ASE-1640-A

FINAL REPORT - TASK 12

AN X-RAY EXPLORER TO SURVEY GALACTIC AND EXTRAGALACTIC SOURCES

CONTRACT NO. NASw-1506

N68-16114

(ACCESSION NUMBER) (THRU)

60 /

(PAGES) (CODE)

CR-92699 31

(NASA CR OR TMX OR AD NUMBER) (CATEGORY)

FACILITY FORM 602

PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

15 JUNE, 1967

AMERICAN SCIENCE AND ENGINEERING

11 Carleton Street, Cambridge, Massachusetts 02142

AS&E

ASE-1640-A

AN X-RAY EXPLORER
TO
SURVEY GALACTIC AND
EXTRAGALACTIC SOURCES

Final Report
Program Definition Phase
Task 12

Prepared under Contract No. NASW-1506 by
AMERICAN SCIENCE AND ENGINEERING, INC.
11 Carleton Street, Cambridge, Massachusetts 02142

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Contracting Officer: Mr. H. L. Tomlinson
Technical Monitor: Mrs. M. Townsend

Program Manager [signature]
M. R. Hoes

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

LIST OF ILLUSTRATIONS

LIST OF TABLES

1.0 INTRODUCTION

1.1 Scope

This document, ASE-1640-A, constitutes the Final Report for Task 12 of Contract NASW-1506. It is prepared in accordance with TID-S-100, Type III, dated August 1962 entitled "Specifications for Contractor Prepared Monthly, Periodic & Final Project Reports".

The Final Report, ASE-1567, for Tasks I through 11, (Basic Contract) was submitted to NASA/GSFC as requested on 13 March 1967.

Submission of documents ASE-1567 and ASE-1640 completed the reporting requirements described in Article VII of the Contract except for NASA approval of ASE-1640 as required by TID-S-100.

1.2 Contract Statement of Work

"The Contractor shall provide all personnel, facilities, and materials to accomplish the study in strict accordance with its proposals ASE-2043 and ASE-2043-IIa, dated 20 January 1966 and 27 July 1966, respectively. The Contractor, during the course of this Contract, will perform the following:

1. Predict expected accuracy of location and size of X-Ray sources.

2. Study methods to optimize signal-to-noise ratios.

3. Prepare assembly drawings of the instrument and outline drawings of the individual instruments for subassemblies.

4. Study thermal design constraints imposed by the instrumentation.

5. Make block diagrams of the instrumentation.

6. Define electrical interface indicating instrumentation requirements for electric power, on-board data handling and command control functions.

7. Define spacecraft attitude and stability requirements imposed by the experiment.

8. Construct a mock-up of the instrumentation.

9. Define experiment schedule and costs.

10. Consider manner of receiving, storaging, transmitting, reducing and analyzing the scientific data.

11. Make estimates of time, manpower, and budgets required for data reduction and analysis.

12. Investigate and evaluate the requirements of tasks one (1) through eleven (11) above and determine the instrumentation tradeoffs necessary to restrict the total weight for the instrument unit to 140 pounds (lbs). This will include:

    a. A re-evaluation of the scientific objectives and the constraints which they impose upon the design of the instrument unit and the components and systems therein. Define the revised scientific objectives based on foregoing evaluation.

b. A redefinition of the expected accuracy of location and size of X-ray sources, signal-to-noise ratio, electronic instrumentation design, mechanical configuration, thermal design constraints, and spacecraft attitude and stability to achieve the required weight specified above.

c. A re-evaluation and redesign of the mechanical structures, counters, collimators, aspect system, and the electronic system, circuits and packaging to obtain the required weight.

d. Prepare a revised mechanical configuration for the weight.

e. Using these configurations, re-evaluate the performance of the instrumentation and the completeness with which the scientific objectives for X-ray Explorer have been fulfilled.

f. Prepare revised interface requirements.

g. Construct a new mechanical mock-up of the instrumentation.

h. Submit a final report summarizing the work performed under this task."

1.3 Organization of Final Report

The Final Report for contract NASW-1506 is supplied in two parts at the request of the NASA/GSFC Program Manager. The first part, ASE-1567, reported performance on Tasks 1 through 11 defined in the Statement of Work. The second part is the Final Report for Task 12.

Task 12 required the re-evaluation of Tasks 1 through 11 for an instrument weight of 140 pounds. It will be seen that this effort is covered by the sub-tasks (a) through (h) of Task 12 as follows:

Task 1 covered by Sub-task 12b

Task 2 covered by Sub-task 12b

Task 3 covered by Sub-task 12d

Task 4 covered by Sub-task 12b

Task 5 covered by Sub-task 12c

Task 6 covered by Sub-task 12f

Task 7 covered by Sub-task 12b

Task 8 covered by Sub-task 12g

Task 9 was completed by preparation of documents, ASE-1550-Ia entitled "Technical Proposal for the X-ray Explorer Experiment, Phase II, Revision B", and ASE-1550-IIb, entitled "Revised Estimated Cost for an X-Ray Explorer Experiment, Phase II, dated 28 April 1967 and submitted to NASA/GSFC on 1 May 1967. Tasks 10 and 11 are not affected by the weight reduction and are covered in ASE-1567.

Section 2 of this report re-evaluates the scientific objectives and presents revised scientific objectives as required by Task 12a.

Section 3 presents revised requirements for the electronic, mechanical, and thermal design and the results of the re-evaluation to reduce weight. The proposed new design is described as required by Tasks 12b, c and d. Photographs of the old and new mechanical mock-ups (Task 12g) also are shown in Section 3.

Section 4 reviews the original and revised scientific objectives in the light of the expected performance of the instrument as required by Task 12e. It details how the reduction in weight, while reducing sensitivity and reliability, will still permit achievement of essentially all the scientific objectives.

Revised interface requirements have been fulfilled (Task 12f) by submission of document ASE-1623.

2.0 SCIENTIFIC OBJECTIVES

2.1 Original Objectives

The original objectives are listed in Section 3.2 of ASE-1567 and are:

1. To conduct a high sensitivity, high resolution, all-sky survey for X-ray sources to produce an X-ray source catalog.
    a. Detect sources of intensity greater than approximately 3×10^{-4} that of ScoX-1, the strongest known source.
    b. Locate sources with an accuracy of 1 arc minute for strong sources and, perhaps, a few arc minutes for weaker sources.

2. To search for temporal variations in X-ray sources intensity over periods of minutes to months and variations of several percent.

3. To measure the angular diameter of X-ray source, if greater than a few arc minutes, and to identify those sources whose diameter is less than this limit.

2.2 Re-evaluation of Objectives

1a. To conduct a high sensitivity survey, large detectors must be used. These contribute to the weight by themselves and also by the requirement for larger background counter area, larger collimator and larger structure. Since this is the prime scientific objective, the detector area will be reduced as little as possible consistent with achievement of the desired weight.

The present design halves the total detector area by reducing the number of channels from 4 to 2. The actual X-ray sensitive area for each channel is not changed. Thus, the sensitivity of a channel remains unchanged, although the net sensitivity is significantly reduced.

1b. The two remaining channels will have fields of view that differ by about a factor of 4. The narrow side will be a 2.5° (full angle) circular field of view. Weight estimates in this report are based on the circular field of view since this collimator configuration appears to be lighter. This will reduce the accuracy of locating sources slightly so that the numbers on page 18 of ASE-1567 must be modified (i.e., for a source of 10^{-2} ScoX-1 the uncertainty in location would be approximately 0.6 arc minute and for 10^{-3} ScoX-1 it would be 6 arc minutes).

2. This objective is not affected by the weight reduction program. It is important to maintain an absolute time reference when acquiring data; no change is planned.

3. To measure the diameter of sources a Modulation Collimator must be used. This requires a considerably more rigid and precise collimator with appreciably greater weight. Because of weight considerations this has been sacrificed.

2.3 Revised Objectives

The revised objectives are:

1. To conduct a high sensitivity, high resolution, all-sky survey for X-ray sources to produce an X-ray source catalog.

a. Detect source of intensity greater than approximately 5×10^{-4} ScoX-1, the strongest known source.

b. Locate sources with an accuracy of 1 arc minute for strong sources and, perhaps, a few arc minutes for weaker sources.

2. To search for temporal variations in X-ray source intensity over periods of minutes to months and variations of several percent.

3.0 DESIGN CHANGES AND PERFORMANCE EVALUATION

The following paragraphs describe the design changes made during Task 12 and contain a performance evaluation of the Experiment as a result of these changes. Reference is made to applicable sections of the Final Report for Tasks 1 through 11, Document ASE-1567, when necessary, to relate work performed under Task 12 to that already accomplished during Tasks 1 through 11.

3.1 Scientific Considerations

3.1.1 Analysis of Prescaling

A large range of counting rates is expected in the X-ray channels. The present plan is to prescale the X-ray counts on board, in order to use the telemetry channel most effectively.

Since prescaling results in the loss of some information, it is necessary to determine whether this loss would adversely affect the ability to observe weak X-ray sources.

The accumulated X-ray counts are read out twice a second in the most sensitive X-ray channel. This readout, indexed according to time of occurence, is telemetered to earth. During data analysis, the direction of the X-ray detector is found as a function of time, so that the X-ray data can be located as coming from a specific direction in the sky. For the weakest sources, the sky will be divided into 1640 areas $5^{\circ} \times 5^{\circ}$. All the counts within each area will be summed over the total observation time. If the data have been prescaled by a factor S, the number of counts in an area will have a counting resolution of S, because the primary data will be integral multiples of S. Theoretically, S could be comparable in size to the standard deviation of the total summed count in each $5^{\circ} \times 5^{\circ}$ area. It is necessary, however, to examine the individual unsummed data samples to verify correct instrument operation and to reject noise and regions of high background. Consequently, the actual value of S is determined by the number of counts in each data sample. A value of S = 4 will be used. This is smaller than the uncertainty in the expected background sample count and will not measurably affect the ultimate precision of the data.

3.1.2 Background Radiation Studies

The Final Report of Tasks 1 through 11 (ASE-1567, para 3.5.3.2) indicates lack of knowledge of the effects of low energy (50-100 keV) electrons. These electrons could cause increased background rates in the X-ray detectors, resulting in a decrease in sensitivity. Therefore, recent literature was searched for experimental results that might be enlightening and several experimenters were contacted.

As an example, L. Peterson of the University of California at San Diego had an X-ray detector in operation for OSO-III which consisted of a 3 mm by 9 cm^2 NaI (Tl) crystal with a 20-mil beryllim window and an anti-coincidence shield. The detector also, had an open view cone of 25° full angle. In the energy range 5- 150 keV, Peterson found that the entire background can be attributed to earth albedo X-rays and diffuse cosmic X-rays. This was true even when the detector was passing through the Van Allen belts where the counting rates in the anti-coincidence shield were increased by a factor of five. Such results are not directly applicable to the proposed Experiment, however, since Peterson's detector has a much thicker window and his experiment would have less sensitivity to the lower energy electron background.

An experiment on Ariel in 1962 used thin beryllium-window proportional counters for detection of solar X-rays. K. A. Pounds reported that all the background during "quiet" parts of the flight could be attributed to cosmic rays (no anti-coincidence shield was used). Considerable increases in background were seen when crossing the Van Allen belts (the orbit being eccentric, with apogee of 1214 km, perigee of 390 km and inclination of 55°). Anomalous increases by a factor of 3 or 4 in background, lasting about a minute, were seen during "quiet" periods. These were attributed to "low-lying clouds" of soft electrons, perhaps from nuclear explosion debris.

Observations by G. A. Kirdina et al from Cosmos 17 were published in Kosmicheskie Issladovaniva and translated in Cosmic Research, vol 4, p 236 (1966). They observed soft particle radiation using a Geiger counter with a mica end window 1 mg/cm^2 thick. The orbit had an apogee of 780 km, a perigee of 260 km and an inclination of 49°. High counting rates attributable to soft electrons were observed over a substantial part of the orbit. It is estimated that high rates would be seen during 57% of a 30° inclined orbit or during 30% of an equatorial orbit.

The data of Kirdina et al appear to be in conflict with the other two reports described. The Experiment most similar to X-ray Explorer is that on Ariel since the detectors are very similar. Their results show that periods of quiet background exist where the count rate can be attributed only to cosmic rays. The only interference is believed to be from occasional regions of soft electrons.

The present conclusion is that no great background interference is expected on the X-ray counters, outside the South Atlantic anomaly. The actual orbit to be selected, whether 3^{o}, 10^{o} or 38^{o} inclination, is still under consideration since other factors must also be considered before a decision can be made.

3.1.3 Performance Re-evaluation Impact on Sensitivity and Location Accuracy

3.1.3.1 X-ray Data Rates - The X-ray data rates described below have been calculated for one half of the Experiment and correspond to one X-ray channel. Refer to ASE-1567, paragraph 3.4.1 for a comparison with rates given for Tasks 1 through 11.

- Total area is 1298 cm^2
- Effective window area (70%) is 905 cm^2
- Effective collimated window area (80%) is 725 cm^2
- The maximum expected signal is ScoX-1 (30 c/cm^2-sec) resulting in 22,000 count/sec peak rate
- The expected signal from 5×10^{-4} ScoX-1 is 11 counts/sec peak rate
- Non-X-ray background without PSD rejection is 250 counts/sec
- Diffuse X-ray background is 40 counts/sec (10^{o} full width field)

3.1.3.2 Source Location Accuracy - The new accuracy of source location (originally calculated in ASE-1567, paragraph 3.4.3) is given in the following table:

Source Strength (ScoX-1 Units)	* $\Delta\epsilon$ (arc min.) for $W = 1^{\circ}$	for $W = 10^{\circ}$
10^{-2}	0.42 (0.21)	1.4 (0.63)
10^{-3}	4.2 (2.1)	14 (6.3)
10^{-4}	42 (21)	141 (63)

*The values of $\Delta\epsilon$ given in parenthesis are those found assuming the use of PSD background rejection.

3.1.4 Change in Signal-to-Noise Ratio as a Result of Weight Reduction

The effect of weight reduction on the signal is that, since the detector area is halved, the signal counting rate is 1/2 the former value. The noise, or background rate, is not quite 1/2 the former rate because the charged particle rejection of the anti-coincidence system will be lowered from 91.5% to approximately 88.5%. The result is a background rate approximately 52% of the original rate.

The sensitivity (inverse of minimum detectable source strength) is proportional to (signal)/$\sqrt{\text{background}}$ Therefore, the new sensitivity is 69% of the previous sensitivity.

Since there is now a total of ten independent X-ray detectors (instead of the original twenty), the effect of a counter failure becomes more serious. Therefore, the effect of weight reduction in this area becomes an important factor in assessing the experiment reliability.

3.1.5 Impact of Weight Reduction on other Aspects of the Experiment

There are no other changes in the requirements for spacecraft orientation. Data handling and the data reduction task will remain unchanged except for a reduction of only a few percent in total data volume.

