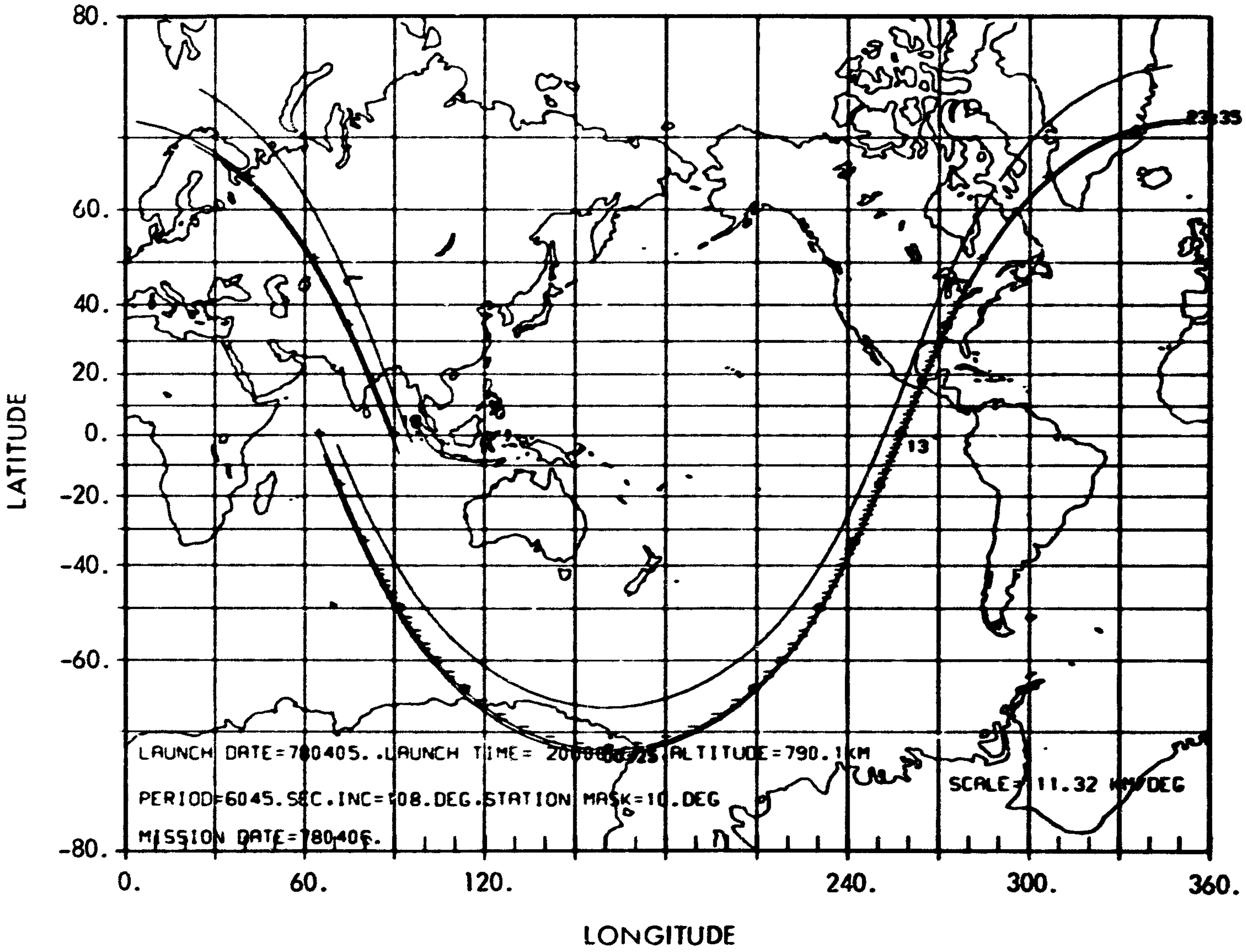


Figure 5-3. Seasat Mercator SMMR Swath

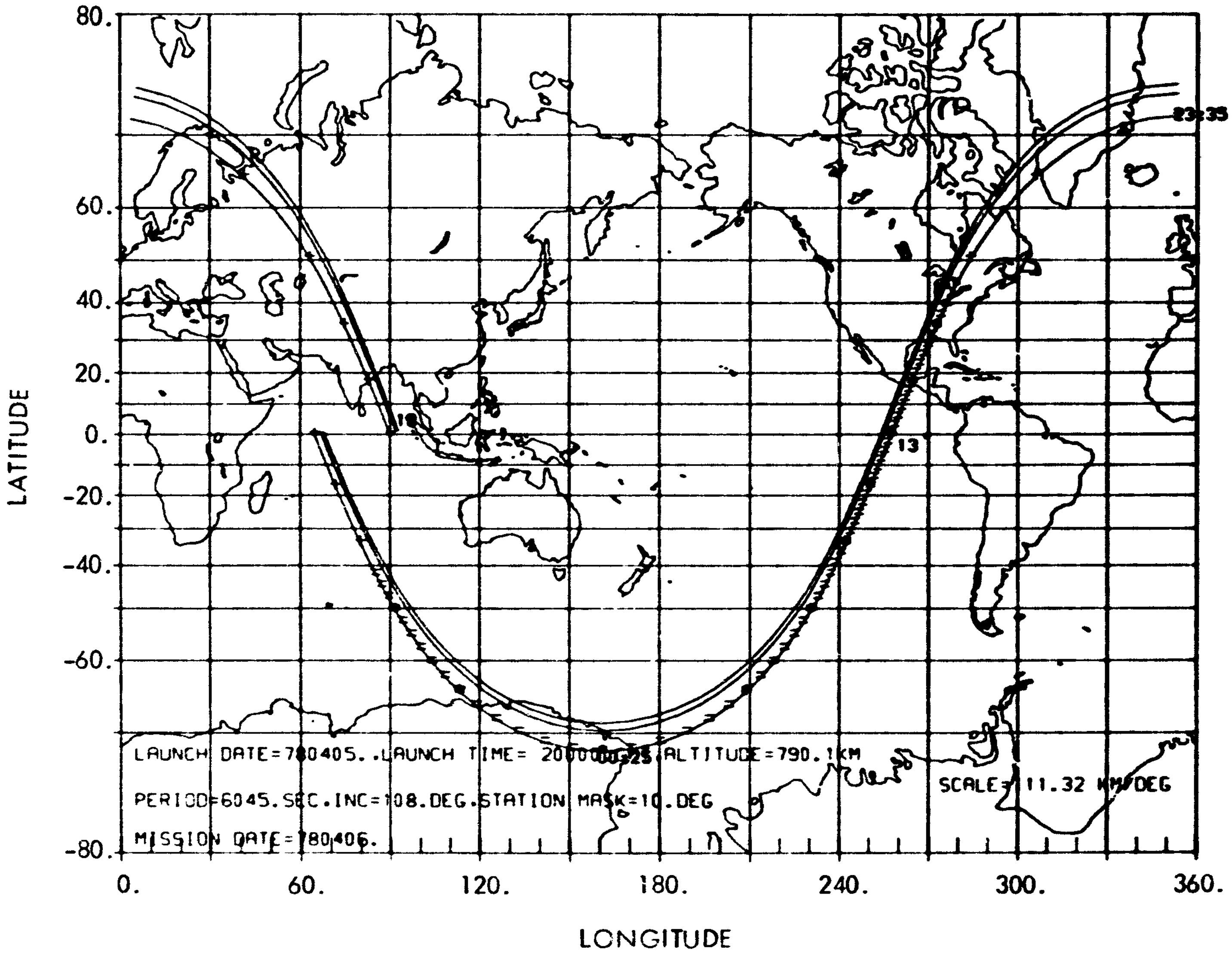


Figure 5-4. Seasat Mercator SAR Swath

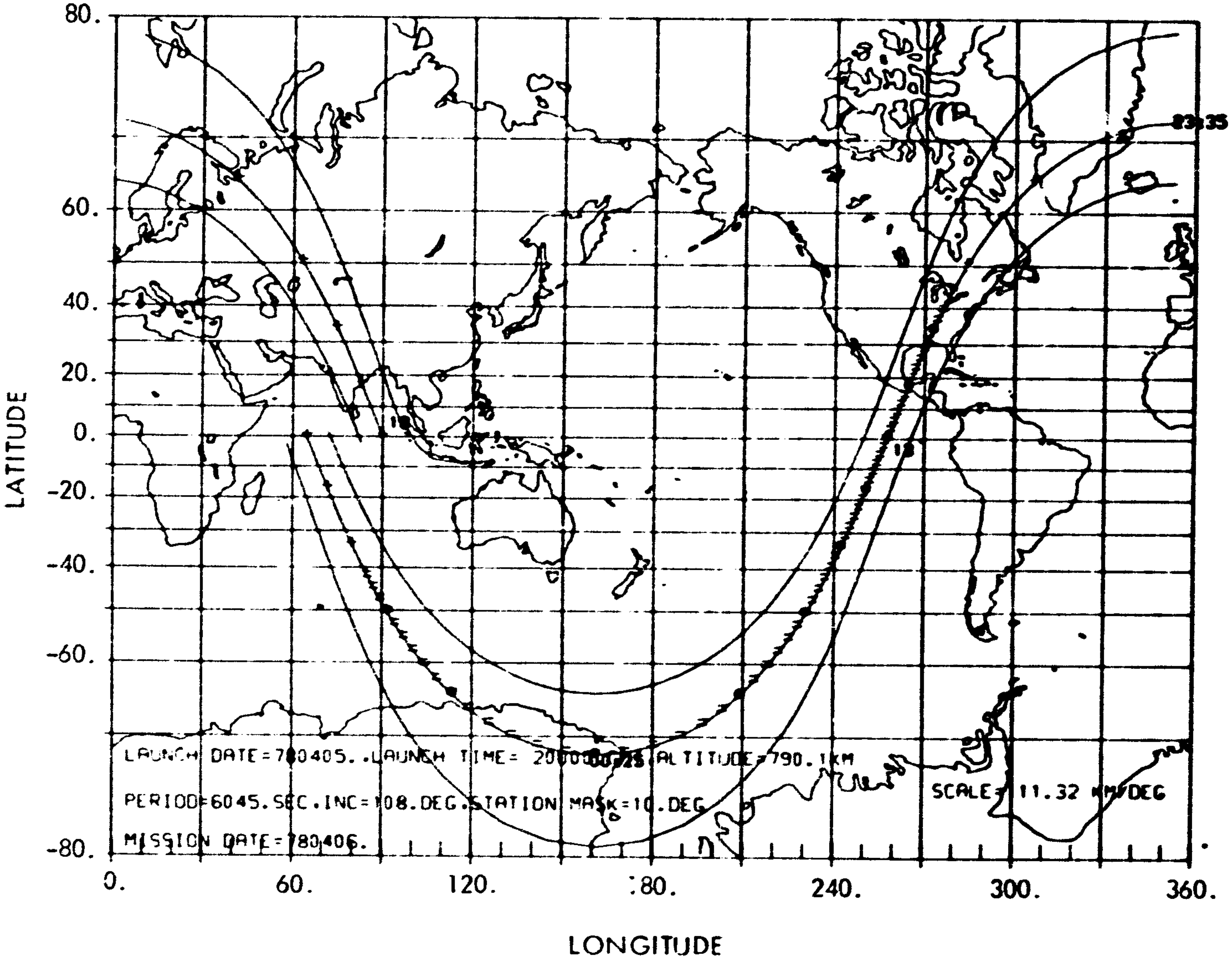


Figure 5-5. Seasat Mercator VIRR Swath

1. Synthetic Aperture Radar Calibration

The objective of the SAR experiment was to demonstrate the capability of a satellite-mounted SAR to obtain high resolution ocean surface imagery, monitor coastal processes, chart ice fields, detect icebergs, and obtain land imagery.

The engineering assessment of the SAR was conducted to evaluate SAR inflight performance and to ensure data quality. The SAR experiment team representative provided the SAR pass selection inputs to the MPT. Operations during the first weeks of the mission proceeded as planned, and included the following accomplishments:

(1) SAR operate/data link on without radar transmitter permitted signature with radar noise at each SAR site.

(2) Data link coverage near station zenith permitted full cuts through the spacecraft antenna.

(3) Passes over corner reflectors were recorded and analyzed.

The normal operation of SAR electronics and data link was confirmed. Areas of evaluation were proper command responses, expected telemetry values, operating temperatures, and transmitter power. The SAR performance evaluation effort covered the following three areas:

(1) Functional operation of the system elements.

(2) Measurement of performance parameters and comparison of predicted values.

(3) Assurance of imaging quality.

These activities took place at: (1) the POCC by the Satellite Performance Analysis Team; (2) STDN SAR sites by SAR team personnel; (3) JPL by review of telemetry data; and (4) JPL by processing and image analysis teams. Table 5-1 summarizes the status of performance evaluation.

2. Radar Altimeter

The objective of the altimeter calibration was to evaluate three basic altimeter geophysical parameters:

(1) Altitude of spacecraft above sea surface (h).

(2) Sea state as measured by the average height of the highest one-third of the waves in the antenna swath ($H_{1/3}$).

(3) Sea state backscatter coefficient (σ°).

Table 5-1. Seasat SAR Engineering Assessment Performance Evaluation

Performance	Evaluation Activity	Status
<u>Functional Verification</u>		
Satellite elements	SPAT participation at POCC	Completed
	Response to commands	Verified
	Telemetry at expected values	Verified
System elements through demodulation	GDS observer	3 sites visited
	MFR and demodulation lock	Verified
	Offset video echo and STC	STC bias
	Simulator RG compression	Observed
	Rechirp	Observed
	Corner reflector echo	Not seen
End-to-end system through SDPS	SDPS processing of point target returns	
<u>System Parameter Values</u>		
Satellite subsystem amplitude stability	Pre-launch analysis of test data	Complete
Satellite thermal characteristics and transmit power stability	Plots of sensor and data link temperatures and transmit power versus time from telemetry	Complete
Data link pattern and horizon mask	MFR AGC versus look angle at GDS	Incomplete
SAR antenna pattern	L-band power (with AAFE receivers) versus look angle	
End-to-end SNR	Offset video signal and noise at GDS	Complete 3 sites
Image spectra	Computer analysis of digitized signal film	Plans only
Image performance parameters	Estimate values from images with point targets and compare with predicted values and tolerances	Plans only

Table 5-1. Seasat SAR Engineering Assessment Performance Evaluation (Continuation 1)

Performance	Evaluation Activity	Status
Image quality assessment	Establish and verify procedures for HDRRs, tapes, and film and assess parameter values and general image quality	Partially

To implement these altimeter evaluations, Seasat-derived altimeter parameter values were compared with independently observed values. Surface truth data obtained from the North Atlantic calibration area, Gulf of Alaska, North Sea, and Joint Air-Sea Interaction Experiment (JASIN) area were used along with laser and S-band observations from Bermuda overflight passes as the primary data set. By obtaining independent measurements of the altimeter parameters, the instrument bias and accuracy were determined. The calibration activity was divided into three phases.

a. Phase I. This phase was based on the first available data processed in the shakedown mode to accomplish early assessment of sensor performance.

b. Phase II. This phase encompassed data collection activity performed during the Bermuda overflight period in September 1978. The use of altimeter data minimized the need for geoid and ocean topography models. The resulting altimeter h-bias information was good to the submeter level.

c. Phase III. This phase covered a definitive evaluation period where the ultimate accuracy and data processing algorithms were assessed. The time frame for this phase extended until mission termination. The objective of this analysis was: (1) to determine the bias in the altimeter measurements with an accuracy of 10 to 20 cm, and (2) to demonstrate that Seasat altimeter $H_{1/3}$ measurements and σ° measurements met the design specifications.

