FINAL REPORT

Contract NAS5-11360

MAPPING X-RAY HELIOMETER

FOR

ORBITING SOLAR OBSERVATORY-8

Submitted: August 1975

Approved: December 1975

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INTRODUCTION

Under Contract NAS5-11360 the Space Astronomy Group of the Lockheed Palo Alto Research Laboratory designed, fabricated, tested and delivered the Mapping X-Ray Heliometer (MXRH) instrument which is part of the OSO-8 satellite. After delivery we also participated in all phases of observatory level activity through launch and turn on, and prepared for the post-launch operation effort.

Throughout this four and one-half year period the activities of the MXRH program have received a high degree of visibility by monthly progress reports, reports on all phases of test activities, three formal design reviews, and more than a half dozen status reviews. This final report will therefore be brief in historical context, principally stating the chronological flow of activities and elaborating on the items which were most troublesome.

During 1973, a Technical Manual was written which describes the instrument and its operation in detail. The revised and updated manual is included as part of this final report.

Finally, although the post-launch activities are being conducted under contract NAS5-22411, their preparation was performed under this contract. It is therefore appropriate to briefly discuss the instrument's in-orbit operation; the status report of ultimate importance.

CHRONOLOGICAL SUMMARY

Work on the program began in January 1971. The initial work statement called for a Protoflight (which was to be refurbished to become a Flight Spare) and a Flight Instrument. This was later modified to be a Design Qualification Instrument, a Flight Instrument and Flight Spare subsystems. After two years of design, breadboard, test and fabrication efforts, the Design Qualification Instrument underwent a full environmental test sequence at qualification levels. Table I subdivides this and subsequent test activities into more detail.

The Flight Instrument was fabricated incorporating a few minor design improvements. It was subjected to Acceptance Testing in early 1974, delivered on March 3, 1974, and the S/C interfaces were verified. In June 1974 a detector which was degrading was replaced and an improved vertical collimator was substituted for the existing unit. The MXRH was then integrated into the observatory. This was followed by about a year of test activities culminating in the launch on 21 June 1975.

Two days after launch, the MXRH was successfully turned ON. All subsystems operated properly. The instrument has now been in operation for two months, providing the observations required to meet the scientific objectives of the program.

TABLE I

CHRONOLOGY OF EVENTS

For The

OSO-I MXRH INSTRUMENT

Activity	Completion Date	Conformance	Resultant Action
QUALIFICATION TESTS	3-16-73		
1. Random Vib.		No	Design Change
2. Sine Vib.		Yes	
3. Acceleration		Yes	
4. Pyroshock		Yes	
5. EMI		No	GSFC Conditional Waiver
6. Thermal Vac.		No	Items Modified and Retested
7. Magnetics		Yes	
ACCEPTANCE TESTS	2-5-74		
1. Random Vib.		Yes	
2. Thermal Vac.		Yes	
3. Magnetics		No	GSFC Unconditional Waiver
4. Mass Properties		No	GSFC Unconditional Waiver
HAC MECH. INSPECT	3-6-74	No	Corrected by LMSC
EIC TESTS	3-26-74		
1. LMSC Side		Yes	
2. HAC Side		No	Corrected by HAC
RETROFIT ACTIONS	6-27-74		
1. Degraded Detector			Replaced Detector Pair Assy
2. Improved Collim.			Exchanged Collimator
EIC RECHECK	6-29-74	Yes	
MECHANICAL INTEG.	7-9-74		
1. LMSC Side		Yes	
2. HAC Side		No	Corrected by HAC and LMSC
ELECTRICAL INTEG.	7-16-74	Yes	
LONG FORM TEST	9-27-74	Yes	
OBS. ENVIRON. TESTS		No/Yes	Stepper Motor Concern at Cold but can work around it.
LONG FORM TEST		Yes	
ETR	6-21-75	No/Yes	SLA PRD malfunction but can be turned OFF by command.
TURN ON	6-22-75	Yes	All systems function properly.

MAJOR DIFFICULTIES

The three major areas of difficulty during the design and fabrication of the instrument were: (1) the proportional counter detectors, (2) the collimators, and (3) the sun-center detectors. A brief discussion in each of these areas will follow.

The proportional counter detector design was fairly straightforward and the design model and protoflight units worked properly. After that, a continual sequence of blunders, by both the subcontractor who was fabricating the detectors and by piece part manufacturers, made the fabrication of good units a difficult task. We eventually did obtain a set of flight detectors which are excellent.

The collimator area was plagued both by difficulties in obtaining in-spec parts and by the state-of-the-art requirement on assembling these parts into a complete collimator. The collimation (two arc minutes for a 5 inch long collimator with a frontal area of 60 in^2), although non-trivial, does not at first seem to push the state of the art. Because the instrument design requires that not only the primary fan beam be proper, but that 26 additional off-axis fan beams must also be proper (spread over 20° in angle) many new tolerances become unusually critical (such as spacing between the grids, flatness of the grid, uniformity across the grid) and the item does become state-of-the-art. Throughout the program we continually modified our procedures and eventually flew three collimators, which though not perfect, are well able to meet the scientific requirements of the experiment.

The sun-center detector was likewise a difficult item to design and develop. The design difficulty resulted from the fact that the transmission function for visible light through the x-ray collimator is extremely complex. The development was difficult because each unit is an integral part of a collimator-sun center detector system which meant its development and test was closely coupled to that of the collimators, which were difficult on their own. Also, proper testing required a complex test set-up including real sunshine, a precision rotating turntable, and a fair amount of the digital control electronics. All these problems were eventually dealt with and the in-orbit operation of the sun center detectors has been excellent.

PREPARATION FOR POST-LAUNCH ACTIVITIES

In early 1975 a data link was set up between GSFC and LMSC to enable us to receive quick look data. The plan was to provide us with approximately one real time pass per orbit and 3-4 full orbit tape recorder playbacks daily. Data format was agreed upon and the software for receiving the data, writing it onto magnetic tape, and transmitting to GSFC a summary of the transmission quality was made operational.

Programs to read these tapes were written. One program displays the engineering status of the start of the data transmission and records all changes and any out-of-limit conditions for the remainder of the data. This is linked with the data reception program so that we can receive data and display status information unattended for periods of up to 24 hours. Another program enables us to process our science words and form spatial distributions around the sun which then enables an interactive capability for locating the x-ray emitting regions on the sun. Several other quick look science programs were also initiated during the pre-launch period. Examples of outputs of these codes are presented in the following section.

A detailed code was written which yields the response of all six detector systems to a source at a given location with a given energy spectra for a stated satellite aspect and spin rate. A code was obtained and modified to run on the LMSC Univac-1110 computer which produces an energy spectra as a function of an input temperature based on the Tucker and Koren formulation for a low density plasma. The combining of these two major codes also began during the pre-launch period.

EARLY IN-ORBIT OPERATIONS

After two months of orbital operations, the MXRH is continuing to perform properly and make observations which contain a wealth of solar information, and which demonstrate the potential for making contributions in the extra-solar field. All subsystems are operating properly at this time.

We are receiving about 70% of the expected quick look data. A few illustrations of these data will follow. Figure 1 shows a sequence of raw data sets wherein one can watch active regions R619 and R618 as the sun rotates. Several small flares were observed in these regions. Figure 2 is a light curve for one of these flares. Several of the raw data sets have been fitted to count histograms which are predicted when the Tucker-Koren formulation is folded through the instrument response code (as discussed in the last section) where Temperature and Emission Measure are the free parameters. The results are consistent with previously known values for similar active regions. It should be emphasized that these results are all based on quick look data with none of the more subtle corrections yet folded in. They do, however, illustrate that the instrument is obtaining the observations for which it was built and promises to provide many worthwhile observations for future analysis. The scientific investigators involved in this experiment are totally satisfied with the instrument performance to date.

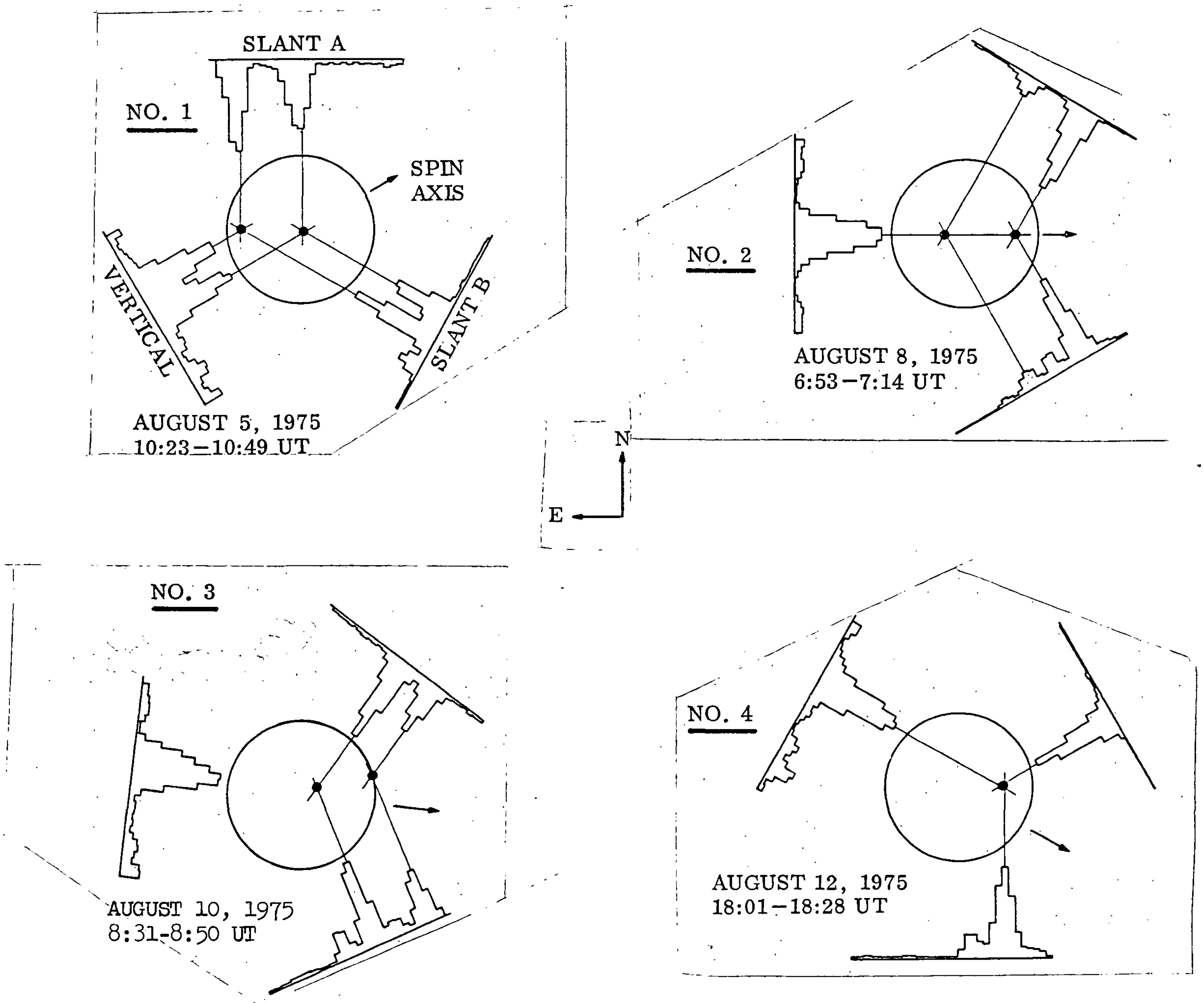

Figure 1 A sequence of data sets showing Active Regions R619 and R618 "move across the sun." The set represents roll angles varying from 63° to 123°.

MASTER

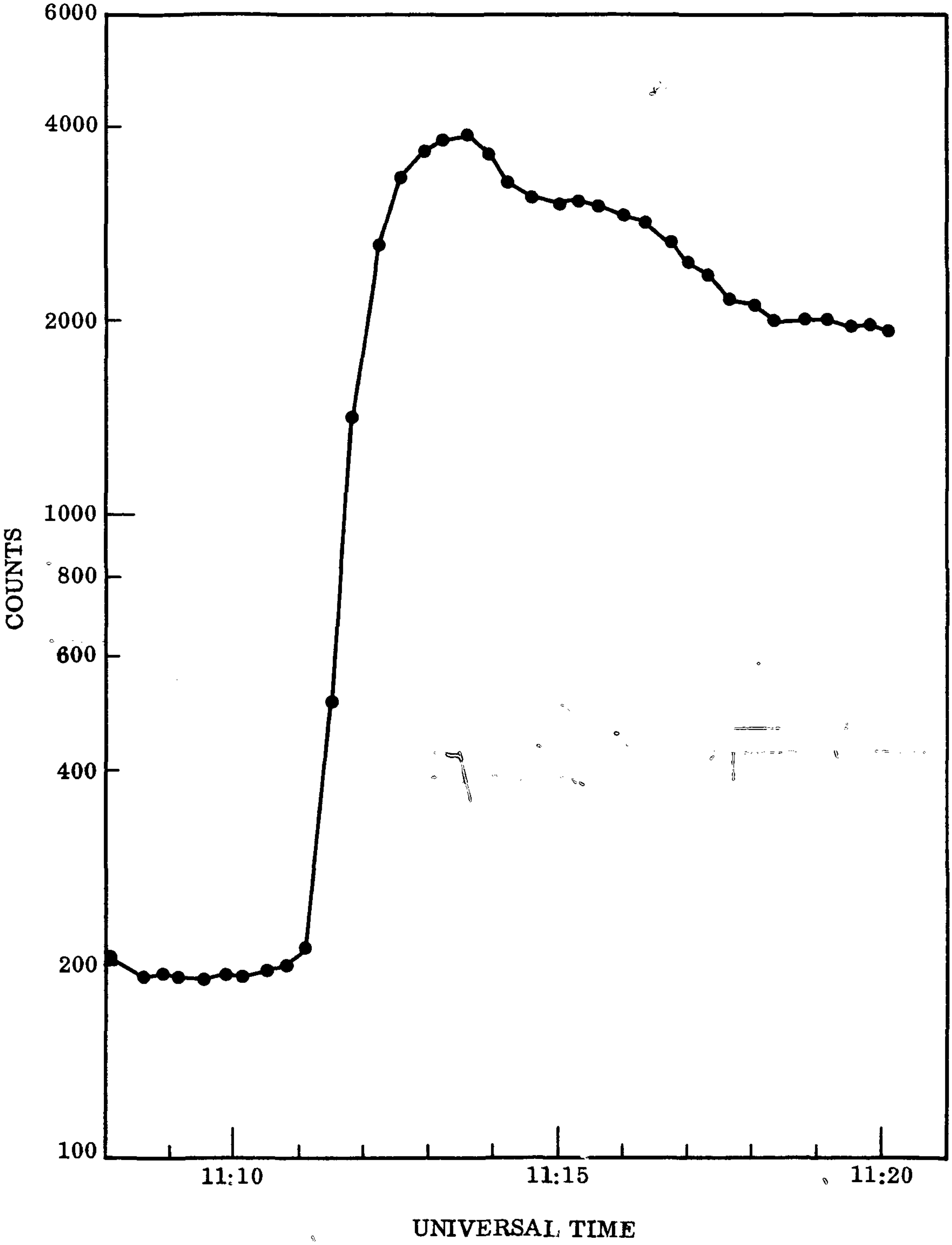

Figure 2 X-ray light curve of a flare on 2 August 1975. These data are from the low sensitivity or flare detector of the MXRH vertical system.

TECHNICAL MANUAL FOR THE MAPPING X-RAY HELIOMETER INSTRUMENT ON OSO-I

(Preliminary Copy: 2-22-73)

(Final Copy: 10-19-73 with Revision of Aug. 20, 1975)

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1. INTRODUCTION

This technical manual is in response to Item 18 of Contract NAS 5-11360. Its purpose is to provide an understanding of the overall operation of the LMSC Mapping X-Ray Heliometer Instrument (MXRH) to the degree needed by personnel who interact with the experimenter during SC/experiment interfacing, experiment testing, observatory integration and testing, pre/post launch data processing, etc. The manual will make no effort to provide a detailed description of the scientific efforts we anticipate performing with the instrument. The manual received its final revision in August of 1975.

The primary objective of the experiment is to record solar x-rays with energies of 2-30 keV with good temporal, spectral and spatial resolution and to provide a portion of this information to the scientific community on a timely basis. Extra-solar x-ray data will also be obtained and used to study a number of the stronger sources.

To accomplish these goals an instrument combining mechanical collimators and proportional counter detectors was designed which would conduct observations from a compartment of the OSO wheel. Figure 1 shows the general layout of the MXRH instrument, while Table I gives a summary of the instrument characteristics.

The MXRH instrument occupies one 40° compartment of the OSO-I wheel. Illustration I is an artist's conception of OSO-I in which the MXRH is indicated. Illustration II is a photo of the MXRH prior to integration into the observatory.

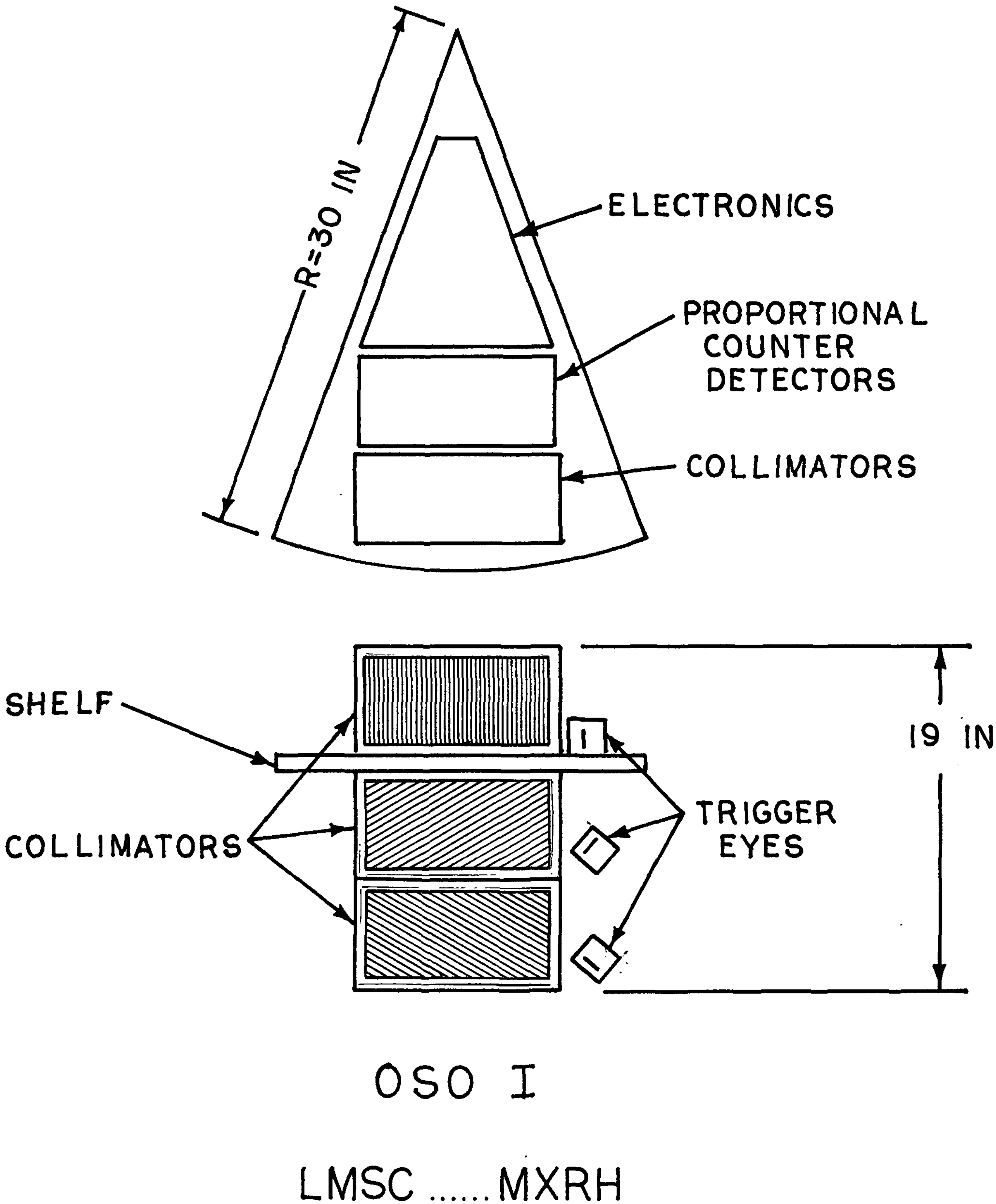


Figure 1 The physical arrangement of the major portions of the Mapping X-Ray Heliometer.

