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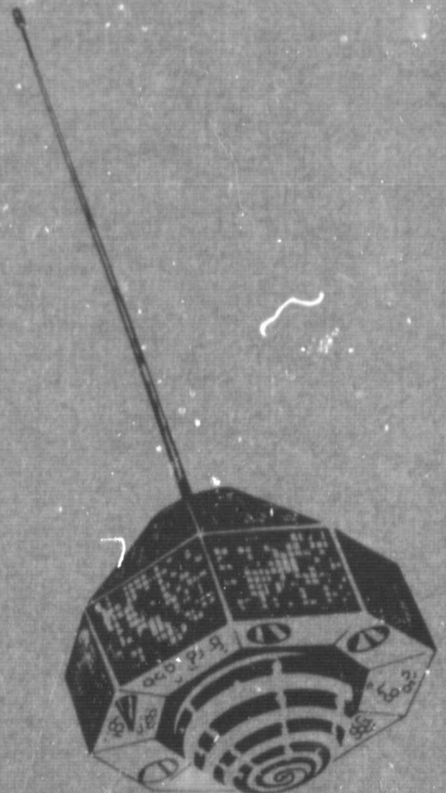

A PERFORMANCE EVALUATION OF GEOS - II

PREPARED BY

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA

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September 1968

A PERFORMANCE EVALUATION OF GEOS-II

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF ABBREVIATIONS

AMS	Army Map Service
AOL	Alternate Optical Logic
APL	Applied Physics Laboratory
CARVON	Carnarvon, Australia, STADAN station
CW	Continuous Wave
GEMTU	Geodetic Explorer Memory Terminal Unit
GEOS	Geodetic Earth Orbiting Satellite
GOCC	Geodetic Operations Control Center
GRARR	Goddard Range and Range Rate
IPD	GSFC Information Processing Division
JHU	Johns Hopkins University
JOBURG	Johannesburg, South Africa, STADAN station
kHz	Kilohertz
km	Kilometer
MHz	Megahertz
MOTS	GSFC Minitrack Optical Tracking System
msec	Millisecond
MSOCC	Multi-Satellite Operations Control Center
MTAD	GSFC Mission and Trajectory Analysis Division
MUSTAP	Mutual Station Predictions
MVE	Mutual Visibility Event
MVES	Mutual Visibility Event Schedule
MVP	Mutual Visibility Program
NASA	National Aeronautics and Space Administration
NEWFLD	Saint Johns, Newfoundland, STADAN station
NGSP	National Geodetic Satellite Program

LIST OF ABBREVIATIONS (Cont'd)

ORORAL	Orroral, Australia, STADAN station
Resync	Clock resynchronization injection
ROSMAN	Rosman, North Carolina, STADAN station
SAM	Solar Array Monitor
SAO	Smithsonian Astrophysical Observatory
SECOR	Sequential Collation of Range
SNTAGO	Santiago, Chile, STADAN station
SPEOPT	GSFC Special Optical Tracking System
SSED	Solar Science Electron Detector
STADAN	Space Tracking and Data Acquisition Network
TAG	Technical Advisory Group (GEOS)
ULASKA	Fairbanks, Alaska, STADAN station
USC&GS	United States Coast and Geodetic Survey
UTC	Universal Time Coordinated - Uniform Atomic Clock Time with known difference from UT_2
VCO	Voltage Controlled Oscillator
WICE	Wallops Island Collocation Experiment
WTR	Western Test Range
Z	Greenwich Mean Time
μsec	Microsecond

SECTION 1

INTRODUCTION

1.1 PURPOSE

The purpose of this report is to document the activities involved in the implementation of the GEOS-II operation, discuss the operational performance of the ground elements and describe the in-orbit performance of each spacecraft and geodetic system. Performance data are presented for the period from launch through 31 July 1968.

1.2 BACKGROUND

GEOS-II is the second in a series of active geodetic spacecraft to be launched under the National Geodetic Satellite Program (NGSP). Like its predecessor, GEOS-I, it is contributing t the achievement of the objectives of the NGSP.

The specific NASA Pre-launch Mission Objectives for the GEOS-II spacecraft are:

Primary Objectives

- To inject the spacecraft into an approximate 1100 km by 1525 km orbit at an inclination of about 106° (79° retrograde) and obtain gravity gradient stabilization.
- To obtain ninety days of precision spacecraft position data to be applied to the gravimetric objectives of the NGSP.
- To support the geodetic positioning of forty reference control points and approximately sixty-four densification observation sites.
- To support the calibration of certain ground based C-Band radars and evaluate their accu-

racy for use as geodetic instrumentation systems.

Secondary Objectives

- Operate the primary instrumentation for a minimum of nine months.
- Obtain post-launch observation data to be applied to the NGSP (i.e., improvement of worldwide geodetic datum accuracies and positional accuracies of satellite tracking sites, studies of the earth's gravitational field, and intercomparison of satellite tracking system accuracies).
- To study the effect of the atmosphere on a CW laser beam.

With the issuing of the GEOS-II Post Launch Mission Operation Report (MOR) No. 3, dated 26 July 1968, the GEOS-II mission was adjudged a success in accordance with the primary pre-launch mission objectives by the NASA Management. The achievements in the mission activity to allow this assessment are included in this document.

1.3 GEOS-II SPACECRAFT INSTRUMENTATION

The GEOS-II instrumentation complement is substantially the same as GEOS-I, however, GEOS-II carries additional instrumentation as summarized below.

	Spacecraft I	Spacecraft II
• Primary Instrumentation		
Optical Beacons (4)	√	√
C-Band Transponders (2)		√
C-Band Passive Reflector		√
SECOR Transponder	√	√
GRARR Transponder	√	√

	Spacecraft I	Spacecraft II
• **Primary Instrumentation**		
Laser Reflectors	√	√
Doppler Beacons (3)	√	√
• **Secondary Instrumentation**		
Laser Detector		√
Solar Science Electron Detector		√

The spacecraft systems used to operate and monitor the instrumentation are also substantially the same as those flown on GEOS-I and consist of the following:

- Spacecraft Systems

  Attitude Control

  Attitude Detection

  Power and Solar Array Monitor

  Telemetry

  Command

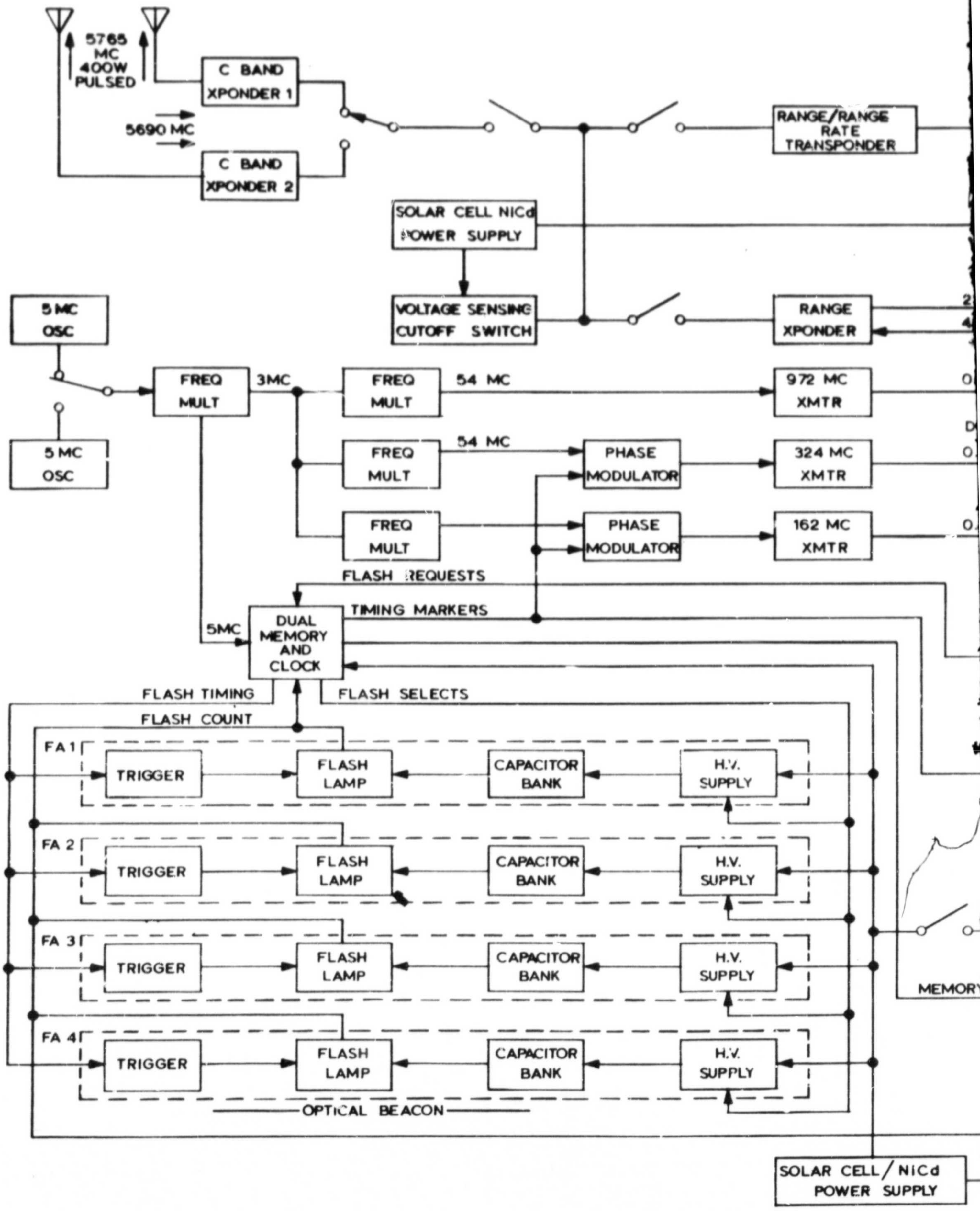
  Memory

A block diagram of GEOS-II is shown in Figure 1-1. The performance of each of the above mentioned spacecraft and instrumentation systems is discussed in Section 3 of this document. A description of the systems is not given, however, as this may be obtained from Report Number R-4035-45-2, "Plan of Operations for the GEOS-B (II) Spacecraft," by Communications & Systems, Incorporated, dated October 1967.

1.4 MISSION EVENTS

A chronology of the mission events is as follows:

- Launched 1/11/68
- Achieved Mission Attitude 1/15/68


5765 MC 400W PULSED
5690 MC
C BAND XPONDER 1
C BAND XPONDER 2
RANGE/RANGE RATE TRANSPONDER
SOLAR CELL NiCd POWER SUPPLY
VOLTAGE SENSING CUTOFF SWITCH
RANGE XPONDER
5 MC OSC
5 MC OSC
FREQ MULT
3MC
FREQ MULT
54 MC
972 MC XMTR
FREQ MULT
54 MC
PHASE MODULATOR
324 MC XMTR
FREQ MULT
PHASE MODULATOR
162 MC XMTR
FLASH REQUESTS
TIMING MARKERS
5MC
DUAL MEMORY AND CLOCK
FLASH TIMING
FLASH SELECTS
FLASH COUNT
FA 1
FA 2
FA 3
FA 4
TRIGGER
FLASH LAMP
CAPACITOR BANK
H.V. SUPPLY
OPTICAL BEACON
MEMORY
SOLAR CELL/NiCd POWER SUPPLY

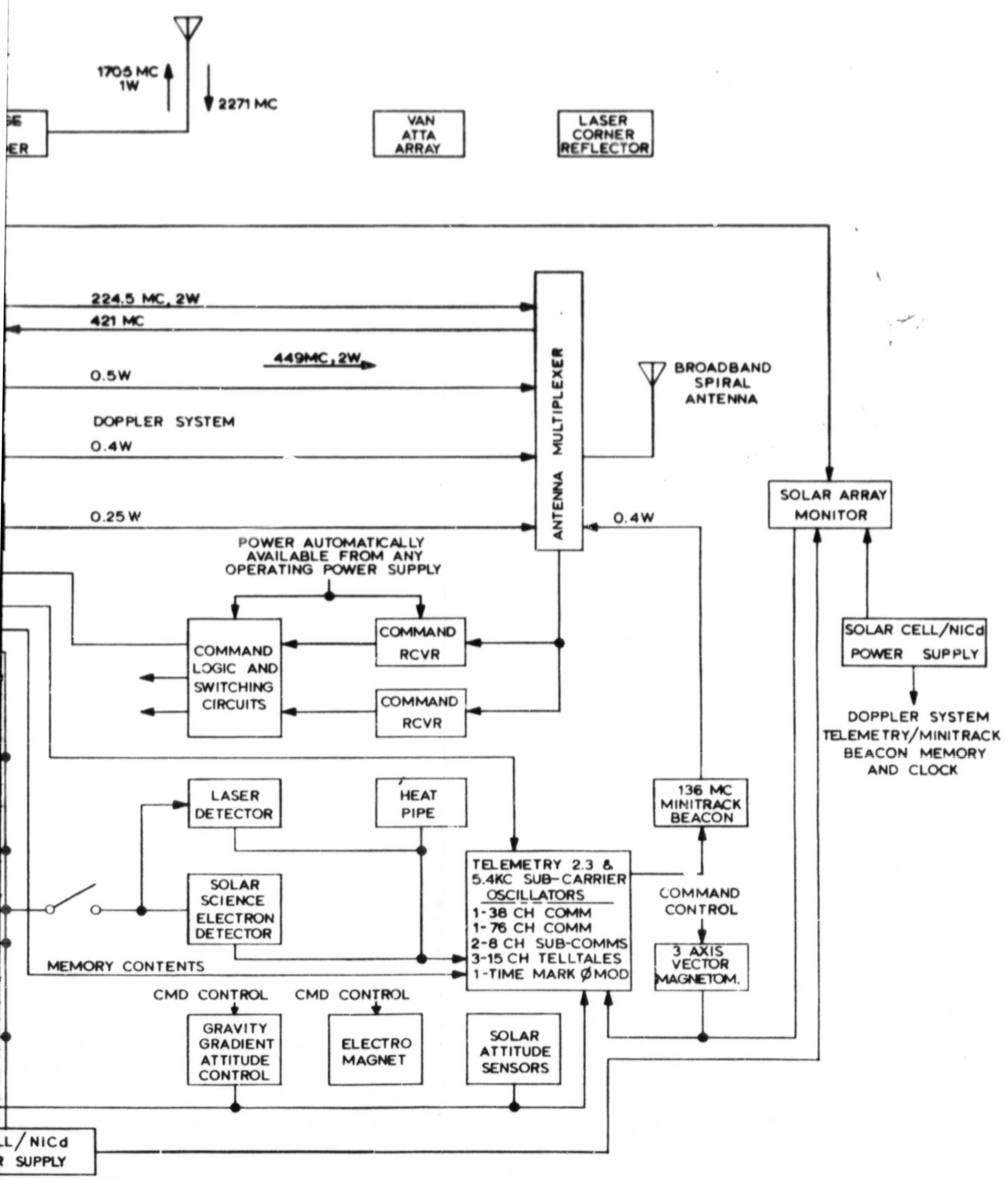


Figure 1-1 Block Diagram - GEOS- II

FOLDOUT FRAME 2

- System Checking Phase Initiated 1/16/68
- Mission Operations Initiated 2/20/68.

From launch through the system checking phase, the primary spacecraft control responsibility resided with the spacecraft contractor, the Johns Hopkins University Applied Physics Laboratory. The purpose of this phase was to erect the spacecraft in the gravity gradient mission attitude and determine the status of all spacecraft subsystems. Data obtained during this phase were used to establish operational guidelines for use in the mission operations of the spacecraft.

With the initiation of mission operations, the responsibility for primary spacecraft control was assumed by the Goddard Space Flight Center, Geodetic Operations Control Center (GOCC). This activity constitutes a major addition to the GOCC workload for GEOS-II over that performed for GEOS-I. Section 2 of this document reviews the activities involved in implementing this responsibility and describes the operational performance of the ground elements through the report period.

SECTION 2

SPACECRAFT CONTROL AND MISSION OPERATIONS

2.1 GENERAL

The ground control functions required to operate GEOS-II do not differ greatly from those of GEOS-I. However, a major change was implemented for GEOS-II with the acceptance by Goddard Space Flight Center of a project request to place primary spacecraft control responsibility within the GSFC Geodetic Operations Control Center (GOCC). For GEOS-I the primary responsibility for spacecraft control resided with the Johns Hopkins University Applied Physics Laboratory.

The shift of spacecraft control responsibility to the GOCC required the design of new operations and the acquiring of equipment, software, and technical capability to support them. In addition, the GOCC retained the responsibilities performed for the GEOS-I mission operation and, therefore, was required to implement these operational areas to support GEOS-II. Finally, because of additional GEOS-II instrumentation (C-Band and Laser Detector), the GOCC was required to implement operations in these areas.

