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17 November 1980

CO-ALIGNMENT SYSTEM (CAS) STUDY

FINAL REPORT ON TASK 1-3

Prepared For

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

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Ball Aerospace Systems Division

BOULDER, COLORADO 80306

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FINAL REPORT
ON
TASKS 1-3

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APPENDIX

FOREWORD

This study was performed by Ball Aerospace Systems Division (BASD), Boulder, Colorado for Goddard Space Flight Center (GSFC) under Contract NAS5-26243. Questions concerning its content may be addressed to GSFC Technical Officer, Mr. Milt Kalet (301/344-5247) or to the BASD CAS Study Manager, Mr. Neal Anderson (303/441-4258).

Section 1
SUMMARY/RECOMMENDED CAS CONFIGURATION

This section briefly summarizes the conclusions of the study and describes the recommended CAS configuration.

1.1 SUMMARY

A summary of BASD's study conclusions are presented in Table 1-1. These conclusions were used to derive the recommended SEUTS CAS configuration.

1.2 RECOMMENDED SEUTS CAS CONFIGURATION

To meet the stated SEUTS requirements, BASD recommends a CAS system which utilizes a sun sensor. The SMM Fine Position Sun Sensor (FPSS) meets all of the requirements except that its linear range is only ±0.5 deg. It is useable to ±1.0 deg.; however, it is no longer linear after 0.5 deg. and therefore would require use of more complex calibration curves.

1.2.1 Structural Configuration

The recommended structural configuration is shown in Figure 1-1. While an 8-inch duplex azimuth gimbal is shown, it is highly desirable to increase this gimbal to 14 inches to provide added margin, insure "quiet-running," and make the overall system more suitable for other payloads.

1.2.2 Actuator

The existing UVSP actuator is suitable except for a minor modification to lengthen the case for greater travel. The ball screw does not need to be replaced for SEUTS.

1.2.3 Sensors

The SMM FPSS is recommended to provide direct readout of position relative to the sun. Direct readout of solar position eliminates the large potential

TABLE 1-1

SEUTS CAS STUDY CONCLUSIONS

STRUCTURAL

- NEITHER THE UVSP OR C/P EXISTING STRUCTURAL DESIGNS IS ADEQUATE FOR SEUTS DUE TO:
  --NATURAL FREQUENCY,
  --LOADS, AND
  --CONFIGURATION PROBLEMS.
- AN ALTERNATE STRUCTURAL CONFIGURATION THAT SATISFIES THE SEUTS REQUIREMENTS WITH LARGE MARGINS IS FEASIBLE.
- AN INCREASE IN THE AZIMUTH BEARING FROM 8 TO 14 INCHES IS DESIRABLE.
- THE EXISTING ACTUATOR DESIGN IS ADEQUATE FROM A LOADS CONSIDERATION.

ACTUATORS

- THE EXISTING UVSP AND C/P ACTUATOR MUST BE LENGTHENED TO PROVIDE ± 1.0 DEG TRAVEL.
- NO OTHER MODS ARE NECESSARY FOR SEUTS.

TABLE 1-1
SEUTS CAS STUDY CONCLUSIONS (CONTINUED)

SENSORS

- A POTENTIOMETER ONLY SYSTEM IS MARGINAL, EVEN IF A BETTER POTENTIOMETER IS USED.
- A POTENTIOMETER ONLY SYSTEM CANNOT CORRECT FOR IPS SUN SENSOR TO SEUTS LAUNCH INDUCED ERRORS OR FOR CAS CROSS-COUPLING ERRORS.
- A SUN SENSOR SYSTEM IS NEEDED TO ACHIEVE THE DESIRED REQUIREMENTS.
- ANY SYSTEM WILL REQUIRE CALIBRATION TO ACHIEVE THE DESIRED REQUIREMENTS.

ELECTRONICS

- THE UVSP ELECTRONICS ARE DIRECTLY USEABLE FOR A POTENTIOMETER ONLY SYSTEM; HOWEVER, SOME MINOR MODS ARE DESIRABLE TO BETTER CONTROL TEMPERATURE AND LOAD INDUCED FLUCTUATIONS.
- THE UVSP ELECTRONICS ARE ALSO RECOMMENDED FOR A SUN SENSOR SYSTEM. SOME SENSOR INPUT RELATED MODS ARE REQUIRED; HOWEVER, THEY ARE LESS THAN THE MODS AND REPACKAGING NEEDED FOR THE C/P ELECTRONICS.

TABLE 1-1

SEUTS CAS STUDY CONCLUSIONS (CONTINUED)

OVERALL

- WHILE A BASEPLATE/GIMBAL SYSTEM REDESIGN IS REQUIRED, THE OTHER EXISTING CAS COMPONENTS CAN BE USED WITH ONLY MINOR MODS.

SEUTS WITH RECOMMENDED CAS DESIGN

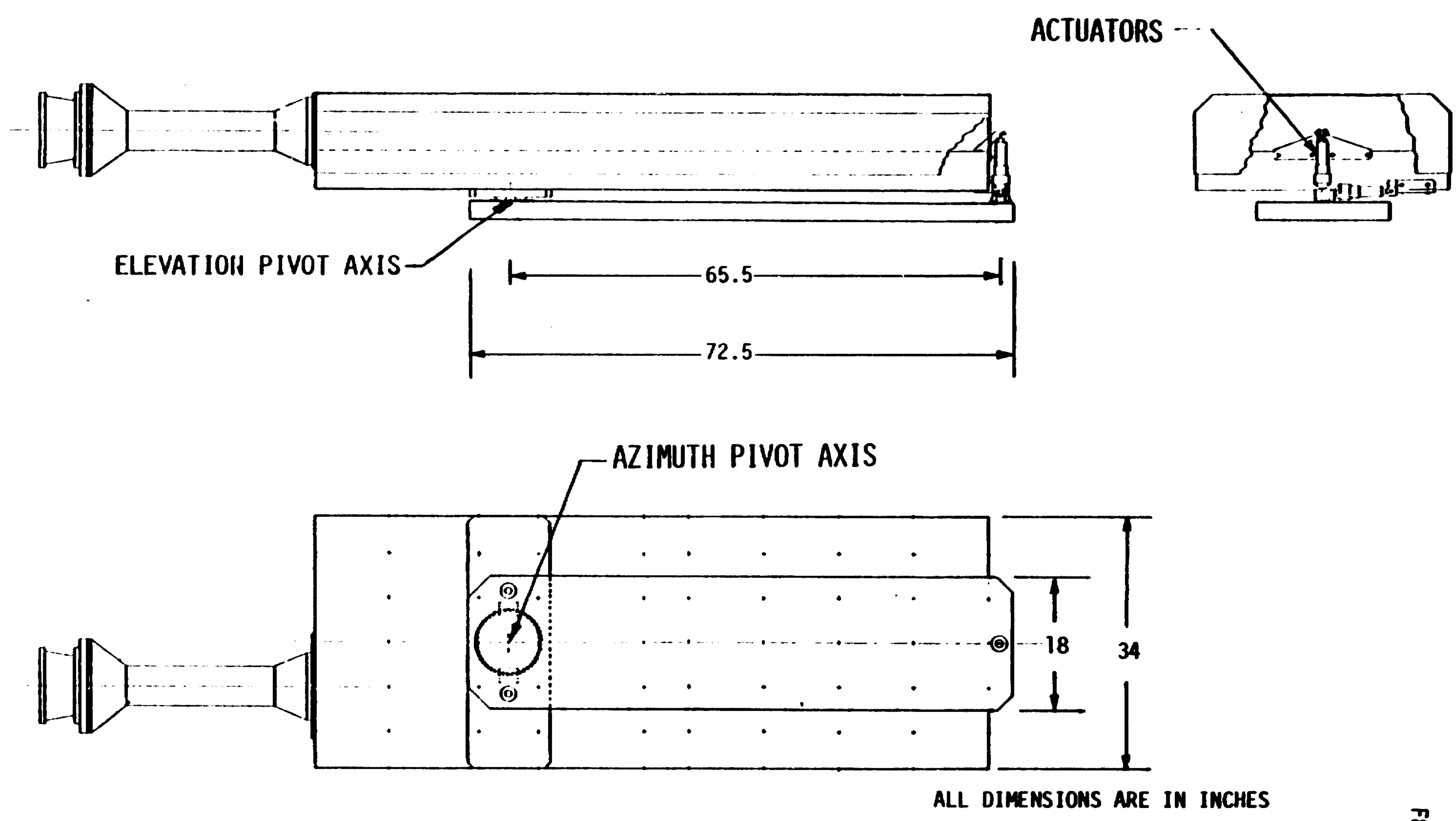

FIG. 1-1

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errors associated with launch induced misalignments and CAS cross coupling. While not essential, it would be desireable to retain the potentiometers for telemetry readout.

1.2.4 Electronics

The UVSP electronics are recommended. They are already separately packaged and they utilize a 12 bit (16-bit total) command word. The sensor input electronics would be modified to accept ±10V inputs of a sun sensor versus the 0-10V input from the potentiometers.

1.2.5 Overall Performance

The expected overall system CAS performance is presented in Tables 1-2 and 1-3 respectively.

TABLE 1-2

OFFSET PERFORMANCE USING THE SMM FPSS

ITEM	REQUIREMENT	RECOMMENDED CONFIGURATION	COMMENT
• ACCURACY	10 SEC	8-12 SEC	CAN BE REDUCED BY UPGRADING V_{REF} SOURCE
• OFFSET STEP CAPABILITY	2 SEC	1.5-1.8 SEC	
• RANGE	±0.5 DEG (REQ'D) ±1.0 DEG (GOAL)	±0.5 DEG LINEAR RANGE ±1.0 DEG AVAILABLE	
• MANUAL STEP	2 SEC	8 SEC AVG	25 THREAD/IN LEAD SCREW REQUIRED TO ACHIEVE 2 SEC
• RATE OF MOVEMENT	20 SEC IN 2 SEC GOAL	BETTER THAN REQM'T	
• REPEATABILITY	NOT SPECIFIED 4 SEC ASSUMED GOAL	2-3 SEC	

TABLE 1-3

OVERALL POINTING ERRORS - SMM FPSS SYSTEM

SOURCE	POSSIBLE ERROR (SEC)	COMMENT
• IPS SUN SENSOR	N/A	USED ONLY FOR "COARSE" CONTROL.
• MECHANICAL MISALIGNMENT	N/A	ELIMINATED BY SEUTS MOUNTED SUN SENSOR.
• CAS OFFSET ACCURACY		
--TEMPERATURE (10°C)	7-10	COULD BE CALIBRATED IF SYSTEM WAS THERMALLY TESTED.
--SUN SENSOR ACCURACY	2-5	ASSUMES CALIBRATION--PROBABLY NOT LINEAR.
--VOLTAGE REGULATION	3	RANDOM
--CROSS COUPLING	N/A	ELIMINATED BY SEUTS MOUNTED SENSOR.
--SUN SENSOR ALIGNMENT	1	
RSS	8-12	
• SEUTS INTERNAL		
--LAUNCHED INDUCED	TBD	
--THERMAL	TBD	

Section 2
INTRODUCTION

2.1 STUDY OBJECTIVES

The overall objective of the study was to identify a suitable Co-Alignment System (CAS) for the Solar Extreme Ultraviolet Telescope and Spectrometer (SEUTS). SEUTS is planned for flight on a Spacelab mission or, potentially, on a Solar Optical Telescope (SOT) mission. In either case, SEUTS would be one of a number of instruments mounted on a single large pointing system such as the Instrument Pointing System (IPS).

While IPS is a large, highly flexible system, it has inherent limitations. It can only point in one direction at a time. When multiple payloads are mounted on IPS, they must either accept this one pointing direction or provide their own offset capabilities to maximize observing time. In this sense IPS is very similiar to the Solar Maximum Mission (SMM) spacecraft. SMM normally pointed at the center of the sun. The individual instruments had to provide their own offset adjustment systems.

BASD provided two versions of co-alignment systems (offset adjustment systems) for the SMM instruments. The specific objectives of this study are to determine whether these existing designs are suitable for the SEUTS configuration and requirements. If these existing designs were not suitable, the necessary modifications were to be identified.

2.2 STUDY PHILOSOPHY

To satisfy these objectives, every effort was made to provide GSFC with insight into the cost and complexity trade-offs. Starting with a definition of the existing system capabilities, parametric data and a range of possible modifications were developed. While detailed cost estimates were not prepared as part of this study, cost drivers were identified. The end result of the study was to be a recommended SEUTS CAS configuration which represents a reasonable balance between cost and performance.

2.3 STUDY TASKS

Study Tasks 1, 2, and 3 were associated with the SEUTS instrument and are presented in this final report. Task 4, an added task, was associated with the SLAC/WLC instrument and is reported in a separate final report.

The study tasks were specified in the contract statement of work. Table 2-1 summarizes the study tasks and sub tasks.

Table 2-1
CAS STUDY TASKS

TASK 1: STRUCTURAL ASSESSMENT

- Examine natural frequencies of SEUTS/CAS.
- Estimate launch loads.
- Identify need for launch locks.
- Evaluate use of SMM Kinematic Mounting System.
- Assess use of cruciform and SOT structures.
- Identify any modifications required.

TASK 2: STUDY OF OFFSET CAPABILITIES

- Assess CAS capabilities versus SEUTS requirements.
- Address repeatability of points and sequences.
- Estimate momentum transferred by CAS/SEUTS to other payloads.
- Estimate CAS power requirements.
- Identify interfaces.
- Assess possible sources of jitter/drift.
- Identify any modifications required.

TASK 3: STUDY OF CLOSED LOOP CAPABILITIES

- Assess feasibility of using CAS in a closed loop mode.
- Estimate CAS power requirements.
- Identify interfaces.
- Assess time constant/settling time for small deviations at high frequency.
- Identify any modifications required.

Section 3
SEUTS DESCRIPTION/REQUIREMENTS

This section describes the SEUTS configuration, requirements, typical operations, and pointing/offset adjustment interfaces with other systems.

3.1 SEUTS CONFIGURATION

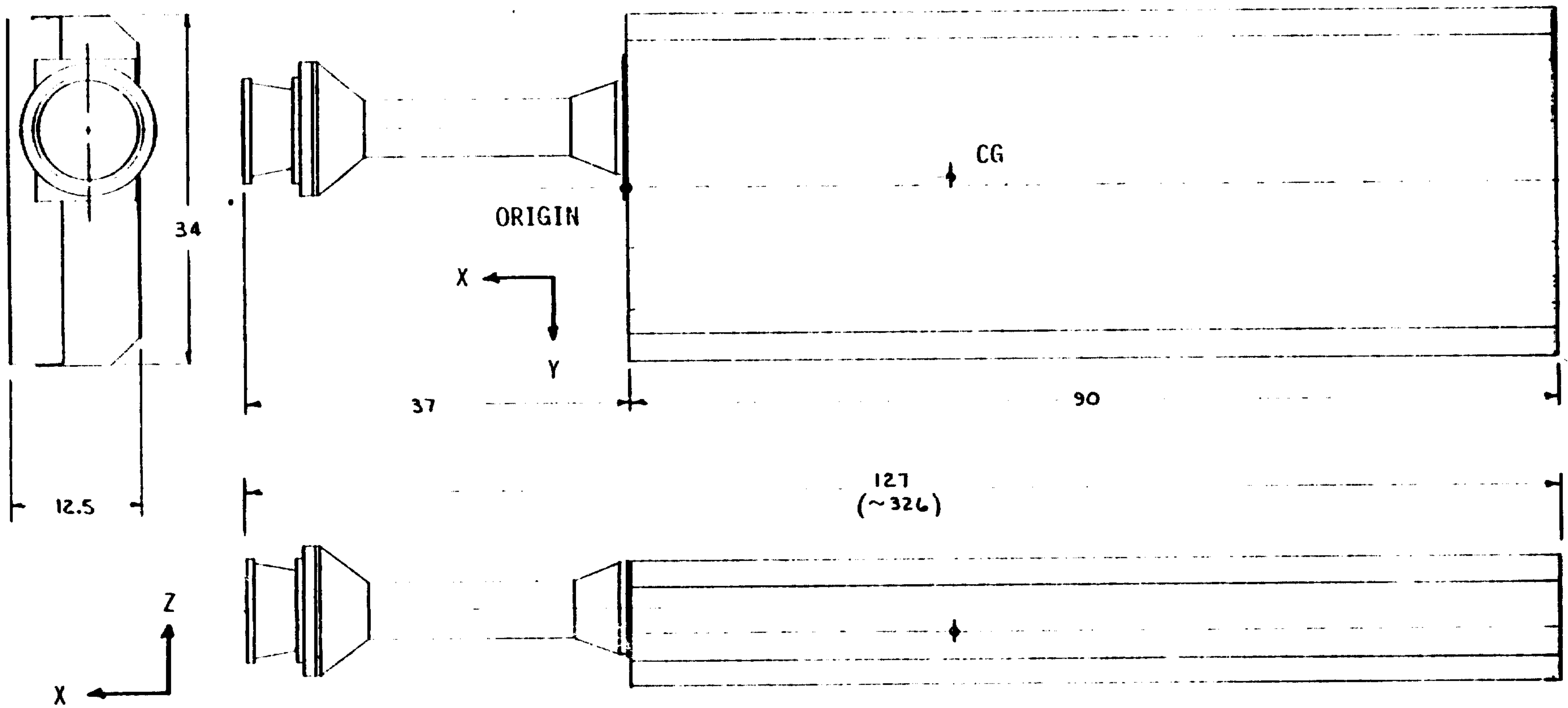
The external physical configuration of the SEUTS instrument is shown in Figure 3-1. A thermal cover was added to the instrument baseplate drawing provided by GSFC. The center of gravity shown on this sketch was based upon the GSFC instrument model except for the Z-Axis position. Since the model did not provide a Z-Axis coordinate for the CG, BASD estimated that it would be at the top of the instrument baseplate.

3.2 SEUTS REQUIREMENTS

A comparison of the SEUTS mechanical requirements versus those of the SMM Ultraviolet Spectrometer Polarimeter and Coronagraph Polarimeter is provided in Table 3-1. As can be seen, the SEUTS instrument is substantially larger and heavier than either of the previous two instruments supported with CAS's. This situation necessitated the careful review of various structural considerations in Task 1.

The SEUTS offset adjustment requirements are presented in Table 3-2 and similarly compared to the UVSP and C/P requirements. Of particular importance is the SEUTS requirement of 2 arc sec offset steps within a 0.5 x 0.5 deg field (1.0 x 1.0 deg field desired) about the sun center. Although not included in this table, repeatability is also a parameter important to SEUTS. For the purpose of this study, BASD assumed that repeatability to within ±4 arc sec for following sequences was desirable. It should be noted that such a ±4 arc sec requirement for repeatability implies that random component of overall pointing accuracy be a similar value.

SEUTS CONFIGURATION



CG: X = -28.4 in.
Y = -1.01 in.
Z = 5.25 in.

FIGURE 3-1

CAS STUDY

TABLE 3-1

COMPARISON OF UVSP, C/P, SEUTS REQUIREMENTS

MECHANICAL

ITEM	UVSP	C/P	SEUTS
INSTRUMENT			
SIZE (IN.)	62 x 16 x 7	96 x 8 x 23	127 x 34 x 13
WT. (LB.)	163	98 + 24 LBS OF ELECTRONICS ON CAS BASEPLATE	267
Ixx $LB - IN^2$ ABOUT C.G.	4794	2984	Ixx = 23,507*
IYY	38147	57660	Izz = 334,223*
Izz	41486	61156	IYY = 310,716*
CG ABOVE INST. BASE	~7.3 INCHES	~8.7 INCHES	~5.25 INCHES
CAS			
WT. (LB.)	96 INCL. 13 ELECT.	41.9 (ELECTRONICS INCL. ABOVE)	TBD
ACTUATORS			
TYPE	TORQUE MOTOR DRIVEN BALL SCREW	TORQUE MOTOR DRIVEN BALL SCREW	TORQUE MOTOR DRIVEN BALL SCREW
FORCE (LB.)	70	70	70
NATURAL FREQUENCY (COMBINED) H_Z	40	37	> 35 REQUIRED

*DERIVED FROM SEUTS MODEL PROVIDED BY GSFC.

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TABLE 3-2

COMPARISON OF UVSP, C/P, SEUTS REQUIREMENTS

OFFSET ADJUSTMENTS

ITEM	UVSP	C/P	SEUTS
1. OPERATING MODES	AUTOMATIC MODE: CLOSED LOOP SERVO SENSES POSITION RELATIVE TO CAS BASE PLATE MANUAL MODE: CAS IS MOVABLE IN SINGLE STEPS	AUTOMATIC MODE: CLOSED LOOP SERVO SENSES POSI- RELATIVE TO SUN CENTER MANUAL MODE: NONE	AUTOMATIC MODES: CLOSED LOOP OFFSETS OR CLOSED LOOP CONTINUOUS ADJUSTMENT MANUAL MODE: 2 ARC SEC STEPS
2. INSTRUMENT POINTING ACCURACY	10 $\widehat{\text{SEC}}$	10 $\widehat{\text{SEC}}$	10 $\widehat{\text{SEC}}$
3. OFFSET POINTING CAPABILITY	OFFSETABLE IN 15 $\widehat{\text{SEC}}$ INCREMENTS WITHIN 2.5 x 2.5 DEGREE FIELD ABOUT MECHANICAL CENTER	OFFSETABLE IN 5 $\widehat{\text{SEC}}$ INCREMENTS WITHIN 5.3 x 5.3 $\widehat{\text{MIN}}$ FIELD ABOUT SUN CENTER	OFFSETABLE IN 2 SEC INCREMENTS WITHIN A 1.0 x 1.0 DEGREE FIELD ABOUT SUN CENTER
4. NUMBER OF AXES IN WHICH MOVEMENT OCCURS	2	2	2

CAS STUDY

TABLE 3-2 (CONT.)

COMPARISON OF UVSP, C/P, SUETS REQUIREMENTS (CONTINUED)

OFFSET ADJUSTMENTS

ITEM	UVSP	C/P	SEUTS
5. RANGE OF MOVEMENT	>2 DEGREES	>1 DEGREE	±0.5 DEG. REQUIRED ±1.0 DEG. GOAL
6. RATE OF MOVEMENT	200 $\widehat{SEC}$ IN LESS THAN 30 SECONDS	0.5 DEGREES IN LESS THAN 30 SECONDS	20 $\widehat{SEC}$ IN 2 SEC AS A GOAL
7. AUTOMATIC SOLAR ALIGNMENT	NONE	POINTS WITHIN 10 $\widehat{SEC}$ OF SUN CENTER OR PRE-SELECTED OFFSET	POINT WITHIN 10 $\widehat{SEC}$ OF SUN CENTER OR PRE-SELECTED OFFSET
8. POSITION SENSOR TYPE	TWO POTENTIOMETERS GIVE POSITION RELATIVE TO CAS BASEPLATE	FOUR PHOTOVOLTAIC CELLS GIVE POSITION RELATIVE TO SUN CENTER	POTENTIOMETERS, SUN SENSORS
9. MANUAL STEP CAPABILITY	MANUAL STEPS OF 20-50 $\widehat{SEC}$	NONE	2 $\widehat{SEC}$ STEPS

It should also be noted that both the repeatability and overall pointing accuracy requirements apply only to the contribution by CAS. For an instrument pointed by IPS, a number of pointing error sources exist. These error sources and a gross estimate of their magnitude are discussed in Section 6.0. The net result of these overall error sources is that the SEUTS optical line of sight could easily be pointed many 10's of arc sec from the intended line of sight. In a system in which offset adjustments are made by sensing the CAS baseplate positions (Task 2) this overall error cannot be removed. However, in systems which rely upon an independent sun sensor mounted on the SEUTS instrument (Task 3) most of these errors can be eliminated.

Throughout the study it was recognized that the requirements discussed in this section were preliminary and to be used as a starting point. GSFC intends to review the results of this study and assess the ultimate costs before firmly specifying the final design requirements for a CAS.

3.3 TYPICAL SEUTS OPERATIONS

SEUTS will use a number of different modes during its operations. These modes define various entrance slit options (reference Figure 3-2). They also tend to define types of SEUTS/CAS operations. Figure 3-3 superimposed the fields of views for these different slit options on a typical active region. During the wide field mode the entire region is observed. In the narrow spectro heliograph and line profile modes the fields of view must be stepped across the region.

3.4 SPACELAB/IPS/SEUTS/CAS POINTING INTERFACES

To provide the pointing and offset adjustments desired by SEUTS a wide variety of hardware and software systems are involved. While the definition of interfaces between all these systems was not part of this study, a top-level understanding is appropriate.

