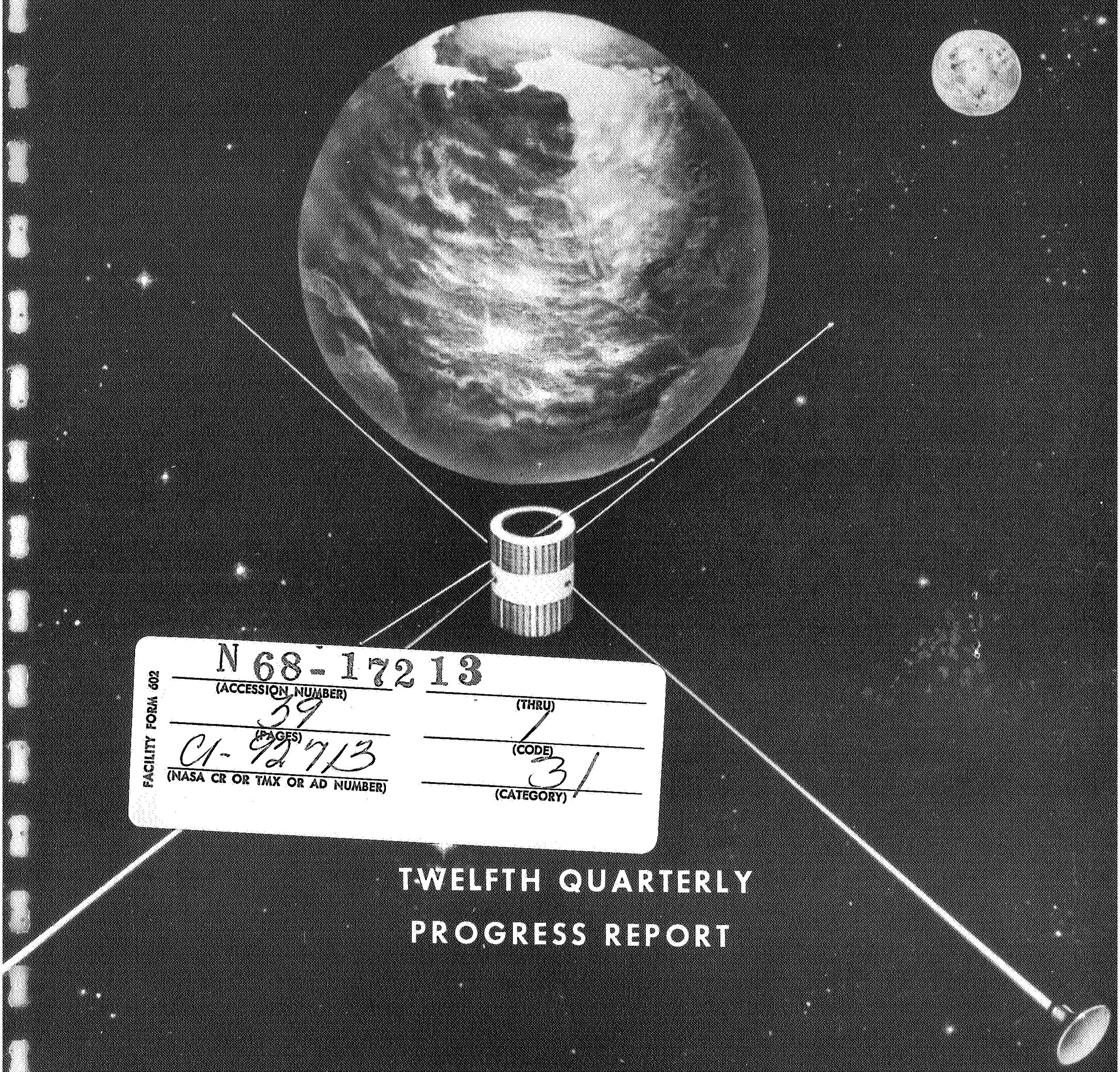
GRAVITY GRADIENT STABILIZATION SYSTEM FOR ATS



TWELFTH QUARTERLY PROGRESS REPORT

GENERAL ELECTRIC
SPACECRAFT DEPARTMENT

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TWELFTH QUARTERLY PROGRESS REPORT
FOR THE
APPLICATIONS TECHNOLOGY SATELLITE
GRAVITY GRADIENT
STABILIZATION SYSTEM

1 MAY 1967 THROUGH 31 JULY 1967

CONTRACT NO. NAS 5-9042

FOR THE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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ATS TECHNICAL OFFICER

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PASSIVE ATTITUDE CONTROL PROGRAMS

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ABSTRACT

During the reporting period, GE furnished detailed reports of ATS-2 analysis for the NASA Technical Data Reports for 21 May, 20 June, and 20 July. Generally, the tumbling of the ATS-2 has continued because of the eccentric orbit, and predictions are that the tumbling will continue for an indefinite time. Rates have been observed from 4 degrees/minute to as high as 51 degrees/minute. The rate of tumbling precluded meaningful attempts to obtain 3-axis attitude determination; however, generation of sun vector coordinates continued because of the omnidirectional characteristics of the gravity gradient system sun sensors. This information has been supplied to NASA/GSFC biweekly for subsequent use by ATS-2 experimenters.

On 9 June, the ATS-2 Primary Booms were scissored (Boom A system to 30.2 degrees and Boom B to 30.4 degrees). The Combination Passive Damper was clutched from the eddy-current to the magnetic hysteresis mode during the same experiment. These tests were conducted in cooperation with NASA and GE from the ATS Operations Control Center (ATSOCC) at Goddard. Telemetry data verified that two boom systems were successfully scissored. A profile of the scissoring is illustrated in Figure 2-1, while Figure 2-2 shows excursions of the damper boom angle in the vicinity of the clutching operation.

Investigation of ATS-2 boom dynamics phenomena was concluded with the publication of GE/PIR 4T75-24. This document substantiates the contention that the observed high frequency components of boom and center body motions are explainable in terms of orbit eccentricity alone, and would not have occurred to any significance if the spacecraft had been put into a circular orbit.

A discussion is presented in Section 2 of each component in the gravity gradient system aboard the ATS-2 including an analysis of the primary boom motions as concluded from latest TV data.

Further participation by GE in ATS-2 flight analysis will be limited to generation of sun vector tapes in response to each new Raw Telemetry Data Tape from NASA/GSFC or participation whenever an ATS-2 gravity gradient experiment is conducted. The balance of the GE effort will be devoted to plans for the ATS-D launch and subsequent flight analysis.

A retrofit of the S/N 100 prototype primary boom unit was performed to ensure that play in the tip masses was virtually eliminated. This test was conducted at qualification levels and completed on 19 July. Efforts continued toward completion of flight acceptance tests for the ATS-D primary boom system to ensure on-time delivery of these units to the vehicle contractor.

Disposition of the damper boom units is discussed in Section 3.4.

Current progress toward the design and test of the two Varying Torque Hysteresis Dampers (VTHD) is discussed in Section 4. The VTHD will replace the former Passive Hysteresis Damper in the Combination Passive Damper units for ATS-D and ATS-E.

The flight unit TV camera subsystems for the ATS-D and ATS-E were subjected to a prescribed 60-day storage test at GE. The details of these tests are discussed in Section 5.1. Some minor modifications to a connection in the flight unit Solar Aspect Sensors for ATS-D and ATS-E were made as described in Section 5.2.

Reports of Quality Assurance, Materials and Processes, and Manufacturing activities are included in separate sections of this document.

SECTION 1
INTRODUCTION

1.1 PURPOSE

This report documents the technical progress made during the period from 1 May to 31 July 1967 toward the design and development of Gravity Gradient Stabilization Systems for the Applications Technology Satellites.

1.2 PROGRAM CONTRACT SCOPE

Under Contract NAS 5-9042, the Spacecraft Department of the General Electric Company has been contracted to provide Gravity Gradient Stabilization Systems for three Applications Technology Satellites: one to be orbited at 6000 nautical miles (ATS-A), and two to be orbited at synchronous altitude (ATS-D and ATS-E). Each system consists of primary booms, damper boom, damper, attitude sensors and the power conditioning unit. In addition to the flight systems, GE provided a thermal model, a dynamic model, an engineering unit and two prototype units. Two sets of aerospace ground equipment were also furnished by GE.

SECTION 2

SYSTEMS ANALYSIS AND INTEGRATION

2.1 EVENT SUMMARY

Events of significance to systems analysis and integration activities during the months covered by this reporting period are summarized as follows:

15-16 May	ATS-2 tumbling rates exhibited a significant increase from a previously noted 28 deg/min maximum to a new maximum of 51 deg/min. This increase was subsequently correlated with the approximate time of disappearance of the "sky-pointing" boom of System 101 B.
17-18 May	The fourth RTDT, containing 37 files of data, was processed and the corresponding NASA sun vector tape was produced and delivered.
19 May	PIR 41M9-010, "Upright Capture of ATS-A" was published summarizing results of computer runs made immediately prior to the launch of ATS-2.
21 May	First monthly input to NASA's ATS Technical Data Report.
22 May	Volume V-A of the Orbit Test Plan, "ATS Supplementary Material," was published and distributed.
24-25 May	The fifth RTDT, containing 16 files of data, was processed and the corresponding NASA sun vector tape was produced and delivered.
3 June	First data indicating crippling of "sky-pointing" boom of System 102 A.
6 June	The sixth RTDT was processed and the corresponding sun vector tape delivered.
9 June	GE participated in operational gravity gradient tests at ATSOCC. ATS-2 primary booms were successfully scissored to their maximum angle and the CPD was clutched from the eddy-current mode to the magnetic hysteresis mode.
12 June	ATS Systems Memo No. 115, "Trip Report: ATS-2 Boom Scissor and Damper Clutch Operations," was issued.
15-16 June	The seventh RTDT, containing 50 files of data, was processed and the corresponding sun vector tape delivered to GSFC. Henceforth, per agreement with GSFC, tapes will be at two week intervals.