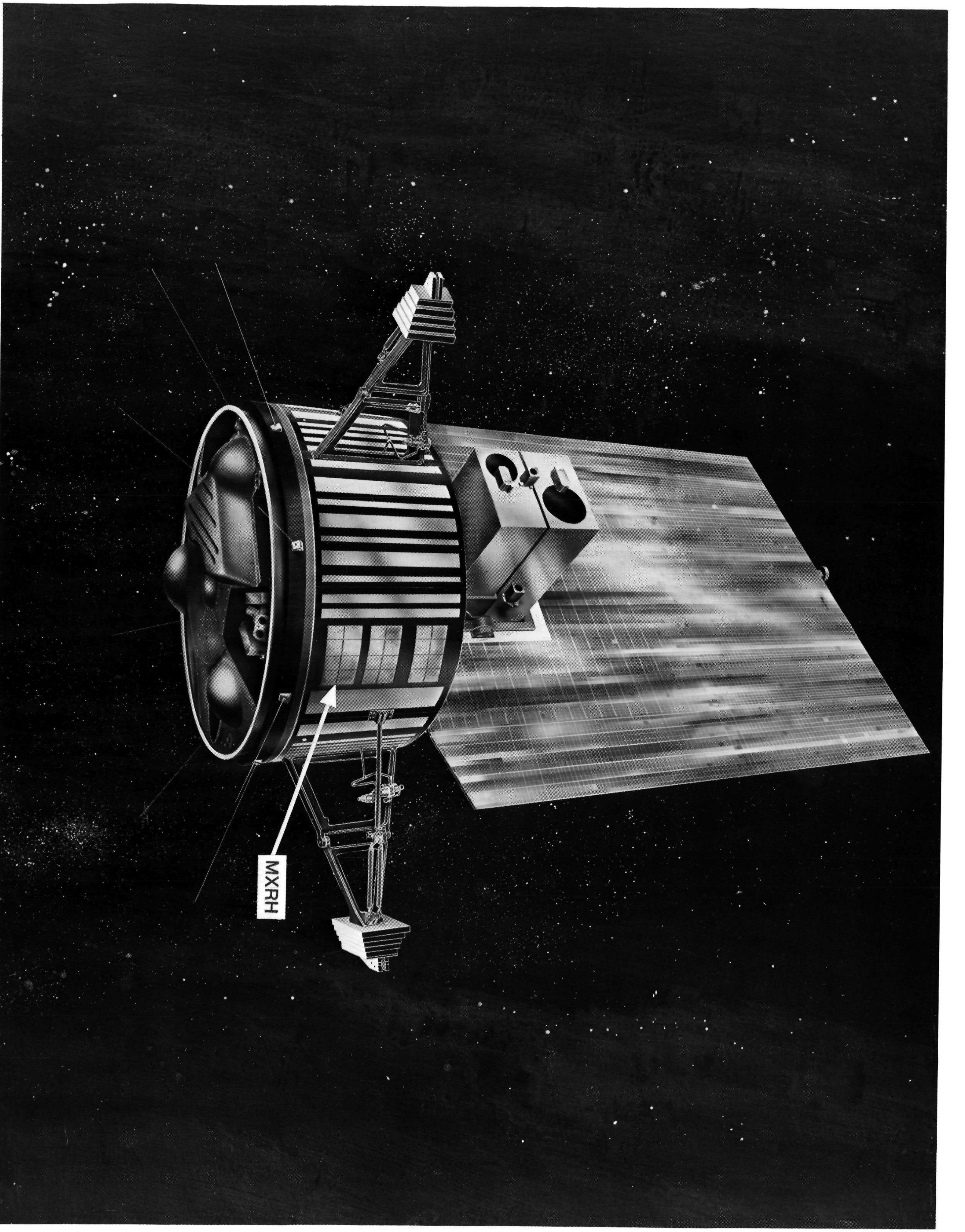
TABLE I

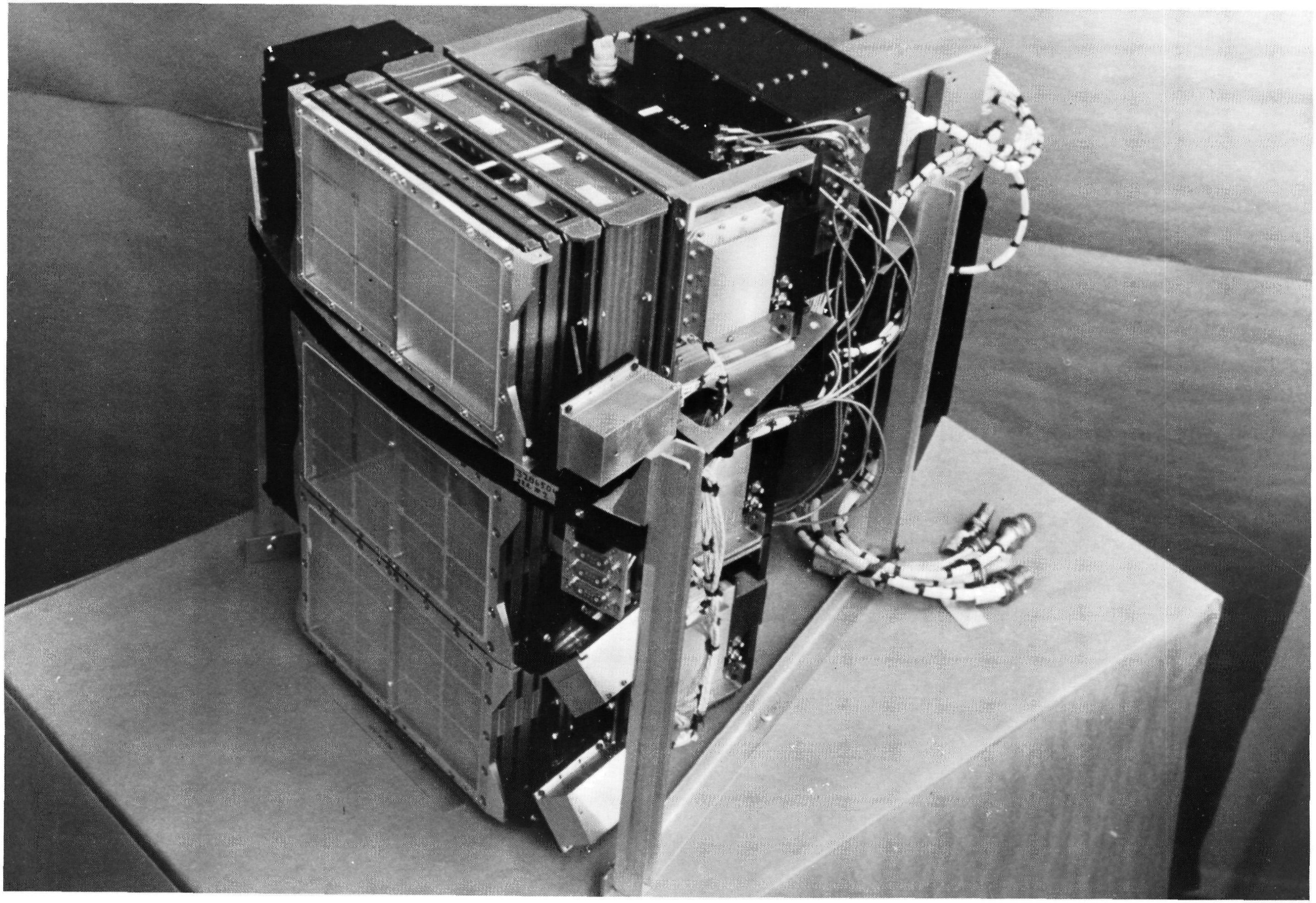
EXPERIMENT SUMMARY

MAPPING X-RAY HELIOMETER

LMSC, OSO-I

PHYSICAL SIZE:	ONE OSO-I WHEEL COMPARTMENT	
WEIGHT:	86 LBS	
POWER:	9.5 WATTS	
TM RATE:	580 BITS/SEC	
DETECTION SYSTEM:	ODA TYPE COLLIMATORS PROPORTIONAL COUNTERS	
SPECTRAL RANGE:	2 - 30 KEV	
SPECTRAL RESOLUTION:	$<$ 20% FWHM AT 6 KEV	
ANGULAR RESOLUTION:	2 ARC MIN FWHM COLLIMATION	
TIME RESOLUTION:	10 SEC	
EFFECTIVE AREA:	3 DETECTORS . . . 60 CM^2 EA	(LARGE DETECTORS)
	2 DETECTORS . . . 2.3 CM^2 EA	(THIN WINDOW DET.)
	1 DETECTOR . . . 1 CM^2	(SMALL FLARE DET.)
DYNAMIC RANGE:	$> 10^5$	
COMMENT:	3 COLLIMATED SYSTEMS (0°, $\pm 60^\circ$ FROM VERTICAL) SCAN THE SUN TO PRODUCE SPECTROHELIOGRAMS.	


MXRH



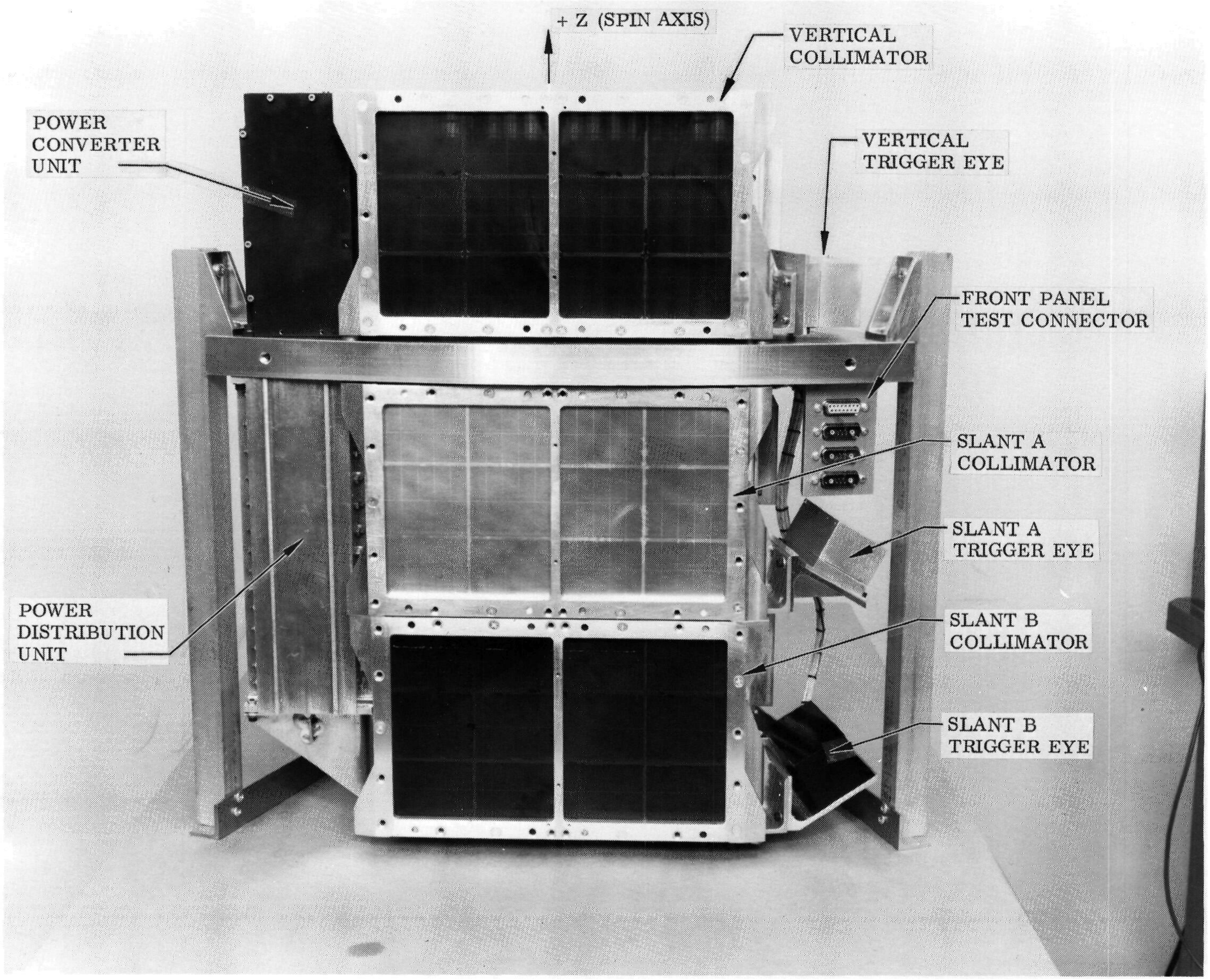
2. INSTRUMENT DESCRIPTION - PHYSICAL

The instrument consists of three x-ray collimation and detection systems, a power supply/distribution system, and a data accumulation/readout system. Figure 2 is a front view photograph of the Design Qualification Instrument with some of the major subsystems labelled. The Design Qualification Instrument is used for Figure 2 (and 3, 4) since it provides subsystem visibility better than any of the Flight Instrument photographs.

The power converter unit (PCU) converts the spacecraft power (+28V) into the various voltages required by the instrument. The power distribution unit (PDU) distributes these voltages to the remainder of the instrument. The voltages for various subsystems of the instrument may be turned on or off in the PDU by ground command. The PDU also contains the control system for stepping the stepper motors which are part of the on board calibration system.

The three x-ray collimators are identical in physical size, but have differently oriented fields of view. The vertical collimator has a field of view which is 2.1 arc minutes full-width-at-half-maximum-transmission (FWHM) in a plane parallel to the OSO wheel and $\sim 5^{\circ}$ FWHM perpendicular to this plane. Slant A and slant B collimators also have narrow fields of view of 2.1 arc minutes FWHM, but these fields are inclined at $+60^{\circ}$ and -60° from the field of view of the vertical collimator. The manner in which these fields of view provide complimentary solar x-ray observations will be made clear in later sections.

Associated with each collimator is a trigger eye unit. Each trigger eye has a field of view 17 arc min FWHM by $> 20^{\circ}$ FWHM. The collimators are used to collimate both x-rays and sunlight while the trigger eye units are used only to collimate sunlight.



+ Z (SPIN AXIS)
VERTICAL COLLIMATOR
POWER CONVERTER UNIT
VERTICAL TRIGGER EYE
FRONT PANEL TEST CONNECTOR
SLANT A COLLIMATOR
SLANT A TRIGGER EYE
POWER DISTRIBUTION UNIT
SLANT B COLLIMATOR
SLANT B TRIGGER EYE

The final labeled item in the photograph of Figure 2 is the front panel test connector which is mounted directly to the shelf. This connector is used only during instrument testing and is covered during flight.

Figure 3 is another frontal view but with two collimators removed in order to display the detection subsystems better. In the flight unit, both slant systems contain Thin Window Detectors while the vertical system contains a Small Flare Detector.

The sun center detectors are units which sense the sunlight which passes through the collimator to determine when the center of a collimator's narrow field of view crosses the center of the sun. This information is used by the data accumulation electronics to control the gathering of solar x-ray data with better spatial accuracy than can be obtained using the spacecraft provided aspect information. The ability to use the spacecraft aspect system as a backup operational mode is retained, however.

The calibration units contain radioactive sources which are exposed or shielded as controlled by commands. This allows in-flight system calibration using x-rays of known energies.

All three types of x-ray detectors in the instrument are sealed proportional counter detectors. The three different detectors types are required in order to obtain useful data from a wide variety of solar conditions as will be described in more detail in Section 5.4.