As a prelude to the project proposal to effect the above change for GEOS-II, a study was undertaken by Communications & Systems, Incorporated, to determine the equipment, manpower, and software requirements. At the termination of this study, recommendations were made in the form of a plan to be used by the NASA Project Manager as the basis for requesting GSFC acceptance of the responsibility for the operation of GEOS-B (II) from the GOCC. With the exception of a data reduction operation, the plan was viewed by GSFC Management to be completely feasible and was accepted.

A detailed document entitled "Plan of Operations for the GEOS-B Spacecraft" was then prepared by C&S to aid in implementing the operations at the GOCC related to spacecraft control and mission operations. The plan delineated, in flow chart form, the interrelations between GOCC, other supporting GSFC elements and the participating networks. The integrated operations diagram for the GEOS-B (II) operation, extracted from the plan, is shown in Figure 2-1. The NASA-GSFC Operations Plan, which details the operational procedures to be used by all project participants, includes portions of the plan.

In summary, the required GEOS-II operations were implemented by the GOCC. It is the intent of this section to more fully describe this activity and the operational performance through the period covered by this report.

2.2 SPACECRAFT CONTROL AND SUPPORTING OPERATIONS

In that the additions to the GSFC responsibilities, over those which were performed for GEOS-I, were mainly in the control area, a significant effort at GSFC and within the GOCC was devoted to implementing the following:

- Telemetry and Commanding Operation
- Injection Operation.

Implementation of operations to support Spacecraft Control and Mission Operations were also required as follows:

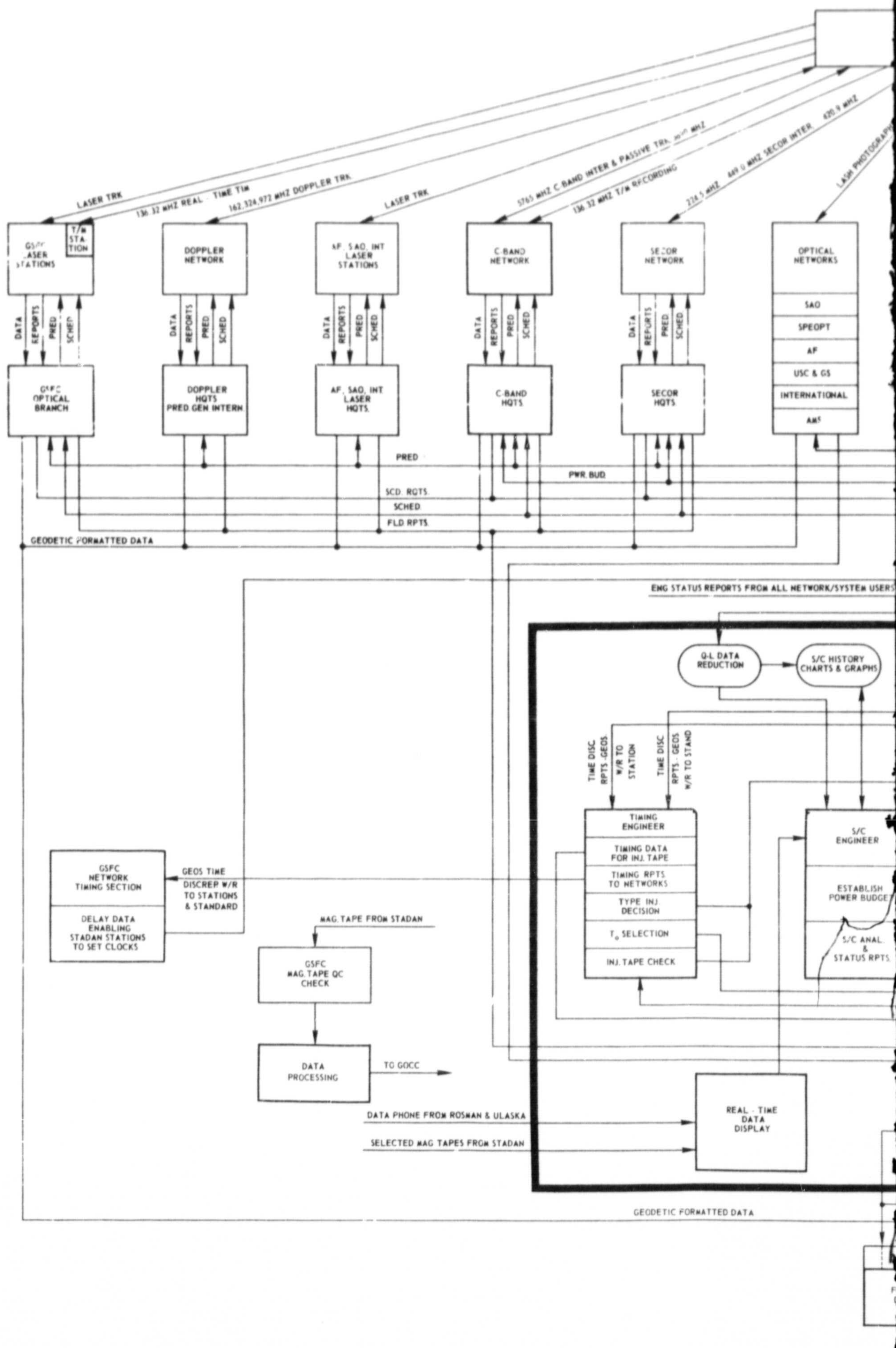
- Operational Computing
- Data Reduction Operation.

The Operational Computing was implemented at GSFC and, with a few additions, is similar to that performed at GSFC for GEOS-I.

Though proposed as an addition to the GSFC workload for GEOS-II, the Data Reduction Operation was not accepted by GSFC and, therefore, is being accomplished by JHU/APL.

The following paragraphs describe the activities involved in the aforementioned operations.

GEOS-B O



FOLDOUT FRAME 1

GEOS-B OPERATIONS DIAGRAM

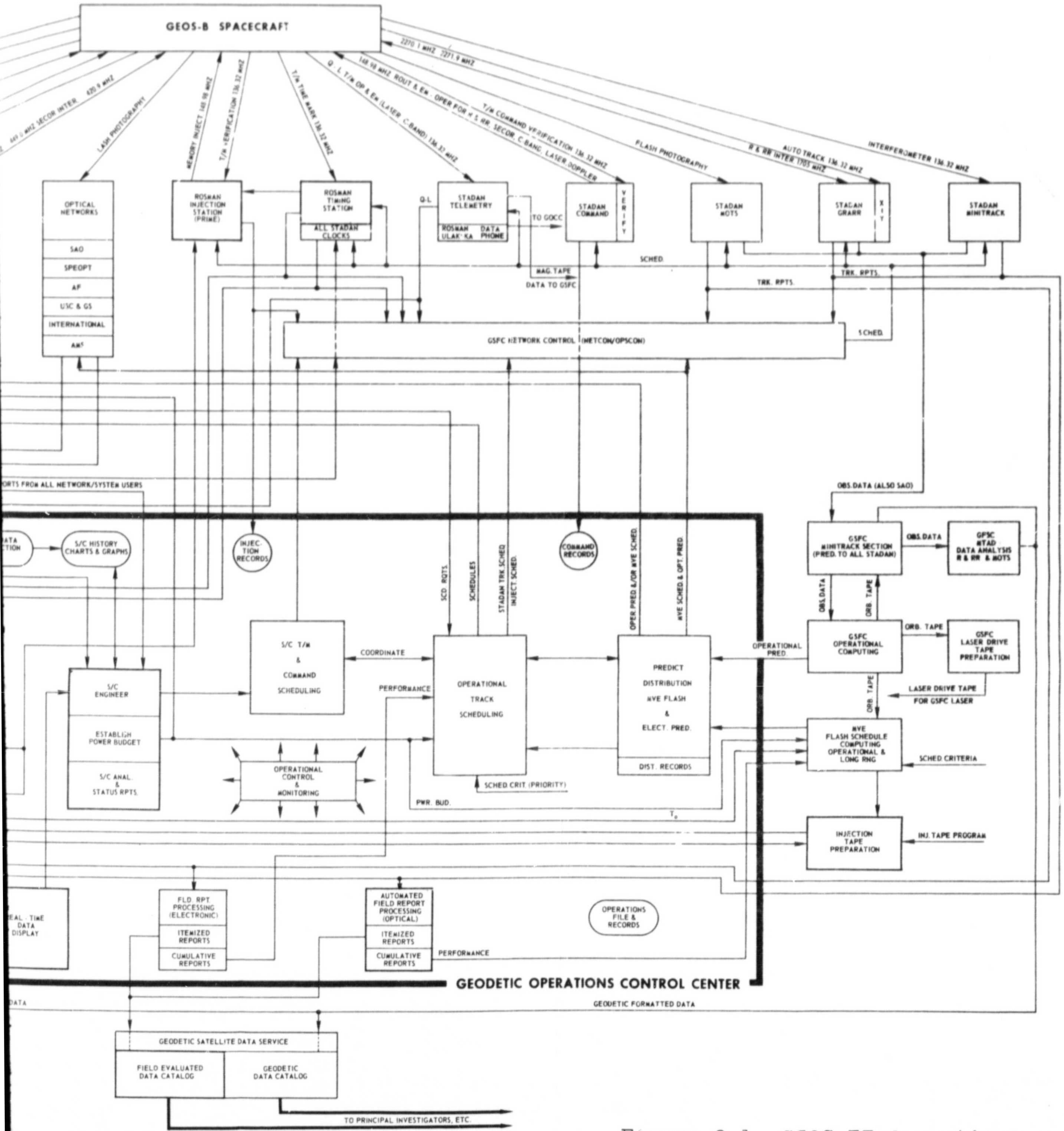


Figure 2-1 GEOS-II Operations Diagram

FOLDOUT FRAME 2

2.2.1 Telemetry and Commanding Operations

Although not explicitly stated in the title of this operation, the key to this activity is technical capability to effect optimum spacecraft use and spacecraft system maintenance.

The project proposal in this area was as follows:

I. Spacecraft Diagnostics

- Provide two engineers to GOCC
  - Spacecraft engineer
  - Timing engineer
- Retain JHU/APL on a consulting basis

II. Primary Telemetry Acquisition

- Utilize existing real-time communications from STADAN
- Provide real-time telemetry Data Display equipment in GOCC
- Utilize all STADAN stations and communications

III. Primary Command Control

- Exercise complete command control within GOCC
  - Spacecraft Mode Determination
  - Routine Operational Commands
  - Emergency Commands
- Execute commands at existing STADAN stations.

The following paragraphs describe the implementation and performance in these areas.

2.2.1.1 Spacecraft Diagnostics

The requirements involved in satisfying the spacecraft diagnostic task were probably the most critical of the new areas assumed by the GOCC. The ultimate responsibility of this task is to provide efficient use of the spacecraft instrumentation and to maintain, where possible, spacecraft health. An associated responsibility is that of maintaining spacecraft timing through analysis of spacecraft oscillator frequency data and STADAN station GEOS-II time recovery data.

The key requirements in implementing this task were:

- Provision of GOCC technical capability commensurate with the responsibilities involved.
- Provision of a computerized routine to allow rapid conversion of telemetry quick-look data to engineering units.
- Provision of a computerized routine to allow efficient handling of time recovery data.
- Provision of spacecraft oscillator frequency data for clock normalization purposes.

With the exception of the last item, oscillator frequency data, the above items were effectively implemented by the GOCC complement, with diagnostic responsibility assumed on 20 February 1968, the date when mission operations were initiated. Because the only direct way of measuring spacecraft oscillator frequency is via measurements of the doppler beacon frequency, this requirement was provided for by the Project Office through negotiations with the Naval Air Systems Command. Oscillator frequency readings, a routine output of doppler data computations, are submitted to the GOCC by the APL as a result of these negotiations.

In order to periodically review the technical status of GEOS-II, a Technical Advisory Group (TAG) was formed with representatives of APL, GOCC, and the Project Office participating. The TAG meetings, held nominally on the second and fourth Wednesday of the month, provide for up-to-date problem reporting and coordinated remedial activities through the assignment of action items to the participants. The project plan of retaining

APL on a consulting basis for the lifetime of the spacecraft is effected primarily through the TAG meetings and related action assignments.

2.2.1.2 Primary Telemetry Acquisition

To provide the means for controlling the spacecraft, housekeeping telemetry data acquisition, over and above that provided in the GOCC for GEOS-I, was required. For GEOS-I, a near real-time quick-look mode of telemetry data reporting was conducted using the NASA Worldwide Communications Network to obtain teletype reports from various STADAN stations. Because of the need for real-time data to more effectively evaluate spacecraft status (by viewing actual strip charts rather than reports derived from strip charts) the GOCC was required to provide real-time data links for use by the spacecraft engineers. The project proposed that this requirement be satisfied by establishing data lines in the GOCC (routed from existing terminals in GSFC) and providing appropriate equipment to reduce the FM data to analog strip chart. However, because of space limitations within the GOCC and the availability of existing equipment and data lines in the GSFC Multi-Satellite Operations Control Center (MSOCC), the GOCC implemented this requirement through utilization of the MSOCC capabilities. The real-time mode of telemetry data acquisition has been used frequently by the GOCC spacecraft engineers. The primary data transmission mode used is the microwave links between the ROSMAN and ULASKA STADAN stations and the GSFC MSOCC.

2.2.1.3 Primary Command Control

With the acceptance of complete spacecraft control within the GOCC, as proposed, the STADAN command facilities provide a near exclusive command link between the GOCC and the spacecraft. While mode commanding of GEOS-II requires no unique STADAN equipment or talents, the increased responsibilities in the GOCC and the addition of payloads on GEOS-II have caused a sizable command schedule to be coordinated and implemented daily (about thirty commands per day). This scheduling plus the scheduling of mission operations for the transponder, Laser Detector, Laser and SSED instrumentation poses a complex coordination task. Throughout the mission operations of GEOS-II, this task has been handled by the GOCC staff in a most efficient manner.

2.2.2 Injection Operations

The purpose of this operation is to provide daily programming of the GEOS-II memory to allow execution of the scheduled optical beacon flashes at the proper time.

The project proposal to GSFC in this area was as follows:

- Prepare injection tape at GSFC
- Perform injections at ROSMAN STADAN station
- Implement ROSMAN as the GEOS-B (II) timing Station.

These proposed additions were also accepted with implementation and performance as described in the following paragraphs.

2.2.2.1 Injection Tape

An integral part of the injection operation is the provision of an injection tape compatible with the injection station equipment. This tape contains the output of the Mutual Visibility Flash Schedule (i.e., flash times, number of lamps and length of sequence) and clock normalization information to be injected into the GEOS-II memory. Normally, the tapes are produced once each week, providing seven injection tapes to be used at the specified time each day.

The responsibility for providing an injection tape program was placed within the GSFC Mission and Trajectory Analysis Division (MTAD). The program was modeled after an existing APL program and has provided injection tapes for all injections since the initiation of operations on 20 February 1968.

2.2.2.2 Injection Station

It was initially proposed by the project that memory injections be accomplished utilizing planned new equipment at the ROSMAN station, and Programmable Command Generator (PCG). However, installation of the PCG at ROSMAN was found not to be in the time frame of GEOS-II. Therefore, the NASA Project Office suggested that an APL fabricated GEOS Explorer Memory Terminal Unit (GEMTU) be placed at ROSMAN to be used as the prime memory injection equipment.

It was planned that the ROSMAN GEMTU would perform memory injections starting 20 February 1968, the day mission operations were initiated and GOCC assumed full control of the spacecraft. However, because it is necessary to provide operations and maintenance information with any new piece of equipment placed in the STADAN, a delay was experienced because of the lack of this documentation.

Project representatives coordinated a plan between APL and GSFC to effect GEMTU installation at ROSMAN as soon after 20 February as possible, using a preliminary set of APL produced documentation on an interim basis.

The aforementioned preliminary documentation was provided GSFC on 23 February. After review by GSFC personnel and the addition of a few minor items to enhance understanding of the logic block diagrams, the preliminary documentation was considered to be sufficient to warrant installation of GEMTU at ROSMAN and subsequent initiation of operations.

GEMTU was trucked from APL to ROSMAN on 7 and 8 March 1968. On 11 March, under the supervision of an APL engineer, GEMTU was installed. Injections on 12 through 15 March were performed using the ROSMAN GEMTU with the APL, using a second GEMTU at the Howard County station, acting as an active backup. The backup capability was not required on any of the initial injections, as the ROSMAN GEMTU and operators performed as required.

With the injection of 16 March 1968, the ROSMAN station utilizing GEMTU became the primary injection station for GEOS-II. ROSMAN is also capable of backing up a failure in GEMTU by utilizing a proven injection system incorporating the OAO unique AD/ECS computer system and peripheral equipment. An additional backup system, available on a forty-eight hour call-up basis, is the APL GEMTU located at the APL Howard County Station.