Figure 3-4 identifies these top-level interfaces. For CAS to execute the appropriate offset commands pointing information must be passed from the

SEUTS OBSERVING MODES

ENTRANCE SLIT OPTIONS

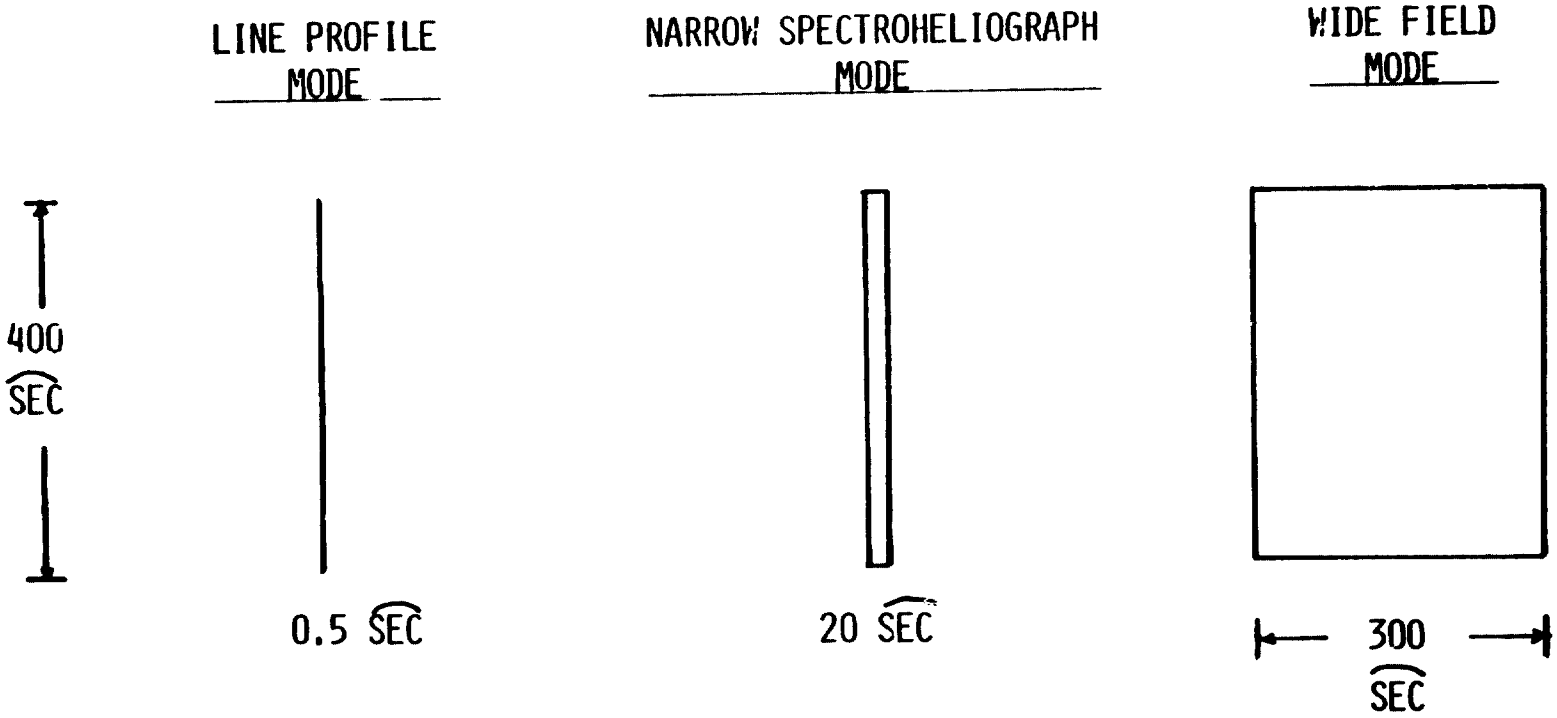

FIG. 3-2

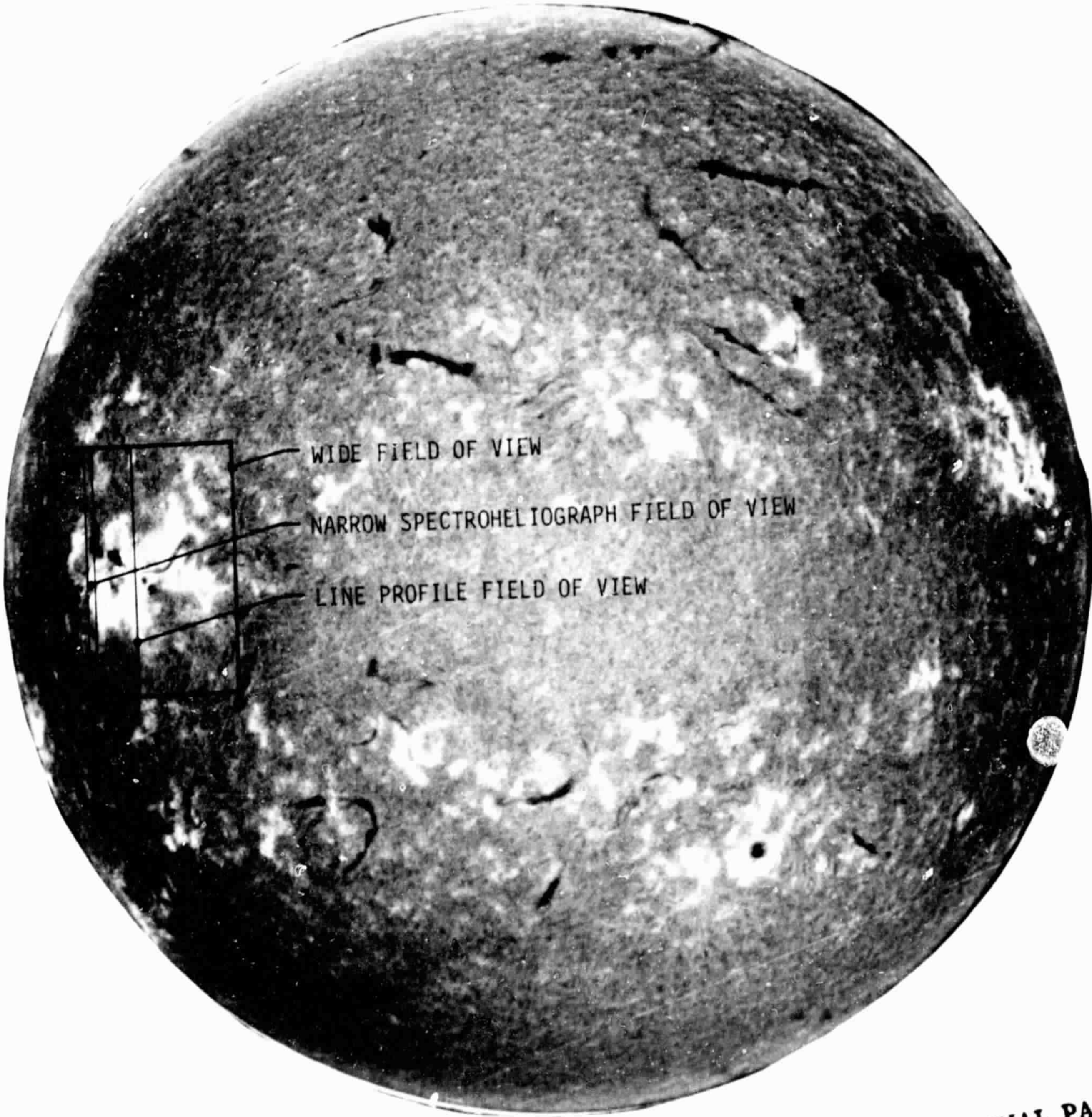

Figure 3-3 SEUTS Fields of View

SPACELAB/IPS/SEUTS/CAS POINTING INTERFACES

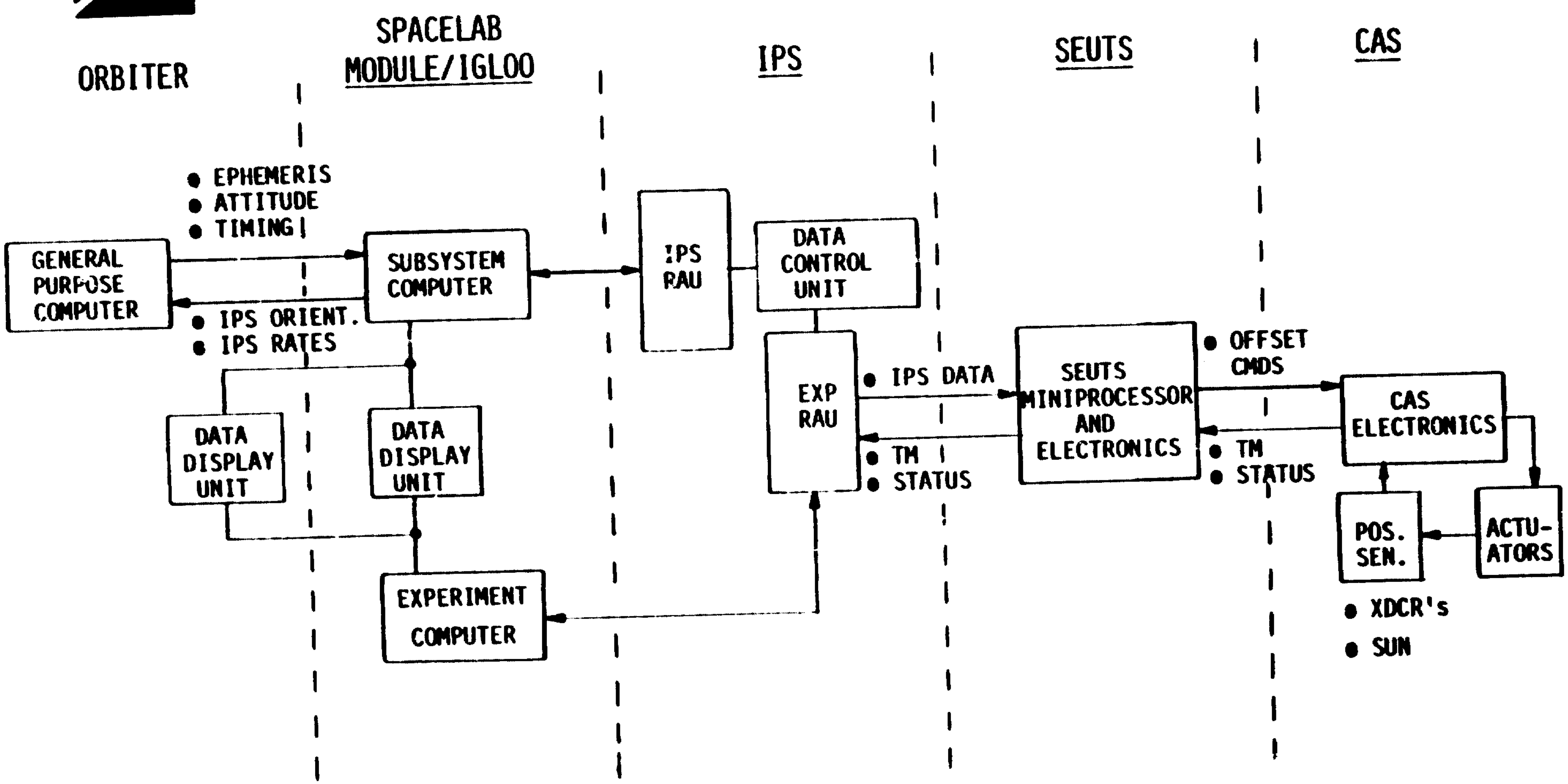

FIG. 3-4

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Orbiter through the Spacelab computers to IPS which in turn must exchange data with SEUTS. SEUTS (or some other electronic unit) must then provide the desired offset commands to CAS. This overall flow must be thoroughly thought out and the detailed interfaces defined and tested if SEUTS is to be successful.

Section 4
EXISTING BASD CAS DESIGNS

This section briefly describes the two existing CAS designs used for the SMM UVSP and C/P instruments.

4.1 UVSP CAS

The UVSP CAS was designed as a system completely separate from the UVSP instrument. (BASD built the CAS and GE built the instrument.) The purpose of the UVSP CAS was to provide infrequent offset adjustments to insure that UVSP was coaligned with other SMM instruments.

The mechanical configuration of the UVSP CAS is shown in Figure 4-1. The system consists of two baseplates connected by a single 8 inch azimuth bearing and an elevation bearing. The instrument mounted to the upper baseplate; the lower baseplate was mounted to the SMM spacecraft using GFE kinematic mounts. The baseplates were moved relative to each other by torque motor ball-screw actuators rated at 70 in-lbs. The position of the baseplates was sensed by inexpensive linear potentiometers (Bourns Model 184).

Electronically, the system compared the analog output of the potentiometers versus a D/A converted command word. In the closed-loop or automatic mode, any error is continuously corrected. A manual back-up mode was also provided in which the feed-back loop was disabled and the torque mators pulsed in an open loop manner. A block diagram of the UVSP CAS electronics is presented in Figure 4-2.

A comparison of the UVSP specification versus test performance is shown in Table 4-1.

4.2 C/P CAS

Whereas the UVSP CAS was designed for infrequent offset adjustments, the C/P CAS was designed as a continuous null and offset tracker using a sun sensor closed-loop system. Because these tracking functions were initially part of

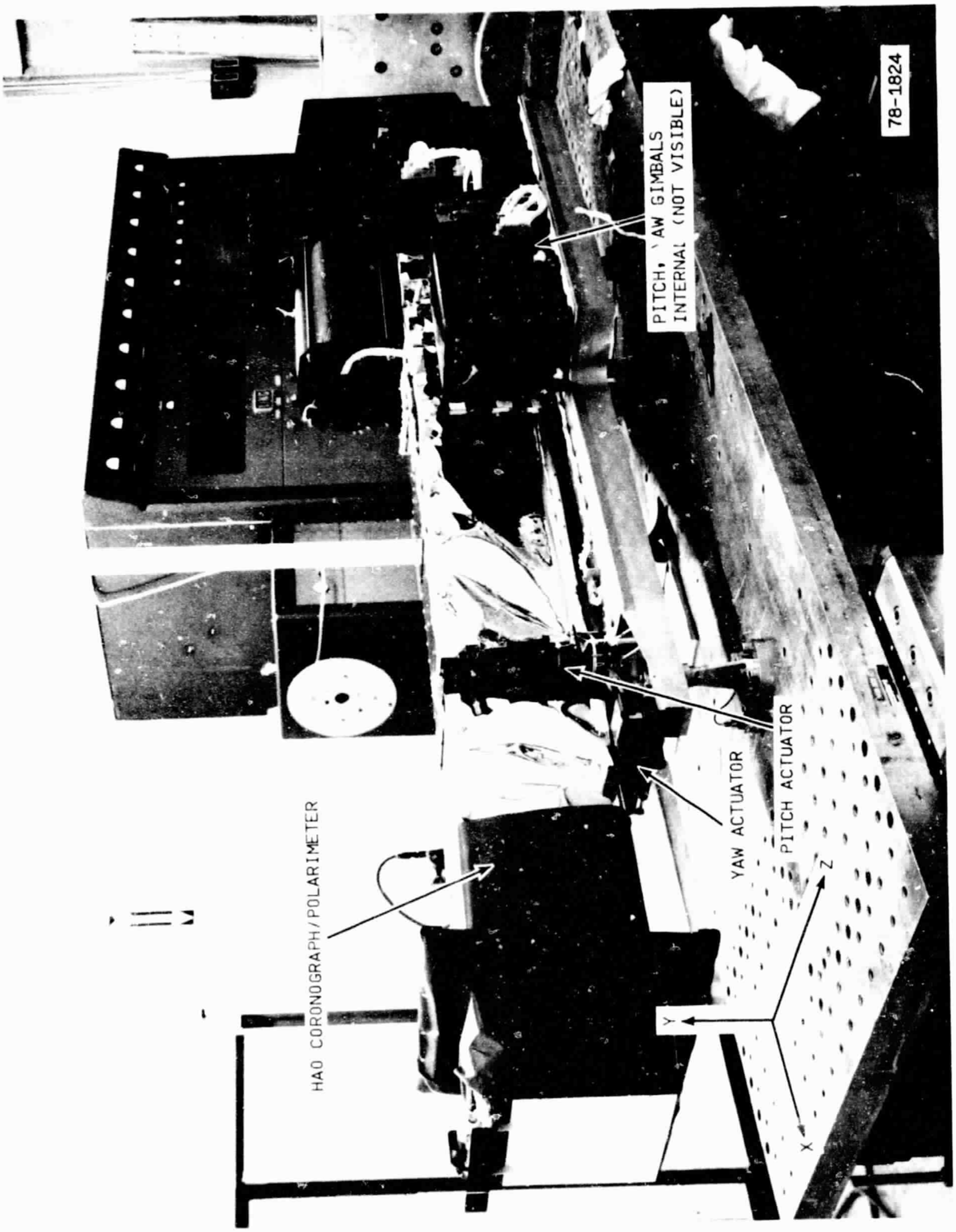

Figure 4-1 CAS and Electronics Box

CAS STUDY

UVSP BLOCK DIAGRAM

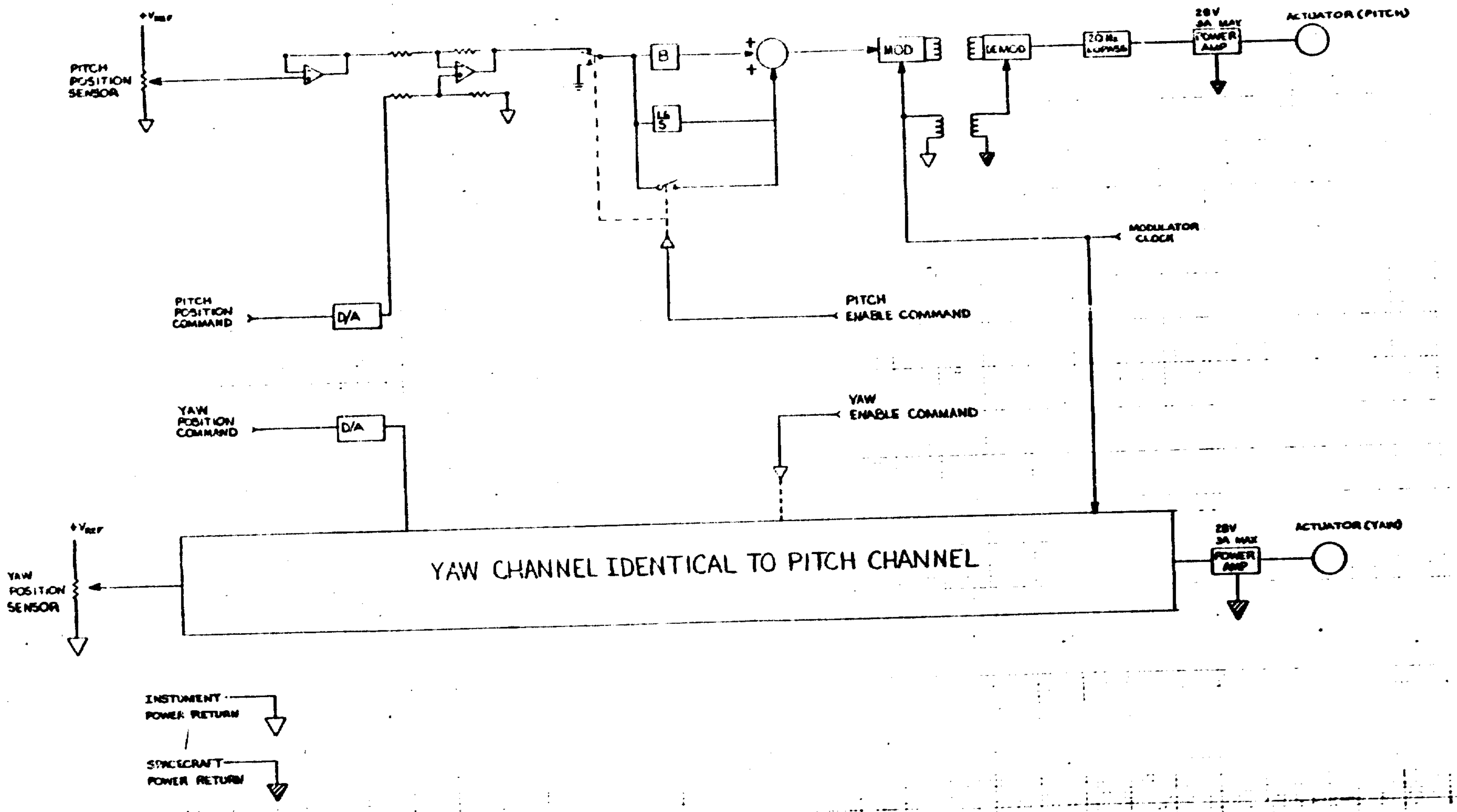

FIG. 4-2

TABLE 4-1

UVSP CAS PERFORMANCE DATA

ITEM	SPECIFICATION*	TEST DATA
1. RANGE	I 3600 $\widehat{SEC}$ (1.0 DEG) IN EACH OF TWO AXES.	PITCH: +5144 $\widehat{SEC}$, -4183 $\widehat{SEC}$ YAW: +4330 $\widehat{SEC}$, -3890 $\widehat{SEC}$
2. RESOLUTION (CMD AND TM)	15 $\widehat{SEC}$	PITCH: 15 $\widehat{SEC}$ YAW: 15 $\widehat{SEC}$
3. ACCURACY	NOT SPECIFIED	
4. REPEATABILITY	NOT SPECIFIED	NO DATA
5. CROSS COUPLING	PITCH, YAW: $<$ 5 $\widehat{SEC}$ ROLL: $<$ 36 $\widehat{SEC}$	PITCH: 6 $\widehat{SEC}$ (FOR YAW = 1000 $\widehat{SEC}$) YAW: 28 $\widehat{SEC}$ (FOR PITCH = 1000 $\widehat{SEC}$) ROLL: 38 $\widehat{SEC}$ (FOR PITCH = 4000 $\widehat{SEC}$)
6. LAUNCH STABILITY (WITH LAUNCH LOCKS)	PITCH, YAW, ROLL: $<$ ±200 $\widehat{SEC}$	PITCH: 67 $\widehat{SEC}$ YAW: 50 $\widehat{SEC}$ ROLL: DATA NOT USABLE, PROBABLY SIMILAR TO PITCH AND YAW.
7. RATE	100 $\widehat{SEC}$ IN $\leq$ 30 SEC	200 $\widehat{SEC}$ IN $\leq$ 30 SEC

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TABLE 4-1 (CONTINUED)

UVSP CAS PERFORMANCE DATA (CONTINUED)

ITEM	SPECIFICATION*	TEST DATA
8. STABILITY ON ORBIT	± 1 $\widehat{\text{SEC}}$ FOR ±0.25°C (EXPECTED VARIATION IN 5 MIN.) ±3 $\widehat{\text{SEC}}$ FOR ±1.0°C (EXPECTED VARIATION IN ONE ORBIT	NONE. REQUIREMENT WAS DEMONSTRATED BY ANALYSIS.
9. MANUAL STEPS	NOT SPECIFIED	PITCH AND YAW AVERAGE: 34 $\widehat{\text{SEC}}$
10. POWER	AT 21 TO 35 VOLTS, WHEN DRIVEN IN ONE AXIS, $\angle$ 57 WATT PER AXIS.	OFFSET MOVEMENT: 58 WATTS STEADY STATE POINTING: 5-18 WATTS
11. WEIGHT	LESS THAN 75 LBS INCLUDING ELECTRONICS	96 LBS. INCLUDING ELECTRONICS
12. FUNDAMENTAL FREQUENCY	> 45 Hz COMBINED UVSP/CAS/ FLEX MOUNTS	40 Hz
13. LAUNCH LOCKS	REQUIRED. NO SINGLE POINT FAILURE.	N/A
	*SMM CAS SPEC#409-2202-001A, GSFC, DATED 10 MARCH 1978.	

C/P instrument contract with BASD, the C/P CAS was designed integrally with the instrument. Mechanically, the baseplate and actuator assemblies can be separated from the instrument; however, distinct sun sensor and electronics units do not exist.

The overall configuration of the C/P CAS and instrument is shown in Figure 4-3. While the baseplate and actuator assemblies were designed along with the instrument, they are readily separable. Identical ball screw actuators were used for both the UVSP and C/P CAS's.

Electronically, the system compared the analog output of a four cell sun-sensor mounted internal to the instrument (reference Figure 4-4). As a coronograph, a full sun image existed in the instrument and could be used both for null tracking (center of sun) and offset adjustments. For offset adjustments the output of the sun sensor was compared to a D/A converted command word. While the C/P CAS was inherently more accurate and capable of smaller offset steps, it operated in a much smaller active range.