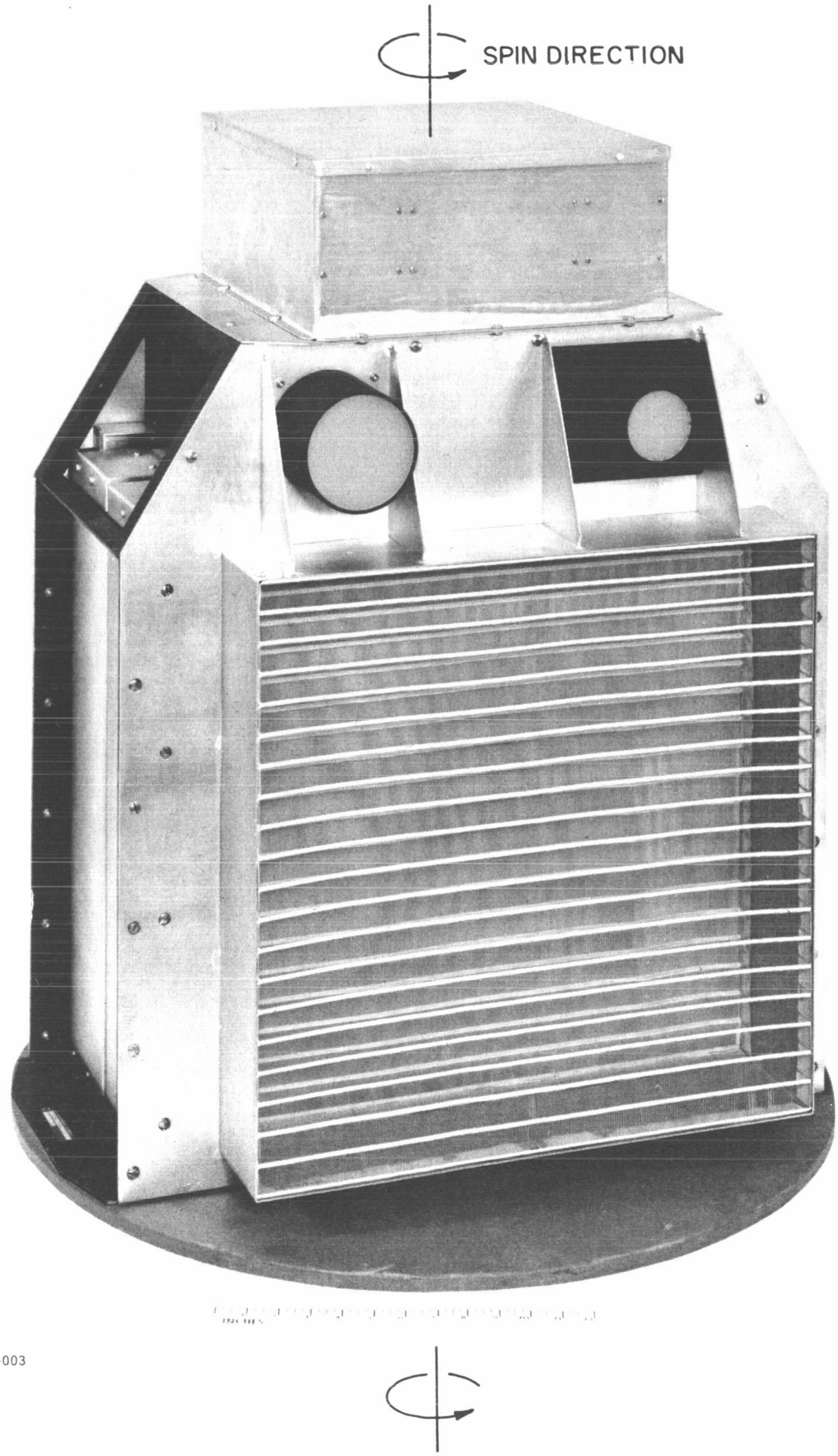
3.2 Mechanical Effort

3.2.1 General Configuration

The Task 12 configuration utilizes the same modular design, planar interface concept as originally conceived. The principal difference between the previous design and the current one is that the detector area has been halved resulting in a package smaller in size and correspondingly less in weitht. Figures 3-1 and 3-2 show the original and revised mechanical mock-ups of the configuration. An exploded view of the present Experiment is shown in Figure 3-3.

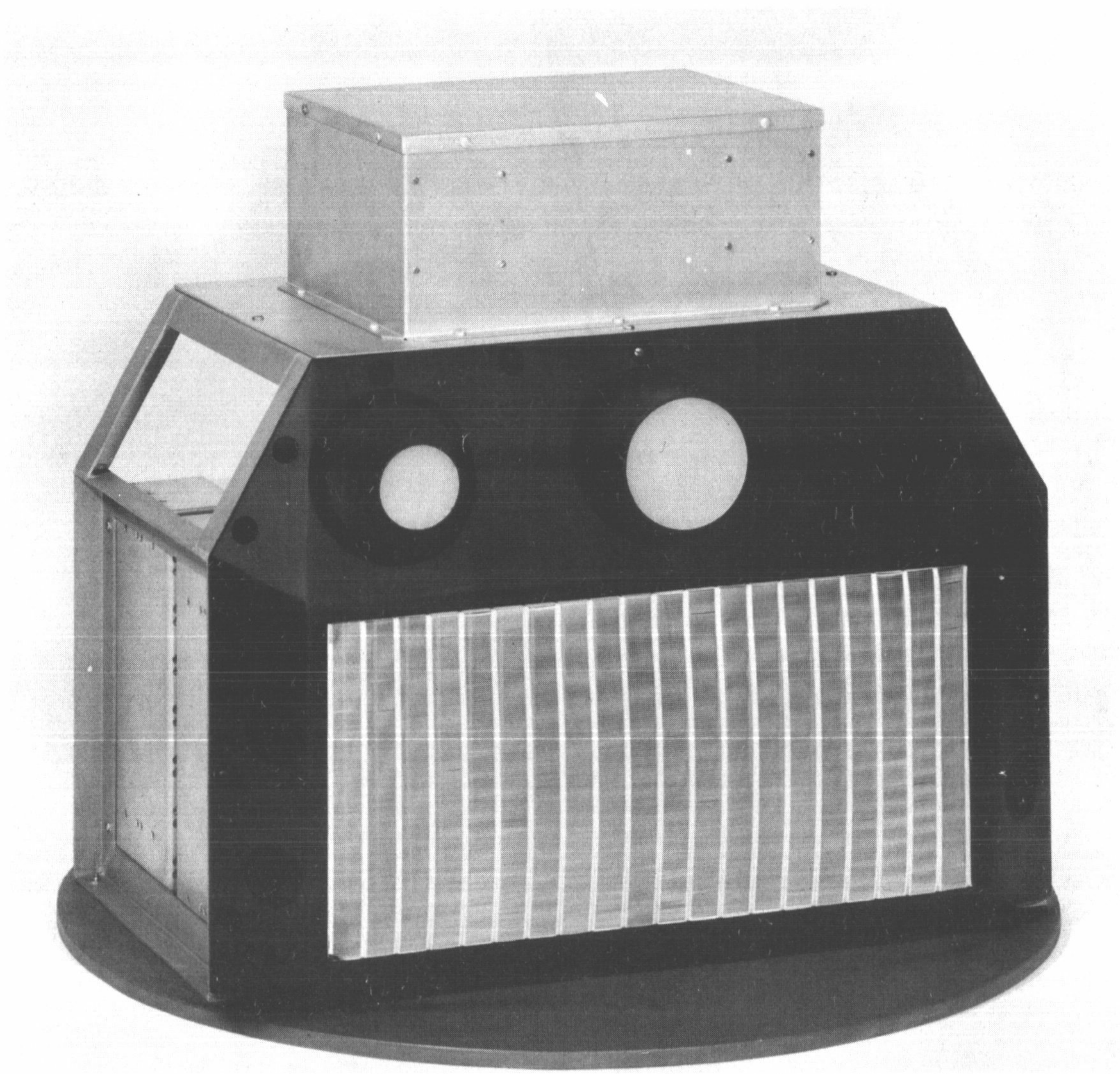
Grouping of the individual components into major subassemblies is the same as in the previous design (i. e., Collimator and Aspect Sensors Assembly, X-ray Counter Assemblies, Background Counter Assemblies, Electronics Box, Thermal Shroud, and Main Frame).

The Collimator and Aspect Sensors Assembly has been modified in two ways. First, the sensors have been relocated so that the star sensor is in the middle with the sun sensor on one side of it. This facilitates the design of the erectable sunshade for the star sensor. The second modification consists of a change in the collimator frame design to provide a more rigid structure and, therefore, more stable alignment. The Collimators have been selected for a 2.5° circular field of view on one side and 10° on the other, with a 210 sq. in. frontal area. They will be fabricated from thin-walled, extruded tubing which will result in light weight and high rigidity, further improving alignment stability. Details regarding these tubes and the Collimators are given in paragraph 3.2.2.1 of of this report.



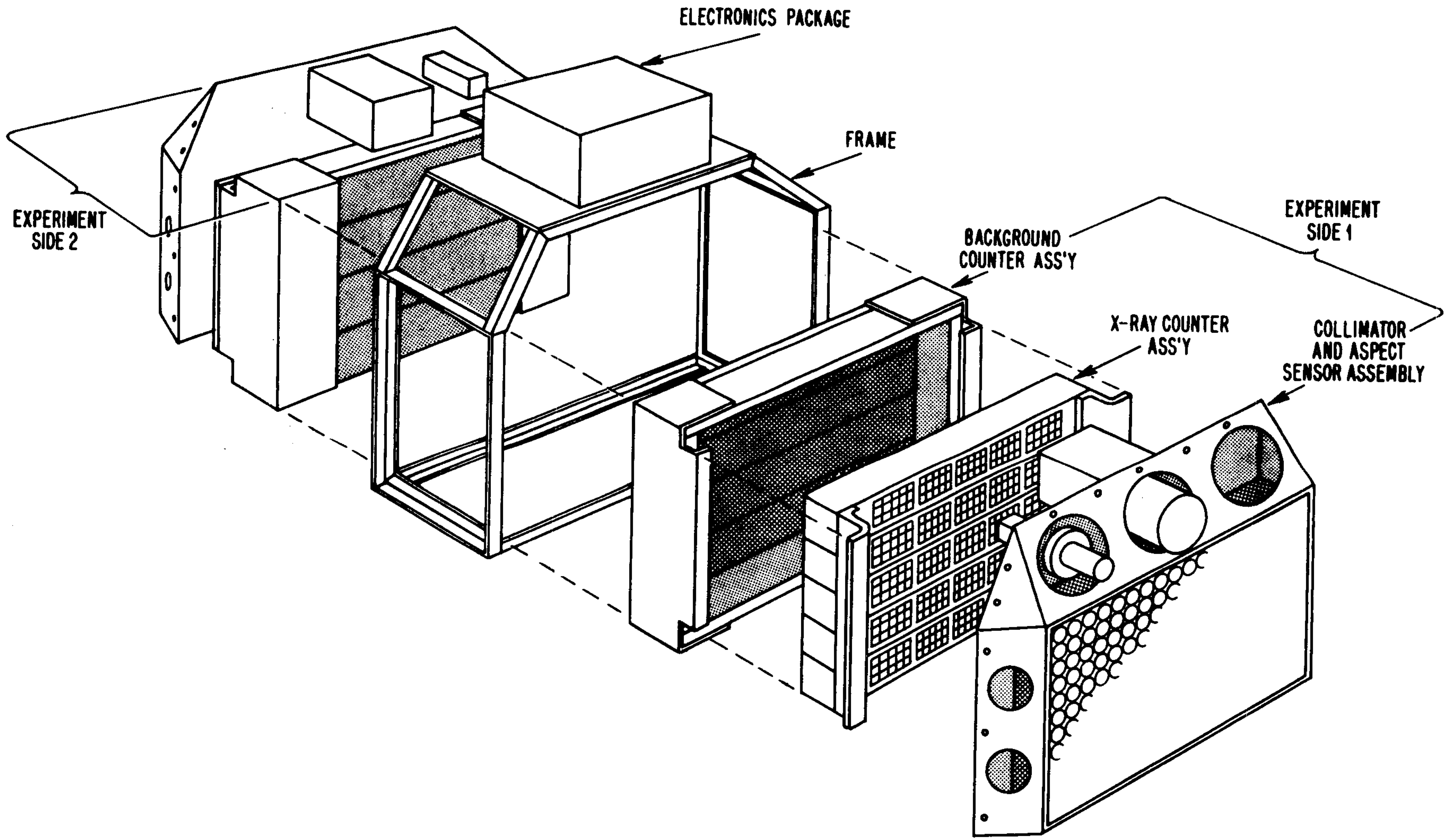
DQ-003

X-Ray Explorer Instrument Package Figure 3-1



Revised X-Ray Explorer Instrument Package

Figure 3-2



X-Ray Experiment Assembly

Figure 3-3

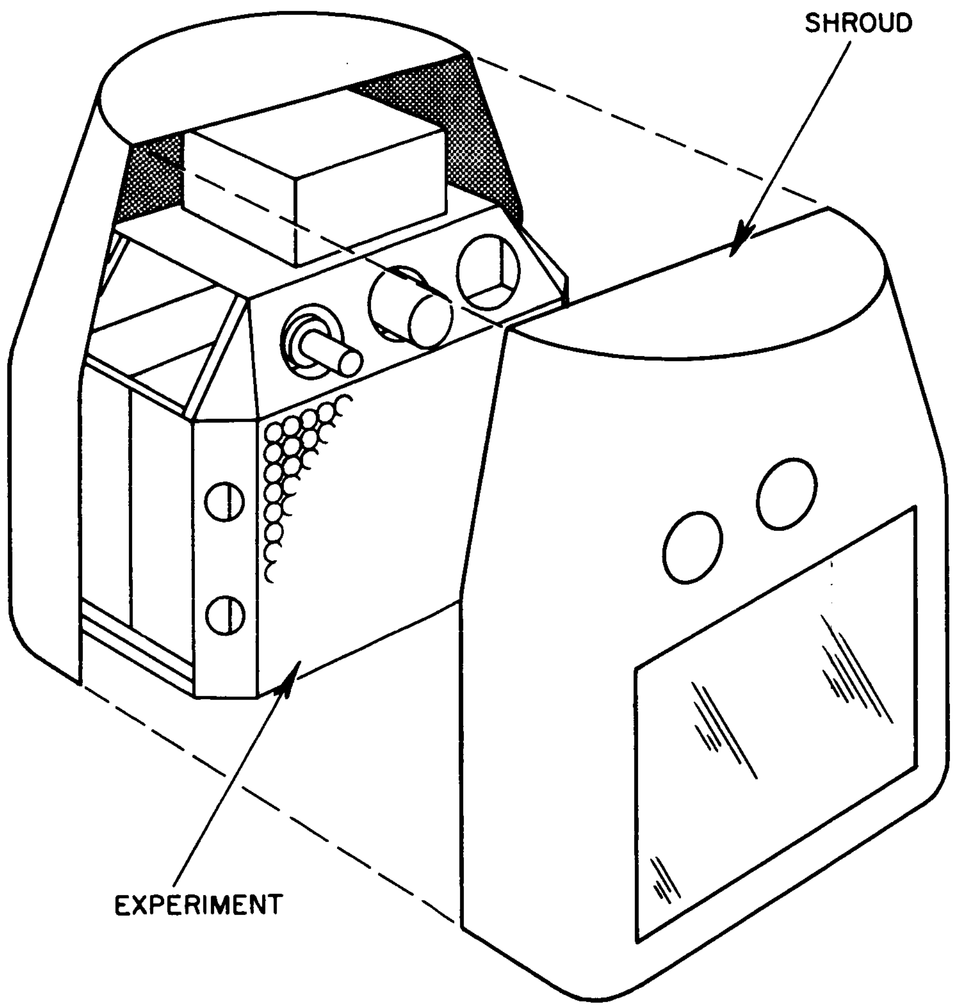
1640 A

The present X-ray Counter Assembly is composed of five X-ray counters, each having a preamplifier mounted on the rear. Brackets at both ends of the counter bank hold the bank together and, in turn, fasten the X-ray Counter Assembly to the Background Counter Assembly. Mounting of the counters to the brackets is accomplished in such a manner that each counter is electrically isolated from the brackets and all other counters. A discussion of the advancements in counter design and testing is contained in paragraph 3.2.2.2 of this report.