There were three possible methods for determining the bias in the Seasat altimeter measurements:

(1) Direct Overflight. This method required the satellite to pass directly over the tracking laser.

(2) Short Arc Triangulation. This method required that the satellite be tracked by three or more lasers during a single pass over the calibration area with the altimeter operating.

(3) Global Long Arc. This method evaluated the altimeter height bias using orbits determined from the globally distributed Tranet Doppler system.

Command sequences required to calibrate the altimeter were provided to the MCT by experimentors through the MPT. Following orbit adjust maneuvers at 22:39:00 GMT on day 250, altimeter calibration data were gathered for 30 days on Bermuda (BDA) overflight passes (every third day) and are listed below:

Rev No.	Time Period
1117	256/0254-0309
1160	259/0306-0321
1203	262/0318-0333
1246	265/0330-0345
1289	268/0345-0400
1332	271/0357-0412
1375	274/0409-0424
1418	277/0421-0436
1461	280/0433-0448
Seasat Failure	283/0426

BDA was required to support these passes and gather as much Doppler data as possible. As the real-time, 25-k/bs data were not available to the POCC from BDA and MIL, trailing passes (overlap of approximately 3 min) were also scheduled. So that BDA could gather maximum Doppler data, MIL was required not to bring up their uplink carrier until BDA's loss of signal, which did not leave enough time for a tape recorder dump (7 min, 12 s required). To achieve this, the tape recording cycles were readjusted by the MPT.

3. SASS Calibration

This instrument provided closely spaced grid measurements of surface wind speed and direction in the range of from 4 to 50 m/s. This could be inferred by sensing the average radar cross section or scattering coefficient (σ^0) of the rough ocean surface. Therefore, the satellite instrument had to be calibrated in terms of σ^0.

The measurements made by the satellite instruments were compared to the values of σ^o obtained by a highly accurate SASS installed on an underflying aircraft. Therefore, the absolute calibration of the SASS was dependent on three major elements:

(1) Calibration of the underflight instrument.

(2) Underflights themselves.

(3) Subsequent data comparison.

Metal spheres of different radii suspended from balloons and a helicopter were used to calibrate the underflight instrument. The value of σ^o for a sphere is easily calculated and varies with the radius squared. Range was accurately determined using a Wallops Flight Center (WFC) tracking radar. Since path losses were negligible, the σ^o could be readily computed. The underflight instrument was calibrated to an accuracy of >0.5 dB.

The underflights were conducted between 23 August and 30 September 1978, primarily in the North Atlantic and Gulf of Alaska, as part of the JASIN and GOASEX programs, respectively. The underflight instrument was installed on the NASA/JSC C-130, NASA-929 aircraft. Table 5-2 lists the data set used for the SASS calibration.

4. Scanning Multichannel Microwave Radiometer Calibration

The principal requirement for the SMMR was to provide all-weather global measurements of sea surface temperature to a precision of 1 to 2 K for oceanographic and climatological research. Another requirement was to use microwave brightness measurements for high wind determination to complement and extend the SASS measurements. The instrument was calibrated on the ground before launch at JPL. No in-flight calibration activities were conducted.

5. Visual and Infrared Radiometer Calibration

The VIRR provided low resolution (9 by 9 km) feature recognition and cloud position information, clear air sea surface temperature (±0.5 K), and cloud top brightness temperatures in support of the microwave instruments. No inflight calibration activities were conducted.

D. FLIGHT SYSTEMS PERFORMANCE

1. Spacecraft Performance

All sensors were operational at the beginning of day 188. The altimeter, SMMR, SASS, and VIRR were operating at 100 percent duty cycle, while the SAR was operating at 45 percent duty cycle. Table 5-3 summarizes the events.

Table 5-2. SASS Calibration Data Set

Location	Date	Rev	Forward Beam Cells	Aft Beam Cells	Polarization	Wind Speed, m/s
JASIN	8/23	0823	1/5-7	2/7-12	Both	10
	8/25	0848	4/1,2,4	3/1,2,4	Both	>10
	8/29	0905	4/4-8	3/3-7	Both	7
		0906	1/2-10	2/3-12	Both	7
	9/04	0991	4/3-11	3/2-9	Both	8
		0992	1/1-10	2/2-11	Both	10-20
GOASEX	9/14	1140	4/1-6,13,15	3/1-5,13,15	Both	30-35
	9/17	1183	4/1-6,13,15	3/1-5,13,15	Both	30
	9/19	1112	1/1-9,13,15	2/1-9,13,15	Both	30
East Coast USA	9/28	1339	1/1-8,13,15	2/2-8,13,15	Both	8-14
	9/30	1367	4/3-12	3/2-12	Both	15-30

The SASS baseplate temperatures were out of specification on the low side up to 16°C an estimated 90 percent of the time as manual cycling of the heater bus began on rev 416 (day 206). However, this condition had no effect on the SASS operation.

There were several planned occasions when some of the sensors were restricted in their operations:

(1) During a spacecraft low power period (days 242 to 252), the VIRR electronics were commanded off to conserve power. The SAR was operated only at 1 percent duty cycle rather than 7 percent as planned for the same reason.

(2) The SASS and altimeter were placed in non-operational modes during spacecraft maneuvers.

2. OACS Performance

Anomalous OACS behavior was first observed on rev 17 (ACN). Backup attitude control modes were available to permit the on-schedule initial power-up

Table 5-3. Summary of Events

Number	Day	Rev	Comments
1	222	641	VIRR detector temperature exceeded limit of 35°C (95°F). VIRR was commanded off.
2	229	681	VIRR detector temperature limit changed to 38°C (100°F). VIRR was commanded on.
3	240	890	VIRR motor stalled. No data was output from the sensor.
4	240	891	Spacecraft bus voltage fell below 22 Vdc. Internal fault detector turn ALT off.
5	240	895	ALT was commanded off.
6	240	897	Several attempts for next 110 revolutions were made to command VIRR motor on. No success.
7	244	953	ALT was commanded on for 60 percent of the time in track mode ard 40 percent of the time in standby mode until rev 1255 (day 265).
8	247	1000	SMMR cold horn temperature. 157°C (315°F) limit. Defined new limit of 160°C (320°F).
9	253	1073	Modified and used the sequence to command VIRR motor on. On 2 occasions, VIRR motor made one revolution and stopped.
10	255	1105	Modified and used new sequence to command VIRR motor turn-on. Motor started running.
11	256	1115	VIRR motor stopped again. Subsequent attempts to start motor again failed. Engineering analysis concluded that the motor stalling could be caused by a particular inclusion in the gear drive, a failure of the bearing supporting the shaft, or in the motor itself.
12	265	1255	New operational mode for ALT; test mode over land and track mode over water.

and checkout of the sensors. The control system performance from rev 130 until final control system trim on rev 327 was adequate. Workaround operations were developed to mitigate the effects of anomalous behavior on the OACS performance.

Five orbit adjusts were performed to support development of a precise orbit over Bermuda for altimeter calibration. The orbit adjusts required switching from the momentum attitude control system to the hydrazine attitude control system, and then back to the momentum system. Control in each mode and switching between modes was performed without operational problems. Orbit adjust maneuvers were performed during the following revolutions:

Maneuver	Rev
1	701-705
2	744-749
3	819-821
4	862-864
5	1072-1073

After an initial workaround was developed, the OACS performed admirably through all orbit adjust maneuvers until spacecraft terminal power failure over the Orroral, Australia tracking station.

3. Power Performance

All electrical power systems performed properly and no hardware failures occurred up to the final rev (1503), when the failure took place. Power consumption in the spacecraft loads was greater because of OACS anomalies and thermal control system thermostat failures; however, bus subsystem loads were in the predicted ranges. Also, solar array output power was within the predicted ranges. During out-of-specification conditions on rev 891, power system control was maintained, including regulation, and no damage to the batteries was indicated. No damage to any other hardware was evident as a result of the out-of-specification voltage condition. No evidence was available to suggest power subsystem design error or malfunction as the cause of the low voltage condition. The out-of-specification low voltage condition was attributed to an LMSC Spacecraft Performance Analysis Team (SPAT) performance lapse. This performance lapse was addressed by LMSC and resulted in extensive operational changes and record keeping and personnel revisions.

During the final revolution of the spacecraft, a massive short circuit developed. The power system maintained normal sensor input for approximately 1 h after the onset of the short circuit, at which time sensor telemetry functions and spacecraft S-band telemetry downlink ceased.

E. GROUND SYSTEM PERFORMANCE

1. POCC Computer System

a. Hardware. There were no significant hardware problems, primarily because of the ample redundance built into the system. Although some passes were conducted using a backup Sigma 5 computer because of maintenance work being performed on the prime system, it had no adverse impact on spacecraft operations. The duration of this maintenance work was approximately 3 to 4 hours a week.

b. Software. Significant problem areas in the software were as follows:

(1) Timecal. This segment of the software was used to compute the offset and drift of the spacecraft clock. Depending on the type of data being processed, the program often produced erroneous results. The impact of this problem was a backlog accumulation of clock offset drift messages that could not be computed on time.

(2) Limit Checking. The programs were used to indicate the measurements that were not within the set of pre-specified limits. The programs functioned properly, but the format of the message transmitted to indicate a certain measurement was beyond normal limits was inadequate.

(3) Data Transmission to ADS. When transmitting data to ADS, the Sigma 5 computer failed occasionally and had to be re-initialized. The reason for this could have been the Sigma 5 programs, the transmission line, or the protocol between the computers. Because of this, the data had to be played back again.

(4) Max/Min. These programs were used to keep a running record of the maximum and minimum values of pre-specified measurements. When using these programs, the telemetry processor of the Sigma 5 computer would fail, resulting in the degradation of data.

(5) Convert Coefficients. The raw PCM counts were converted to engineering values using coefficients stored in a table. On several occasions, this table changed without any reason. To correct this, the complete system had to be reloaded. This presented a severe problem.

(6) Erroneous Data Values. On a few occasions, the telemetry processor failed and produced erroneous data values. The system had to be rebooted to correct this.

All of the above problems, except limit checking, were corrected by Version 12 of the software, which was delivered by Univac on 12 September 1978.

2. Mission Operations Room/Sigma 5 Interface

This interface functioned well. There were no significant hardware or software problems.

3. Attitude Determination System/Sigma 5 Interface

As mentioned earlier, a few problems were encountered. However, there were no serious impacts on operations.

4. Orbit Determination System

a. Predicts. It was the responsibility of ODS personnel to provide predicts for station view periods of the spacecraft to the MCT. On three occasions, the predicts were late by more than 2 days. This presented somewhat of a problem, especially immediately after orbit adjust maneuvers. On two different occasions, the revolution numbers of the spacecraft were off by more than one. To correct the latter problem, the predicts had to be regenerated.

b. Range Tape. This set of data provided by ODS personnel to the MCT contained range information for the MIL, GWM, and MAD STDN sites. This data was needed to compute the spacecraft clock offset and drift. There were various problems encountered. On many occasions, the tape was defective and had to be regenerated. This usually required about 2 days and further aggravated the problem of computing clock offsets on time.

5. Command Management System

The performance of the CMS supporting personnel for Seasat was outstanding. The MSOE memory loads were produced well in advance. There were few occasions when the transmission line between CMS and the POCC was not functional. The MSOE was hand-carried to the POCC. This procedure had no adverse impact on the operations.

6. Ground Stations

a. Tape Recorder Dumps. On 8 August 1978, because of timing problems in building up store and forward tapes, the MCT decided not to dump the tape recorders over ACN, MAD, and QUI. However, on 8 September 1978, the previous decision had been modified. The tape recorders could then be dumped over these sites, and the analog tapes could be shipped to MIL for transmission to the IPD at GSFC. From GDS, the shipping could be accomplished overnight, but times from the other sites were more variable and longer. Consequently, it was less desirable to dump tape recorders over the other sites. The priority established, in decreasing precedence, was ULA, MIL, MAD, and GDS.

b. <u>STDN Scheduling</u>. The STDN scheduling procedures established at GSFC worked satisfactorily. During the early part of this phase, the unavailability of STDN sites (GDS and MAD) presented a problem. These two STDN sites were used extensively by Skylab. MAD was one of the sites where tape recorder dumps were desirable, while GDS was one of two sites used for SAR data processing. As the schedule was received by MCT at approximately 1930 GMT for the next day, and the command load for the same day was already fabricated at that time, a few SAR pass commands in the load had to be no-ops because of the inability to schedule GDS. Similarly, if MAD was required for tape recorder dumps and was not available, the dumps were scheduled over less desirable sites.

c. <u>Spacecraft Command Encoder Problems</u>. SCEs at the STDN sites were used to uplink commands to the spacecraft. The command uplinking process involved a series of communication messages between the POCC computer and the SCEs. The characteristics of these communication messages were different for non-critical commands, critical commands, and memory loads. If this series of communication messages was not completed in its entirety on time, commands could not be uplinked to the spacecraft. The most frequent problem at the POCC was the failure to receive messages from the SCEs. This was indicated by a "SCE TIMED OUT" printout, meaning that the expected communication message from the SCE was not received by the POCC computer. The problem could be in either the SCE itself or in the NASCOM line from the STDN to the POCC. In the former case, the solution was to re-initialize the SCE. In the latter case, another attempt to uplink the commands had to be made. If the attempt was unsuccessful, a line check would be required. In any case, the uplinked commands would be delayed from the intended uplink time. This was a problem for SAR turn-on and starting the tape recorder readout. This problem was not investigated by the Seasat Project.

7. TELOPS/IPD

TELOPS/IPD had six major interfaces in the Seasat configuration that were used either as an input or output interface. In this paragraph, only POCC-related input and output interfaces will be discussed. There were one hard interface (voice line) and three soft interfaces where some data products were hand-delivered to either the POCC or TELOPS/IPD. The data delivered from TELOPS to the POCC were Seasat quick-look whole-orbit telemetry tapes. The POCC-supplied data products were daily copies of the Command Master Data File and the satellite time offset messages.

The interface that worked best was that for the time offset messages. This message was delayed a few times where its delay impeded TELOPS/IPD data processing operations. The SFOP procedure stated that the SPAT would provide the data so that the message could be transmitted by 1600 GMT on the following day. During this phase only a limited number of time correlation passes were scheduled at the STDN sites. If for some reason one or two of these passes were lost or the data proved to be erroneous, it could delay that day's message until more time correlation passes were made, the data plotted, and a fit established. Also, for ease in data reduction, it proved better to have one person take all of the time offset data for that time period and perform a batch process for the day. It was this specialization in performing the task that also resulted in some delays in processing non-real-time data. A lower priority on the processing of non-real-time data by real-time operations personnel caused a delay at times. All of these delays were minor, and, as it turned out, the facilities using this information to process Seasat data were also behind schedule with their own processing functions and the delays had no impact on their final output. As stated earlier, when this process was delayed because of problems with the ODS range tape, the output of time offset messages would fall behind by several days. When this occurred, there was an impact that caused some processing delays by TELOPS/IPD.