15 June — Examination of TV film data confirmed the crippling of one boom of System 102 A and established the point of crippling to be about 20 feet from the scissor pivot point.

20 June — First data on appearance of 3 booms in field of view of GG TV system; this was subsequently determined to be the "missing" boom from System 101 B. The same data also indicated that the previously crippled boom of Boom System 102 A is now "straight;" the point of previous crippling is detectable in subsequent pictures of the "straight" boom.

20 June — Second monthly input to NASA's ATS Technical Data Report.

23 June — A 3-file RTDT, containing data from the 9 June gravity gradient tests, was received. Initial difficulties in recovering the scissor maneuver dwell mode data were encountered due to the continuation of normal mode data recording at Mojave during the dwell mode data recording at Rosman. The overlap of station passes was interpreted as redundant data in the operations of GE's Attitude Determination Program per SVS-7429. A re-run of tapes beginning with time of Rosman acquisition eliminated the problem.

27 June — PIR 4T75-24, "ATS-2 Boom Dynamics in Elliptical Orbit," was issued. This document substantiates the contention that the observed boom dynamics on ATS-2 are explainable in terms of orbit eccentricity alone and would not have occurred to any degree of significance if the orbit had been circular. The cross coupling between modes, necessary to the explanation of observed high frequency oscillations, is a direct consequence of orbit eccentricity forcing functions. Aerodynamics, or the impact of damper booms against the stops, are not necessarily (nor are they considered sufficient) explanations of observed phenomena.

30 June — The eighth RTDT, containing 44 files of data covering the time period 8 June through 19 June, was processed and the corresponding NASA sun vector tape shipped to GSFC.

6 July — PIR 41M9-015, "Excess Potential Energy of a Rigid Body," was published. This PIR, together with PIR 4T22-017, "Excess Kinetic Energy of a Rigid Body," dated 15 March 1967, describes the additions to the ATS Math Model which will allow a direct evaluation of spacecraft damping efficiency in terms of energy removal rates.

7 July — Volume I of the Orbit Test Plan, "Test Philosophy and Objectives," was published and distributed. Included is a bibliography of published material associated with the accomplishment of systems analysis and integration tasks to date.

7 July — ATS Systems Memo No 116, Pre-Launch System Requirements and Analysis Task Summary, was published and distributed. This memo summarizes all recognized systems tasks through launch of ATS-D.

9 July	Loss of GG regulated power, due to low voltage output from spacecraft power supply, rendered the GG camera sun shutter system inoperative. Resultant camera degradation due to excessive sunlight exposure was only temporary. Recovery of spacecraft power supply and turn-on of GG regulated power reactivated the sun shutter mechanism and saved the cameras from permanent degradation. Spacecraft power loss was due to a combination of poor attitude relative to the sun and two eclipse periods causing an excessive drain on spacecraft battery supply.
11 July	PIR 41M9-020, "Results of the Computer Simulation of the ATS-D Variable Torque Hysteresis Damper," was published. Significant improvements in damping time over the constant torque hysteresis damper are demonstrated.
13 July	The ninth RTDT, containing 52 files of data and covering the period 17 June through 5 July, was processed and the corresponding NASA sun vector tape shipped to GSFC.
20 July	Third monthly input to NASA's ATS Technical Data Report. Henceforth, inputs will be limited to letter reports.
20 July	Decision made, per agreement with the GSFC technical officer, to eliminate GE flight analysis activities on ATS-2 except for periods of active gravity gradient experimentation. The NASA sun vector tape will continue to be generated on a biweekly basis.
24-25 July	Interface meeting with GSFC and HAC at GSFC. Primary topics of discussion were the interface specification, S2102-2, and ATS-D system contraints.
27 July	The tenth RTDT, containing 40 files of data and covering the period 5 July through 17 July, was processed and the corresponding NASA sun vector tape shipped to GSFC.
31 July	PIR 41M9-018, "Revision of Mathematical Model to Include Variable Torque Hysteresis Damper," was published.
31 July	ATS Systems Memo No. 118, "Trip Report ATS Interface Meeting at GSFC on 24-25 July 1967," was published.
31 July	ATS Systems Memo No. 119, "Preliminary Information on ATS-D Ion Engine," was published.
1 August	Analysis of TV film data from ATS-2 substantiates the contention that the "missing" boom of System 101B is merely crippled and is seen periodically in the field of view of both TV systems No. 1 and

2. Prior observations of 3 booms in the field of view of TV No. 1 are believed to be the crippled boom of System 101B rather than the damper boom as initially postulated. The previously crippled boom of System 102A remains "straight" in latest data received.

2.2 ATS-2 FLIGHT ANALYSIS

2.2.1 SUMMARY OF RESULTS

Detailed reports on GE flight analysis of ATS-2 data have been provided as formal inputs to the NASA Technical Data Report. Inputs were provided on 21 May, 20 June, and 20 July covering data for the ATS-2 flight through 19 April, 16 May and 9 June, respectively. Generally speaking, the tumbling of the ATS-2 due to the high eccentricity orbit, has continued throughout the reporting period and is expected to continue indefinitely. Rates as low as 4 deg/min and as high as 51 deg/min have been observed. The absence of valid POLANG data or IR sensor data, due to the rate of spacecraft tumble, has precluded any meaningful attempts at 3-axis attitude determination or gravity gradient system experimentation. The omnidirectional characteristics of the gravity gradient system sun sensors, however, have allowed the continued generation of information on sun vector orientation in spacecraft body-system coordinates. This information has been supplied biweekly, in the form of a NASA Sun Vector Tape, to GSFC for subsequent use by ATS-2 experimenters.

2.2.2 ATS-2 BOOM SCISSOR AND DAMPER CLUTCH OPERATIONS

On 9 June, the ATS-2 primary booms were successfully scissored to their maximum angle and the CPD was clutched from the eddy-current mode to the magnetic hysteresis mode. GE participated in the definition and conduct of tests from ATSOCC. A discussion of the the test operation is presented in ATS Systems Memo No. 115. The scissor motor command was transmitted for a total of 150 seconds to accommodate the maximum angle and minimum rate anticipated for boom systems A and B and to ensure that both boom systems be driven into their respective limit switches. Telemetry data verified the proper scissoring operation and indicated boom systems A and B scissored to 30.2 and 30.4 degrees, respectively. A profile of scissoring performance is presented in Figure 2-1. The Combination Passive Damper was clutched on command after real-time monitoring of damper boom angle and