The Background Counter Assembly consists of eight background counter pairs, two frames and associated preamplifiers. The counter pairs are of the same twin-tube construction as was employed in the previous design. However, the present tubes are 1 by 1-1/2 inches in cross section instead of 1 x 2 inches. Tube lengths are 24 inches for six of the pairs and 10 inches for the other two pairs. These changes were made to accommodate the reduced size of the counter bank surrounding the five X-ray counters.

The main frame has been reduced in size and is of simpler construction than the previous design. Choice of material will be dictated by further thermal design study (see paragraph 3.4). At present, magnesium appears to be the most likely choice, although other materials, including possible combinations, are also being considered.

The thermal shroud (see Figure 3-4), is presently considered to be a two-piece structure, both pieces being identical. Each piece is a fiberglass honeycomb structure which supports a blanket of multi-layer insulation fastened to the inside. There are two viewing ports for the aspect sensors in each piece of the shroud. There will also be a collimator window, covered by aluminized Mylar, in each piece. There will



Thermal Shroud

Figure 3-4

be a minimum number of attachment points between the shroud and the Experiment to reduce the heat flow into or out of the Experiment.

3.2.2 Mechanical Component Development

3.2.2.1 Collimators — The requirement for maximum effective collimator area dictates that tubing with a minimum wall thickness be used. It was determined that a minimum practical wall thickness was 0.0015 inch for a tube of suitable length and diameter. However, aluminum tubing with this ratio (125 to 1) of O. D. to wall thickness had never been produced, although ratios as high as 500 to 1 had been produced in such materials as paladium silver.

A manufacturer was selected who had experience in producing tubes with a high ratio of O. D. to wall thickness, utilizing a technique, involving ultrasonic excitation of the die and mandrel. This process results in a very uniform wall thickness and O. D. with good surface finish. A pilot order for aluminum tubing was placed to verify the manufacturer's capability. The tubing was delivered ahead of schedule and passed AS&E incoming inspection.

3.2.2.2 X-ray Counters — The original counter design proposed essentially an all-beryllium counter. This design was used in an attempt to minimize stresses on the thin beryllium window attributable to a difference in coefficient of thermal expansion between the window material and that used for the window supports. By using beryllium exclusively, the coefficient mismatch and weight problems were eliminated.

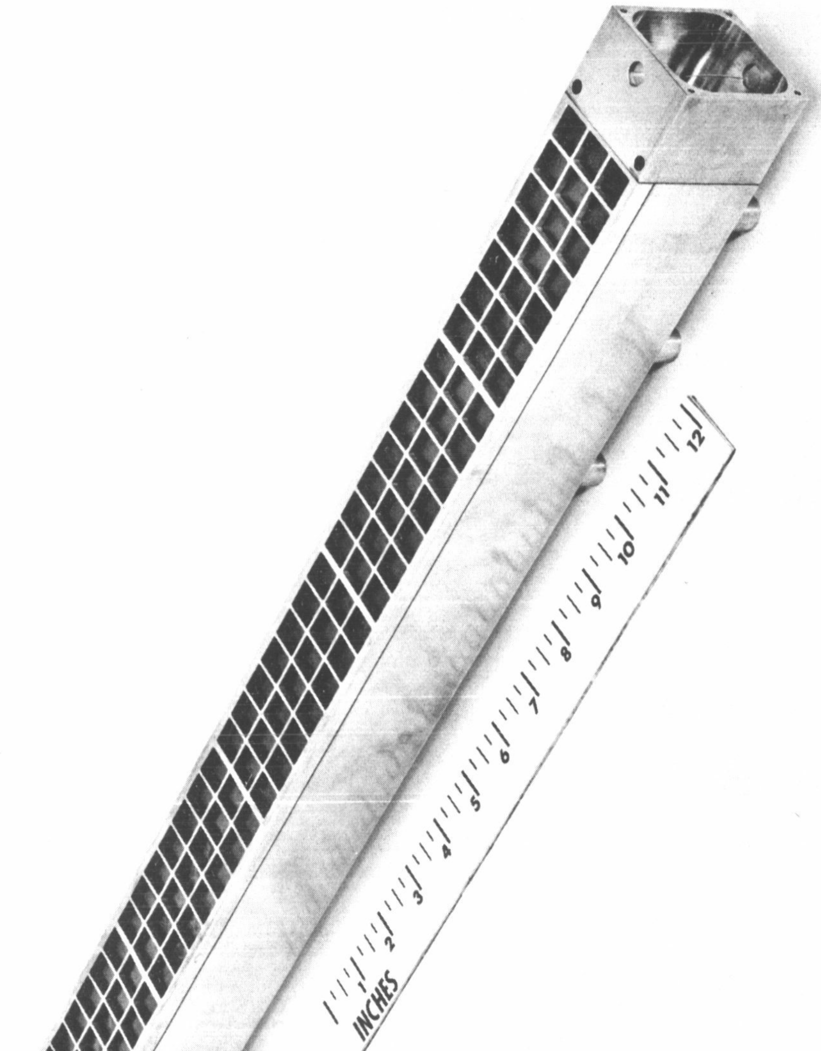
The high cost of the all-beryllium counter is a serious consideration. One counter manufacturer indicated that his window bonding techniques were developed to a point where magnesium could be used without failure despite the fact that magnesium and beryllium have considerably different coefficients of expansion.

Three counters (see Figure 3-5) were received and preliminary results of initial testing indicated that the windows are capable of withstanding temperature cycling over a range of -20° to $+160^{\circ}F$. However, a degradation in counter resolution as a function of decreasing temperature was observed. This was ultimately traced to sagging of the anode wire, resulting from improper setting of the wire tension to compensate for the differential expansion between the wire and the body. Analysis of stresses in the wire at different temperatures shows that the wire will cycle from no stress to a stress approaching the yield strength, even with the proper tension setting. In order to reduce this large variation in stress and thereby improve reliability, a spring-like device will be placed in series with the anode wire.

The counters completed Acceptance testing, but must be subjected to Qualification Tests (shock, acceleration, vibration and long-range temperature cycling) to provide data necessary to estimate counter life expectancy.

3.2.2.3 Star Sensors — A prototype star sensor (Figures 3-6 and 3-7) was fabricated to the present design except that (1) it did not have a shutter, (2) it used a photographic negative instead of a metal reticle, and (3) was not fabricated for minimum weight. The lens, photomultiplier configuration, electronics and housings were of the current design.

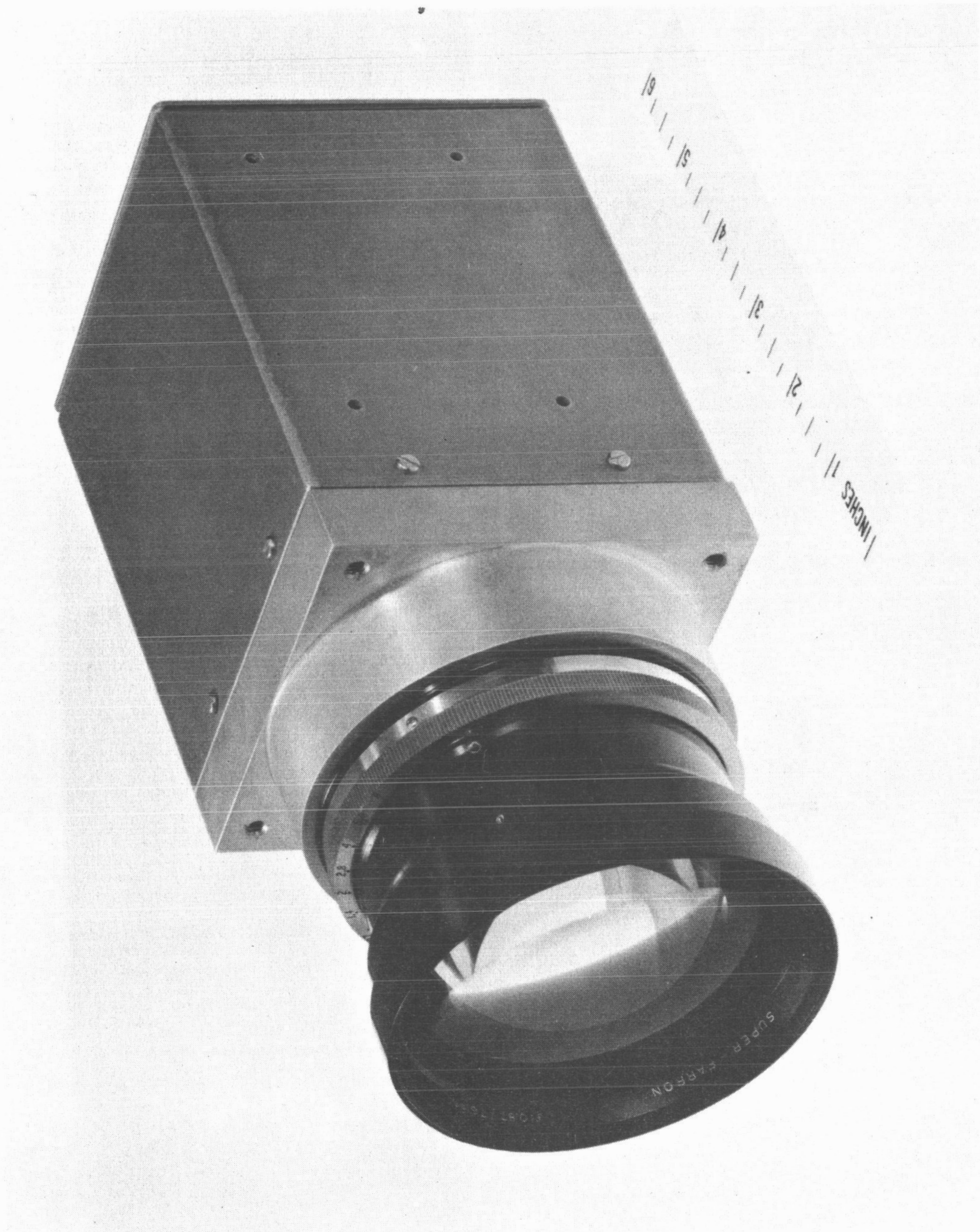
The sensor was constructed for testing the operation of the optical and electrical systems in a configuration as close to flight configuration as was possible. The sensor will also be used in the evaluation of sun shade designs.



X-Ray Proportional Counter

DQ-009

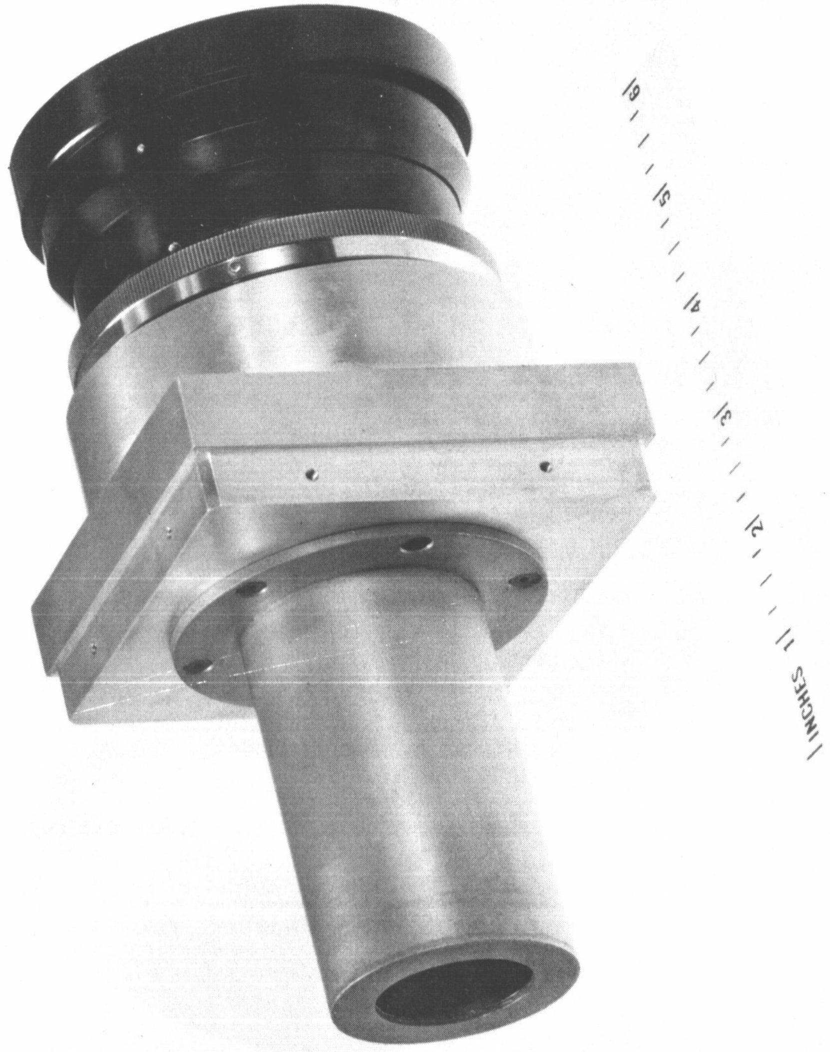
Figure 3-5



DQ-018

Star Sensor (Front View)

Figure 3-6



Star Sensor (Rear View - Cover Removed)

Figure 3-7

3.2.3 Mechanical Interface

Configuration

Outline Size, Fields of View and CG Location -	See Figure 3-8
Total Experiment Weight -	135.9 pounds
Interface Plane Location -	Sta 17.00

Mounting

Type -	Four-point mounting with thermal insulators to be provided by JHU/APL.
Fastener Locations -	See Figure 3-9
Fastener Size -	1/4-28 or 3/8-24. Fasteners to be provided by JHU/APL.
Alignment -	Experiment and spacecraft to be pinned by JHU/APL after dynamic balancing.