Since the beginning of injection operations at ROSMAN, there have been no serious problems. However, a requirement for formal documentation, a GEMTU Operations and Maintenance Manual, still exists. This manual is presently being developed by APL.

2.2.2.3 Timing Station

One of the requirements of the optical investigators of the GEOS-II project is to know the time bias of any given GEOS-II flash sequence with reference to UTC.

The GEOS-II memory system provides a burst of time modulation on the 136-MHz, 162-MHz and 324-MHz frequencies once each minute. Proper detection of this modulation will allow the ground observer to determine the occurrences of the spacecraft minute mark. The optical beacon flashes are initiated on the spacecraft minute mark, defined as Word 1 Bit 1 of the GEOS memory operation. Therefore, comparison of the spacecraft minute mark to a reference time at a ground station (synchronized to UTC) will allow determination of GEOS-II flashes with respect to UTC.

In view of the above, an additional responsibility of the GOCC was the establishment of a timing station with the capability of accurately synchronizing the station clock to UTC and comparing the spacecraft clock to the station clock.

The GSFC implemented the ROSMAN station as the GEOS-II timing station. The ROSMAN station clock can be accurately synchronized to the GSFC atomic standard, which, in turn, is synchronized to UTC by transmission of timing data over the GSFC/ROSMAN microwave communications link. Once properly synchronized, ROSMAN utilizes a GEOS time recovery unit (equipment fabricated during

GEOS-I lifetime) to detect the spacecraft minute mark and compare it with the station minute mark, thus, providing the data required for GOCC to obtain time biases of GEOS with respect to UTC for use by the optical investigators.

2.2.3 Operational Computing

Because of the addition of the C-Band transponders on GEOS-II, the NASA Project Office proposed that the computational support for station predictions required by the C-Band Network be added to the Operational Computing at GSFC. This proposal was accepted and implemented.

Since the initiation of mission operations, all networks have been serviced in a routine and efficient manner. A summary of the support provided in this area is listed below:

SECOR Network

Operational look angle predictions for approximately six stations.

STADAN

Operational look angle predictions for ten minitrack, four GRARR and approximately two laser locations.

C-Band Network

a. Long range Mutual Visibility C-Band Station Predictions (MUSTAP) for seven participating agencies incorporating approximately sixteen locations.

b. Operational look angle predictions for approximately sixteen locations.

JHU/APL

Station look angle predictions for the Howard County station.

2.2.4 Data Reduction Operation

The purpose of this operation is to enable computerized reduction of GEOS-II telemetry data recorded on magnetic tape.

In general, the GEOS-II telemetry channel allocations are devoted to spacecraft system housekeeping parameters. Therefore, there is not a requirement for routine telemetry data reduction as exists on scientific spacecraft. However, because of the possibility of spacecraft anomalies requiring the reduction of such a large volume of data that hand reduction from analog records would be unwieldy, the NASA Project Office arranged for accomplishment of this operation at the JHU/APL as an add-on to the consultant services already discussed. As expected, the facility has been used in studies related to the main power system anomaly (see Paragraph 3.3).

2.3 MISSION OPERATIONS

Many of the mission operations implemented for GEOS-II are very similar to those accomplished within the GOCC for GEOS-I. These are as follows:

- MVE Operations
- GRARR Operations
- SECOR Operations
- Doppler Operations
- Laser Operations.

Because of the additional payloads on GEOS-II, a GSFC requirement for enhanced STADAN timing and the continuation of the requirement for system intercomparison studies, the following additional operations were required:

- C-Band Operations
- Wallops Island Collocation Experiment (WICE) Operations
- Laser Detector Operations
- SSED Operations
- Network Timing Operations.

The following paragraphs describe the activities involved in these operations.

2.3.1 MVES Operations

The Mutual Visibility Event Schedule (MVES) Operations have scheduled coordinated observations for approximately 5,000 seven-flash sequences since launch by the GSFC Minitrack Optical Tracking System (MOTS), GSFC Special Optical Tracking System (SPEOPT), Smithsonian Astrophysical Observatory (SAO), United States Coast and Geodetic Survey (USC&GS), U.S. Air Force and international optical participants.

As was the case for GEOS-I, the key element in this operation is the Mutual Visibility Program (MVP), which selects the optical events to be observed and produces corresponding predictions that are forwarded by the GOCC to the applicable stations. The MVP is run for the GOCC by the GSFC Mission and Trajectory Analysis Division.

A significant change in the GEOS-II operation in this area was the organization of the data flow to allow the participants to select (if desired) specific events from the long range MVES. The sequence of events leading to the production of an operational optical schedule, provides the investigator with a listing of the potential events far enough in advance so that if a specific event or events is desired, enough time remains to coordinate a request through the GOCC to effect the scheduling of that event for the operational period.

The GOCC provides predictions to the optical participants as follows:

Network	Approximate Number of Instruments	MVE Operational	MVE Long Range	MVE Plate Reduction
GSFC MOTS	12	√		√
GSFC SPEOPT	10	√	√	√
Air Force	8	√	√	√

Network	Approximate Number of Instruments	MVE Operational	MVE Long Range	MVE Plate Reduction
SAO	19	√		√
USC&GS	14	√	√	√
International	10	√	√	√

In addition to the MVE distribution to the optical participants, the C-Band and SECOR networks are also provided the operational and long range MVE schedule for schedule coordination purposes.

2.3.2 GRARR Operations

The GRARR operations remain essentially the same as those performed for GEOS-I. The GRARR tracks are scheduled by the GOCC to complement the schedules of the MVE program within the limitation of the GRARR portion of the transponder power budget.

Through the period of this report, about seventy-five hours of GRARR interrogations have been scheduled.

2.3.3 SECOR Operations

The Army Map Service (AMS) SECOR operation is also essentially the same as that performed for GEOS-I. As dictated by the time-oriented sequence of events for SECOR participation, the AMS requests specific interrogation times. If these requests are within the allocated power budget, the requests are approved by the GOCC.

Through the period of this report, about twenty hours of SECOR interrogations have been scheduled.

2.3.4 Doppler Operations

Doppler data are acquired by the Navy Tracking Network according to their existing priorities. Through the period of this report, approximately 14,000 doppler data sets have been recorded.

A significant accomplishment of the GEOS-II mission has been the provision of approximately 150 days of doppler data yielding precision spacecraft positioning results.

2.3.5 Laser Operations

Significant Laser operations have been performed in conjunction with the Wallops Island Collocation Experiment (WICE), using the GSFC Optical Systems Branch pulsed ruby-laser system. During the data acquisition phase of the WICE (1 April 1968 to 28 June 1968), about thirty-two laser tracks were recorded simultaneously with other system data.

The GSFC laser operations are predominantly conducted during ground station darkness periods when the spacecraft is illuminated by the sun for all or a portion of the pass. These conditions are necessary, as the most reliabile acquisition mode used to date has been telescope optical sighting of the spacecraft. Generally, once the spacecraft is optically acquired and an epoch adjustment to the prediction drive tape is introduced, correct laser pointing can be sustained.

2.3.6 C-Band Operations

Since the C-Band instrumentation was new on GEOS-II, it was recommended by the NASA Project Office that the operational control of the C-Band tracking effort be placed in the GOCC. This recommendation was accepted.

The primary purpose of the GEOS-II C-Band effort is to support the calibration of certain ground-based C-Band radars to evaluate their accuracy for use as geodetic instrumentation systems. Through the period of this report, over fifty-five hours of radar ranging data have been scheduled in support of this effort.

The overall C-Band tracking effort is coordinated by the C-Band Project Manager at NASA Wallops Island, Virginia. The C-Band participants include the following agencies:

- NASA Wallops
- NASA/GSFC (Manned Space Network)
- NASA/FRC (Flight Research Center)
- Air Force Eastern Test Range
- Air Force Western Test Range
- Edwards Air Force Base
- Pacific Missile Range
- White Sands Missile Range.

Using Mutual Visibility C-Band Station Predictions (MUSTAP) and the long range Mutual Visibility Event Predictions (both provided in advance by the GOCC), each participant submits a tracking request to Wallops delineating specific tracking times desired. These requests are coordinated by Wallops and submitted to the GOCC as a composite request. If within the allowable power budget, the GOCC approves the request, arranges for the appropriate command support and optical support, if requested, and provides operational predictions to the participants.

2.3.7 Wallops Island Collocation Experiment Operations

A majority of the C-Band interrogations to date have been performed at Wallops Island using the FPQ-6 and FPS-16 C-Band systems. These data will be used for calibration purposes and also to support the Wallops Island Collocation Experiment (WICE). The WICE data acquisition phase began on 1 April 1968 and continued through 28 June 1968. It is managed by the GEOS-II principal investigator for system intercomparison at GSFC. The Wallops Island collocated systems include the following:

- C-Band Radars (FPS-16 and FPQ-6)
- SECOR
- GSFC Pulsed Laser
- TRANET Doppler

- Two BC-4 Cameras
- Pth-100 Camera.

The WICE provides excellent conditions for performing intercomparison studies because of the known location of the participating instrumentation and the relative ease of data coordination.

The intercomparison studies are being performed in three general modes:

a. Collocation mode: comparison of data from collocated systems (one to the other) on arcs over the collocation area only.

b. Short arc mode: comparison of each collocated system to an Eastern United States short arc derived from optical data.

c. Long arc mode: comparison of each collocated system to a long arc (one revolution or more) derived from all participating systems.

2.3.8 Laser Detector Operations

With the introduction of the CW laser detector experiment on GEOS-II, requirements exist for real-time telemetry data acquisition during the laser detector operational passes and operational control of the activities. The project recommended that the operational control be placed with the GOCC. Because of the complications that could be present in scheduling real-time data from a remote STADAN site, and because of the relative ease in establishing a GEOS telemetry reception station, the project recommended that a simplified telemetry station be established at the GSFC CW laser site. Both of these recommendations were accepted.

This experiment is being managed and performed by the GSFC Optical Systems Branch under the operational control of the GOCC. The GOCC provides the required command and telemetry support through STADAN facilities.

The purpose of this experiment is to study the effects of the atmosphere on the CW laser beam. To date, sufficient data have been acquired to allow preliminary conclusions in this area. A report, being prepared by the GSFC Optical Systems Branch, will discuss these results.

2.3.9 Solar Science Electron Detector (SSED) Operations

This experiment is being managed and performed by the JHU/APL under the operational control of the GOCC. The objective of the experiment is to investigate the relationship between precipitating electrons and magnetic disturbances in the auroral oval. Because the electron detector appears to be malfunctioning (see Paragraph 3.15), only magnetic field data have been acquired to date.

2.3.10 Network Timing Operations

Because of the timing signal available at 136 MHz from the GEOS-II spacecraft and the project requirement to control and determine the GEOS-II timing error relative to UTC, an option was proposed to GSFC by the NASA Project Office to utilize this data base to enhance and synchronize the STADAN station clocks as follows:

- Install GEOS time recovery units at all STADAN stations
- Establish procedures within GSFC to time synchronize the STADAN utilizing the GEOS timing station and existing GEOS clock capabilities.

This option was accepted and implemented as follows: Initially, the operation would consist of collecting time comparison data at the participating STADAN stations (GEOS time with respect to station time) in order to perform analyses of these data to determine station time with respect to UTC. If these analyses yielded repetitive and precise results over a given period (approximately one to three months), further decisions would then be made to consider implementing a STADAN time synchronization program using the GEOS-II spacecraft.

The initial phase of this operation did prove successful, and in May 1968, the Winkfield, England, and Fairbanks, Alaska, STADAN stations were directed by the GSFC Network Timing Section to adjust their station clock time. The adjustments were calculated by comparison of the respective station time relative to GEOS time. In June 1968, six additional STADAN stations were directed to adjust to a new epoch as dictated by the GEOS comparisons. In September 1968, it is anticipated that one additional station, Lima, Peru, will join the program.

The significance of this program is best described by the following listing of the initial clock adjustments required at the various stations:

Station	Adjustment
Fairbanks, Alaska	460 μsec advance
Carnarvon, Australia	200 μsec retard
Johannesburg, South Africa	500 μsec retard
Tananarive, Malagasy Republic	1300 μsec retard
Orroral, Australia	1650 μsec advance
Quito, Ecuador	No adjustment
Santiago, Chile	900 μsec advance
Winkfield, England	750 μsec retard.

The Quito, Ecuador, STADAN station clock did not require an adjustment, as that station had previously been synchronized to a portable atomic standard carried to the station by GSFC personnel.

It is apparent at this time that the GEOS technique has enhanced the STADAN station timing accuracy by an order of magnitude, at least.

SECTION 3

SPACECRAFT STATUS

3.1 GENERAL

The GEOS-B spacecraft was launched on 11 January 1968 at 1616:00:006Z from Satellite Launch Complex 2 at the Western Test Range (WTR)[1]. The Improved Thrust Augmented Delta Vehicle (Delta 56) using an FW-4D Third Stage provided a nominal orbit as follows:

Parameter	Expected	Actual
Apogee (kilometers)	1572.8	1574.5
Perigee (kilometers)	1100.0	1079.5
Inclination (degrees)	105.977	105.8
Period (minutes)	112.392	112.18
Eccentricity	0.0306	0.0321

Upon achieving orbit, GEOS-B was designated GEOS-II (1968-02A).

The following paragraphs describe the status and problems encountered with the onboard systems. Table 3-1 is a listing by system of the anomalies encountered since launch. The last two columns show the paragraph and page in this report where the problem is discussed.

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[1] For more details concerning the launch phase, refer to:

a. NASA, John F. Kennedy Space Center, GEOS-B/DELTA-56 Final Flight Report, ULOW 84, 30 April 1968.

b. Douglas Aircraft Corporation, Flight Report for Delta Vehicle S/N 20214, Delta Program Mission Number 56; Spacecraft, GEOS-B, DAC 58711, April 1968.

c. Communications & Systems, Incorporated, GEOS-B Launch Evaluation Report, Report Number R-4035-40-2, February 1968.

TABLE 3-1

GEOS-II ANOMALIES

System	Characteristic	Paragraph	Page
Power	1) Main power system degradation	3.3	3-5
Telemetry	1) Memory converter #2 data not available	3.4	3-6
	2) Erratic subcommutator operation	3.4	3-6
	3) Optical battery current calibration change	3.4	3-7
Command	1) Command inconsistencies	3.5	3-7
Memory and Clock	1) Memory #2 failure	3.6.1	3-11
	2) Memory #1 inconsistencies during checkout	3.6.2	3-12
	3) Memory #1 memory address anomaly	3.6.2.1	3-12
	4) Memory #1 fixed marker anomaly	3.6.2.2	3-13
	5) Memory #1 command disruption	3.6.2.3	3-21
	6) Oscillator #1 abnormality	3.6.3	3-22
Optical Beacon	1) Anomalies detected during checkout	3.7	3-27
	2) Spacecraft time anomaly	3.7.1	3-30
	3) Erratic flash anomaly	3.7.2	3-32
C-Band	1) Telemetry data calibration uncertainties	3.11	3-35
	2) Data fade and dropout problem	Appendix A	A-1
SECOR	1) Interference with Doppler	3.13	3-36
SSED	1) Failure	3.15	3-37

3.2 ATTITUDE CONTROL AND DETECTION SYSTEMS

Data obtained immediately after launch showed a spin rate of 4.8 rpm. Because this was higher than the expected 3 rpm spin rate, the Applied Physics Laboratory (APL) advised that the planned initial boom extension (to about three feet) and the subsequent gravity gradient capture would be delayed until the spin rate was significantly lower.

Telemetry data taken on 12 and 13 January showed a steady increase in the three spacecraft battery temperatures. This was attributed to an undesirable satellite/sun attitude (with the spacecraft in 100% sunlight). The main battery temperature increased to 125°F and the transponder and optical batteries to about 112°F by 1120Z on 13 January. All manual and automatic power dumps and main systems were commanded on in an attempt to lower the battery temperatures, however, the temperatures remained too high. APL decided that extending the gravity gradient boom would change the attitude significantly and reduce the temperatures to safer levels. Therefore, at 2350Z on 13 January, commands were sent from the Howard County station to uncage the end mass and extend the boom about three feet. The spin rate at that time was approximately 2.1 rpm. This maneuver resulted in the temperatures rapidly decreasing to a level within the nominal limits (all below 100°F).

With the eddy current damper released from the magnetic influences of the spacecraft, it functioned to rapidly reduce the remaining spin. At 0140Z, 14 January, the electromagnet was turned on by APL to allow alignment of the spacecraft spin axis with the earth's magnetic field. By 1400Z on 14 January, the spin rate had decreased to virtually zero and magnetic stabilization was established. At 1350Z, 15 January, the boom was extended, by command from the Howard County station, to 29 feet 11 inches and gravity gradient stabilization was established in the right side up mode. A graphic illustration of the spin rate versus time is shown in Figure 3-1 with the significant events as discussed above annotated.