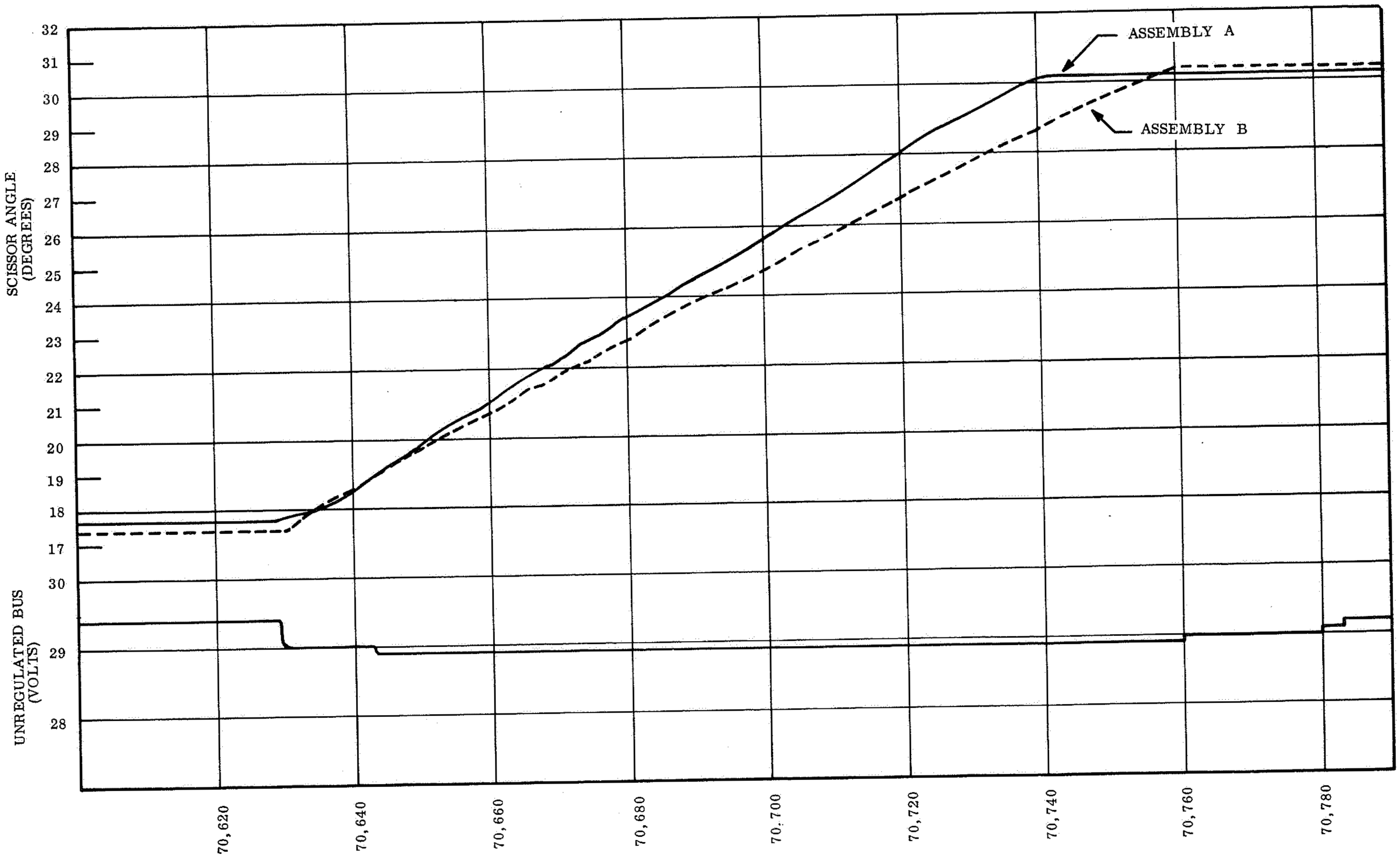

Figure 2-1. Boom Scissoring Profile

assurance that the angle was within the ± 2 degree range considered acceptable for clutching. Telemetry data verified a proper clutching operation and subsequent flight data indicates proper operation of the passive hysteresis damper. Figure 2-2 illustrates the excursion of the damper boom angle in the vicinity of the clutching operation.

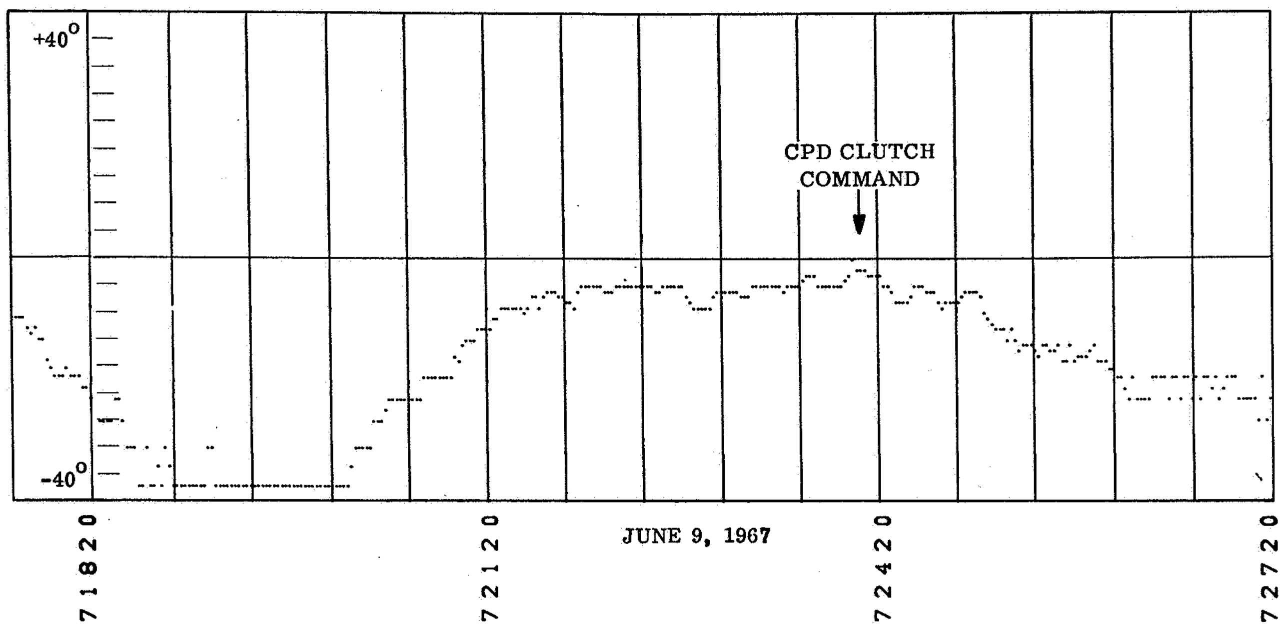

Figure 2-2. Damper Boom Angle in the Vicinity of Clutching

2.2.3 ATS-2 BOOM DYNAMICS

Investigation of ATS-2 boom dynamics phenomena was concluded with the issuance of PIR 4T75-24. This document substantiates, by mathematical simulation and analysis, the contention that the observed high frequency components of boom and central body motion are explainable in terms of orbit eccentricity alone and would not have occurred to any degree of significance if the orbit had been circular. The cross coupling between modes, necessary to the explanation of high frequency oscillations typified by Figure 2-3, is a direct consequence of forcing functions related to orbit eccentricity. Aerodynamics, or the impact of damper booms against stops, are not necessarily (nor are they considered sufficient) explanations of observed phenomena.

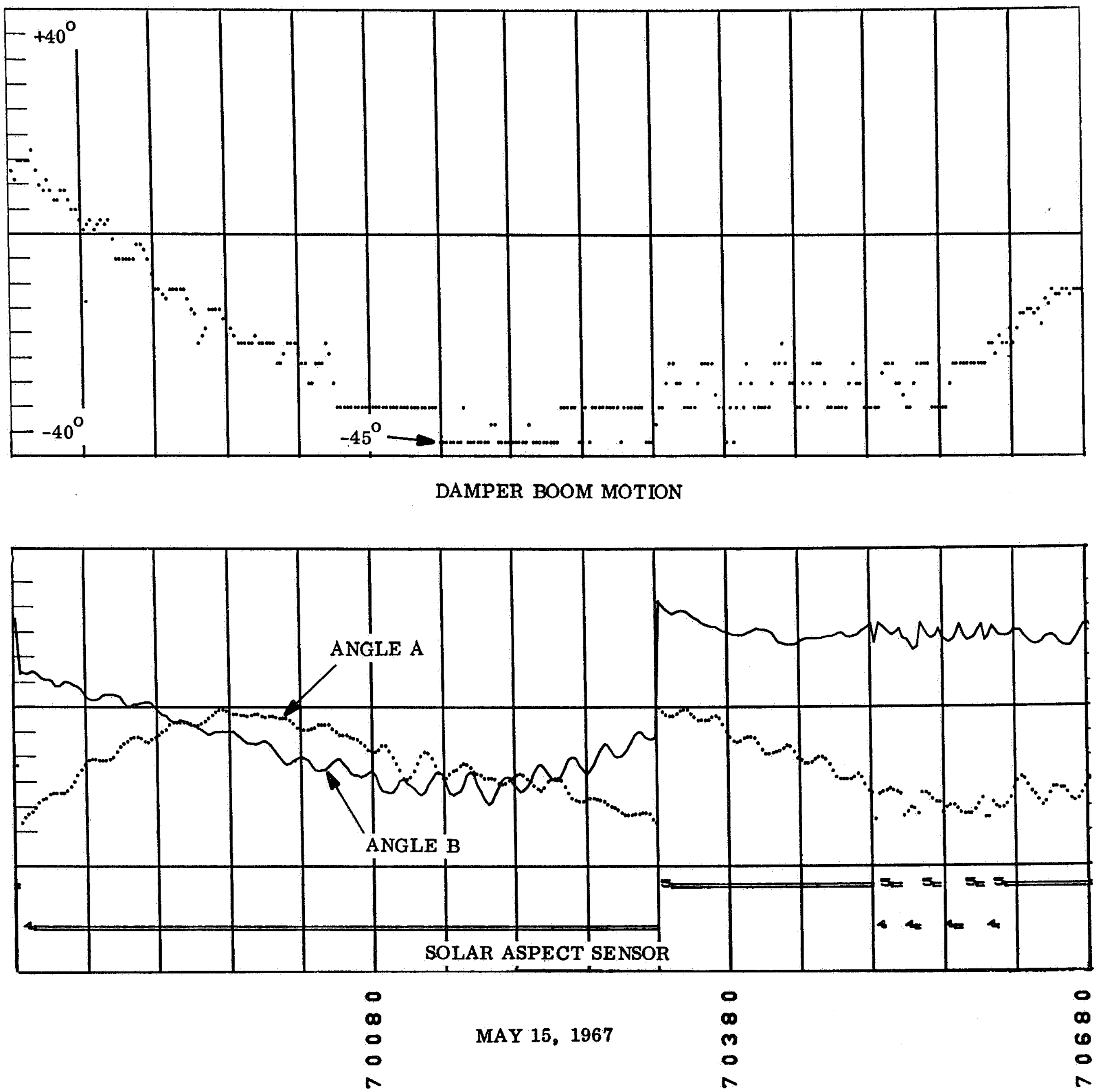

Figure 2-3. High Frequency Oscillation

2.2.4 COMPONENT PERFORMANCE

All components of the gravity gradient system have continued to perform satisfactorily, through the date of this report, with exceptions previously noted in the Eleventh Quarterly Progress Report. Actions relative to these exceptions are noted below. Updates on operating characteristics have been included in monthly inputs to the NASA Technical Data Report.