The second interface was the voice interface between TELOPS and the POCC. This voice line was normally used only when real-time operations were being conducted with the STDN. This interface was activated by the Communications Manager when TELOPS/IPS was scheduled to receive playback from a tape recorder dump or a playback of an STDN store and forward tape. No notable real-time problems occurred with this voice line. The POCC personnel had expected to use this voice interface for non-real-time coordination of delivery of TELOPS quick-look tapes. In this respect, the interface failed. A second attempt to coordinate quick-look tapes was made using the standard telephones. This effort generally failed also because no knowledgeable single-point contact within TELOPS could consistently be established either by telephone or voice line. Ultimately, the Seasat Mission Support Manager provided this non-real-time coordination function. It was thought necessary to have a non-real-time POCC to TELOPS/IPS coordination effort. This interface requirement arose because of the impact of the late delivery of quick-look tapes from TELOPS to the POCC. This requirement diminished after TELOPS/IPD had solved their initial start-up problems encountered on Seasat data processing, and quick-look tapes were later provided within their specified delivery time of 4 to 6 h after capture of the data.

The interface that resulted in the most problems was the quick-look tapes. Basically, the POCC required quick-look tapes for three reasons: (1) playback to the ADS; (2) playback to analyze the electrical power profile; and (3) playback to analyze the performance of a discrete sensor. Initially, the prime interest was in the areas of ADS and power evaluation. As these two subsystems and their performances became better understood under flight conditions, the requirements to analyze whole orbit data decreased. The evaluation of whole orbit data for sensor performance was on an "as required" basis.

The MCT performed a total of 724 tape recorder dump cycles. Generally, each tape recorder contained approximately 230 min of data. This was equal to about two and one-third orbits of real-time data. Therefore, when a whole orbit of data was requested from TELOPS by the nature of the recorder cycles and TELOPS processing, over two orbits of playback data were received to be processed through the POCC Sigma 5 computer. Of the 724 playback cycles, four cycles were repeat playbacks from the satellite. These were normally the result of some ground system problem that caused a certain or probable loss of playback data.

The total number of quick-look tapes requested, sometimes defined as whole orbit data, was 32. This was equal to approximately 4.44 percent of the total number of tape recorder cycles that were played back. It did not include the pre-planned quick-look requests through launch and approximately the first

30 orbits. Nine of these dump cycles occurred during the first 2 weeks, which was the Orbital Cruise Phase. During this phase, as noted in Section IV, the delay of the quick-look tapes severely handicapped the MCT and the SPAT, who required this data in a timely manner to evaluate the satellite and the attendant ADS and power system programs.

Following this phase, and up to the point of the low voltage problem on orbit 891, 47 days and 10 quick-look requests elapsed, or an average of one request every 4.7 days. A review of the Seasat tape recorder management log illustrates that these requests were spaced relatively evenly throughout the overall time period. Delivery throughout this time period continued to lag 1 or 2 days behind the request for quick-look data until the time of the under-voltage problem cited. Over a 2-day period (47 h) 7 of 13 tape recorder dumps were requested to be delivered to the POCC as quick-look tapes. On some of these orbits, two tapes (duplicate copies) were requested for individual GSFC experiment teams that had the capability to analyze the data on their own computer systems. Because of the size of the request at this time of the mission, the total process was somewhat slow. However, this event and the delivery of tapes from TELOPS did prove that the TELOPS/IPD system could deliver data products across the interface within the prescribed time of 4 to 6 h after capture.

Quick-look requests from the POCC from this time period to the time of spacecraft failure were again on a relatively evenly spaced basis. The TELOPS/IPD concept of providing data for quick-look analysis was at the threshold of being consistently reliable within the desired time at the termination of the mission. In conclusion, the concept of individual POCC capture of data for real-time operations analysis should be strongly recommended for future missions.

8. ULA Program 3 and 1.544-Mb/s Wideband Data Service

A simplex 1.544-Mb/s wideband data service was provided from ULA with a simultaneous transmit capability to Fleet Numerical Oceanographic Center (FNOC) and to GSFC. This system was used to transmit the 800-kb/s playback telemetry data to FNOC and TELOPS/IPS at GSFC and the 25-kb/s real-time data to the Seasat POCC.

ULA had two computer systems designated the 642B (Phase I) and the PDP-11 (Phase II). These computers required Digital Data Processing System (DDPS) program 2 and DDPS program 3 software, respectively. To utilize 1.544-Mb/s data circuit capabilities, the DDPS program 3 had to be used. DDPS program 2 was the backup to DDPS program 3, and its use was intended in case of DDPS program 3 failure only for real-time support. The 800-kb/s playback telemetry data were to be retained on station until the restoration of program 3 capabilities.

During this phase of the mission, it was discovered that the dump data transmitted from ULA to TELOPS using DDPS program 3 contained timing problems. An extensive series of data flow tests were conducted between ULA and TELOPS to analyze this problem. The participation of the spacecraft operations team in these tests was not required. The timing problem revealed by these data flow tests were attributed primarily to the time code translator at ULA. Before the installation of this unit, it was checked at GSFC. However, one of the output cables was not terminated properly at the site. This cable was subsequently replaced, resolving all problems by 1 October 1978.

SECTION VI

ORBIT MANEUVERS

A. INTRODUCTION

The Seasat spacecraft was launched at 01:12:44 GMT on 27 June 1978 from the Western Test Range at Vandenberg Air Force Base, California. The launch and orbit injection were near-nominal, but post-launch attitude control anomalies and the resultant hydrazine usage caused the pre-launch maneuver plans to be modified. Following the development of a workaround for the attitude anomalies, five maneuvers were executed. The following paragraphs summarize pre-launch maneuver plans, launch results, post-launch plans, mission operations activities, and maneuver evaluations.

B. PRE-LAUNCH MANEUVER PLANS

The pre-launch maneuver strategy was to correct the achieved launch orbit within 30 days after injection. These corrections had the following objectives:

(1) Achieve proper instrument operating altitudes.

(2) Synchronize ground traces to match the pre-launch-generated ascending nodes (Earth-fixed) and dates.

(3) Minimize altitude variations in the Northern Hemisphere.

(4) Provide a 3-day, near-repeating ground trace for calibration activities.

(5) Maintain the above properties against drag effects through periodic maneuvers.

(6) Provide an exact 3-day repeat ground trace in early September for Bermuda laser experiments.

Maneuvers were planned to correct semi-major axis (α), eccentricity (ε), and argument of perigee (ω). Corrections to ascending node locations (Ω) were made by adjusting the semi-major axis, which affects the nodal precession rate ($\dot{\Omega}$). Therefore, node control was performed by in-plane maneuvers rather than by expensive out-of-plane maneuvers.

Parameters of the nominal launch orbit are listed in Table 6-1. The selection of these values is discussed in detail in Reference 6-1. The values of semi-major axis and inclination determine the orbit precession rate and, coupled with the Earth spin rate, determine the Earth-fixed ground trace pattern. Figure 6-1 shows how the ground trace pattern builds up over a typical equator segment. The plot shows the Earth-fixed longitudes of ascending nodes plotted against time. The solid lines connect node locations that differ in time by 3 days. The nominal orbit produces a 3-day near-repeating pattern that drifts 18.5 km (10 nm) east every 43 revolutions (3 days). After 5 months, the

Table 6-1. Nominal Launch Orbit

Parameters	Values
Semi-major axis, km	7168.3 (3863.7 nm)
Eccentricity	0.0008
Inclination, deg	108.0
Argument of perigee, deg	90.0
Time of perigee, nominal launch date	00:46:00 GMT, 18 May
Ascending node, deg	298

complete equator has been crossed every 18.5 km, setting up a uniform instrument sampling grid.

The nominal values of ε and ω were chosen to minimize altitude variations by providing a circular orbit and essentially no precession of periapsis. As shown in Figure 6-2, the motion of ε and ω moves counterclockwise on the closed contours at the apsidal period (about 120 days). It can be seen that if $\varepsilon \leq 0.002$ and $\omega \sim 90$ deg, perigee precession is restricted to a small range of values. Near the "frozen" point, the motion will be essentially constant and, therefore, maintain the spacecraft altitude constant over any given point on Earth. This phenomenon is due to balancing the precession influence of the second zonal harmonic with the odd zonals by achieving a very small eccentricity. Details and equations to support these characteristics are given in References 6-2 through 6-4.

Nominal ground trace spacing is achieved once the nominal semi-major axis is achieved. However, launch date slips from 18 May, or an anominal launch performance causes the post-launch Earth-fixed ascending nodes to differ from the pre-launch nominal set (published in Reference 6-5). The nodal positions and times in Reference 6-5 were distributed before the initial planned launch date (18 May) to permit the instrument experiment teams to plan post-launch surface truth activities and to coordinate with other oceanographic activities. Therefore, it was planned to maneuver the spacecraft so that the actual nodes would agree with the published values. In other words, the effects of launch slips and launch trajectory errors on nodal positions would be compensated for with maneuvers. The nodal crossings were to be synchronized with nominal values by varying the semi-major axis so that the accumulated nodal errors would be offset within 30 days after launch.

Reference 6-6 provides the maneuver strategy details and optimization techniques for correcting launch errors in α, ε, and ω at the same time as node synchronization. Once node synchronization and launch error corrections were

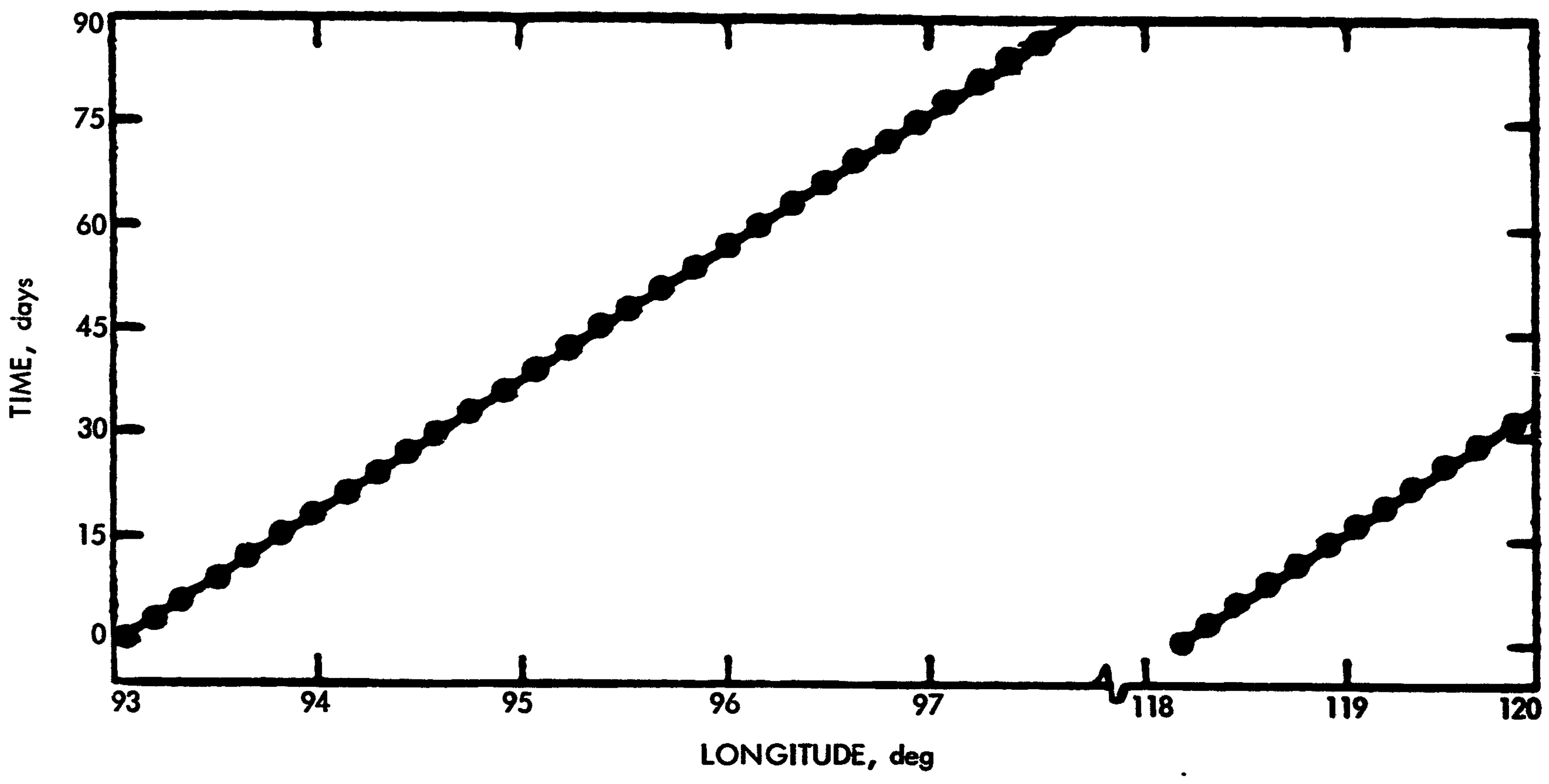


Figure 6-1. Baseline Orbit Ascending Node Pattern

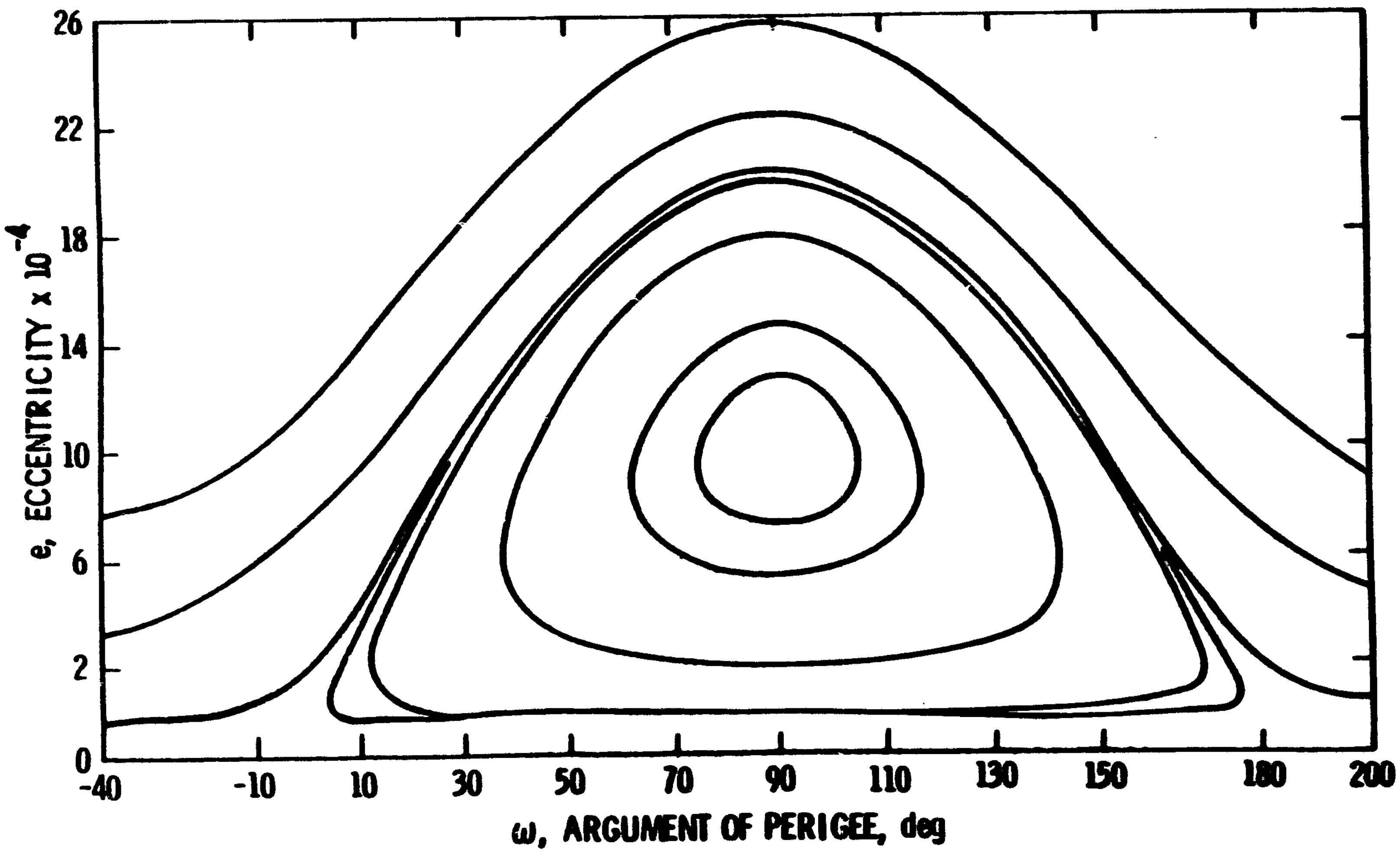


Figure 6-2. Frozen Orbit Conditions

completed, the Bermuda Island overflight would have occurred in early September. A small maneuver (approximately 700 m (2296 ft) in semi-major axis) would then be required to modify the orbit from the near 3-day repeat (nominal orbit) to an exact 3-day repeat over Bermuda Island. The equations for computing the ΔV magnitude and location as a function of required changes to orbit parameters Δa, $\Delta \varepsilon$, and $\Delta \omega$ are derived in Reference 6-2 and listed in Table 6-2.