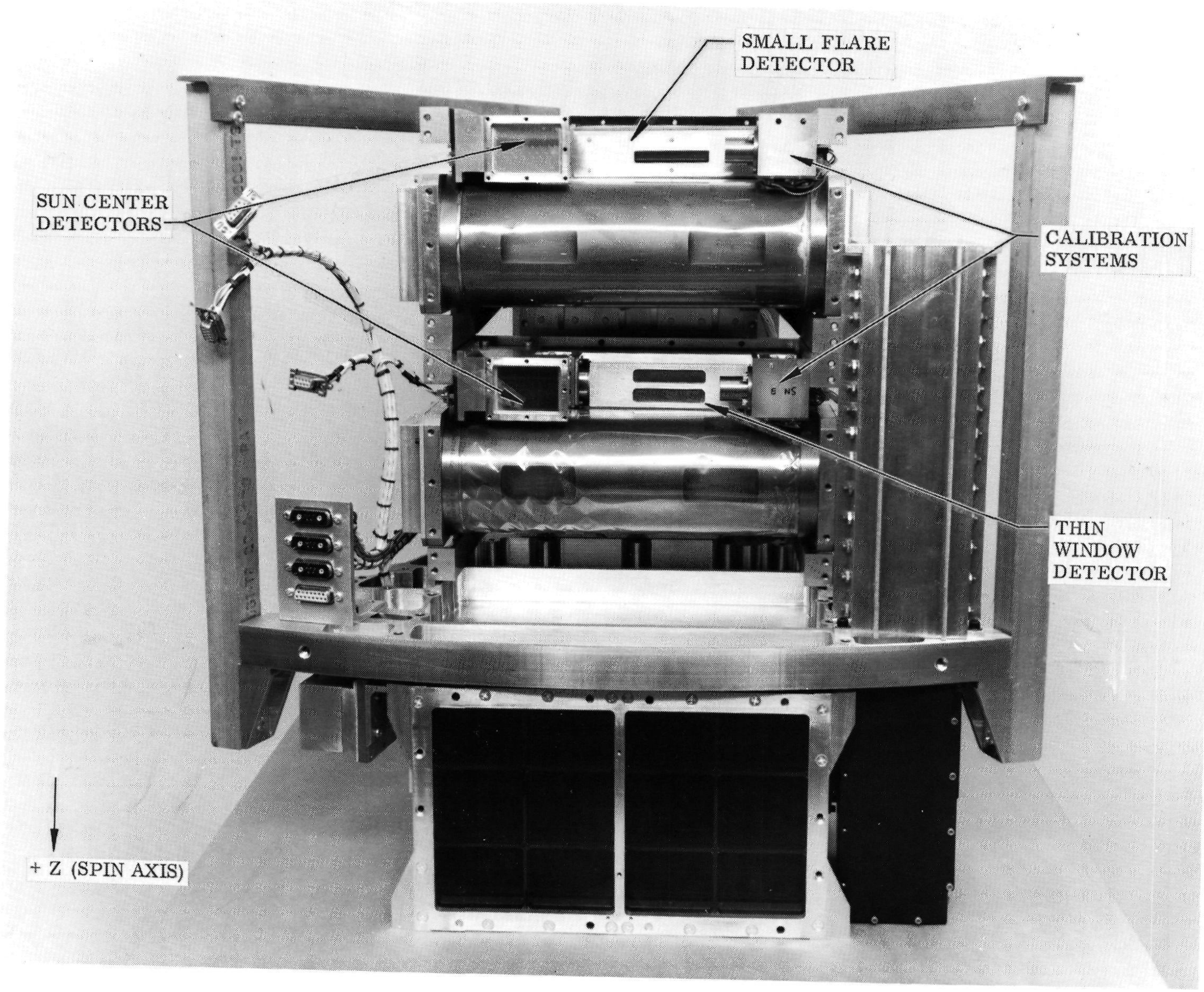
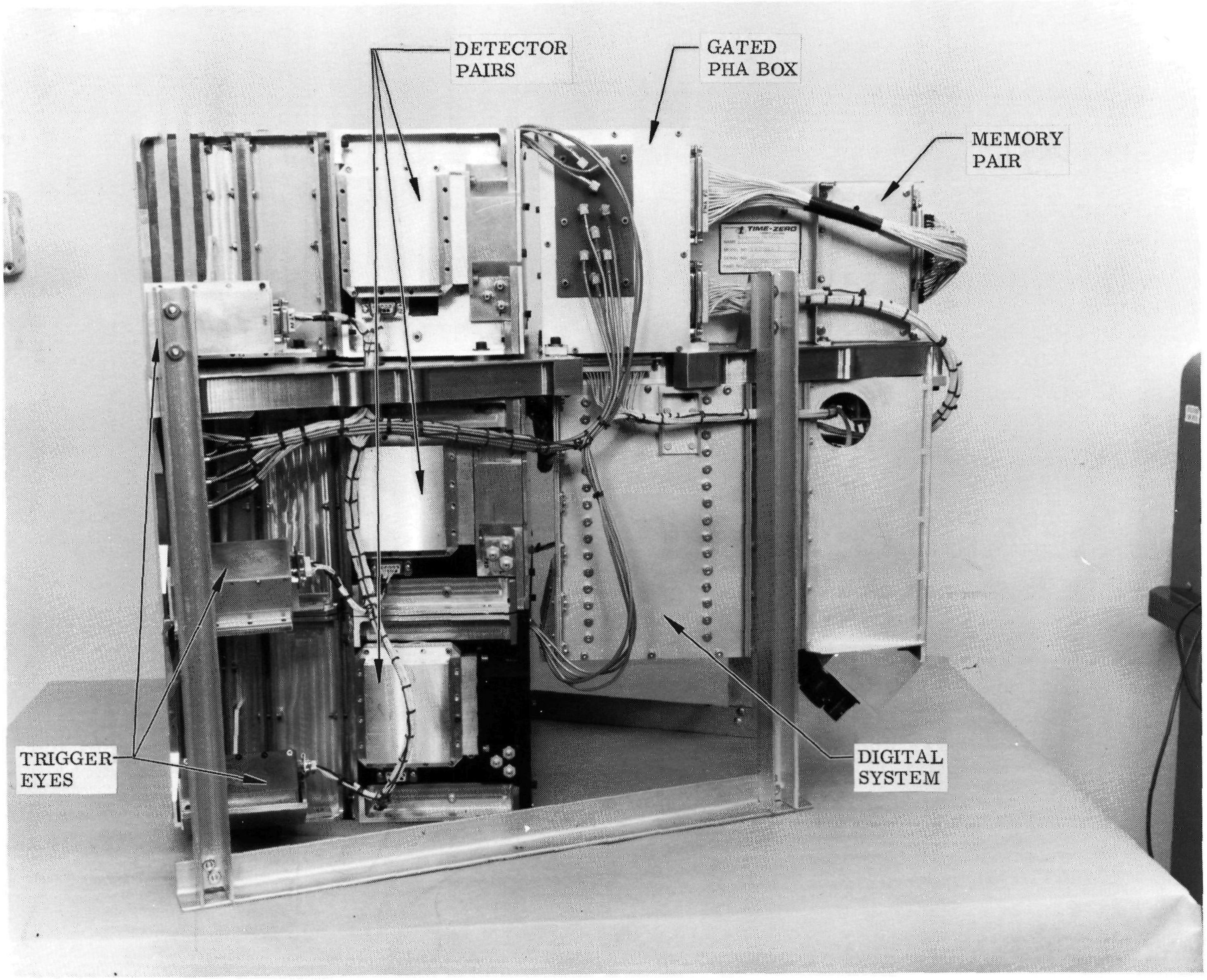

SMALL FLARE DETECTOR
SUN CENTER DETECTORS
CALIBRATION SYSTEMS
THIN WINDOW DETECTOR
+ Z (SPIN AXIS)

Figure 4 is a side view photograph of the instrument. In addition to many of the previously mentioned items, this view shows the gated pulse height analyzer (PHA) box, a pair of memories, and the signal distribution/digital electronics assembly.

The signal distribution assembly is the interface point for all electrical signals and power lines between the spacecraft and the instrument. Attached directly to the signal distribution assembly is the digital electronics system which controls the data accumulation sequence and the data readout sequence.

The output of the proportional counter detectors is a signal whose amplitude is proportional to the energy of the x-ray which was detected to an accuracy imposed by the statistics of the detection process. This signal is amplified in the detector electronics box and then goes to the gated PHA box. Here, providing conditions are proper for its acceptance, its analog amplitude is converted to a digital number. This energy information is combined with a number specifying the collimator viewing direction for that x-ray event to form a 9 bit memory address and a one is added to the existing number in the memory word of that address. As will be described in detail in Section 3.4 3, this process asynchronously repeats during the data collection period; the memories are read out to telemetry during the data readout period.


DETECTOR
PAIRS
GATED
PHA BOX
MEMORY
PAIR
TRIGGER
EYES
DIGITAL
SYSTEM

3. FUNCTIONAL OPERATION - TYPICAL MODE

This section describes a typical operational mode of the instrument in a manner which indicates the purposes and interrelationships of the various sub-systems. Variations from this typical operational mode will be discussed in Section 4. For aid in understanding the instruments functioning, an electronic block diagram has been included as Appendix V.

The typical mode is one in which the sun is the target of observation and all three systems are in operation. For an aspect having zero pitch, the instrument gathers data for approximately 20° of wheel rotation (~ .5 seconds) centered on the sun and transfers the contents of one memory to telemetry (TM) during the remainder of the revolution. The instrument has three data gathering systems and two memories; one memory is used only by the vertical system while the other memory is shared by the two slant systems. This results in data from two successive solar passes being accumulated in one memory before that memory is readout. In addition to the solar data, background data are gathered for about one second of time in the anti-solar direction. The background data are gathered by the system which is not reading out but which will be reading out next. Figure 5 displays such a sequence. Note that the vertical system gathers data on every solar pass while a specific slant system gathers data for two passes and is inactive for the next two passes; thereby gathering data for half as much total time as the vertical system.

To describe a data gathering interval in more detail, consider the vertical system. As the wheel rotates, the sun comes into the the view of the instrument. As will be explained in detail in Section 5.1, the vertical Oda collimator produces fan beams of transmission spaced 42 arc minutes apart, which

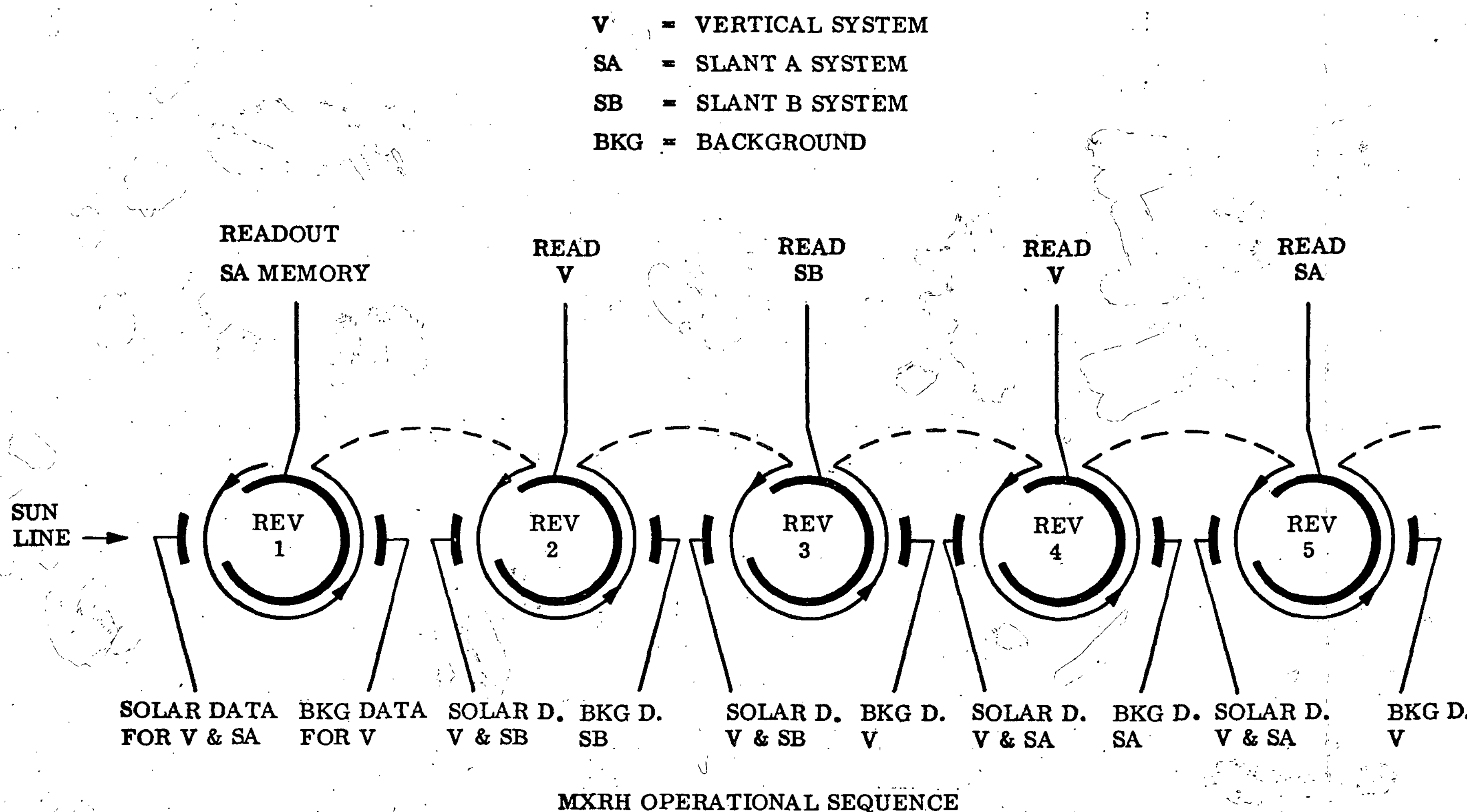


Figure 5 The operational sequence when all three systems are gathering solar data. Note that twice as much data is recorded by the vertical system as by a single slant system and that the data for two solar passes are always combined before a system is readout.

successively sweep across the solar disk. This result is a response similar to a sine wave in the sun center detector which is responding to sunlight intensity in proportion to the amount of solar disk in the collimator field of view. Pulses, formed at the successive maxima of this signal, correspond to sun center. Figure 6 displays such a sequence. The single transmission beam of the vertical trigger eye is oriented so as to lead the central fan beam of the collimator by about 10°. It therefore lies between fan beams #-16 and #-15 of the collimator where #0 is the transmission beam normal to the collimator front face and where negative numbered beams contact the sun first as the wheel rotates.

Still referring to Figure 6, a 128 kHz clock is counted to establish the time between sun center pulses #-15 and -14. This count is called N_1. The next N1/2 clock pulses are counted, thereby approximately locating the point at which fan beam #-13 begins its traversal of the 42 arc minute target area. The next N_1 clock pulses are counted to locate where/when it should complete its traversal. This process of using the preceeding optical signals to define solar transit of the next fan beam for x-ray data collection is updated with each sun center signal (i.e. N2/2 and N2 define fan beam #-12, etc.). In this manner, solar data collection operates independently of any small spin rate variations as well as independently of the spacecraft aspect system and of the spacecraft/instrument alignment. In the slant system this also automatically compensates for pitch variations which would otherwise result in azimuthal variations.

Consider a single fan beam (#-13 again) crossing the sun under the control just described. We use N_1 to form $N_1/32$ and count clock pulses to form 32 successive spatial area segments which are $N_1/32$ counts wide. The x-ray data

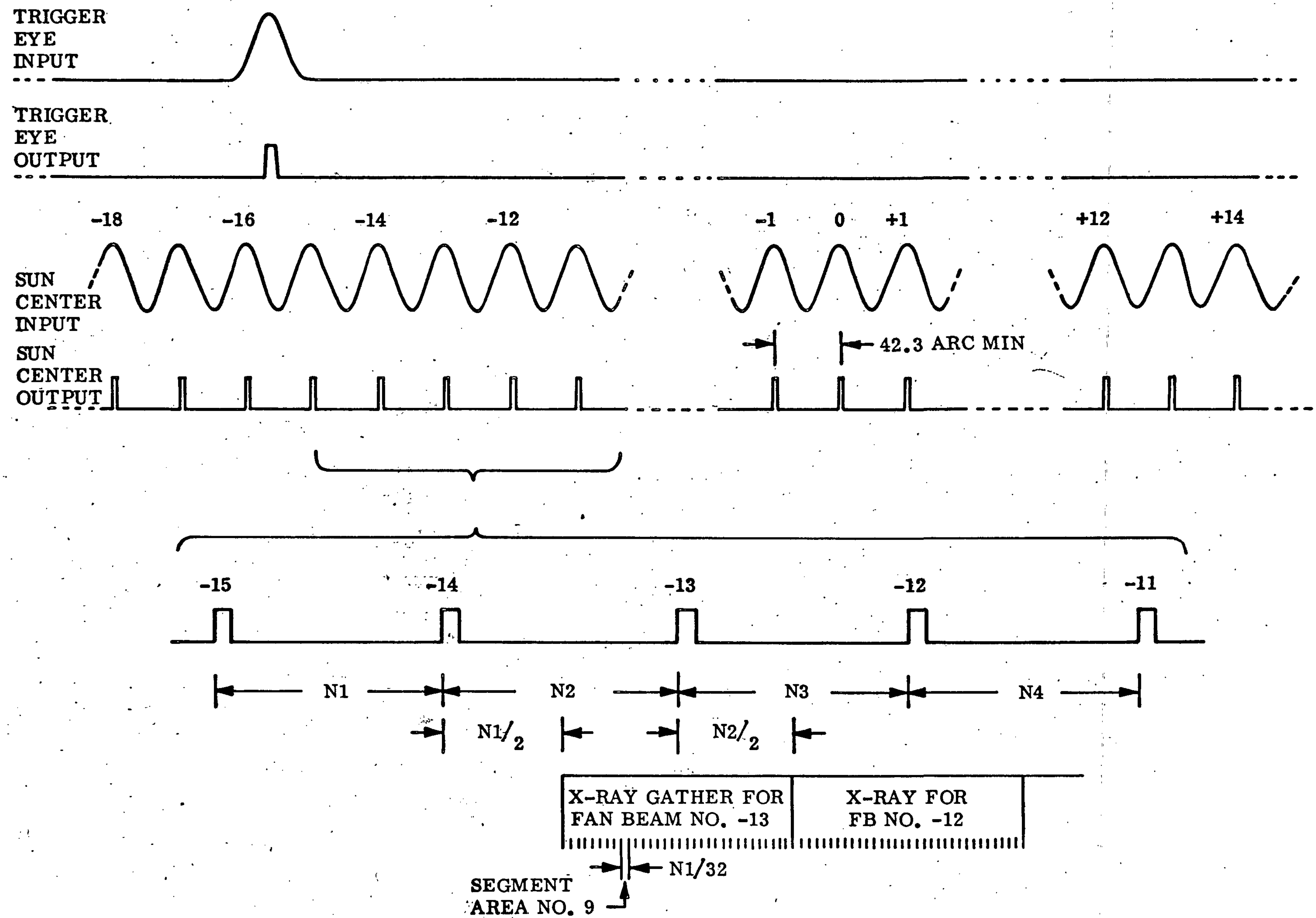


Figure 6 A single solar pass data gathering sequence for the vertical system when it is obtaining data in the whole-sun spatial mode. See the text for a detailed description of the procedure.

are then stored into 31 separate buffers which represent area segments ~ 1.3 arc minutes (1!3) wide. No data are collected for area segment 32. As fan beam # -12 crosses the target area under the control of N2, N2/2 and N2/32, a similar process takes place and the data from each area segment are added to that obtained for that area segment by fan beam # -13. This continues for all 27 fan beams. Both slant systems operate in an analogous and independent manner, but gather data for 13 instead of 27 fan beam sweeps.

Although we have used 42 arc minutes as a constant angular separation between adjacent fan beams, this is an approximation based on the assumption that the angle (θ) between the normal fan beam and a side fan beam is small enough that $\theta \approx \tan \theta$. As the number (n) of fan beams used increases, the error in this approximation becomes larger. The N_i used to generate x-ray data gathering scans thus has an error which increases for large n. Only fan beams for which this error has an rms value of < 20% of an area segment width are used to gather x-ray data. This results in the usage of 27 fan beams for the vertical system and 13 for the slant.

Each x-ray event for a detector which is gated open at that time is pulse height analyzed and put into one of 15 energy channels. Fourteen of these are differential energy channels, and one is an integral channel for energies in excess of 13.6 keV, the upper differential channel boundary. Events in the large detector which are classified as non-x-ray by a signal from the pulse risetime discriminator are put into channel 1 of the 16 channel distribution. Table II shows the usage of the PHA channels for the low and medium sensitivity detectors. The energy values must be divided in half for the thin window detector. Since this is done for 32 individual

TABLE II

CHANNEL DEFINITION FOR THE LOW AND MEDIUM SENSITIVITY DETECTORS*

Decoded PHA Channel	Channel Contents
1	PRD Events
2	1.3 - 1.8 keV x-rays
3	1.8 - 2.3 keV x-rays
4	2.3 - 2.8 keV x-rays
5	2.8 - 3.3 keV x-rays
6	3.3 - 3.8 keV x-rays
7	3.8 - 4.3 keV x-rays
8	4.3 - 5.3 keV x-rays
9	5.3 - 5.8 keV x-rays
10	5.8 - 6.3 keV x-rays
11	6.3 - 6.8 keV x-rays
12	6.8 - 7.3 keV x-rays
13	7.3 - 7.8 keV x-rays
14	7.8 - 9.8 keV x-rays
15	9.8 - 13.8 keV x-rays
16	≥ 13.8 KeV (Integral Channel) X-rays

* Divide the energies by two for the high sensitivity detectors.