Connectors

Type (provisional) -	Cannon PV series
Number of Connectors and Pins -	Two 50-pin Two 25-pin
Location -	To be supplied.

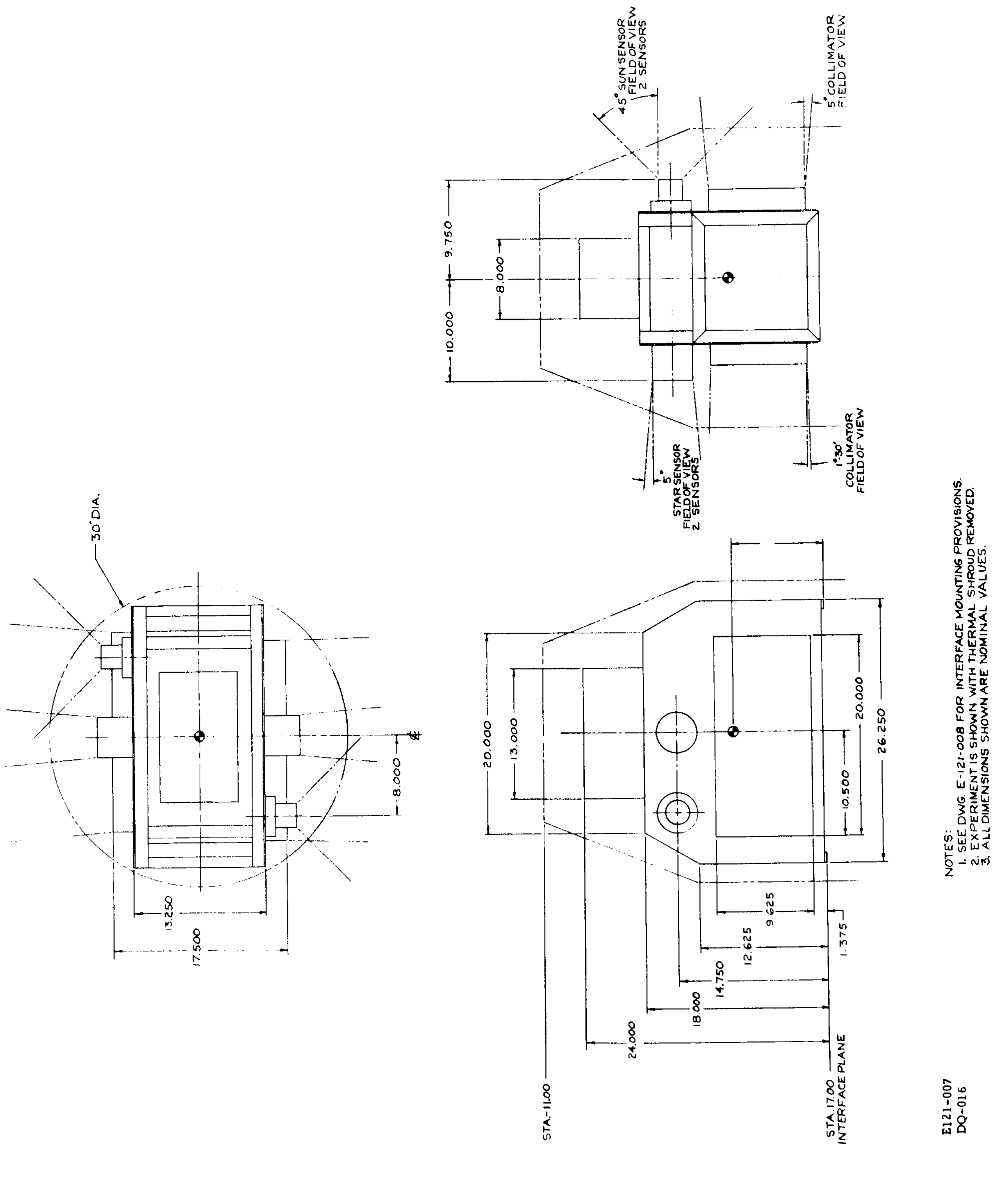
3.2.4 Estimated Weights

Estimated weights for the mechanical portion of the Experiment are given in Table 3-1.

TABLE 3-1

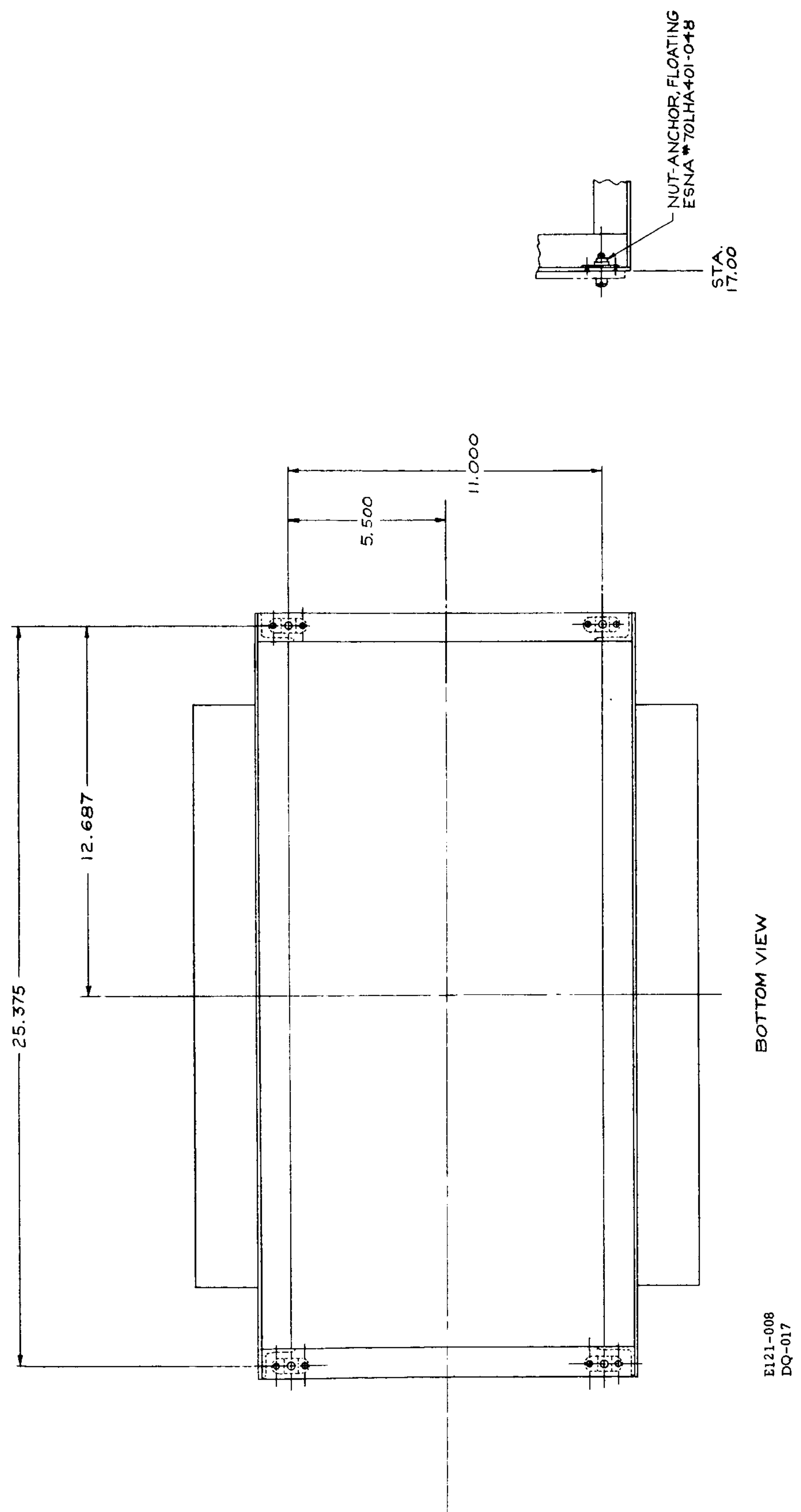
ESTIMATED WEIGHTS (MECHANICAL)

X-ray Counter Assembly	Weight (lb)	Total Weight (lb)
5 Counters	6.25	
2 Brackets	0.48	
	6.73 x 2 Req'd	13.5



Outline Drawing

Figure 3-8



Interface Mounting

Figure 3-9

TABLE 3-1 (cont'd)

		Total Weight (lbs.)
Background Counter Assembly		
6 24-in. Counters	6.00	
2 10-in. Counters	0.96	
2 Frames	1.90	
	8.86 x 2 Req'd.	17.7
Collimator Assembly Side 1		
Collimator	4.70	
Frame	3.76	
	8.46	8.5
Collimator Assembly Side 2		
Collimator	1.88	
Frame	3.76	
	5.64	5.6
Star Sensor		
Lens	2.75	
Housings	1.05	
	3.80 x 2 Req'd.	7.6
Sun Sensor		
Lens	0.30	
Housings	1.65	
	1.95 x 2 Req'd.	3.9
Main Frame		5.0
Thermal Shroud		6.0
X-ray Calibration Unit	0.40 x 2 Req'd.	0.8
Sunshade	1.00 x 2 Req'd.	2.0
Hardware		1.5
Total Mechanical Weight		72.1
Total Electronics Weight		63.8
	Total Weight	135.9 pounds

3.3 Electronics Effort

The X-ray Explorer detectors consist of two banks of proportional counters. Each bank of counters provides the signal for an independent X-ray processing channel. Background counters and pulse shape discrimation will be used in conjunction with the X-ray counters to provide anti-coincidence capability. Digital and analog output information will be obtained from each of the X-ray channels. A three-channel digital pulse height analyzer will be used to obtain spectral information from either of the two X-ray channels.

Aspect information will be obtained from sun and star sensors. There will be one each of the above sensors associated with each bank of the Experiment to maintain aspect independence.

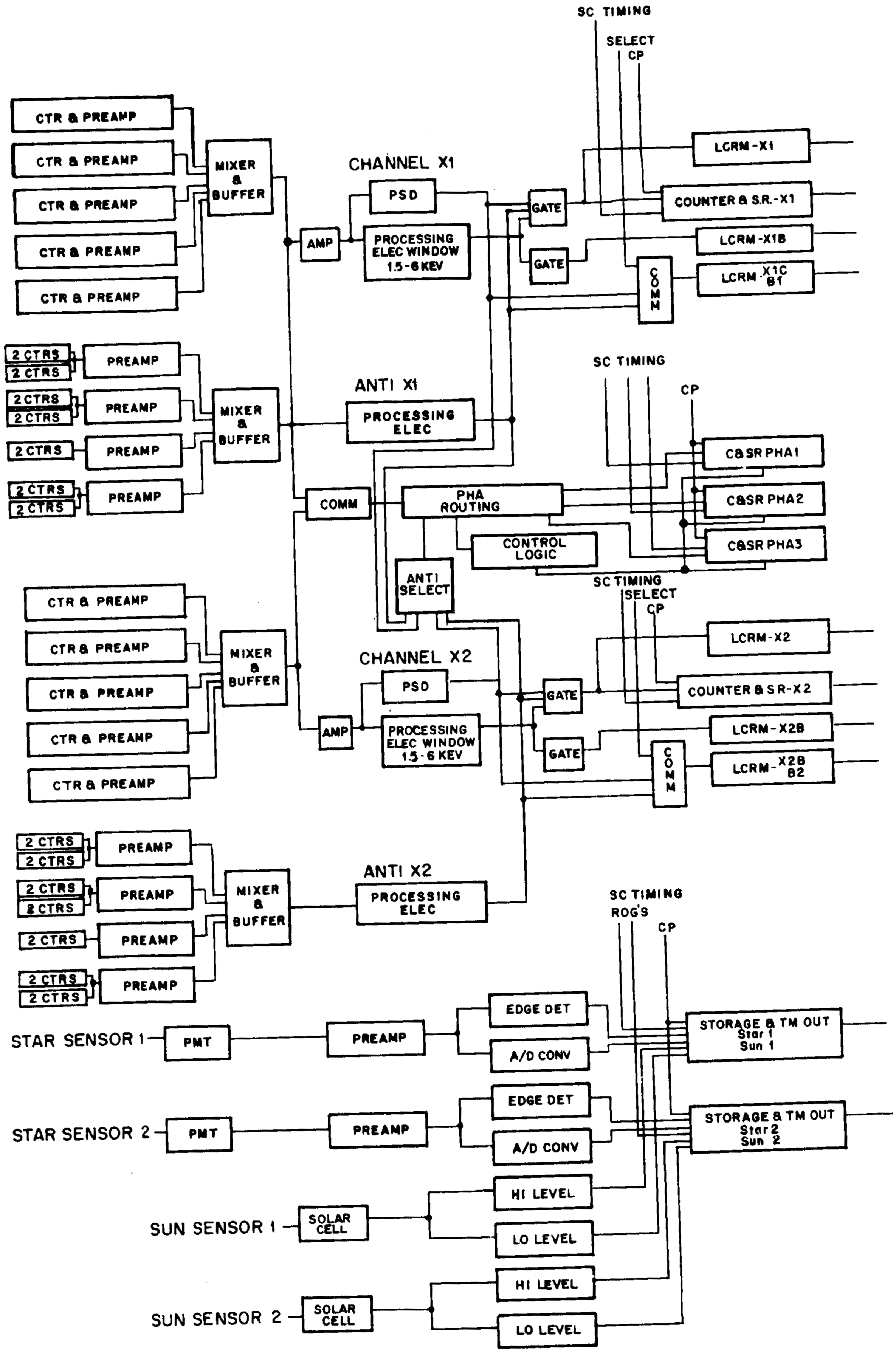
3.3.1 Experiment Electronics

The block diagram of the signal processing portion of the redefined Experiment is shown in Figure 3-10. The significant changes to the system from the previously described system (ASE-1567) are as follows:

Because of weight considerations, the following functions have been deleted from the Experiment.

(1) The number of proportional and background counters has been reduced by 50%. This effectively eliminated two of the four X-ray processing channels and reduced the background channel preamps and counters by a similar factor.

(2) The pulse height analyzer has been cut back in scope to be a three-channel analyzer.