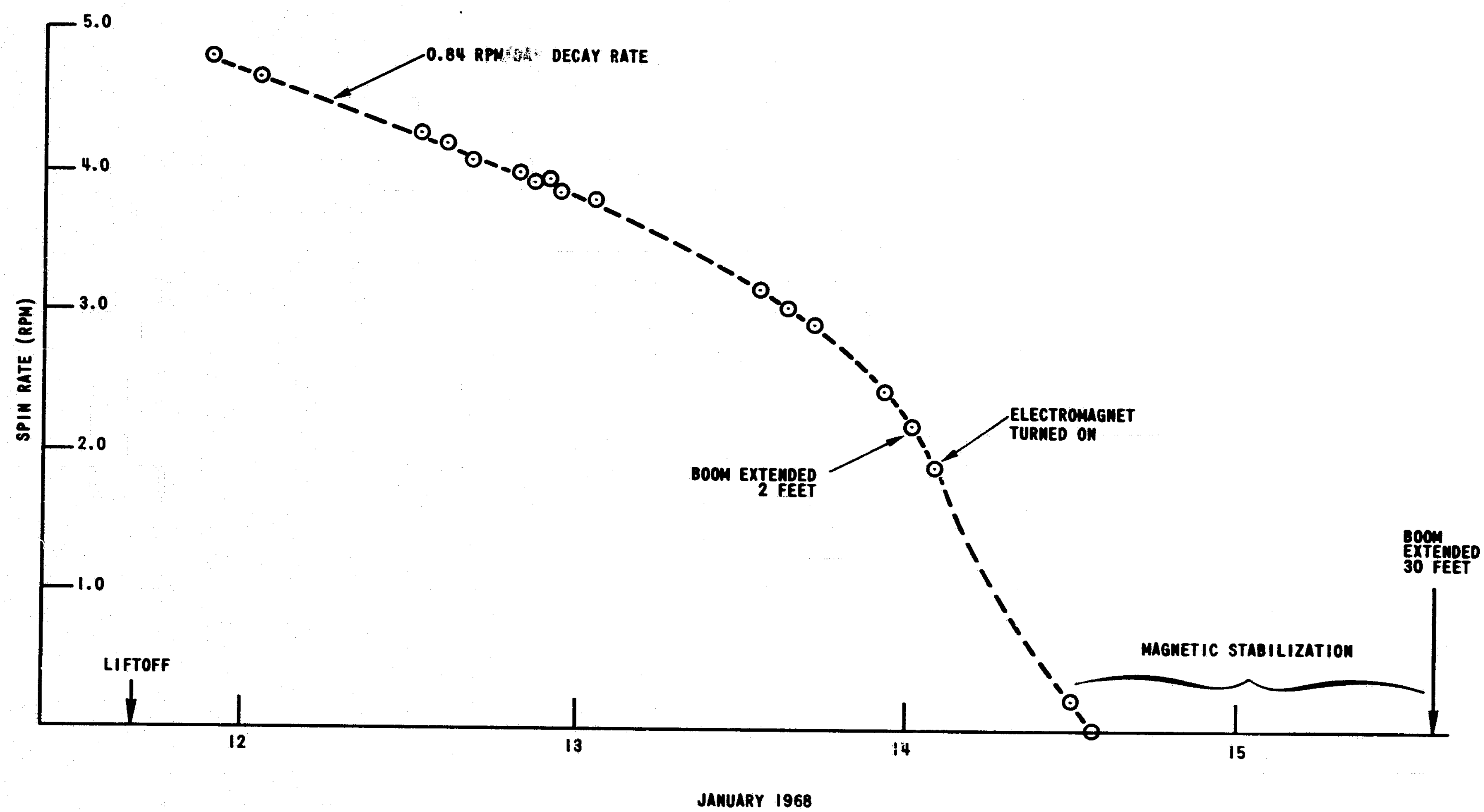

Figure 3-1 GEOS-II Spin Rate Versus Time

Throughout the period covered by this report, all elements of the attitude control and measurement systems have operated as expected. The initial attitude determination performed by APL from data obtained from 22 through 26 January showed a maximum deviation from the normal of 4.7°, with excursions of less than 3° being typical. Additional attitude determinations computed from data recorded in February, March and May yield generally the same results.

3.3 POWER AND SOLAR ARRAY MONITOR (SAM) SYSTEMS

Prior to launch it had been noted by APL that a deterioration of the solar cell silicon monoxide coating had taken place during storage of the solar panels. Therefore, it was estimated that a 2 to 4% degradation in solar current would occur in orbit. Initially, an approximate 5% degradation from the design output was seen on all three power systems, a decrease in reasonable agreement with that expected.

The optical and transponder power systems have continued to operate as expected through this report period. Battery temperatures and voltages have been maintained well within limits. A comparison of the SAM readings with the expected (design less 5%) has been in very close agreement.

The main power system has not operated as well as expected. The departure from the expected nominal was first detected on 22 February 1968 and characterized by distinct drops in the current being supplied by the main solar array. Because of these current drops, the integrated current being supplied the main system, as detected by the main SAM, has shown a decrease from the expected of about 17%. This decreased output has continued through the period covered by this report.

Investigations into the problem by APL have shown the current drops to be in two general categories; drops from the expected nominal of 400 milliamps and 800 milliamps. Because the 800 milliamp value is larger than the current that can be supplied by one solar panel, it is probable that these drops (observed as two 400 milliamp drops or, possibly because of the forty-eight second cycle time of the commutator, as one 800 milliamp drop) involve two panels. Also, because forty-five of the fifty drops investigated were at a sun angle with respect to the boom axis of 90° or greater, indicating near normal sun incidence on the equatorial panels, the APL concludes that the equatorial panels are probably causing the problem.

Because the problem did not occur when GEOS was in a 100% sunlight orbit (through 18 February), and all drops investigated to date have occurred within five to twenty-six minutes after spacecraft entrance from shadow to sunlight, APL conclusions to date state that the problem is probably caused by open circuits on the equatorial panels which are temperature induced. Attempted correlation of the problem to the operational mode of the spacecraft (i.e., other system usage, flashing lights, et cetera) have produced negative results, that is, no correlation exists.

Because of this problem, as the spacecraft approached minimum sunlight conditions in June, main power had to be conserved by periodic turn-offs of the telemetry and 162-MHz and 324-MHz doppler beacons. It is expected that power conservation will be required until the spacecraft approaches 85% sunlit orbits sometime in late December 1968.

3.4 TELEMETRY SYSTEM

With only three exceptions, all channels of the 162-channel telemetry system have operated as planned. The modulated RF output has proven to be quite adequate for data transmission and for interferometer tracking purposes. A description of the characteristics of the three exceptions is given below:

a. When memory converter number two is in use, there is no indication of memory converter (number two) input current on Commutator 1, Channel 20. This deficiency was noted prior to launch.

b. During the initial check-out phase, it was noted by APL that, on two occasions, the subcommutators on Channel 18 of each of the commutators stepped incorrectly. The subcommutators stepped correctly from Channel 8 through Channel 3 but then, instead of stepping to Channel 4, skipped to Channel 8 and then properly stepped to Channel 3 where the sequence ended. Improper stepping of the subcommutators has also been noted during the investigations associated with the erratic optical beacon operation discussed in Paragraph 3.7 and were probably caused by noise generated by the beacons.

c. The calibration of Channel 19 of Commutator Number 1, the optical battery current function, changed at about the time the squib was fired to uncage the boom end mass. The telemetered value for this channel is about 40% lower than expected. Since the squib is actuated by the optical battery, it is probable that the optical battery current telemetry resistor was shunted when the squib fired. This additional parallel resistance caused the effective resistance of the telemetry resistor to be decreased. Because of the reduction in resistance, the voltage generated for a given current level is lower than expected; therefore, the telemetered value reads low.

This condition required an in-orbit recalibration of the optical battery current telemetry function. This was accomplished by performing optical system manual dump on and off command operations during a portion of an orbit when the spacecraft was in darkness. As the load of the dump resistor is known and the absence of solar current input required that all the current be supplied by the optical battery, an analysis of the resulting telemetered values of the optical battery current function allowed a recalibration of this channel to be accomplished.

3.5 COMMAND SYSTEM

The command system has been operated extensively since launch. Through 31 July 1968 over 3,600 commands have been actuated by the spacecraft command system with no recurring problems encountered. However, some instances of abnormal operations have been noted. The abnormalities are characterized by additional commands being actuated during periods when the spacecraft was being commanded by a GEOS-II command station.

The first instances of command abnormalities were observed on 22 and 23 January 1968, while the spacecraft was undergoing the initial systems checking phase. The spacecraft was under the control of APL personnel who reported that the abnormalities were characterized by an additional command being actuated on board the spacecraft at or near the time of the actuation of a desired command. Because of the forty-eight second commutation period of the telemetry system, it could not be verified whether or not both the desired and undesired commands were actuated simultaneously. However, it was verified that all undesired commands were actuated within (at most) one telemetry commutation period of the desired commands. The commands in question are as follows:

Abnormality Number	Day/Time (UT)	Desired Command Function (Tones)	Additonal Command Function (Tones)
1	22/1424	Transponder power dump off (CED)	C-Band transponder manual interrogate (CDD)
2	22/1602	972-MHz transmitter on (CCE)	Range and range rate transponder manual interrogate (CBD)
3	22/1609	Range transponder off (CBC)	Optical power dump switch (CDC)
4	22/2123	Commutator No. 1 hold on (DCD)	C-Band transponder on (EBD)
5	22/2130	Commutator No. 1 hold off (DCB)	C-Band transponder off (EBB)
6	23/1242	Memory No. 2 select (DBB)	Memory converter No. 1 on (BDB)

Although verification of the simultaneity of the desired and additional commands is impossible, an interesting charge/fire line relationship exists with the group of six command inconsistencies as follows:

Abnormality Number	Desired Command		Additional Command	
	Charge	Fire	Charge	Fire
1	7	4	7	2
2	5	8	5	2
3	1	6	3	6
4	6	3	6	2
5	2	3	2	2
6	2	1	3	1

On four occasions, specifically abnormality numbers 1, 2, 4 and 5, the additional command occurred in fire line number 2 and the same charge line as the desired command. This is the same type of problem that caused failure of the command subsystem in GEOS-A, except that the problem occurred on fire line number 1 in that spacecraft. Analysis of the GEOS-A failure indicated that the associated fire line SCR was probably remaining in the triggered state.

Additional commands on the other two occasions, specifically abnormality numbers 3 and 6, occurred in the same fire line as the desired command, but both occurred in charge line number 3. This problem could be caused by several marginal conditions, for example, noise triggering the charge gate transistor control circuitry or the charge gate transistor remaining on.

The second of the instances of command anomalies was observed on 18 April 1968. The spacecraft was being utilized in normal operations and the Newfoundland STADAN station was executing a scheduled GEOS-II command assignment, a commutator stop operation for magnetometer data acquisition. Analysis of the NEWFLD strip chart recorded during this pass (starting at 0052Z) reveals the following:

Time	Command Transmitted	Command Executed	Comments
005900	11a (DCD) - Comm 1 hold on (Ch 71)	Same	Wrong channel stopped on 72
≈005930	11a (DCD) - Comm 1 hold on	S/C already in 11a configuration	
≈005950	11b (DCB) - Comm 1 run	Same	
≈010040	11a (DCD) - Comm 1 hold on (Ch 71)	Same	OK - stopped on Ch 71
010308	None	13b (DBB) - Memory Number 2 on	
010341	None	13a (DBD) - Memory Number 1 on	
010800	11b (DCB) - Comm 1 run	Same	

Unlike the command abnormalities of 22 and 23 January 1968, the two abnormalities during the 0103 minute above can be verified as not having occurred simultaneously with another command. This verification was possible as NEWFLD was recording both commutator data and its command times during the pass. The nature of the extraneous functions allowed determination of the exact time of their execution as the switching of memories caused a memory read-out to be telemetered on Commutator Number 2 (5.4 kHz VCO) and these times were well separated from the NEWFLD commands.[1] The command problems of 22 and 23 January could be, as explained, attributed to spacecraft command system malfunctions. However, this does not rule out the possibility of some other station inadvertently commanding the spacecraft. The command problems of 18 April suggest more strongly that this is actually the case.

Another command problem was experienced on 1 June 1968. The ROSMAN station was unable to command the spacecraft to the memory

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[1]The problems that were caused by this command abnormality are explained under the memory paragraph of this section.

load mode. However, subsequent evaluation of the ROSMAN strip chart showed a strong interfering signal present at the time of the scheduled command, which blocked the command receiver from accepting the ROSMAN command. The source of the interference has yet to be determined.

A few other command irregularities have been noted; however, many of these have been traced to ground station errors. The remainder are characterized by an unexplained inability of an apparent properly operating ground station to command the spacecraft. This group of inconsistencies has had negligible effect on the operation as additional command attempts, very near in time to the initial attempt, have proven successful.

3.6 MEMORY AND CLOCK SYSTEM

The performance of this system has been sufficient to fully support GEOS-II operations; however, a memory number two failure in the redundant memory system has caused the loss of memory backup capability. In addition, oscillator number one has demonstrated erratic operation causing it to be replaced by oscillator number two.

The following subparagraphs more fully delineate the problems encountered with the memory and clock system.

3.6.1 Memory Number Two

Since launch, successful operation of memory number two has not been possible. During the system checking phase, APL repeatedly attempted to load memory number two with negative results. During all instances of attempted operation, it appeared to be in a steady dumping mode and would not cycle through the four load conditions or accept a memory load message.

Although it is possible that the cause of this failure is organic to the memory itself, there is a possibility that the relay in the power switching matrix which switches the -32 volts between memory one and two is not making contact in the memory two position. APL has duplicated the characteristics of the failure by removing the -32 volts from a GEOS memory during bench experiments.

3.6.2 Memory Number One

Memory number one has completely sustained GEOS-II memory related operations since launch. Through about the middle of May 1968, only a few isolated memory anomalies occurred. These anomalies are explained below.

In mid-May, spacecraft timing began to experience anomalous drift rates and on approximately 1 June 1968 erratic optical beacon operations became apparent. Subsequent investigations into these problems uncovered a malfunctioning optical beacon assembly. While the malfunctioning beacon caused many memory disruptions and the anomalous drift rates seen are surely related to the memory, these problems will be discussed under the optical beacon portion of this document (Paragraph 3.7).

Memory one anomalies noted during the APL system checking phase are as follows:

a. During one load period, Word 1, the flash inhibit word, was spuriously updated by two binary counts causing the inhibit signal to occur two minutes early. This anomaly is attributed to noise with the probable source being the flash tubes.

b. During one load period, Word 9, Bit 15 changed from a programmed data 0 to data 1, causing lamp number three to be included in the flash sequence dictated by Word 9. It is also probable that this problem was caused by noise generated by the flash tubes. Word 9, Bit 15 is coincident with the third flash of a given sequence.

After the spacecraft was declared operational, the following anomalies were noted:

3.6.2.1 Memory Number One Memory Address Anomaly

On 23 March 1968, during the 0156Z minute, a one bit (≈44 msec) jump in timing was observed at the APL Howard County station via their time recovery unit. During this pass over the United States, a laser detector operation was scheduled which requires a turn-on of the detector (which also causes a turn-on of the SSED) and commutator stop and start operations. These commands (14a, b and 12a, b) were executed by the ROSMAN station. An analysis of the ROSMAN command record revealed that only two commands were sent during the period 0156-0157Z, 23 March, these being a Commutator 2 stop and start command. It is very unlikely that these commands had anything to do with the timing jump. Another possible, but very unlikely, cause for the timing jump could have been SSED generated noise interference, as this system was not commanded off until 015930Z. However, the most likely cause of this problem is flash tube generated noise interference to the memory system, as a flash sequence was initiated at the 0156Z minute mark. The flash tubes included in this sequence were numbers 2, 3 and 4. Noise probably interfered with one of the 22.75-Hz memory scan signals, causing the memory to miss one memory address and, therefore, caused the corresponding time lag of approximately 44 msec.

This memory anomaly caused a 44-msec timing error to be present until the next injection at 1525Z, 23 March. However, the timing problem was not known by the ROSMAN injection station personnel. They proceeded with a scheduled normal mode injection, causing the memory load to be translated by one bit (i.e., Word 1, Bit 1 data stored in Word 65, Bit 21, et cetera). This improper memory load invalidated the scheduled flashes and time normalization until the next ROSMAN injection (clock resynchronization mode) on 24 March at 1544Z.