During this orbit sequence, maneuvers to compensate for drag were to be performed as needed. Drag caused the orbit to decay and the ground trace pattern to drift more easterly. Maneuvers were scheduled to return the semi-major axis, and ε and ω, if required, to their original values. As maneuver responsibilities were shared between operations teams at JPL and GSFC, a planning cycle and formal Maneuver Operations Planning Team (MOPT) were organized.

C. LAUNCH RESULTS

The powered flight trajectory produced an injection orbit that was within specifications, although somewhat off the nominal values (Table 6-3). Some of the nominal values in Table 6-3 differ slightly from those of Table 6-1, apparently due to round-off and precision requirements in LMSC ascent simulations. Figure 3-2 shows Lockheed Monte Carlo-modeled distributions for the orbit parameters of interest. The ΔV required to correct the launch orbit was 6.3 m/s compared to a nominal value of 4.4 m/s and a 99 percent probability level of 11 m/s.

The coverage from the launch orbit is plotted in a dot diagram in Figure 6-3. The dots show the Earth-fixed longitudes of ascending nodes plotted against time. The abscissa shows a typical equator segment, with the plotted pattern being repeated around the equator. A long-term 17-day repeat pattern with a larger miss distance of 160 km (86 nm) is evident. The curvature in the 17-day near-repeat pattern is due to drag effects on the semi-major axis that changed the nodal precession rate, which in turn affected coverage. Note that the 17-day pattern does not exactly repeat itself, but misses to the west for a while and then misses to the east. Either an east or west stepping pattern could be maintained with maneuvers.

The 17-day pattern was advantageous in that it provided an almost 18-km (9.7 nm) spacing between adjacent ground traces. This corresponded to the altimeter long-term mapping requirement. A disadvantage of the launch orbit was that the 3-day pattern had a miss distance about 50 percent larger than the SAR swath width of 100 km (54 nm). Therefore, the SAR and instruments with smaller coverage swaths did not have contiguous coverage for long periods of time. As both the Baseline and Cambridge orbits (Table 6-4) were configured to provide overlap coverage consistent with the instrument swaths, it was decided not to stay in the launch orbit but to comply with the initial maneuver objectives.

D. MISSION OPERATIONS ACTIVITIES

Twenty-six hours after launch, vehicle attitude control was transferred from the Reaction Control System (RCS), which used gyros and hydrazine gas, to the Orbital Attitude Control System (OACS), which used horizon sensors and momentum wheels. Subsequent to the transfer, large transients were observed

Table 6-2. Locat on and Magnitude of Thrusts

Orbital Element	Thrust Location		Thrust Magnitude and Direction	
	θ_1	θ_2	ΔV_1	ΔV_2
a only	arbitrary	$\theta_1 + 180°$	$\frac{1}{2}\Delta a\sqrt{\frac{2\mu_\oplus}{(a_o + a_1)^3}}$	ΔV_1
e only	at ω_o if $e_o < e_1$ at $\omega_o + 180°$ if $e_o > e_1$	$\theta_1 + 180°$	$\frac{1}{4}\sqrt{\frac{\mu_\oplus}{a_o}\left(e_o^2 + e_1^2 - 2e_o e_1\right)}$	$-\Delta V_1$
ω only	$\tan^{-1}\left(\frac{\sin\omega_1 - \sin\omega_o}{\cos\omega_1 - \cos\omega_o}\right)$	$\theta_1 + 180°$	$\frac{e_o}{4}\sqrt{\frac{2\mu_\oplus}{a_o}\left[1 - (\sin\omega_o \sin\omega_1 + \cos\omega_o \cos\omega_1)\right]}$	ΔV_1
a, e, ω (or any two)	$\tan^{-1}\left(\frac{e_1 \sin\omega_1 - e_o \sin\omega_o}{e_1 \cos\omega_1 - e_o \cos\omega_o}\right)$	$\theta_1 + 180°$	$\frac{1}{4}\underbrace{\sqrt{\frac{2\mu_\oplus}{(a_o+a_1)}}}_{X}\left[\underbrace{\frac{2\Delta a}{a_o+a_1}}_{Y} + \underbrace{\sqrt{e_o^2+e_1^2-2e_1e_o\left(\sin\omega_o \sin\omega_1 + \cos\omega_o \cos\omega_1\right)}}_{Z}\right]$	$X(Y-Z)$

$\mu_\oplus$ = earth gravitational constant

Subscript o = initial value

Subscript 1 = desired value

$\Delta a = a_1 - a_o$

$\theta = f + \omega_o$

f = true anomaly

positive ΔV is in direction of motion

Table 6-3. Achieved Injection Conditions

Parameter	Value		Cumulative Probability Level, (%)	Pre-Launch Specification
Semi-major axis, km	Mean	7170.271	50.45	7150 to 7186
	Nominal	7168.7	30.93	
	Actual	7162.770	0.89	
Eccentricity	Mean	0.001560	54.84	0.0 to 0.0052
	Nominal	0.0008	15.75	
	Actual	0.000667	9.99	
Inclination, deg	Mean	108.09	51.80	107.5 to 108.5
	Nominal	108.00	20.10	
	Actual	108.023	27.07	
Argument of perigee, deg	Mean	71.7	61.82	0 to 360
	Nominal	90.4	87.68	
	Actual	254.0	99.86	

in both the roll and yaw attitudes. The spacecraft was returned to RCS control, and all pre-launch maneuver plans were cancelled pending resolution of the problem.

Data analysis showed that the attitude disturbances occurred at specific locations in each revolution, suggesting that the anomalies were attributable to sunlight entering the field-of-view of one or both horizon sensors. By late July, it was determined that orbit precession had sufficiently changed the sun geometry, and the spacecraft was returned to OACS control using only the right horizon sensor head. No additional disturbances were observed, and permission was given to begin the maneuver series on 15 August.

Because of the delay caused by the attitude anomaly, the original maneuver plan was revised. The Baseline orbit was established with the frozen orbit condition by 26 August. Node control for the Bermuda orbit was to be such that a descending pass occurred directly over Bermuda Island on 8 September. The spacecraft was then to be maneuvered into an exact 3-day repeat orbit that passed over Bermuda every third day. This orbit was to be used for approximately 1 month, when a Cambridge orbit would be established to provide a gradually shifting coverage pattern. The orbit definitions are given in Table 6-4.

The revised schedule is presented in Table 6-5. Six maneuvers were scheduled to meet experiment objectives. All pre-launch defined maneuver interfaces were exercised as planned. The MOPT was convened twice during each maneuver cycle, and maneuver plans and results were widely distributed.

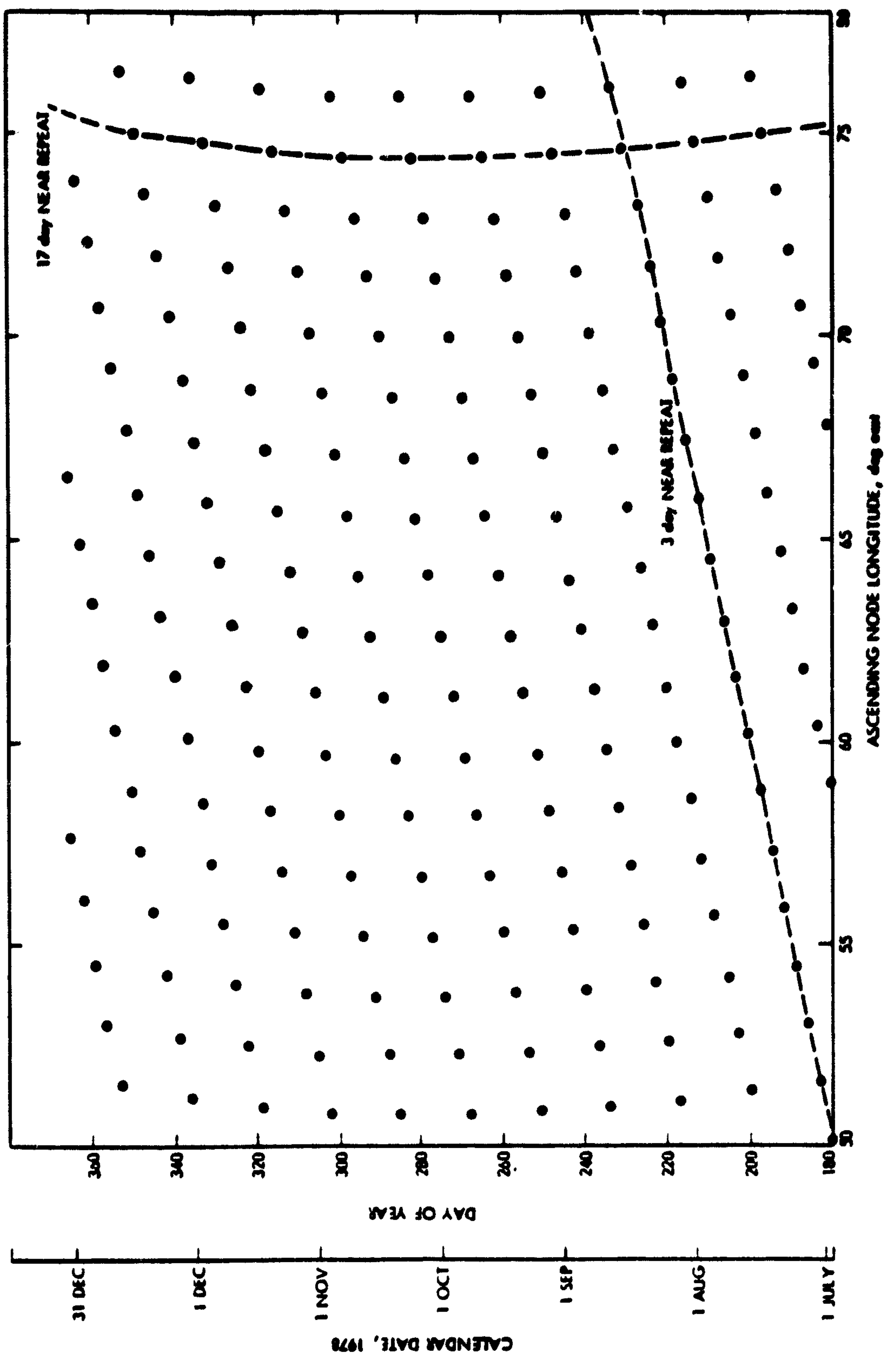


Figure 6-3. Seasat Launch Orbit Ascending Node Pattern

Table 6-4. Orbit Definitions

Baseline orbit	A 3-day near-repeat orbit which moves 18.5 km (10 nm) to the east every 3 days. Has advantages of multiple coverage of fixed locations and good orbit stability with respect to drag.
Cambridge orbit	A 25-day near-repeat orbit which moves 18.5 km to the east every 25 days. Has advantage of fast global coverage and optimum SAR swathing.
Exact 3-day repeat orbit	A 3-day exact-repeat orbit which provides near-zenith descending node passes over BDA every 3 days. Has advantages for ALT calibration.
Launch orbit	The orbit actually achieved by the spacecraft on June 27. This orbit has identifiable 3-day and 17-day cycle components (see Figure 6-3). The orbit spacing changes with time due to drag (i.e., no maintenance maneuvers).
17-day near-repeat orbit	17-day near-repeat orbit which is close to the launch orbit. Moves 18.5 km to the west every 17 days (other spacings are possible).
Node control condition	The condition which exists when the node control maneuver synchronizes the ascending node longitudes and times to the pre-flight plan.
Frozen orbit condition	The condition which exists when the orbit adjust maneuver achieves orbital elements which freeze perigee at the maximum north latitude excursion, thereby minimizing altitude and altitude rate variations in northern hemisphere (desirable for the SAR).

The first orbit adjust thruster (OAT) firing occurred at 07:41 UTC on 15 August. This maneuver was to calibrate the $-\Delta V$ thruster. Subsequent maneuvers were then performed to change the nodal precession rate, calibrate the $+\Delta V$ thruster, synchronize with nominal ascending node locations, and achieve the 3-day repeating orbit over Bermuda. Each maneuver after the first calibration burn was modified slightly to adjust for errors in the previous burn and to correct for drag prediction errors. The error from maneuver 4 caused the Bermuda overflight to slip from 8 September to 10 September. This was acceptable to the altimeter team, and the trim maneuver scheduled for 1 September was cancelled.

Table 6-5. Maneuver Timeline

Date	Maneuver	Description
15 August	Calibration No. 1	Calibrate $-\Delta V$ thruster 60-s burn. $\Delta a \simeq -1$ km
18 August	Orbit adjust No. 1	Orbit adjust No. 1 changed nodal precession rate. Post-maneuver orbit: $\bar{a} \simeq 7160.1$ $e \simeq 0.00143$ $\omega \simeq 146.27$ $i = 108.023$ $\Omega \simeq 87.7$
23 August	Calibration No. 2	Calibrate $+\Delta V$ thruster 60-s burn. $\Delta a \simeq +1$ km
26 August	Orbit adjust No. 2	Orbit adjust No. 2 achieved the nominal preflight nodes. The orbit was a baseline ground trace with about 11-km spacing (east) and a near-frozen orbit: Post-maneuver orbit $\bar{a} \simeq 7168.6$ $e \simeq 0.0008$ $\omega \simeq 95$ $i = 108.023$ $\Omega \simeq 104.3$
1 September	Trim No. 1	Trim No. 1 was to correct any execution error resulting from OA No. 2. This maneuver would ensure that the Bermuda overflight would occur on 10 Sep ±1 day.
8 September	Orbit change No. 1	Orbit change No. 1 achieved the 3-day exact-repeat which was a descending leg over Bermuda Island. Post-maneuver orbit: $\bar{a} \simeq 7169.0$ $e \simeq 0.0008$ $\omega \simeq 90.0$ $i = 108.023$ $\Omega \simeq 126.7$

E. MANEUVER EVALUATIONS

The Seasat maneuvers were all executed successfully with near-perfect results. All maneuver objectives were attained, and no abnormalities occurred. The performance results for the maneuvers are summarized in Table 6-6.