Signal Processing Block Diagram
Figure 3-10

1640 A

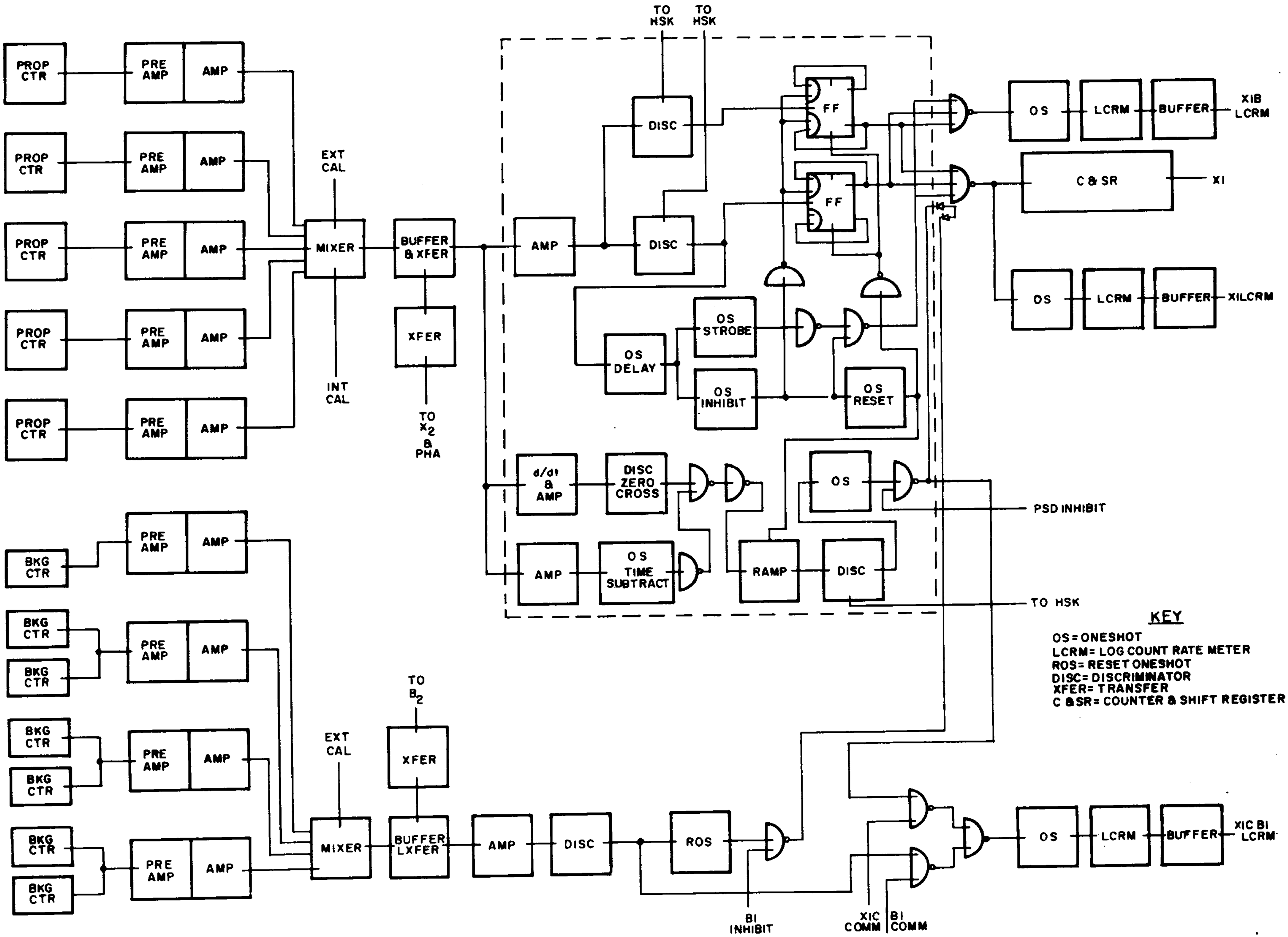
(3) A number of the log count rate meters (LCRM) have been deleted from the instrument package consistent with the reduction in the X-ray channels.

(4) A more complete command system has been added to the system to partially compensate for the loss in redundancy and reliability.

The following changes should also be noted.

(1) Each X-ray channel consists of five proportional counters and their associated preamplifiers. The processing channel consists of a window discriminator and its associated pulse shape discrimination (PSD) electronics. The settings of the upper and lower window edges can be varied; the optimum values will be determined later. Tentatively, they are set at 6 keV and 1.5 keV respectively. The channel (1.5-6 keV) has digital and analog output information including log count rate meter (LCRM) outputs of the major channel before and after PSD and background anti-coincidence, as well as sampling of these anti-coincidence signals. A block diagram of the X-ray channel is shown in Figure 3-11. The digital processing utilizes the same prescaled counter as described in previous reports and as shown in Figure 3-12.

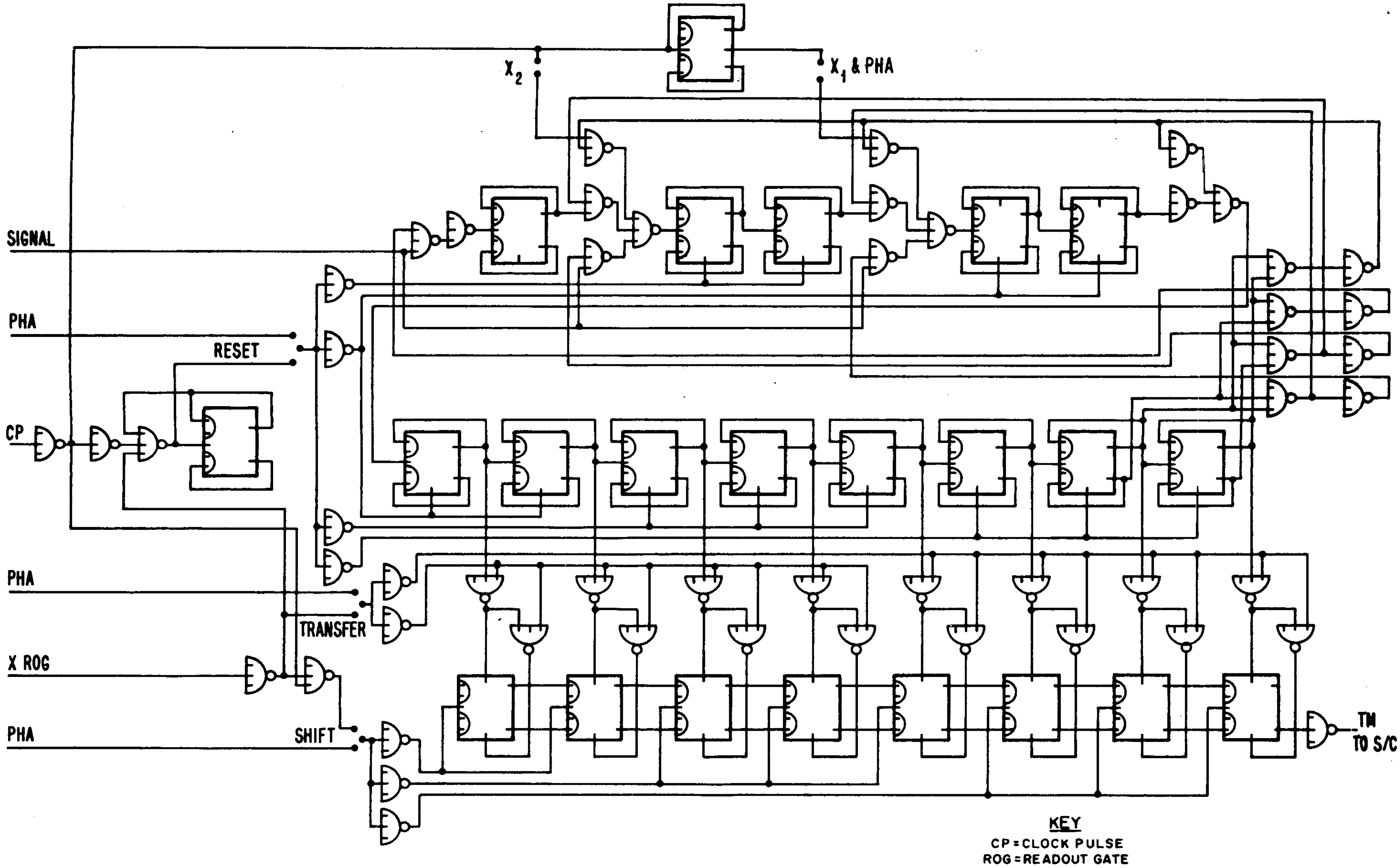
The pulse height analyzer will be a three-channel unit similar to the pulse height analyzer previously described (ASE-1567). The outputs will not be commutated but will each have its own independent readout gate. The PHA will be a synchronous entry, serial readout type of system utilizing prescaled counters identical with those used in the X-ray channels. A PSD network will be used with the PHA, and the PHA will be capable of being switched to either of the two X-ray channels through the command system. A block diagram of the PHA is shown in Figure 3-13.



X-Ray Channel

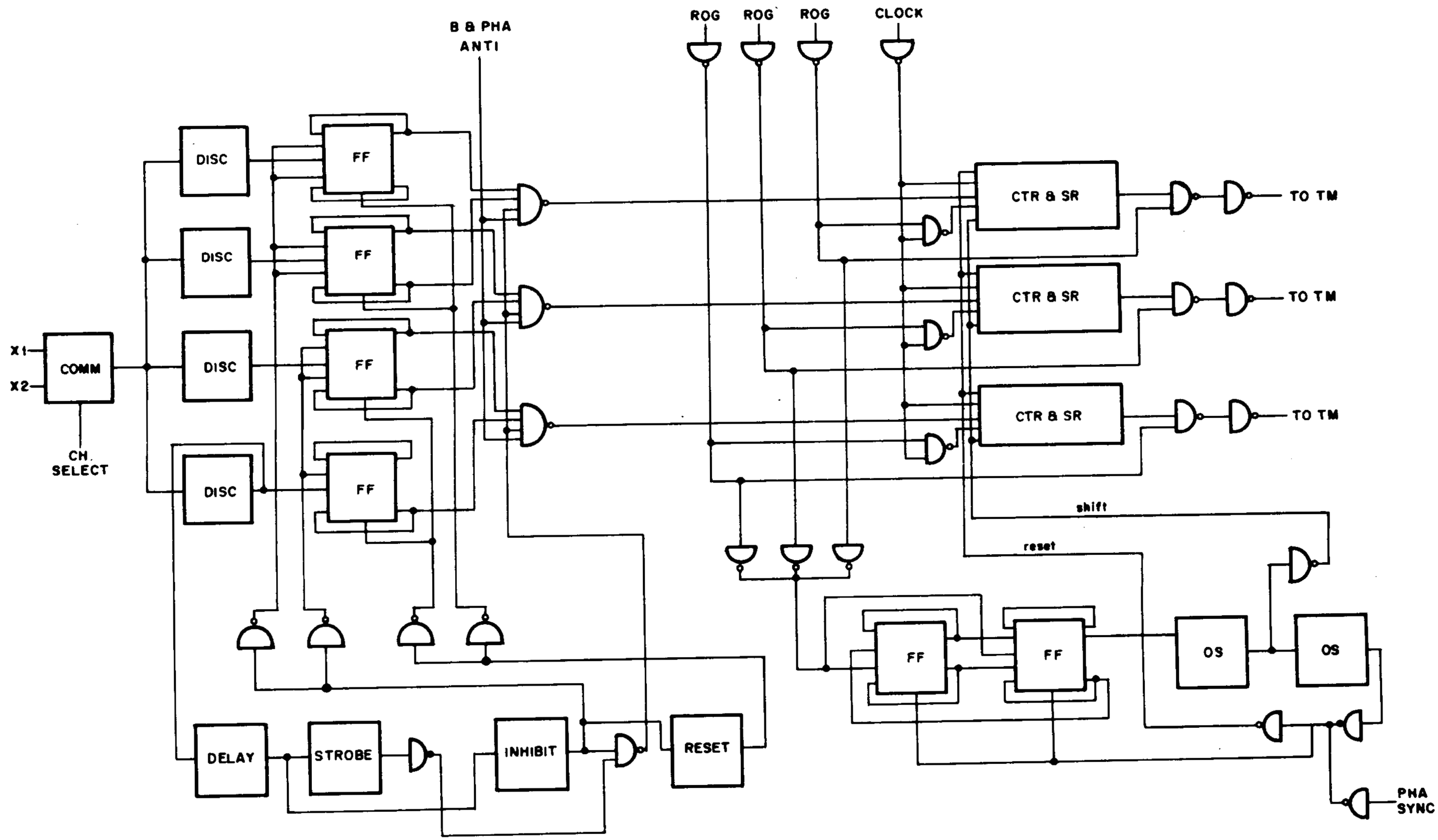
Figure 3-11

1640 A



Counter and Shift Register Block Diagram

Figure 3-12



PHA Block Diagram

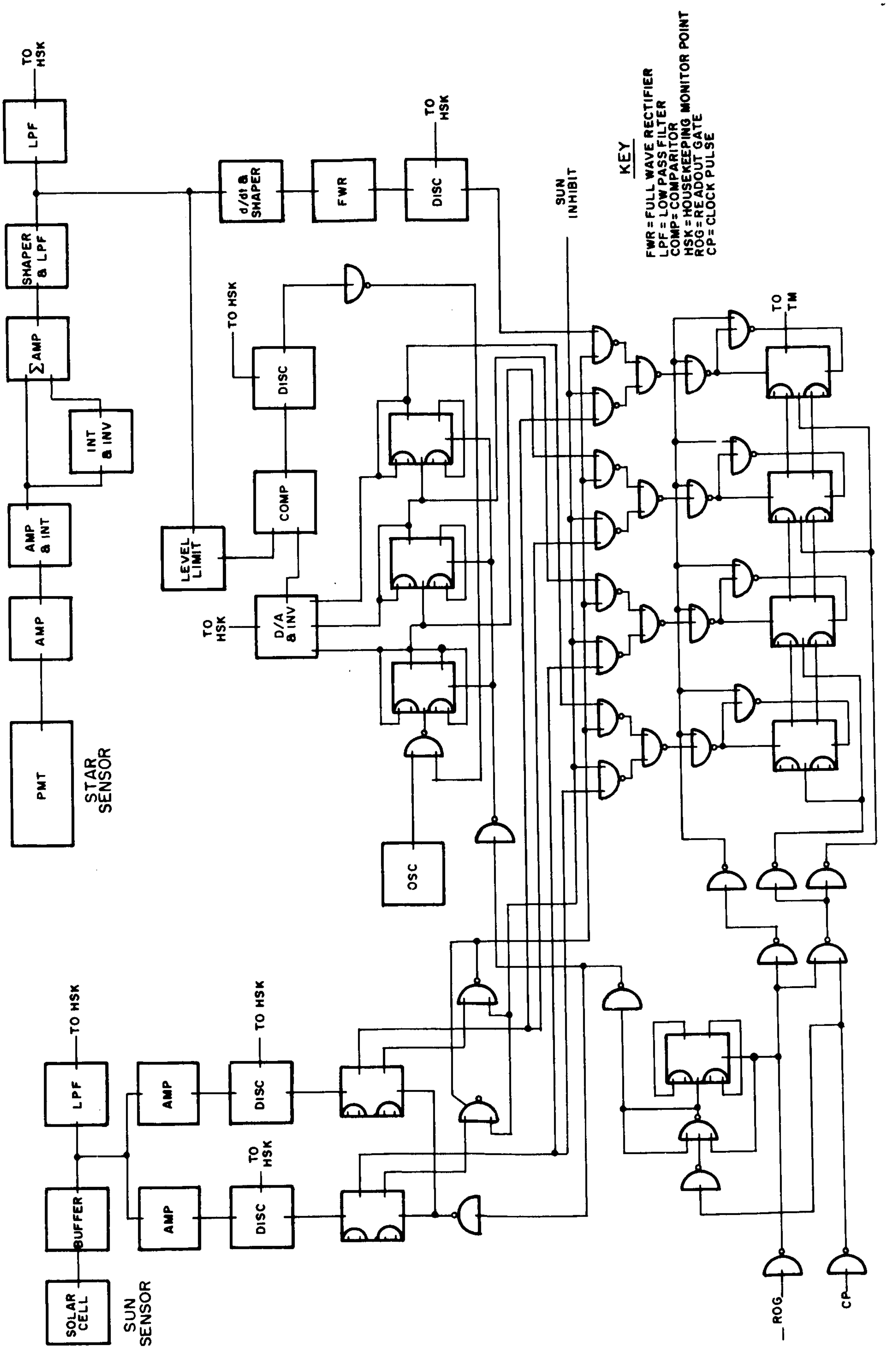
Figure 3-13

On-board calibration capability will be maintained. Electronic and radioactive x-ray source calibration techniques will be used.