NOTE: These are nominal values. Actual values for the six flight detectors may be found in Appendix VI.

area segments, one ends up with a 32 x 16 matrix of numbers. This matrix is stored in the 512 word (8 bits each) memory associated with that system.

As mentioned in Section 1 (See Figure 3) there are 3 types of detectors in the instrument. They are of varied sensitivities in order to enable the instrument to respond to a wide range of solar conditions. To obtain useful data, the data must not saturate the detector or the 8 bit memory words under high flux conditions, while still being statistically significant for low flux conditions. The detector nomenclature is: thin window detector or high sensitivity, large detector or medium sensitivity, and small flare detector or low sensitivity. The vertical system contains a flare detector and a large detector. Both Slant A and Slant B systems contain a large detector and a thin window detector.

When a system is functioning both of its detectors are responding to x-rays. However, which of the detectors is connected to the pulse height analyzer/memory is controlled by an analog gating system placed between the detector main amp outputs and the PHA input. We have grouped the 32 area segments into 16 sensitivity segments (area segments 2 and 3, 4 and 5, ...32 and 1). As a fan beam crosses the sun, either detector of a pair may be gated on for any sensitivity segment. When the next fan beam crosses the sun, the same sequence of sensitivity selection is repeated. This is true for a full data gather period (2 OSO wheel rotations in a typical operational mode), but may be changed for the next data period. The three systems have independent sensitivity sequences. Normal operation is the Automatic Sensitivity Switching Mode. In this mode, the sensitivity selections for a data gather period are based on information from the last data gather period. Consider the higher sensitivity detector as the normal state. A sensitivity switch for any sensitivity segment is then made from the higher sensitivity detector to the lower sensitivity if the counts in any differential energy channel exceed C1 (where C1 = 64 or 128 or 192 as selected by ground command) counts. A switch back to the higher sensitivity is made as soon as we fail to record more than C2 (where C2 = 4 or 8 or 16 as selected by ground command) counts for that sensitivity segment. Different values of C1 and C2 may exist simultaneously for the vertical and slant systems.

Anytime the counting rate is such that either C1 or C2 are exceeded for the vertical system, the instrument attempts to issue a Flare Event signal to command memory. The signal is only issued however if we have enabled this action by issuing the Event Flag Reset command.

4. ALTERNATE OPERATIONAL MODES

Besides the typical mode of operation there are other operational modes which are variations from the typical mode.

4.1 Configured Sensitivity Mode

Rather than allow automatic sensitivity switching we can send a 16 bit serial magnitude command and specify a pattern of sensitivities that gates in and out the detector outputs accordingly without regard to the actual collected data. Each of the three systems may independently be operating in an automatically switching or a configured mode and the configuration may be different for each system.

4.2 Fine Spatial Mode

As described above, the target area is typically 42 arc min (42'.0) (84'.0 for slant) wide in azimuth. If desired, this width can be reduced by a factor of 4. The resultant 10'.5 target may be established as either of the central two quadrants of the initial 42'.0 target. This target is then divided into 32 area segments as always so the area segments are now ~ 0'.3 wide. Each of the three systems can be independently placed into fine or coarse mode and into either of the possible fine spatial mode target quadrants as desired. The sensitivity switching options are the same as before for a 32 area segment target.

4.3 Selected Systems Only Mode

Through use of the proper combination of commands the instrument can be configured so that any subset of the three systems can be operating instead of all three. The motivation for such operation is either to improve the time resolution while sacrificing some spatial resolution, or to disable a malfunctioning system in the most advantageous manner for total instrument operation.

If we go to a single system (any of the three), we collect data for a single solar pass, read out that memory during the remainder of the revolution, and repeat the process on the next pass. No anti-target background data are collected. This allows us a new snapshot every 10 seconds from the same system thereby improving the time resolution of the instrument. We are now collecting only half the available data however.

We can also use any two systems. If this is a slant system and the vertical system, each system stores data for two target passes and the memories are read out alternately as in normal operation. Anti-target background data are collected as normal. If the two slant systems are selected, one system collects data for a single target pass and reads it out immediately, and the other system collects data for the next target pass and read it out immediately, etc. Since we are only using one memory, only half as much data are collected as is available. No background data are collected.

4.4 Extra Solar Mode

The instrument will also be used to study sources of extra solar x-rays. The operation is nearly identical to that for normal daytime operation except that the target location does not contain the sun. Instead of originating the data gather sequence by the trigger eye pulse, we now use the information available in the spacecraft aspect pulses; i.e., the Master Index Pulse (MIP) and Shaft Angle Encoder (SAE). Using a serial magnitude command, one defines the target location as a number of SAE pulses (each separated by 2'.6) away from the MIP pulse. The instrument counts SAE pulses until this location is reached and then issues a psuedo solar trigger pulse. The collimators were designed so that the nominal separation between successive fan beams is 16 SAE pulses (42'.08) for the vertical collimator and 32 SAE pulses for the slant collimators. Psuedo sun center pulses may thus be generated by either every 16th or every 32nd SAE pulse. Using these psuedo solar pulses, the data is gathered and read out exactly as in the day mode; and background is collected in the anti-target direction as normal. All systems now begin a data gather period at the same time so that the actual target location in the sky for the slant systems will require an after-the-fact pitch correction using the spacecraft aspect information.

4.5 Calibration Mode

Each detector pair has its own radioactive calibration assembly. This assembly consists of a source of Fe-55 and Pu-238 (on a Cd backing) which provides x-rays at 3.0, 5.9, 13.5 and 15.5 keV. The detectors may be exposed to the source by command.

To understand the Calibration Mode of operation consider first the vertical system. During normal experiment operation, data are gathered for 27 fan beam target sweeps (i.e., for $\sim$ 0.52 seconds) and then no more data are collected for the remainder of the revolution (i.e. $\sim$ 9.48 seconds). The 0.52 seconds is shared by the two detectors of a pair. The detectors are responding throughout the revolution, of course, but we only record them $\sim$ 5.2% of the time. If one simply introduced a calibration source into the picture, 95% of the calibration x-rays would be using up the lifetime of the detector pair while not being used for calibration, and it would take a fairly long calibration period to obtain the desired statistics.

To remedy this, a High Duty Mode was designed. This mode is automatic when we are in a Night Mode of operation and in a Calib. Mode for the system being discussed. A normal vertical data collection cycle uses 2 fan beams to establish its sequence and records data for 27 fan beam sweeps. In the High Duty Mode, we combine seventeen similar cycles in a row before allowing a read out period. Actually, each cycle is now composed of 2 fan beams of no data, 27 fan beams of data, and 3 fan beams of no data.

In Night Mode a vertical psuedo sun center pulse is formed every 2^4 SAE pulses. Thirty-two (2 + 27 + 3) fan beams means $2^5 \times 2^4 = 2^9$ SAE pulses and sixteen cycles means $2^9 \times 2^4 = 2^{13}$ SAE pulses = one revolution. So the series of 17 data gather cycles lasts one revolution plus one cycle. We then read out one system for the remainder of the 2nd revolution. Thus, we record data for 8.84/20 = 45% instead of 5% of the exposed time. As always, two data gather sequences are normally combined into a memory before it is read out.

A slant system works in a similar manner, where now in the High Duty Mode a sequence is: 2 fan beams of no data, 13 fan beams of data and 1 fan beam of no data. Psuedo sun center pulses are now separated by 2^5 SAE pulses and sixteen cycles gives $2^4 \times 2^4 \times 2^5 = 2^{13}$ = 1 revolution. The percentage of time that data is being recorded by the slant memory is thereby increased from .51/10 = 5.1% to 17 x .51/20 = 43%.

In a situation where all three systems are powered up, the ~ 45% must be shared by 2 vertical detectors and the 43% must be shared between 4 slant detectors. Nothing can be done to inhibit one detector of a pair while the other is collecting data, however by using appropriate combinations of the discrete commands for turning voltage busses ON/OFF and for turning calibration assemblies ON/OFF we can eliminate having one slant pair exposed to calibration x-rays while the other slant pair is being calibrated; thus a slant detector pair can also have a ~ 45% "useful" duty cycle.

4.6 Alternate Data Mode

The instrument has an alternate mode of handling data which may be selected by ground command. In this mode the memories and a major portion of the digital readout system are bypassed when processing science data. This mode is a backup mode for handling solar data and an alternate mode for handling extra solar data; the major motivation for incorporating it being to improve our reliability with respect to accomplishing the solar physics goals of the experiment.

In the alternate data mode only one system (Vertical or Slant A or Slant B) is powered up at any given time. Each x-ray event into that system is processed as usual with regard to detectors, detector electronics and the PHA, but rather than input that event to the memories a single TM serial word is used to describe the event. Four bits of the TM word are used to define the energy (i.e., the normal 16 channels), three bits are used for spatial information and one bit defines the detector selected. Thus, the target area is now subdivided into 8 rather than 32 area segments. Data is gathered (and readout) constantly rather than only at the target area since there are no memories to readout when not looking at the target. When not pointing to the target area the spatial address is frozen at eight.

The event rate which can be processed in this manner is now limited to 75 cts/sec; the rate of our prime serial data words. This will decrease our ability, but in no way prevent us from doing worthwhile solar physics. In the extra solar work it will decrease our ability to study a specific source, but actually increase our ability to scan for sources and to examine several sources at once. Thus, it will be used for some extra solar work even with a fully functioning instrument.

5. SUBSYSTEM DETAILS

5.1 Collimators

Each collimator is of the Oda design (Space Sci.Rev.,8, 471, 1968). Figure 7. illustrates the principal of an Oda collimator using the vertical collimator as an example. The series of 0.003 inch openings gives a transmission perpendicular to the collimator face having a FWHM of 2.1 minutes of arc. Using 0.0047 inch lands and 5 grids spaced in the geometrical series shown in Figure 7 yields a second transmission beam (Fan Beam #1) 42.3 arc minutes away from the normal beam with no transmission between beams. Similarily a full sequence of fan beams spaced about every 42.3 arc minutes from one another is formed.

The collimator assembly consists of grids, grid mounting plates and spacers. The grids are photo-etched from 0.002 inch BeCu stock. They are then given a nickle flash, a deposit of ~ 0.00025 inch of gold (to provide proper x-ray attenuation characteristics) and a nickle flash. The outermost grid also receives a deposition of aluminum for high thermal reflectivity while the interior grids receive a black nickle flash to enhance the optical properties of the collimator. The grids are bonded to a 6" x 10" x 1/4" BeCu mounting plate in a mechanically precise manner using alignment holes in the plate and grids. Aluminum spacers are used to separate the grids by the required distances while each grid is kept aligned with all others by snugging the precision feet of each mounting plate up against a high tolerance parallel set of right angle rails. BeCu was used for the mounting plates so that the collimator transmission characteristics would not be altered by differences in thermal expansion between the grids and their mounting surfaces.

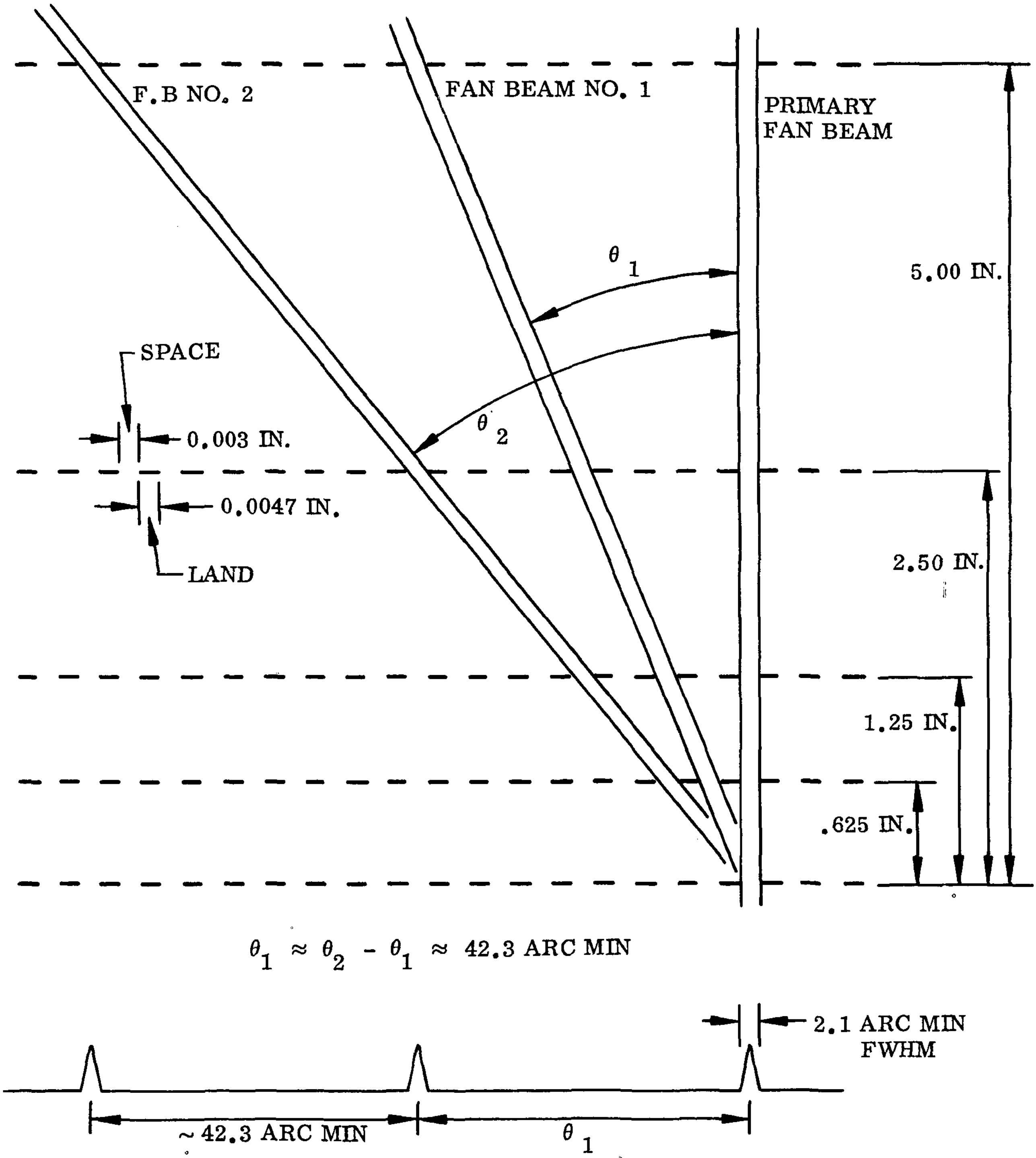


Figure 7. Successive fan beams of transmission formed about every 42.3 arc minutes for the vertical collimator.

5.2 Trigger Eyes

A trigger eye unit is a single slit mechanical collimator with a FWHM transmission of about 17 arc minutes. The collimation slit is 0.010 inch wide and 2.0 inches long. Behind the slit is a grouping of phototransistors. As a trigger eye sweeps past the sun a current pulse is generated by these phototransistors; the peak of the pulse occurs when the field of view includes the center of the sun. This signal is processed by electronic circuitry which determines the signal peak and outputs a TTL digital signal.

The peak detection circuitry transforms the current pulse into a voltage via a transimpedance amplifier circuit. The pulse is simultaneously fed to a threshold detector and to a differentiator. The differentiated waveform is fed to a comparator amplifier resulting in the generation of a positive step voltage coincident with the peak of the phototransistor array signal. The positive step voltage and threshold circuit output are then combined by a logical 'and' to form a TTL compatible digital output pulse.

Included in each trigger eye is a set of light emitting diodes (LED) which, during testing, can be pulsed by an external ground support unit to provide a solar simulation flash of light. They have no function during flight and cannot be pulsed since the only method of providing power to the units is externally.

5.3 Sun Center Detectors

As described in Section 3.0, the sunlight transmission through the collimator is used to control the data gather sequence. A sun center detector unit consists of: (a) a wideband interference filter (4,000 - 5,000Å) selected to provide a light signal whose diffraction characteristics are least detrimental to obtaining a true geometrical response of the collimator; (b) a diffuser to decrease the light signal distortions which result from shadowing the small light receiver surfaces of the photo transistors by the support structures of the grids and mounting frames; (c) a set of phototransistors which are wired in a series/parallel cross strapping manner to improve functional reliability and further decrease the effect described in item (b); and (d) a set of 'peak-finding' electronics.

The peak-finding electronic circuitry consists of a transimpedance amplifier, a logarithmic amplifier, and a buffer amplifier followed by an operational amplifier differentiator circuit whose output is a positive going voltage step coincident with the peak of the phototransistor array signal (i.e. at sun center). A TTL compatible pulse which is formed by the leading edge of this positive step is the output pulse of the unit.

Included in each sun center detector is a set of LED's which during test emit a train of light pulses to provide a simulation of the instrument rotating by the sun. As with the trigger eye units, during flight these units are not powered.

5.4 Proportional Counter Detectors

There are three designs of proportional counters used in the MXRH instrument. Classified according to sensitivity and quantity we have: (a) one low sensitivity or small flare detector which will record a significant number of counts only from flaring solar regions, (b) three medium sensitivity or large detectors which will principally be the detector in use, and (c) two high sensitivity or thin window detectors which will enable us to study the weak active regions which will be commonplace during the period of solar minimum (which corresponds to a portion of the OSO-I lifetime). These detectors were designed by LMSC and were assembled, with Lockheed furnished parts, by Twentieth Century Ltd. in England. They are all sealed, gas-filled detectors.

Appendix VI shows the effective areas for the different detectors when placed behind the collimators. Figure 8 illustrates the sensitivities of the three detectors by comparing the two small detectors to the large detector. As can be seen, the thin window detector is more than 50 times as sensitive as the large detector at low solar temperatures (which corresponds to low flux rates and a steep energy spectrum), while the small flare detector is about 20 times less sensitive at high solar temperature (which corresponds to high flux rates and a less steep energy spectrum). This combination of detectors gives the instrument a dynamic range of operation in excess of 10^5.

The large detector has a 3"diameter x 10" long cylindrical Be body with .070" walls except for a pair of 1" long machined flats with a minimum thickness of .008". These were added to optimize the detector spectral response characteristics. They have a .003" anode wire and are filled with 90% Argon - 10% CH_4. Dual-voltage field shaping electrodes are included at the detector ends to maintain a uniform gain (within ±2%) over the central 9" of the detector length.

The small flare detector has a 1"diameter x 5" long cylindrical Be body with .025" walls, of which only about the central 2" is used for x-ray detection. It is filled with 90% Xenon - 10% CH_4 and has a .003" anode wire.