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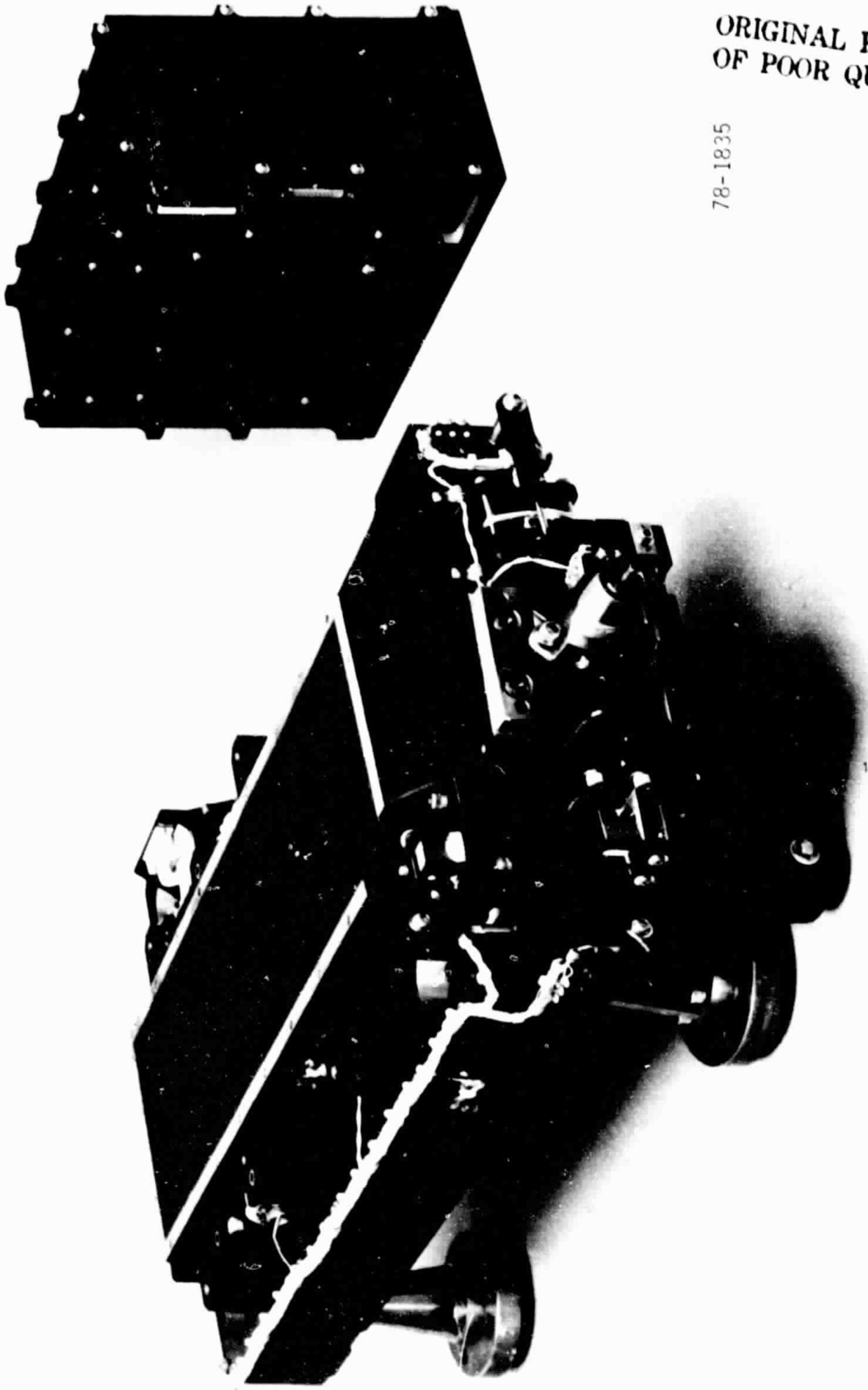

Figure 4-3 SMM HAO Coronagraph/Polarimeter with Integral CAS

CAS STUDY

C/P BLOCK DIAGRAM

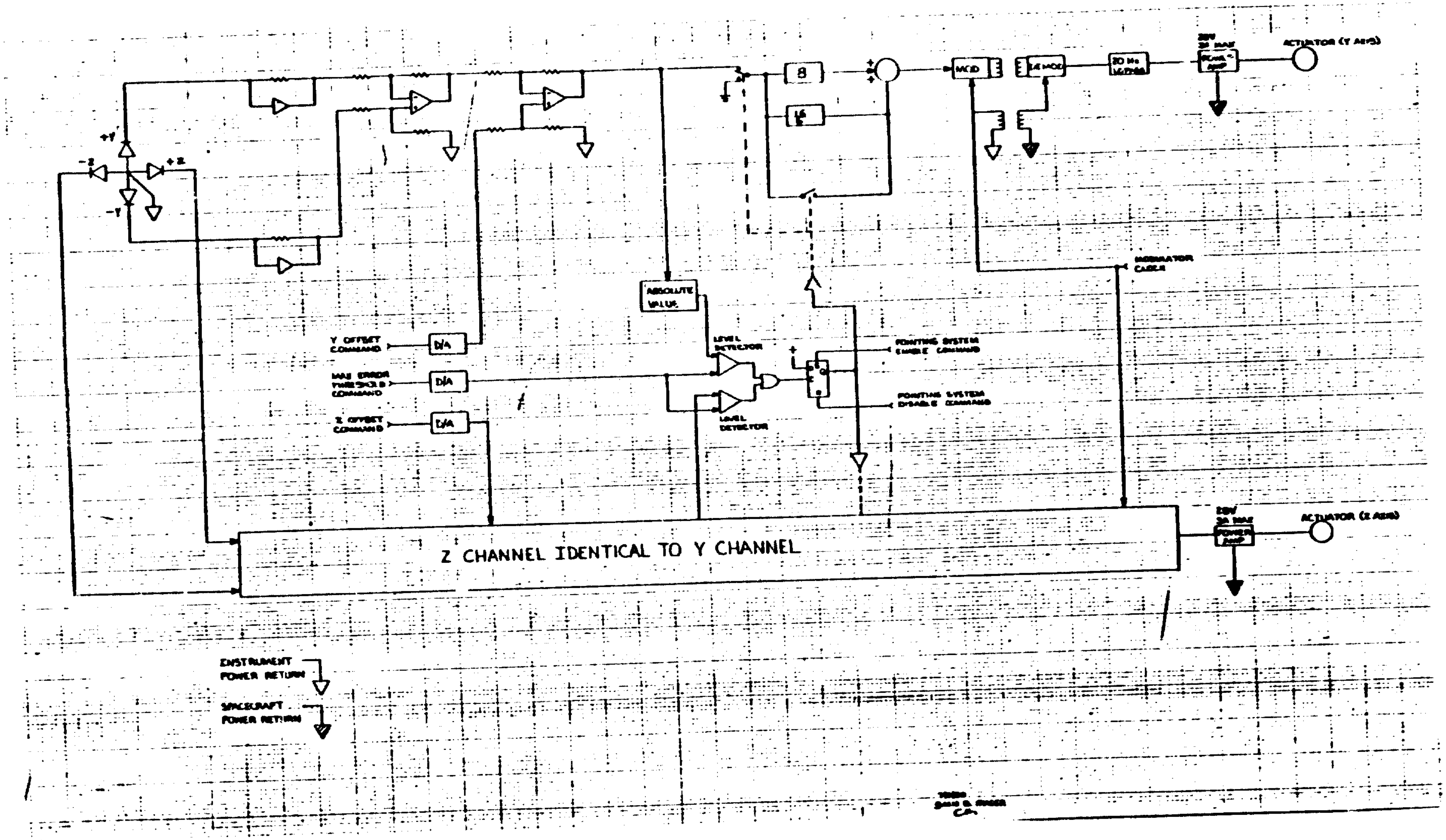

FIG. 4-4

Section 5
STRUCTURAL ASSESSMENT

This section addresses the compatibility of SEUTS versus the existing UVSP and C/P CAS designs. Due to structural configuration and natural frequency problems neither of these existing designs satisfies the SEUTS requirements. A recommend CAS configuration is then presented. The final portion of this section then addresses compatibility with the SMM kinematic mounts, the Spacelab cruciform structure, and the SOT structure.

5.1 COMPATIBILITY OF SEUTS VERSUS THE UVSP CAS

The basic mechanical configuration of SEUTS mounted on the UVSP CAS is shown in Figure 5-1. Since the UVSP CAS was designed for a much smaller and lighter instrument (reference Table 2-1 is Section 3.2) it has a number of disadvantages/problems. These are identified in Table 5-1.

While the disadvantages of instrument mounting, actuator clearance, and poor access could conceivably be accepted or solved, BASD believes the UVSP is not compatible with SEUTS for two major reasons:

1. Natural Frequency: The natural frequency of the combined instrument/CAS/kinematic mount system for various instrument weights is estimated in Figure 5-2. The value at 40 Hz for the UVSP instrument is based upon test data while the value of 16 Hz for the SEUTS instrument is based upon a computer run using the UVSP CAS model and a simple SEUTS model provided by GSFC. A more complete summary of runs made for SEUTS is shown in Table 5-5. This analysis determined that the SEUT/UVSP CAS combination will not meet the 35 Hz requirement due to bending of the lower baseplate and lack of stiffness in the single azimuth bearing. Since 16 Hz value is so far below the requirement, no minor modification will solve the problem.

SEUTS WITH UVSP CAS

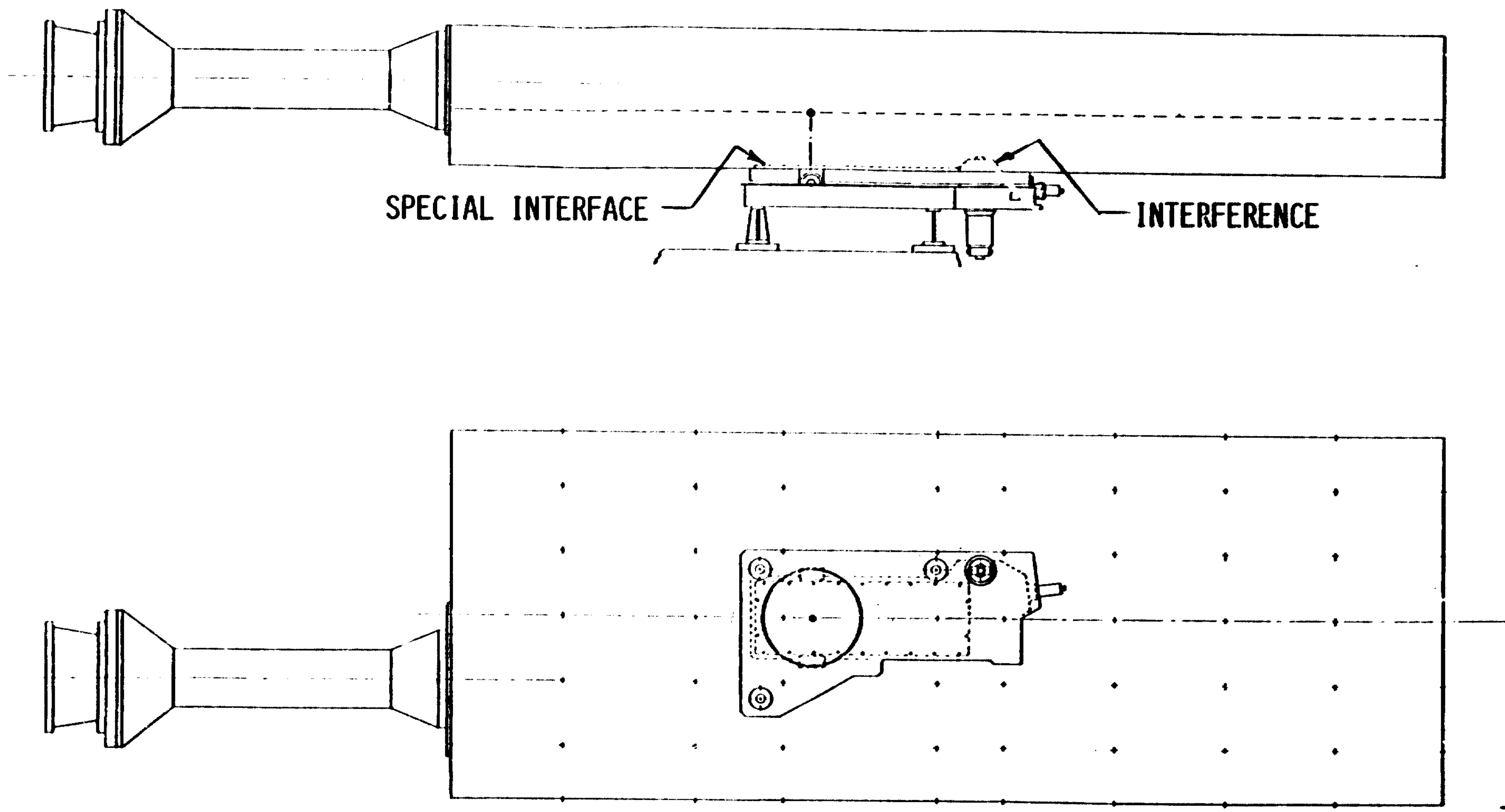

FIG. 5-1

TABLE 5-1

SEUTS VS. UVSP CAS DESIGN

MECHANICAL CONFIGURATION

ADVANTAGES

- EXISTING DESIGN.

DISADVANTAGES/PROBLEMS

- INSTRUMENT MOUNTING - DISASSEMBLY OF CAS OR ACCESS THROUGH SEUTS BASEPLATE.
- ACTUATOR CLEARANCE - PROTRUDES INTO SEUTS BASEPLATE AND POSSIBLY INTO SPACELAB MOUNTING STRUCTURE.
- POOR LOAD DISTRIBUTION - UPPER PLATE COVERS TWO GRID POINTS. LOWER PLATE/KINEMATIC MOUNTS DESIGN FOR SMM.
- POOR ACCESS FOR ALIGNMENT, ADJUSTMENT, ETC.
- NATURAL FREQUENCY - 16 Hz.

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UVSP CAS DESIGN

NATURAL FREQUENCY VS. INSTRUMENT WEIGHT

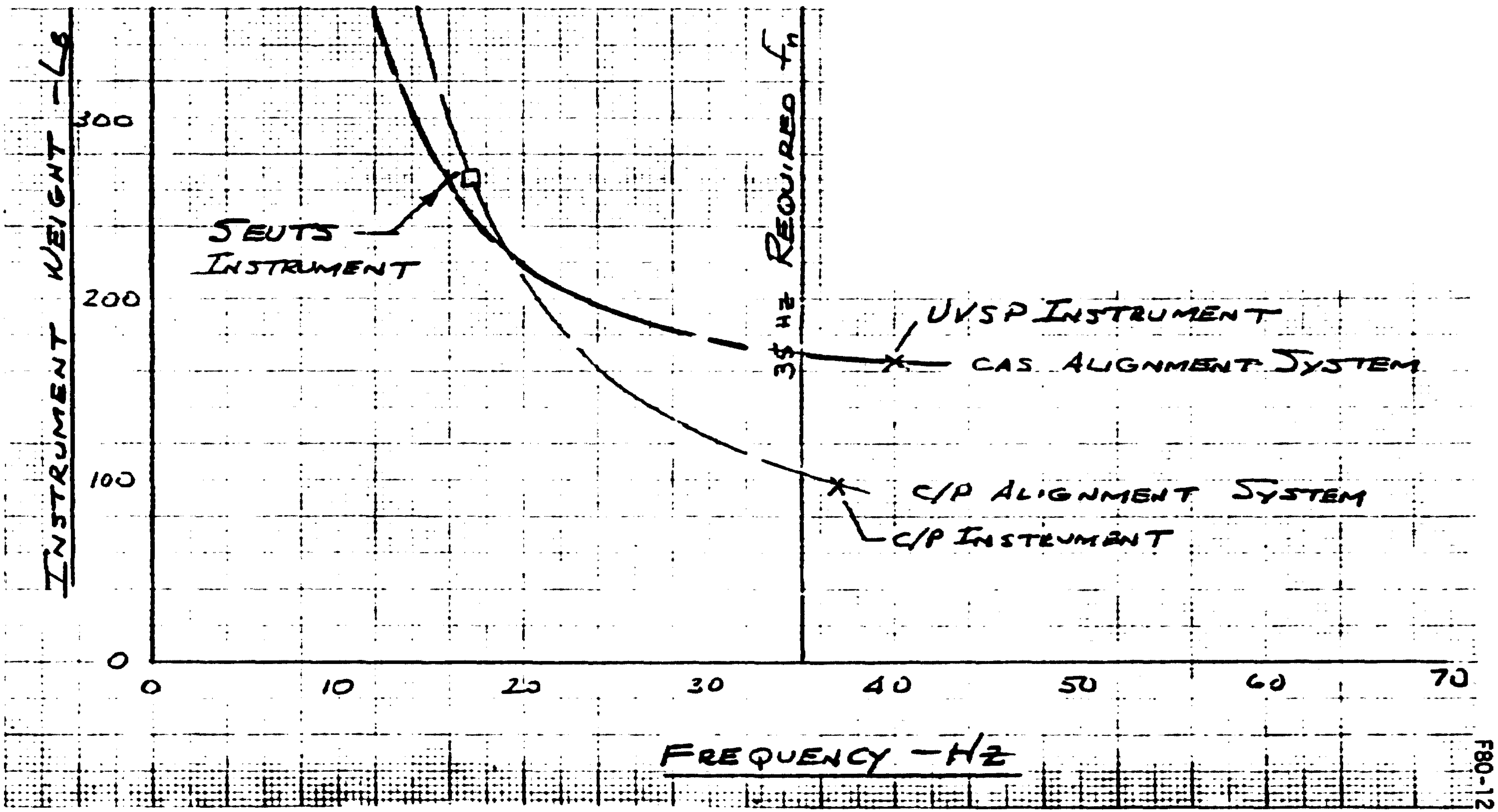


FIG. 5-2

2. Poor Load Distribution: The upper mounting plate represented by the dotted lines in Figure 5-1 offers a very small area for mounting the SEUTS instrument. This would pose severe design constraints on SEUTS. Also, the load distribution into the lower baseplate/kinematic mounts would most likely be unacceptable.

5.2 COMPATIBILITY OF SEUTS VERSUS THE C/P CAS

SEUTS mounted on the C/P CAS is shown in Figure 5-3. Similar to the UVSP CAS, the C/P CAS was designed for a smaller lighter instrument. The disadvantages/problems of using it for SEUTS are listed in Table 5-2.

Assuming that the problem of poor access for alignment and adjustment can be worked around, there are a number of major problems which preclude using the existing C/P design for SEUTS:

1. Natural Frequency: Figure 5-4 provides an estimate of the natural frequency for various weight above a C/P CAS. The 37 Hz value for the C/P Instrument is based upon test data, while the value of 17 Hz for the SEUTS instrument was analytically derived by considering weights and moments of inertia. Obviously, the C/P CAS cannot meet the 35 Hz requirement.

2. Instrument Mounting: There is no upper mounting plate. Attached to the elevation gimbal assembly is a yoke-type bracket which mated to the case of the C/P instrument. Either SEUTS would have to design to this interface or the C/P CAS design be modified to add an upper baseplate.

SEUTS WITH CP CAS

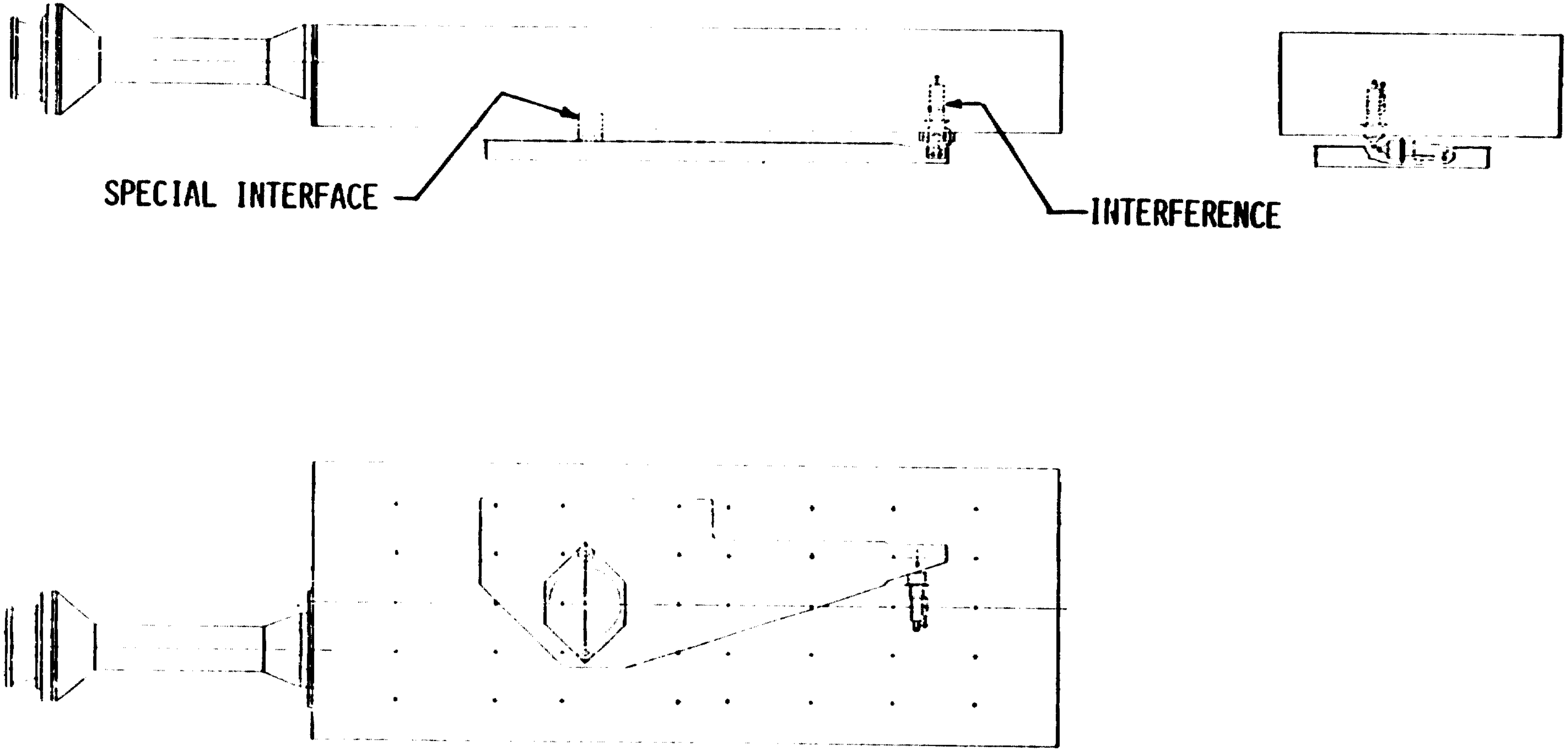


FIG. 5-3

TABLE 5-2

SEUTS VS. C/P CAS

MECHANICAL CONFIGURATION

ADVANTAGES

- EXISTING DESIGN.

DISADVANTAGES/PROBLEMS

- INSTRUMENT MOUNTING - NO UPPER MOUNTING PLATE.
- ACTUATOR CLEARANCE - PROTRUDES INTO SEUTS BASEPLATE.
- POOR LOAD DISTRIBUTION - NO UPPER PLATE. LOWER PLATE/KINEMATIC MOUNTS DESIGNED FOR SMM.
- POOR ACCESS FOR ALIGNMENT, ADJUSTMENT, ETC.
- NATURAL FREQUENCY - ESTIMATE 17 Hz.

SEUTS VS. C/P CAS

NATURAL FREQUENCY VS. INSTRUMENT WEIGHT

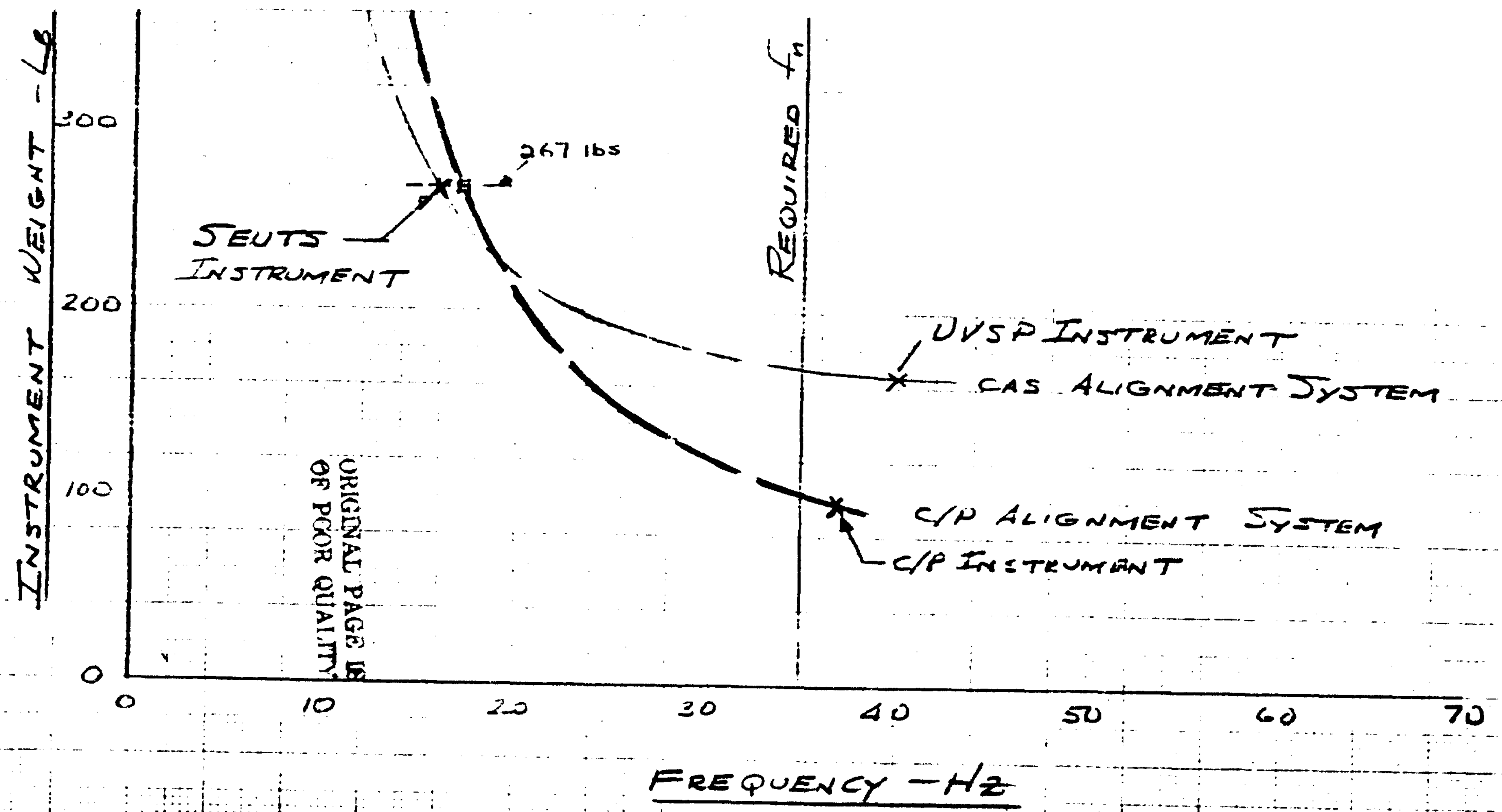


FIG. 5-4

3. Actuator Clearance: As can be seen from Figure 5-3 one of the actuators totally interfers with the SEUTS baseplate. Either clearance would have to be negotiated or the actuator relocated.

4. Poor Load Distribution: As in the case of the UVSP CAS, we did not perform computerized loads analyses due to the existence of other major problems. Problems of load distribution to SEUTS and through the kinematic mounts can be expected.

5.3 RECOMMENDED CAS CONFIGURATION

The previous two paragraphs discussed the disadvantages/problems associated with mounting SEUTS on either the UVSP or C/P CAS. This addresses a recommended configuration which satisfies the SEUTS requirements.

5.3.1 Mechanical Configuration

The UVSP and C/P CAS had a number of problems in accommodating an instrument as large and heavy as SEUTS. These problems and the associated solutions are summarized in Table 5-3. Each of these solutions were incorporated in the recommended CAS configuration shown in Figure 5-5. This configuration represented a relatively simple, straightforward design and would be applicable to a wide range of instruments. A preliminary weight statement is provided in Table 5-4.

5.3.2 Natural Frequency

Natural frequency problems with the UVSP and C/P CAS precluded their use with SEUTS. To insure that our recommended configuration satisfied the 35 Hz requirement with adequate margins we developed a simplified model and combined it with the SEUTS model provided by GSFC. We were also interested in determining the influence of the flexible kinematic mounts. Consequently, computer runs with both flexible and rigid mounts were made.