(2) The star sensor preamplifier and processing electronics are as previously described. A sun sensor,utilizing a lens, reticle (multiple N's), sensor and processing electronics,has been substituted for the commercially available unit previously considered. The block diagram of the sun and star sensor is shown in Figure 3-14. The outputs of the two sensors are time shared in the output shift register since the two sensors will never be operated simultaneously (proximity to the sun will inhibit the star sensor). This also enables reduction of the telemetry bit rates.

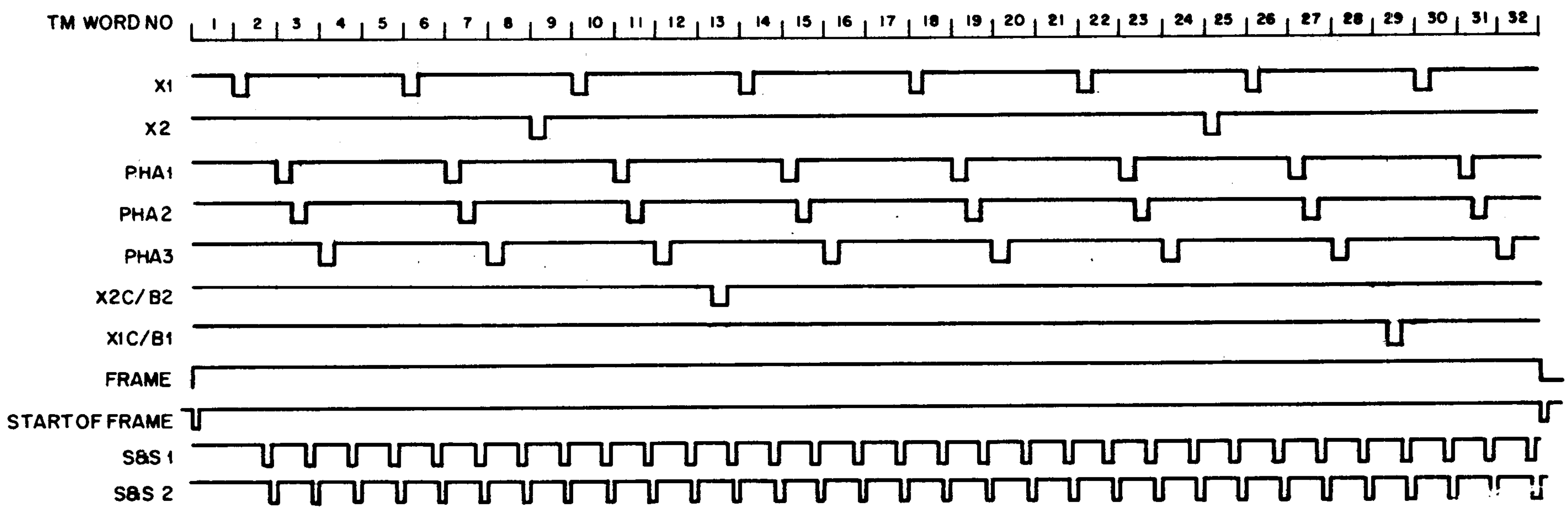
A listing of output signals and their required sampling rates is shown in Table 3-2. A typical example of the required digital signal timing and TM format is shown in Figure 3-15 and Table 3-3. The housekeeping points to be monitored are shown in Table 3-4.

The digital interface will consist of an integrated circuit gate terminating both ends of the interface line. The analog interface is defined in Figure 3-16. Five classes of analog signals are used to maintain maximum resolution consistent with as simple an interface as possible.



Sun and Star Sensor Block Diagram

Figure 3-14



Digital TM Timing Signals

Figure 3-15

TABLE 3-2

AS&E X-RAY EXPLORER TELEMETRY DATA REQUIREMENTS

INFORMATION	NO. OF BITS	SAMPLE PERIOD (0.5^{o}/SEC SPIN RATE)	BIT RATE (BITS/FRAME)
X_1	8	4 arc min	64
*X-1 LCRM	8	4 arc min	64
*X-1B LCRM	8	4 arc min	64
*X-1C LCRM	8 **	64 arc min **	8
*B-1 LCRM	8	64 arc min	
X2	8	16 arc min	16
*X-2 LCRM	8	16 arc min	16
*X-2B LCRM	8	16 arc min	16
*X-2C LCRM	8 **	64 arc min **	8
*B-2	8	64 arc min	
PHA #1	8	4 arc min	64
PHA #2	8	4 arc min	64
PHA #3	8	4 arc min	64
Star & Sun #1	4	1 arc min	128
Star & Sun #2	4	1 arc min	128
*Housekeeping (64 Channels)	8	32 arc min	8

* Data must be converted from analog to digital

** Commutated by AS&E

TABLE 3-3

PRELIMINARY FRAME FORMAT X-RAY EXPLORER

Word	Syllable 1	Syllable 2	Syllable 3
1	Frame Sync	Frame Sync	Frame Sync
2	X1	X1 LCRM	Sun and Star Sensor
3	PHA 1	PHA 2	Sun and Star Sensor
4	PHA 3	X1 B LCRM	Sun and Star Sensor
5	Frame Ident.	APL HSKPG # 1	Sun and Star Sensor
6	X1	X1 LCRM	Sun and Star Sensor
7	PHA 1	PHA 2	Sun and Star Sensor
8	PHA 3	X1 B LCRM	Sun and Star Sensor
9	X2	X2 LCRM	Sun and Star Sensor
10	X1	X1 LCRM	Sun and Star Sensor
11	PHA 1	PHA 2	Sun and Star Sensor
12	PHA 3	X1 B LCRM	Sun and Star Sensor
13	X2 B LCRM	X1C/B1 LCRM	Sun and Star Sensor
14	X1	X1 LCRM	Sun and Star Sensor
15	PHA 1	PHA 2	Sun and Star Sensor
16	PHA 3	X1 B LCRM	Sun and Star Sensor
17	5-8 bit TT 1-8 bit MSB of time 2-8 bit rotor speed	Telltales	Sun and Star Sensor
18	X1	X1 LCRM	Sun and Star Sensor
19	PHA 1	PHA 2	Sun and Star Sensor
20	PHA 3	X1 B LCRM	Sun and Star Sensor
21	LSB of Time	ASE HSKPG	Sun and Star Sensor
22	X1	X1 LCRM	Sun and Star Sensor
23	PHA 1	PHA 2	Sun and Star Sensor
24	PHA 3	X1 B LCRM	Sun and Star Sensor
25	X2	X2 LCRM	Sun and Star Sensor
26	X1	X1 LCRM	Sun and Star Sensor
27	PHA 1	PHA 2	Sun and Star Sensor
28	PHA 3	X1 B LCRM	Sun and Star Sensor
29	X2 B LCRM	X2C/B2 LCRM	Sun and Star Sensor
30	X1	X1 LCRM	Sun and Star Sensor
31	PHA 1	PHA 2	Sun and Star Sensor
32	PHA 3	X1 B LCRM	Sun and Star Sensor

TABLE 3-4

X-RAY EXPLORER EXPERIMENT HOUSEKEEPING REQUIREMENTS

1. Power Supply Monitor 5V A
2. Power Supply Monitor +6.75 A
3. Power Supply Monitor -6.75 A
4. Power Supply Monitor +HV 1 A
5. Power Supply Monitor -HV 1 A
6. Power Supply Monitor +HV 2 A
7. Power Supply Monitor -HV 2 A
8. Temperature Monitor CTR 1
9. Temperature Monitor CTR 2
10. Temperature Monitor Back
11. Temperature Monitor SS 1
12. Temperature Monitor SS 2
13. Temperature Monitor ELEC 1
14. Temperature Monitor ELEC 2
15. Discriminator Ref. Monitor PHA 1
16. Discriminator Ref. Monitor PHA 2
17. Discriminator Ref. Monitor PHA 3
18. Discriminator Ref. Monitor PHA 4
19. Discriminator Ref. Monitor X1 UPPER
20. Discriminator Ref. Monitor X2 UPPER
21. Discriminator Ref. Monitor X1 LOWER
22. Discriminator Ref. Monitor X2 LOWER
23. PSD Rej. Level X1
24. Amplitude Rej. Level B1
25. PSD Rej. Level X2
26. Amplitude Rej. Level B2
27. PSD Rej. Level PHA
28. Star Sensor Output Bias 1
29. Star Sensor Output Bias 2
30. Sun Sensor Output Bias 1
31. Sun Sensor Output Bias 2
32. Star Sensor 1A-D Ref. Volt.
33. Star Sensor 2A-D Ref. Volt.
34. Star Sensor 1 Comparator Ref. Volt.
35. Star Sensor 2 Comparator Ref. Volt.
36. Sun Sensor 1 Ref. A Volt.
37. Sun Sensor 2 Ref. A Volt.
38. Sun Sensor 1 Ref. B
39. Sun Sensor 2 Ref. B
40. Int. Cal. Ref. Volt.
41. Int.Cal. D-A Verification
42. Power Supply Monitor 5V B
43. Power Supply Monitor +6.75 B
44. Power Supply Monitor -6.75 B
45. Power Supply Monitor +HV 1 B
46. Power Supply Monitor -HV 1 B
47. Power Supply Monitor +HV 2 B
48. Power Supply Monitor -HV 2 B

49 - 61 Spare

62. + Cal.
63. Zero
64. - Cal.

ANALOG SIGNAL REQUIREMENTS

Channel	Function	Full Scale Value	RS	R1	R2	RP	Atten.
1	Class A	± 7.50 V.	5.00	133.00	2.15	4.60	39.0
2	B	± 5.00 V.	5.00	90.90	2.61	4.79	20.0
3	C	± 2.50 V.	5.00	42.20	2.87	4.72	10.0
4	D	± 1.25 V.	5.00	17.80	3.16	4.56	5.0
5	E	± 0.50 V.	5.00	4.22	6.81	4.51	2.0

Attenuator

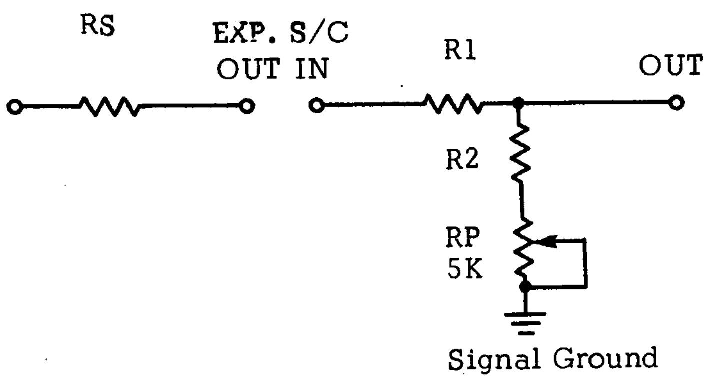


Figure 3-16

3.3.2 Command System

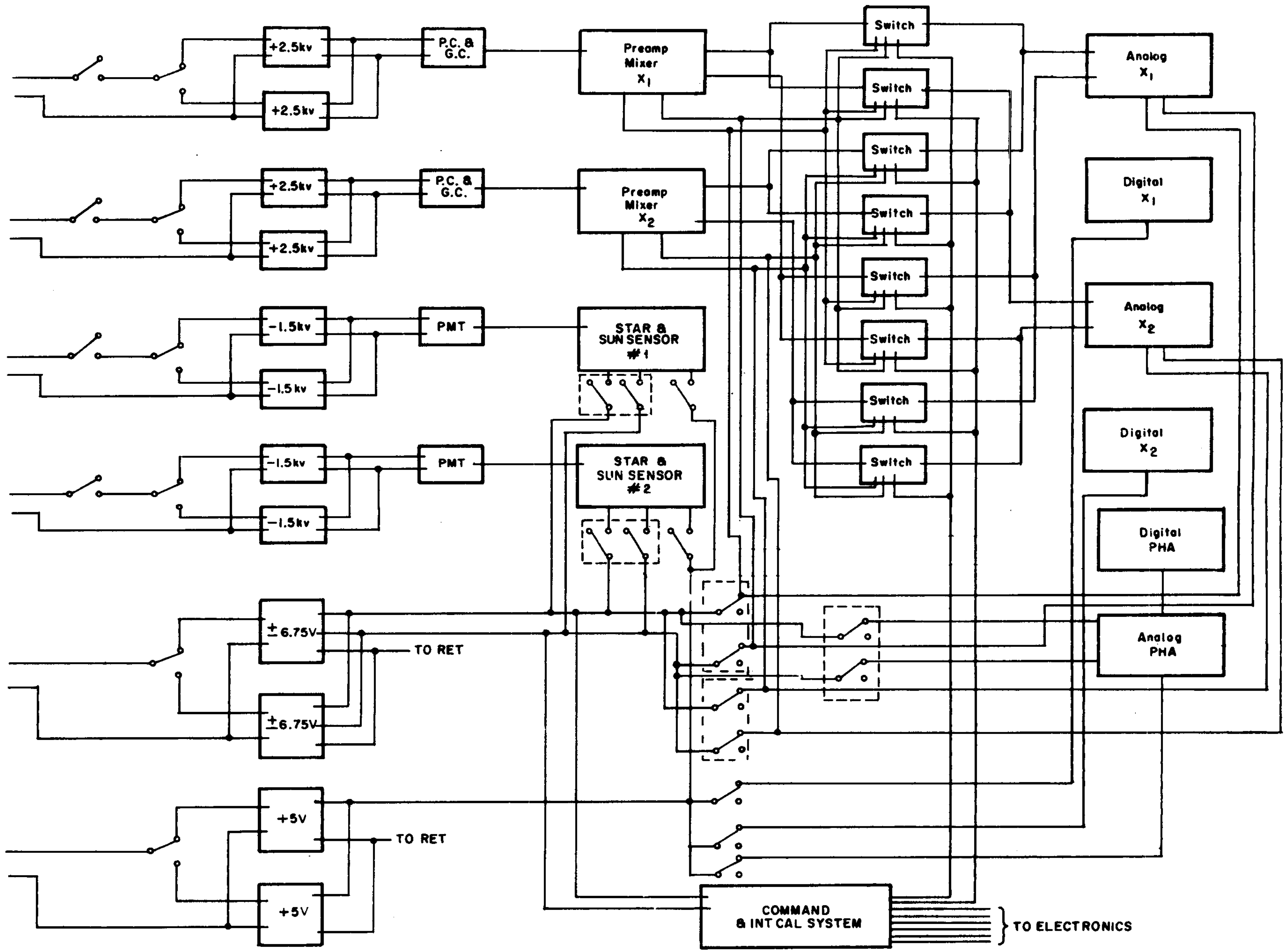
A number of changes, in addition to those associated with the processing electronics, have also been incorporated and are shown in Figure 3-17. These changes include the following:

(1) Back-up redundancy for all power supplies has been adopted to improve the reliability of the basic experiment.