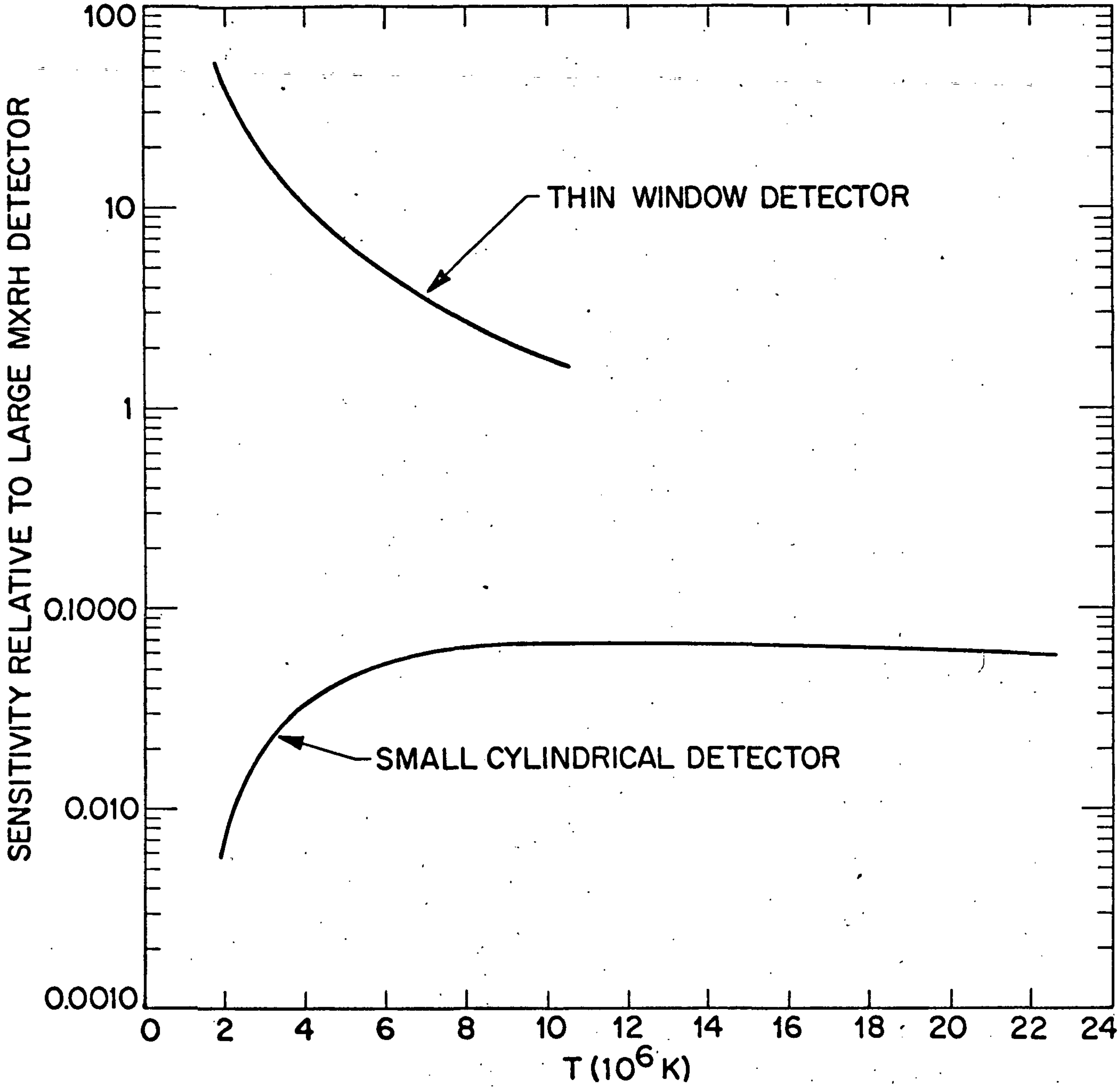


Figure 8. Illustrates the relative sensitivities of the three proportional counter detector styles which are included in the MXRH instrument. The data is calculated for a constant emission measure of 10^{48} cm^{-3} and an isothermal solar emitting region of temperature T.

The thin window detector has a 5" long x 1" x 1" rectangular aluminum body. The front side of the detector contains a pair of 2" x 3/8" Be windows, .003" thick. The detector has a .004" anode wire and is filled with 90% Argon - 3% CO_2. The thin window detector and small flare detector are physically interchangeable in a detector pair assembly.

The high voltage to the detectors will be turned off when the instrument is in the South Atlantic Anomaly region. This will be done from spacecraft command memory after an anomaly entrance has been declared either by one of the other wheel experiments or by orbit software. Our instrument has no internal capability for recognizing the anomaly. About 100 passes through the anomaly without turning the high voltage off would begin to degrade the performance of these detectors.

5.5 Detector Associated Electronics

The output of each proportional counter is coupled into a charge sensitive preamplifier which drives a pulse shaping amplifier (Main Amplifier). The resultant output is a bipolar signal having a positive peak amplitude that is proportional to the energy deposited by the photon (or energetic particle) which penetrated the detector. This signal goes to a Pulse Height Analyzer (PHA) via an Analog Gate Pair (AGP). In addition, each large detector has associated with its preamplifier/shaping amplifier string a Pulse Risetime Discriminator (PRD) whose purpose is to generate a TTL level signal when the event being processed was caused by something other than an x-ray. This TTL signal is utilized to suppress the non-x-ray background signals and thereby enhance our ability to detect the x-rays of interest.

A High Voltage Converter (HVC) is associated with each detector pair. This HVC supplies the voltages needed for the two detector's anodes and for the two field shaping electrodes of the large detectors.

5.5.1 High Voltage Converter

The high voltage converter is a highly stable converter utilizing a variable pulse width oscillator to drive a resonant transformer. The output of the transformer is parallel fed into a voltage multiplier stack from which the various output voltages are tapped. All voltages are pi filtered prior to being output to the detectors. A voltage is also generated which is fed into one side of a voltage comparator and compared with a precision reference voltage. The output of this comparator controls the energy input from the oscillator into the resonant transformer and thence the output voltage levels. The HVC was detail designed and built by the Time Zero Corporation. Some of the important characteristics are given in the following data table:

HVC Summary of Performance

Inputs:

Voltage	+ 20 Vdc ± 5%
Current	5 ma maximum

Outputs:

Voltage	Stability*
Anode No. 1= +2550 Vdc	4 Vdc max. variation band
Anode No. 2= +2450 Vdc	4 Vdc max. variation band
Field Tube No.1= +839 Vdc	2 Vdc max. variation band
Field Tube No.2= +403 Vdc	2 Vdc max. variation band

Output Ripple is less than 1 mV p-p on all outputs and Crosstalk is less than 1 mV for 1 Volt pulse on any other output. Any output may be grounded without changing the other voltages by more than 0.5%.

*Stability is over any combination of input voltage variations (± 5%) and ambient temperature changes over the range of -15°C to +40°C.

5.5.2 Preamplifier and Main Amplifiers

The charge sensitive preamplifier is a cascode design utilizing a bootstrapped emitter follower output stage and an FET input stage. Current sources are utilized to establish the proper bias current levels while maintaining the required high impedances to the signals path. An input gate protection circuit is employed to preclude damage to the preamplifier in the event of high voltage arcing at any point in front of the input.

The preamplifier has a voltage-to-charge conversion factor of approximately 1×10^{12} Volts/Coulomb, a rise time of less than 100 nanoseconds (less than 40 nanoseconds with no input protection) and an overall noise level less than 800 electron pairs equivalent (less than 550 electron pairs with no input protection) when used in combination with the shaping (main) amplifier.

The pulse shaping amplifier consists of 2 cascade stages of cascode amplification separated by a gain adjusting network. Each stage of the amplifier is connected as an operational amplifier type of integrating differentiator having equal differentiating and integrating time constants in each stage. The final output stage is a push-pull emitter follower design which allows one to drive several feet of coaxial cable and various test equipment with little effect on the output signal.

The pulse shaping amplifier when used in combination with the MXRH preamplifier has a linear output range of approximately 7 V

The combination of the MXRH preamplifier and main amplifier ~~[illegible] range~~ is stable to within than 0.1% of full scale over a temperature range of -10°C to +40°C and a bus voltage variation of ±1%.

(positive peak), a shaping time (FWHM positive peak) of 500 ns (for a 50 ns risetime test input signal), and will recover completely from a X100 overload pulse within 8 μseconds. The combination of the MXRH preamplifier and main amplifier is stable to better than 0.1% of full scale over a temperature range of -10°C to +40°C and a buss voltage variation of ± 1% from nominal levels of ± 10 Volts.

5.5.3 Pulse Risetime Discriminator

Based upon the fact that low energy x-ray events typically cause a faster risetimes of charge buildup at the center wire of a gas filled proportional counter than do charged particle events, a pulse risetime discriminator unit has been incorporated into the design of the Mapping X-Ray Heliometer Experiment in order to effectively reduce the background events caused by charged particles.

The pulse risetime discriminator circuit consists of an input emitter follower which feeds two separate circuit chains simultaneously. One circuit chain serves to doubly-differentiate the input signal from the preamplifier and creates a positive going voltage step corresponding in time to the point of maximum slope of the preamplifier signal. The other circuit chain serves to create a pulse with a fixed width whose leading edge corresponds in time to the start of preamplifier signal and whose trailing edge corresponds in time to the point just past the point of maximum slope of the preamplifier signal when the signal is from a desirable x-ray event. The two signals thus created are combined in a "D" type of flip-flop. The flip-flop gives a high (logic "1") output if the time of occurrence of maximum preamplifier signal slope was after the disappearance of the fixed width pulse, thus signaling that the event just processed was not an x-ray event but should be logged as a PRD event. The "D" flip-flop output remains low (logic "0") if the event processed is an x-ray event within the range of interest.

5.6 Pulse Height Analyzer and Decode

The Pulse Height Analyzer and Decode (PHA/Decode) system consists of a noise threshold and postive rise discriminator circuit, a peak storing circuit, a successive approximation analog-to-digital converter, a set of decoding logic circuitry, and control logic and clearing circuitry.

The noise threshold and positive rise discriminator circuit performs the function of not allowing signals smaller than approximately 200 millivolts peak amplitude to become peak stored and most importantly, it does not allow the storing of any signal peak unless the incoming signal started from the 0 Volts level (i.e. or below) with a positive slope and maintained that slope up to the positive peak amplitude.

The peak storing circuit consists of buffer amplifiers that are specifically designed so that a charge is stored in a capacitor that is exactly representative of the peak positive voltage amplitude of the incoming signal. This charge is then presented to the analog to digital converter (ADC) section of the PHA by means of a Impedance Buffer/Driver Circuit in order that the ADC sees an essentially constant voltage during the conversion process.

The ADC portion of the PHA is a successive approximation type having its own 1.024 MHz oscillator and utilizing a 10 bit DAC in order to obtain a resolution capability of approximately 0.1% of full scale. The timing of the ADC is such that conversion is complete after 10 μsec.

Only the five high order bits of the DAC are used in the conversion process, resulting in effectively a 32 channel PHA. These 32 channels are then five-line to four-line decoded via the decode circuitry such that 16 PHA addresses are presented to the memory units in accordance with Table II of Section 3.

able II of Section 3.

The control logic and clearing circuitry of the PHA performs the various functions such as allowing only one signal to be accepted at a time, telling the data storing system when to accept a converted signal, clearing the peak storing circuit contents once conversion is complete and resetting the whole PHA system to be ready for the next signal event to be processed.

An important and unique feature of the PHA system is that the five low order bits of the DAC are wired to logical "1's" and "0's" such that in combination with the 4th bit of the DAC the analog signal is set to a 0.4 volt level. Hence, the last step of each 12 μsec PHA cycle is to set in the 4th bit of the DAC so that we have a very stable (±5 mV) digitally generated threshold voltage without resorting to the usual approaches to the problem. The 1st step in the conversion process then becomes one of clearing out the 4th bit while setting in the 1st bit of the DAC.

5.7 Memory System

The memory system is a 4096 bit core memory arranged in 512 8-bit words. It was designed and built under subcontract by the Time Zero Corporation, Torrance, California. In the MXRH instrument two memories are used; one in the vertical system, one in the slant system. For this reason, the memories are designed for ease of interchangeability. The two memories (see Figure 4 of Section 2) are mounted back-to-back with basic dimensions of 4.7 x 7.0 x 2.8 inches.

The block diagram of the memory system, showing all electrical interfaces with the rest of the Heliometer system, and the basic internal organization of the memory, is shown in Figure 9. The electrical interfaces of data and control lines are the inputs and outputs of low power TTL (54L Series) digital integrated circuits with protected inputs. These digital integrated circuits, as well as the hybrid current drivers and sense amplifiers, are flat-pack type of packaging mounted on two multilayer printed circuit boards. Between these two boards is mounted the core stack.

The organization of the address into 4 bits of X address, and 5 bits of Y address is not explicitly shown in the block diagram. Thus, the memory system is organized as a 16 x 32 matrix of 8-bit words. It should be noted that the power system is strobed during the memory cycle for minimal power dissipation.

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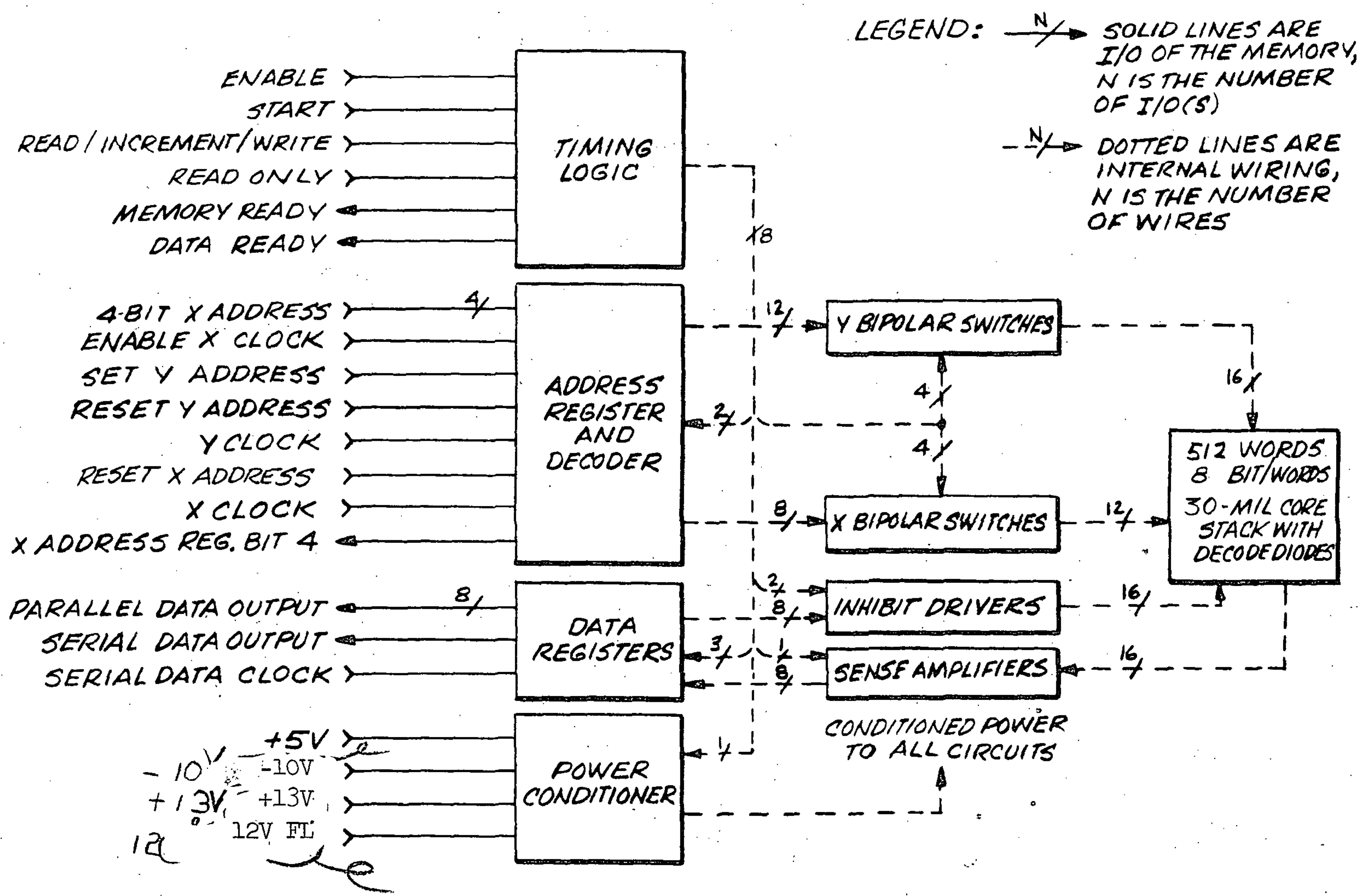


Figure 9 MEMORY SYSTEM BLOCK DIAGRAM

A memory unit has the following general specifications:

Total Cycle Time	4 microseconds
Mean Cycle Rate	10 KHz
Peak Cycle Rate (25 cycles)	250 KHz
Power Consumption	Standby 225 mW
	Operating (225 + 68f) mW max.
	(f = cycle rate in kHz)
Weight	2 lbs

5.8 Calibration System

In-flight calibration of the x-ray detectors and their associated electronic chain is accomplished by periodically exposing the detectors to radioactive sources which emit x-rays of known energies. Each detector pair has its own calibration system which consists of a source on the shaft of a three-position stepper motor and a .062 thick tungsten shield over the source with slit apertures in line with the two detectors. To calibrate the detectors the source is stepped to the "on" location where the source aligns with the slits; to turn the calibration "off" the source is stepped to either of the other two positions. The unit thus has a basically redundant calibration "off" ability. In normal operation, we will not step back and forth between the "on" and "off" positions but will always step clockwise thereby crossing both "off" locations before the "on" location. This inhibits the building up of a residue on the bearings which might freeze the motor.

The stepper motors were built for LMSC by Computer Devices Corporation of Sante Fe Springs, California. The motors are size 11 with permanent magnet rotors, Barden Bartemp Bearings and Duroid retainers. Each motor is subjected to a 24-hour run-in and a 24-hour vacuum outgassing immediately after assembly. The minimum static torque for each motor is 86.4 gr-cm, with only 1/8 of this torque required to start the rotor, shaft, source and source holder during our application.

The motors are connected and operated in a three phase "w y e" type configuration with the common point connected to the spacecraft unregulated buss. Only one winding shall be energized at any one time. With the common point of the "w y e" connected to the spacecraft buss, any of the three positions may be obtained by pulsing the appropriate winding to ground for approximately 150 milliseconds. The motor is then held in the desired position by a zero-power-input detent torque of 21.3 grams-cm.

Each calibration source is a mixture of eleven μ-Curies of Fe-55 and fifty μ-Curies of Pu-238 on a Cd backing. The Fe-55 yields 5.9 keV x-rays. The Pu-238 produces 13.6 and 15.5 keV x-rays. The alpha bombardment of the Cd produces fluorescent x-rays which provide some $\sim$ 3.2 keV x-rays. Some high energy gamma rays at 150 and 720 keV are also emitted with fluxes of less than 0.01 and 0.003 photons/steradian-second, respectively.

The overall source strength is high enough that, when used in the Long Duty Mode (see Section 4.5), we can obtain a reasonable calibration for a single detector in about five minutes, but low enough that if it accidentally stayed on we could still sort out a superimposed signal from a solar active region.

5.9 Digital Electronics Control System

The Digital Electronics Control System consists of low power, TTL, (54L series) digital integrated circuits in dual-in-line packages mounted on two-sided printed circuit boards. The packaging concept consists of fifteen circuit boards plugged into a single interconnection board. There are several subsystems of the Digital Electronics Control System which will be briefly described.