3.6.2.2 Memory Number One Fixed Marker Anomaly

The first indication of this anomaly was also evidenced by a timing inconsistency. Figure 3-2 is a graphic representation of this timing inconsistency. Sometime after 0900Z, 3 April 1968, the spacecraft minute mark began to drift rapidly in the lagging direction with respect to UTC. This occurrence was

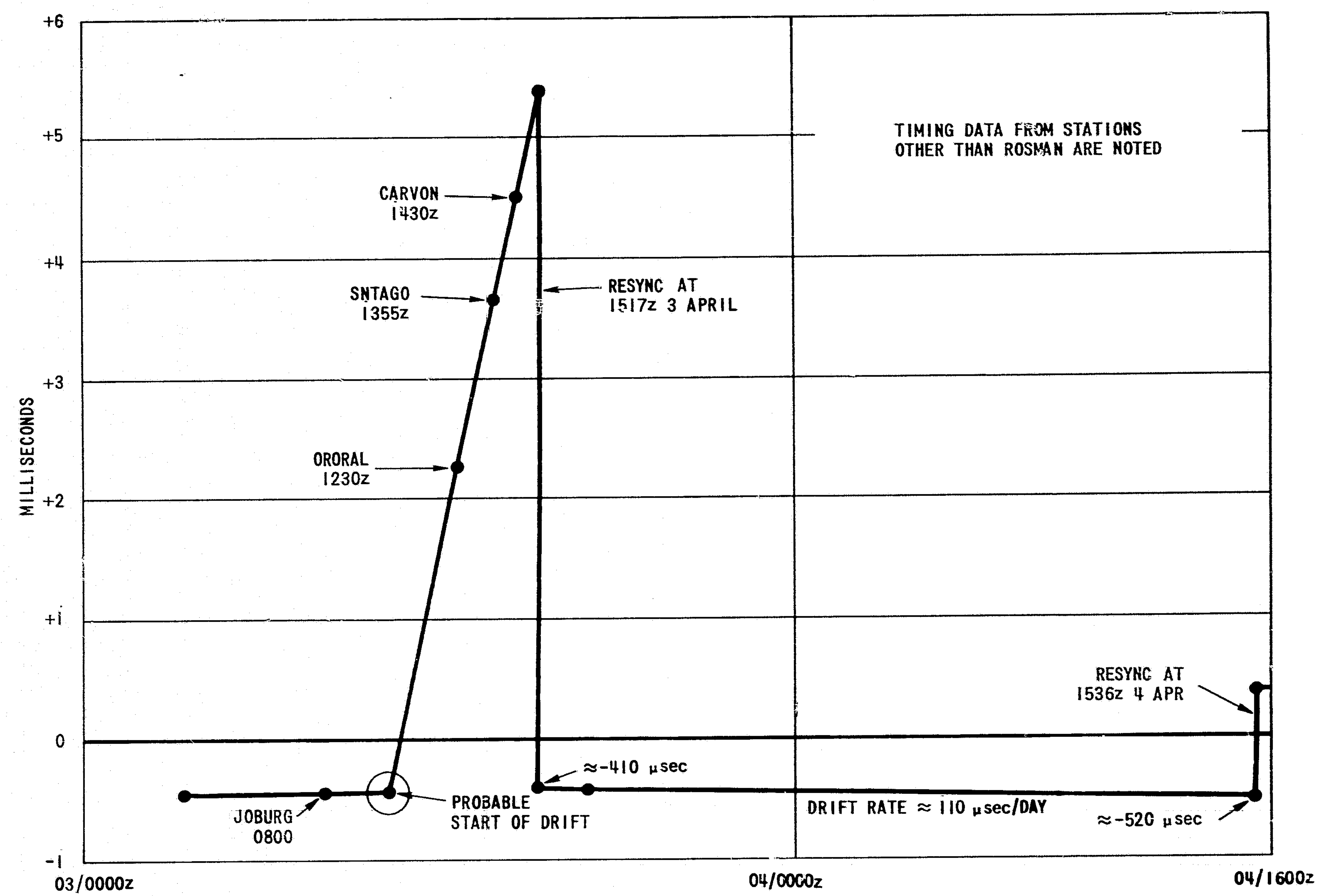


Figure 3-2 GEOS-II Minute Mark Versus Time

detected by five stations (Orroral, Australia; Santiago, Chile; Carnarvon, Australia; Rosman, North Carolina; and APL, Howard County). The magnitude of the drift was about 20 µsec/minute in the direction having the effect of lengthening the spacecraft minute. At the time of the scheduled resync injection (scheduled not for this problem but because time monitoring had shown the spacecraft to be out of the ± 400 µsec tolerance with respect to UTC) at ROSMAN, the spacecraft minute mark was lagging UTC by about 4.38 msec. APL was also monitoring time at the resync and confirmed this reading.

After the resync injection at 1517Z, 3 April, the drift terminated. This would lead one to believe that possibly two additional normal deletes (which would yield a drift rate of 19.6 µsec/minute) were incorrectly stored in the flash time words to cause this problem. This is not to say that the deletes were incorrectly injected because then the drift would have been seen from injection to injection (1457Z, 2 April, to 1516Z, 3 April); this was not the case.

After receipt of the 3 April injection record (GEMTU printout) from the ROSMAN station; it was established that errors existed in that day's preload readout. Specifically, errors were indicated in three words of the preload, they being Words 24, 25 and 61. In order to describe the cause of this anomaly, it is necessary to analyze, in detail, each of these words showing its relationship to the anomalous spacecraft operation.

Word 61 is the flash count accumulator word. The first nine bits of this word store in binary count the number of flashes executed since the last injection without regard, however, for the number of flash assemblies used to produce any given flash. The flash count was low by twenty-one counts. From previous experience with GEOS-II, noted before launch, it is known that the flash detector associated with flash assembly number three is defective and, therefore, any flash sequence incorporating assembly number three alone will not increment the flash count accumulator word. Over the period in question, 2 April/1457Z to 3 April/1516Z there were a total of four seven-flash sequences using only assembly number three. Therefore, the accumulator should have recorded twenty-eight flashes less than that programmed. Since the accumulator recorded only twenty-one flashes less, it is probable that an additional unprogrammed seven-flash sequence was executed during the period in question.

Words 24 and 25 are flash time words. The first twelve bits are incremented one binary count each minute and store a binary representation of the number of minutes after injection (T_o) that a flash sequence will occur. When the first twelve bits of any flash time word are read out of memory as all data 1's, then circuitry is set to execute a flash sequence on the next minute mark. Bits 13 through 15 select the flash assemblies to be incorporated in the sequence and Bit 17 determines the length of the sequence. Bits 18 through 21 command deletes at the normal (9.8 μsec/delete) rate in the clock divider. Each data one in Bits 18 through 21 command one normal delete each minute and therefore have the effect of lengthening the interval between spacecraft minute marks by 9.8 μsec/minute.

The predicted and actual binary representation of Words 24 and 25 during the preload readout on 3 April is as follows:

Word 24

Predicted	111 111 010 100 101 111 010
Actual	111 111 010 100 101 111 111

Word 25

Predicted	101 111 010 100 010 011 010
Actual	110 101 001 000 010 011 010

Bits 18 through 21 of Word 24 are actually 1111 instead of the correct 1010. Therefore, two extra normal deletes are present which would cause a lengthening of the minute mark interval by 2x9.8 μsec/minute - 19.6 μsec/minute. Thus, a causal relationship with the drifting minute mark seen between approximately 1000/3 April and 1516Z, the injection time on 3 April, is established.

The predicted count of Word 25, first twelve bits, was 701. This means that 701 minutes (11 hours 41 minutes) prior to T_{O}+1 time on 3 April (1517Z) a flash was scheduled to occur by Word 25 (1517Z - 11 hours 41 minutes = 0336Z). This is verified by the 2 April injection. A seven-flash, lamp number two sequence was scheduled for 0336Z, 3 April 1968 and was programmed in Word 25. However, Word 25 did not read the predicted value; rather, it read 299. This indicates that 299 minutes (4 hours 59 minutes) prior to 1517Z/3 April (1517Z - 4 hours 59 minutes = 1018Z) a flash was executed by Word 25. This assumption ties directly into the extra seven counts in the flash accumulator word (Word 61). Word 25 actually caused two seven-flash, lamp number two sequences on 3 April 1968. This first sequence was executed as programmed at 0336Z. Word 25 then proceeded to increment one binary count each minute until 1016Z when it was incorrectly restored to memory as all data 1's. During the 1017Z minute, Word 25 was read out as all data 1's and therefore caused a flash sequence to begin on the spacecraft minute mark at 1018Z.

In accounting for all the words in error during the preload minute on 3 April 1968, another interesting relationship exists. Words 24 and 25 caused two seemingly unrelated effects to satellite operation during the period in question. The former caused the approximate 20 μsec/minute timing drift of the spacecraft minute mark and the latter caused an extra flash sequence to occur. Analyzing these effects in relationship to data presented in Figure 3-2 one can see that the extra flash sequence occurred very close in time to the probable start of the spacecraft minute mark drift as determined from time recovery data taken on 3 April 1968.

It is probable that the cause (as established above) of these two errors occurred during the same time interval, namely, during the data handling of Words 24 and 25 between 1016Z and 1017Z, 3 April 1968. Specifically, the anomaly occurred at Word 24, Bit 16, which effected memory data from that point through Word 25, Bit 12.

As the data handling circuitry serially operated on Word 24 and Word 25 during the 1016 minute, it is probable that the following occurred:

	Word 24
Read cycle	010 010 011 000 101 111 010
Should have restored as	110 010 010 011 000 101 111 010
Restored as	110 010 011 000 101 111 111

	Word 25
Read cycle	000 010 011 000 010 011 010
Should have restored as	100 010 011 000 010 011 010
Restored as	111 111 111 111 010 011 010

As was stated above, the addition of two extra normal delete bits in Word 24 caused the minute mark drift and, during minute 1017Z, Word 25 was read as all data 1's causing the extra seven-flash sequence to occur at 1018Z, 3 April.

The error was introduced by the restoring of the data 1's shown in the boxed area above. Since Bits 16 through 18 of Word 24 were already data 1's, it cannot be clearly seen that Bit 16 of Word 24 was the first bit involved in the anomaly. However, through analysis of the data handling of all memory words, a clear correlation can be constructed. This correlation appears in Words 63 and 64, the satellite inserted marker words (fixed marker).

The bit scheme for these words is generated internally in the data handling circuitry and is as follows:

Word 63	Word 64
000 000 000 000 000 111 111	111 111 111 111 000 000 000

Thus, the boxed-in data 1's above clearly correlate to the incorrectly restored data 1's discussed in Words 24 and 25.

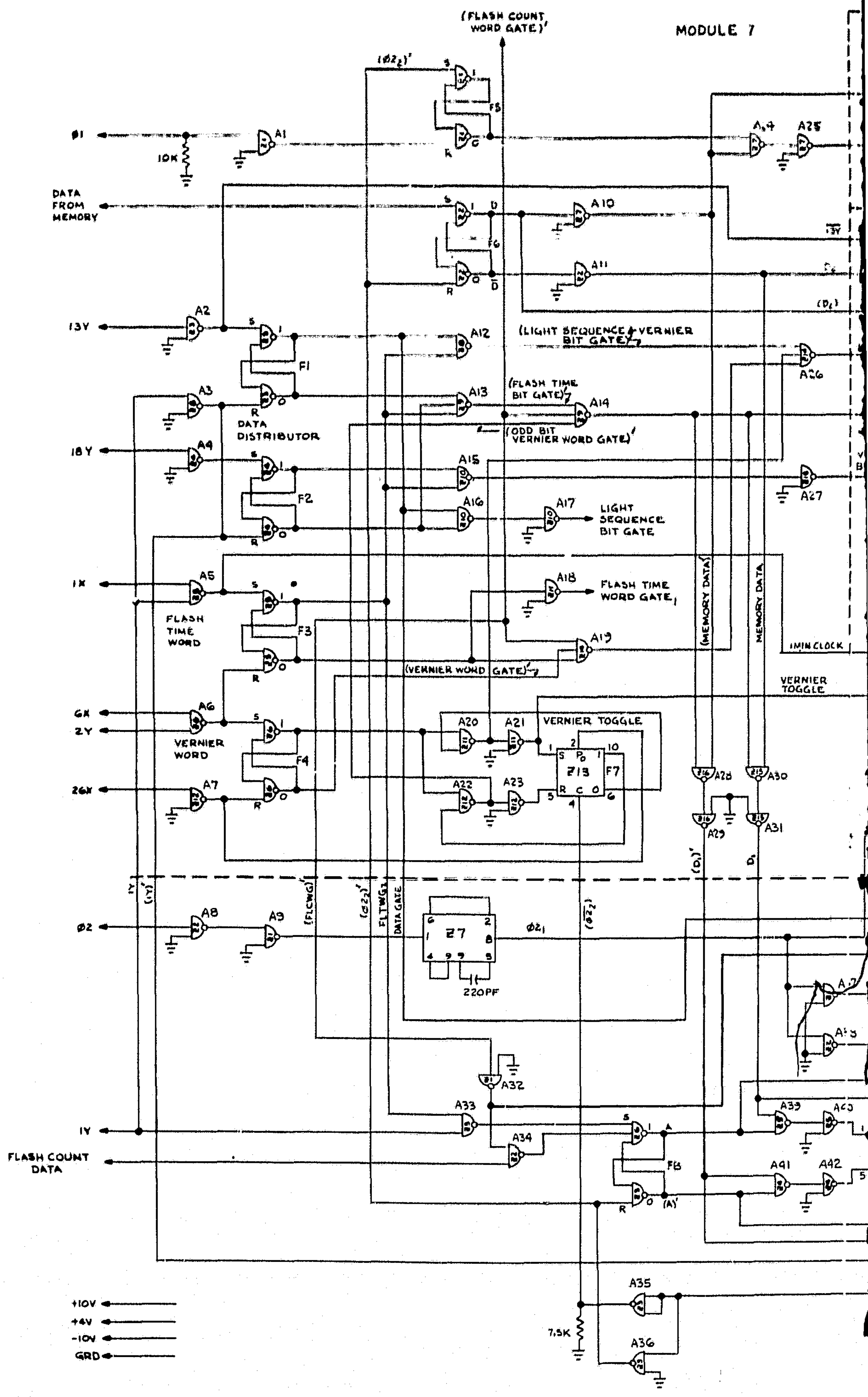
The mechanism for generating the data 1's in Words 63 and 64 is explained with reference to Figure 3-3 (Data Handling, Logic Diagram extracted from JHU/APL TG-896, April 1967). At memory position 18X, 16Y (coincident with Word 63 Bit 16), the following occurs:

- A44 output goes high, setting F10
- Output of lower gate of F10 goes high
- A45 output goes low
- A58 output goes high
- A53 output goes low (logic level 1).

Logic level 1's are restored to memory from this point (Word 63, Bit 16) until the next memory position 13Y. For the fixed marker, this condition is satisfied coincident with Word 64, Bit 13, F10 is reset, the output of A53 goes high (logic level 0), and data 0's are restored to memory.

Relating the above logic to the anomaly of Words 24 and 25, one can see that with the exception of the 18X condition, all other conditions are present to generate the fixed marker on any given adjacent words. That is, 16Y occurs at Bit 16 of all words and 13Y occurs at Bit 13 of all words. The unique condition associated with the fixed marker is the occurrence of 16Y and 18X simultaneously. This condition is satisfied only at Word 63, Bit 16. Word 24, Bit 16 is coincident with memory position 16Y, 44X. Position 44X is far removed from 18X; however, it is probable that the 18X condition was satisfied during Word 24, Bit 16 causing the error as previously discussed.

At the time of the memory anomaly, no spacecraft operations were being conducted. All transponders were off battery with the exception of SECOR which was in the standby mode. No commands were being executed and no flash sequences were in progress. 162-MHz and 324-MHz doppler beacons were on with 972 MHz off.