Figure 6-4 shows the variation of ε and ω from launch until 26 August 1978. The normal precession of ε and ω prior to maneuvers is evident, and the maneuvering to the "frozen" (zero precession) point is illustrated. Since 10 September, when the frozen orbit was established, the values of ε and ω, while not entirely constant, show very small amounts of motion (Figure 6-5). The small remaining variation in ε and ω is due to scatter in OD solutions plus the effects of high-order harmonics, solar radiation pressure, atmospheric drag, sun and moon gravity, etc. Figure 6-5 also shows the GSFC predicted motion of ε and ω for the next year with constant values of drag and solar radiation pressure.

It can be seen that the values would vary between $0.00075 \leq \varepsilon \leq 0.00084$ and 86.5 deg $\leq \omega \leq$ 94.5 deg in a slow spiral during the next year. Perturbation analyses at JPL and GSFC have shown the main cause of the non-zero precession to be solar radiation pressure and drag. These small variations are well within the design goals needed to keep the altitude variation essentially constant over any latitude. Also, corrections to ε and ω would have been made when maneuvers were made to correct semi-major axis decay due to drag (about every 2 months), or when the orbit ground trace pattern was changed. The next maneuver on 26 October would have been to go to the Cambridge ground trace pattern. The values of ε and ω would have been targeted to 0.0008 and 90 deg, respectively.

The semi-major axis history during the maneuver period is plotted in Figure 6-6, which shows both the actual and nominal values. The OD precision is ±30 m (98 ft) or better in semi-major axis. The largest execution error (absolute value) was 57 m (187 ft) from maneuver 4 (Table 6-6). The effect of drag on semi-major axis can be seen in Figure 6-7. Although the scatter in OD is evident, a clear decay of about 3 m/day is predominant, especially after 18 September. Figure 6-8 shows a plot of solar activity since launch. Atmospheric drag generally followed the solar flux activity. JPL and GSFC orbit prediction programs used an average value of flux of 150 for most periods, and generally had good agreement with actual results.

Achieving the exact 3-day repeat orbit over Bermuda on a specific date was the most challenging requirement. The nominal pre-launch Bermuda overflight was 2 September. After launch, if no maneuvers were made, passes over Bermuda would occur about every 17 days. However, because of the large difference in semi-major axis between the launch orbit and the 3-day repeat orbit, a single corrective maneuver would not be advisable because of the size of likely execution errors. Also, the overflight dates without maneuvers were 31 August and 16 September. Because of the previously discussed attitude problems, the earliest first maneuver date was 15 August. The maneuver sequence of Table 6-5 was designed to produce a Bermuda overflight on 8 September. The slip from 2 September was necessary because of the late maneuver start date and the number of maneuvers required. Figure 6-9 shows the ground trace position relative to Bermuda Island during the maneuver period. The first two maneuvers changed $\dot{\Omega}$

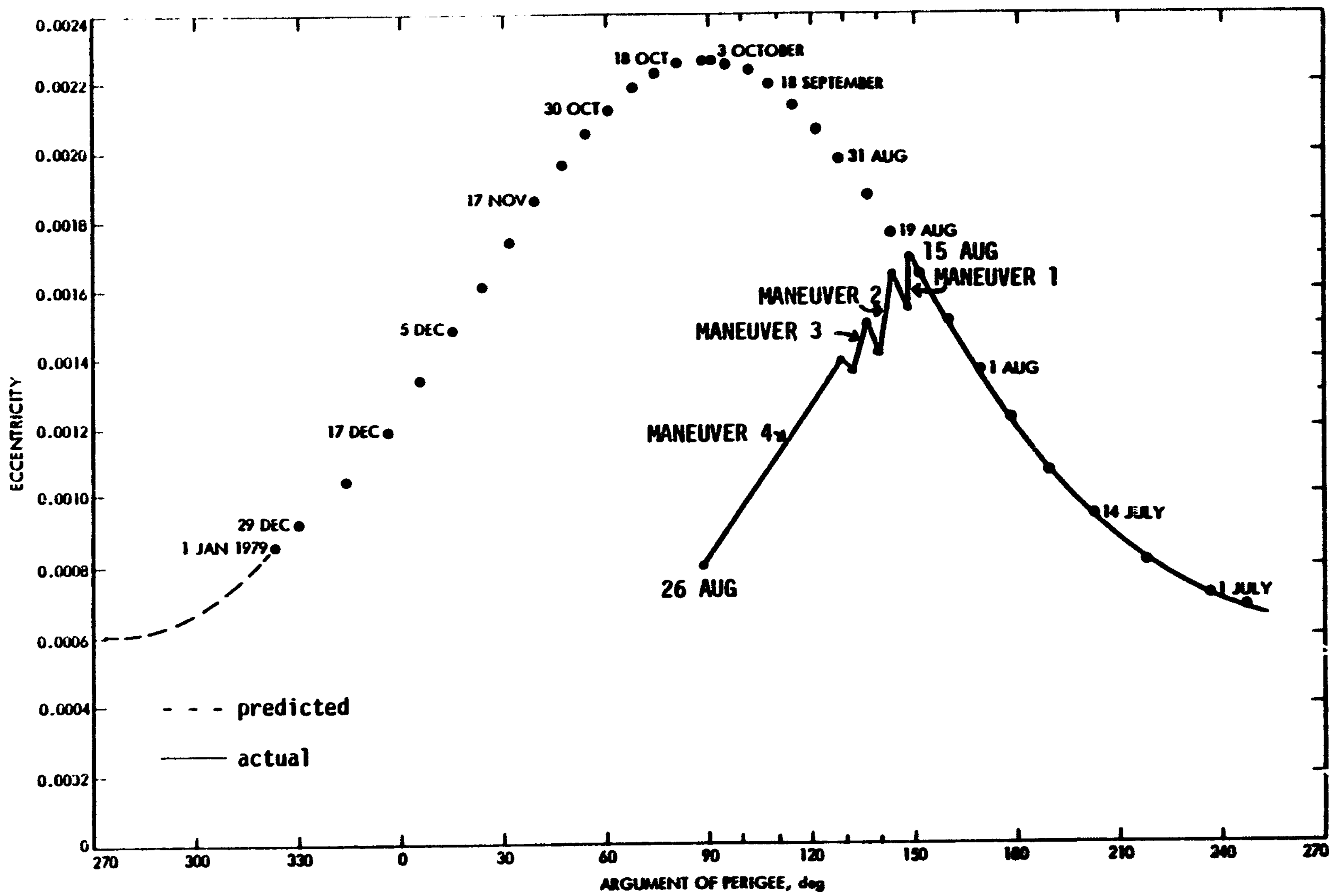


Figure 6-4. Eccentricity vs Perigee History

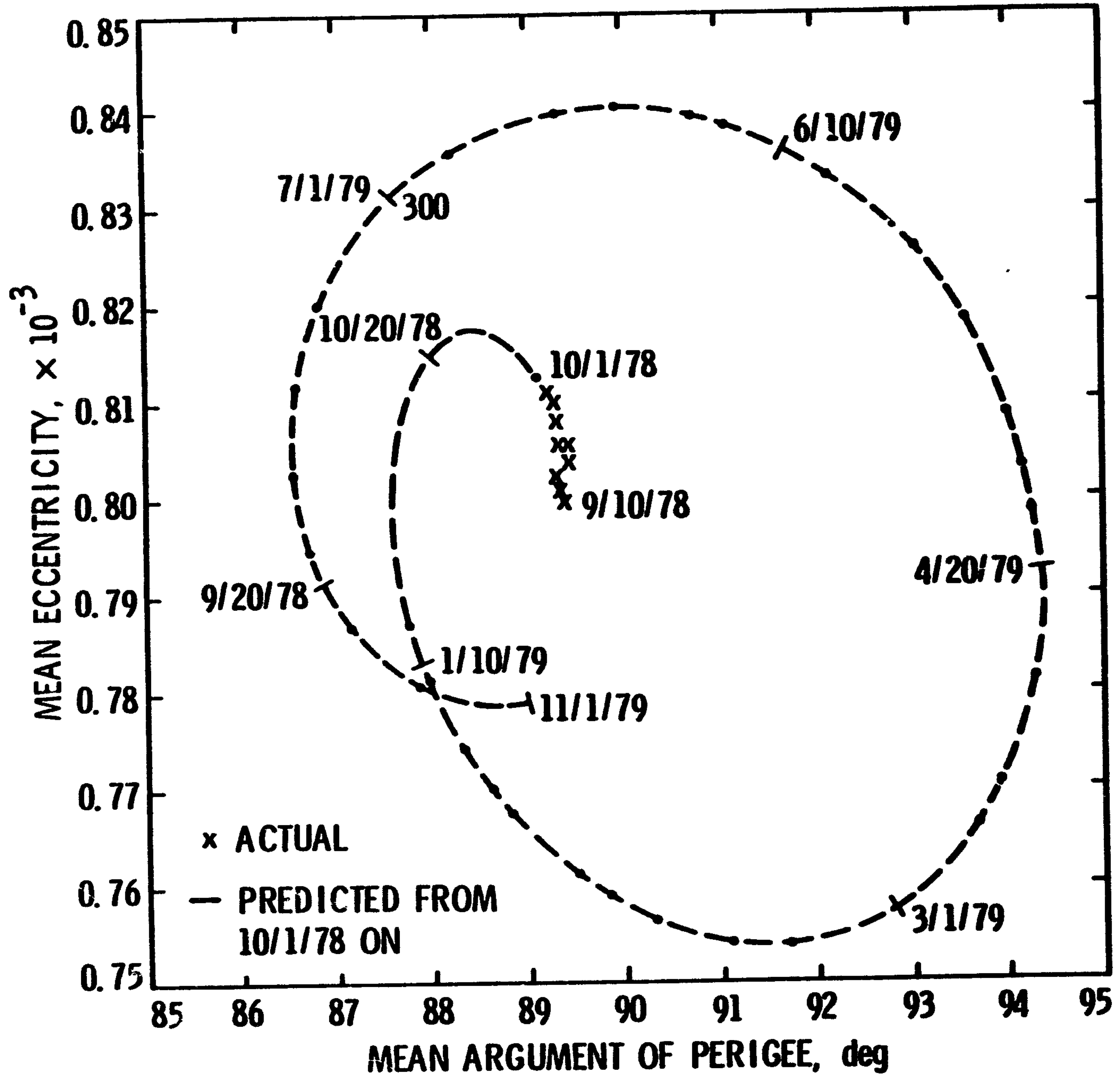


Figure 6-5. Eccentricity vs Perigee Near "Frozen" Condition

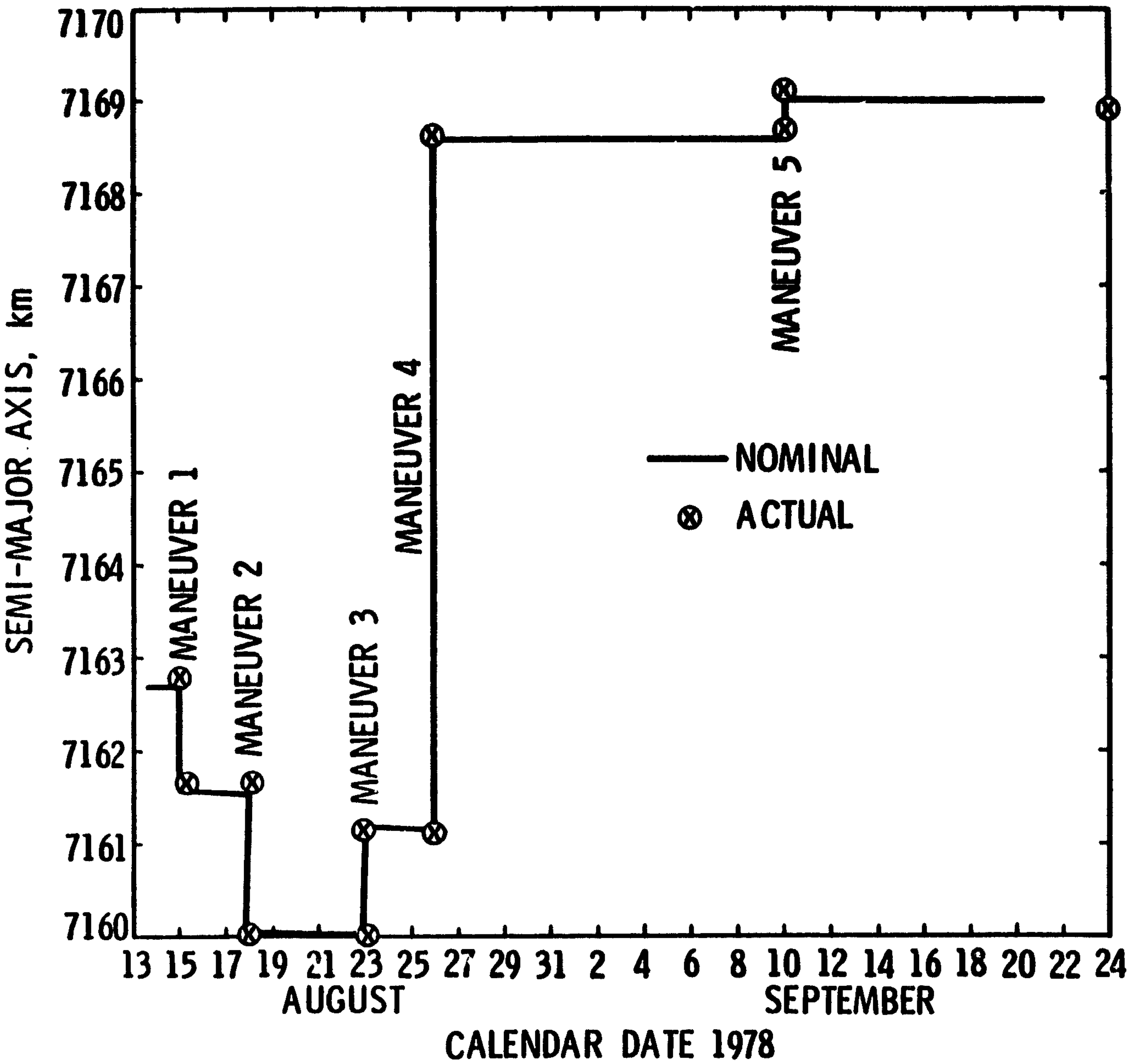


Figure 6-6. Semi-Major Axis History

Table 6-6. Maneuver Performance

Maneuver Number	1	2	3	4	--	5	6
Purpose	Calibration ($-\Delta v$)	Change $\dot{\Omega}$	Calibration ($+\Delta v$)	Launch Error Correction	Trim	Exact 3-Day Repeat	Cambridge Orbit
Date	8/15/78	8/18/78	8/23/78	8/26/78	9/1/78	9/10/78	10/26/78
Rev. No.	705	748	820	863		1073	
Start Time (GMT), h:min:s	07:41:08	07:46:58	09:20:36	09:22:08	Cancelled	01:10:22	Power Failure Precluded Execution
Burn Duration, s	60	84	60	439		28	
Predicted Δa, m	-1.137	-1.531	+1.111	+7.426		+0.441	
Predicted Δe, x 10^{-3}	-0.155	-0.205	-0.132	-0.645		+0.025	
Predicted $\Delta\omega$, deg	-1.066	-2.261	-3.189	-43.648		+4.081	
Actual Δa, km	-1.120	-1.515	+1.078	+7.483		+0.438	
Actual Δe, x 10^{-3}	-0.154	-0.203	-0.127	-0.629		+0.025	
Actual $\Delta\omega$, deg	-0.981	-2.163	-3.199	-45.367		+4.014	
Fuel Consumed, kg (lbm)	0.65 (1.43)	0.87 (1.92)	0.62 (1.36)	3.42 (9.52)		0.25 (0.55)	
Thrust Correction Factor, (%)	-1.5 ($-\Delta v$)	-1.0 ($-\Delta v$)	-3.1 ($+\Delta v$)	+0.8 ($+\Delta v$)		-0.7 ($+\Delta v$)	