5.9.1 Data Gather Control System

The Data Gather Control System depends on either solar trigger pulses from the trigger eye units or pseudo-solar trigger pulses from the Night Sky Control System to start the Data Gather Cycle. Provided the Data Readout System has finished its activity, either of these pulses will enable the Data Gather Control System. A Fan Beam Counter counts either the sun pulses that come from the sun center detectors or the pseudo-sun pulses that come from the Night Sky Control System to define the end of the data gather period.

As described in Section 3, each fan beam gathers data as it sweeps across the solar disk so provisions must be made to start the data gather sequence at a point prior to contacting the solar edge. This is accomplished by using a redundant, ground selectable, crystal oscillator as a timer. The first accepted sun center pulse enables this oscillator into a counter and the second sun pulse stops the counter. The count (N_1), which is now a measure of the time between sun centers, is loaded into a storage register. By using this number divided by two (which in binary is a simple shift operation) as one input to a digital comparator and a counter enabled to count at the same frequency as the original N_1 counter as the other input, one determines electronically the position half-way between sun center pulses. This defines the start of a fan beam's sweep across the sun. Likewise, the number N_1 divided by thirty-two is loaded into a second storage register which is used as one input to a digital comparator. The other input to the comparator is the output of a counter which counts at the same frequency as the original N_1 counter. When the two inputs compare, the output pulses of the comparator define the edges between each of the thirty-two spatial area segments on the sun into which the x-ray data is grouped. Each of these area segment pulses is used to increment the memory Y-address so that the Y-address of the memory array define one of the thirty-two area segments of the sun.

The oscillator that generates N_1 is also enabled into a counter during the occurrence of area segment number fifteen for each fan beam. This counter thus contains a total count proportional to the total time data was collected in that area segment. Since all area segments of each fan beam are of equal width, this elpased time value is applicable for every area segment.

elapsed

At the completion of data gather, the SAE pulse is enabled into a counter. After 2^{12} SAE counts have occurred, the instrument has rotated approximately 180° and is pointing in the antitarget direction where the appropriate detector is then enabled to record background for approximately 1.25 seconds. This data is stored in memory Y-address thirty-two.

The Fine Spatial Mode capability that was described in Section 4.2, comes about by electronically adjusting the starting points to be either $3N_1/4$ or N_1 while adjusting the widths of the area segments to be $N_1/128$.

5.9.2 Detector Selection System

The vertical and slant systems each have Detector Selection Systems. The vertical system will be described here. The slant system is similar but somewhat more complex since it must control both slant A and slant B detector pairs independently.

The heart of the Detector Selection System is the Sensitivity System portion of the digital electronics. Consider an initial condition where the higher sensitivity detectors are in use for all area segments. For each data gather period, the Sensitivity System examines the data as they are accumulated and determines if the counts for any differential energy channel have exceeded the specified upper count threshold. If this is the case, the Sensitivity System records that fact in a sixteen bit accumulator shift register. Each bit of the sixteen is assigned to two area segments: area segment 32&1 to bit 1, 2&3 to bit 2, and so on. The data gather period is normally two revolutions of the spacecraft.

After the data readout period, the accumulated sensitivity status in the accumulator register is parallel transferred to a sixteen bit storage shift register. The information in this storage register is then used during the next data gather period to control which detector is selected to gather data for each group of two area segments. In a similar manner if the system is in low sensitivity for a specific area segment pair and the specified lower threshold is never crossed during a data gather period, the system will return to high sensitivity for that area segment for the following data gather period.

The contents of the storage register are read out prior to each memory readout to describe the sensitivities which were used to gather that memory of data.

The pulses that define area segments edges, divided by two, are used to serially shift the sixteen bit shift registers. Thus, during the observing of each two area segments the correct bit is presented to the Analog Gate Pair Selector System. The Analog Gate Pair (AGP) is a combination gating/selection system for controlling which detector transfers data to the Pulse Height Analyzer. It is a pair of single-pole single-throw break-before-make action FET switches built from discrete parts in order to conserve power (a typical pair of gates requires only 6 mw of power) while still meeting the specific requirements of the instrument.

The storage register design of the Sensitivity System makes it possible to program the sensitivity status from the ground. By loading this register with a magnitude command and inhibiting parallel loading of the accumulator information, while leaving all other aspects normal, any sensitivity pattern across the surface of the sun can be established.

One additional capability of the system is sensitivity overrides. In this mode, one can command the sensitivity selection to all high sensitivities or all low sensitivities until changed by a new command. It will be used if a failure developes in the more elaborate techniques.

5.9.3 Data Readout System

The Data Readout System takes control of the MXRH instrument upon completion of the data gather period, i.e. after both vertical and slant systems have accumulated the required number of fan beams. It looks for the first minor frame sync after being enabled. Upon detection of minor frame sync, the Data Readout System becomes responsive to serial data read envelopes. The response is to count these read envelopes.

For the first three read envelopes, data words of all logical "ones" are presented at the output, and these become the MXRH data sync words. The fourth read envelope causes various bits of status information to be assembled in an eight bit shift register which is then clocked out by the serial data clock. These bits include which memory is being read out with data from which system, whether the data is in the day or night mode, whether the system is in normal or vertical only readout, whether the system is in calibration or not, whether the system is in fine or coarse mode, and whether the fine mode is for the first or fourth quadrant. For the fifth word, the eight bit shift register is loaded with the elapsed time data and then clocked out. For the sixth and seventh words, the sixteen bits of sensitivity states are serially shifted such that the sixth word contains bits one through eight and the seventh word contains bits nine through sixteen. See Appendix II, Table V, for the exact bit description of these prime serial data words.

For the eighth through the five-hundred-nineteenth serial read envelopes, the five-hundred-twelve words of memory are read out. This is done in an order such that area segment 1 has all sixteen PHA channels beginning with channel 1, area segment 2 has all sixteen PHA channels, and so on. Upon completion of the memory data output, the data readout system provides all zero data until the next data readout period.

After counting five-hundred-twenty read envelopes, the Data Readout System reconfigures so that the next data readout period will read out the other memory. The Data Readout System then passes control back to the Data Gather Control System.

5.10 Power System

The power system of the MXRH consists of a Power Conversion Unit (PCU) and a Power Distribution Unit (PDU).

The PCU is basically made up of two identical Power Conversion Modules (PCM) and a set of power converter module selecting relays which perform the function of switching in one or the other of the redundant power converter modules as desired.

The power conversion module performs the function of transforming the regulated 28 Vdc from the spacecraft into the various voltages required to operate the MXRH. The PCM is basically a conventional design with several unique variations incorporated in order to increase the power conversion efficiency. The power conversion efficiency is better than 75% on the "production" units. The PCM is overload protected via fold back current limiter circuits in both regulated outputs and the input regulator. The following table summarizes the important performance characteristics of the PCM.

Nominal Voltage	Maximum Allowable Variation*	Nominal Average Load Current Range
20 Vdc ± 0.2 Vdc (floating)	± 0.60 Vdc	5 ma to 16 ma
12 Vdc ± 0.2 Vdc (floating)	± 0.60 Vdc	7 ma to 14 ma
+5 Vdc ± 0.1 Vdc	± 0.25 Vdc	400 ma to 920 ma
+10 Vdc ±0.05 Vdc	± 0.05 Vdc	60 ma to 150 ma
-10 Vdc ± 0.05 Vdc	± 0.05 Vdc	60 ma to 120 ma
+13 Vdc ± 0.3 Vdc	± 0.60 Vdc	5 ma to 8 ma

* The output voltages do not change more than the amount listed for any combination of variations in input voltage (±2%), ambient temperature (-15°C to +40°C) and load current (as shown in the table).

The power converter unit selecting relays perform the function of switching the +28 Vdc regulated buss voltage into the desired PCM and simultaneously switching that same PCM output voltages onto the main voltage buss lines for use within the various MXRH subsystems. Only one PCM is in operation at a time while the other PCM is in standby.

Since the MXRH is made up of three essentially separate x-ray detection systems, each of which has a solar mode and an extrasolar mode of operation, it becomes apparent that one can greatly enhance the probability of experiment success if one can switch on or off at will the various portions of the MXRH in any desired manner. Also, if spacecraft power becomes rationed, the MXRH instrument could operate in a decreased power situation (say two of the three systems) without totally compromising the scientific goals of the experiment. For these reasons, a PDU was designed and built.

The PDU contains all the power distributing relays, relay drivers, wiring, connectors, etc. that are needed in order to execute the commands required to configure the MXRH into its various desired basic operating modes as previously described.

6. DATA FORMAT

The MXRH experiment has 12 telemetry words (TM) per minor frame and an additional 20 words per major frame. The minor frame words are serial digital. The major frame words are: 2 serial digital, 6 parallel digital, 12 analog. A brief description of the TM usage will be given here; a bit-by-bit TM definition is contained in Appendix II. Combinations of these TM words enable us to verify the receipt of every command, to routinely assess the instrument's 'health' and to obtain the scientific data for which the instrument was designed.

6.1 Major Frame Analog Words (12 ea)

These words are used to monitor the 'health' of the instrument and are read to telemetry every 20.42 seconds. The items monitored are: +5V buss voltage, +10V buss voltage, -10V buss voltage, 20V FLT buss voltage, 12V FLT buss voltage, the current being used by each of the HVC, and hot spot temperatures for the PCU, the gated PHA Box, a detector electronics box and the digital system.

6.2 Major Frame Parallel Digital Words (6 ea)

These words provide instrument status information which allows one to quickly observe if a command has 'taken' and also provide information that is useful in interpreting a malfunctioning condition.

6.3 Major Frame Serial Words (2 ea)

These two words provide 16 bits of serial information. Thirteen of these bits are used to define the desired extrasolar target location as a binary number (from 1 to 2^{13}) of SAE pulses away from the MIP pulse. Bit 4 of Word 1 is the most significant bit and bit 8 of Word 2 is the least significant bit. The definition changes in the alternate data mode. The 2^{13} number becomes the number of photons, exclusive of PRD's and overloads, processed by the PHA in the last major frame and the three "extra" bits define status (see Appendix II).

6.4 <u>Minor Frame Serial Words (12 ea)</u>

The minor frame serial word stream is the mechanism for reading the science data out of the instrument memories as well as the status information which contains the characteristics of that memory. As previously described (Figure 5), we gather and readout data in sync with an azimuthal direction rather than with spacecraft TM sync points like major frame start, etc. To provide for software grouping of the data, we generate an instrumental internal sync in the minor frame data stream as follows. At the end of a data collection pass, we wait until the next time the first LMSC read envelope of a new minor frame is received. This word becomes the first word of an LMSC record and is forced to be all "ones." The next two words are treated likewise. The 4th, 5th, 6th and 7th words contain information which is required to understand how the instrument was configured for the data collection pass(es) whose memory is about to be readout. The next 512 words are the readout of one memory. For a 6 RPM spin rate, we have 750 minor frame words per revolution. After using 519 of them in the manner just described, logical "zeros" are placed in the remainder until another data collection and internal sync occurs. Thus, our data stream sync is at least 120 all "zero" words followed by three all "one" words, the first of which is the first of LMSC's minor frame words.

In analyzing the data, the 519 significant words will be combined with a set of major frame words, in a yet to be established format, and with various pertinent spacecraft status data (such as pitch, clocktime, MIP location, spin rate, horizon sensor, etc.) to form a data set.

7. DAILY SOLAR X-RAY MAP

An x-ray map will be provided each day showing the location, intensity and spectral properties of each x-ray source on the solar disk. These maps will be made available to the National Oceanic and Atmospheric Administration for publication in the Solar Geophysical Data Prompt Reports. Daily maps will be readily available to other experimenters for use on concurrent observing programs, and will therefore be made as often each day as required and feasible.

As presently envisioned each active region that has detectable x-ray emission will be indicated on a solar disk in a manner which gives a measure of relative intensity and indicates if the region is flare active. In addition, the temperature and emission measure for each region (based on the Tucker and Koren model for a low density plasma) is stated. Figure 10 is an example of what this will look like.

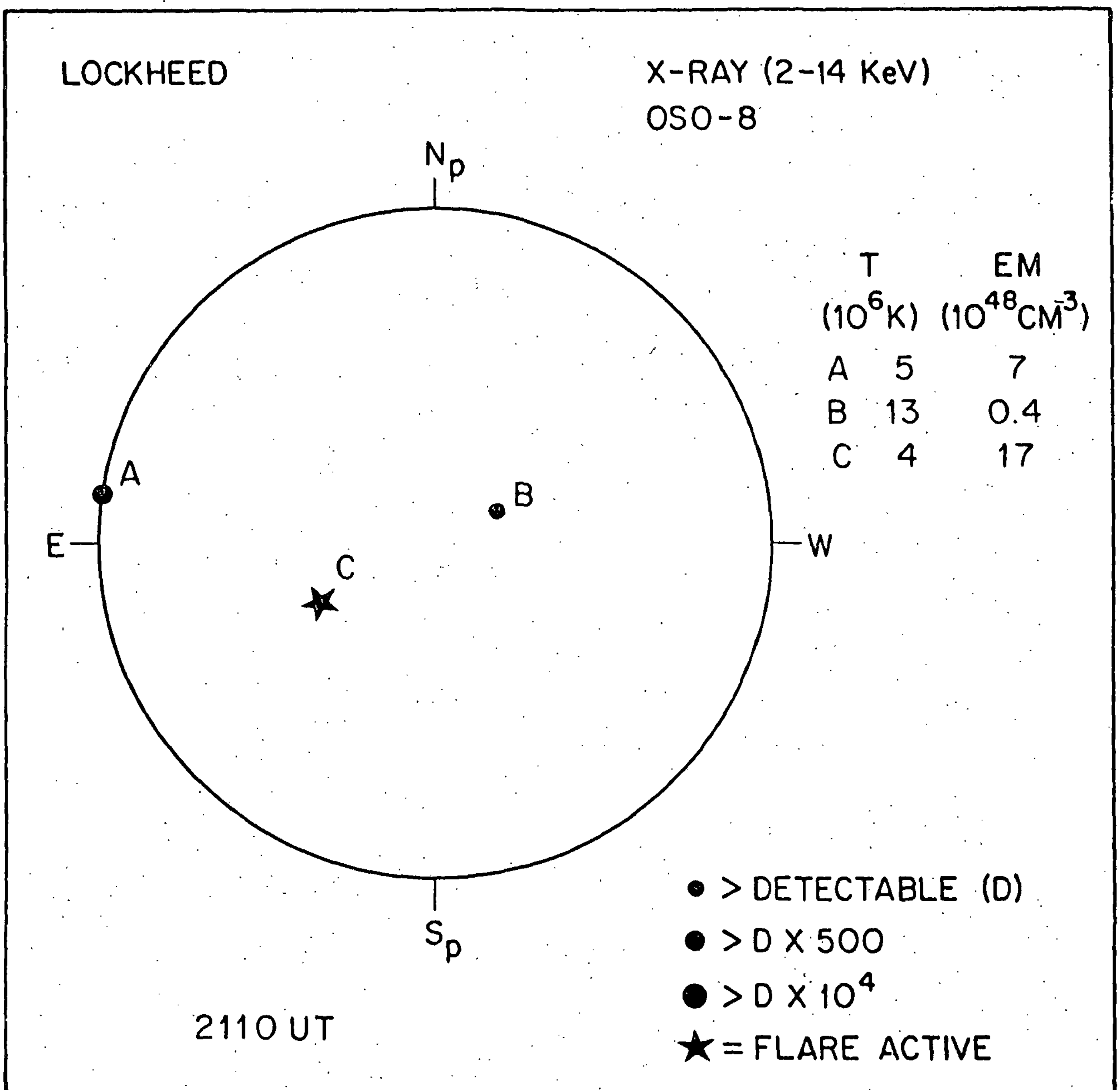


Figure 10 Example of the daily map which will be generated from the MXRH observation and provide to NOAA for publication.

8. HANDLING/SAFETY PRECAUTIONS

The instrument presents no hazards to the personnel who handle it as it contains no pyrotechnic devices and the radioactive sources within it are both well shielded and of a level well below that which would present a hazard.

In handling the instrument, the normal high degree of carefulness given to all flight hardware is adequate for assuring the safety of this instrument. This includes lifting only on the LMSC provided hanging bracket and the two eyebolts which screw into the front of the shelf. The four specific areas for extra precautions are:

a) Red tag covers should protect the collimator fronts at all possible times and when removed extreme care should be exercised to not touch, impact, etc. the frontal grids.

b) Red tag covers will usually be used to protect the top and bottom instrument surfaces where the collimator-to-detector interface exposes detectors and the collimator back grid. Again, when these covers must be removed extreme care should be exercised to not damage the detectors (which have thin beryllium windows and flats) and collimator grids.

c) When the bottom cover of case b) is removed, the optical surface of Slant B's sun center detector is exposed and care should be exercised to not touch, impact, etc. this surface.

d) The collimators have outgassing holes. When uncovered care should be exercised to not drop something into these holes.

APPENDIX I

COMMAND LIST AND DESCRIPTION

The following will be a description of each of the MXRH commands. The entire list is shown at the end of this Appendix. Discrete commands are coded DC while serial magnitude commands are coded SM.

<u>DC #1. Select PCM-A</u>: In the instrument there are a pair of redundant DC-DC power converters available for use. DC #1 selects the unit called A.

<u>DC #2. Select PCM-B</u>: Selects the other unit, called B.

<u>DC #3. Vertical B^+'s OFF</u>: The power distribution system of the instrument is such that power to subsystems which are similar in all 3 systems may be turned off and on for each system independently. Likewise, for subsystems which are similar from slant to vertical. This improves the total instrument reliability. DC #3 turns off B^+ busses for the vertical system in areas where it does not affect the slant systems.

<u>DC #4. Slant A B^+'s OFF</u>: Turns off busses which are unique to Slant A subsystems or common to general slant subsystems, but do not affect the vertical subsystems.

<u>DC #5. Slant B B^+'s OFF</u>: Similar to DC #3 but for slant B.

<u>DC #6. Vertical B^+ & PRD ON</u>: Turns on all buss voltages required to make the vertical system totally function.

Note: To go from a full powered-up state to a state of only slant A powered-up, not only must DC #3 and DC #5 be issued, but DC #7 must be issued to repower the common portions of the slant systems.

DC #7. Slant A B^+ & PRD ON: Like DC #6 but for slant A. Note it turns on all busses common to the two slants as well as those unique for slant A.

DC #8. Slant B B^+ & PRD ON: Like DC #7 but for slant B.

DC #9. Vertical PRD OFF: This turns off the +5V buss to the PRD and thereby disables it from rejecting pulses. The remainder of the detector electronics works normally. Issuing DC # 6 will repower the PRD without affecting the remainder of the system.

DC #10. Slant A PRD OFF: Similar to DC #9 but for slant A.

DC #11. Slant B PRD OFF: Similar to DC #10 but for slant B.

DC #12. All high voltages OFF: Turns off all three high voltage converters.

DC #13. Vertical HV ON: Turns on the vertical system HVC.

DC #14. Slant A HV ON: Turns on the slant A HVC.

DC #15. Slant B HV ON: Turns on the slant B HVC.

DC #16. Calib. OFF A: The radioactive calibration source for each detector pair is on the shaft of a three position stepper motor. Two of these positions leave the source shielded from the detectors and one position leaves it exposed. DC #16 selects one of the shielded positions and does it for all three motors.