FOLDOUT FRAME 1

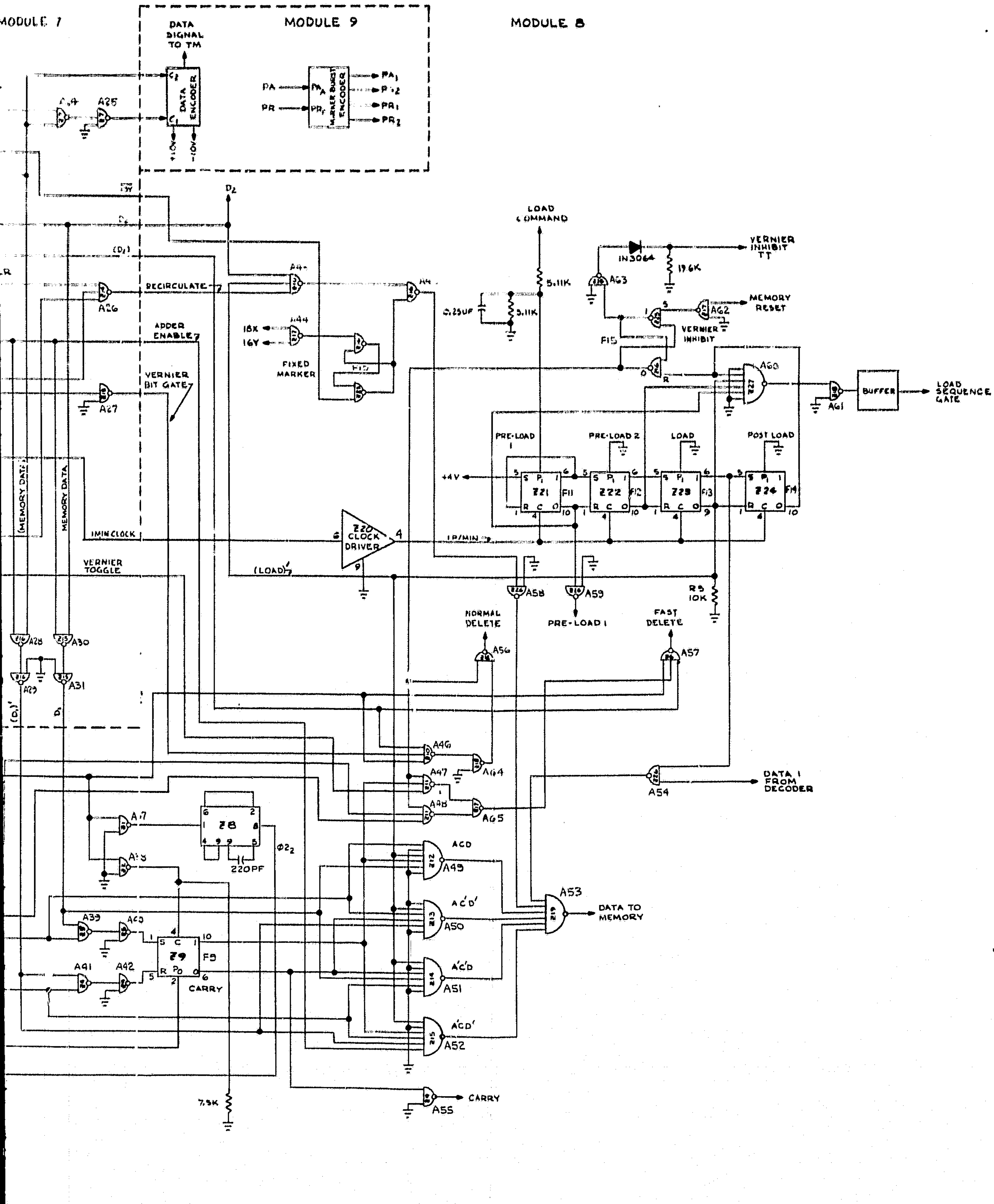


Figure 3-3 Data Handling, Logic Diagram

FOLDOUT FRAME 2

SSED and Laser Detector were off and no passive operations were in progress. The telemetry transmitter and functions were on, however, no station was recording telemetry data as the satellite was at 35° West Longitude and 60° South Latitude and not in sight of any STADAN station.

As the effects of this anomaly were corrected by a resynchronous mode injection at 1517Z, 3 April, the effect on the overall operation (rapid time drift) was restricted to about a five-hour period.

3.6.2.3 Memory Number One Command Disruption

Data obtained on 18 April 1968 seemed to indicate the occurrence of another memory anomaly. However, when all data were collected, the probable cause was attributed to command problems either internal or external to the spacecraft (see Paragraph 3.5).

The first indication of the malfunction was observed by APL time monitoring via doppler beacons. This assessment indicated that during the period 0103Z to 0104Z, 18 April, the spacecraft minute mark assumed a new epoch (approximately thirty-three seconds lagging UTC) and began drifting toward the leading side of UTC at a rate of about 1 msec/minute. This assessment was not verified by GSFC time monitoring, as no time monitor data were obtained after 1752Z, 17 April, through 1629Z, 18 April.

At injection time on 18 April (T_0 = 1624Z) the ROSMAN GEMTU preload readout did verify a memory disruption. This injection record showed that beginning with Word 11, all normalization bits were data zero. This condition caused a drift rate due to the lack of ninety-eight normal deletes, the magnitude being 98 x 9.8 μsec/delete = 960 μsec/minute, thus verifying the APL assessment with respect to magnitude. In examining the flash time words in error (Words 12 through 59) it was possible to count back to the time when these words were read from memory as all data zeros. This time corresponded to 0104Z, thus confirming the APL assessment with respect to time. The malfunction occurred during the data handling of Word 11 of the 0103Z minute, 18 April, causing all bits thereafter to be restored to memory as data zeros.

Upon examining a strip chart recorded by the Newfoundland STADAN station during this period, (refer to Paragraph 3.5), the causes of this memory interruption were explained. The strip chart indicated that at approximately 010308Z the spacecraft switched from memory number one (the one in operation) to memory number two. Thirty-three seconds later, approximately 010341Z, a switch back to memory number one occurred. This, then, explains the thirty-three second jump in the spacecraft minute mark, as memory number one was cycled out of operation for that period. Since switching of memories causes the data handling circuitry to switch to the memory load portion of the load cycle, the restoring of data zeros after Word 11, Bit 12 and the corresponding approximate 1 msec/minute clock drift (fast) are explained. Since there were no ground data inputs to memory at the time of the undesired load, it is proper for the memory to restore all data zeros.

3.6.3 Oscillator Number One

Figures 3-4 through 3-7 are plots of the 5-MHz oscillator number one frequency deviation from launch through 16 April 1968, the day this oscillator was switched out of operation. The data were obtained from reports submitted to the GOCC by APL and are derived from Navy Doppler tracking data.

By 20 February 1968, the day mission operations were initiated, oscillator number one had stabilized to a drift rate of about 1.5 parts in 10^{10} per day. If reasonably predictable, this drift rate would have been completely satisfactory to sustain operations. However, on 21 February 1968, the frequency changed, either instantaneously or at a very rapid rate, by approximately sixteen parts in 10^{10}. As can be seen in Figures 3-4 through 3-7, its drift then became erratic and difficult to