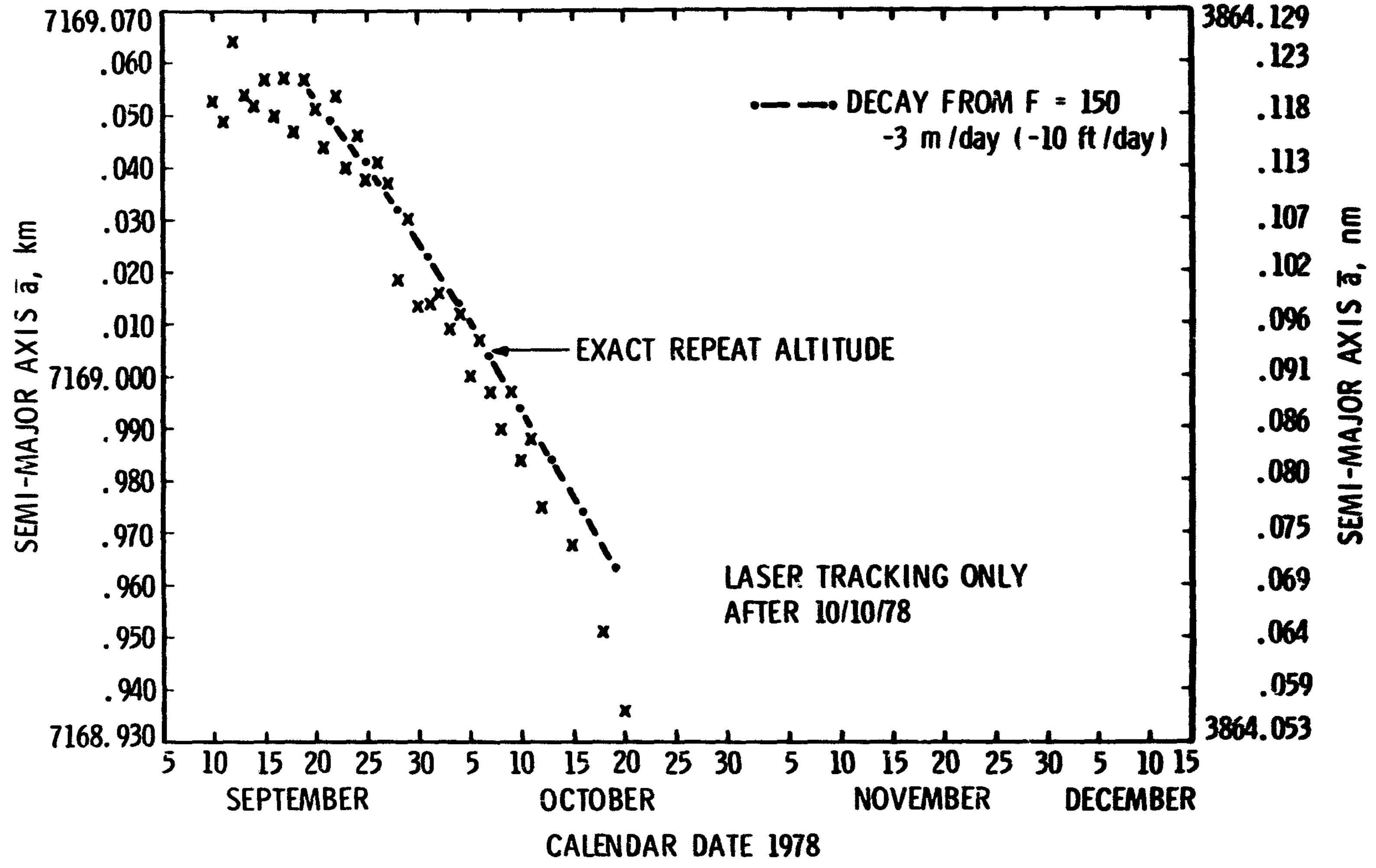


Figure 6-7. Semi-Major Axis Decay in Exact Repeat Orbit

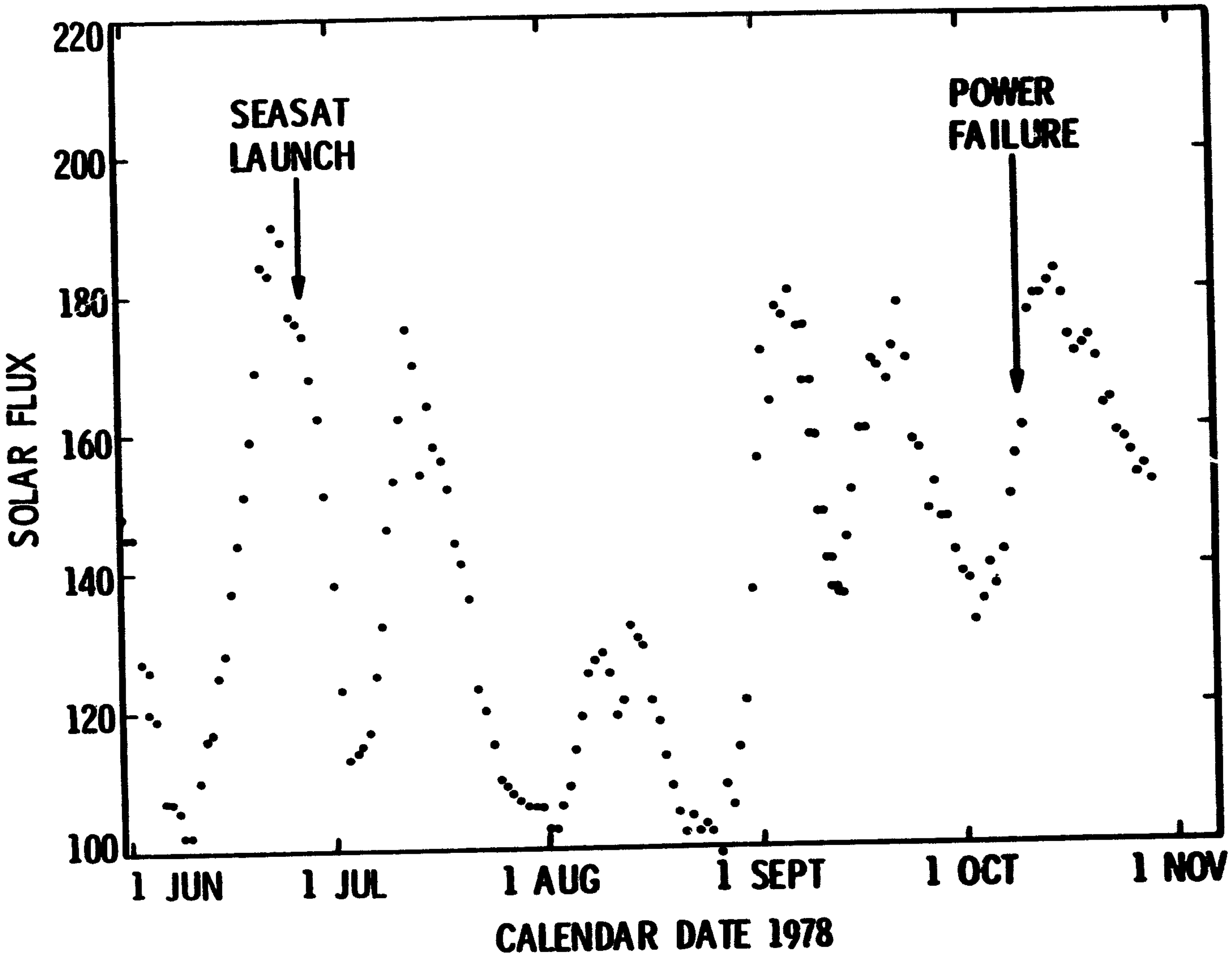


Figure 6-8. Solar Activity During Seasat Mission

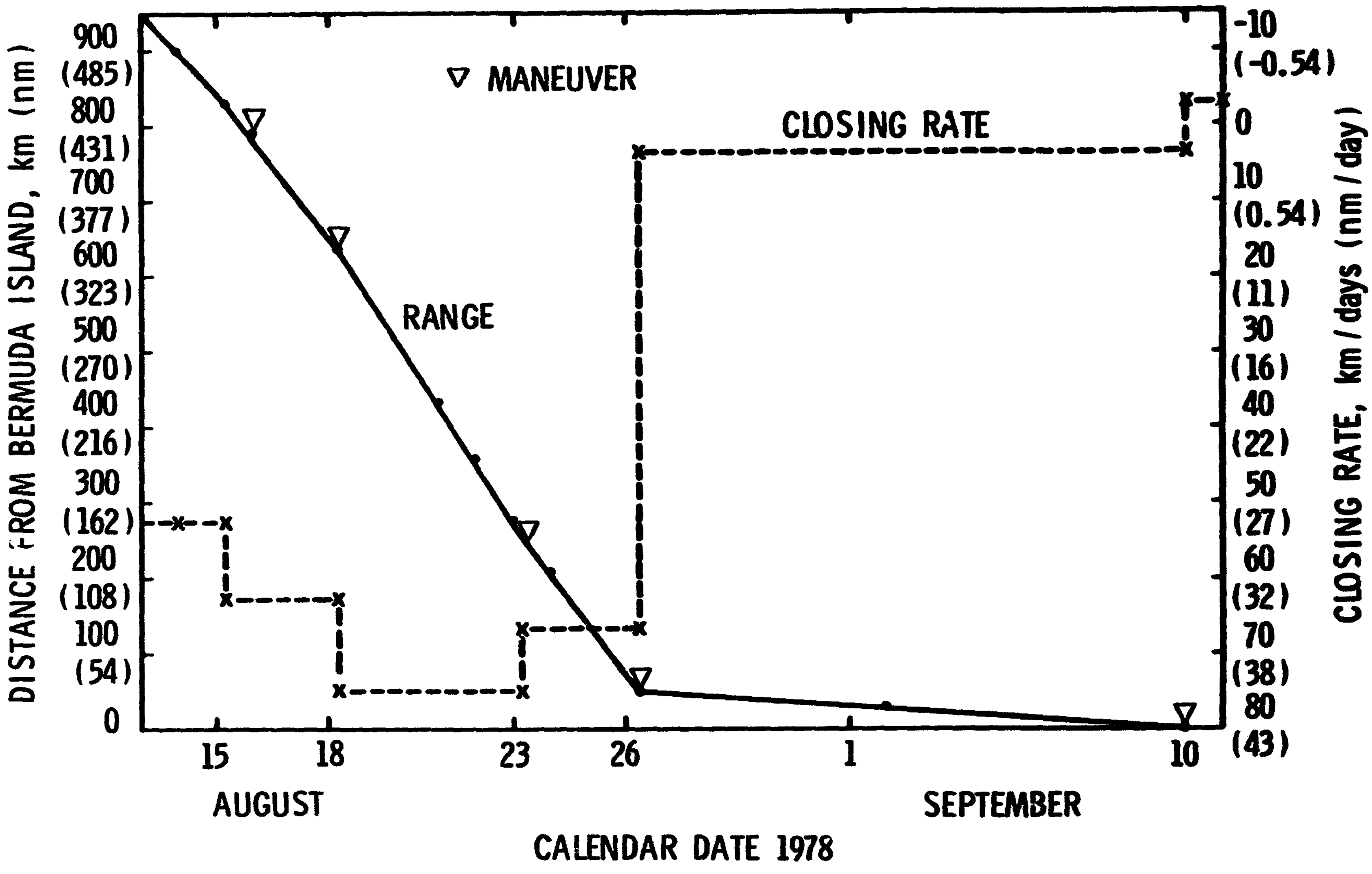


Figure 6-9. Bermuda Miss Distance and Closure Rate

so that the nominal pre-launch nodes were matched on 26 August. The second two maneuvers changed Ω to match the nominal baseline orbit value (i.e., cause a 3-day near-repeat ground trace). After 26 August, the ground trace was about 42 km (23 nm) west of Bermuda and every 3 days the ground trace precessed 9 km (5 nm) closer. The ascending nodes for a Bermuda overflight were achieved on 10 September at 01:10:36 GMT. A 28-s burn was centered around this time to change $\dot{\Omega}$ so that the 3-day drift rate was zeroed out (i.e., an exact 3-day repeat was achieved).

Actually, a slight westward drift of 0.7 km (0.38 nm) every 3 days was intentionally introduced to oppose the effects of drag and, therefore, increased the time during which the Bermuda overflights would stay within tolerance. This maneuver was intentionally small so that thrust or timing errors would not cause a large miss distance or introduce large drift rates. This maneuver was essentially perfect. The first Bermuda overflight was 100 m (328 ft) west of the Bermuda laser site. Figure 6-10 shows the predicted and actual miss distances relative to Bermuda (i.e., at 30-deg latitude) from 10 September to 30 October. The maximum west miss was 3.7 km (2 nm). The ground trace stayed within 5 km (2.7 nm) of the laser site for 45 days. The ground trace actually drifted farther west than anticipated. This occurred because the semi-major axis did not decay as much as predicted from 10 to 20 September (Figure 6-7) even though the solar flux predictions were very close to actual values (Figure 6-8).

The hydrazine usage is shown in Figure 6-11. The ascent and early orbit usages were much higher than nominal because of the attitude anomaly and the delay in going to the wheel attitude control system. Table 6-7 lists the pre-launch and actual ΔV budget. It can be seen from Table 6-7 that nearly one-half of the total hydrazine was uncommitted and could have been used for additional orbit changes or attitude maneuvers. To illustrate the capabilities of the remaining hydrazine supply, enough fuel remained aboard the spacecraft to complete all planned maneuvers and do maintenance trims to compensate for drag for over 40 years.

As the power failure precluded any additional maneuvers, the spacecraft will remain in a 3-day near-repeat orbit. The miss distance as of 1 November 1978 was 3 km (1.6 nm) west, which would grow to 7 km (3.8 nm) west every 3 days by 1 January 1979. The spacecraft will remain in a 3-day near-repeat orbit for years, although the 3-day drift rate constantly increases. It is possible that the spacecraft could be useful in future geodesy applications because it is large, has a laser reflector ring, and is in an easily predicted orbit. Despite the early end to experiment data collection, all maneuver objectives were demonstrated, except for long-term maintenance. The power failure also prevented long-term data collection from a uniform global coverage pattern.