2.2.4.1 IR Earth Sensor

The sensitivity to Television Camera System turn-on has continued throughout the reporting period. Data "spikes" are observable in computer plots of IR sensor output for each TV system turn-on command. No action is contemplated relative to this phenomena for four reasons: (1) the data "spike" does not create a problem in attitude determination due to data smoothing options inherent in the GE Attitude Determination Program; (2) the TV system for ATS-D will be a modification of that used on ATS-A and will not necessarily exhibit the same sensitivities; (3) even if the same sensitivity does exist on ATS-D, the data "spikes" provide a convenient time mark for the correlation of analog data with command event data; and (4) if ATS-D achieves a nominal orbit, the frequency of TV system ON-OFF commands will be considerably reduced from that of ATS-A.

A more significant IR sensor anomaly is the indication of an earth-in-view output when the sensor is viewing cold space. By ground test, this problem has been identified as resulting from a reflection off the sensor window. Characteristics of data received at GE have been duplicated in component tests at GSFC. A decision to remove this window on ATS-D flight units has been made and the sensor is being recalibrated under conditions better approximating the actual space environment. The removal of the window will change the sensor output characteristics (due to the elimination of the associated filter) but the changed characteristics will be inherent in calibration curves provided GE for incorporation in the GE Attitude Determination Program.

2.2.4.2 Solar Aspect Sensor

The sensitivity to Television Camera System turn-on has also been observed, although less consistently, in the Solar Aspect Sensor identification code. This, together with anomalies reported in the Eleventh Quarterly Progress Report, led to a recommendation by GE for the incorporation of improved grounding and shielding techniques on Flights D and E. At the 24-25 July interface meeting at GSFC, however, the decision not to shield the SAS cables was made; the problem potential will be reexamined during system tests at Hughes. No further action is contemplated due to the fact that the anomalies are erratic and infrequent, producing only 2-1/2 hours of anomalous data in 1560 hours of operation.

2.2.4.3 Television Camera System

The only "anomaly" observed in the TV system is a hotter than anticipated temperature range on TV No. 2 electronics. This is probably due to a hotter thermal environment for that unit than had been anticipated. Since ATS-D will fly only one TV system and the thermal configuration for that unit closely resembles that of TV No. 1 on ATS-A (which has consistently operated at temperature levels within the anticipated range) no problems are anticipated for ATS-D. The deactivation of the sun shutter system due to a gravity gradient regulated power loss (experienced once on ATS-A, 9 July) is a characteristic of the system that will remain on Flights D and E. No problem is anticipated, however, under normal flight conditions and the cameras on ATS-A have demonstrated their ability to recover from a temporary degradation of no worse magnitude than occurred on 9 July.

2.2.5 ANALYSIS OF ATS-2 TELEVISION DATA

Television data taken on 20 June 1967 includes pictures of three boom tips in the field of view of Camera 1 and two boom tips in the field of view of Camera 2. Analysis of this data reveals that the third boom in the earth-pointing pictures and second boom in the sky-pointing pictures is the "missing" primary boom.

2.2.5.1 Background

On 16 May 1967, GSFC personnel reported that one of the sky-pointing primary booms was missing from the field of view of TV Camera 2. On the same day, the spacecraft tumble rate, which had consistently been below 27 degrees per minute previously, suddenly increased to 51 degrees per minute. Television data obtained from 16 May 1967 to 20 June 1967 consistently showed the boom missing from the field of view of the camera.

2.2.5.2 Discussion

During ATS-2 orbit number 510 (20 June 1967), the Rosman, North Carolina ground station recorded real-time television data on 35 mm film. Preliminary analysis of this data revealed that, for the first time since 15 May 1967, two boom tips were present in several picture sequences taken by the sky-pointing TV camera (TVCS 2). In addition, a sequence of pictures taken by the earth-pointing TV camera (TVCS 1) clearly showed three boom tips.

A detailed analysis was initiated to determine whether the "new" boom tips are those of the damper booms or of the previously "missing" primary boom. Under the existing ATS-2 orbit conditions, positive identification of any boom tip from any one TV photograph, when the boom is not visible, is difficult. The boom tip position information contained in 136 photographs was therefore transferred onto six sequence plots. Figures 2-4 through 2-9 are reconstructions of these plots drawn in reference to a fixed point (reader looking along the spacecraft-X axis) in the spacecraft coordinate system.

Sequence 1 (Figure 2-4)

Number of photographs contained:	3
Time of first photograph:	18:11:21 GMT
Time of last photograph:	18:11:26 GMT
TVCS in use:	No. 1

Both earth-pointing primary boom tips are clearly in view.

Sequence 2 (Figure 2-5)

Number of photographs contained:	16
Time of first photograph:	18:15:00 GMT
Time of last photograph:	18:16:41 GMT
TVCS in use:	No. 2

The first 9 photographs show the sky-pointing boom and primary boom tip of Assembly A. No boom tips are in view of photographs 10 through 12. Photographs 13 (18:16:26 GMT) through 16 (18:16:41 GMT) clearly show the appearance of a second boom tip. The location of the boom tip might suggest that it is that of a damper boom; however, examination of

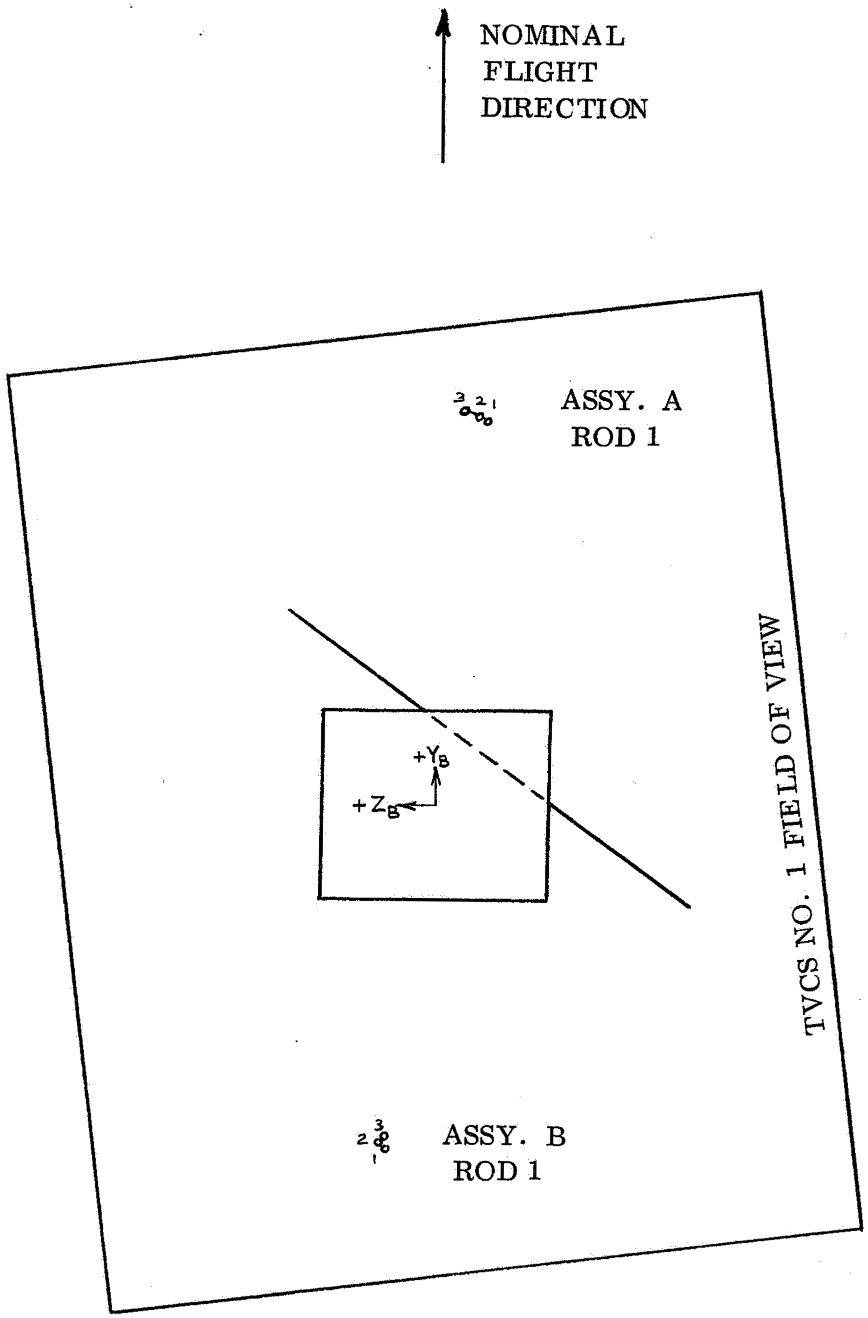

Figure 2-4. Photograph Sequence 1
(Earth-Pointing Camera)