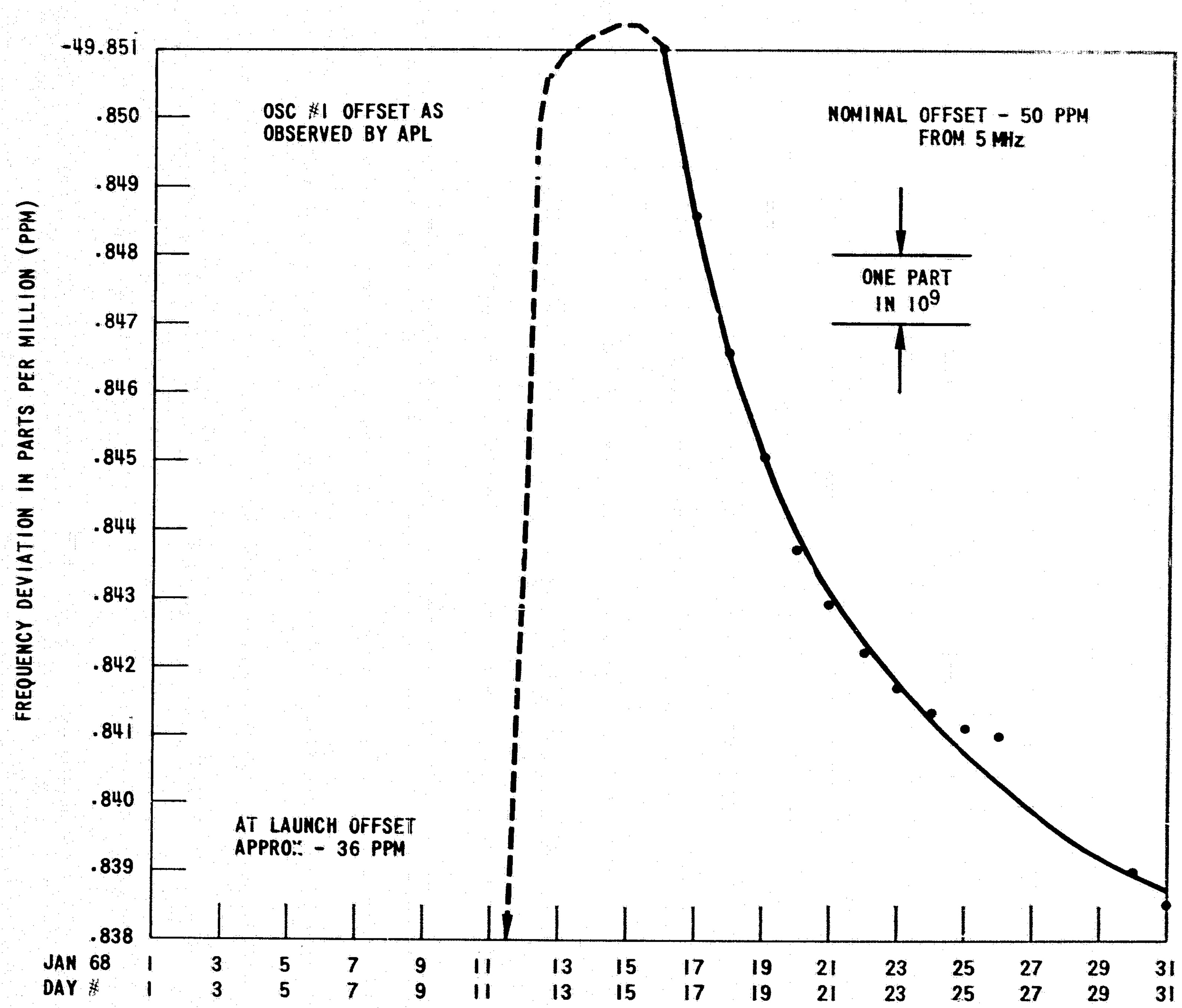


Figure 3-4 Oscillator Number One Frequency Deviation Versus Time

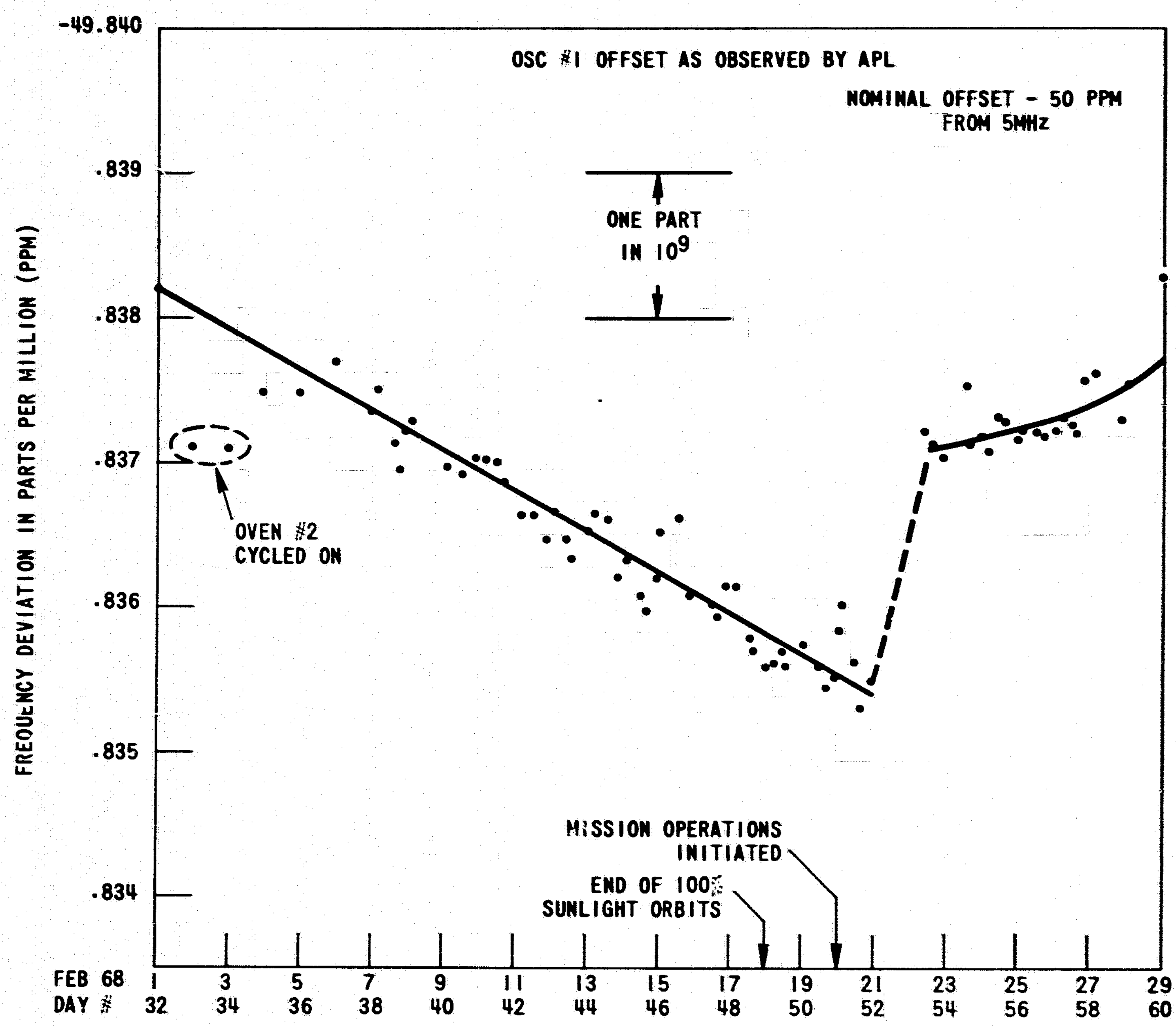


Figure 3-5 Oscillator Number One Frequency Deviation Versus Time

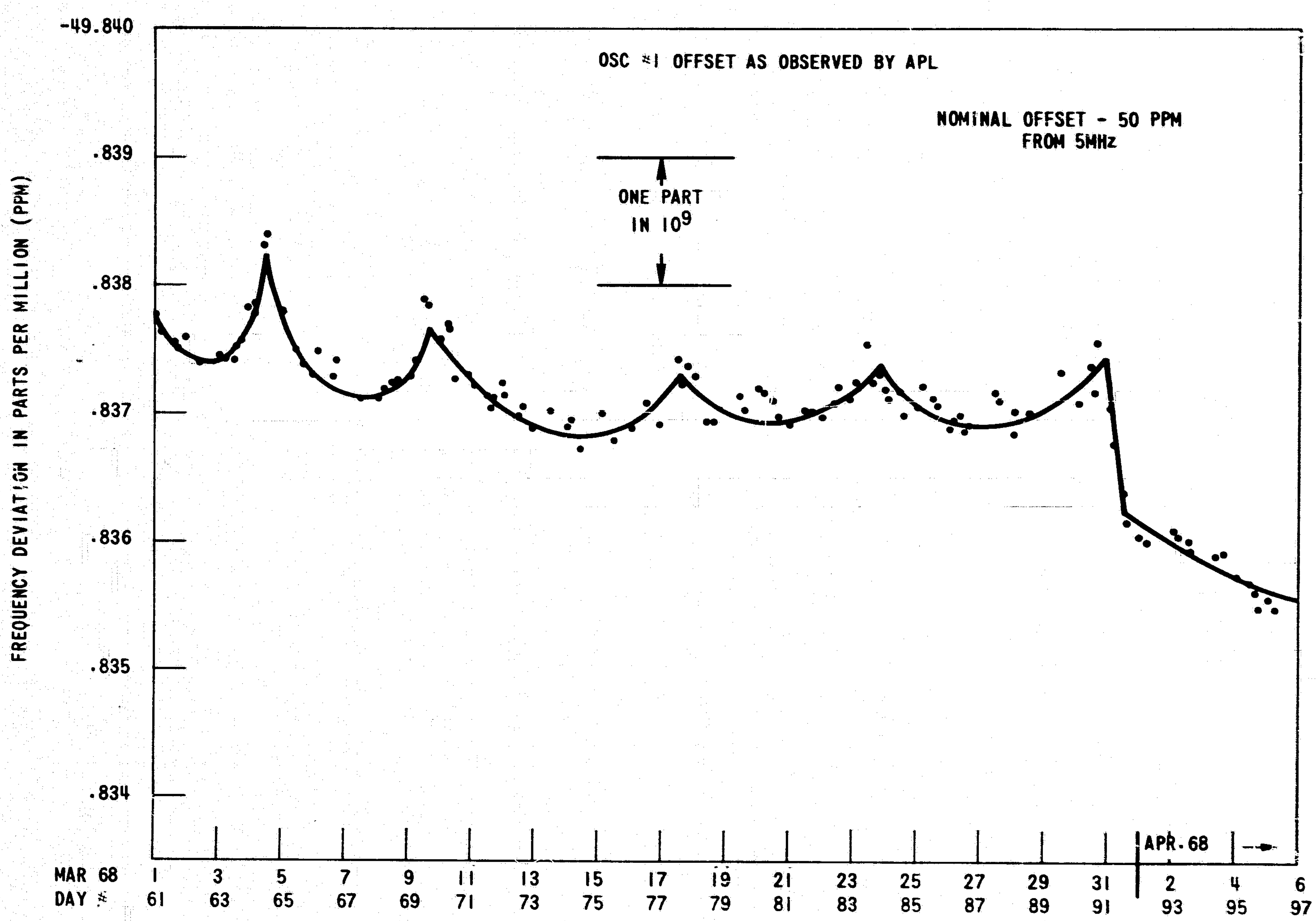


Figure 3-6 Oscillator Number One Frequency Deviation Versus Time

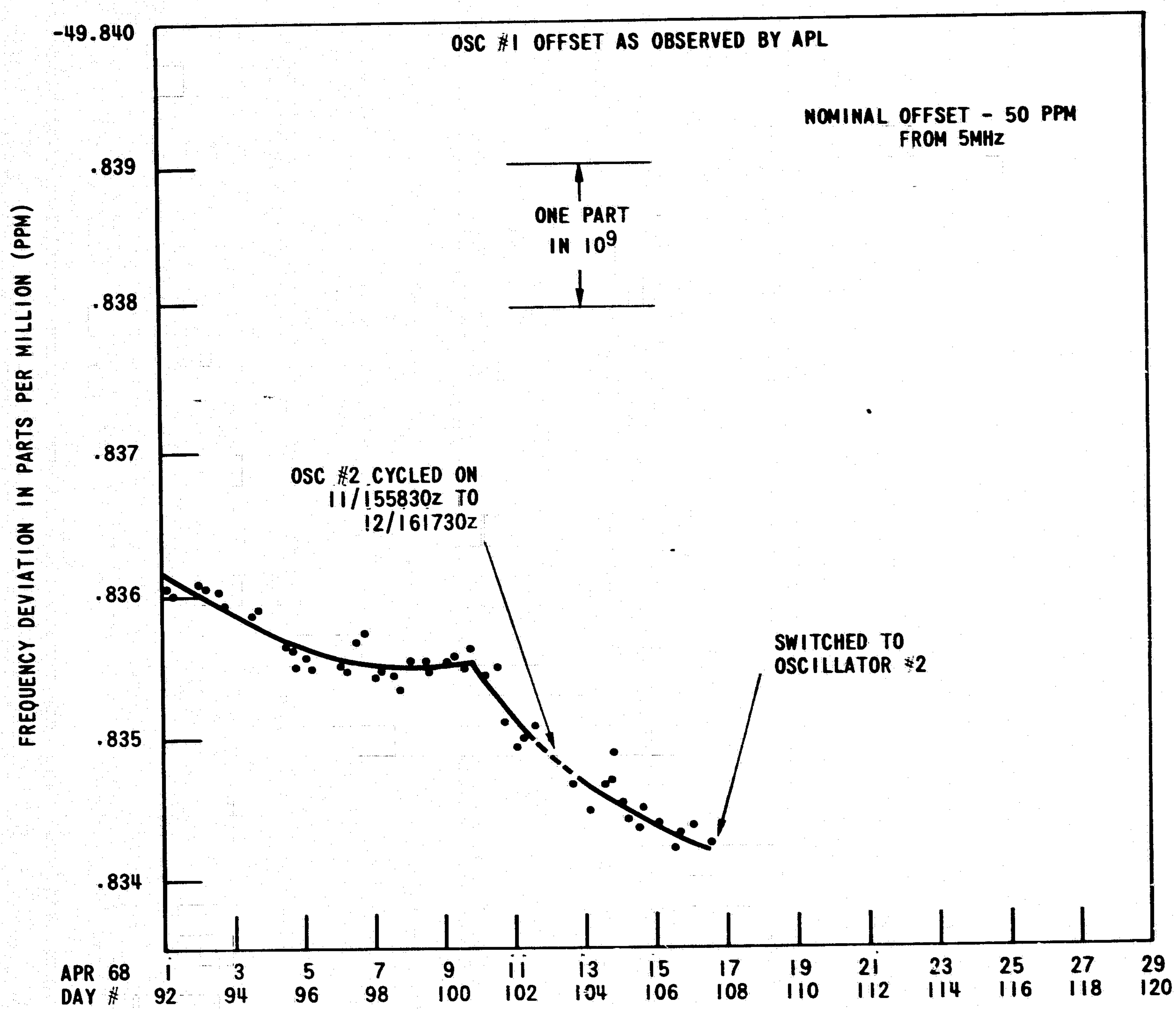


Figure 3-7 Oscillator Number One Frequency Deviation Versus Time

predict. On 31 March, another frequency shift appeared with magnitude of approximately twelve parts in 10^{10} within one day. On 10 April, on advice from the Technical Advisory Group it was decided to switch to oscillator number two, and on 16 April 1968, the switch was accomplished.

The cause of the frequency shifts and erratic drift of oscillator number one is unknown. The erratic behavior began about two days after the orbit of the spacecraft entered partial darkness suggesting that oscillator number one is extremely temperature sensitive, that is, sensitive to the allowable fluctuations of the oven. It is apparent that the oven was not at fault, as the same oven (number one) is being used with oscillator number two and similar behavior has not been noted.

3.6.4 Oscillator Number Two

Figures 3-8 and 3-9 are plots of the 5-MHz oscillator two frequency deviation from 16 April 1968 through 31 May 1968. Again, the data were obtained from reports submitted to the GOCC by APL and are derived from Navy Doppler tracking data.

Oscillator number two has performed very well with a smooth drift rate of about one part in 10^{10} per day. From the day it was put into operation, through the end of this reporting period, frequency predictions for normalization purposes have been more accurately obtained. The drift rate during June and July is typical of that presented in Figures 3-8 and 3-9.

3.7 OPTICAL BEACON SYSTEM

From launch through approximately the middle of May 1968, only two minor anomalies were detected in the optical beacon system as follows:

a. Assembly Number Three Flash Count

The flash detector of assembly number three has insufficient sensitivity and, therefore, will not increment the flash count memory word when assembly three is used alone in a sequence. This problem was noted during the assembly vibration tests.

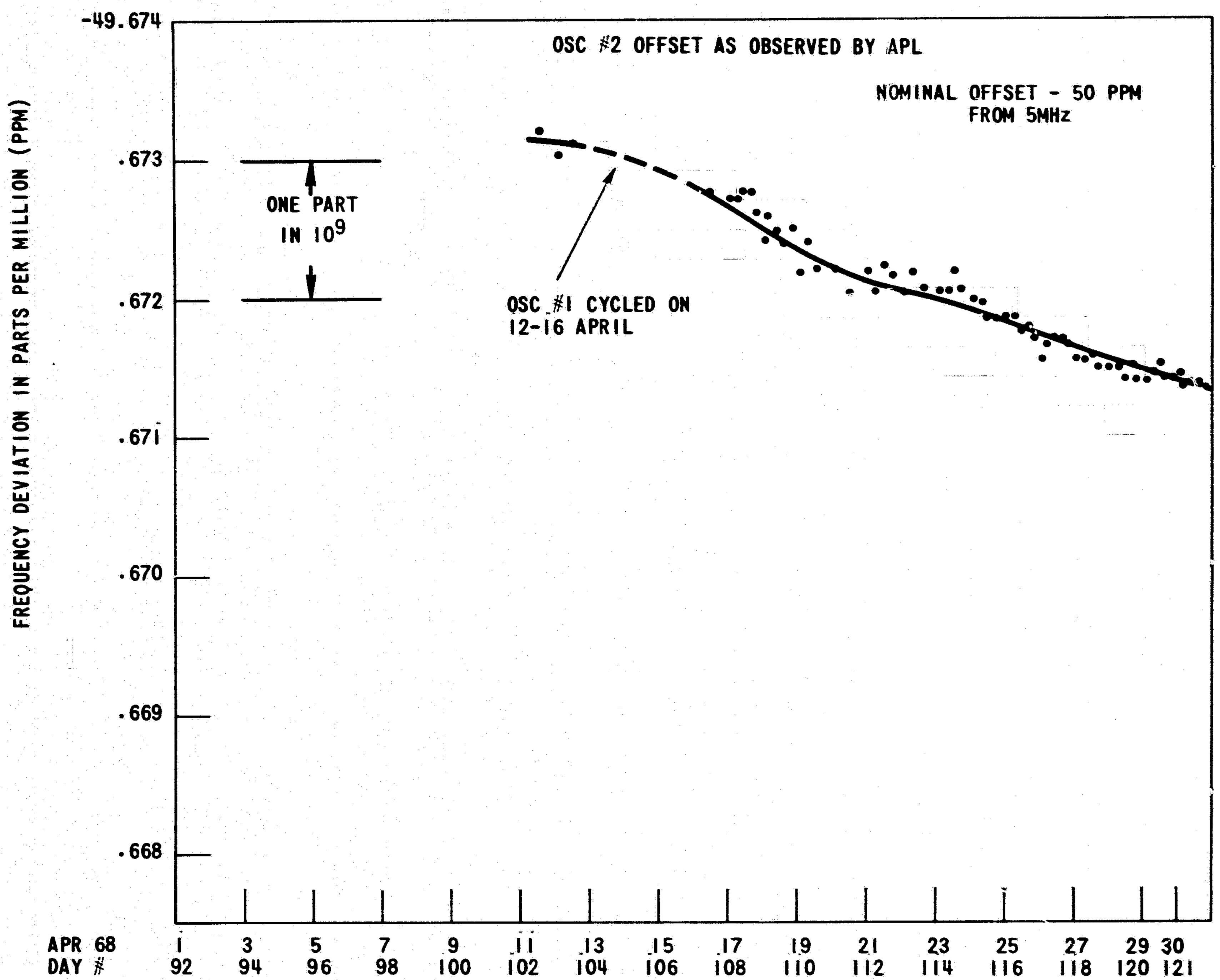


Figure 3-8 Oscillator Number Two Frequency Deviation Versus Time

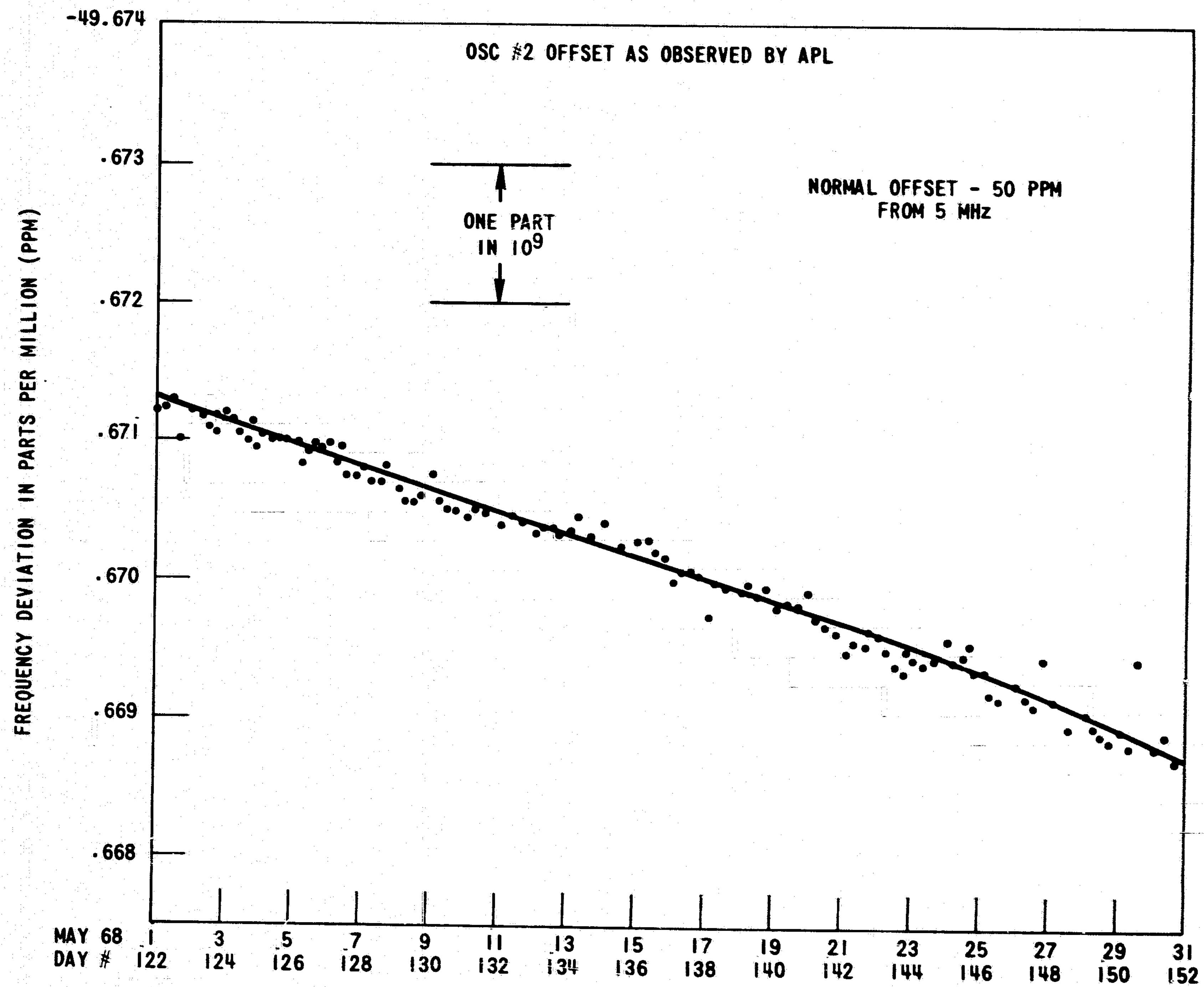


Figure 3-9 Oscillator Number Two Frequency Deviation Versus Time

During these tests, the output of assembly number three dropped to 20% of the design value. The problem was assessed as having very small impact; therefore, in view of the tight schedule, it was not rectified. Close inspection of assembly number three did not uncover the cause of the reduced detector output.

b. Assembly Number Two Extra Flash

On many occasions, assembly number two has flashed eight times when scheduled for the normal seven flashes. The extra flash occurs at the four second clock immediately preceding the clock on the integer minute. Although the assembly capacitors begin to charge at about 4.6 seconds before the integer minute, the tubes are designed to be insensitive to the initial trigger (four seconds prior to integer minute) as the voltage across the tube is relatively low. However, in this case, it is probable that tube number two is over sensitive and, at times, will discharge at the lower voltage level. This anomaly has been of negligible consequence.

3.7.1 Spacecraft Time Anomaly

Beginning in mid-May, an anomalous time drift was apparent. Normally, by knowing the spacecraft ultra-stable 5-MHz oscillator frequency (derived from doppler tracking frequency calculations) and programming the spacecraft memory to delete cycles of the oscillator output, the frequency can be normalized to the rate consistent with maintaining the occurrence of the spacecraft minute mark within ± 400 μsec of ground reference time, UTC. Although it is difficult to program the memory to effect zero minute mark drift, for a properly operating system the resultant drift caused by an error in normalization can be easily calculated. However, since mid-May, this has not been the case.

The anomalous drift is in the direction characteristic of additional, unprogrammed deletes being executed at the delete circuits. The anomalous drift is always to the lagging side of UTC. The actual drift has been, at times, as much as 200 μsec per day positive (spacecraft lagging UTC) when the error in normalization should have caused a negative (spacecraft leading UTC) drift of 150 μsec/day (i.e., net anomalous drift of about 350 μsec per day positive).

Data obtained by the GOCC relative to this problem indicate that the drift is present during high density optical beacon activity. Also, tests were conducted to analyze timing data during twenty-four hour periods when no flashes were programmed. The spacecraft minute mark drift during these periods was normal, supporting the theory that the problem is caused by optical beacon interference to the timing circuits.

During tests conducted to isolate the causes of erratic optical beacon flashes (discussed in Paragraph 3.7.2) a decision was made to discontinue the use of optical beacon assembly number four. Timing data analyzed during the three beacon operation (commencing 18 July 1968) has shown a significant reduction in the magnitude of the anomalous drift; however, a small unpredicted drift of about 40 μsec per day is still present.

Tests conducted by APL on 31 July and 1 August in connection with the optical beacon anomalies again demonstrated the influence of beacon number four on spacecraft timing. During Alternate Optical Logic number two tests (beacon assemblies two and four), the GSFC ROSMAN station was monitoring GEOS-II time. On two separate occasions, GEOS-II time was seen to slow down (to move to the lagging side of UTC) an amount characteristic of one extra normal delete per AOL Number two flash. It is probable that assembly number four was the cause of these errors.

In summary, existing data indicate the following:

a. Timing anomaly is caused by flash induced deletes in the spacecraft clock divider.

b. Assembly number four flashes either alone and/or in combination with other assemblies cause major time disturbances.

c. Assemblies one, two and three used alone and/or in combination with each other cause minor time disturbances.