The results are presented in Figure 5-6. The fundamental mode of 38 Hz was determined to a SEUTS instrument mode and was essentially unaffected by either

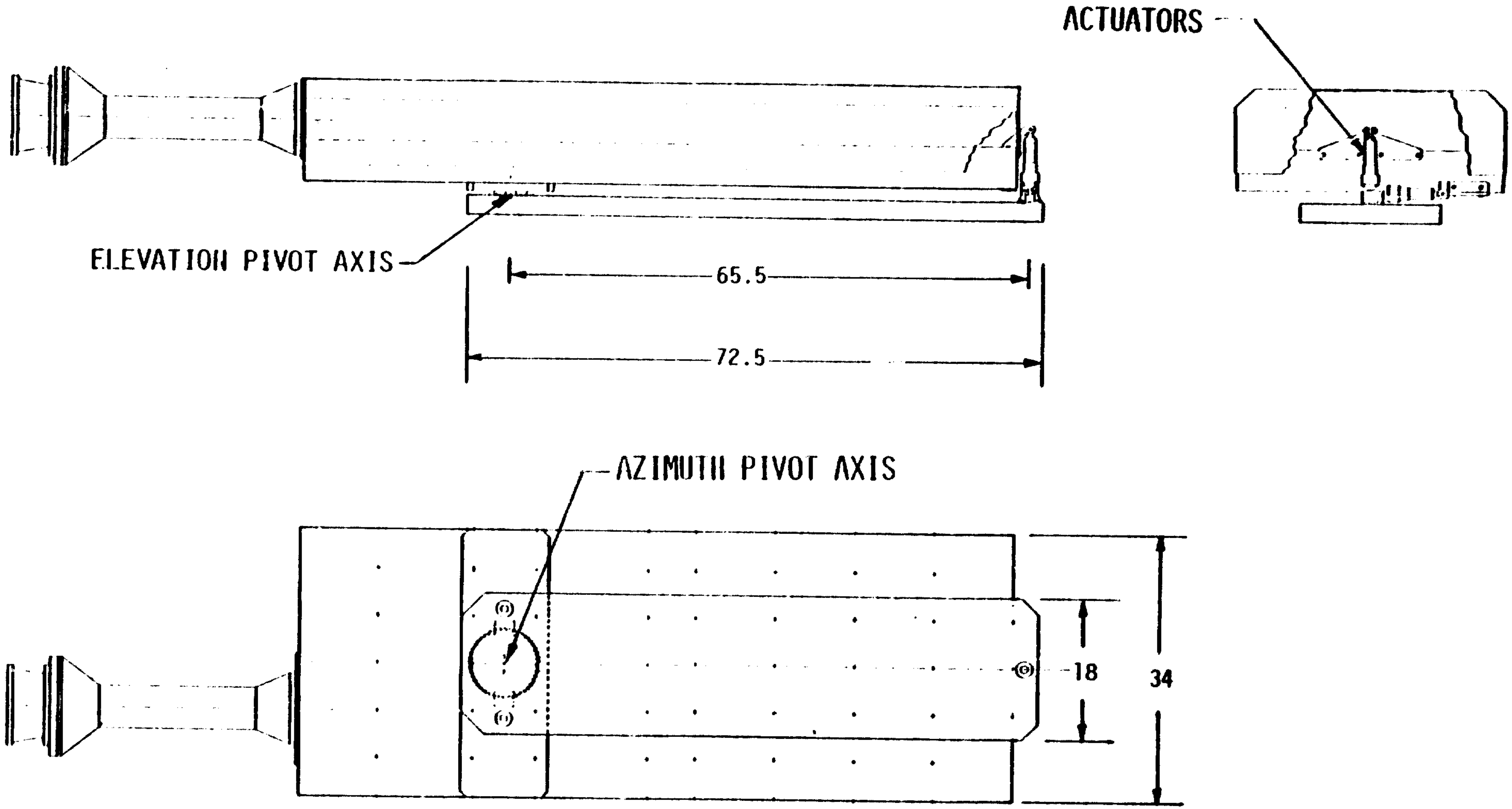
TABLE 5-3

RECOMMENDED CAS CONFIGURATION

SUMMARY OF PROBLEMS/SOLUTIONS

PROBLEMS	SOLUTIONS
• NATURAL FREQUENCY	• DUPLEX AZIMUTH BEARINGS • ACTUATORS IN LINE WITH KINEMATIC MOUNTS • STIFFER LOWER PLATE • STIFFER KINEMATIC MOUNTS
• INSTURMENT MOUNTING	• ACCESS PROVISIONS
• ACTUATOR CLEARANCE	• ACTUATORS AT END OF INSTRUMENT
• POOR LOAD DISTRIBUTION	• STIFFER LOWER BASEPLATE • GREATER SEPARATION OF MOUNTS • ACTUATORS IN LINE WITH MOUNTS
• POOR ACCESS	• ACTUATORS AT END OF INSTRUMENT

SEUTS WITH RECOMMENDED CAS DESIGN



ALL DIMENSIONS ARE IN INCHES

FIG. 5-5

F80-12

TABLE 5-4

RECOMMENDED CAS CONFIGURATION

STRUCTURE WEIGHT BREAKDOWN

UPPER PLATE	25
LOWER PLATE	48
INTERMEDIATE STRUCTURE	12
ELEVATION BEARINGS (2)	3
AZIMUTH BEARINGS (2)	3
ACTUATORS (2)	5
BRACKETS	2
HARDWARE	4
	102
ELECTRONICS	13
SUN SENSOR	3
	118 LBS.

RECOMMENDED CAS CONFIGURATION

NATURAL FREQUENCY

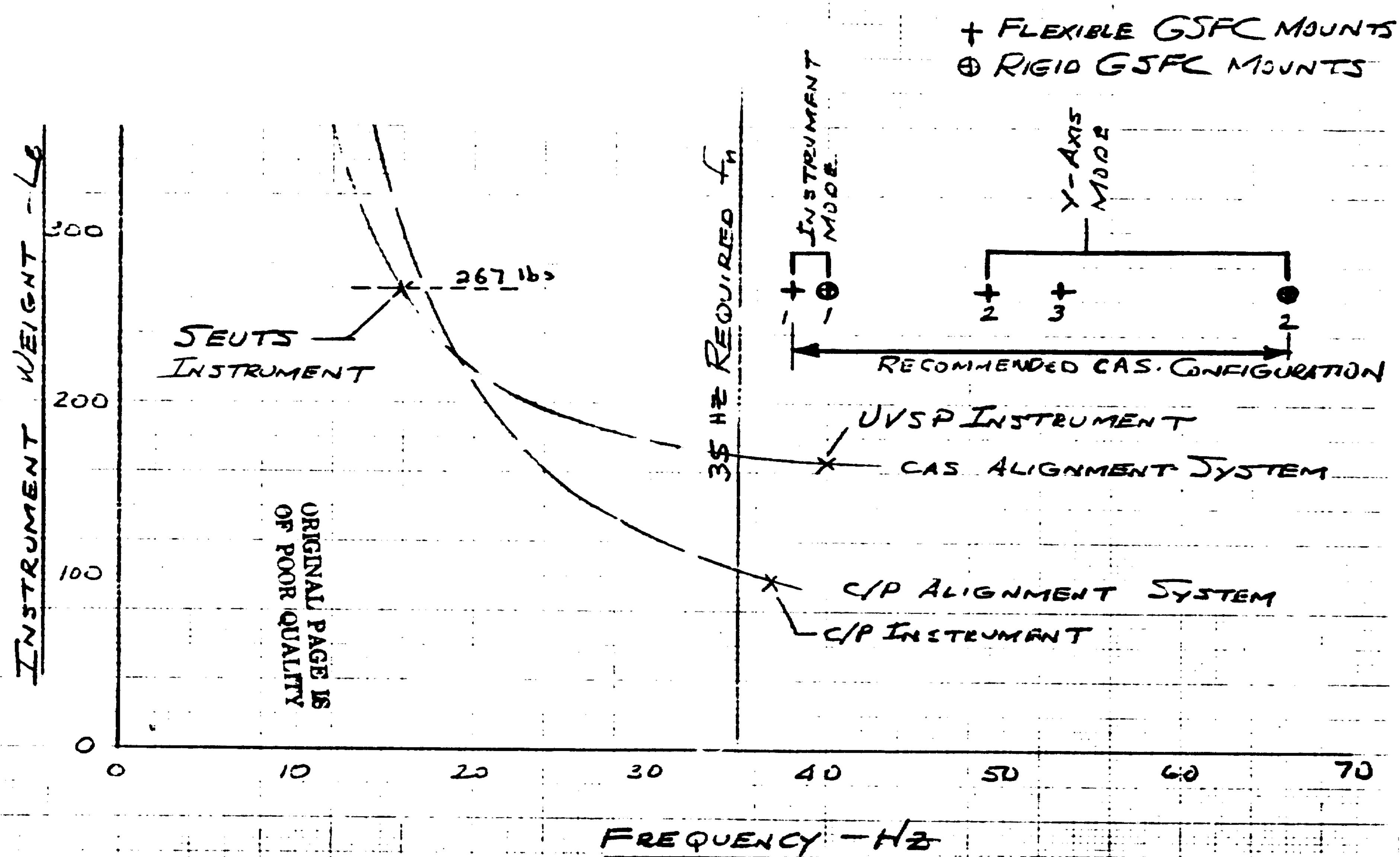


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FIG. 5-6

CAS or the mounts (ref. Figure 5-7). The second mode is a CAS mode (ref. Figure 5-8) and is affected by flexible vs. rigid mounts. The various modes are summarized in Table 5-5 and compared with the UVSP and C/P CAS results.

If one assumes that the 38 Hz mode in SEUTS can be eliminated, then the recommended configuration satisfies the 35 Hz requirements with substantial margins. However, due to the criticality of this area and the fact that neither SEUTS or CAS are designed, we also identified methods of further improvement. These are presented in Table 5-6.

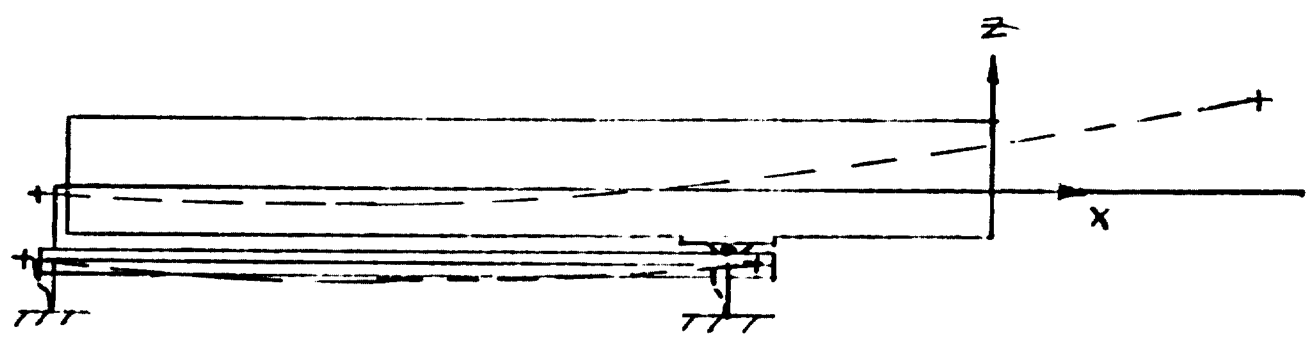
5.3.3 Loads

The CAS-SEUTS configuration was stress-analyzed on the basis of loads supplied to us by Bill Case and Bob Coladonato of GSFC. Limit load factors of 15g were applied simultaneously along the three orthogonal axes for all possible load combinations. In addition, loads on the GSFC flexure mounts were evaluated and compared to the allowable loads supplied to BASD by George Honeycutt of GSFC.

The results of analysis indicate the flexures are inadequate for the 15g limit load times a 1.4 ultimate factor of safety. The 8 inch diameter azimuth duplex bearing pair is marginal if the requirement for quiet-running after load is imposed. Quiet-running, in the classic sense, doesn't apply since only slight azimuth motions are required. However, to avoid any uncertainty in performance and to make CAS applicable for other instruments, increasing the bearing diameter is desireable. (An assessment (Task 4 of this study) performed for the Spacelab Lyman Alpha Coronograph/White Light Coronograph indicated that a 14-inch diameter duplex pair would be required for strength and natural frequency reasons. While not directly required by SEUTS, it is logical to incorporate a 14-inch diameter bearing initially-rather than redesign the CAS structure for each application). All other primary structural elements show low stresses and indicate the design concept is feasible. The actuator screw drives are loaded to 931 lbs. ultimate but have a capability of 2800 lbs. for the Ball screw. Table 5-7 summarizes the loads in the primary structural elements.

RECOMMENDED CAS CONFIGURATION

<u>FUNADMENTAL MODE SHAPE AND FREQUENCY</u>



MODE 1   38 Hz (FLEXIBLE GSFC MOUNTS)

MODE 1   40 Hz (RIGID GSFC MOUNTS)

<u>THIS IS PRIMARILY AN INSTRUMENT MODE</u>

<u>UNAFFECTED BY THE CO-ALIGNMENT</u>

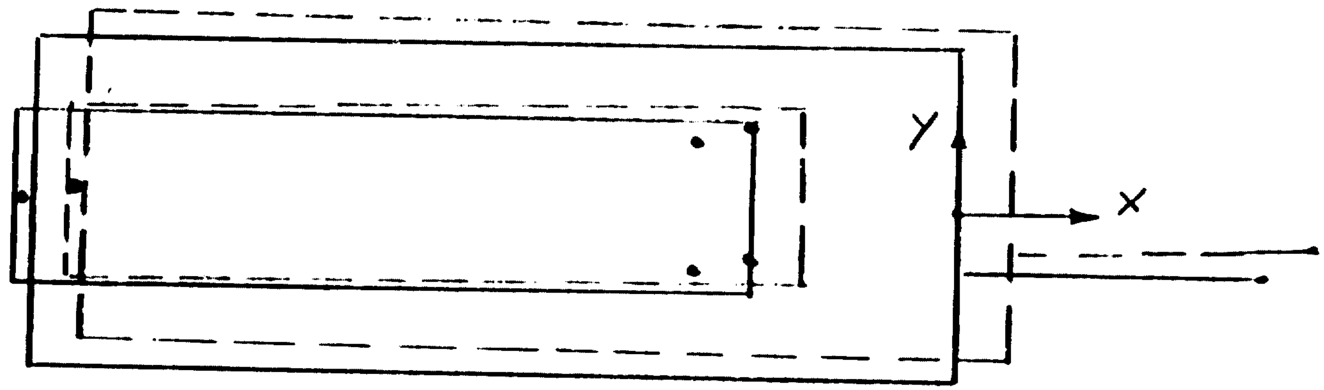
<u>ADJUSTMENT SYSTEM</u>

FIG. 5-7

RECOMMENDED CAS CONFIGURATION

MODE 2 SHAPES AND FREQUENCIES

MODE 2 49 Hz (FLEXIBLE MOUNTS)



MODE 2 66 Hz (RIGID GSFC MOUNTS)

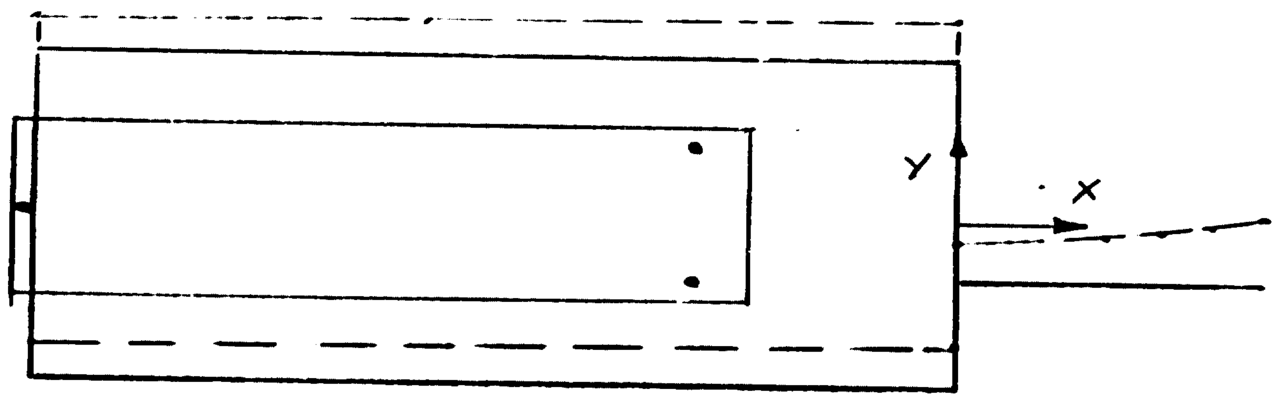


FIG. 5-3

TABLE 5-5

SUMMARY OF STUDY MODE SHAPES

MODE DESCRIPTION	FREQUENCY (Hz)		
	CAS	C/P	PROPOSED
PITCHING ABOUT ELEVATION AXIS	16	17	1
LATERAL AXIS TRANSLATION COUPLED WITH ROTATION ABOUT X-AXIS AT YAW BEARING CENTER LINE	19	--	49 66*
Z AXIS TRANSLATION COUPLED WITH Y AXIS TRANSLATION	34	--	53 97*

1 DOES NOT SHOW BELOW 99 Hz

* RIGID GSFC MOUNTS

F80-12

TABLE 5-6

RECOMMENDED CAS CONFIGURATION

FREQUENCY IMPROVEMENT CAN RESULT FOR THE RECOMMENDED CONFIGURATION.

- IF A 10 INCH DUPLEX BEARING PAIR IS USED INSTEAD OF 8 INCH

	FREQUENCY (Hz)
FLEXIBLE GSFC MOUNTS AND 8 INCH D.P. BEARINGS	49
RIGID GSFC MOUNTS AND 8 INCH D.P. BEARINGS	66
8 INCH D.P. BEARINGS AS ONLY SPRING	75
10 INCH D.P. BEARINGS AS ONLY SPRING	127

- AND INSTRUMENT HARD-MOUNTED RESONANCE DOES NOT CONTROL LOWEST FREQUENCY.
- EVEN GREATER IMPROVEMENTS CAN BE MADE IF A 14 INCH D.P. AZIMUTH BEARING IS USED.

TABLE 5-7

RECOMMENDED CAS CONFIGURATION

LOADS ANALYSIS

ITEM	TYPE OF LOADING	STRESS OR LOAD	ALLOW STRESS OR LOAD
GSFC MOUNTS	AXIAL	6918 LB.	4000 LB.
GSFC MOUNTS	LATERAL	7812 LB.	5000 LB.
AZIMUTH BRG. (8 IN. DUPLEX PAIR)	BALL MEAN HERTZ STRESS	415000 PSI	500000 PSI
CAS BASEPLATE BARS	BENDING	3094 PSI	42000 PSI*
CAS BASEPLATE PLATES	TENSION/COMP	3153 PSI	42000 PSI*
SEUTS INSTRUMENT BEAMS	BENDING	6730 PSI	42000 PSI*
ACTUATORS	AXIAL	931 LB.	2830 LB.

ALL ABOVE LOADS ARE ULTIMATE: ± 15 G's x 1.4 FACTOR OF SAFETY = 21 G's

*ASSUMING 6061-T6 ALUMINUM

5.3.4 Launch Locks

Typically, launch locks are required for two reasons:

1) To unload a mechanism; that is, to prevent launch vibrations from damaging sensitive components such as bearing, cams, etc.

2) To hold a particular pre-launch position or alignment when motion due to launch loads is unacceptable.

A need associated with the first reason is usually determined by the mechanical designer. BASD did not use launch locks on the C/P CAS; they were not required from either an instrument or a CAS standpoint. We do not believe they will be required for SEUTS.

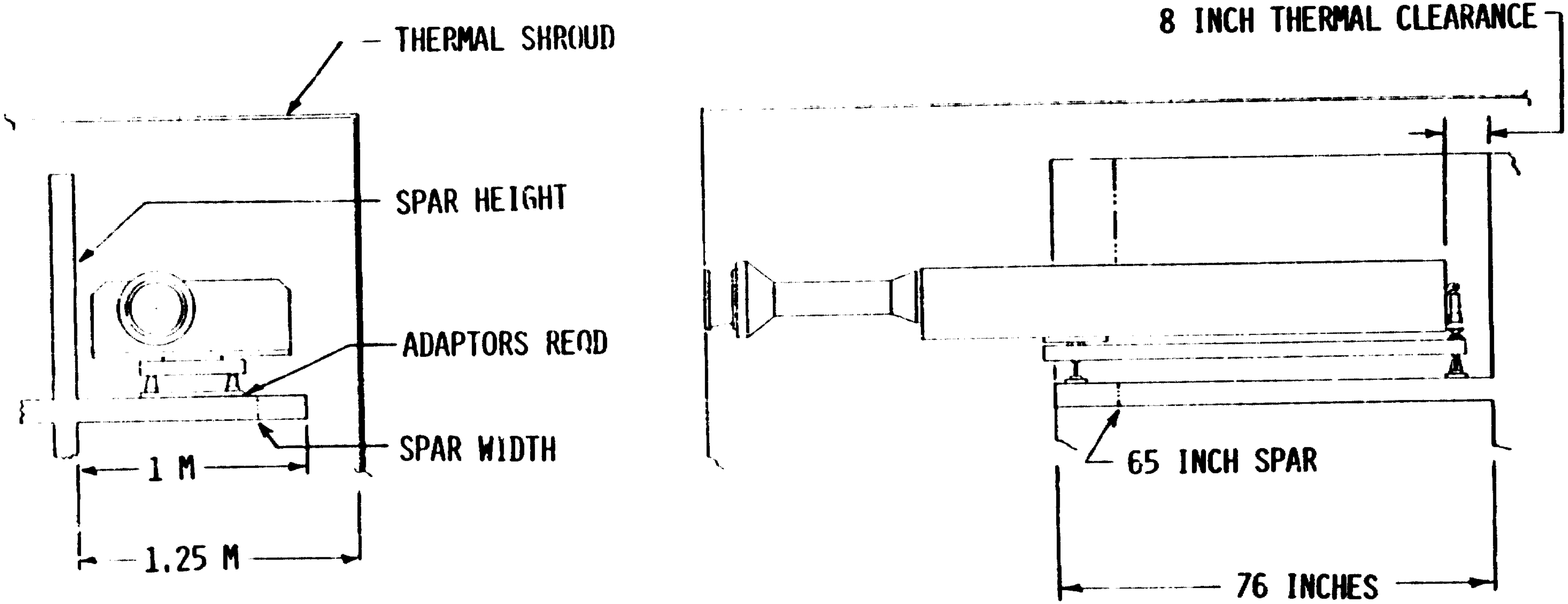
A need associated with the second reason is normally determined by the Principal Investigator. A launch lock was used on the UVSP CAS because the PI was uncertain that CAS would be required. If the co-alignment between the UVSP and other SMM instruments was not degraded during launch or on-orbit operations, then CAS would not be activated. The launch lock was to hold the instrument in its original position. However, SEUTS and UVSP differ greatly in their planned operations. SEUTS, like the C/P will require frequent offset motions. It is essentially meaningless to hold SEUTS in its prelaunch position.

In summary, BASD does not belive the cost and complexity of launch locks are warranted for the SEUTS mission.

5.3.5 Compatibility with the Cruciform and SOT Structures

Spacelab Cruciform: Figure 5-9 shows SEUTS/Recommended CAS mounted on the Spacelab Cruciform structure. The dotted lines indicate the spar height, width and length used for SL-2, whereas the solid outline indicates a cruciform size BASD has been given for planning purposes.

SEUTS VS. SPACELAB CRUCIFORM STRUCTURE



CONCLUSION: ALLOWING FOR THERMAL CLEARANCE/ACTUATOR PLACEMENT AT REAR OF INSTRUMENT, THE 65 IN."EXISTING" SPAR IS NOT LONG ENOUGH

FIG. 5-9

The conclusion determined by this sketch is that SEUTS/CAS is not readily compatible with the cruciform structure. Allowing for thermal clearance at rear of the instrument, the length of the spar is not adequate. Also, the IPS Optical Sensor Package (OSP) supports are not shown on the sketch, under the assumption that they can be reconfigured for individual missions. If this assumption is not correct, they will interfere with a SEUTS/CAS combination or SEUTS, by itself.

This incompatibility with the cruciform should be given early consideration. The following should be considered:

1) Perform a preliminary thermal analysis to indicate the thermal clearance required;

2) Assess the potential of shortening the SEUTS instrument or providing actuator clearance within the instrument envelope;

3) Decrease the CAS length by mounting the CG ahead of the azimuth bearing;

4) Firm up plans for a longer, larger cruciform.

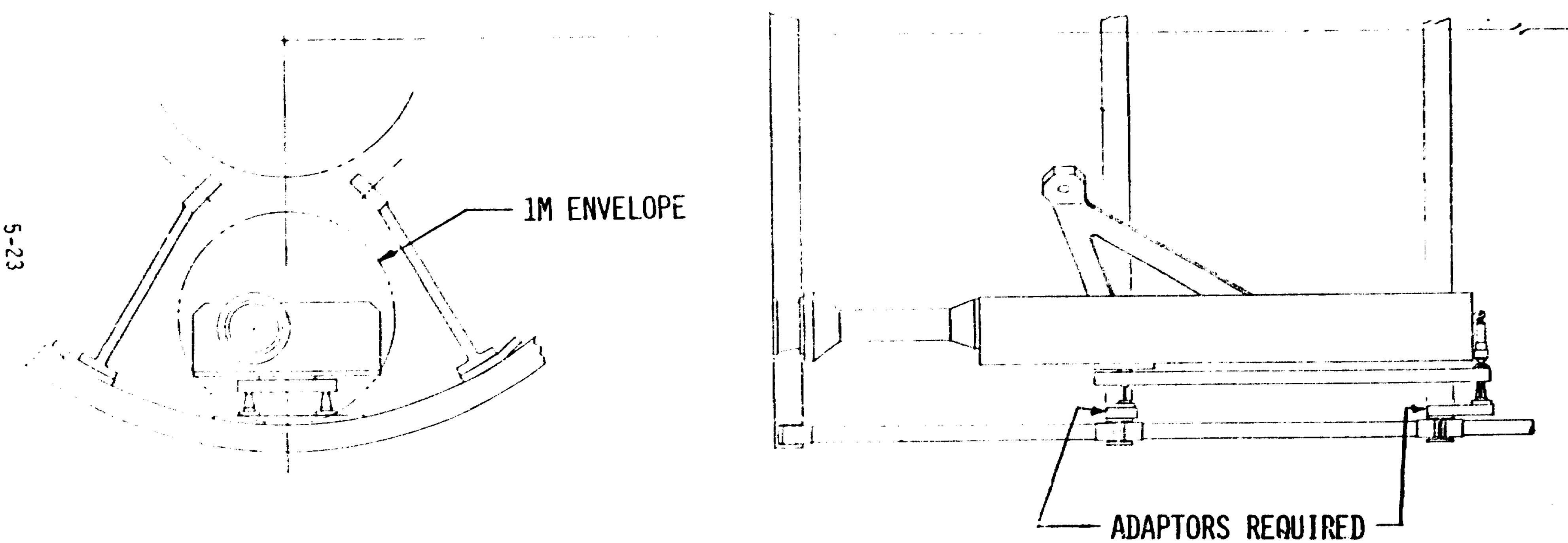
Solar Optical Telescope Structure: Figure 5-10 shows SEUTS/CAS mounted in the SOT structure. Given the opportunity to design adequate adapters SEUTS/ CAS is compatible with the SOT structural concept.