DC #17. Calib. OFF B: Similar to DC #16 but selects the other shielded position for all three motors.

DC #18. Calib. ON V: Puts the calibration source for the vertical system into the unshielded orientation. Does not affect the other two motors.

DC #19. Calib. ON SA: Like DC # 18 but for the slant A system.

DC #20. Calib. ON SB: Like DC #18 but for the slant B system.

DC #21. Fine Mode Enable: This command allows the instrument to be put into a fine spatial mode of operation by issuing SM #3 with the desired bit pattern.

DC #22. Day-Night: This allows the spacecraft DAY/NIGHT event level to set the instrument into either Day or Night Mode of operation in phase with Orbit Day and Orbit Night.

DC #23. Day Mode Only: Puts the instrument in the Day Mode of operation and leaves it there through Orbit Day and Orbit Night.

Note: To get to a frozen-in Day or Night Mode, one must go to the Day-Night Mode via DC #22 and then to the desired frozen-in mode.

DC #24. Night Mode Only: Like DC #23 but for a frozen-in Night Mode.

DC #25. Config. Sens. V: This command allows SM #2 to be loaded into the vertical sensitivity system. One of the modes of the sensitivity system in the MXRH is to be ground programmable with 16 bits of sensitivity status information. Since one magnitude command is used for all three systems, the Configure Sensitivity discrete commands enable each system to accept the serial magnitude command independently.

Note: The sequence of commands required to accomplish this in the vertical system is to first remove any sensitivity overrides via DC #37, then configure the vertical sensitivity via DC #25, followed by SM #2.

DC #26. Config. Sens. SA: Like DC #25 but for the slant A system.

DC #27. Config. Sens. SB: Like DC #25 but for the slant B system.

DC #28. Sens. Auto V: This command places the vertical sensitivity system in the automatic switching mode, where actual gathered data determine the future sensitivity status.

DC #29. Sens. Auto SA: Like DC #28 but for the slant A system.

DC #30. Sens. Auto SB: Like DC #28 but for the slant B system.

DC #31. Normal Readout: This command places the MXRH in a mode where the vertical TLM and memory are read out during the readout period, then the data are gathered during the data gather period, then the slant TLM and memory are read out during the readout period, then data gather repeats, then the vertical TLM and memory is read out and the cycle repeats. This is the "Normal" readout. This command also resets the instrument from the alternate data mode (see Section 4.6 and DC #33).

DC #32. Vertical Only Readout: This command places the MXRH in a mode where for every data readout period only the vertical TLM and memory are always read out.

DC #33. Alternate Data Mode: This command activates an alternate mode of collecting and reading out data, whereby each prime serial word contains the energy and spatial information for a single photon. See Section 4.6 for details.

DC #34. Sensitivity Override V ON-Med: This command forces the vertical sensitivity system to select only the Medium sensitivity detector of the vertical system and overrides the sensitivity auto and configured sensitivity modes.

Note: To go to any sensitivity override from any other sensitivity override, one must give DC #37, sensitivity override OFF, first.

DC #35. Sensitivity Override S ON-Hi: Like DC #34 except this selects the High sensitivity detector in both slant systems.

DC #36. Fine Mode Disable: This command forces both the vertical and slant systems to be in coarse mode regardless of the condition of SM #3.

DC #37. Sensitivity Override OFF: This command removes all overrides from both vertical and slant systems and returns them to whatever mode is currently active.

DC #38. Sensitivity Override V ON-Lo: Like DC #34 except this selects the Low sensitivity detector in the vertical system.

DC #39. Sensitivity Override S ON-Med: Like DC #34 except this selects the Medium sensitivity detector in both slant systems.

DC #40. Event Flag Reset: This command resets the Flare Event Flag. The Flare Event Flag becomes set at the Flare Event. It will remain set forever unless this command is given. But, once reset, if the Flare Event is present, the Flare Event Flag will become set within 20 seconds.

SM #1. Night Sky Position: This command is used to determine how many SAE pulses, m, must occur, after the MIP pulse, before the MXRH will start gathering data from the night sky in the Extra-Solar mode. Since $m \leq 2^{13}$ the 13 least significant bits of this command are used to determine m, where bit 16 of SM #1 is the least significant bit. Bits 1, 2 and 3 are not used. The numeric code is binary.

SM #2. Sensitivity Configuration: This command is used in conjunction with DC #25, DC #26, and DC #27 as explained under DC #25. Each bit of this command assigns a fixed sensitivity to two area segments. The area segments are grouped 32&1, 2&3, 4&5, 6&7,..., 30&31. Bit 1 is assigned to area segments 32&1, bit 2 is assigned to area segments 2&3, and so on until bit 16 is assigned to area segments 30&31. Bit 1 is the MSB. The bit definition is such that a logical "1" selects the Medium sensitivity detector in the vertical system and the High sensitivity detector in either slant system, and a logical "0" selects the Low sensitivity detector in the vertical system and the Medium sensitivity detector in either slant system.

SM #3. Sensitivity Threshold Levels and Fine Mode Definition and Formatter A/B Select and Oscillator A/B Select: This command is divided into several functions as the name implies.

Bits 5, 6, 7, 8, 13, 14, 15 and 16 define the Sensitivity Threshold levels in the sensitivity control system. The following is the definition:

	LOWER THRESHOLD					UPPER THRESHOLD				
SYSTEM	VERTICAL		SLANT		COUNTS	VERTICAL		SLANT		COUNTS
BITS	16	15	8	7		14	13	6	5	
	0	0	0	0	4	0	0	0	0	64
	1	0	1	0	4	1	0	1	0	64
	0	1	0	1	8	0	1	0	1	128
	1	1	1	1	16	1	1	1	1	192

The upper threshold is the number of counts above which a change from a higher sensitivity detector to a lower sensitivity detector will occur when in the Sensitivity Auto Mode. The lower threshold is the number of counts below which a return from a lower sensitivity detector to a higher sensitivity detector in the Sensitivity Auto Mode will occur.

Bits 1, 2, 3, 4, 11 and 12 are used to define the fine mode capability of the MXRH. The following is the definition:

	FINE MODE ENABLE				FINE MODE QUADRANT			
SYSTEM	VERTICAL	SLANT A	SLANT B	ENABLED	VERTICAL	SLANT A	SLANT B	QUADRANT
BITS	11	3	1		12	4	2	
	0	0	0	No	0	0	0	Fourth
	1	1	1	Yes	1	1	1	First

The first quadrant is defined as the quadrant of the sun immediately after the center of the sun. The fourth quadrant is defined as the quadrant of the sun immediately before the center of the sun. It is necessary when operating in Fine Mode to initially give DC #21 - Fine Mode Enable, which transfer control to SM #3.

Bit 9 is used to select one of the redundant oscillators in the Data Gather Control System. If bit 9 is a logical "1" oscillator A is selected. If bit 9 is a logical "0" oscillator B is selected.

Bit 10 is used to select the TLM formatter from the spacecraft. If bit 10 is a logical "1" formatter B is selected. If bit 10 is a logical "0" formatter A is selected.

APPENDIX II

TABLE III LMSC Command List

Discrete Commands

Item*	Title	(RD-CH)
1	Select PCM-A	(2-1)
2	Select PCM-B	(2-2)
3	Vertical B^+'s OFF	(2-3)
4	Slant A B^+'s OFF	(2-4)
5	Slant B B^+'s OFF	(2-5)
6	Vertical B^+ & PRD ON	(2-6)
7	Slant A B^+ & PRD ON	(2-7)
8	Slant B B^+ & PRD ON	(2-8)
9	Vertical PRD OFF	(2-9)
10	Slant A PRD OFF	(2-10)
11	Slant B PRD OFF	(2-11)
12	All high voltages OFF	(2-12)
13	Vertical HV ON	(2-13)
14	Slant A HV ON	(2-14)
15	Slant B HV ON	(2-15)
16	Calib. OFF A	(2-16)
17	Calib. OFF B	(2-17)
18	Calib ON V	(2-18)
19	Calib. ON S_A	(2-19)
20	Calib. ON S_B	(2-20)
21	Fine mode enable	(2-21)
22	Day-Night	(2-22)
23	Day mode only	(2-23)
24	Night mode only	(2-24)
25	Config. sens. V	(2-25)
26	Config. sens. S_A	(2-26)
27	Config. sens. S_B	(2-27)
28	Sens. auto V	(2-28)
29	Sens. auto S_A	(2-29)
30	Sens. auto S_B	(2-30)
31	Normal readout	(2-31)
32	Vertical only readout	(2-32)
33	Alternate Data Mode	(2-33)
34	Sensitivity override V ON-MED	(2-34)
35	Sensitivity override S ON-Hi	(2-35)
36	Fine mode disable	(2-36)
37	Sensitivity override OFF	(2-37)
38	Sensitivity override V ON-Lo	(2-38)
39	Sensitivity override S ON-MED	(2-39)
40	Event Flag Reset	(2-40)

Serial Mag. Commands

Number	Title	(RD-CH)
1	Night Sky Position	(2-71)
2	Sensitivity Configuration	(2-72)
3	Sensitivity Threshold Levels and Fine Mode Definition and Formatter A/B Select and Oscillator A/B Select	(2-73)

* RD = Remote Decoder

TABLE IV. Digital Major Frame Words

Digital Word Number and Bit	LRV No.	Logical One	Logical Zero
WORD 2 (M.Frame=25, Word=99)			
Bit 1, PCU A	4264	On	Off
Bit 2, PCU B	4265	On	Off
Bit 3, Vertical PRD	4266	On	Off
Bit 4, Slant A PRD	4267	On	Off
Bit 5, Slant B PRD	4268	On	Off
Bit 6, Vertical HVC	4269	On	Off
Bit 7, Slant A HVC	4270	On	Off
Bit 8, Slant B HVC	4271	On	Off
WORD 3 (M.Frame=56, Word=99)			
Bit 1, Vert. Sensitivity	4272	Auto	Programmed
Bit 2, Slant A Sens.	4273	Auto	Programmed
Bit 3, Slant B Sens.	4274	Auto	Programmed
Bit 4, Vertical Med Sens. Override	4275	Off	On
Bit 5, Slant High Sens. Override	4276	Off	On
Bit 6, Vertical Low Sens. Override	4277	Off	On
Bit 7, Slant Med Sens. Override	4278	Off	On
Bit 8, Event Trigger	4279	None	Occurred
WORD 4 (M.Frame=57, Word=99)			
Bit 1, Formatter Selected	4256	B	A
Bit 2, Commanded Day Mode	4257	No	Yes
Bit 3, Commanded Night Mode	4258	No	Yes
Bit 4, Oscillator Selected	4259	A	B
Bit 5, Second TM Mode	4260	No	Yes
Bit 6, Vertical Only Mode	4261	No	Yes
Bit 7, Vertical Memory	4262	Cycled	No Cycled
Bit 8, Slant Memory	4263	Cycled	No Cycled
WORD 5 (M.Frame=88, Word=99)			
Bit 1, Vertical B^+ Buss	4280	On	Off
Bit 2, Slant A B^+ Buss	4281	On	Off
Bit 3, Slant B B^+ Buss	4282	On	Off
Bit 4, Unused			
Bit 5, Unused			
Bit 6, Unused			
Bit 7, Unused			
Bit 8, Unused			

WORD 1 (M.Frame = 24, Word = 99)

Bits 1 and 2, Vertical Low-to-Medium Sensitivity Switch Level.Level equals:

a) 4 for B1=0 and B2=0; or B1=1 and B2=0
b) 8 for B1=0 and B2=1
c) 16 for B1=1 and B2=1

Bits 3 and 4, Vertical Medium-to-Low Sensitivity Switch Level Level.Level equals:

a) 64 for B3=0 and B4=0, or B3=1 and B4=0
b) 128 for B3=0 and B4=1
c) 192 for B3=1 and B4=1

Bits 5 and 6, Slant Medium-to-High Sensitivity Switch Level.Level equals:

a) 4 for B5=0 and B6=0, or B5=1 and B6=0
b) 8 for B5=0 and B6=1
c) 16 for B5=1 and B6=1

Bits 7 and 8, Slant High-to-Medium Sensitivity Switch Level.Level equals:

a) 64 for B7=0 and B8=0, or B7=1 and B8=0
b) 128 for B7=0 and B8=1
c) 192 for B7=1 and B8=1

APPENDIX II (Continued)

TABLE V. Analog Major Frame Words

LMSC Analog Word No.	TM Location: Minor Frame No.	TM Location: Word In Minor Frame	Description
1.	40	99	HIGH VOLTAGE MONITOR, VERTICAL SYSTEM - Current being drawn by the supply (LRV 0245).
2.	41	99	HIGH VOLTAGE MONITOR SLANT A SYSTEM - Current being drawn by the supply (LRV 0246).
3.	39	99	HIGH VOLTAGE MONITOR SLANT B SYSTEM - Current being drawn by the supply (LRV 0247).
4.	104	99	+10V MONITOR - Voltage of the +10V buss (LRV 0248).
5.	106	99	-10V MONITOR - Voltage of the -10V buss (LRV 0256).
6.	105	99	+5V MONITOR - Voltage of the +5V buss (LRV 0249).
7.	7	99	FLOATING 12V MONITOR - Voltage of the floating 12V line (LRV 0250).
8.	8	99	+20V MONITOR - Voltage of the +20V buss (LRV 0251).
9.	116	97	PCU TEMP. SENSOR - Temperature of hottest point in the PCU (LRV 0252).
10.	117	97	DETECTOR ELECTRONICS TEMP. SENSOR - Temperature of the PRD case in the Slant A Detector Electronics Box(LRV 0253)
11.	118	97	PHA TEMP. SENSOR - Average Temperature of hottest spot on the two PHA electronics boards (LRV 0254).
12.	119	97	DIGITAL ELECTRONICS TEMP. SENSOR - Temperature near middle of the Digital Electronics Box (LRV 0255).

TABLE VI Serial (Prime) Minor Frame Words**

Word Location* and Bit	Logical One	Logical Zero
WORD 1: Sync of all "ones"	All bits always	None
WORD 2: Sync of all "ones"	"	"
WORD 3: Sync of all "ones"	"	"
WORD 4:		
Bit 1, Vert. Memory	No	Yes
Bit 2, Slant Memory Type	A	B
Bit 3, Day or Night	Day	Night
Bit 4, Normal TM Mode	Yes	No
Bit 5, Vert. Calib.	On	Off
Bit 6, Slant Calib.	On	Off
Bit 7, Fine Mode	No	Yes
Bit 8, Quadrant	First	Fourth
WORD 5: Elapsed Time	Decimal Number	
WORD 6: Sensitivity Status	16 bits define the sensitivity of the detector used for each of 16 spatial area segments "1" = higher sensitivity of the pair.	
WORD 7: Sensitivity Status		
WORDS 8-519: Memory Contents	Decimal Numbers	
WORDS 519-1': Zeros (1' is the beginning of a new readout, i.e. a sync of all "ones")		

* Word location 1 may be from any minor frame but must be Word 10 of that minor frame.

** This table is applicable to the Normal Data Mode. In the Alternate Data Mode (see Section 4.6) each minor frame serial word represents a photon event. Bits 5-8 (Bit 5 = MSB) identify the 16 pulse height channels described in Table II. Bits 1-3 define 8 spatial area segments with Bit 1 = MSB for these three bits. Bit 4 defines the detector being used with '1' = higher sensitivity and '0' = lower sensitivity.

APPENDIX II (Continued)

Serial Major Frame Word Definition

A. Normal Readout Mode

1. Word 1 (Word 99 of Minor Frame 72)

The first three bits (Bit 1 = MSB) have no meaning. The next five bits are combined with Word 2 to form a 13 bit binary number which defines the night sky target location in terms of SAE pulses away from the MIP. Bit 4 of Word 1 is the MSB. Bit 8 of Word 2 is the LSB.

2. Word 2 (Word 99 of Minor Frame 73)

Is combined with Word 1 as just described.

B. Alternate Data Mode

1. Word 1.

a. Bit 1 (MSB) ... Defines Calibration ... '1' = No, '0' = Yes.

b. Bit 2 .... Defines Fine Mode ..... '1' = No, '0' = Yes.

c. Bit 3 .... Defines Quadrant ...... '1' = Fourth, '0' = First.

d. Bits 4-8 ...... Combines with Word 2 in a manner analagous to that described for Normal Readout to form a 13 bit binary number. The number is no longer the night sky position, however, rather it is now the total number of photon events, exclusive of PRD's and overloads, processed by the PHA during the last major frame time period (excluding our read envelope time periods).

2. Word 2.

Combines with Word 1 as just described.

APPENDIX III

TURN ON SEQUENCE/OPERATIONAL VERIFICATION

Note: In describing this sequence, the Hughes generated last reported value (LRV) numbering scheme will be referred to for status monitoring.

1. Using S/C status (the specific LRV's will be selected by HAC) verify that all power busses are proper.

2. Verify all instrument temperatures are from 15°C to 30°C; where Power Converter Unit (PCU) = LRV 0252, Detector Electronics = LRV 0253, Pulse Height Analyzer (PHA) = LRV 0254, and Digital Electronics = LRV 0255.

3. Command the instrument to a minimum power state configured as definitively as possible via Discrete Commands (DC) No. 12, No. 1, No. 3, No. 4, No. 5. Verify voltage of +28V regulated buss via LRV 0006. Apply to instrument and verify via LRV 4434. If possible, verify proper current (~ 70 mA) via LRV 0039. Verify the states configured in paragraph 2.3 by observing the proper LRV's: High Voltages OFF (4269, 4270, 4271, 0245, 0246, 0247, 0251), PCU A ON and PCU B OFF (4264, 4265); B^+'s OFF (4280, 4281, 4282); PRD's OFF (4266, 4267, 4268); Low Voltage Busses are proper (0248, 0256, 0249, 0250). Note:that the 20V Monitor (LRV 0251) will not read 20V presently since no high voltages are on. Apply the Unregulated Voltage Buss to the instrument and verify via LRV 4431.

4. Turn ON Vertical B^+ and PRD via DC No. 6 and observe LRV 4266, 4280. Observed regulated 28V buss current increases to ~ 160 mA. Turn ON Slant A B^+ and PRD via DC No. 7 and observe LRV 4267, 4281. Observe the regulated

28V buss current increases to $\sim$ 250 mA. Turn ON Slant B B^+ and PRD via DC No. 8 and observe LRV 4268, 4282. Observe the regulated 28V buss current increase to $\approx$ 275 mA.

5. Put the instrument into a well defined operating state. Send DC No.17 to establish non-calibration orientations. Send DC No. 22, No. 24, No. 22, No. 23, No. 22 and observe that we are not in either a Commanded Day nor a Commanded Night Mode via LRV 4257 and 4258. Send DC No. 31 and observe that we are not in either the Alternate Data Mode nor the Vertical System Only Mode via LRV 4260 and 4261. Remove all Sensitivity Overrides via DC No. 37, and set all sensitivities to AUTO via DC No. 28, No. 29, No. 30. Observe proper configuration via LRV 4275, 4276, 4277, 4278, 4272, 4273 and 4274.