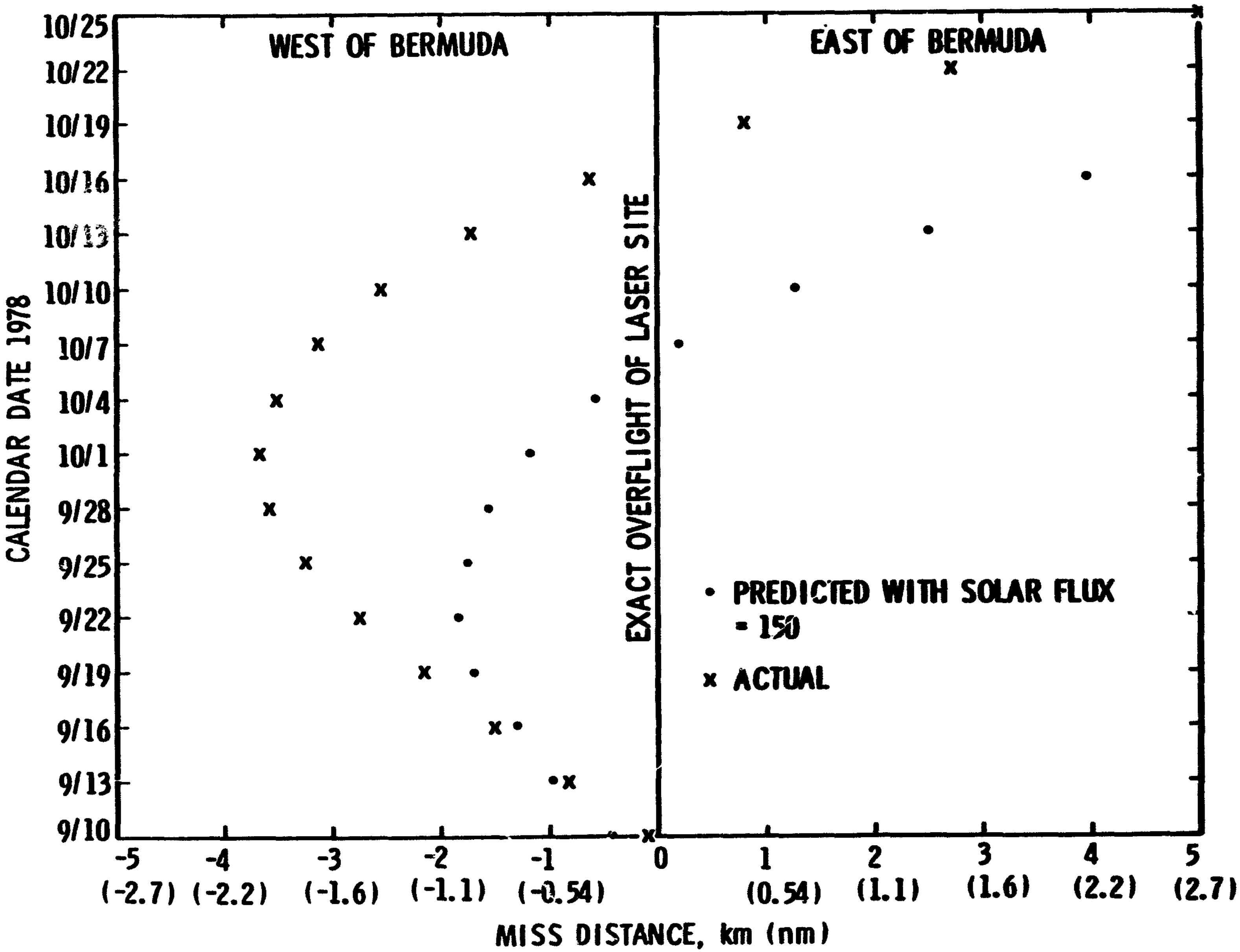


Figure 6-10. Bermuda Miss Distance

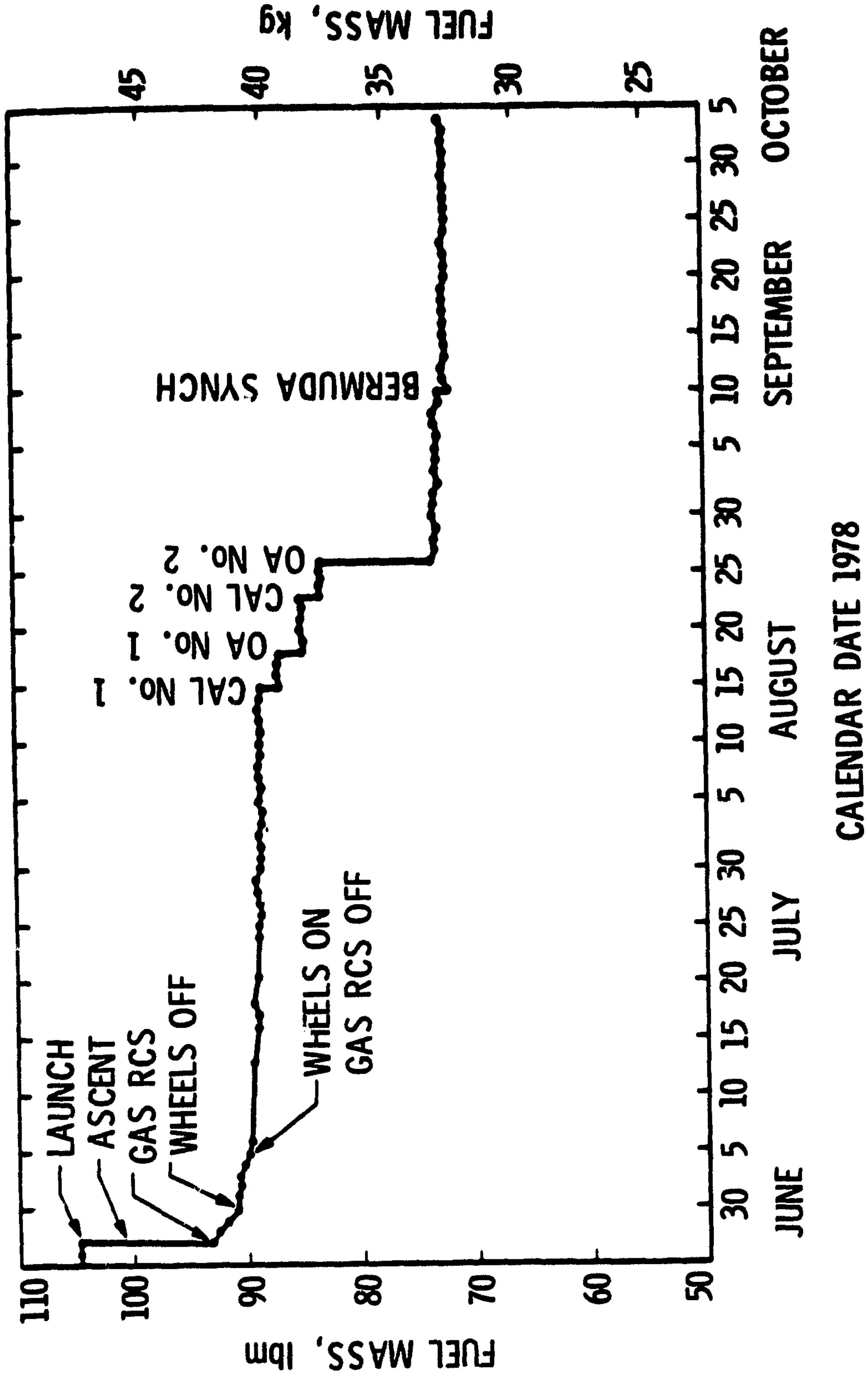


Figure 6-11. Hydrazine Remaining

Table 6-7. Pre-Launch and Actual ΔV Hydrazine Allotment

	Pre-Launch		Post-Launch	
	$\mu + 3\sigma$, m/s	Nominal (μ), m/s	Actual, m/s	Planned, m/s
Ascent attitude control	4.16	2.82	7.28	--
Orbit adjust (incl. node control)	25.78	4.40	7.27	--
Baseline to exact 3-day repeat	0.52	0.48	0.45	--
Exact 3-day to Cambridge	3.75	3.62	--	3.62
Cambridge to baseline	3.06	3.01	--	3.01
Maintenance trims (3 yr)	7.18	1.49	--	1.39
Thruster resolution (0.5 s)	0.31	0	--	--
Total usage	38.0 ($\mu + 3\sigma$, σ = 1550 i)	15.8	23.02	
Total capability	47.2	47.2	47.51	
Margin	9.2	31.4	24.5	

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SECTION VII

SATELLITE FAILURE

A. INTRODUCTION

Seasat ceased downlink transmission following an electrical power system failure on 10 October 1978. Subsequent attempts to re-establish communications with the satellite were unsuccessful, and flight operations were discontinued on 10 November 1978. The contents of this section summarize Project Operations System (POS) activities from first observation of the malfunction until termination of mission operations.

B. MISSION OPERATIONS ACTIVITIES

The first indication of a satellite malfunction was observed during a rev 1503 contact by the Santiago, Chile (AGO) tracking station. At the AGO acquisition time of 03:29 UTC, satellite engineering data indicated a number of out-of-tolerance conditions for electrical power and thermal systems measurements. On observing these data, the on-duty mission controller and lead spacecraft analyst agreed on a course of action that included validation of the ground data system, investigation of a potential Telemetry/Sensor Interface Unit (TSU) failure, and analysis of the power system measurements to identify a potential short circuit.

The supposition that the problem could be attributable to ground processing was based on pre-launch and early mission experience in which frequent instances of erroneous data display were encountered. Data reliability was also questioned in view of a TSU multiplexer failure potential identified during vehicle pre-flight testing. Finally, detailed analysis of the power system measurements was considered necessary because the available data were indicative of a shorted load, but no abnormal satellite subsystem loads could be identified.

1. Failure Observation

A detailed chronology of the events and activities that followed discovery of the power anomaly is given in Table 7-1. Analyses were not completed before the loss of signal at AGO at 03:42 UTC, and additional priority monitoring was requested for 03:59 UTC at the Orroral, Australia (ORR) tracking station. The majority of the ORR data were not observed in real time because of data system restarts and, following the loss of signal at 04:08 UTC, the station was requested to replay the satellite data from analog station tapes. By the completion of the ORR playback at 04:20 UTC, both ground system and TSU failure modes had been discounted, and the investigation centered on isolation of a satellite short circuit.

At the next scheduled contact at 04:44, the Shoe Cove, Newfoundland (SNF) station reported no acquisition of the satellite downlink. Following a second report of no acquisition at 04:52 from the Merritt Island, Florida (MIL) station, a spacecraft emergency condition was declared, and contingency command sequences

Table 7-1. Failure Event Chronology, 10 October 1978 (Day 283)

Time (UTC)	Event
03:29:43	AGO acquisition
	Unregulated bus voltage 24.03 V
	Battery 1 current 51.50 A
	Battery 2 current 51.80 A
	Structure current 0.199 A
	Vehicle and sensor subsystem loads normal
	Discussion of data condition and course of action
	1. Potential ground processing problems
	2. Potential TSU failure
	3. Potential vehicle short circuit
03:31:37 to 03:32:01	Restart of control center computer
03:33:08 to 03:33:40	Restart of stati decom and data processing computers
03:40:00	Request for additional tracking coverage from ORR
03:42:53	AGO loss of signal
03:43:00 to 03:59:00	Status of analysis
	1. Control center engineering unit conversion suspect
	2. TSU failure potential unresolved
	3. Vehicle short circuit could not be attributed to a particular system failure

Table 7-1. Failure Event Chronology, 10 October 1978 (Day 283) (Continuation 1)

Time, UTC	Event
03:59:09	ORR acquisition
	Unregulated bus voltage 21.00 V
	Battery 1 current 43.10 A
	Battery 2 current 41.10 A
	Structure current 10.00 A
	Vehicle and sensor subsystem loads normal
04:03:08 to 04:06:58	Swap out control center disk containing engineering unit conversion tables (unsuccessful)
04:08:28	ORR loss of signal
04:09:00 to 04:20:00	ORR playback from analog tape
04:20:00 to 04:44:00	Status of analysis 1. Ground processing valid 2. TSU failure not indicated 3. Vehicle short circuit indicated, but not localized; contingency commands planned for MIL.
04:44:00	SNF (receive-only site) reports no acquisition
04:52:00	MIL reports no acquisition
04:55:00	Spacecraft emergency condition declared
05:01:00 to 05:04:00	Contingency commands to remove sensor loads transmitted from MIL

Table 7-1. Failure Event Chronology, 10 October 1978
(Day 283) (Continuation 2)

Time, UTC	Event
05:09:00	QUI reports no acquisition
05:10:00 to 05:13:00	Contingency commands to remove sensor loads transmitted from QUI
06:32:00	MIL reports no acquisition
06:35:00 to 06:38:00	Contingency commands to remove sensor loads transmitted from MIL
08:11:00	GDS reports no acquisition; both 9- and 26-m antennas searching for downlink
08:15:00 to 08:18:00	Contingency commands for downlink recovery transmitted from GDS

designed to remove the sensor loads from the satellite power bus were transmitted. Spacecraft controllers then continued to transmit these commands, as well as a downlink recovery sequence, at each potential contact.

The spacecraft emergency was declared at 04:55, and project personnel at JPL, GSFC, and LMSC were notified. Under the direction of the Mission Manager, an anomaly investigation team was formed, and communication circuits were obtained for team coordination. The organization, activities, and findings of the anomaly team are documented in Volume II of this report.

2. Data Retrieval and Distribution

The role of the POS during the anomaly investigation included the retrieval and distribution of pertinent satellite data as listed in Table 7-2.

3. Recovery Strategies

The implementation of recovery strategies recommended by the anomaly team is given in Table 7-3.

Table 7-2. Failure Data Distribution

Site	Orbit	Data Type	Data Time	Via	Format	To IC Heads
MAD	1501	PB	282/1803-2153	IPD	PMDF	JPL/PDPS
ORR	1502	PB	282/2148-283/0137	IPD	Quicklook	GSFC/POCC
				IPD	PMDF	JPL/PDPS
UKO	1502	RT	283/0122-0136	WNK	Analog	ETC
				ETC	NASCOM	GSFC/POCC
				ETC	NASCOM	IPD
				IPD	PMDF	JPL/PDPS
ORR	1502	RT	283/0217-0231	IPD	PMDF	JPL/PDPS
UKO	1503	RT	283/0300-0313	WNK-1	Analog	ETC
				ETC	NASCOM	GSFC/POCC
				ETC	NASCOM	IPD
				IPD	PMDF	JPL/PDPS
AGO	1503	RT	283/0329-0342	GSFC/ POCC	History Tape	JPL/PDPS
				IPD	PMDF	JPL/PDPS
ORR	1503	RT	283/0359-0408	IPD	PMDF	JPL/PDPS

Note: UKO 1502 and 1503 data transmitted from Winkfield, UK via Data Transmission System (DTS) to GSFC Multi Satellite Operations Control Center I (MSOCC I)

4. Possible Contacts

An intense tracking schedule was maintained through 21 October 1978, when attempts to reacquire the downlink were reduced to periods during which the satellite was in sunlight. During intensive tracking, a number of weak signals were reported at the Seasat downlink frequency; however, these were subsequently discovered to be other spacecraft transmitting at the same frequency or station internally generated signals (Table 7-4).

On 10 November 1978, following 31 days of attempts to re-establish satellite communications, flight operations were discontinued, and project activities were directed to detailed failure analysis and science data evaluation.