3.7.2 Erratic Flash Anomaly

Beginning about 2 June 1968, reports from the optical participants indicated that the programmed optical beacon flashes were, at times, being executed erratically. The proper execution of a flash sequence places the first flash on the integer minute with subsequent flashes occurring on the four second marks. On numerous occasions, various flashes in a programmed sequence were reported to have occurred about 1.5 seconds prior to the scheduled time, either replacing the scheduled flash or occurring in addition to it. The problem became progressively worse during June.

On 27 June, during a scheduled lamp number four sequence, a frequency normalizer inhibit occurred causing timing to drift rapidly until the next injection. Because the operation was being seriously hampered by the frequent occurrence of optical system anomalies, mission operations were suspended on 28 June in order to diagnose the problem.

During the period 28 June through 17 July, a comprehensive testing program was conducted. The optical assemblies were programmed singularly and in various combinations for observation by selected optical sites and for telemetry observation, via real-time telemetry facilities, at the GOCC. Real-time Alternate Optical Logic operations were also accomplished.

The results of the testing program are summarized below:

Lamp One

a. Erratic flashing detected only when operated in sequence along with number four.

b. When operated alone, does not affect timing.

c. Caused normalizer inhibit on 5 July.

d. AOL number one testing normal.

Lamp Two

a. Erratic flashing (weak) on four second clock before minute mark.

b. Erratic flashing (other than a.) only when operated in sequence along with number four.

c. When operated alone, does not affect timing.

Lamp Three

a. No erratic flashes detected.

b. When operated alone, does not affect timing.

c. AOL number one testing normal.

Lamp Four

a. Involved in all erratic flashes detected.

b. Caused normalizer inhibit on 27 June, 8, 14 and 16 July.

c. Caused normalizer and flash inhibit on 6 July.

d. During AOL number two testing, flashes about every 2.5 seconds without commanding.

In addition, erratic operation of the telemetry system was detected during the testing. It is probable that this was induced by interference from the optical beacon system, as all telemetry anomalous operation occurred while flashes were being executed in either the AOL or memory controlled mode. The characteristics of the anomalous telemetry operation are summarized below:

a. On occasion, main commutator one skips channels during memory controlled flash sequences.

b. On occasion, after being stopped on subcommutator, main commutator one will step from the subcommutator channel to Channel 8 during AOL number two operation.

c. AOL number two operation produces assembly two and four flash about every 2.5 seconds without commanding. Subcommutator steps on each 2.5 second flash (i.e., without flash clock) and, at times, steps out of sequence.

d. During memory controlled sequences incorporating assembly four, subcommutator, at times, steps out of sequence.

e. AOL number one operation produces no telemetry anomalies.

f. Subcommutators step only on four second clock during memory controlled sequences, even if erroneous (extra) flashes are present.

In reviewing the test data, it was obvious that lamp number four was deeply involved in the anomalies analyzed. The Technical Advisory Group (TAG), therefore, recommended that lamp number four flashes be suspended. Since the resumption of normal operations on 18 July 1968, excluding lamp number four, no anomalous optical beacon flashes or telemetry malfunctions have been detected.

A normalizer inhibit condition did occur on 5 August, however, during a seven-flash sequence incorporating assemblies one, two and three. On 5 July lamp number one was the cause of a normalizer inhibit. These two bits of information, plus the fact that a small anomalous clock drift is present during the three assembly operation, suggest that a problem may exist in one or some combination of the remaining three operational optical beacons.

3.8 DOPPLER BEACONS

The doppler system is operating well within specification with doppler data being obtained from the 162- and 324-MHz beacons on a daily basis. Because of the main system power problem (Paragraph 3.3) the 972-MHz beacon has only been operated for about 500 hours since launch, as compared to 5,000 hours for the other two beacons; however, no problems have been encountered.

3.9 LASER REFLECTORS

The laser reflectors have been successfully tracked. No anomalous operations have been reported.

3.10 LASER DETECTOR

The GSFC Optical Systems Branch reports the laser detector to be operating completely as expected. Sufficient data have been taken to allow analyses and preliminary conclusions in this area.

3.11 C-BAND RADAR TRANSPONDERS

The attached report (Appendix A) was requested of the Wallops Island C-Band Project Manager for inclusion in this document. It discusses the C-Band abnormalities detected to date by the NASA Wallops Station C-Band radars.

In addition to the data contained in the Wallops report, a problem exists in the telemetry channels associated with transponder received signal strength. It is the opinion of the Wallops Station C-Band Project Manager that the data provided by these channels are not within the accuracy range required to allow precise determination of the delays associated with the respective transponders. The design specifications called for telemetry calibrations, which would allow delay determination to ± 10 nanoseconds. As the delay is a function of the received signal strength at the spacecraft borne transponder, accurate readings of this parameter are required to be transmitted to the ground via the spacecraft telemetry system. However, the telemetry data are so sensitive to temperature variations that an uncertainty exists in the readings. Because of this problem, the Wallops Station personnel assess the delay determinations using the telemetry technique to be accurate only to about ± 30 nanoseconds and, therefore, have abandoned this technique.

3.12 PASSIVE REFLECTOR

Because the predominant C-Band tracking to date has been in the transponder mode, there is insufficient data available to fully evaluate the passive radar reflector. The reflector has been tracked, however, on a few occasions by Wallops Station and AFETR. Although deep nulls were recorded during the tracks, the fact that passive tracks were accomplished suggests that the reflector is adding to the spacecraft radar target area.

It is expected that Wallops Station will have a report forthcoming in this area.

3.13 SECOR TRANSPONDER

A radio frequency interference problem was detected during the GEOS-II ground testing causing interference to the SECOR transponder system. It was determined by APL that the primary cause was a mixing of the 224.5-MHz and/or 449-MHz SECOR transmitter frequencies with the fundamental and/or second harmonic of the 324-MHz doppler beacon frequency producing an RF very near 420.9 MHz, the SECOR transponder receiver frequency. This condition caused distortion of the SECOR data.

To rectify this problem, APL used a bandpass filter with traps at 224.5 MHz and 449 MHz on the output of the 324-MHz transmitter. This solution was effective, however, some low level interference was still present.

Additional tests were performed prior to launch to determine if the remaining interference would affect SECOR data quality. The results were that the SECOR ground station power capability would completely override the interference and, therefore, cause no data distortion.

SECOR in-orbit tracking of GEOS-II has proven that the interference can be overridden during an interrogation. Because of the four station sequential mode of operation of the SECOR system, however, the transponder is not being interrogated continuously. Therefore, during the one to two millisecond dead time between station interrogations, the interference is seen as oscillations or blooming and does affect data quality. Also, during the acquisition phase of the four station SECOR tracking, all stations are not synchronized in their proper time slots immediately. This is a normal acquisition condition. In the case of the GEOS transponder, however, the dead periods caused because a particular station is not interrogating, or is not synchronized properly in the allocated slot, results in undesirable oscillations due to interference, which pose an operational problem. Because of this condition, four station acquisition is much more difficult.

To rectify the four station acquisition problem, SECOR personnel have modified the station equipment so that one station can effectively simulate a four station interrogation, thus, allowing no dead time for oscillations to occur while the other three stations are adjusting to the proper time slots. This modification has been effective in satisfying the problem.

To rectify the problem after all four stations are adjusted in their proper time slots, another modification has been added to lengthen the interrogation period of each station so that one RF uplink overlaps the next in time, which results in no dead period between station interrogations. This modification has also been effective.

In every other respect, the GEOS-II SECOR system has operated completely as expected.

3.14 GRARR TRANSPONDER

There have been no reports of anomalous operation with this system. The Goddard Range and Range Rate stations have routinely tracked the transponder since the initiation of mission operations with nominal results.

3.15 SOLAR SCIENCE ELECTRON DETECTOR (SSED)

The magnetic field detection portion of the SSED has operated as expected. However, the electron detector itself has not operated properly since launch. An arcing problem in the high voltage module is considered by APL to be the probable cause of this failure.

APPENDIX A

ABNORMALITIES IN RECEIVED SIGNAL AT THE WALLOPS STATION C-BAND RADARS FROM THE GEOS-II TRANSPONDERS

by

A. R. Selser/NASA-Wallops Station

August 1, 1968

The data used in this report was collected during the Collocation Project at Wallops Station from the FPQ-6 and FPS-16 radars. During this project the Wallops Station radars tracked 109 passes: fifty-four on the long delay transponder and fifty-five on the short delay transponder. The radar data outputs used were the analog AGC records, digitized AGC, and pulse-to-pulse film recording of non-track video (non-track video is ungated and does not have AGC applied). Due to the high speed of the pulse-to-pulse camera, only about two minutes of film data is available for passes in which this type of data was recorded. The radars nominally obtain eighteen minutes of metric data per pass; thus, the film data represents only a small portion of the pass during which it was recorded.

The items discussed are separated into four categories: signal fade, drop-out, countdown, and other. Examples of most items are available on film.

1. Signal Fade - A signal fade is a long term decrease in signal amplitude and is usually accompanied by a return to the previous signal level. Fade durations nominally ranged from twenty seconds to two minutes. Film data shows that fades are not the result of missing pulses, but are gradual changes in return pulse amplitude. The typical depth of fade is ten decibels (dB). Fades are characteristic of both transponders and are seen by both radars at the same time. They appear to be a function of satellite aspect angle. This indicates that they are caused by lobing in the transponder antenna patterns. Antenna patterns run by the Applied Physics Laboratory on the GEOS-B mock-up show that patterns cut in certain planes across the

satellite have severe lobing with depth of null greater than 10 dB in isolated cases. These antenna patterns and all Wallops tracks during the Collocation Project were run in linear polarization.

During revolution 1,237, the FPS-16 lost track during a fade. The same fade caused the FPQ-6 Signal-to-Noise Ratio (SNR) to drop to 16 dB. It cannot be determined whether loss of track was due to failure of the FPS-16 to interrogate the transponder, or the signal was too weak to be detected. During revolution 2,118, the FPS-16 SNR dropped to 1 dB and the FPQ-6 SNR dropped to 13 dB; neither radar lost track in this fade. These are the two worst cases for fades and both were on the long delay transponder. AGC records show that the received SNR of the two radars normally differed by 5-13 dB.

2. Drop-Out - A drop-out is a sudden loss of return signal which, if its duration is longer than two seconds, will cause the radar to lose track. Typical durations range from a few tenths of one second to several seconds. Many of the drop-outs have been about two seconds long, but the ones which last longer cause the radar to lose track making it impossible to determine when the signal actually returned.

Table A-1 lists the passes during which Wallops Station radars experienced one or more drop-outs, the origin of which cannot be determined. In isolated cases drop-outs occurred that were directly attributed to a malfunction in the radar system; these are not included in the table. Note in the table that there are twelve passes in which both radars were beacon tracking simultaneously and only one had a drop-out. Listed in Table A-1 are revolution number, transponder, the radar affected by and number of drop-outs, the status of the other radar at the time of the drop-outs, and the effective beacon pulse repetition frequency (PRF) the instant before the drop-out occurred.

The cause of these drop-outs has not been determined; however, the fact that the worst cases arise when one radar is

TABLE A-1

Revolution Number	Transponder	Drop-Outs Radar	Drop-Outs No.	Status of Other Radar Radar	Status of Other Radar Track Mode	Effective Beacon PRF
1096	Short Delay	FPS-16	1	FPQ-6	Beacon	320
1186	Long Delay	FPS-16	1	FPQ-6	Beacon	320
1309	Long Delay	FPQ-6	7	FPS-16	No Track	160
1353	Long Delay	FPQ-6	1	FPS-16	Beacon	320
1378	Long Delay	FPQ-6	1	FPS-16	Beacon	320
1391	Long Delay	FPS-16	1	FPQ-6	Skin	160
1391	Long Delay	FPS-16	1	FPQ-6	Beacon	320
1506	Long Delay	FPS-16	1	FPQ-6	Beacon	302
1699	Short Delay	FPQ-6	1	FPS-16	No Track	800*
1725	Short Delay	FPQ-6	1	FPS-16	Beacon	320
1789	Long Delay	FPS-16	1	FPQ-6	Skin	160
1789	Long Delay	FPS-16	1	FPQ-6	Beacon	320
1866	Long Delay	FPS-16	1	FPQ-6	Skin	160
1963	Long Delay	FPS-16	1	FPQ-6	Skin	160
1976	Long Delay	FPQ-6	1	FPS-16	Beacon	320
2027	Long Delay	FPS-16	3	FPQ-6	Beacon	320
2052	Long Delay	FPQ06	4	FPS-16	No Track	160
2079	Long Delay	FPQ-6	4	FPS-16	No Track	160
2118	Long Delay	FPS-16	1	FPQ-6	Beacon	320
2122	Long Delay	FPS-16	1	FPQ-6	Beacon	320
2130	Long Delay	FPS-16	1	FPQ-6	Skin	160
2168	Long Delay	FPQ-6	4	FPS-16	No Track	160

*Four AFETR radars were tracking at the time of this drop-out.

tracking at a PRF of 160 indicates that there might be a PRF relationship. Conversation with personnel at the Vega Precision Laboratories, Incorporated, the transponder manufacturer, has resulted in the theory that for certain spacecraft conditions the high voltage cutoff circuit in the transponder may be in marginal operation at a PRF of 160. Several times when the FPQ-6 had experienced a drop-out, the operator selected a 640 PRF and the transponder replied immediately.

Three drop-outs have been recorded on film: one each during revolutions 2,052 and 2,079 for the FPQ-6, and one in revolution 2,118 for the FPS-16. In revolution 2,052, the FPQ-6 reply pulse amplitude dropped on a pulse-to-pulse basis from a 35 dB SNR to noise in about 5 PRF intervals (approximately 31 milliseconds). There were no missing pulses (countdown) during that interval. In revolution 2,079, the same type sequence occurred to the FPQ-6 in about 7 PRF intervals (approximately 44 milliseconds). In both of these cases the FPQ-6 was the only tracking radar. Vega personnel feel that this could be caused by having the power cutoff from the transponder's transmitter. This, in turn, could be the result of a failure in the high voltage cutoff circuit. In revolution 2,118, the FPS-16 had something different happen. The reply signal was constant in amplitude with a SNR of 20 dB. Countdown (missing pulses) began to appear, randomly at first, and then became severe until no replies were seen by the radar. The sequence lasted about 2.5 seconds from the time countdown first appeared until the pulses completely disappeared. During the countdown sequence the reply pulses, when present, were all the same amplitude. Both the FPQ-6 and FPS-16 tracked this pass, but only the FPS-16 experienced the drop-out.

So far most of the drop-out problems have been with the long delay transponder, and the worst cases for drop-outs have been when the FPQ-6 was tracking alone on that transponder. Of the 109 Collocation tracks, the FPQ-6 tracked alone seventeen times: six on the long delay and eleven on the short delay transponder.

Of those six long delay transponder tracks, four had serious drop-out problems, while none of the eleven short delay tracks had a single drop-out.

3. Countdown - Countdown is defined as randomly spaced missing pulses. Both radars have experienced countdown from both transponders. Some tracks had none, while other tracks had many missing pulses. Both radars experienced about the same amount of countdown per pass. Countdown can be seen on the analog AGC record and on pulse-to-pulse film, and both records of the same pass correlate in time for missing pulses.

So far in the GEOS-II program countdown has not been a problem. Even in tracks when countdown was termed severe the percentage of missing pulses to total interrogations was usually less than 0.01%, which is 100 times better than that specification for the transponder.

Once in a while a single reply pulse appeared approximately 8 microseconds ahead of where it should have been. This has been seen on film five times: three times on the long delay and two times on the short delay transponder. It must be remembered that the film data represents only a small portion of the total track time, so this type of event may have happened more times. When the range pulse appears early, it looks like countdown to the radar tracking system because the pulse is not in the range gate. Talks with Vega indicate that noise may have set the 8-microsecond decoder in the transponder enabling it to reply to the first pulse in the interrogation code. This is one cause of countdown, but the film data indicates that it is a minor cause. Most of the countdown is the result of something else.

It is not known at this time whether countdown and drop-outs are related as to their causes. An effort is being made now to determine if missing pulses are the fault of the radars, the transponders, or both.

4. Other Abnormalities

a. Occasionally missing pulses appeared in groups of two to four. This type of event happened more often to the FPS-16 and FPQ-6. It is usually caused by radar phasing, when more than one radar is tracking, or by some kind of interference, the origin of which has not been determined.

b. Once in a while one or two extra pulses appeared after the range pulse, approximately 2 to 8 microseconds later. The cause of these is unknown; however, they were probably the result of random noise in the radar system. These extra pulses did not affect the tracker because they were outside the range gate.

c. The radar operators have had scattered problems, such as the transponder replying three minutes late or being cut-off early. These problems were few and appeared to be operations oriented. They will not be discussed here.

This report has attempted to show the types of problems the Wallops Station C-Band radars have encountered tracking the GEOS-II transponders and offers some possible causes; although, at this time, it is not possible to draw any significant conclusions as to the causes of these problems.

APPENDIX B

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