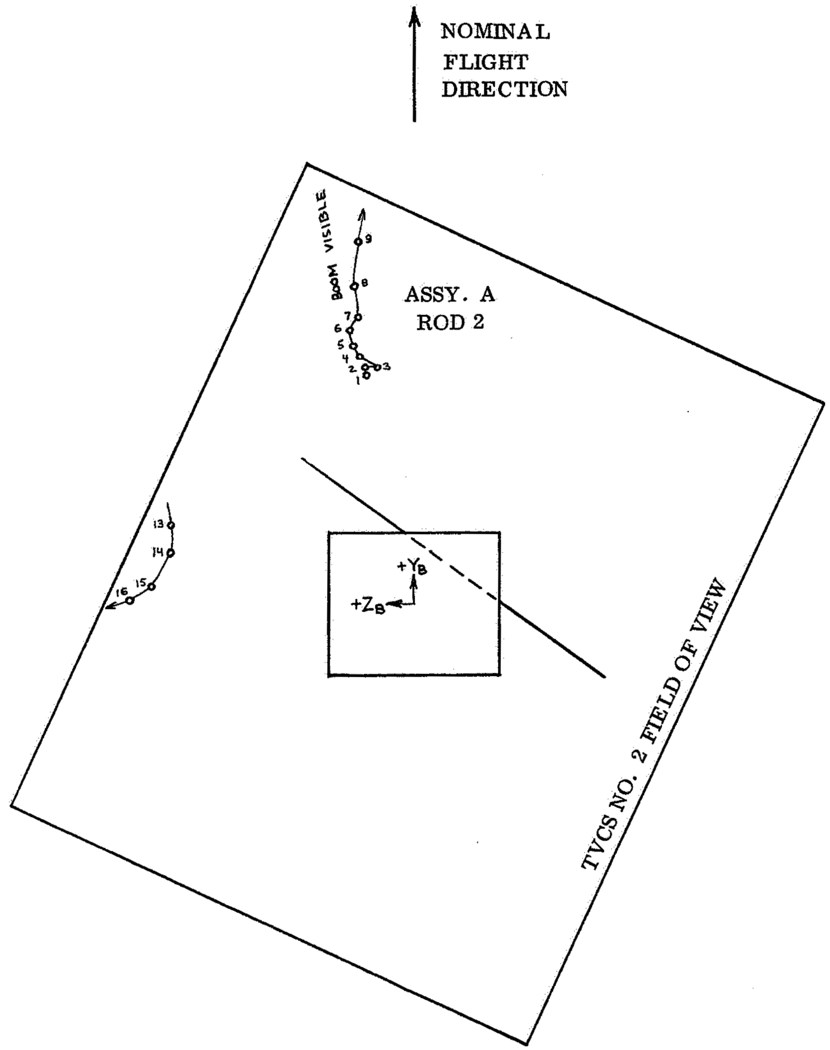

Figure 2-5. Photograph Sequence 2
(Sky-Pointing Camera)

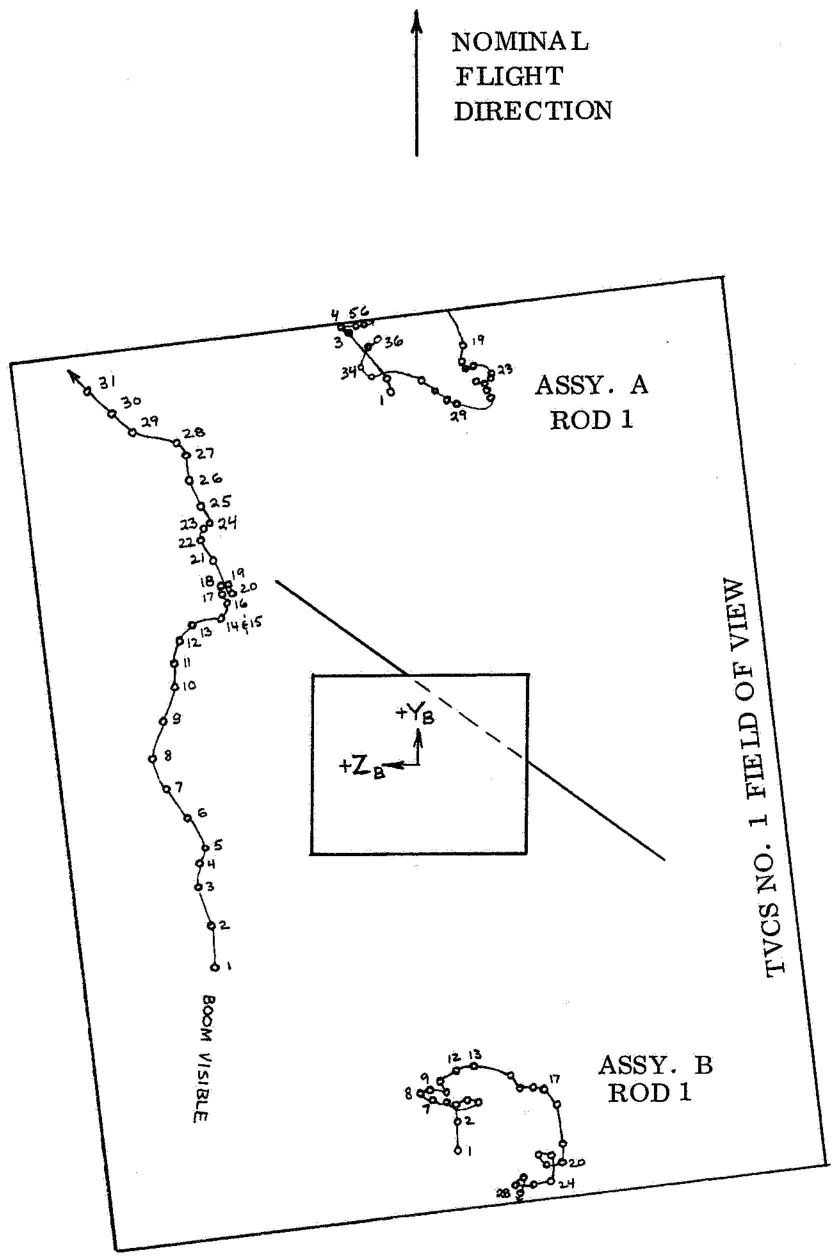

Figure 2-6. Photograph Sequence 3
(Earth-Pointing Camera)

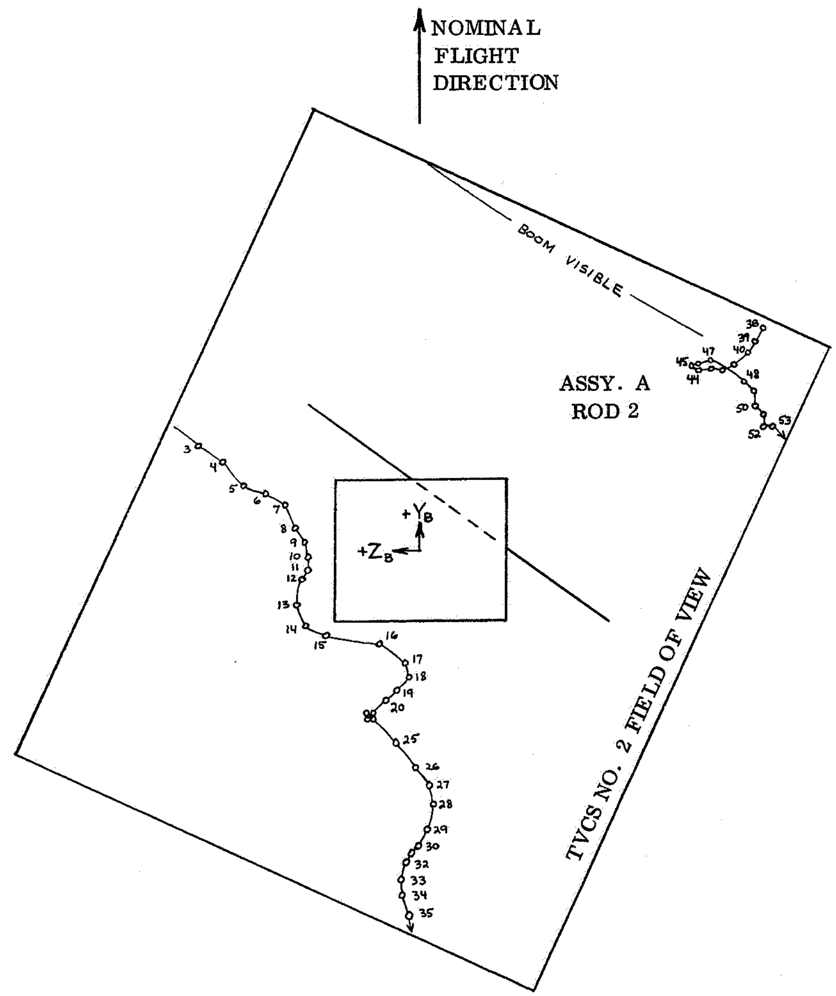

Figure 2-7. Photograph Sequence 4
(Sky-Pointing Camera)