5.3.6 Use of SMM Kinematic Mounts

On SMM the kinematic mount system was used to limit moments being induced into an instrument from thermal or other distortions of the spacecraft structure. The mounts were designed for the loads typical of moderate weight instruments on a Delta launch vehicle. For a SEUTS Spacelab or SOT mission they have the following disadvantages:

- Natual Frequency: As discussed in Paragraph 5.3.2, they tend to lower the natural frequency of the combined SEUTS/CAS. However,

SEUTS VS. SOT STRUCTURE



CONCLUSION: WITH ADEQUATE ADAPTORS SEUTS IS COMPATIBLE WITH SOT STRUCTURE

FIG. 5-10

F80-12

they are not the cause of the lowest mode and should not be eliminated for this reason.

- Mount Strength: As discussed in Paragraph 5.3.3, the SMM mounts are not adequate for the ±15g load condition. They would have to be redesigned for a SEUTS mission if the loads remain this high.

- Envelope Size: The use of the mounts raises SEUTS/CAS, thereby requiring a larger envelope for the system. Whether this is a real problem depends upon the structure used to carry the system. If interference exists with the OSP support on the cruciform, the use of the mounts would aggravate the problem.

The value of the SMM mounts lies in their availability and their ability to eliminate one more pointing error concern. However, the gimbals of CAS approximate a kinematic system. Given that the SMM mounts may not be usable from a load standpoint, consideration should be given to eliminating them from the system.

Section 6
TASK 2: STUDY OF OFFSET CAPABILITIES

This section addresses the capabilities of the existing CAS designs to provide offset pointing using closed loop sensing of CAS baseplate positions. No direct sensing of position relative to the sun is performed. Task 3 addresses the same basic question, except that a sun sensor is used to provide a direct readout of solar position. Both tasks address closed-loop control. The difference between these tasks lies essentially in the sensors used.

6.1 ANALYSIS OF SEUTS REQUIREMENTS

Table 6-1 identifies the significant SEUTS offset adjustment requirements and their design implications. These requirements apply only to the contribution by CAS and not to an overall pointing error requirement. The overall pointing error will involve many potential sources of error other than CAS. While a detailed analysis of the overall pointing errors was beyond the scope of this study, estimates were made to help understand the overall problem and to place CAS performance in the proper perspective. The next sections will first analyze the SEUTS requirements relative to CAS actuators, sensors, and electronics and then summarize both the expected CAS and overall system performance.

6.2 ACTUATORS

To be suitable for a SEUTS application the actuator must satisfy requirements relative to:

- Loads
- Total travel
- Shaft rotation for a 2 arc sec step
- Jitter (backlash)

These requirements versus the UVSP and an alternate actuator are shown in Table 6-2. With the exception of the total travel and 2 arc sec manual step requirement, the UVSP actuator is suitable for SEUTS. Therefore, BASD

TABLE 6-1

OFFSET REQUIREMENTS ANALYSIS

ITEM	REQUIREMENT	DESIGN IMPLICATION
ACCURACY	10 $\widehat{SEC}$	RANDOM ERRORS: $<$ 10 SEC. ALL OTHER ERRORS CALIBRATIBLE.
OFFSET STEP CAPABILITY	2 $\widehat{SEC}$ STEPS	LINEAR TRAVEL*: 6.35×10^{-4} IN
RANGE	±0.5 DEG (REQD) ±1.0 DEG (GOAL)	TOTAL TRAVEL*: 1.144 IN; CMD WORD: 11 BITS TOTAL TRAVEL*: 2.287 IN; CMD WORD: 12 BITS
MANUAL STEP	2 $\widehat{SEC}$	MOMENTARY, OPEN LOOP PULSE MUST CAUSE $\backsim 6.35 \times 10^{-4}$ IN TRAVEL
RATE OF MOVEMENT	20 $\widehat{SEC}$ IN 2 SEC (GOAL)	ACTUATOR FORCE: $<<$ 70 LBS.
REPEATABILITY	NOT SPECIFIED 4 $\widehat{SEC}$ ASSUMED GOAL	RANDOM ACCURACY ERRORS: $<$ 4 SEC. ALL OTHER ERROR CALIBRATIBLE. REPEAT SEQUENCE ASSUMED TO OCCUR WITHIN 1-2 HOURS.

*LEVER ARM = 65.5 INCHES

TABLE 6-2

ACTUATOR ANALYSIS

ITEM	AS DESIGNED FOR UVSP	IF USED FOR SEUTS	IF MODIFIED FOR SEUTS	
			TRAVEL ONLY	TRAVEL & SCREW
1. LEVER ARM	16 IN	65.5 IN	65.5 IN	65.5 IN
2. TOTAL TRAVEL				
-REQUIRED	$\pm1.0^{o}/\pm0.28$ IN	$\pm0.5^{o}/\pm.57$ IN	$\pm1.00^{o}/\pm1.14$ IN	$\pm1.0^{o}/\pm1.14$ IN
-AVAILABLE	$\pm1.75^{o}/\pm0.50$ IN	$\pm0.43^{o}/\pm0.50$ IN	$\pm1.09^{o}/\pm1.25$ IN	$\pm1.09^{o}/\pm1.25$ IN
3. INCREMENT TRAVEL				
-ANGULAR	15 $\widehat{SEC}$	2 $\widehat{SEC}$	2 $\widehat{SEC}$	2 $\widehat{SEC}$
-LINEAR	1.16×10^{-3} IN	6.35×10^{-4} IN	6.35×10^{-4} IN	6.35×10^{-4} IN
4. THREADS/INCH	8	8	8	25
5. SHAFT ROTATION	3.34^{o}	1.83^{o}	1.83^{o}	5.72^{o}
6. SCREW TYPE	BALL	BALL	BALL	PLANETARY ROLLER
7. LOAD CAPACITY				
-REQUIRED	N/A	931	931	931
-AVAILABLE	N/A	2,830	2,830	3,136

recommends that the UVSP actuator be modified slightly by extending the case and the length of the Ball screw. This option is cheaper than modifying the actuator to accept a planetary roller screw. Figure 6-1 presents the existing actuator and the modifications that would be necessary to add the planetary roller screw. Figure 6-2 illustrates the difference between a ball screw and a planetary roller screw.

6.3 SENSORS

The UVSP CAS used an inexpensive linear potentiometer, Bourns Model 184. The specification values are shown in Table 6-3. To verify this performance a Model 184 potentiometer residual from the C/P program was tested. The test results are also presented in Table 6-3.

The Model 184 potentiometer used an Infinitron element which in theory has continuous resolution. However, it also appears to have mechanical inaccuracies which make it unsuitable for SEUTS:

- The wiper appears to lag the direction of motion such that there is a 40-60 mv difference in the reading depending upon the direction of motion. For example, if the potentiometer is moved from 0.0 in. to 0.5 in. the reading at 0.5 in. is 4990.6 mv. If the potentiometer is moved from 1.0 in. to 0.5 in. the reading at 0.5 in. is 5032.2 mv. This difference of 42 mv represents a 28 arc sec error for a SEUTS application.

- The wiper appears to jump such that essentially continuous resolution cannot be assured. A slow advance of the potentiometer produced changes ranging for 0.1 mv to approximately 10 mv (6.6 arc sec).

- The wiper jumps 4-6 mv (2.6-4.0 arc sec) if subjected to tapping on the case. This implies a stress build-up which is relieved by vibration.

CAS ACTUATOR

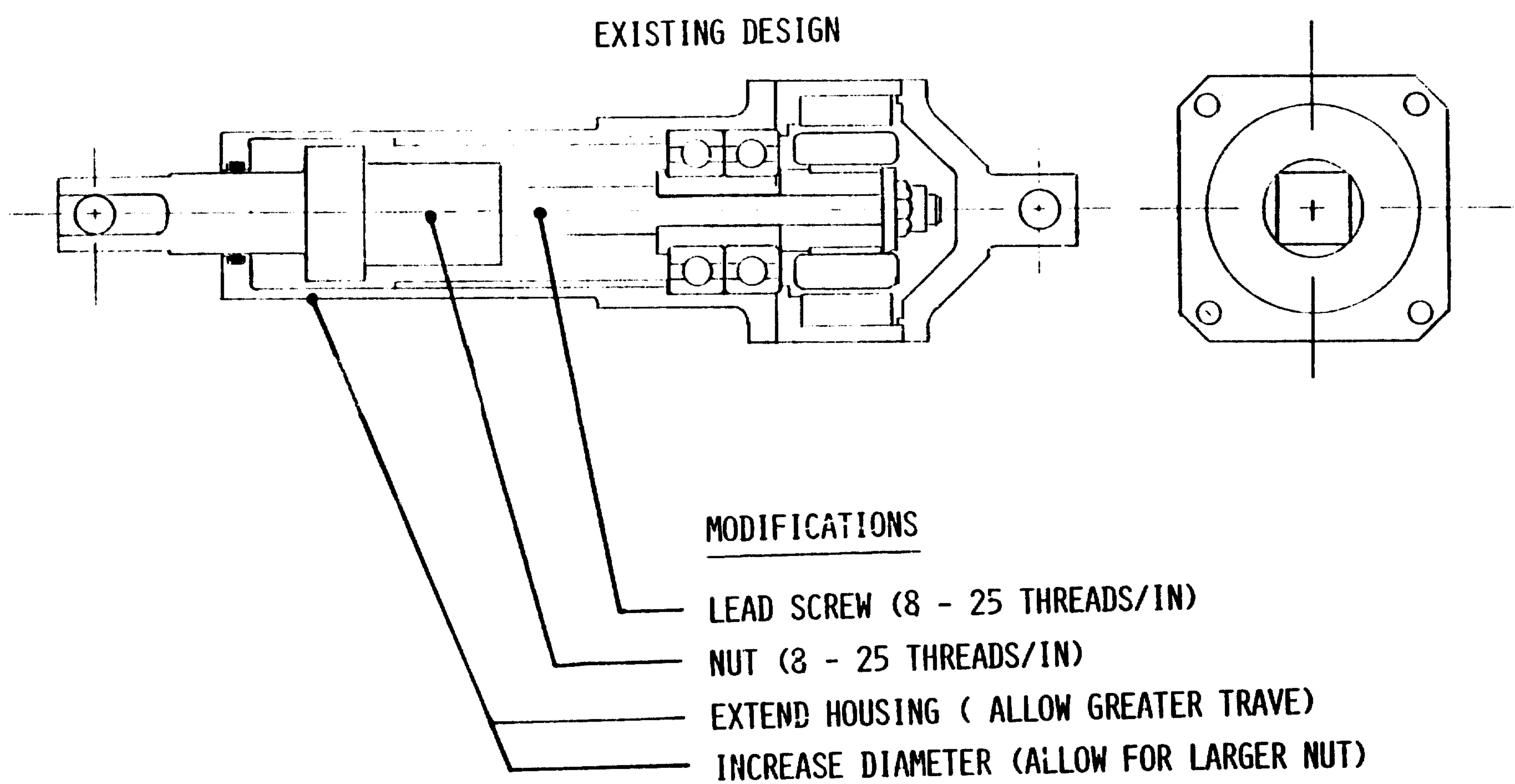
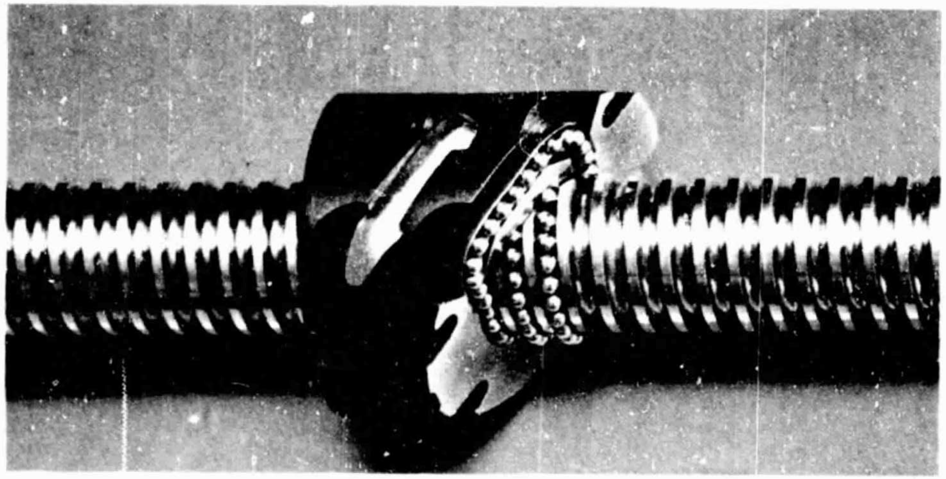
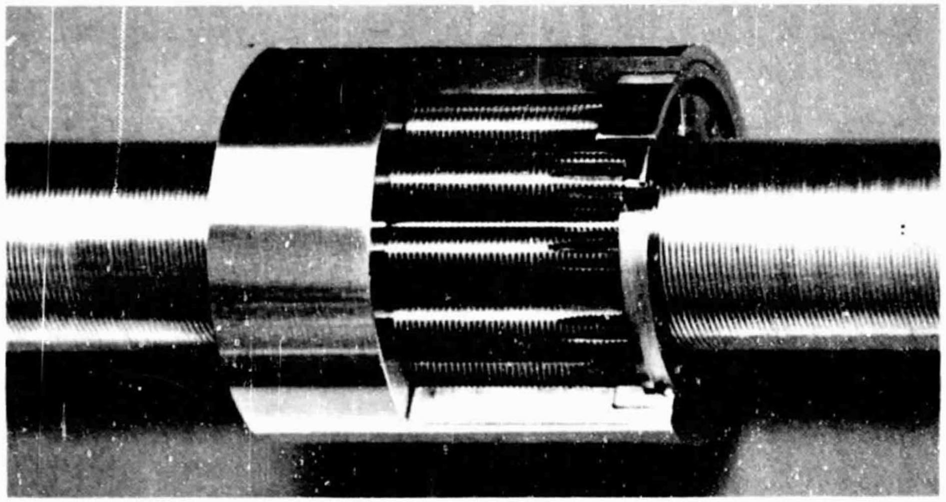


FIG. 6-1



UVSP CAS TYPE
BALL SCREW



ALTERNATIVE
PLANETARY ROLLER
SCREW

FIG. 6-2 POTENTIAL CAS ACTUATOR SCREWS

TABLE 6-3

EXISTING UVSP CAS POTENTIOMETER
(BOURNS MODEL 184)

ITEM	SPEC VALUE	TEST RESULTS
RANGE	1.0 IN	- - -
LINEARITY	1.0% MAX: 100MV (66 SEC.)	~ 2.5% MAX: 250 MV (164 SEC)
ACCURACY	NOT SPECIFIED	MAX: 70 MV (46 SEC) SIMPLE CALIB. TYP: 20-30 MV (13-20 SEC) SIMPLE CALIB.
RESOLUTION	INFINITE	0.1 - 10 MV (.1 - 7 SEC)
REPEATABILITY	± 0.1% (10 MV)	FROM SAME DIRECTION: 1-4 MV (.6 - 2.6 SEC) FROM DIFF. DIRECTIONS: 40-60M (26-40 SEC)

F80-12

These problems limit the useful resolution of the system and contribute to the accuracy errors.

BASD also had a Bourns Model 108 wire wound potentiometer which was procured many years ago, but which is still produced. While we recognized that it would have resolution problems associated with internal wire width, we were interested in its mechanical properties. The test results indicated that its mechanical properties were superior to the Model 184 potentiometer:

- The unit was more linear permitting use of a simple linear calibration curve to achieve 10 arc second accuracy.
- The difference between the readings depending upon direction of motion was much smaller (1-10 mv).
- The reading did not change when the case was tapped.

Unfortunately, the Model 108 potentiometer did exhibit the resolution limitations of a wire wound unit. As the wiper was moved across a wire, the reading changed less than 1 mv; however, as the wiper changed wires it would abruptly increase about 6 mv. For the point tested, the stair-steps were about 0.0017 in. wide or 5-6 arc sec (the Bourns specification indicates a 0.0013-0.0047 in.: 4-15 arc sec resolution). This type of potentiometer would also tend to cause jitter in the system. In reality only specific outputs are produced by each step. If a command were input that represented a voltage half-way between the steps, the system would "hunt" for the voltage by moving back and forth between steps, causing about 4 arc secs of jitter.

The solution to the potentiometer selection would be to combine the Infinitron continuous resolution element with a unit having mechanical properties similar to Model 108. Bourns indicates that their Model 178 is such a combination. However, without test data it is impossible to accurately assess its performance. If a potentiometer only system is selected for a SEUTS CAS an early procurement and test of this unit would be appropriate.

A number of other sensor alternatives were also investigated. These are listed in Table 6-4. All involve modification to the existing UVSP CAS electronics, whereas a potentiometer approach does not. Should greater accuracy be desired either the rotary potentiometer/LED or optical encoder/LED would be the recommended approaches. The rotary potentiometer/LED approach would be the least expensive.

6.4 ELECTRONICS

The UVSP CAS electronics shown in Figure 6-3 was used as the baseline for this analysis since they were specifically designed for potentiometer input and because they are packaged as a separate unit.

The UVSP CAS electronics operate by comparing the analog output from the potentiometer to a D/A converted command word. For the UVSP CAS, this command word was 16 bits with 12 bits used for position information. In theory, the UVSP CAS could be commanded to any of 4096 positions within ±1.79 deg. travel available from the potentiometer. Thus the command word has a resolution of 3.14 arc sec. However, the potentiometer lacked reliable resolution at this value and the system was specified for a 15 arc sec resolution. The last several bits of the command word are essentially irrelevant.

Relative to the SEUTS requirements, a command word of 12 bit is adequate to achieve 2 arc sec steps over the desired ±1.0 deg range. Consequently, the UVSP CAS electronics are satisfactory for a SEUTS application.

6.5 OVERALL SYSTEM PERFORMANCE

Table 6-5 compares the SEUTS requirements versus the performance of a system using UVSP components and versus a system using a presumably more accurate potentiometer.

For the purposes of the table, the accuracy values are the contribution of a CAS only, not the total system error. Furthermore, they assume a considerable amout of calibration testing to characterize potentiometer accuracy and cross-coupling. Table 6-6 identifies the CAS and overall system error sources and indicates which ones are calibratible.

TABLE 6-4

SENSOR ALTERNATIVES

SENSOR OPTIONS	RESOLUTION	ELECTRONICS/ACTUATOR MODS	SENSOR/MOD COST
• EXISTING POTENTIOMETER	6 $\widehat{SEC}$	NONE	\$100/\$0
• IMPROVED POTENTIOMETER	2 $\widehat{SEC}$	NONE	\$200/\$0
• ROTARY POT WITH LED REF FOR REVOLUTIONS	.2 $\widehat{SEC}$	• ADD LED COUNTER • ADD ROTARY POT ON SHAFT	\$400/\$30-40K
• SHAFT ENCODER WITH LED REF FOR REVOLUTIONS	1.3 $\widehat{SEC}$	• ADD LED COUNTER • ADD DIGITAL CONTROL ELECTRONIC • ADD SHAFT ENCODER TO ACTUATOR	\$2,000/\$60-75K
• INDUCTOSYN WITH COARSE REFERENCE	0,3 $\widehat{SEC}$	• ADD OSCILLATOR ELECTRONICS • ADD RESOLVER ELECTRONICS • MORE COMPLICATED MECH DESIGN	\$5,000/\$100K

CAS STUDY

UVSP BLOCK DIAGRAM

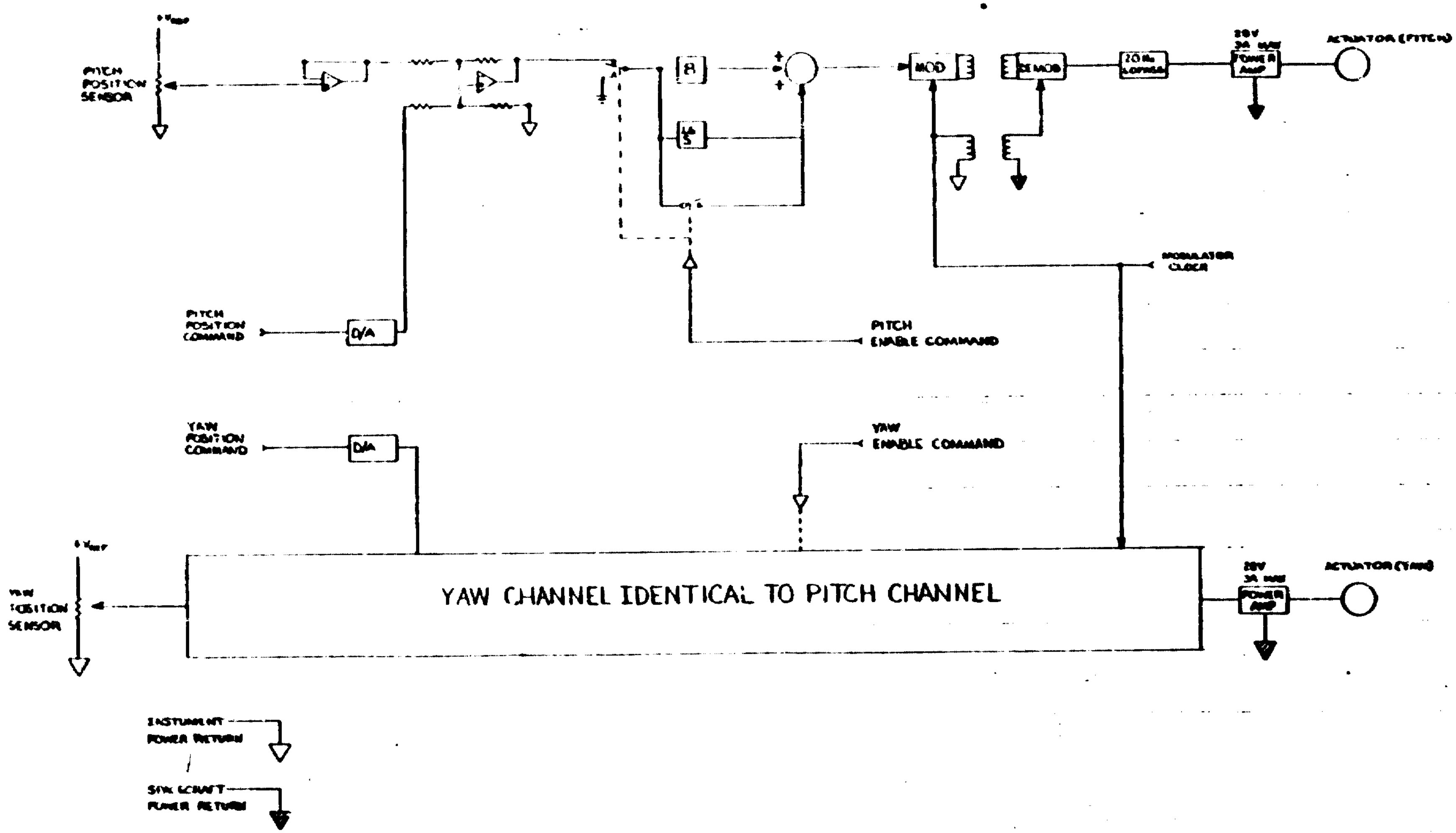


FIG. 6-3

TABLE 6-5

OFFSET PERFORMANCE

ITEM	REQUIREMENT	EXISTING CAS COMPONENTS	IMPROVED POT CONFIGURATION
• ACCURACY	10 SEC WITH CALIBRATION	15-48 SEC LINEAR POT. CAL. SOLID GEO C.C. CAL. NO TEMP. CAL.	9-18 SEC LINEAR POT. CAL. SOLID GEO C.C. CAL. NO TEMP. CAL.
• OFFSET STEP CAPABILITY	2 SEC	2-7 SEC	1.5-2 SEC
• RANGE	±0.5 DEG (REQ'D) ±1.0 DEG (GOAL)	±0.43 DEG	±0.86 DEG ASSUMES A 2.0 INCH STD. TRAVEL
• MANUAL STEP	2 SEC	8 SEC	8 SEC
• RATE OF MOVEMENT	20 SEC IN 2 SEC (GOAL)	BETTER THAN REQUIREMENT	BETTER THAN REQUIREMENT
• REPEATABILITY	NOT SPECIFIED 4 SEC ASSUMED GOAL	4-5 SEC SAME DIRECTION 27-41 SEC DIFF. DIRECTION	4.6 SEC

TABLE 6-6

OVERALL POINTING ERRORS

SOURCE	POSSIBLE ERROR (SEC)	COMMENT
• IPS SUN SENSOR (IPSSS)		(VALUES SIMILAR TO SMM FPS)
--LAUNCHED INDUCED NULL SHIFT	5	RANDOM
--NULL ACCURACY	0.1	
-LINEARITY	2	ASSUMES IPS USES CAL CURVES
• MECHANICAL MISALIGNMENTS		
--PRE-LAUNCH IPSSS TO SEUTS	1	MEASUREMENT UNCERTAINTY
--LAUNCH INDUCED IPSSS TO SEUTS	60-120	RANDOM
--POST-LAUNCH CRUCIFORM THERMAL	TBD	
• CAS OFFSET ACCURACY		
--TEMPERATURE (10^oC)	7-10	COULD BE CALIBRATED IF SYSTEM WAS THERMALLY TESTED
--POTENTIOMETER ACCURACY	5-10	ASSUMES GOOD POT AND SIMPLE LINEAR CALIBRATION
--VOLTAGE REGULATION	3	RANDOM
--CROSS COUPLING	220 @ 1^o 57 @ 0.5^o 14 @ 0.25^o	CAN BE REDUCED SHARPLY WITH SIMPLE LINEAR ESTIMATE OR TO 2-5% WITH REAL-TIME CALCULATION AND CORRECTION.
• SEUTS INTERNAL		
--LAUNCHED INDUCED --THERMAL	TBD	

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While much of the discussion in the previous paragraphs has concerned actuator, sensor, and electronics error sources, the largest problems in the system are associated with mechanical misalignments induced by vibration and cross-coupling within CAS. The mechanical misalignments throughout the large structural elements which make-up the overall system could easily be 60-120 arc seconds. They cannot be calibrated.