The eleven required switchover and turn-off commands for the power supplies are located in the spacecraft relay command matrix. A list of these command functions is shown in Table 3-5.

(2) An additional 24-bit command system has been added as an integral part of the Experiment package. The command information is obtained from bits 29 - 52 of the PCM Instruction Command word format. The command information is obtained from the spacecraft in a 24-bit shift register shown in Figure 3-18. Two of the 24 bits are used for a parity check and an execute command to permit selective acceptance of command signals. A listing of the command functions provided by this system is shown in Table 3-6 and is self-explanatory.

The commands are monitored through the use of a telltale register shown in Figure 3-19, which may be alternately connected to groups of various command functions to permit monitoring of all digital command states. The timing interface for the command and telltale system is shown in Figure 3-20.



Power Supply and Command System Block Diagram

Figure 3-17

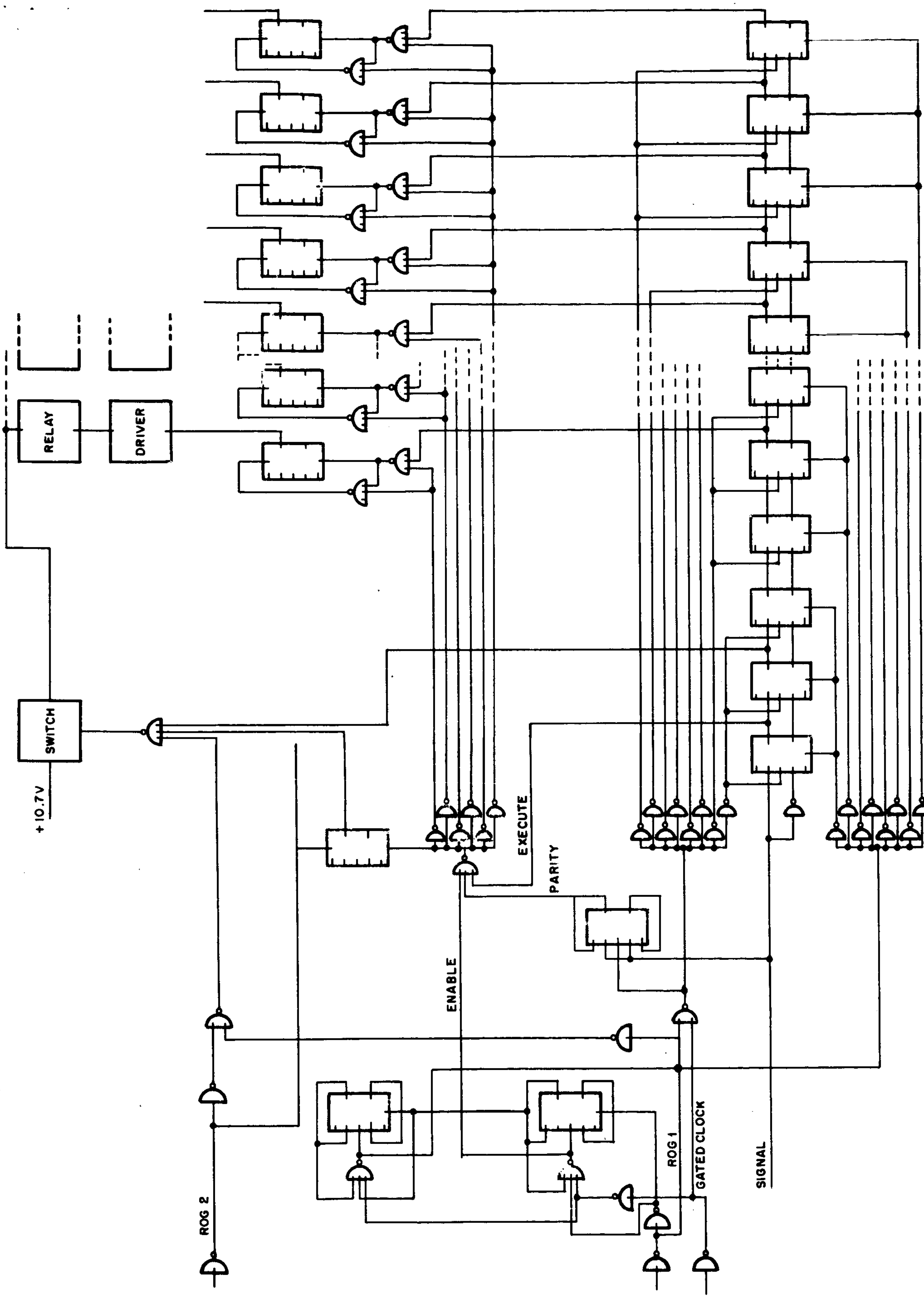
TABLE 3-5

X-RAY EXPLORER

EXTERNAL COMMAND

REQUIREMENTS

CMD. NO.	FUNCTION		OPERATION	POWER
1.	Analog P S	Switchover	A & B	5.4 W
2.	Digital P S	Switchover	A & B	3.4 W
3.	Digital P S		ON & OFF	
4.	X1 HVPS		ON & OFF	0.45 W
5.	X1 HVPS	Switchover	A & B	
6.	X2 HVPS		ON & OFF	0.45 W
7.	X2 HVPS	Switchover	A & B	
8.	S1 HVPS		ON & OFF	0.38W
9.	S1 HVPS	Switchover	A & B	
10.	S2 HVPS		ON & OFF	0.38W
11.	S2 HVPS	Switchover	A & B	



Internal Command System Block Diagram

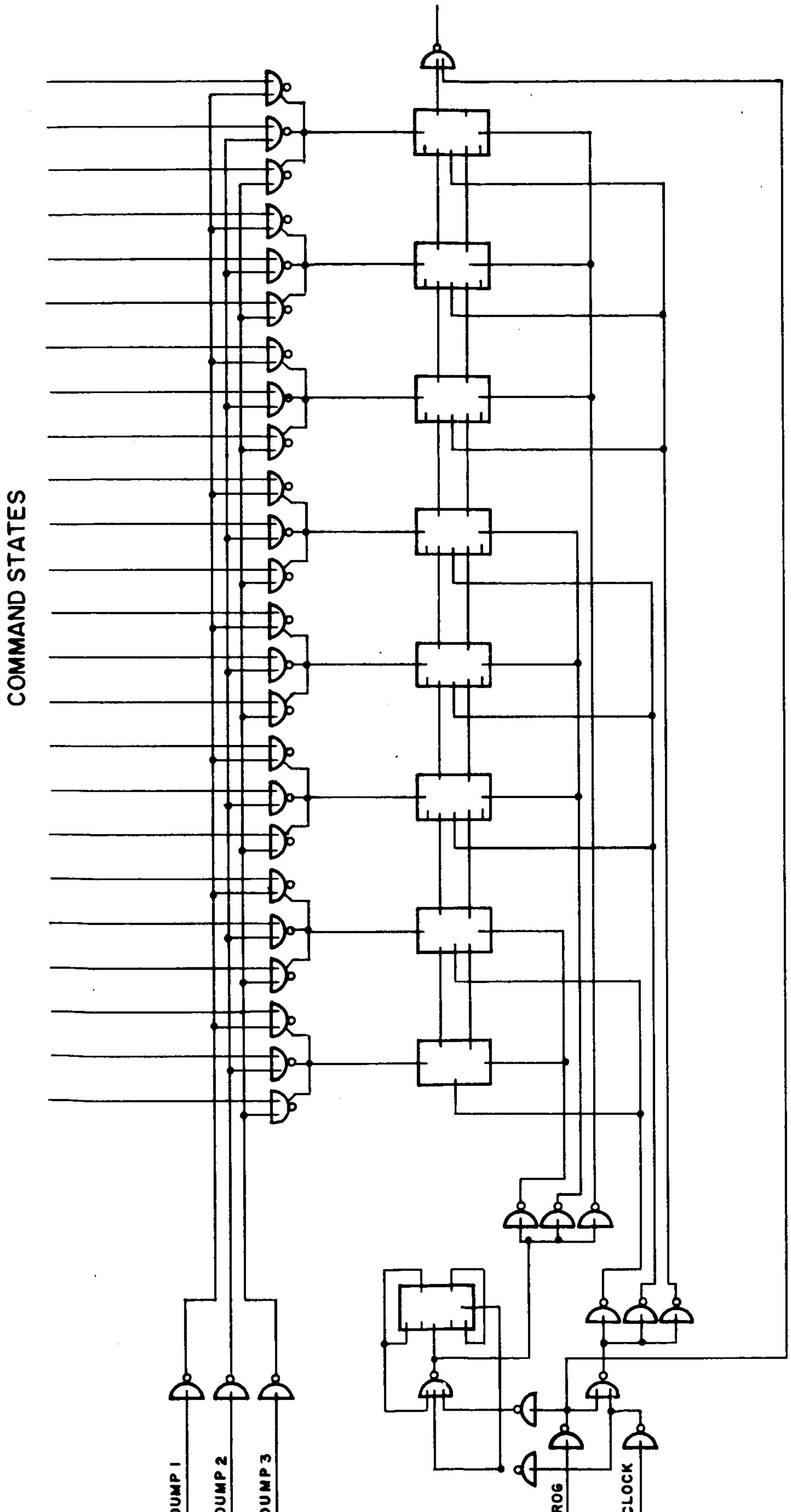
Figure 3-18

TABLE 3-6

X-RAY EXPLORER

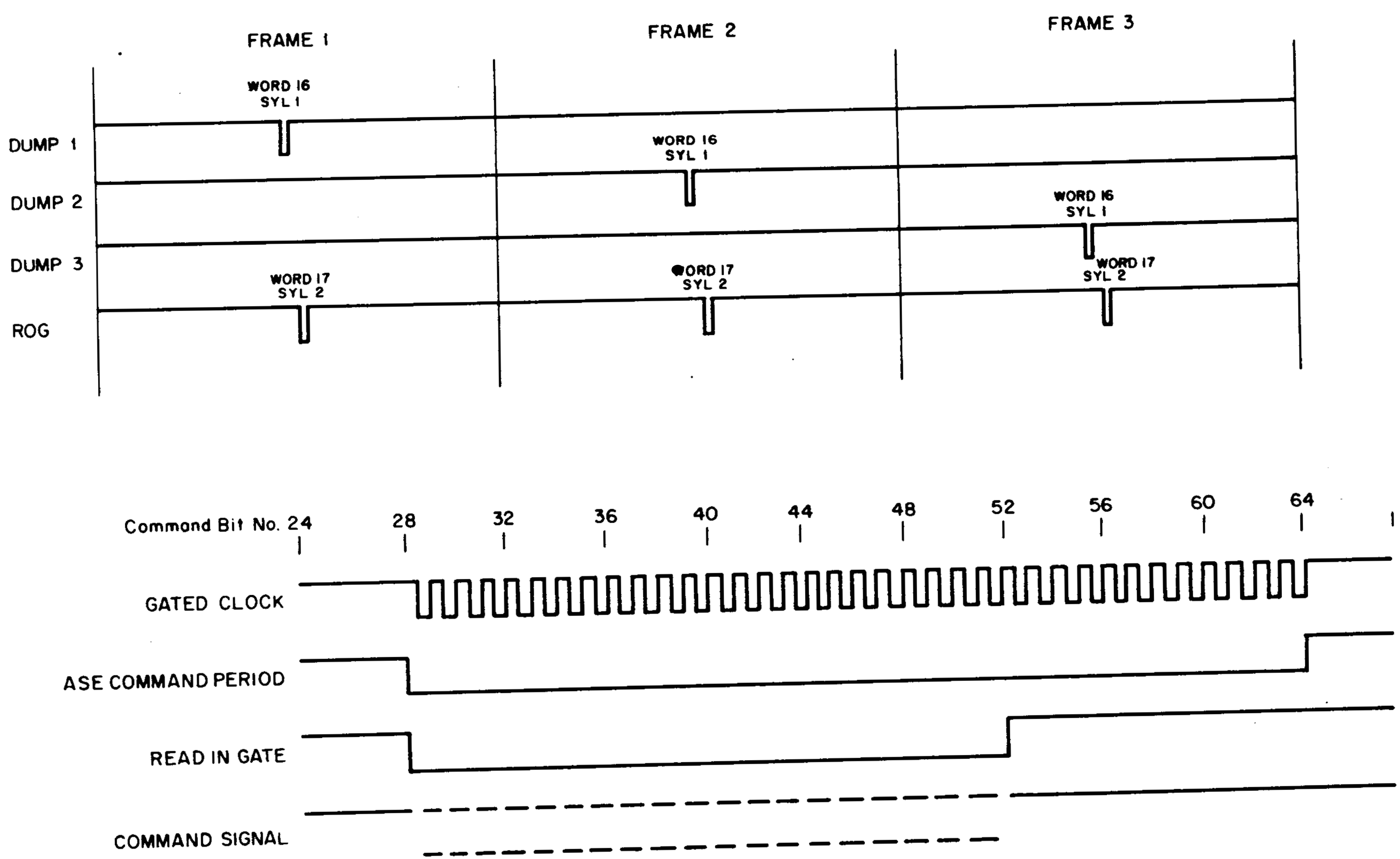
INTERNAL COMMAND REQUIREMENTS

CMD. NO.	FUNCTION		OPERATION
1.	Power Distribution	X1 Digital	OFF
2.	Power Distribution	X1 Analog	OFF
3.	Power Distribution	X2 Digital	OFF
4.	Power Distribution	X2 Analog	OFF
5.	Power Distribution	S&S #1	OFF
6.	Power Distribution	S & S #2	OFF
7.	Power Distribution	PHA Analog	OFF
8.	Power Distribution	PHA Digital	OFF
9.	Signal Transfer	Side Switch	OFF
10.	Signal Transfer	Side Switch	OFF
11.	Calibrate	Time Period 1	ON
12.	Calibrate	Time Period 2	ON
13.	Inhibit	Sun Sensor 1	OFF
14.	Inhibit	Sun Sensor 2	OFF
15.	Inhibit	Background 1	OFF
16.	Inhibit	Background 2	OFF
17.	Inhibit	PSD X1	OFF
18.	Inhibit	PSD PHA	OFF
19.	Inhibit	PSD X2	OFF
20.	Inhibit	Spare	
21.	PHA Input	Select (X1)	OFF
22.	Spare		
23.	Parity		
24.	Execute		



Telltale Register Block Diagram

Figure 3-19



Command and Telltale Timing Diagram

Figure 3-20

1640A

3.3.3 Power Distribution

The following power supply levels and quantities will be required:

QUANTITY	POWER SUPPLY LEVELS REQ.	
2	1	+6.75 Volt Analog Electronics
2	1	-6.75 Volt Analog Electronics
2	1	+5.00 Vclt Analog Electronics
4	2	+2.50 kV Prop-Ctrs. & Background Ctrs
4	2	-1.50 kV Star Sensor Photomultiplier

As shown in the above table, back-up redundancy will be used for all power supplies to obtain maximum reliability.