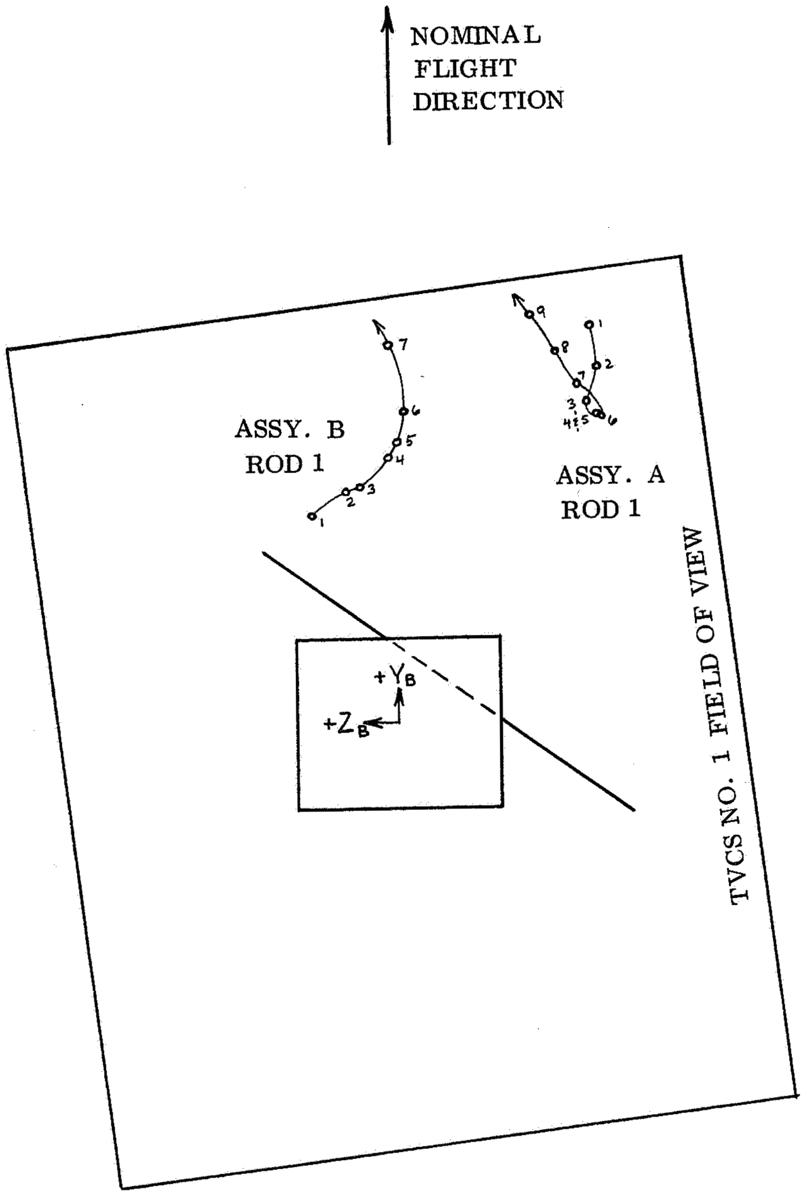

Figure 2-8. Photograph Sequence 5
(Earth-Pointing Camera)

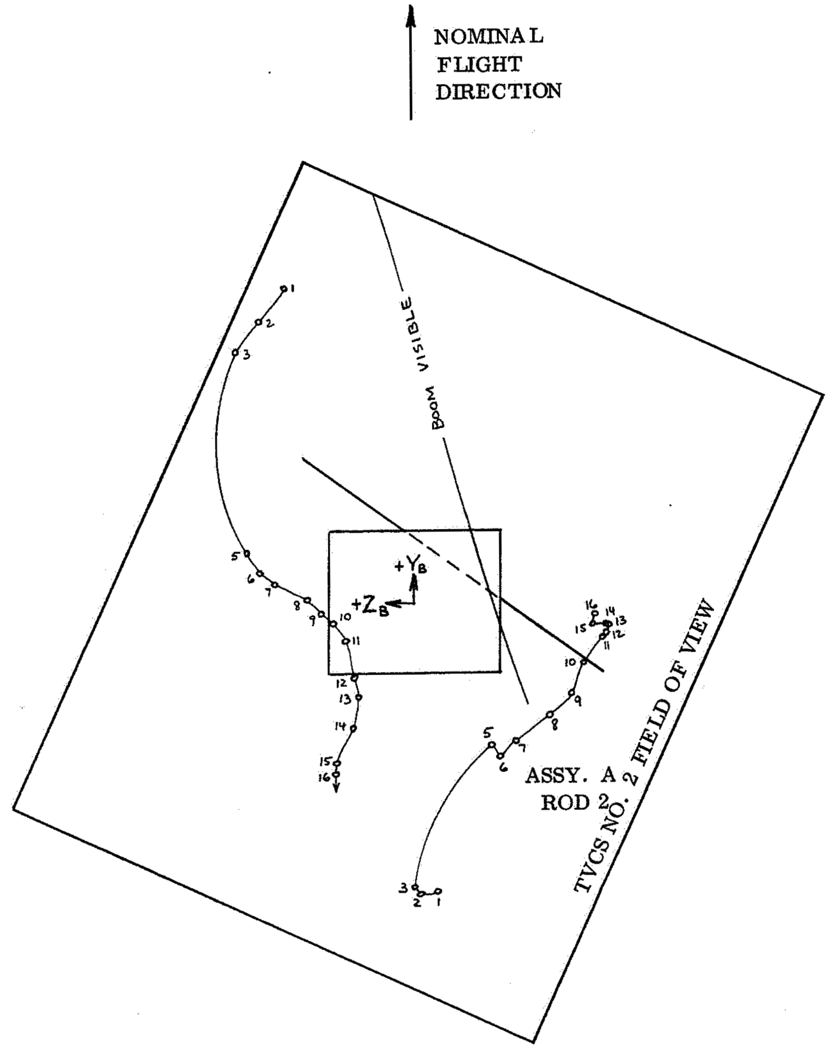

Figure 2-9. Photograph Sequence 6
(Sky-Pointing Camera)

damper boom angle data at times of the photographs shows that the damper is at $+9^o$, $+9^o$, $+7^o$, and $+5^o$, respectively (photographs 13 through 16). In order for the damper boom tip to appear in the field of view of the camera, the damper boom angle would either have to be at its maximum negative value (-45 degrees) or the damper boom would have to be damaged. The latter does not seem likely in light of the normal performance of the damper. The conclusion is, therefore, that the second boom tip is that of primary boom Assembly B.

Sequence 3 (Figure 2-6)

Number of photographs contained:	36
Time of first photograph:	18:22:14 GMT
Time of last photograph:	18:23:46 GMT
TVCS in use:	No. 1

Most of the photographs of this sequence clearly show the presence of three boom tips. The boom tips of the two earth-pointing primary booms appear at the top and bottom of Figure 2-6. The third boom tip (with boom partially visible) travels from bottom to top. Since the direction of the partially visible boom is normal to the damper boom plane and since the damper boom angle is between -30 and -6 degrees, it is concluded that the boom tip is not of the damper boom, but of the sky-pointing primary boom of Assembly B.

Sequence 4 (Figure 2-7)

Number of photographs contained:	53
Time of first photograph:	18:26:47 GMT
Time of last photograph:	18:29:23 GMT
TVCS in use:	No. 2

Photographs 3 through 35 show a boom tip traveling across the field of view. The position of the boom tip relative to the damper boom plane, and the fact that the damper boom angle is +42 degrees throughout the picture sequence, suggests that the boom tip is that of the sky-pointing primary boom of Assembly B. The sky-pointing boom and boom tip of Assembly A appear in photographs 38 through 53.

Sequence 5 (Figure 2-8)

Number of photographs contained:	12
Time of first photograph:	18:32:55 GMT
Time of last photograph:	18:33:57 GMT
TVCS in use:	No. 1

The two boom tips appearing in most of the photographs of this sequence are believed to be those of the earth-pointing primary booms.

Sequence 6 (Figure 2-9)

Number of photographs contained:	16
Time of first photograph:	18:37:02 GMT
Time of last photograph:	18:38:37 GMT
TVCS in use:	No. 2

The primary boom and boom tip of Assembly A are clearly visible in all the photographs of this sequence. The second boom tip is included to be that of the sky-pointing primary boom of Assembly B due to its position relative to the damper boom plane and the fact that the damper boom angle is between +5 and -5 degrees during this picture sequence.

Analysis of raw attitude sensor data shows the spacecraft to be tumbling about the spacecraft +Z axis at an inertial rate of 35.2 degrees per minute during the time the television data was taken. The sky-pointing primary boom of Assembly B is shown to be rotating about the spacecraft -Z axis at approximately the same rate (measured in the spacecraft body system). Although the exact failure mode of the boom cannot be determined from the data available, the fact that the boom appears in both TV camera pictures suggests that the crippling point is in close proximity of the spacecraft central body.

2.2.6 TERMINATION OF ATS-2 FLIGHT ANALYSIS

GE activities associated with the remainder of the ATS-2 flight period will be limited to the following:

a. Generation of a NASA Sun Vector Tape in response to each receipt of an RTDT (Raw Telemetry Data Tape) from GSFC; this is currently scheduled as a biweekly event.

b. Participation, at ATSOCC, in any ATS-2 gravity gradient experiments and flight analysis of resultant data when available on the RTDT from GSFC.

c. Provision of monthly letter reports on ATS-2 activities for incorporation in NASA's Technical Data Report.

d. Generation of a final ATS-2 flight analysis report after termination of ATS-2 data shipments to GE; this report will be compatible with the NASA Technical Data Report format.

The balance of the effort prior to launch of ATS-D, will be devoted to planning of flight analysis for the ATS-D post-launch period. This includes specific plans for gravity gradient orbital experiments and improvements in the efficiency of data processing and analysis.

SECTION 3
BOOM SUBSYSTEM

3.1 KEY EVENTS

13 April	S/N 12 (P-2B) Primary Boom shipped to deHavilland.
19 April	S/N 100 (P-1) Primary Boom shipped to deHavilland.
3 May	S/N 102 (F-3) Damper Boom ATP started at deHavilland.
23 May	S/N 10 (F-3A) Primary Boom ATP started at deHavilland.
26 May	S/N 10 Primary Boom (ATS-A) shipped to GE.
1 June	S/N 102 (F-3) Damper Boom shipped to GE.
15 June	S/N 100 (P-1) Primary Boom shipped to GE.
20 June	S/N 101 (F-2) Damper Boom shipped to GE.
20 June	S/N 100 (P-1) Primary Boom (ATS-D/E) Qual Test started at GE.
26 June	S/N 100 (P-1) Primary Boom shipped to deHavilland.
30 June	Dynamic Model Primary Boom (ATS-D/E) shipped to GE.
30 June	Dynamic Model Damper Boom (ATS-D/E) shipped to GE.
13 July	S/N 100 (P-1) Primary Boom shipped to GE.
14 July	S/N 100 (P-1) Primary Boom Qualification Test restarted.
19 July	S/N 100 (P-1) Primary Boom (ATS-D/E) Qualification Test completed.
27 July	S/N 10 Primary Boom shipped to deHavilland.