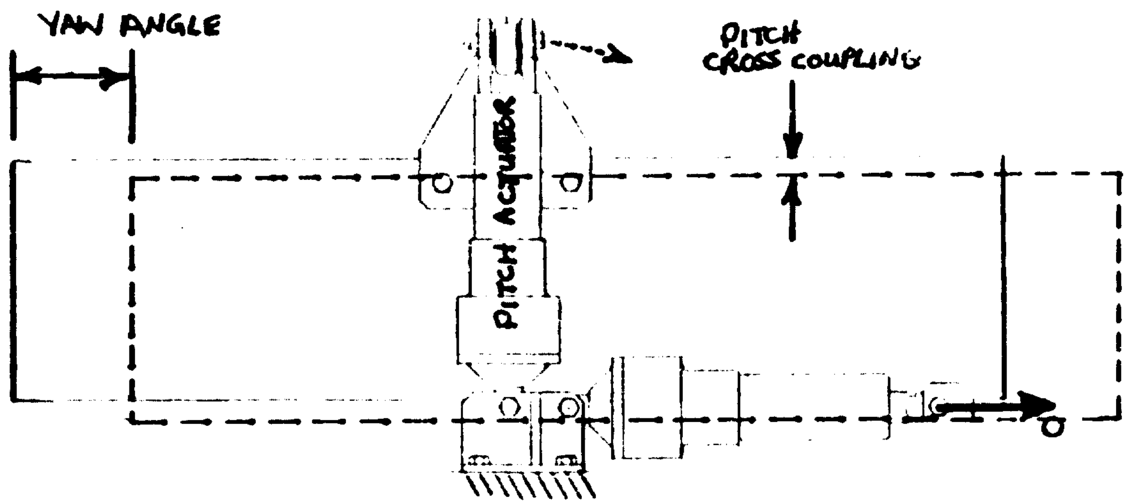
The CAS cross-coupling results from relying upon linear actuators offset from the gimbal center lines. Normally a minor concern, the 65.5 inch lever arm when moving small amounts such as a degree is capable of causing cross-coupling very significant to SEUTS. Figure 6-4 presents a sketch of what causes the cross-coupling. This sketch approximates the problem by assuming planar/motion. Figure 6-5 shows the cross-coupling pitch error versus yaw motion and some simple linear approximations.

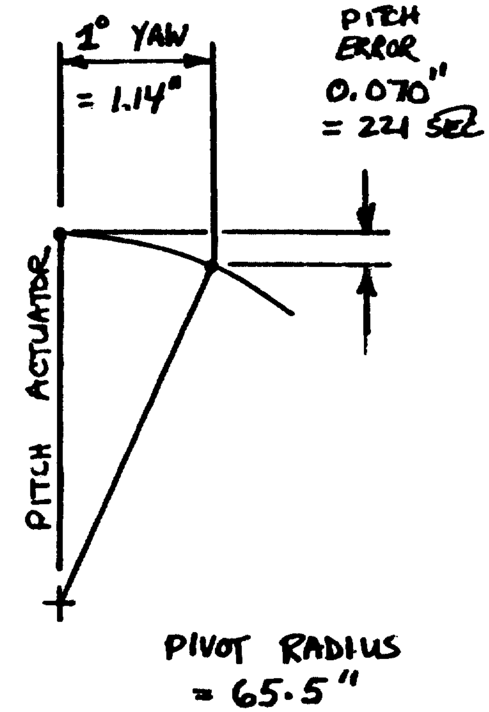
To reduce the cross-coupling problem to an acceptable value one could calibrate by test for all pitch and yaw positions. This is unrealistic for 2 arc second steps through a ±1.0 degree square field-of-view. The other alternative is to mathematically calculate the amount of cross-coupling (using either linear approximations or solid geometry) expected for a particular position and correct for it by adjusting the input commands. Such an approach assumes a computer either on the ground, in Spacelab, or in SEUTS. While a solid geometry computational approach could theoretically eliminate the cross-coupling errors, in reality, some small percentage would remain due to manufacturing tolerances.

An analysis of typical repeatibility and short term drift errors was also performed. The results are presented in Table 6-7 and 6-8, respectively.

Based upon the forgoing analysis, BASD's conclusion is that a CAS based upon a better potentiometer is marginal relative to the SEUTS requirements. Furthermore, without directly sensing position relative to the sun, large errors undectable by CAS exist.

DESCRIPTION OF CROSS COUPLING SOURCE





ACTUATOR DESIGN

GEOMETRY EFFECTS

FIG. 6-4

CROSS COUPLING ERRORS

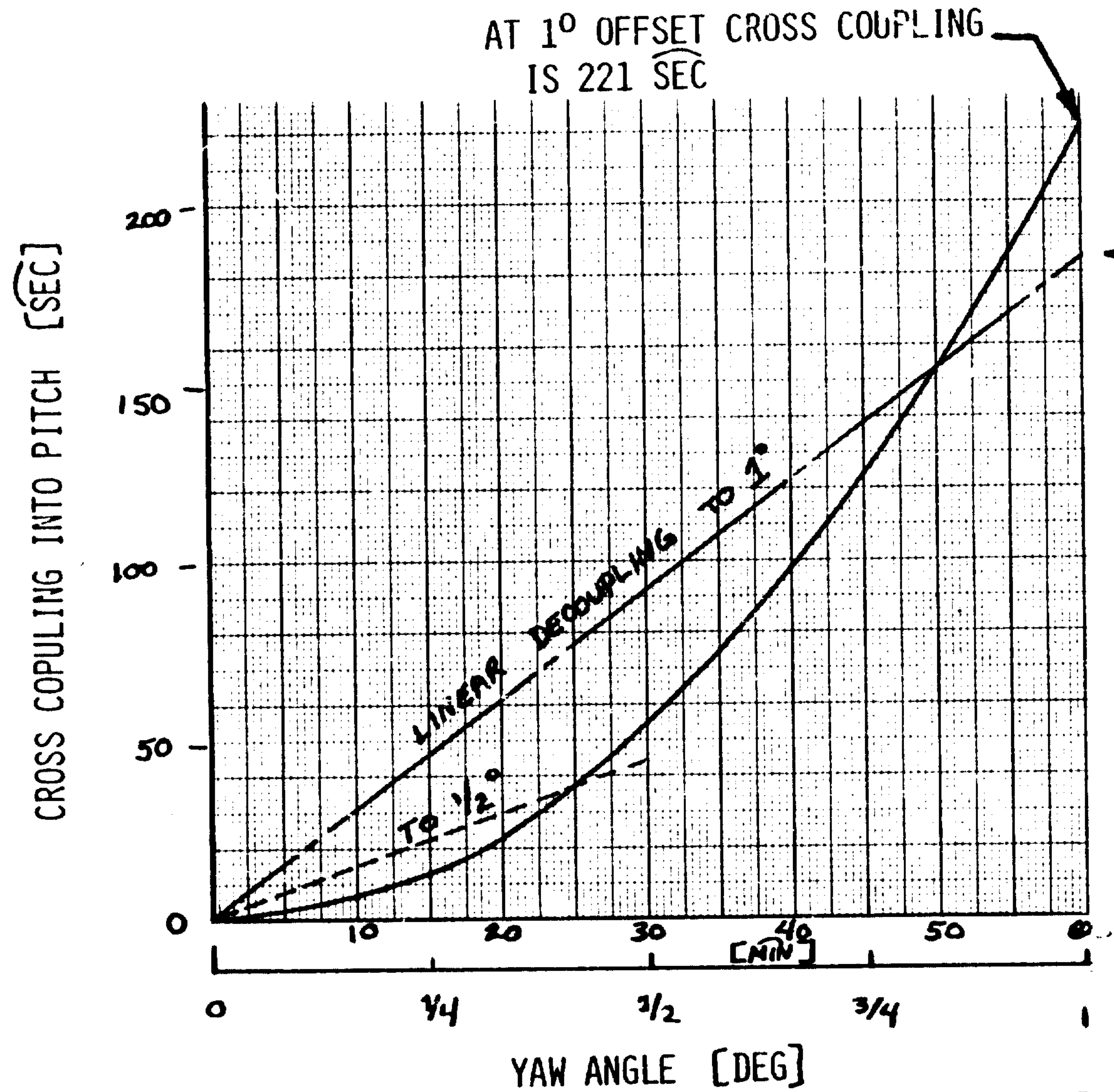


FIGURE 6-5

- LINEAR (SIMPLEST) DECOUPLING TO 1° REDUCED MAX. ERROR TO 38 SEC
- LINEAR DECOUPLING TO 1/2° REDUCES MAX. ERROR TO 10 SEC
- ERRORS ARE REPEATABLE AND PREDICTABLE
- PITCH TO YAW COUPLING IS SAME AS YAW TO PITCH COUPLING

TABLE 6-7

TYPICAL REPEATABILITY ERROR

CAUSE	COMPONENT	POSSIBLE EFFECT	POSSIBLE ERROR
• TEMPERATURE CHANGES $1^{O}C$ OVER 1.5 HOURS	• POWER SUPPLY (±15V)	.2% IN ± 15V	.3 $\widehat{SEC}$ MOSTLY DUE TO D/A
	• V_{REF} SOURCE (+10V)	.7MV	.3 $\widehat{SEC}$
	• OTHER COMPONENTS	VARIOUS	.1 $\widehat{SEC}$
• EXTERNAL BUS VARIATIONS 24-32 VDC	• POWER SUPPLY	1% IN ± 15V	1.5 $\widehat{SEC}$ MOSTLY DUE TO D/A
• INTERNAL LOAD VARIATIONS (LINE DRIVERS, ETC)	• POWER SUPPLY	1% IN ± 15V	1.5 $\widehat{SEC}$ MOSTLY DUE TO D/A
• POSITION SENSING REPEATABILITY	• POTENTIOMETER	+ 6 MV	4 $\widehat{SEC}$
• MECHANICAL	• ACTUATOR LEAD SCREW	.0001 IN	.3 $\widehat{SEC}$
• INTERNAL AND EXTERNAL NOISE	• VARIOUS	• MINOR DUE TO FILTERING AND NARROW BANDWIDTH	.2 $\widehat{SEC}$
			RSS TOTAL: 4.6 $\widehat{SEC}$

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TABLE 6-8

TYPICAL SHORT TERM DRIFT ERRORS

CAUSE	COMPONENT	POSSIBLE EFFECT	POSSIBLE ERROR
• TEMPERATURE CHANGES .25°C OVER 5 MIN.	• POWER SUPPLY (±15V)	.04% IN ± 15V	.1 $\widehat{SEC}$ (D/A)
	• V_{REF} SOURCE	.2 MV	.1 $\widehat{SEC}$
	• OTHER COMPONENTS	VARIOUS	NEGLIGIBLE
• EXTERNAL BUS VARIATIONS- 2 VDC	• POWER SUPPLY	.2% IN ± 15V	.3 $\widehat{SEC}$ (D/A)
• INTERNAL LOAD VARIATIONS (LINE DRIVERS, ETC)	• POWER SUPPLY	NEGLIGIBLE FOR A FIXED POSITION	NEGLIGIBLE
• POSITION SENSING	• POTENTIOMETER	.1 MV	NEGLIGIBLE
• MECHANICAL	• ACTUATOR LEAD SCREW	.0001 IN	.3 $\widehat{SEC}$
• INTERNAL AND EXTERNAL NOISE	• VARIOUS	• MINOR DUE TO FILTERING AND NARROW BANDWIDTH	.2 $\widehat{SEC}$
			RSS TOTAL: 0.5 $\widehat{SEC}$

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Several other items of interest are indicated below:

Power: Typical Offset Motion: 58W during acquisition, total both axes.

Steady State: 5-18W to maintain pointing.

Max Power: 228W for a 32 VDC bus (assumes system is against the stops)

Momentum Imparted to IPS By a Step Motion: Assuming a 10 arc sec/sec rate, the momentum imported to IPS by initiating a CAS motion is 0.0038 ft. lb. sec (one axis). For a small step, this momentum would almost be instanteously removed as CAS stopped upon reaching the commanded offset.

Movement and Settling Time For a 2-20 Arc Sec Steps: Less than 0.5 sec.

Interfaces: Since the modifications to the UVSP CAS electronics are internal, the interface section of the SMM Co-alignment Adjustment System (CAS) Specification #409-2202-0001A can be used for a preliminary definition. The applicable portions of this specification have been reproduced as Appendix A to this document. We recommend that the digital output of the SMM FPSS be used for telemetry readout and be routed directly to SEUTS or to a RAU.

Section 7
TASK 3 - STUDY OF CLOSED LOOP CAPABILITIES

The previous section analyzed the capabilities of a CAS which uses potentiometers to sense offset motions of the CAS baseplate. This section will address the capabilities of a CAS which uses a sun sensor mounted on the front of the SEUTS instrument. This form of closed-loop control based upon continually sensing solar position was used for the Coronograph/Polarimeter instrument/ CAS.

7.1 ANALYSIS OF SEUTS REQUIREMENTS

The SEUTS requirements in this mode of operation are the same as described in Section 6.1. Similiar to the preceding section these requirements will first be analyzed at the actuator, sensor, and electronics level and then summarized at the system level.

7.2 ACTUATORS

The actuators required for a closed-loop sun sensor mode are the same as described in Section 6.2.

7.3 SENSORS

The sun sensor for the C/P CAS was mounted internal to the C/P instrument in the optical path. However, since no full sun image exists within SEUTS this particular sensor is not applicable. An externally mounted sensor coaligned with the SEUTS line of sight is required.

Several sun sensor alternatives exist and are compared in Table 7-1.

<u>SMM Fine Position Sun Sensor</u>: The SMM fine position sun sensor is the most accurate sensor currently available. It clearly has the required resolution although it is marginal if one directly combines the potential null shift and linearity errors. However, the linearity errors can be calibrated such that 10 arc sec accuracy can be obtained within ±0.5 degrees. The one limitation

TABLE 7-1

SUN SENSORS

ITEM	SMM FPSS	SPARCS FSS	BASD S-100 (OSO-6)
1. FOV	± 2.0 DEG	± 3.0 DEG	± 15 DEG
2. LINEAR RANGE	± 30 $\widehat{\text{MIN}}$	± 2.5 $\widehat{\text{MIN}}$	± 20 $\widehat{\text{MIN}}$
3. ACCURACY			
• NULL	0.01 $\widehat{\text{SEC}}$ AFTER A 5 $\widehat{\text{SEC}}$ LAUNCH SHIFT	2 $\widehat{\text{SEC}}$	5 $\widehat{\text{SEC}}$ TEST
• OVER LINEAR RANGE	± 10 $\widehat{\text{SEC}}$ OF LINEAR SLOPE FOR ± 20 $\widehat{\text{MIN}}$ ± 20 $\widehat{\text{SEC}}$ OF LINEAR SLOPE FOR ± 20 $\widehat{\text{MIN}}$ TO ± 30 $\widehat{\text{MIN}}$	2 $\widehat{\text{SEC}}$ ± 10% OF INPUT ANGLE	± 20 $\widehat{\text{SEC}}$ OF LINEAR SLOPE
4. RESOLUTION	0.01 $\widehat{\text{SEC}}$	0.2 $\widehat{\text{SEC}}$	VIRTUALLY INFINITE
5. OUTPUT	± 10 V	± 10 V	35 μA/$\widehat{\text{MIN}}$

of this sensor is that the linear range is defined as ±0.5 deg. which would make calibration more difficult and potentially less accurate. A spare SMM FPSS does exist and conceivably could be used for SEUTS.

SPARCS Fine Sun Sensor: The SPARCS fine sun sensor is far less accurate than either the SMM FPSS or BASD's S100 fine eye block. It is recommended only if it is available as GFE and SEUTS can tolerate its lower performance.

BASD S100 Fine Eye Block: BASD has used the S100 series of fine solar eyes on its OSO and USAF P78-1 spacecraft. While the specification sheets indicate an accuracy of $\leq$ 1 arc min., test data shows that the null accuracy is better than 5 arc sec. and variations from the linear slope to be 5-20 arc sec. Resolution is adequate to achieve 2 arc sec steps. With calibration, the S100 fine eye block is adequate for SEUTS and would cost around $25K. However, the electronics for these units were generally part of the control systems and used parts that are out of date today. An electronics unit would have to be designed using modern parts.

7.4 Electronics

Table 7-2 compares the electronics modifications necessary for the UVSP and C/P CAS electronics. The UVSP CAS electronics represents the easiest and cheapest to modify and, therefore, is recommended.

7.5 Overall Performance

Table 7-3 compares the SEUTS requirements versus the performance of a system using the SMM FPSS. The overall system performance is shown in Table 7-4. Using a SEUTS mounted sun sensor eliminates the major errors associated with launch vibration and CAS cross-coupling. However, depending upon how much the actual SMM FPSS output (not the specification value) departs from linearity a non-linear calibration curve may be required. This represents no problem if all offset commands are generated on the ground, but it may require considerable storage if the commands are issued on-board the Orbiter.

TABLE 7-2

ELECTRONICS

MODIFICATIONS REQUIRED

SENSOR	UVSP CAS	HAO C/P CAS
SMM FPSS SENSOR	ANALOG SENSOR OUTPUT WILL BE USED IN PLACE OF POT OUTPUT. MINOR MODS TO TWO BOARDS ARE REQUIRED TO ACCEPT ± 10 VDC VS. 0-10 VDC: MINOR REDESIGN. ALREADY PACKAGED IN A SEPARATED BOX.	REPLACE 6 BIT OFFSET D/A WITH 12 BIT D/A, REMOVE SENSOR ELECTRONICS AND USE FPSS ANALOG OUTPUT. EXTENSIVE REDESIGN. REQUIRE PACKAGING IN A SEPARATE BOX.

CONCLUSION: USE UVSP CAS ELECTRONICS FOR EITHER SENSOR.

TABLE 7-3

OFFSET PERFORMANCE USING THE SMM FPSS

ITEM	REQUIREMENT	RECOMMENDED CONFIGURATION	COMMENT
• ACCURACY	10 $\widehat{SEC}$	8-12 $\widehat{SEC}$	CAN BE REDUCED BY UPGRADING V_{REF} SOURCE
• OFFSET STEP CAPABILITY	2 $\widehat{SEC}$	1.5-1.8 $\widehat{SEC}$	
• RANGE	±0.5 DEG (REQ'D) ±1.0 DEG (GOAL)	±0.5 DEG LINEAR RANGE ±1.0 DEG AVAILABLE	
• MANUAL STEP	2 $\widehat{SEC}$	3 $\widehat{SEC}$ AVG	25 THREAD/IN LEAD SCREW REQUIRED TO ACHIEVE 2 $\widehat{SEC}$
• RATE OF MOVEMENT	20 $\widehat{SEC}$ IN 2 SEC GOAL	BETTER THAN REQM'T	
• REPEATABILITY	NOT SPECIFIED 4 $\widehat{SEC}$ ASSUMED GOAL	2-3 $\widehat{SEC}$	

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TABLE 7-4

OVERALL POINTING ERRORS - SMM FPSS SYSTEM

SOURCE	POSSIBLE ERROR (SEC)	COMMENT
• IPS SUN SENSOR	N/A	USED ONLY FOR "COARSE" CONTROL.
• MECHANICAL MISALIGNMENT	N/A	ELIMINATED BY SEUTS MOUNTED SUN SENSOR.
• CAS OFFSET ACCURACY		
--TEMPERATURE ($10^{o}C$)	7-10	COULD BE CALIBRATED IF SYSTEM WAS THERMALLY TESTED.
--SUN SENSOR ACCURACY	2-5	ASSUMES CALIBRATION--PROBABLY NOT LINEAR.
--VOLTAGE REGULATION	3	RANDOM.
--CROSS COUPLING	N/A	ELIMINATED BY SEUTS MOUNTED SENSOR.
--SUN SENSOR ALIGNMENT	1	
RSS	8-12	
• SEUTS INTERNAL		
--LAUNCHED INDUCED	TBD	
--THERMAL	TBD	

Several other items of interest are indicated below.

Power: Typical Offset Motion: 60W for during acquisition, total both axes (includes 2W for SMM FPSS).

Steady State: 5-20W to maintain pointing (includes 2W for SMM FPSS)

Max Power: 230 watts for a 32 VDC bus (assumes system is up against stops).

Momentum Imparted to IPS By a Step Motion: Assuming a 10 arc sec/sec rate, the momentum imparted to IPS by initiating a CAS motion is .0038 ft. lb. sec (one axis). For small steps, this momentum would be almost instanteously removed as CAS stoped upon reaching the desired offset.

Movement and Settling Time For a 2-20 arc sec Steps: Less than 0.5 sec

Interfaces: Since the modifications to the UVSP CAS electronics are internal, the interface section of the SMM Co-alignment Adjustment System (CAS) Specification #409-2202-0001A can be used for a preliminary definition. The applicable portions of this specification have been reproduced as Appendix A to this document. We recommend that the digital output of the SMM FPSS be used for telemetry readout and be routed directly to SEUTS or to a RAU.

APPENDIX A

This excerpt from the SMM Co-Alignment Adjustment System (CAS) Specification #409-2202-0001A will serve as a preliminary definition of electrical and mechanical interfaces. As the SEUTS design evolves, these interfaces will be subject of normal definition and updating.

4. INTERFACE

An Electrical Block Diagram for the CAS is shown in Figure 4-1.

4.1 GROUNDING

4.1.1 General

A single point ground system will be used in the SMM spacecraft. In order to ensure that the Co-Alignment Adjustment System grounding configuration will be compatible with the spacecraft, it is required that the grounds be wired as described in the following paragraphs.

4.1.2 Chassis Ground

a. The chassis ground shall be DC isolated from all input and output circuitry.

b. DC isolation between the chassis and all internal circuitry shall be at least 10 megohms tested with a 50 volts source.

c. The mounting surfaces of the chassis shall be finished with an electrically conductive finish. All chassis junctions shall be electrically conductive to optimize shielding.

d. The chassis will be grounded to the spacecraft structure directly or via bonding straps.

e. The shells of all connectors interfacing with the spacecraft harness shall be grounded to the chassis.

4.1.3 Shield Grounds

a. At least one shield ground contact shall be provided on each connector interfacing with the spacecraft harness.

b. Shield ground contacts shall be connected to the chassis internally via very short leads.

c. Shields on high level circuitry (0-5V, etc.) internal to the CAS shall be connected to the chassis, at only one end, via short internal leads.

d. Shields on low level circuitry within the CAS may be treated as required for optimum performance.

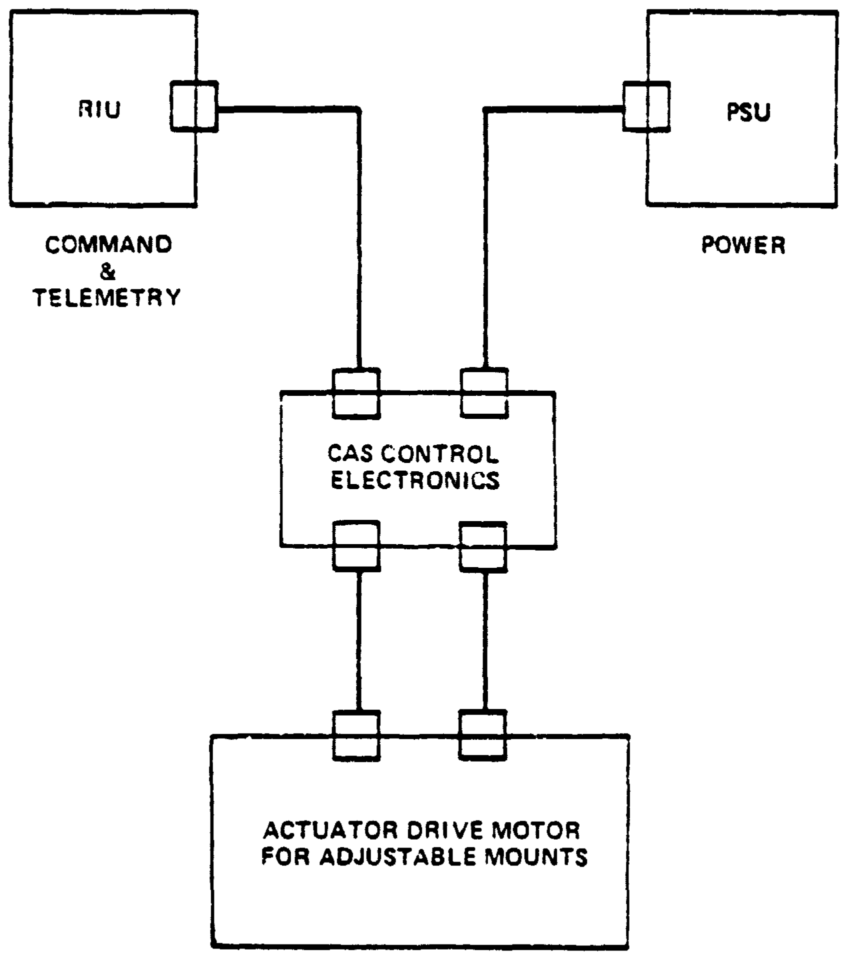


Figure 4-1. Electrical Block Diagram

4.1.4 Signal Return

a. For direct currents, the signal return shall be electrically isolated from the power return and chassis.

b. The DC isolation resistance shall be at least 10 megohms to the chassis or the power return.

c. The signal return may be connected to chassis ground internally via AF/RF bypass capacitors (less than 0.5 μfd total) to minimize the effects of the impedance of the signal return lead at high frequencies.

d. All input/output circuitry except power and internal command relay drives shall be referenced to the signal return.

e. Redundant signal return contacts shall be provided on data output connectors and the test connector. Signal ground contacts shall be provided on other connectors to increase system flexibility.

f. The signal return will be connected to the spacecraft structure at a point to be determined by the SMM Project.