Table 7-3. Recovery Sequences

Seq.	Downlink	Uplink	Commands	First Use	Results
1	Freq: 2287.5 MHz Tune: +5/-10 MHz	None	None	MIL 1512	Neg
2	Standard procedure	Freq: 2106.4 MHz + Doppler Sweep: ±45 kHz/20 s (auto)	Sensors off. Downlink recovery	GDS 1513	Neg
3	Standard procedure	10° rise Freq: 2106.32 MHz Sweep: ±25 kHz/20 s (auto) 6 sweeps: command	Sensors off. Downlink recovery	HAW 1514	Neg
		10° set Freq: 2106.4 MHz Sweep: ±25 kHz/20 s (auto) 1 sweep: command	Sensors off. Downlink recovery		
4	Standard procedure	AOS: 3 min Freq: 2106.373 MHz + Doppler Sweep: ±45 kHz/20 s (auto) 3 sweeps: command	Sensors off. Downlink recovery	HAW 1515	Neg
		LOS: 3 min Freq: 2106.373 MHz + Doppler Sweep: ±45 kHz/20 s (auto) 1 sweep: command	Sensors off. Downlink recovery		
5	Standard procedure	Freq: 2106.373 MHz Sweep: ± Doppler, +50 kHz/ 20 s (manual) 1 sweep: command	Sensors off. Downlink recovery	GDS 1535	Neg
6	AOS Freq: 2287.495 MHz -AOS Doppler Tune: ±50 kHz (manual)	None	None	ULA 1541	Neg
7	1-way sequence Freq: 2287.5 MHz Tune: ±300 kHz	2-way sequence Freq: 2101.373 MHz + Doppler Sweep: ±45 kHz/20 s (auto) 3 sweeps: command	0072,0040, 0245, 0266, 0030, 0042, 0064, 0106, 0200, 0231, 0300 Contingency sequence 1 Contingency sequence 2	GWM 1544	Neg

Table 7-4. Possible Seasat Contacts

Orbit	Site	Time, UTC	Description	Data Recorded	Probable Source
1506	UKO	283/08:10	Tranet contact	No	GEOS-3
1507	UKO	283/09:47-09:51	Tranet contact	No	GEOS-3
1508	UKO	283/11:12:45-11:12:52 283/11:13:20-11:13:24	Two bursts (7 s and 4 s) at 2282.5 MHz. No receiver lock.	No	Downlink frequency not Seasat
1509	ULA	283/13:13:00	Momentary signal at 2280.0 MHz	No	Site internal signal
1510	BDA	283/14:32-14:38	Approximately 6-min weak signal at 2287.5 MHz. No receiver lock.	No	Landsat-3
1510	MIL	283/14:37:20-14:37:25	5-s weak signal at 2287.5 MHz. No receiver lock.	No	Landsat-3
1511	SNF	283/16:18	Momentary signal at 2287.5 MHz. Decom output SAR quicklook data. SAR data erroneous.	Yes	Data not Seasat
1518	UKO	284/04:20:00	Momentary signal at 2280.0 MHz. No receiver lock.	No	Downlink frequency not Seasat
1518	SNF	284/04:28:00	Momentary signal at 2287.5 MHz. Decom output SAR quicklook data. SAR data erroneous.	Yes	Data not Seasat
1524	SNF	284/14:04	Momentary signal at 2287.5 MHz. No decom output.	No	Undetermined
1538	SNF	285/13:36:00	Momentary signal at 2287.5 MHz. Decom output SAR quicklook data. SAR data erroneous.	Yes	Data not Seasat
1542	ULA	285/20:46	Approximately 1-min weak signal at 2287.5 MHz. No receiver lock.	No	Landsat-3
1551	SNF	286/11:33	Momentary signal at 2287.5 MHz. Decom output SAR quick-look data. SAR data erroneous.	Yes	Data not Seasat
1552	SNF	286/13:10	Momentary signal at 2287.5 MHz. Decom output SAR quick-look data. SAR data erroneous.	Yes	Data not Seasat
1553	SNF	286/14:41	Receiver lock on strong signal at 2287.5 MHz. No decom output.	No	Landsat-3
1554	MIL	286/16/26:11-16:28:30	Approximately 20-s signal at 2287.1 MHz.	No	Site internal signal
1555	GDS	286/18:12-18:16	4-min weak signal at 2287.5 MHz. No receiver lock.	No	Landsat-3
1556	ULA	286/19:55-19:57	2-min weak signal at 2287.4 MHz. No receiver lock.	No	Landsat-3
1557	ULA	286/21:33:40	Momentary signal at 2287.5 MHz. No receiver lock.	No	Landsat-3
1575	SNF	288/04:10	No indication of signal, but decom output SAR quick-look data. SAR data erroneous.	Yes	Data not Seasat

Table 7-4. Possible Seasat Contacts (Continuation 1)

Orbit	Site	Time, UTC	Description	Data Recorded	Probable Source
1580	UKO	288/12:08-12:09	3-signal bursts at 2287.5 MHz. No receiver lock.	No	Landsat-2
1580	SNF	288/12:20:35	Same as orbit number 1575.		
1582	ETC	288/15:29:10-15:38:30	9-min weak signal at 2287.5 MHz Doppler rate not indicative of Seasat track.	No	Landsat-2
1582	SNF	288/15:32	Same as orbit number 1575		
1585	ULA	288/20:37:40-20:42:00	4-min weak signal at 2287.5 MHz. Doppler rate not indicative of Seasat track.	No	Landsat-2
1595	UKO	289/13:20-13:22	Two momentary signal bursts at 2287.5 MHz. No receiver lock.	No	Landsat-3
1596	ULA	289/15:14-15:21	8-min weak and intermittent signal at 2287.5 MHz. No receiver lock.	No	Site internal signal
1599	ULA	289/20:08-20:13	Several signal bursts at 2287.5 MHz. No receiver lock.	No	Landsat-3
1622	MAD	291/10:41:00-10:43:40	Over 2-min weak signal at 2287.5 MHz. Doppler rate not indicative of Seasat track.	No	Landsat-2
1623	MAD	291/12:23:20	Momentary signal burst at 2287.5 MHz. No receiver lock.	No	Landsat-2
1627	ULA	291/19:14:00-19:15:30	1 1/2-min weak signal at 2287.5 MHz. No receiver lock.	No	Landsat-2
1662	SNF	294/06:19	Same as orbit number 1575.		
1663	SNF	294/07:53	Same as orbit number 1575.		
1665	MAD	294/10:45:50-10:58:10	Over 2-min weak signal at 2287.5 MHz. Doppler rate not indicative of Seasat track.	No	Landsat-2
1690	SNF	295/05:18	Same as orbit number 1575.		
1691	SNF	295/06:57	Same as orbit number 1575.		
1704	SNF	297/04:51	Same as orbit number 1575.		
1718	SNF	298/04:21	Same as orbit number 1575.		
1719	SNF	298/06:03	Same as orbit number 1575.		
1720	SNF	298/07:41	Same as orbit number 1575.		
1733	SNF	299/05:33	Same as orbit number 1575.		
1734	SNF	299/07:11	Same as orbit number 1575.		

APPENDIX

ABBREVIATIONS AND ACRONYMS

APPENDIX

ABBREVIATIONS AND ACRONYMS

AAFE	Advanced Application Flight Experiment
ACMO	Assistant Chief of Mission Operations
ACN	STDN Station at Ascension Island, United Kingdom
ACS	Attitude Control System
AD	Attitude Determination
ADF	Algorithm Development Facility
ADL	Analog Data Link
ADR	Auxiliary Data Record
ADS	Attitude Determination System
AE	Atmospheric Explorer
AFB	Air Force Base
AFIOS	Air Force Indian Ocean Station
AFSCF	Air Force Satellite Control Facility
AFSTC	Air Force Satellite Test Center
AFWTR	Air Force Western Test Range
AGC	Automatic Gain Control
AGO	STDN Station at Santiago, Chile
ALT	Radar Altimeter
AM	Amplitude Modulation
A/O	Attitude/Orbit
AOS	Acquisition of Signal
AOT	Attitude Orbit Tape
APL	Applied Physics Laboratory, Johns Hopkins University

ARIA	Advanced Range Instrumentation Aircraft
ATT	Attitude
BDA	STDN Station at Bermuda, United Kingdom
BECO	Booster Engine Cutoff
BED	Block Error Decoder
CCOM	Control Center Operations Manager
CCRS	Canadian Center for Remote Sensing
CCSM	Control Center Systems Manager
CCT	Computer Compatible Tape
CDR	Critical Design Review
CLA	Control Logic Assembly
CMD	Command
CMDF	Command Master Data File
CMDR	Command Master Data Record
CMF	Command Management Facility
CMO	Chief of Mission Operations
CMS	Command Management System
CRP	Command Request Profile
CRT	Cathode Ray Tube
CSTA	Computer Sciences Technicolor Associates
CTU	Central Timing Unit
CTV	Compatibility Test Van
CY	Calendar Year
DAF	Definitive Attitude File
DAL	Data Accountability Log
DDPS	Digital Data Processing System
DMT	Data Management Team

DoC	Department of Commerce
DoD	Department of Defense
DOY	Day of Year
DREO	Defense Research Establishment, Ottawa
DRS	Data Records System
DSC	Data Set Controller
DTS	Data Transmission System
ESA	European Space Agency
ETR	Eastern Test Range
FMOC	Flight Maneuver Operations Center
FNOC	Fleet Numerical Oceanographic Center (U.S. Navy), Monterey, CA (formerly Fleet Numerical Weather Central)
FSK	Frequency-Shift Keyed
FY	Fiscal Year
GDS	Ground Data System; STDN Station at Goldstone, CA
GDSE	Ground Data System Engineer
GE	General Electric
GIC	Geocentric Inertial Coordinate
GMT	Greenwich Mean Time (Zulu Time)
GOASEX	Gulf of Alaska Seasat Experiment
GPS	Global Positioning System
GRTS	Goddard Real-Time System
GSFC	Goddard Space Flight Center
GWM	STDN Station at Guam, Marianas Islands

HAW	STDN Station at Kauai, HA
HDDR	High Density Digital Recorder
HMRCC	High Mode Reaction Control Cluster
HSD	High-Speed Data
HSDL	High-Speed Data Line
HSK	High-Speed Keying
HVPS	High Voltage Power Supply
IBM	International Business Machines
ICD	Interface Control Document
IDPS	Instrument Data Processing System
IF	Intermediate Frequency
IP	Input Processor
IPD	Information Processing Division
IR	Infrared
IRV	Interrange Vector
ISEE	International Sun-Earth Explorer
JASIN	Joint Air-Sea Interaction Experiment
JPL	Jet Propulsion Laboratory (NASA), Pasadena, CA
KSC	Kennedy Space Center (NASA), FL
LMSC	Lockheed Missiles and Space Company, Inc., Sunnyvale, CA
LOB	Launch Operations Building
LOS	Loss of Signal
LOX	Liquid Oxygen
LRT	Low-Rate Telemetry

LRTS	Low-Rate Telemetry System
LSWA	Left Scan Wheel Assembly
LTWG	Launch Test Working Group
MAD	STDN Station at Madrid, Spain
MCA	Magnetic Control Assembly
MCCC	Mission Control and Computing Center
MCCO	Mission Control Center Operations
MCR	Mission Control Room
MCT	Mission Control Team
MDMT	MCCC Data Management Team
MDR	Mission Dress Rehearsal; Master Data Record
MDS	Mission Data System
MFR	Multifunction Receiver
MIL	STDN Station at Merritt Island, FL
M&O	Maintenance and Operations
MOA	Memorandum of Agreement
MOCF	Mission Operations Computing Facility
MOP	Mission Operations Plan
MOPT	Maneuver Operations Planning Team
MOR	Mission Operations Room
MOS	Mission Operations System
MOSS	Mission Operations Software System
MPS	Mission Planning Subsystem
MPSS	Mission Planning Software System
MPT	Mission Planning Team
MSA	Mission Support Area
MSC&AD	Mission Support Computing and Analysis Division

MSDR	Master Sensor Data Record
MSOCC	Multi-Satellite Operations Control Center
MSOE	Mission Sequence of Events
NASA	National Aeronautics and Space Administration
NASCOM	NASA Ground Communications System
NOAA	National Oceanic and Atmospheric Administration (DoC)
NOSP	Network Operations Support Plan
NSP	NASA Support Plan
NSSDC	National Space Science Data Center
OA	Orbit Adjust
OACS	Orbital Attitude Control System
OAMP	Orbit Adjust Maneuver Program
OAT	Orbit Adjust Thruster
OCC	Operations Control Center
OCD	Operating Control Directive
OD	Orbit Determination; Operations Directive
ODS	Orbit Determination System
OJT	On-the-Job Training
O&M	Operations and Maintenance
OPSCON	Operations Control
OR	Operations Requirement
ORB	Orbit
ORPA	Operational Readiness and Performance Assurance
ORR	STDN Station at Orroral, Australia
ORT	Operational Readiness Test
OSO	Orbiting Solar Observatory

PCM	Pulse Code Modulation
PDP	Project Data Package
PDPS	Project Data Processing System
PM	Phase Modulation
PMDF	Project Master Data File
PMW	Pitch Momentum Wheel
POCC	Project Operations Control Center
POS	Project Operations System
POST	POCC Operations Support Team
PRD	Program Requirements Document
PRF	Pulse Repetition Frequency
PRT	Prepass Readiness Test
QUI	STDN Station at Quito, Ecuador
RBM	Real-Time Batch Monitor
RCS	Reaction Control System (LMSC)
RF	Radio Frequency
RFI	Radio Frequency Interference
RG	Range
RRW	Roll Reaction Wheel
RRWG	Range Requirements Working Group
RSWA	Right Scan Wheel Assembly
RT	Real Time
RTUDDS	Real-Time User Data Demonstration System
SAGE	Stratospheric Aerosol and Gas Experiment
SAMDPO	Satellite Mission Design Program

SAMSO	Space and Missile Systems Organization (USAF), Los Angeles, CA
SAMTEC	Space and Missile Test Center (USAF)
SAO	Smithsonian Astrophysical Observatory
SAR	Synthetic Aperture Radar
SARPLN	SAR Plan
SASS	Seasat Scatterometer System
SCE	Satellite Command Encoder
SCSRS	Shoe Cove Satellite Receiving Station
SDPS	SAR Data Processing System
SDR	Sensor Data Record; Software Design Review
SDUP	Seasat Data Utilization Project
SEAC	Seasat Applications Program
SECO	Sustainer Engine Cutoff
SFOP	Space Flight Operations Plan
SIRD	Support Instrumentation Requirements Document
SLC	Space Launch Complex
SMMR	Scanning Multichannel Microwave Radiometer
SNF	STDN Station at Shoe Cove, Newfoundland, Canada
SNR	Signal-to-Noise Ratio
SOCC	Simulation Operations Control Center
SOE	Sequence of Events
SOWM	Spectral Ocean Wave Model
SPAT	Satellite Performance and Analysis Team
SPC	Stored Program Command
SPE	Static Phase Error
SR	Scanning Radiometer

SSI	Software Support Instructions
STC	Sensitivity Time Control
STDN	Spaceflight Tracking and Data Network
STDS	System Test Data System (LMSC)
STG	Space Test Group
Sursat	Surveillance Satellite Project of the Canadian Government
SWA	Scan Wheel Assembly
TDPS	Telemetry Data Processing System
TELOPS	Telemetry On-Line Processing System
TLM	Telemetry
TPS	NASA Telemetry Processing System at VAFB
TRPLAN	Tape Recorder Plan
TRS	USAF Telemetry Receiving Station at VAFB
TSU	Telemetry/Sensor Interface Unit
TTY	Teletype
TV	Television
UKO	STDN Station at Oakhanger, Farnsborough, England, United Kingdom
ULA	STDN Station at Fairbanks, Alaska
USAF	United States Air Force
USB	Unified S-Band
UTC	Universal Time Corrected
VAFB	Vandenberg Air Force Base, CA.
VECO	Vernier Engine Cutoff
VIRR	Visual and Infrared Radiometer

WBDL	Wide Band Data Line
WFC	Wallops Flight Center (NASA), Wallops Island, VA
WLOD	Western Launch Operations Division
WTR	Western Test Range, VAFB, CA