3.2 UNIT DESIGNATION

The serial numbers and the application of primary and damper boom units are summarized in Table 3-1.

Table 3-1. Boom System Identification

Designation		Serial No.	Use
Engineering Units			
T-1A	Primary Boom	S/N 2	Development Program
T-1B	Primary Boom	S/N 3	" "
T-1	Damper Boom	S/N 2	" "
Prototype Units			
P-1	Primary Boom	S/N 100	Component Qualification
P-2A	Primary Boom	S/N 11	System Qualification
P-2B	Primary Boom	S/N 12	System Qualification
P-1	Damper Boom	S/N 11	Component Qualification
P-2	Damper Boom	S/N 10	System Qualification
Flight Units			
F-1A	Primary Boom	S/N 102	Flight Unit, ATS-A
F-1B	Primary Boom	S/N 101	Flight Unit, ATS-A
F-1 (BU)	Primary Boom	S/N 103	Flight Unit, ATS-A
F-2A	Primary Boom	S/N 104	Flight Unit, ATS-D/E
F-2B	Primary Boom	S/N 105	Flight Unit, ATS-D/E
F-3A	Primary Boom	S/N 10	Flight Unit, ATS-D/E
F-3B	Primary Boom	S/N 103	Flight Unit, ATS-D/E
F-1	Damper Boom	S/N 100	Flight Unit, ATS-A
F-2	Damper Boom	S/N 101	Flight Unit, ATS-D/E
F-3	Damper Boom	S/N 102	Flight Unit, ATS-D/E

3.3 PRIMARY BOOMS

3.3.1 ENGINEERING UNITS

3.3.1.1 Engineering Unit T-1B (S/N3)

All testing relative to the ATS-D/E tip masses with the use of the S/N 3 Primary Boom unit was discontinued during the previous reporting period, and the unit is stored at deHavilland awaiting disposition from NASA/GSFC.

3.3.1.2 Engineering Unit T-1A (S/N2)

All planned tests using the S/N2 Primary Boom have been completed, and the unit is retained by deHavilland awaiting disposition from NASA/GSFC.

3.3.2 PROTOTYPE UNITS

3.3.2.1 Prototype Unit P-1 (S/N 100)

Prior to conducting any ATS-D/E configuration testing, a spring plate reinforcement was incorporated into the design. The basis for this reinforcement was fully discussed on pages 3-4 and 3-5 of the Eleventh Quarterly Progress Report. As a result of the S/N 3 vibration uncaging, the latching spring installation was improved and additional pinning was incorporated into the tip mass side plates and the structural wedges. As a result of the original uncaging difficulties encountered on S/N 100 (as discussed in GE Failure Analysis Report 295-E-45 and Supplements 1 and 2), the use of a tip mass uncaging support fixture became standard test equipment for the ATS-D/E Primary Booms, and tip mass kickoff springs were incorporated. During retrofit of S/N 100 to the ATS D/E configuration upon completion of the ATS-A Qualification Program, a vibration uncaging failure was experienced (GE Failure Analysis Report 311-E-51). Addition of shims between the latching spring locking insert and the tip mass side plates resulted in the completion of the vibration test, but examination revealed that the latching springs had cracked.

S/N 100 was returned to deHavilland where the unit underwent a series of reconfigurations of the latching springs and spring plate assemblies. The final configuration as submitted to the ATS-D/E Qualification Test Program, which was completed on 19 July 1967, contained integral stiffened reinforced spring plate assemblies and reconfigured latching springs with a stainless steel backing plate. The integral spring plates combined the original separate spring plates and reinforcing plates plus additional stiffening. The latching spring material was changed from stainless steel to beryllium copper and the thickness was doubled. In addition, the spring bend radius was increased to 0.125 inch, while the locking engagement width was decreased by one third (from 1.5 to 1.0 inches). The tip mass fitting procedures at deHavilland were revised to ensure that play in the tip masses, when fully caged, was virtually eliminated.

3.3.2.2 Prototype Units P-2A (S/N 11) and P-2B (S/N 12)

All planned tests involving the S/N11 and S/N12 Primary Booms have been completed. S/N11 is retained by GE awaiting disposition from NASA/GSFC. S/N12 was returned to deHavilland for retrofit to ATS-D/E and was to be utilized as a test bed. This retrofit never materialized and the unit is retained by GE awaiting disposition from NASA/GSFC.

3.3.3 FLIGHT UNITS

3.3.3.1 Flight Units F-1A (S/N102) and F-1B (S/N101)

The F-1A and F-1B units were flown in the ATS-A spacecraft. All booms from both units were successfully uncaged and deployed to full length and have been subsequently viewed by the TV cameras on board the spacecraft. Scissoring to maximum scissor angle was accomplished about one month after launch.

3.3.3.2 Flight Units (S/N10)

The S/N10 Primary Boom experienced a retraction failure, as outlined in the Tenth Quarterly Report, due to excessive loading during testing. This unit was rebuilt at deHavilland, and subsequently shipped to GE in the ATS-A configuration for possible use on an ATS-A prototype spacecraft.

3.3.3.3 Flight Unit (S/N103)

The S/N103 Primary Boom was supplied to GE as an ATS-A backup unit. While it was undergoing leak testing after welding of the enclosure cover an excessive unidirectional inward leak was discovered. After numerous unsuccessful attempts to stop this leak at GE, the unit was returned to deHavilland for a complete failure analysis and rework. The source of the leak was discovered to be at the enclosure/bellcrank housing interface weld. Improved manufacturing and leak testing techniques initiated on this unit during rework will be utilized on all subsequent units to ensure no recurrence of this failure. After rework of the discrepant weld, the S/N103 Primary Boom was subsequently received at GE as a ATS-A backup unit. The unit successfully completed the required acceptance test and is being held at GE.

3.3.3.4 Flight Units F-2A (S/N104) and F-2B (S/N105)

The S/N104 and S/N105 Primary Booms are in the manufacturing cycle at deHavilland. Upon successful completion of acceptance testing, these units will be placed in bonded storage at GE for later delivery.

3.4 DAMPER BOOM

3.4.1 ENGINEERING UNITS

3.4.1.1 Engineering Unit T-1 (S/N2)

Prior to launch of the ATS-A spacecraft, a series of simulated spacecraft damper boom deployment tests was conducted on S/N2 Damper Boom at GE to ensure that the spacecraft opening was sufficient to allow proper damper boom tip mass deployment in orbit. These tests indicated that the spacecraft opening was more than adequate for proper deployment of the ATS-A configuration damper boom, but the more pronounced tip mass rotation inherent in the ATS-D/E configuration damper boom will necessitate a modification to the tip mass which deploys through the spacecraft opening. This modification will replace the existing socket head cover mounting screws with flat head countersunk screws.

All planned tests involving the S/N2 Damper Boom have been completed, and the unit is retained by GE awaiting disposition from NASA/GSFC.

3.4.2 PROTOTYPE UNITS

3.4.2.1 Prototype Unit P-2 (S/N10)

All planned tests involving the S/N 10 Damper Boom have been completed and the unit is now being retained at GE awaiting final disposition by NASA/GSFC.

3.4.2.2 Prototype Unit (S/N11)

All planned tests involving the S/N11 Damper Boom have been completed, and it is retained by GE awaiting disposition from NASA/GSFC.

3.4.3 FLIGHT UNITS

3.4.3.1 Flight Unit F-1 (S/N100)

The S/N100 Damper Boom was installed in the ATS-A spacecraft. Both booms from this unit were successfully deployed to full length.

3.4.3.2 Flight Unit F-3 (S/N102)

The S/N102 Damper Boom has successfully completed acceptance testing at deHavilland. The unit has been placed in bonded storage at GE for later delivery. The modification to the tip mass will be incorporated prior to delivery.

3.4.3.3 Flight Unit F-2 (S/N 101)

The S/N101 Damper Boom experienced premature tip mass release during shipment to Acton Laboratories for acceptance environmental testing. Subsequent testing and inspection at deHavilland revealed no resultant damage and the unit was resubmitted for acceptance environmental testing which was completed. During the post environmental deployment test at deHavilland, hesitation and cracking anomalies were experienced (see Preliminary Failure Analysis Report 296-E-46 and Supplements 1 and 2). A complete failure analysis is in process at deHavilland but preliminary results indicate that the cracking is due to a more severe overtest than the previous configuration tests, and the hesitation is probably due to improper oscillation damping.

SECTION 4

COMBINATION PASSIVE DAMPER

4.1 STATUS OF HARDWARE

a. Flight No. 2. Unit is presently in post environmental phase of acceptance test.

b. Flight No. 3. Unit is nearing completion in final assembly.

4.2 TESTING AND TEST RESULTS

4.2.1 FLIGHT NO. 2

All tests to date have been successful. The only tests remaining are post environment damping and torsional restraint test. Results of post environment radial and axial force tests were essentially the same as pre-environment results.