4.1.5 Power Returns

a. The power returns shall be isolated from the signal ground and the chassis.

b. Power returns for redundant assemblies shall be isolated from each other. The design shall be such that a failure in one of the redundant units shall not open the power return of the other unit.

4.1.6 Command Relay Returns

The CAS shall provide a separate return for the coil current of relays controlled by the spacecraft command circuitry. Diodes or other types of transient suppressors for the relay coils shall be connected directly across the coils and located as close as possible to the relay.

4.2 CONNECTORS

4.2.1 Allowable Interface and Intra-Instrument Harness Connector Types

Connectors used on the CAS which will interface with the spacecraft harness shall be of the subminiature rectangular "HD 20" or "HD 22" series. These connectors shall conform to GSFC S-311-P4. These type connectors have previously been designated as "Cannon Golden-D" or "DMA" series, and are available in standard density contacts (i.e., 9 to 50 pins) and high density contacts (i.e., 15 to 104 pins).

The standard connectors to be utilitzed are keystone shaped connectors manufactured primarily by ITT Cannon Electric Company and AMP, Inc. The following chart details the interface connectors and pin arrangements which shall be used.

Shell Size	1	2	3	4	5	6
HD 20	9	15	25	37	50	
HD 22	15	26	44	62	78	104
Coaxial		3	5	8		
Hybrid		7W2	17W2			

Table 4-2 is a GSFC/Vendor Cross Reference List. "HD 20" is the current proper nomenclature to be used when requesting connectors previously referred to as "Cannon Golden-D" or "DMA" series. Three contacts are available: one for #26 Awg wire and smaller, one for #20 through #24 Awg wire, and one for #18 Awg wire. "HD 22" is the proper nomenclature to be used when requesting high density interface connectors. Two contacts are available: One for #26 Awg wire and smaller and one for #22 through #24 Awg wire. Coaxial interface requirements will be met with co-ax only arrangements. Hybrid arrangements (i.e., co-ax and power contacts in the small shell) will be supplied when no other solution is feasible.

4.2.1.1 <u>Connector Tools.</u> Tools required to crimp the contacts to wires are as follows:

M22520/2-01 - Hand Crimping Tool
M22520/2-08 - HD 20 Contact Positioner
M22520/2-06 - HD 22 Socket Contact Positioner
M22520/2-09 - HD 22 Pin Contact Positioner

4.2.1.2 <u>Connector Shell Finish.</u> The shells of all receptacles and plugs shall be finished with an electrically conductive finish (cadmium finishes shall not be employed). Because of the potentially high R. F. fields at 2.2 GHz to 2.4 GHz, care must be taken to ensure the connector to electronic frame surfaces are electrically tight and sealed. The external harness connector mate must be capable of accommodating a harness outer shield termination.

Table 4-2
GSFC/Vendor Connector Cross Reference List

Description	Space Flight Quality			Non-Flight MIL-SPEC Blocks and Contacts
	GSFC Part Number	AMP Inc.	ITT Cannon Electric	
HD20 9 Pos Female Blocks Only	311P409-1-S-B-15		DEMA-9S-NMB-76-FO	M24308/2-1
HD20 9 Pos Male Blocks Only	311P409-1-P-B-15		DEMA-9P-NMB-76-FO	M24308/4-1
HD20 15 Pos Female Blocks Only	311P409-2-S-B-15	206799-1	DAMA-15S-NMB-76-FO	M24308/2-2
HD20 15 Pos Male Blocks Only	311P409-2-P-B-15	206798-1	DAMA-15P-NMB-76-FO	M24308/4-2
HD20 25 Pos Female Blocks Only	311P409-3-S-B-15	206801-1	DBMA-25S-NMB-76-FO	M24308/2-3
HD20 25 Pos Male Blocks Only	311P409-3-P-B-15	206800-1	DBMA-25P-NMB-76-FO	M24308/4-3
HD20 37 Pos Female Blocks Only	311P409-4-S-B-15	206803-1	DCMA-37S-NMB-76-FO	M24308/2-4
HD20 37 Pos Male Blocks Only	311P409-4-P-B-15	206802-1	DCMA-37P-NMB-76-FO	M24308/4-4
HD20 50 Pos Female Blocks Only	311P409-5-S-B-15	206805-1	DDMA-50S-NMB-76-FO	M24308/2-5
HD20 50 Pos Male Blocks Only	311P409-5-P-B-15	206804-1	DDMA-50P-NMB-76-FO	M24308/4-5
HD20 18 Awg Female Contacts Only	Reference		031-1007-0055	
HD20 18 Awg Male Contacts Only	GSFC-S-311-P-4/10		330-5291-036	
HD20 20 Awg Female Contacts Only	G 10 S 1	206793-1	031-1007-010	M24308/10-1
HD20 20 Awg Male Contacts Only	G 10 P 1	205089-1	330-5291-002	M24308/11-1
HD20 26 Awg Female Contacts Only	Reference	206795-3	031-1007-031	
HE20 26 Awg Male Contacts Only	GSFC-S-311-P-4/10	206794-4	330-5291-031	

Table 4-2 (Continued)

Description	Space Flight Quality			Non-Flight MIL-SPEC Blocks and Contacts
	GSFC Part Number	AMP Inc.	ITT Cannon Electric	
HD20 Contact Removal Tool		91067-2		M24308/18-2
HD22 15 Pos Female Blocks Only	311P407-1-S-B-15	206499-1		M24308/2-17
HD22 15 Pos Male Blocks Only	311P407-1-P-B-15	206498-1		M24308/4-17
HD22 26 Pos Female Blocks Only	311P407-2-S-B-15	206501-1		M24308/2-18
HD22 26 Pos Male Blocks Only	311P407-2-P-B-15	206500-1		M24308/4-18
HD22 44 Pos Female Blocks Only	311P407-3-S-B-15	206064-2		M24308/2-19
HD22 44 Pos Male Blocks Only	311P407-3-P-B-15	206063-2		M24308/4-19
HD22 62 Pos Female Blocks Only	311P407-4-S-B-15	206503-1		M24308/2-20
HD22 62 Pos Male Blocks Only	311P407-4-P-B-15	206502-1		M24308/4-20
HD22 78 Pos Female Blocks Only	311P407-5-S-B-15	206505-1		M24308/2-21
HD22 78 Pos Male Blocks Only	311P407-5-P-B-15	206504-1		M24308/4-21
HD22 104 Pos Female Blocks Only	311P407-6-S-B-15	206065-2		M24308/2-22
HD22 104 Pos Male Blocks Only	311P407-6-P-B-15	206066-2		M24308/4-22
HD22 22 Awg Female Contacts Only	G 08 S 1	206071-1		M24308/12-1
HD22 22 Awg Male Contacts Only	G 08 P 1	204370-2		M24308/13-1
HD22 26 Awg Female Contacts Only	Reference	206496-1		
HD22 26 Awg Male Contacts Only	GSFC-S-311-P-4/8	206495-3		

Table 4-2 (Continued)

Description	Space Flight Quality			Non-Flight MIL-SPEC Blocks and Contacts
	GSFC Part Number	AMP Inc.	ITT Cannon Electric	
11922 Contact Insertion/Removal Tool		91067-1		M24308/18-1
Coax 3 Pos Female Blocks Only	G311P10-7-S-B-15		DAM-3W3S-NMB-76	
Coax 3 Pos Male Blocks Only	G311P10-7-P-B-15		DAM-3W3P-NMB-76	
Coax 5 Pos Female Blocks Only	G311P10-10S-B-15		DBM-5W5S-NMB-76	
Coax 5 Pos Male Blocks Only	G311P10-10P-B-15		DBM-5W5P-NMB-76	
Coax 8 Pos Female Blocks Only	G311P10-15S-B-15		DCM-8W8S-NMB-76	
Coax 8 Pos Male Blocks Only	G311P10-15P-B-15		DCM-8W8P-NMB-76	
Hybrid 7 Pos Female 2 Coax 5 Power	G311P10-8S-B-15		DAMB-7W2S-NMB-76	
Hybrid 7 Pos Male 2 Coax 5 Power	G311P10-8P-B-15		DAMB-7W2P-NMB-76	
Hybrid 17 Pos Female 2 Coax 5 Power	G311P10-13S-B-15		DBMB-17W2S-NMB-76	
Hybrid 17 Pos Male 2 Coax 15 Power	G3-1P10-13P-B-15		DBMB-17W2P-NMB-76	
Coax 50 ohm Female Contacts Only Straight RG 188 Coax Wire	Reference GSFC S311-P10		DM 53742-5095	
Coax 50 ohm Male Contacts Only Straight RF Coax Wire	Reference GSFC S311-P10		DM 53740-5109	
Coax 50 ohm Female Contacts Only Right Angle RG 188 Coax Wire	Reference GSFC S311-P10		DM 53743-5083	
Coax 50 ohm Male Contacts Only Right Angle RG 188 Coax Wire	Reference GSFC S311-P10		DM 53741-5064	

Table 4-2 (Continued)

Description	Space Flight Quality			Non-Flight MIL-SPEC Blocks and Contacts
	GSFC Part Number	AMP Inc.	ITT Cannon Electric	
Coax 95 ohm Female Contacts Only Straight RG 195 Coax Wire	Reference GSFC S311-P10		DM 53742-5098	
Coax 95 ohm Male Contacts Only Straight RF 195 Coax Wire	Reference GSFC S311-P10		DM 53740-5110	
Coax 95 ohm Female Contacts Wire Right Angle RG 195 Coax Wire	Reference GSFC S311-P10		DM 53743-5003	
Coax 95 ohm Male Contacts Wire Right Angle RG 195 Coax Wire	Reference GSFC S311-P10		DM 53741-5003	
Coax Contact Removal Tool			CET-C6B	
Screw Lock Assembly-Male-Small Clip Gold Plated Brass-NMB			D20419-74	
Screw Lock Assembly-Male-Large Clip Gold Plated Brass-NMB			D20420-67	
Screw Lock Assembly-Female-Stand-Off Gold Plated Brass NMB			D20418-52	

4.2.2 Connector Use and Pin Allocation

4.2.2.1 Contact Redundancy. Connector contact redundancy on circuits critical to successful operation of the CAS shall be used. Redundant contacts and wire shall be used as required on power circuits to stay within the space derated current ratings of the contacts and wire.

4.2.2.2 Power and Grounds. A single connector shall be dedicated for all power inputs and power grounds with the exception of pyrotechnic interfaces. This connector shall be a male connector.

4.2.2.3 Data Outputs. All data and monitoring outputs shall be located on female connectors. Signals less than 50 mv should be fed through coax connectors.

4.2.2.4 GSE Interfaces. Electrical interfaces which may be required for test stimulus and/or special prelaunch checkout of the CAS shall be routed to a separate female connector spacecraft interface. Power shall not be applied through a GSE connector. Signal isolation shall be provided at the GSE connector for all signals and functions such that no degradation of the normal spacecraft data would exist under open or shorted conditions.

4.2.2.5 Power Input and Return Contacts. Power input and return contacts shall be located on adjacent pins to facilitate twisting of power and return leads for magnetic field cancellation.

4.2.2.6 Chassis Ground Pins. At least two pins of the power input connector shall be dedicated to the chassis ground.

4.2.2.7 Shield Contacts. The contact(s) allocated for shield grounding shall be adjacent to the contact(s) connected to the shielded lead(s).

4.2.2.8 Spare Contacts. A minimum of 10 percent or 2 spare contacts shall be provided on each connector.

4.2.2.9 Connector Keying and Identification. Connector type and placement on the instrument shall be selected to minimize the possibility of mating incorrect pairs. Positive keying for round connectors and connectors requiring blind mating shall be employed.

4.3 POWER SUBSYSTEM

4.3.1 General Discussion

The Solar Maximum Mission (SMM) power subsystem will use solar cells as the primary source of power, and nickel-cadmium batteries for energy storage. The power buses will provide unregulated voltage to all loads according to the characteristics given in Paragraph 4.3.3. The power lines to all loads considered non-essential to the operation of the SMM will contain fuses.

4.3.2 Power Distribution

Spacecraft power will be distributed to the subsystems and payload from positive power buses (negative grounded) located in the Modular Power Subsystem (MPS). Distribution buses and the impedance of circuitry within the MPS will be designed to minimize common impedances which could cause cross coupling of bu noise between spacecraft loads. The negative bus will be grounded to the spacecraft structure at the Central Ground Point (CGP) per Paragraph 4.1.

4.3.3 Power Subsystem Characteristics

The following MPS characteristics are defined at the structure side of the power subsystem/structure interface connector. The line loss between the MPS interface connector and the CAS connector shall be limited to the requirements of Paragraph 4.3.5.

4.3.3.1 Voltage. 21 to 35 Volts dc, negative grounded to structure.

4.3.3.2 Source Impedance.

Maximum:	0.1 ohm	- 1 Hz to 1 KHz
	0.15 ohm	- 1 KHz to 20 KHz
	0.3 ohm	- 20 KHz to 100 KHz

4.3.3.3 Transients.

a. Normal Transients

Normal transients on the power bus, those due to MPS operation and load switching, will not exceed the following values:

zero to 10 μs	3.0 Volts, Maximum
10 μs to 1.0 ms	1.0 Volts, Maximum
>1.0 ms*	±5.0 Volts, Maximum within the 21 to 35 Volt operating range

*Rate of rise	<0.5 Volt per μs
Rate of fall	<5.0 Volts per ms

b. Abnormal Transients

During abnormal transients, the MPS output voltage will remain within the range of zero to 40 volts dc. The duration of abnormal transients will not exceed 500 milliseconds. Abnormal transients are those transients that may occur as a result of internal faults in the MPS or external faults on the spacecraft power bus.

Note: The CAS shall survive abnormal transients without permanent damage. The loss of stored data or change of state of circuitry under these conditions is acceptable.

4.3.3.4 <u>Output Ripple</u>. The output ripple of the power subsystem alone will be less than 750 mv, peak-to-peak over all frequency ranges, 1 Hz to 10 MHz. The output ripple of the power subsystem including the effect of all loads will not exceed 1.5 volts peak-to-peak.

4.3.4 Power Interface Requirements

The following requirements shall be placed on the CAS.

4.3.4.1 <u>Turn-On Transients</u>. Transient turn-on current drawn by the CAS shall not exceed the following limits:

a. The initial inrush current due to distributed capacitance, EMI filters, etc., shall not exceed 10 amperes peak for 10 microseconds.

b. The rate of change of inrush current after the initial surge shall not exceed 20 milliamperes per microsecond.

c. For loads of 50 watts or less, the transient current shall not exceed 300 percent of the maximum steady-state current.

d. For loads greater than 50 watts, the transient current shall not exceed 200 percent of the maximum steady-state current.

e. Steady state operation shall be attained within 50 milliseconds from the start of the transient.

4.3.4.2 Turn-Off Transients. The peak voltage of transients generated on the power lines (load side) of the CAS during turn-off due to inductive effects shall not exceed plus 55 or minus 20 volts dc with respect to ground. (The designer shall take adequate precautions to prevent damage of parts such as capacitors or semi-conductors due to polarity reversal.)

4.3.4.3 Operational Transients. Operational transients, those occurring after initial turn-on, shall not exceed 125 percent of the maximum peak operational current drawn during normal operation. The maximum duration of the transients shall not exceed 50 milliseconds. The rate of change of current during the transients shall not exceed 20 milliamperes per microsecond. The maximum incremental change in load on the MPS bus shall not exceed 500 watts during a one-second time interval for increasing or decreasing loads.

4.3.4.4 Reflected Ripple Current. The peak-to-peak amplitude of steady-state load current ripple generated by the CAS shall not exceed 5 percent of the maximum, average, steady-state current. The fundamental frequency of load current ripple shall not exceed 50 kHz.

4.3.4.5 Current Limiting. Passive or active current limiting shall be employed as required to limit in-rush current. In-rush current limits shall be imposed on all switched power circuitry. Peak current shall not exceed 50 percent of the current rating of relay contacts during make and break operations. (Paralleling of contacts does not increase current rating.) Turn-on transient requirements are defined in Section 4.3.4.1.

4.3.5 Power Wiring

Power will be distributed via twisted pairs of leads originating at the +28 volt and power ground buses in the MPS. Power distribution wiring losses between the power subsystem module interface connector and the CAS connector will not exceed 0.01 volts/amp/ft. for the +28 volt and return leads. Distribution and bus protection circuitry losses within the CAS shall be the responsibility of the contractor. Redundant circuitry shall be provided in all areas critical to a successful mission.

4.3.6 Undervoltage Behavior

If, for some reason, a battery undervoltage is sensed, all power to the nonessential loads will be removed to allow the batteries to recharge. After recovery of the battery bus, the individual relays may be opened prior to restoring unregulated power to prevent simultaneous power application to all equipments. The CAS shall survive, without permanent degradation, steady-state undervoltage of 21 Vdc and transient undervoltage from 21 Vdc to 0 Vdc for a period of 500 milliseconds, after which the bus voltage will be zero.

4.3.7 Overvoltage Behavior

The CAS shall survive, without permanent degradation, a transient overvoltage to +40 Vdc for 250 milliseconds after which the bus will return to +35 Vdc or less.

4.3.8 Load Profile

The contractor shall furnish the expected power profile at 21, 28, and 35 volts (watts versus time) and for the nominal and worst case modes of operation. The load profile curve shall delineate the following loads:

a. Power dissipation which is constant with input voltage variation

b. Resistance loads

c. Loads which have constant current versus voltage characteristics

4.4 COMMUNICATIONS AND DATA HANDLING

Command distribution, data acquisition, timing and synchronization functions are interfaced with a Standard Telemetry and Command Components Remote Interface Unit (RIU). The RIU has the following output signals that may be used by the CAS.

4.4.1 RIU Output Signals

The four types of output signals that are available from the RIU are:

Type 1	Switch closure-to signal ground
Type 2	+28 volt pulse
Type 3	Differential signal
Type 4	1 ma constant current pulse

4.4.1.1 Type 1 Signal. The type 1 signal is an open collector output. The normal state of the switch is open (inactive state) and the CAS shall provide a pull-up resistor with a diode in series to the voltage used when type 1 signals are used with logic circuits. Type 1 signals are used for discrete logic commands, discrete relay driver commands, enables, major frames, minor frames, and

C-2

telemetry word rate signals. The closure duration time will vary for different functions. The voltage and impedance characteristics of a type 1 signal are:

V_{oh} (inactive state)	Typical +5.0 Vdc, maximum +30.0 Vdc
I_{oh} (inactive state)	300 µamps max @ 30 Vdc
V_{01} (active state)	0.5 Vdc maximum @ 20 ma
I_{01} (active state)	Discrete commands 200 ma max. Enables and syncs 20 ma max.

4.4.1.2 Type 2 Signal. The type 2 signal is a +28 volt pulse with the following characteristics:

V_{01} (inactive state)	0.5 Vdc maximum
V_{oh} (active state)	28 ± 2 Vdc nominal
Source impedance	100 ohms
Current drive capability	200 ma min.
Pulse duration	6.5 to 7.0 ms (see Figure 4-4 for details and tolerances)

4.4.1.3 Type 3 Signal. The type 3 signals are differential outputs generated by a National Semiconductor DM-7830 Line Driver or equivalent. The voltage and impedance characteristics of a type 3 signal are:

Signals to be Transmitted	Driver Terminal Voltage with Respect to Signal Ground
Logical "1"	Positive voltage appears on "AND" output terminal V_{oh} = +5.0 Vdc max. V_{oh} = +2.4 Vdc min. Zero voltage appears on "AND" output terminal V_{01} = +0.4 Vdc max. V_{01} = 0.0 Vdc min.
Logical "0"	Zero voltage appears on "AND" output terminal V_{01} = +0.4 Vdc max. V_{01} = 0.0 Vdc min.

Positive voltage appears on "AND" output terminal
V_{oh} = +5.0 Vdc max.
V_{oh} = +2.4 min.

4.4.1.4 Type 4 Signal. The type 4 signal is a constant current output (in pulse form) of 1 ma ± 0.5 percent. This pulse has a duration of 46 microseconds and is used to drive passive transducers to produce analog voltage signals.

4.4.2 Command Distribution

Commands shall be distributed to the CAS by a Remote Interface Unit (RIU). One serial magnitude command will be distributed to the CAS and shall be used to generate the pointing offset voltage. Discrete logic or discrete relay driver commands are available to the CAS.

4.4.2.1 Serial Magnitude Command. The Serial Magnitude Command is 16 bits in length. Three signals are required to effect the transfer of a serial magnitude command from the RIU to the CAS. They are a command data signal, a command clock signal (gated clock pulses at a 256 kHz rate) and a serial magnitude command enable. The command data and command clock outputs are type 3 signals described in Paragraph 4.4.1.3.

The CAS interface circuit receiving the serial magnitude command data and command clock shall be a National Semiconductor DM-7820 line receiver or equivalent. The serial command enable is a type 1 signal, described in Paragraph 4.4.1.1, having a duration of 72.2 microseconds. Figure 4-2 shows the RIU timing for the serial magnitude command. Figure 4-3 shows the interface circuitry required to interface the CAS with redundant RIU's.

4.4.2.2 Discrete Commands. The discrete relay driver commands consist of a type 2 signal, described in Paragraph 4.4.1.2, that is common to all relay windings in the CAS, and a switch closure to ground for each relay winding. The switch closure to ground shall have the following characteristics:

V_{oh} (inactive state)	Floating, or Local (User) VCC (+30 volts, maximum)
Z_{oh} (inactive state)	1 Megohm
V_{01} (active state)	0.5 volts maximum @ 20 ma
I MAX	200 ma
Approximate closure time	6.5 to 7.0 milliseconds

Figure 4-4 shows the timing for the 28-volt pulse and switch closure to ground. Figure 4-5 shows the required interface circuitry to interface the CAS with the RIU.

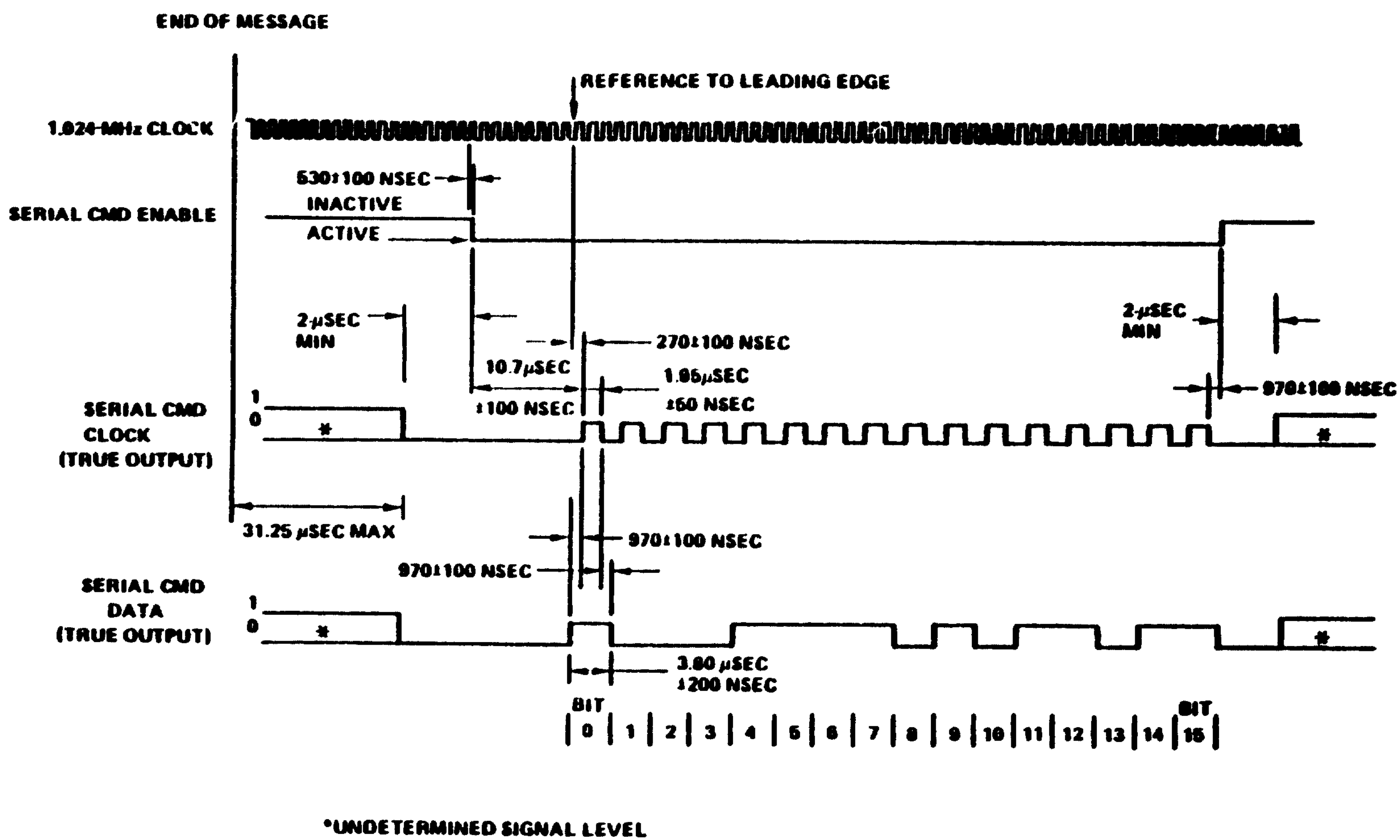


Figure 4-2. Timing for Serial Magnitude Commands

4.4.3 Timing and Synchronizing Signals

The RIU has a clock and four synchronizing signals that are available to the CAS.