A power analysis of the experiment is outlined in Table 3-7.

3.3.4 Electronics Packaging

The packaging concepts previously defined will undergo no substantial changes except for reductions consistent with the previously described electronics changes. Reduction in circuit board thickness and use of foam encapsulation (instead of conformal coating) are being considered. The new configuration of the electronics box layout is shown in Figure 3-21. The electronics box consists of 4 compartments. Two compartments house 2-3/4" x 4-1/2" x 1" analog assemblies. The remaining two compartments house the digital assemblies (7" x 4-1/2" x 1") and the power supplies.

A detailed weight analysis of the electronics portion of the experiment is shown in Table 3-8.

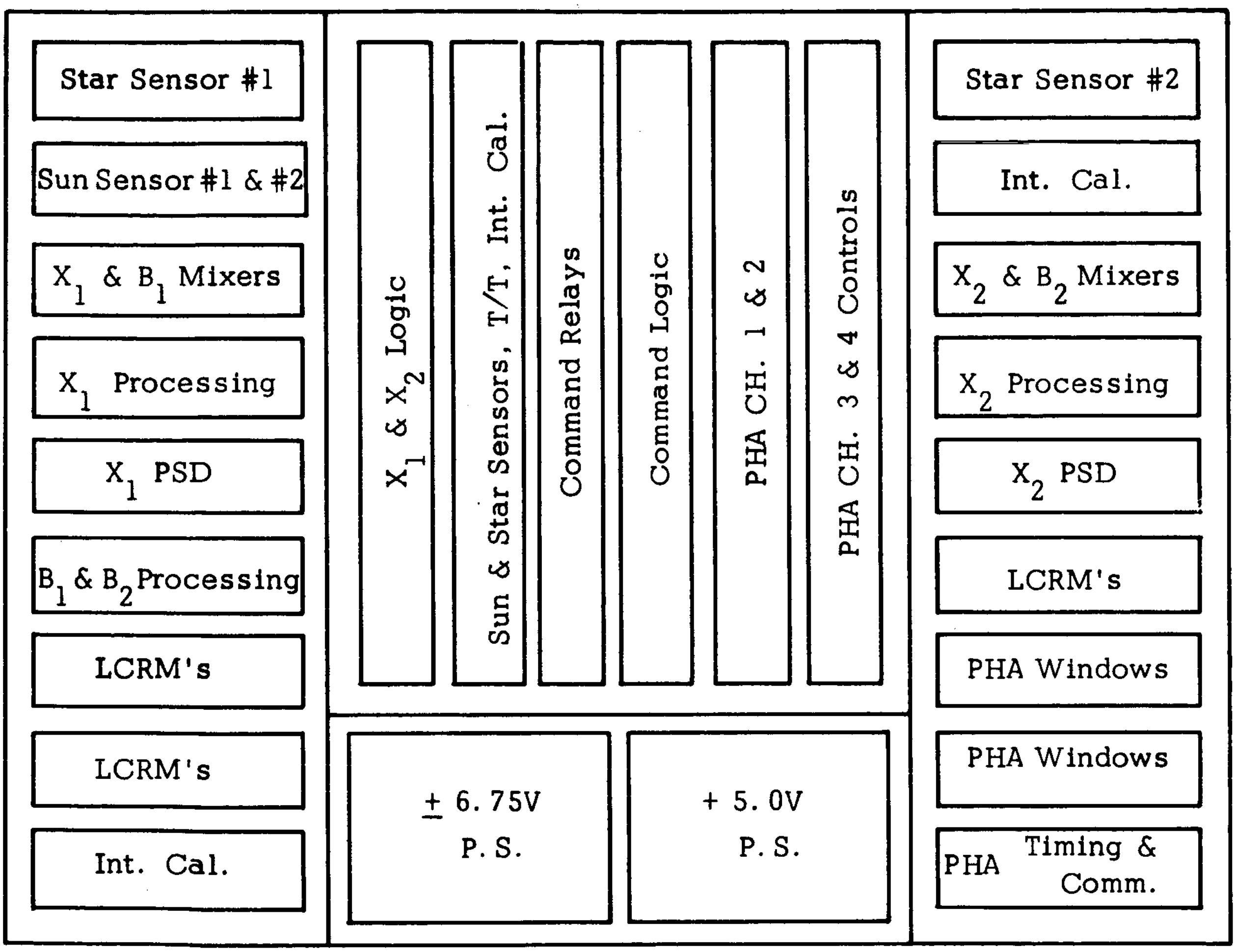
TABLE 3-7

POWER DISSIPATION

	Analog	Digital	H.V.
Preamps 10 X-ray, 8 G.C.	470 mw		200 mw
Mixers, Buffers, Transfers	170 mw		
X_1 and X_2 Analog Processing	290 mw		
X_1 and X_2 PSD	260 mw		
X_1 and X_2 Logic		380 mw	
PHA (3 Ch)	330 mw	660 mw	
Bkg. Channels	160 mw		
LCRM's	510 mw		
Sun Sensor (2)	220 mw		
Star Sensor Preamp (2)	230 mw		50 mw
Processing Elect.	410 mw	230 mw	
Int. Cal. (1)	200 mw	100 mw	
Command System		360 mw	
Telltale System		120 mw	
	3.25 W	1.85 W	0.25 W

TOTAL POWER DRAIN

Analog Supply @60% Eff.	5.42
Digital Supply @ 55% Eff.	3.37
+2.5 kV HVPS	0.90
-1.5 kV HVPS	0.75
	10.44 W



Electronics Box Layout

Figure 3-21

TABLE 3-8

COMPONENT WEIGHTS, ELECTRONICS PORTION

Function	Total Weight Pounds		Grams
Preamps	11.12		
Circuit Cards		3.58	1601
Cavities		7.54	3400
Electronics Box	32.47		
Analog Assemblies		13.35	6050
Power Supplies		2.65	1210
Digital Assemblies		4.64	2105
Relay Assembly		1.51	683
Connector Mates		3.82	1730
Wire		1.52	690
Structure (Ribbed .040" Material)		4.98	2260
Interface Wiring	7.53		
Connectors		4.08	1830
Cables		3.45	1545
Sun Sensor (2 Req) (Less Housing)	1.22		550
Star Sensor (2 Req)	4.48		2035
H.V. Distribution (2 Req)	7.02		3180
Totals	63.84		28,869

3.4 Thermal Interface

3.4.1 Distribution and Levels of Temperatures

The distribution and levels of temperatures within the X-ray Explorer Experiment are dependent on a number of items, namely;

a. The locations and magnitudes of heat dissipations within the Experiment.

b. The magnitudes of heat fluxes to the Experiment's surface from the Sun and the Earth, the magnitudes depending on the Explorer satellite's orientation in space.

c. The magnitude of heat flux radiated from the Experiment's surfaces to deep space.

d. The thermal characteristics of the Experiment's internal structure.

e. The thermal properties of the Experiment's outer walls and surfaces.

f. The thermal characteristics of the interface between the Experiment and the spacecraft to which it is mounted.

3.4.2 Experiment Complement

The Experiment consists of an Electronics Box, Collimators (which collimate X-ray fluxes and, thermally, are black bodies), Proportional Counters (which are located behind the collimators and detect X-rays), and four optical instruments - two Star Sensors and two Sun Aspect Sensors.

3.4.3 Possible Thermally Extreme Orientations

Two possible thermally extreme orientations of the Experiment are considered in the thermal analysis. In one, the spin axis of the Experiment is kept pointing toward the sun; in the other, the spin axis is perpendicular to the earth-sun line. Normal spin rate for the Experiment is one revolution every twelve minutes. The former orientation is termed the cold case; the latter is called the hot case.

3.4.4 Basic Thermal Configuration

The basic thermal configuration of the Explorer Experiment is as follows:

The bulk of the heat dissipated within the Experiment is the 10 watts dissipated in the Electronics Box. A small amount of power, about 0.5 watts total, is dissipated by electronic components located in the Counters. The Electronics Box, the Counters, and the Collimators are all mounted to a structure consisting essentially of four angle brackets. The Electronics Box is mounted to the top of the structure and the Counters and Collimators along its side; the structure is itself attached to the interface plate. There are two sets of collimators on opposite sides of the Experiment, with two sets of counters behind them. The Star and Sun Aspect Sensors are mounted side by side on the outside of the Experiment, one set above a set of collimators. The collimators and counters may be thermally insulated from the structure. The Experiment is covered with a shroud of insulating material everywhere except in front of the collimators. There, windows constructed of aluminized Mylar, coated on the outside with Si_2O_3, will regulate the magnitudes of heat fluxes to and from the Experiment. Aluminized Mylar controls the magnitude of solar absorptance; the thickness of Si_2O_3 controls the magnitude of thermal emittance. The required magnitudes of solar absorptance and thermal emittance of these windows have not yet been determined. The Mylar must be kept very thin (0.1 mil) to minimize X-ray absorption.

3.4.5 Thermal Design Rules

Thermal design of the Explorer Experiment is predicated on providing an operating temperature range for its experimental and electrical components of $0^{\circ}F$ to $140^{\circ}F$. The design follows these general rules:

a. Heat transfer between the Experiment and earth, sun and space will occur only through the windows covering the collimators. The remaining portions of the outside walls of the Experiment will be well insulated.

b. Thermal resistance between the Experiment and the spacecraft will be made high. Thermal resistance between the collimators and counters and the interface plane will be equal to, or greater than, $2^{\circ}F$/BTU/hr. Thermal resistance between the interface plane and the APL Radiator will be equal to, or greater than, $6^{\circ}F$/BTU/hr. The thermal resistance of the cable between the AS&E Electronics Box and the APL Books will be greater than $25^{\circ}F$/BTU/hr.

To permit computation of temperature distribution and levels within the Experiment, interface temperatures have been determined as functions of heat leak across the interface plane, for both the hot and cold cases (Figure 3-22). Also, thermal analogs of both the Experiment and the Spacecraft will be made available to facilitate interchange of thermal design information.

Interface Temperature as a Function of Heat Leak

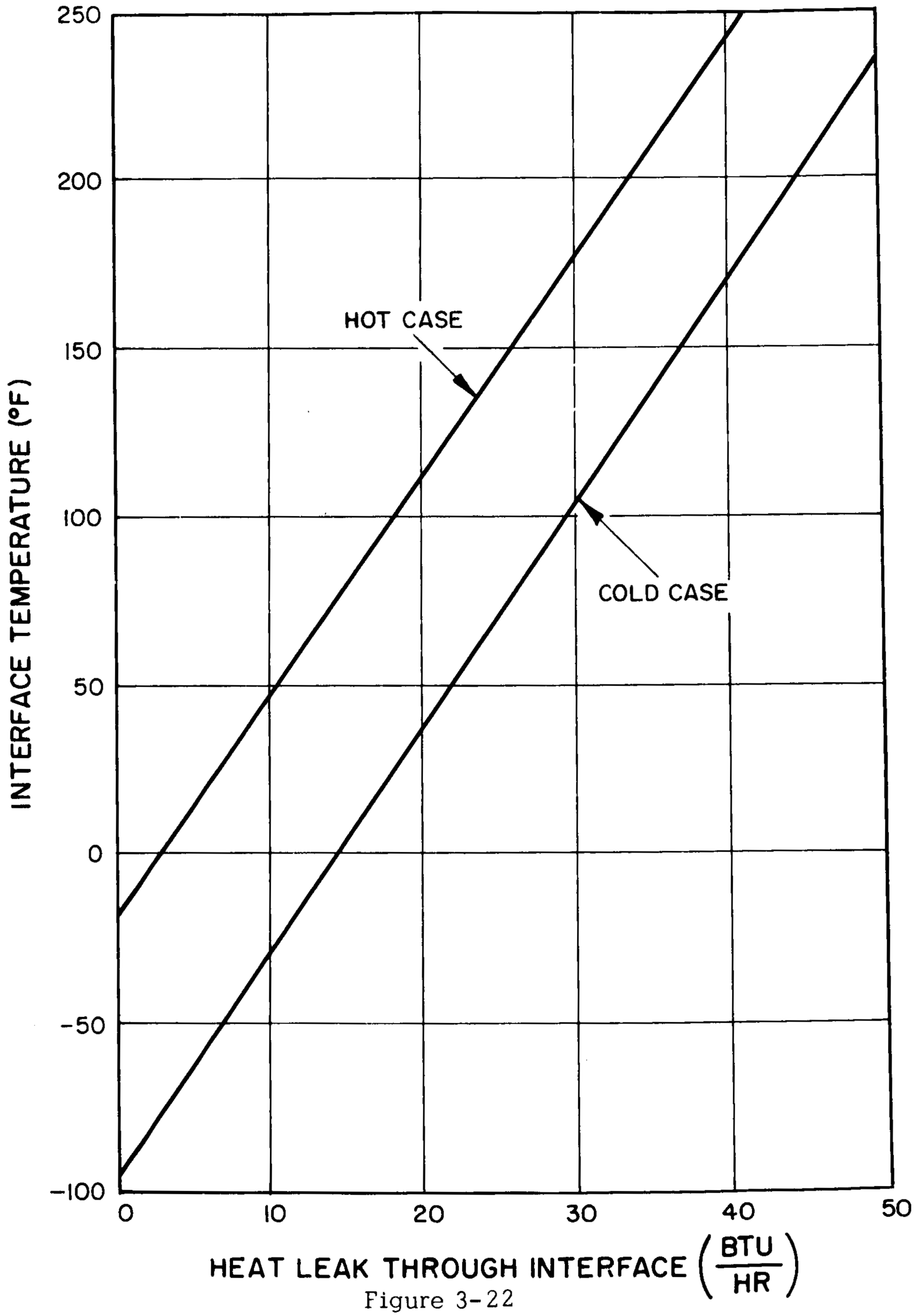


Figure 3-22

4.0 CONCLUSIONS

As a result of the Task 12 effort, the following conclusions can be drawn:

(1) The Experiment design will be modified to give a total weight of approximately 140 pounds by reducing the area of the X-ray detectors.

(2) The planar interface between Experiment and Spacecraft can be maintained at some weight penalty.

(3) The modified design presented in this document will yield scientific data of good quality which will allow all the scientific objectives (with the one exception given in (4) below) to be achieved.

(4) Modulation collimators will not be included due to their weight and the weight increase in the supporting electronics.

(5) The weight reduction will decrease the probability of a long lifetime in orbit by the elimination of two of the four counter banks and associated electronics. To offset this decrease, the ability to cross-switch detectors and electronics in the two remaining channels has been incorporated. This requires additional commands which the spacecraft system cannot supply. A command system has been added.