4.3 VARYING TORQUE HYSTERESIS DAMPER (VTHD)

During the past quarter, the piece parts were fabricated and assembled into the VTHD's to be used on Flights ATS-D and ATS-E. The VTHD for the ATS-D Combination Passive Damper was acceptance tested successfully and installed into the CPD. The VTHD for the ATS-E flight is presently undergoing the final acceptance testing prior to installation into the CPD. This testing will be completed in early August.

The building of the VTHD's was accomplished utilizing the following parts:

The ATS-D unit was made from the TRW S/N 007 Passive Hysteresis Damper (PHD), with the discs replaced by the GE-SD design and the magnets replaced by the magnets from the TRW S/N 005 PHD (Component Qual Unit).

The ATS-E unit was made from the TRW S/N 5108 PHD, with the discs replaced by the GE-SD design and the magnets replaced by the magnets from the TRW S/N 003 PHD (Engineering Unit No. 1). These magnets were converted to prime use by first inspection, painting (to prime configuration) and reinspection. All magnet assemblies were built to the prime configuration drawings with the exception of painting.

SECTION 5

ATTITUDE SENSOR SUBSYSTEM

5.1 TV CAMERA SUBSYSTEM

The TVCS (S/N 5109) designated for use on the ATS-D flight passed the 60-day storage test and was returned to bonded storage.

The TVCS (S/N 5108) designated for use on the ATS-E flight failed the second consecutive 60-day storage test and has been returned to the IR crib storage area. The unit failed in that the peak-to-peak video signal is 1.04 volts and the maximum allowed by the specification is 1.00 volt. An attempt to get NASA buyoff is presently being negotiated, since the video level falls to about 0.96 volt peak-to-peak after 10 to 15 minutes of ON time, and also because this condition will not degrade the performance of the TVCS in flight usage. If the unit is opened for readjustment of the video signal level, it will have to be completely acceptance tested again.

5.2 SOLAR ASPECT SENSOR

The only activity on the SAS during this period has been the addition of dummy connectors which mate with test jack J8 on the SAS Electronics Units for Flights D and E. J8 is used only for ground testing and has no flight function. To preclude the possibility of some metallic fragments entering the connector and shorting pins, a mating connector is being added. This dummy plug has no wires. The well at the rear of the connector will be filled with potting compound and the connector fastened to J8 with the integral locking screws. When use of J8 is no longer required for ground testing, the screws will be permanently set with Locktite.

SECTION 6

GROUND TESTING

After launch of the ATS-A (ATS-2) in April, the GE ground testing activities were temporarily discontinued. GE will resume this responsibility as the date for launch of the ATS-D approaches, and progress will be reported in this section. In the meantime, flight equipment for the ATS gravity gradient stabilization systems is retained in bonded storage at GE and checked out on a regular basis in accordance with a prescribed plan that ensures their readiness for delivery.

SECTION 7
QUALITY CONTROL

7.1 GENERAL

The Quarterly Product Assurance Audit Report for the second quarter of 1967 was completed and delivered to the ATS Program Manager.

Component qualification test reports on Damper Booms Flight A, D, and E and Primary Booms Flight A were reviewed and accepted by NASA during the period.

Four items of GE test equipment were recalibrated at HAC. A letter has been sent to NASA requesting copies of the calibration records in order that the GE master files can be updated. A visit to HAC was made by Vendor Quality Assurance to ensure that the GE test equipment is properly stored while awaiting future ATS flight testing.

Monthly inspection of ATS components in storage is taking place on a regular schedule. This inspection verifies proper packaging and that the components are free from the effects of humidity.

7.2 PRIMARY BOOMS

QCE Test Report 4315-QC-027, pertaining to the qualification test of Primary Boom S/N100 was issued. The unit passed qualification testing to the requirements of Flight ATS-A. A detailed discussion of primary and damper boom testing is included in Section 3. Continuous Surveillance Inspection is taking place at deHavilland.

Supplement 1 to Failure Analysis Report 299-E-49 was issued pertaing to takeup mechanism problems experienced during extension tests of S/N 103. This report is now complete.

Supplement 2 to Failure Analysis Report 269-E-33 pertaining to Primary Boom S/N 10 was issued. This report is now complete.

Failure Analysis Report 300-E-50 pertaining to shorting problems that occurred during systems test at HAC on Primary Boom S/N 11 was issued. This report is now completed.

Supplement 1 Failure Analysis Report 264-E-30 pertaining to qualification failures on S/N 100 was issued. The report is now complete.

Supplement 1 to Failure Analysis Report 292-E-43 was issued pertaining to problems encountered on S/N 12 after systems test. The report is now complete.

Supplement 1 to Failure Analysis Report 295-E-45 pertaining to problems on S/N 100 was issued. This is a continuing report pending corrective action.

Failure Analysis Report 311-E-51 pertaining to vibration failures on Primary Boom S/N 100 was issued. This is a continuing report.

Failure Analysis Report 316-E-52 pertaining to extension problems on S/N 100 was issued.

7.3 DAMPER BOOMS

QCE Test Report 4315-QC-031 pertaining to qualification test of S/N 11 was issued.

Acceptance testing of Damper Booms S/N 101 and 102 was completed.

Supplement 1 to Failure Analysis Report 279-E-38 pertaining to problems encountered during test of Damper Boom S/N 11 was issued. The report is now complete.

Supplements 1 and 2 to Failure Analysis Report 296-E-46 pertaining to problems encountered at deHavilland on S/N 101 was issued. This report is now complete.

7.4 COMBINATION PASSIVE DAMPER

Acceptance test of Flight No. 2 Variable Torque Hysteresis Damper (VTHD) was completed and installed in the CPD. Assembly of the CPD was completed and the unit is now in acceptance test.

CPD SI 237016 was revised to include VTHD testing and to improve test procedures.

7.5. TELEVISION CAMERA SYSTEM

Sixty-day shelf life tests were conducted on S/N 5108 and 5109. QCE Test Reports 4315-QC-034 and 4315-QC-037 were issued.

Supplement 1 to Failure Analysis Report 293-E-44 pertaining to original acceptance test problems on S/N 5109 was issued.

SECTION 8

MATERIALS AND PROCESSES

The materials quality assurance work involved inspection coding of two material requests, the completion of 11 materials acceptance/process control testing jobs, and the recommended disposition of four materials by the noncomplying Materials Review Team.

SECTION 9
MANUFACTURING

Technical support was provided by the Manufacturing operation during assembly and test of the ATS gravity gradient stabilization system. The manufacturing status of the system is summarized as follows:

a. Prototype 1

Fabrication of all units comprising the Prototype 1 system is completed. The primary boom unit was converted to the ATS-D/E configuration and is now undergoing tests to this design at GE.

b. Prototype 2

Fabrication of all components is complete.

c. Flight Units

1. Flight 1 - This hardware was launched onboard the ATS-A, 5 April 1967.

2. Flight 2 - SAS, TV Camera, and PCU are complete and in bonded storage at GE. The variable torque hysteresis damper was installed in the CPD and the unit is undergoing acceptance tests. Damper Boom (S/N 102) was accepted and stored at GE. See Section 3 for details of the primary and damper boom progress.

3. Flight 3 - SAS, TV Camera, and PCU are complete and stored at GE. Assembly of the CPD was completed up to the point of installation of the variable torque hysteresis damper; assembly will be completed upon completion of VTHD tests now in progress. Primary and damper booms are undergoing acceptance tests as described in Section 3.

d. AGE

Fabrication of all AGE has been completed.

e. Test Equipment

Fabrication of all test equipment is complete.

f. Bonded Storage

Formulation of plans are continuing for inventory disposition of the ATS flight equipment that is in bonded storage at GE.

SECTION 10

NEW TECHNOLOGIES

There are no new technologies to report for the quarter. Efforts to monitor the analytical and developmental areas will continue, and resulting new technologies will be reported in future reports.

SECTION 11

GLOSSARY

The following is a list of abbreviations and definitions for terms used throughout this report:

ADTF	Advanced Damping Test Fixture (used for CPD testing)
ATS-A	Medium Altitude Gravity Gradient Experiment (6000-nautical mile orbit flight)
ATS-D/E	Synchronous Altitude Gravity Gradient Experiment (24-hour orbit flight)
CPD	Combination Passive Damper
Crab Angle	Out-of-orbit angle flight caused by changes in X-rod angle
DME	Dynamic Mission Equivalent (Accelerated Functional Program)
GE-MSD	General Electric Company Missile and Space Division
GGS/ATS	Gravity Gradient System/Applications Technology Satellite
HAC	Hughes Aircraft Company
ITPB	Integrated Test Program Board
Local Vertical	Imaginary line extending from the satellite center of mass to the center of mass of the earth
LOFF	Low Order Force Fixture (used for CPD testing)
MTBF	Mean Time Before Failure
MTTF	Mean Time to Failure
PCU	Power Control Unit
PIR	Program Information Request/Release, GE documentation
SAS	Solar Aspect Sensor
Scissoring	Changing the angle included between the primary booms in a manner that maintains a symmetrical configuration about the satellite yaw axis
STEM	Storable Tubular Extendable Member
Stiction Torque	That amount of torque required to overcome the initial effects of friction
SVA Fixture	Shock and Vibration Attachment Fixture
Thermal Twang	Sudden thermal bending which the booms experience in passing from a region of total eclipse into a region of continuous sunlight or vice versa
TR	Torsional restraint
TVCS	TV Camera Subsystem
VTHD	Varying Torque Hysteresis Damper