4.4.3.1 Clock Signal. A 1.024 MHz square wave at a nominal 50-percent duty cycle will be provided to the CAS as the differential output described in Paragraph 4.4.1.3. The 1.024 MHz signal is derived by the Remote Interface Unit from the signals it receives via the Spacecraft Multiplex Data Bus. Typical delay difference output will be determined within an expected tolerance of ±200 nanoseconds.

4.4.3.2 Telemetry Synchronizing Signals. Telemetry synchronizing signals will be available. These signals are:

a. Major Frame Rate. The major frame pulse occurs once every 8.192 seconds.

b. Minor Frame Rate. The minor frame pulse occurs once every 64 milliseconds.

c. Telemetry Word Rate. The telemetry word sync pulse occurs every 500 microseconds.

These signals are type 1 signals, described in Paragraph 4.4.1.1, having a closure time of 47.2 microseconds.

4.4.4 RIU Analog-to-Digital Conversion

The RIU will have an A/D converter that will convert analog inputs to digital words with the following characteristics:

Resolution:	8 bits
Conversion Time:	16 microseconds
Accuracy:	±25 millivolts

4.4.5 CAS Output Signals

The CAS may have four types of output signals:

Type 5	Conditioned Analog
Type 6	Analog
Type 7	Bilevel Digital
Type 8	Serial Digital

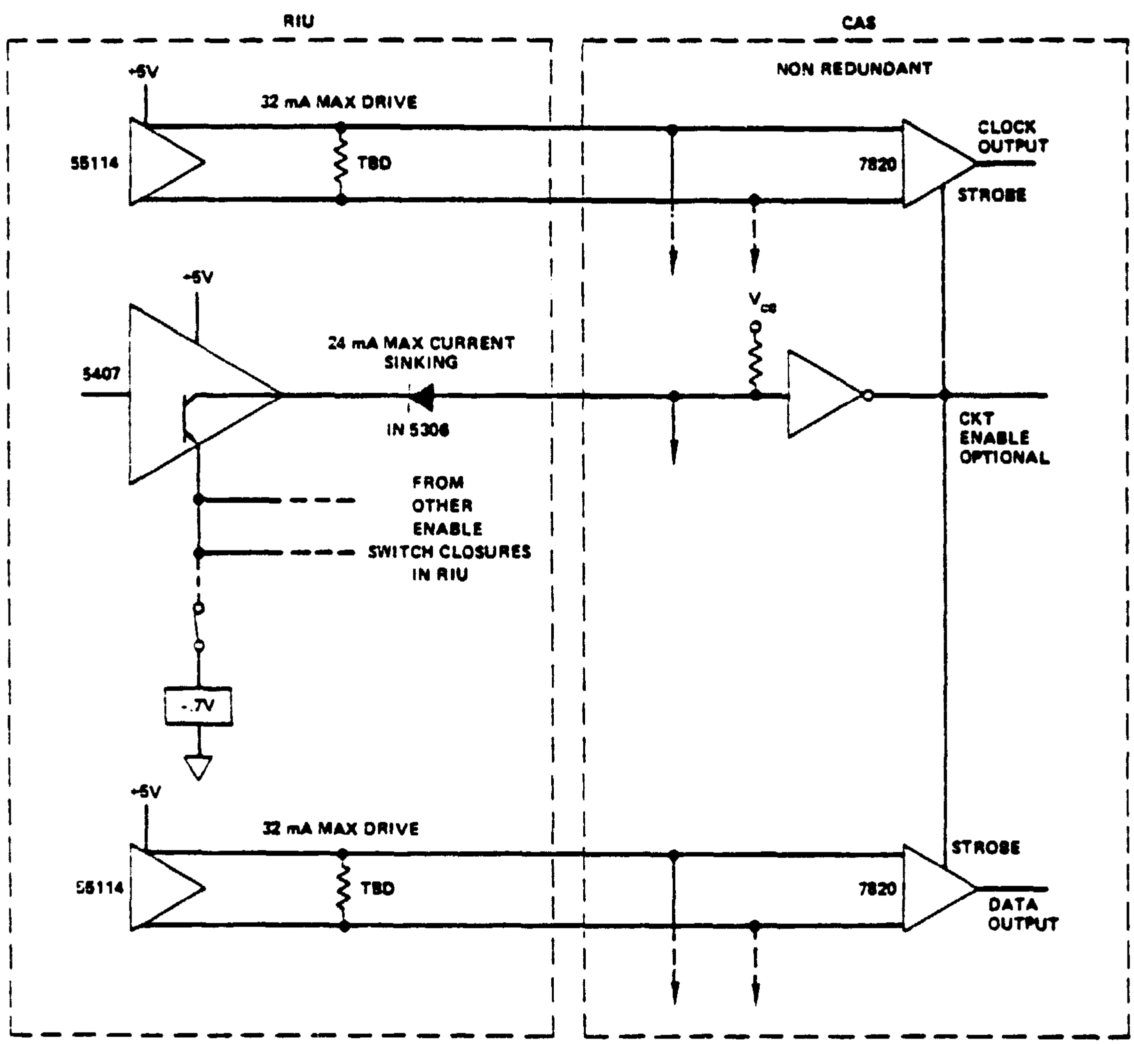


Figure 4-3. CAS Serial Magnitude Command RIU Interface Circuit

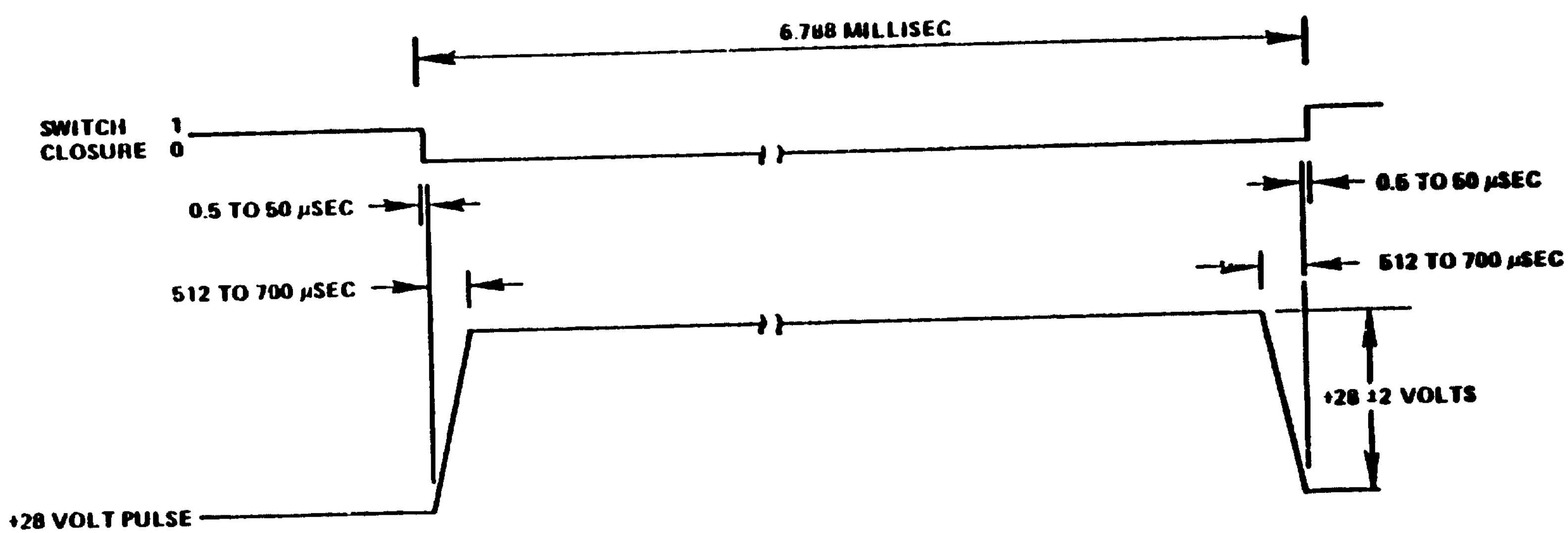
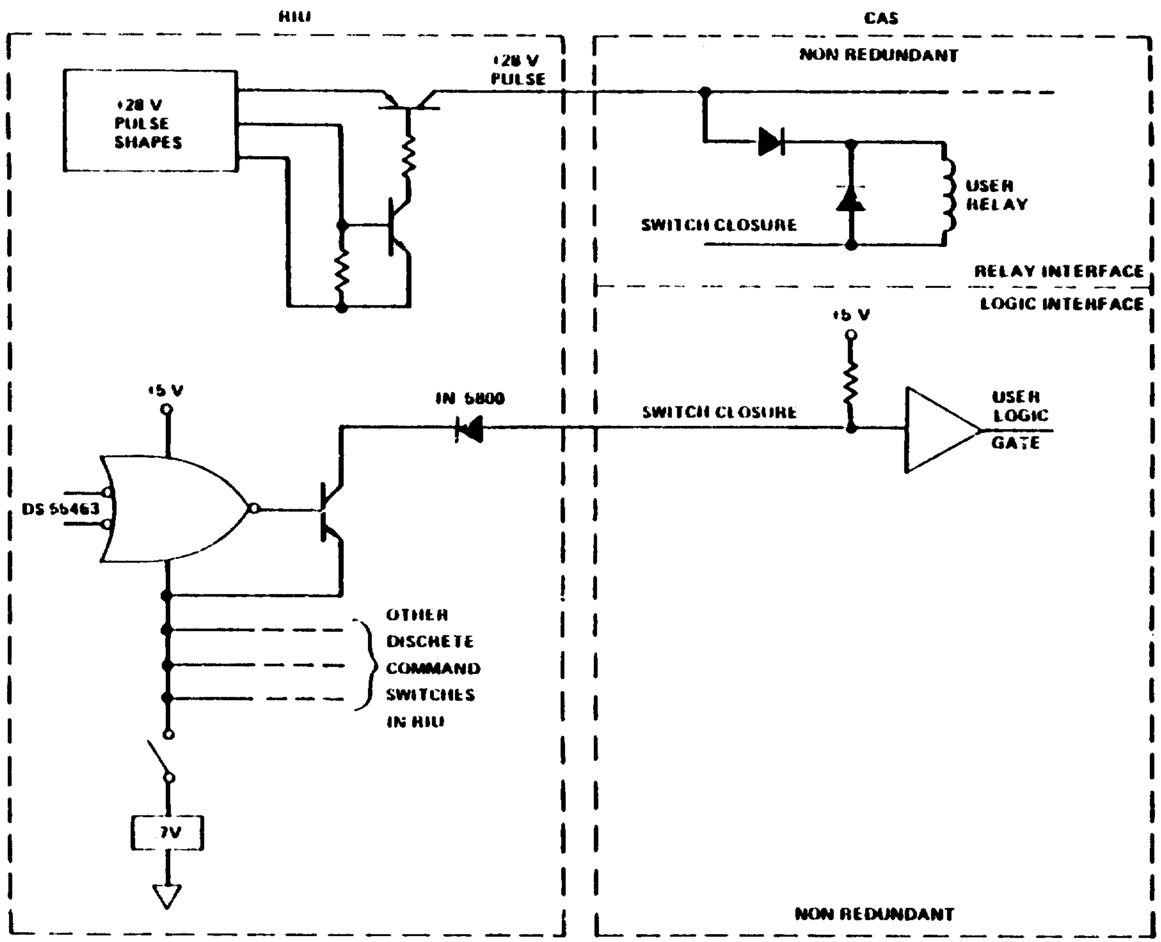


Figure 4-4. Timing for +28 Volt Pulse



THIS INTERFACE MAY BE USED.
A. AS A SWITCH CLOSURE TO GROUND (FOR DRIVING LOGIC) OR
B. AS A SWITCH CLOSURE TO GROUND FOR A +25V PULSE (FOR DRIVING RELAY)

Figure 4-5. Discrete Relay Driver Command RIU Interface Circuits

4.4.5.1 Type 5 Signal. The conditioned analog signals are sampled and converted to digital form during a 48 microsecond window. The CAS shall generate an output between 0 and +5.12 volts dc when energized by a one milliampere constant current pulse.

4.4.5.2 Type 6 Signal. The analog signals are sampled and converted to digital form during a 16 microsecond window. The analog signal and signal ground are both switched, by the RIU to a differential amplifier during sampling. The CAS shall generate analog signals with the following characteristics:

Range	0 to +5.12 volts dc
Source Impedance	5 kilohms, maximum

4.4.5.3 Type 7 Signal. The bilevel digital outputs are sampled in parallel in 8 bit bytes by the RIU. The bilevel digital signals shall have the following characteristics:

Logical "1"	+3.5 to +15 volts dc
Logical "0"	-1.0 to +1.5 volts dc
Source Impedance	5 kilohms, maximum

4.4.5.4 Type 8 Signals. The serial digital signals are sampled at 8 serial bits per sample. Three lines are required to effect the transfer of serial data to the RIU. They are a common experiment clock line and switched, paired data and enable lines. The experiment clock signal (eight gated clock pulses at a 256 KHz rate) is a type 3 signal described in Section 4.4.1.3. The CAS interface circuit receiving the experiment clock shall be a National Semiconductor DS-7820 Line Receiver or equivalent. The CAS shall be capable of interfacing the experiment clock with the RIU as shown in Figure 4-6. The serial digital enable signal is a Type 1 signal as described in Paragraph 4.4.1.1 with a duration of 47.2 microseconds. The serial digital data from the CAS shall have the following characteristics:

Logical "1"	+2.4 to +15 volts
Logical "0"	-1.0 to +1.5 volts
Source Impedance	500 ohms maximum

Figure 4-7 shows the timing for serial digital data retrieval.

4.4.6 CAS Input and Output Signals

The CAS shall be limited to the following signals.

4.4.6.1 Input Signals. The CAS shall be limited to the following input signals:

a. One serial magnitude command

b. Eight discrete commands (for relay switching or logic functions)

c. Two serial digital enables

d. One major frame pulse

e. One minor frame pulse

f. One word rate pulse

g. One 1.024 MHz clock

4.4.6.2 Output Signals. The CAS shall be limited to four output telemetry channels. Any combination of the following types may be used to make up the four.

a. Serial digital data

b. Conditioned analog

c. Analog

d. Bilevel data

4.5 MECHANICAL INTERFACE

4.5.1 General Configuration

The Co-alignment Adjustment Mechanism and electronics unit shall be packaged separately. No heat dissipating electronics are permitted in the mechanism when not in use. The electronics unit shall be remotely located.

The mechanism will be located on the Instrument Support Plate (ISP). The CAS mechanism shall interface with the instrument per Interface Control Drawing GE-1091601 and Drawing 47-E-240070. The electronics unit will be located on an equipment panel which is parallel to the ISP but attached to the Mission Adapter. The intra-connecting electrical cable will be approximately 10 ft in length depending on the final placement of electronics.

The electrical harness routing and length will be determined by the SMM Project Office. The contractor shall fabricate the non-flight harness to be used for all testing purposes. The type of connectors and material used must meet flight harness standards.

4.5.2 Mounting Provisions

4.5.2.1 Mechanism. The CAS shall be mounted as per drawing GE-1091601.

4.5.2.2 Electronics Unit. The contractor shall determine the mounting hole pattern and the fastener size. Electronics unit fasteners shall be number 6 or larger. Straight line clearance in the direction of attachment shall be provided for all fasteners. The base of the unit should provide full surface contact with the equipment panel and a surface flatness less than 0.003 inches. Installation will occur from the y direction as per Figure TBD. The dimensions of the electronics unit shall be no greater than $11 \times 7 \times 5$ inches and shall be mounted on the 11×7 inch side as per Reference 2.1.

4.5.3 Connector Location

4.5.3.1 Mechanism. Electrical connectors shall be accessible during assembly to the instrument and blade mounts.

4.5.3.2 Electronics Unit. Electrical connectors can be located on any surface except the -y which is the mounting surface. However, connector locations on other than the +y surface are discouraged because of the inability at this time to guarantee accessibility and to determine neighbor package separation distances.

4.5.4 Venting

Components and multilayer insulation will vent from pressure differences caused by the launch and retrieval environments, by outgassing of materials, and by depletion of expandables. The venting of all materials must be in a controlled direction. The direction must be negotiated before hardware implementation.

4.5.5 Optical Reference Surfaces

Both the ISP and instrument base brackets must have optical reference surfaces to aid in mounting alignment and testing. The location of the optical cube on the instrument base bracket shall be dimensioned the same relative to the twenty-two instrument holes as per GE drawing 47-E-240070. Reference surfaces are not required on the electronics unit. The optical cubes are GFE.

The optical reference surface shall be a polished optical flat of $\lambda/4$ quality with a reflectivity of 70 percent or greater in the visible. References may be faces of a single cube or separate mirrors. They must retain flatness of one quarter of a wavelength through all operations. It is the responsibility of the contractor to select and guarantee the method of reference surface attachment. The optical reference surfaces may be machined into the structure and suitably coated or may be separate pieces which are securely bolted, pinned or cemented to the structure.

The contractor should be aware of the stability, optical properties, and outgassing profile of each method of attachment, especially with the adhesive, before a selection is made.

The optical reference surfaces shall be visible when the mechanism is mounted to the instrument support plate. The assembly or disassembly of any component to achieve visibility is prohibited.

4.5.6 Interface with ISP

The CAS shall interface with an instrument per ICD GE-1091601. These surfaces shall have a minimum bearing area (1-1/2 in.) in diameter and be 5/8 inch thick. Surfaces will be controlled to ±0.013 cm (±0.005 in.) and ±1/2 degree or better.

4.6 THERMAL

4.6.1 Mechanism Requirements

4.6.1.1 Operating Temperature Range. The flight operating temperature shall be in the range of 10°C to 30°C.

4.6.1.2 Temperature Gradients. The contractor shall define the maximum allowable CAS operating temperature gradients.

4.6.1.3 Heaters. If temperature gradient-control heaters and temperature sensors are necessary, they shall be supplied by the contractor as part of his thermal design.

4.6.1.4 Storage Temperature Limits. The storage temperature for the CAS shall be from -15°C to +50°C.

4.6.1.5 Thermal Conductance. The thermal conductance through all three ISP mounts is limited to 0.2 watt per degree centigrade.

4.6.1.6 Temperature Monitoring. The contractor shall install temperature sensor for measuring temperatures at critical locations. Temperature sensor electrical characteristics shall be defined by the contractor.

4.6.2 Electronics Unit

4.6.2.1 Temperature Limits. The operational temperature requirements for the CAS electronics unit shall be 20 ± 15°C at the unit mounting surfaces. The storage temperature for the electronics unit shall be -15°C to +50°C.

4.6.2.2 Heat Dissipation. The heat dissipation during operation of the CAS electronics unit shall be defined by the contractor.

4.6.2.3 Finish. The electronics units will be hard mounted to the spacecraft wall. The five inward facing surfaces of each electronics unit shall be painted black with Chemglaze Z-306. The contractor shall strictly follow the Hughson Chemglaze application procedures as defined in Appendix A of Reference 2.1. The electronics baseplate/spacecraft interface surface shall have a flatness within 0.003"/ft. and a surface finish of 32 micro-inches RMS or better.

4.6.2.4 Radiant Environment. The electronics unit baseplate will be hard mounted to the spacecraft wall. The other five sides of the unit will be radiating to an environment with an average temperature of from 10° to 30°C and an emittance of from 0.83 to 0.92 on both the electronics unit and heat sink surfaces.

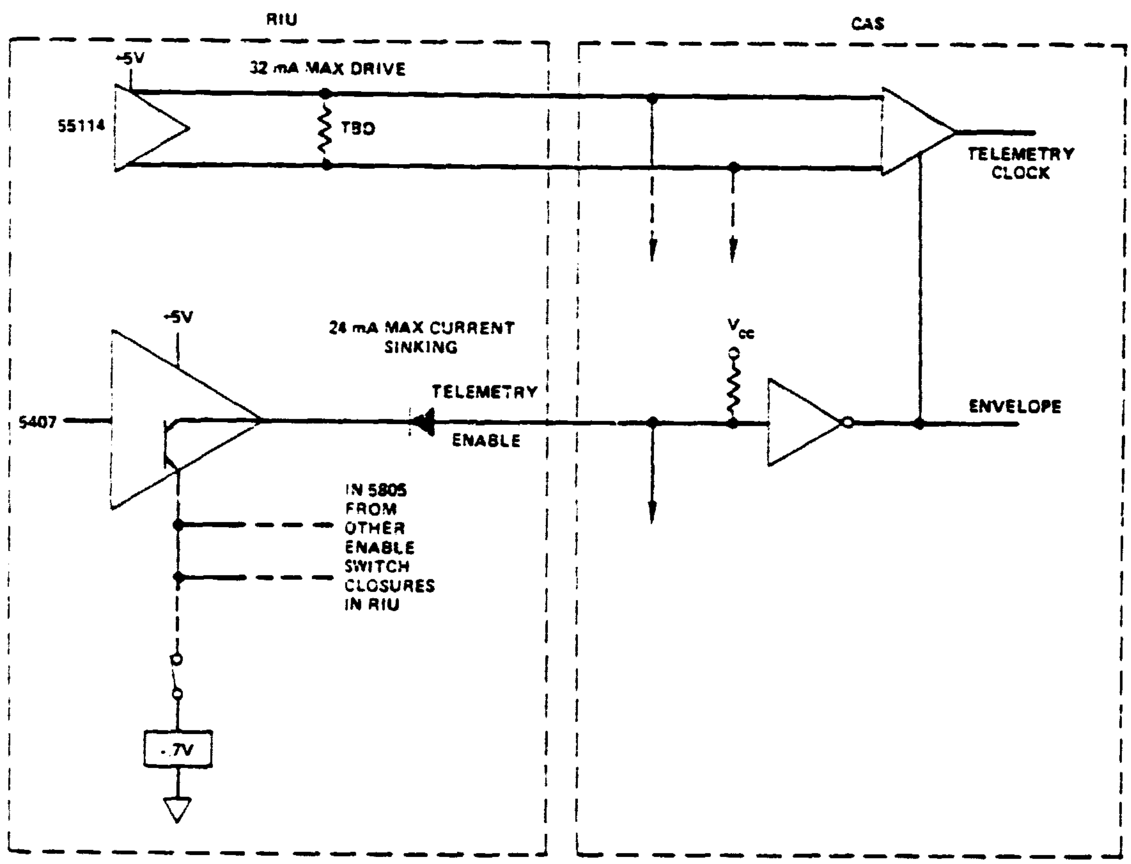


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Figure 4-6. CAS Clock RIU Interface Circuit

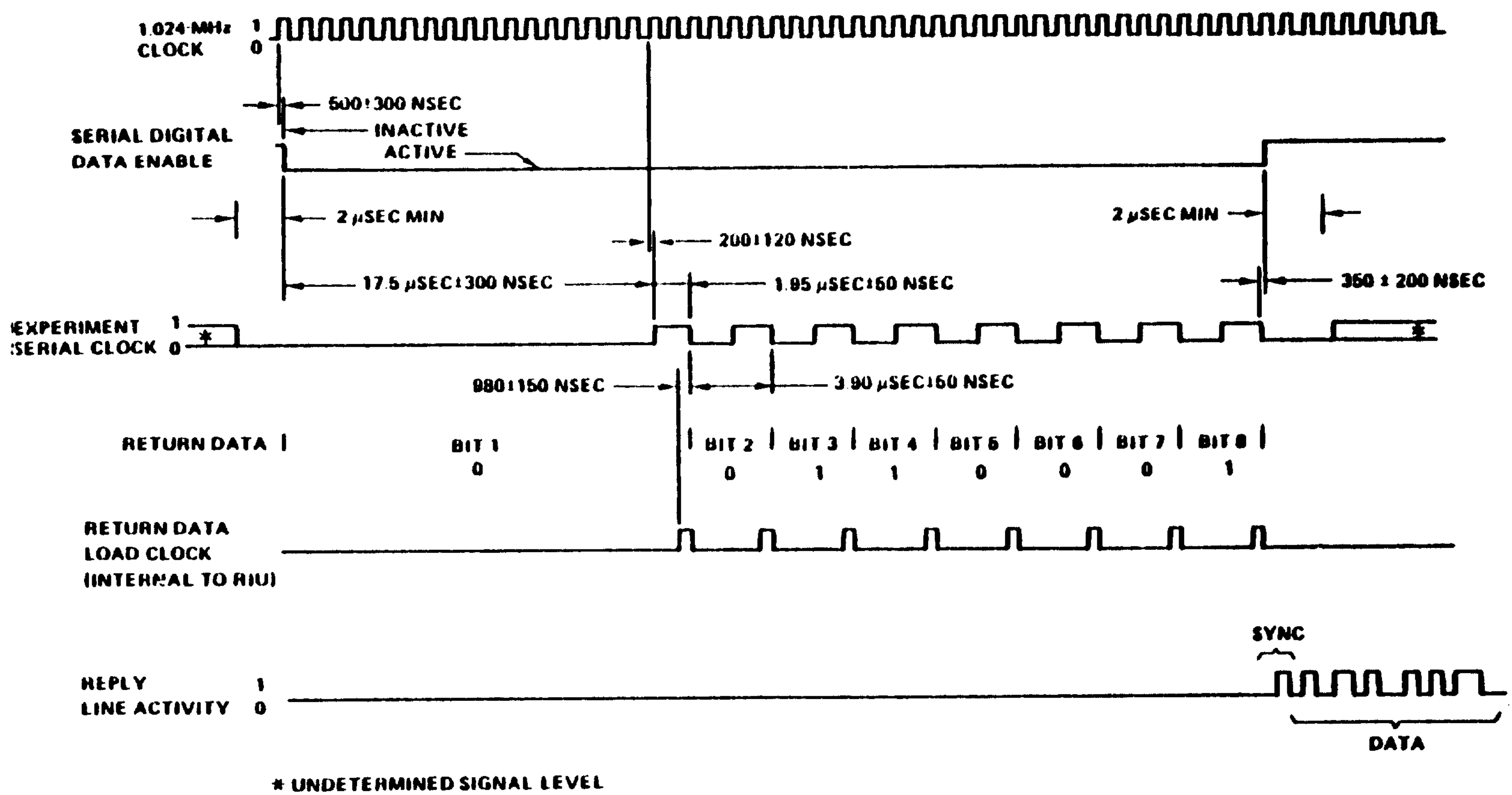

Figure 4-7. Timing for Serial Digital Data Retrieval