6. Observe which S/C Format Generator and Mode are in use via LRV 4000 and 4001. Issue Serial Magnitude Command (SMC) with all Bits = "1" except Bit 10 which is set to agree with the S/C Format Generator ("1" = B, "0" = A). Verify configuration by observing LRV 5011 (CTS = 16), 5012 (CTS = 16), 5013 (CTS = 192), 5014 (CTS = 192), 4259 (oscillator = A) and 4250 (Format selection agrees with S/C Format Generator).

7. Issue DC No. 40 to reset the Event Flag and observe LRV 4279.

8. Issue SMC No. 1 with decimal value 8191 and observe the corresponding Night Sky Position via LRV 2028.

9. Observe that the memories are cycling via LRV 4262 and 4263 being primarily "YES."

10. Observe the prime serial minor frame data to verify that all systems are cycling in a manner wherein:

(a) No system is in CAL.

(b) No system is in FINE MODE.

(c) DAY/NITE status agrees with the S/C status as defined by LRV 4372.

(d) Elapsed time values agree with the S/C Spin Rate as defined by LRV 3002 and 3003.

11. Initiate full functional testing.

10 copies 80%

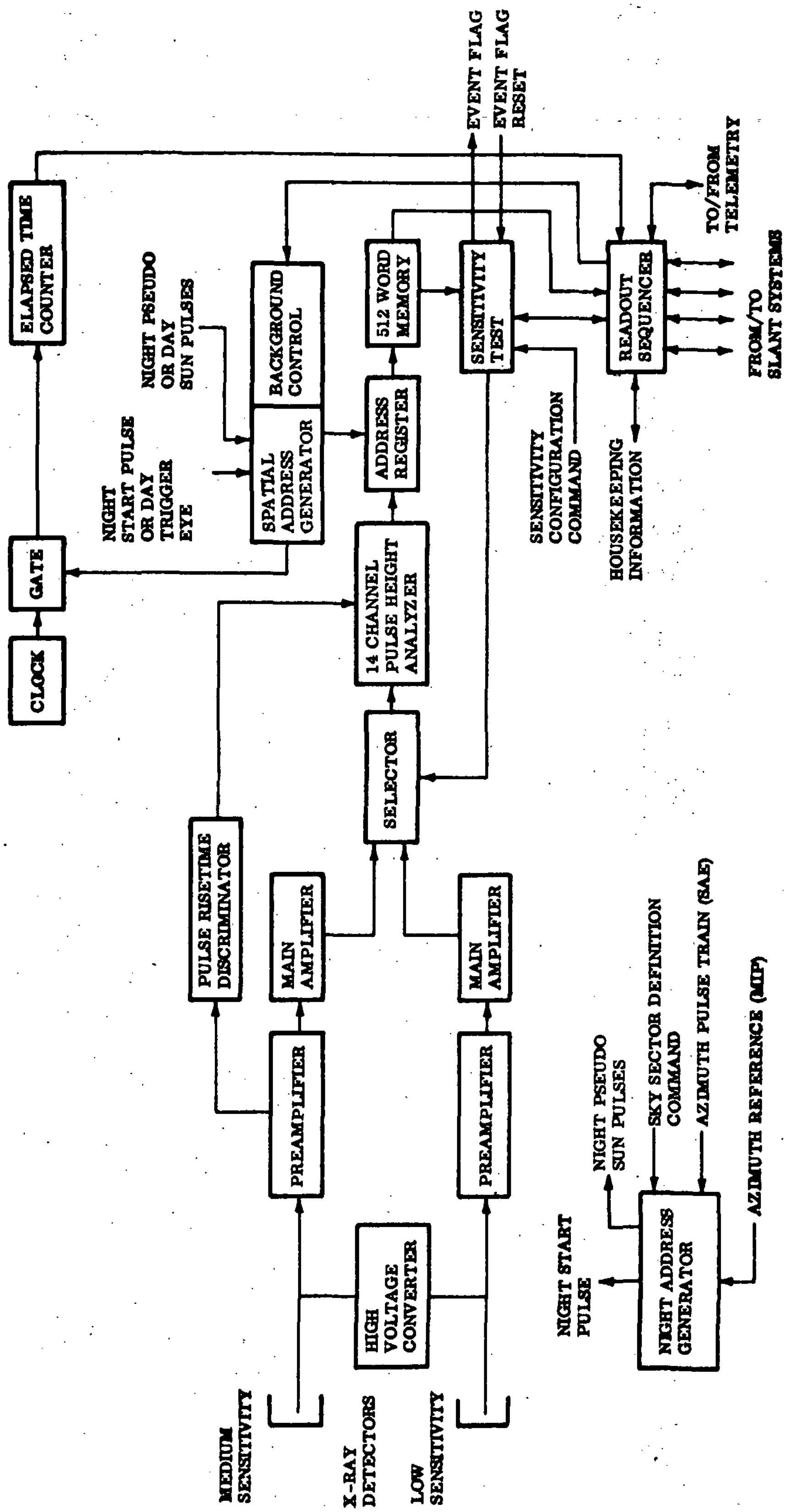
APPENDIX IV

USEFUL MXRH NUMBERS

Spin Rate (rpm)	5	6	7
Period (sec)	12	10	8.57
Time for one vertical system Fan Beam to cross a 42' target (msec)	23.4	19.4	16.7
Time for 27 vertical Fan Beams to cross the target area (sec)	.63	.52	.45
Time for one slant system Fan Beam to cross an 84' (azimuth) target (msec)	46.8	38.8	33.4
Time for 13 slant Fan Beams to cross the target area (sec)	.61	.51	.43
Time for one vertical Fan Beam to cross 1/32 of target area (msec)	.73	.61	.52
Time for 27 vertical Fan Beams to cross 1/32 of target area twice (msec)	39.4	33.0	28.0
Time for one slant Fan Beam to cross 1/32 of target area (msec)	1.46	1.22	1.04
Time for 13 slant Fan Beams to cross 1/32 of target area twice (msec)	38.0	31.8	27.0
Time available for TM readout (sec) (IF pitch = 0)*	11.2	9.4	8.0
Maximum TM words available (12 per minor frame) (pitch = 0)	840	705	600
Time available for TM readout (sec) (IF pitch = $\pm 4^{\circ}$)**	10.7	8.9	7.7
Maximum TM words available (pitch = $\pm 4^{\circ}$)	805	670	580
Anti-target background collection time (sec)	1.28	1.28	1.28
Time value of each elapsed time unit in coarse mode (sec)	.00025		
Time value of each elapsed time unit in fine mode (sec)	.0000625		

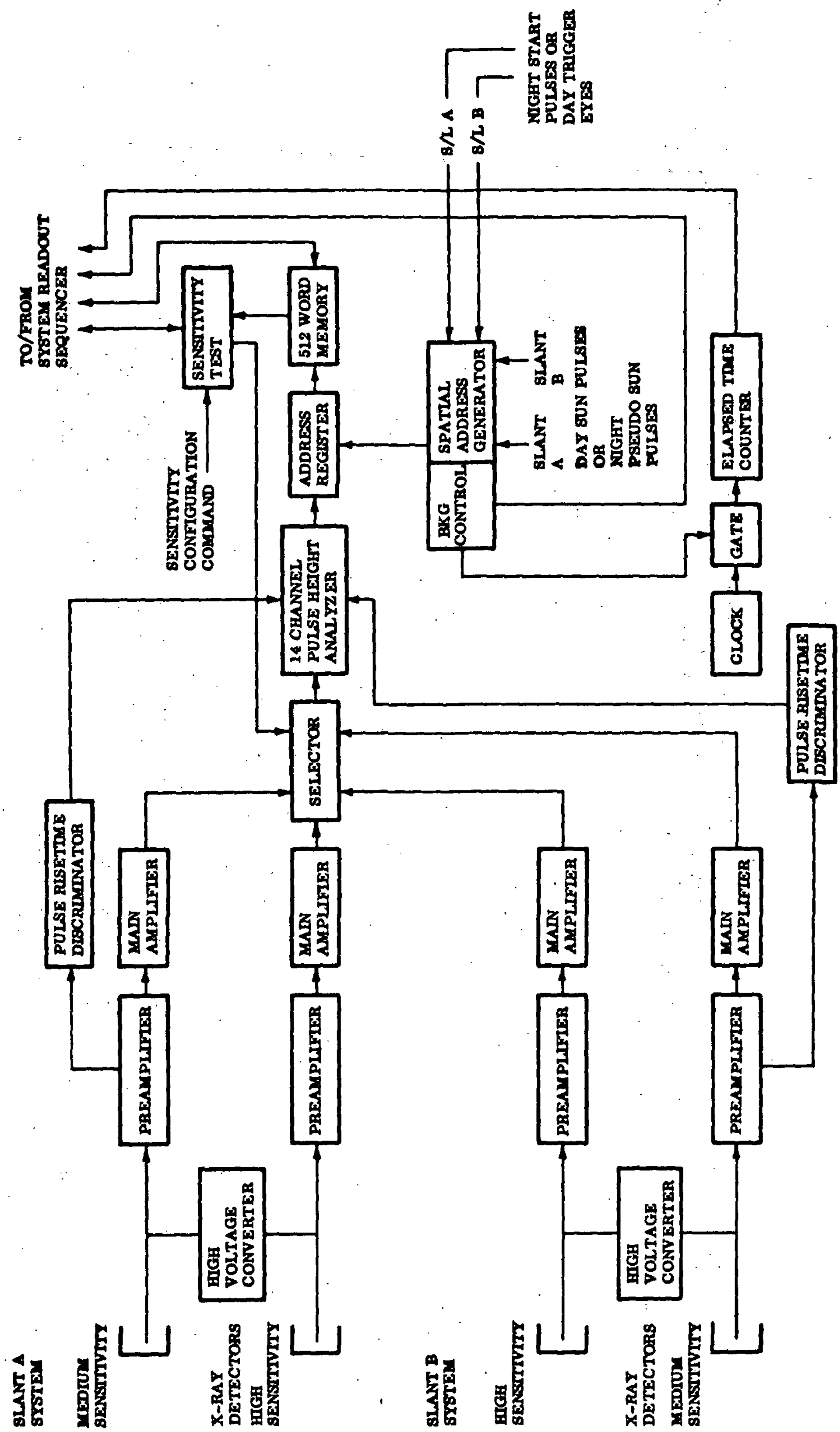
* Includes time required for trigger eye and initial two sun center findings to set up data taking sequence.

** Non zero pitch imposes a lead and a lag into the slant systems data taking and therefore an overall decrease in non-data taking time.



(a) VERTICAL SYSTEM ELECTRONICS

Figure 11(a)

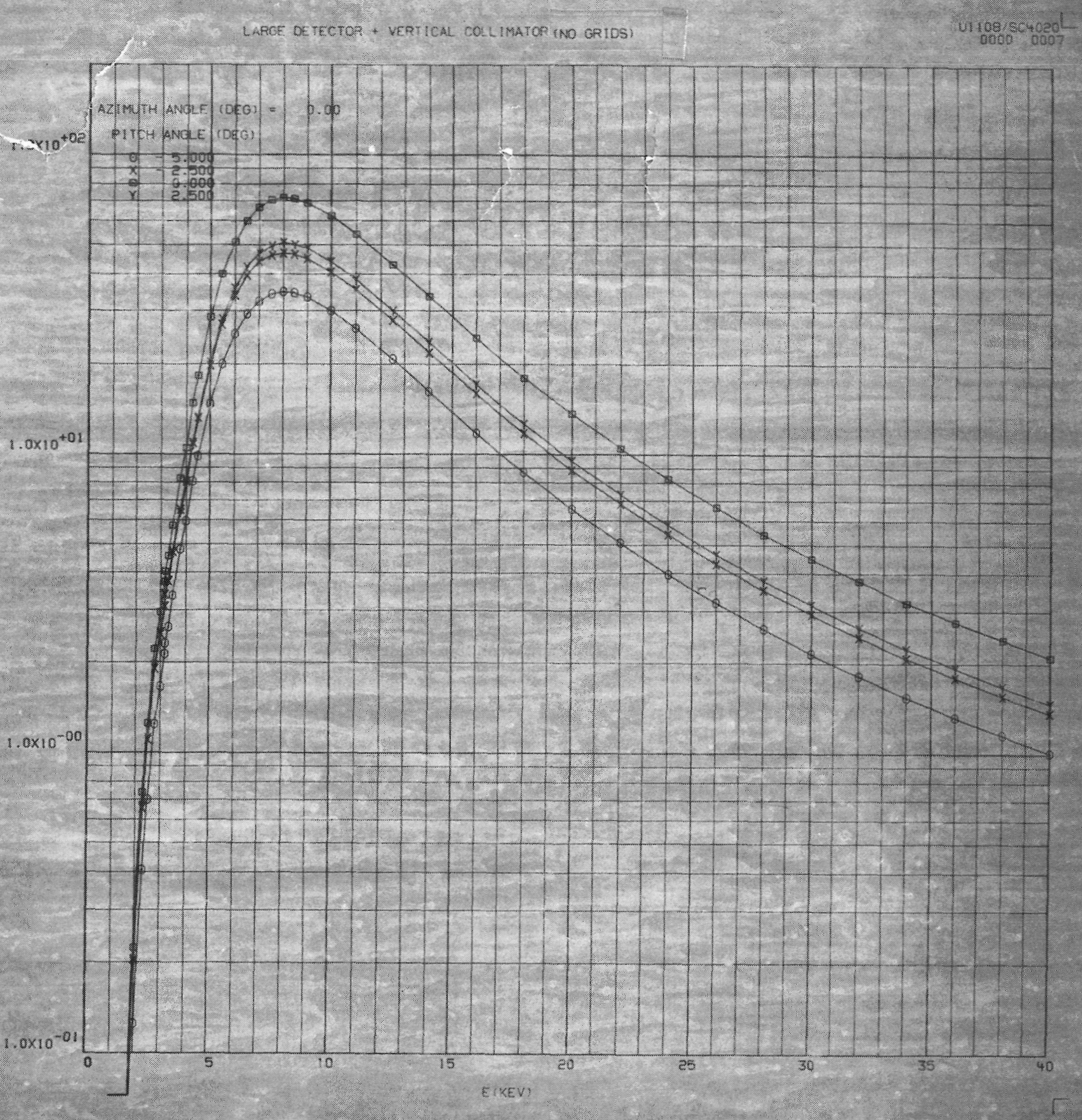


(b) SLANT SYSTEM ELECTRONICS

Figure 11 (b)

APPENDIX VI

This appendix contains some details of the flight detector responses which are needed by anyone who wishes to do quantitative work with the instrument. Figures 12a through 12f display effective areas vs. energy for several aspect angles. The geometrical shadowing of the collimator support structure is included but the transmission (40% for normal incidence) of the grid mesh has not been included. Table VI contains the measured PHA channel boundaries for the six flight detectors.



LARGE DETECTOR + VERTICAL COLLIMATOR (NO GRIDS)
U1108/SC4020
0000 0007
AZIMUTH ANGLE (DEG) = 0.00
PITCH ANGLE (DEG)
O 5.000
X 2.500
⊡ 0.000
Y 2.500
1.0X10^+01
1.0X10^-00
1.0X10^-01
0
5
10
15
20
25
30
35
40
E(KEV)
EFF. AREA CM**2

Figure 12 a

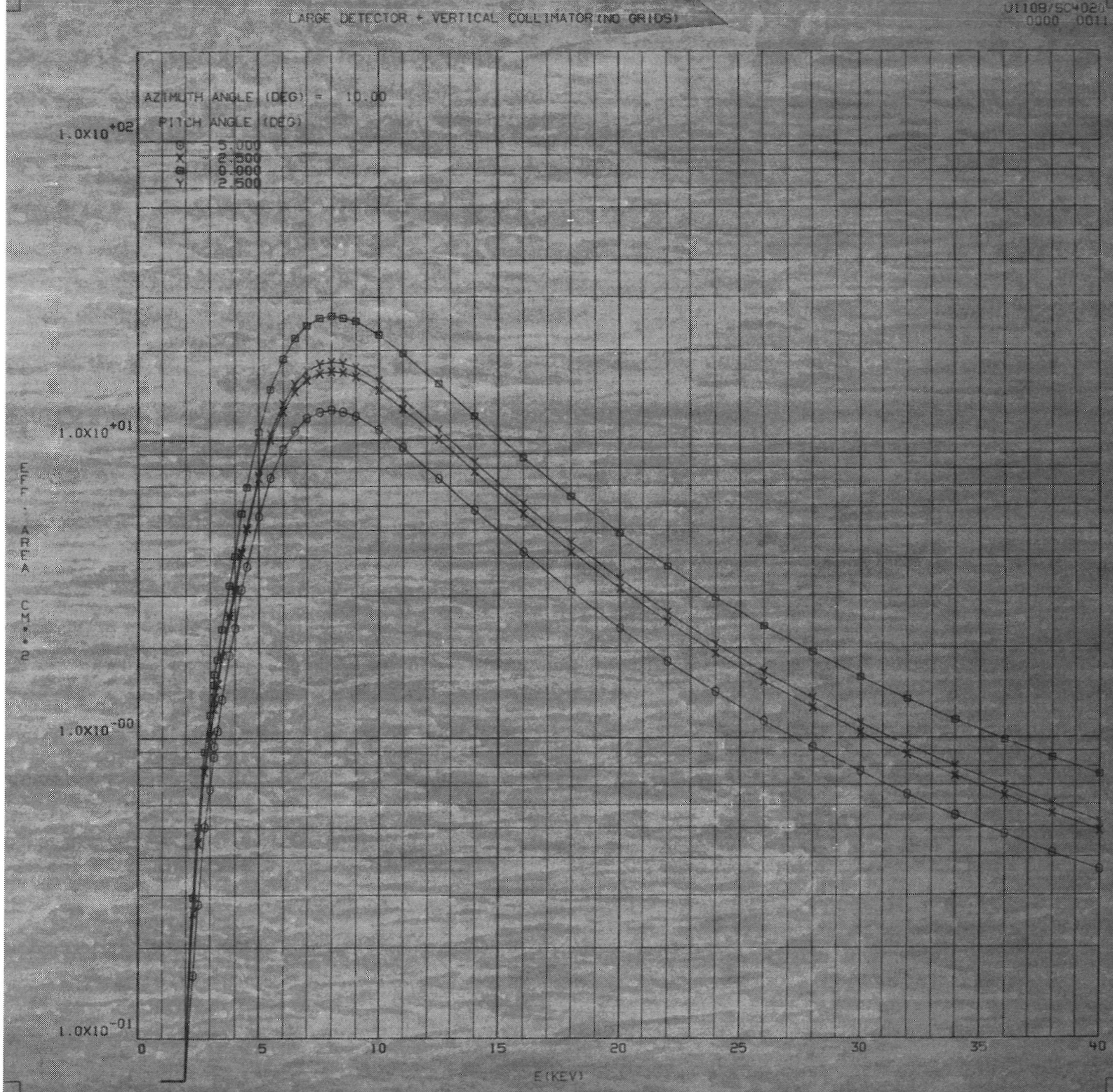

LARGE DETECTOR + VERTICAL COLLIMATOR(NO GRIDS)
UI108/SC4020
0000 0011
AZIMUTH ANGLE (DEG) = 10.00
PITCH ANGLE (DEG)
-5.000
-2.500
0.000
2.500
1.0X10+02
1.0X10+01
1.0X10-00
1.0X10-01
EFF. AREA CM**2
0
5
10
15
20
25
30
35
40
E(KEV)

Figure 12 b

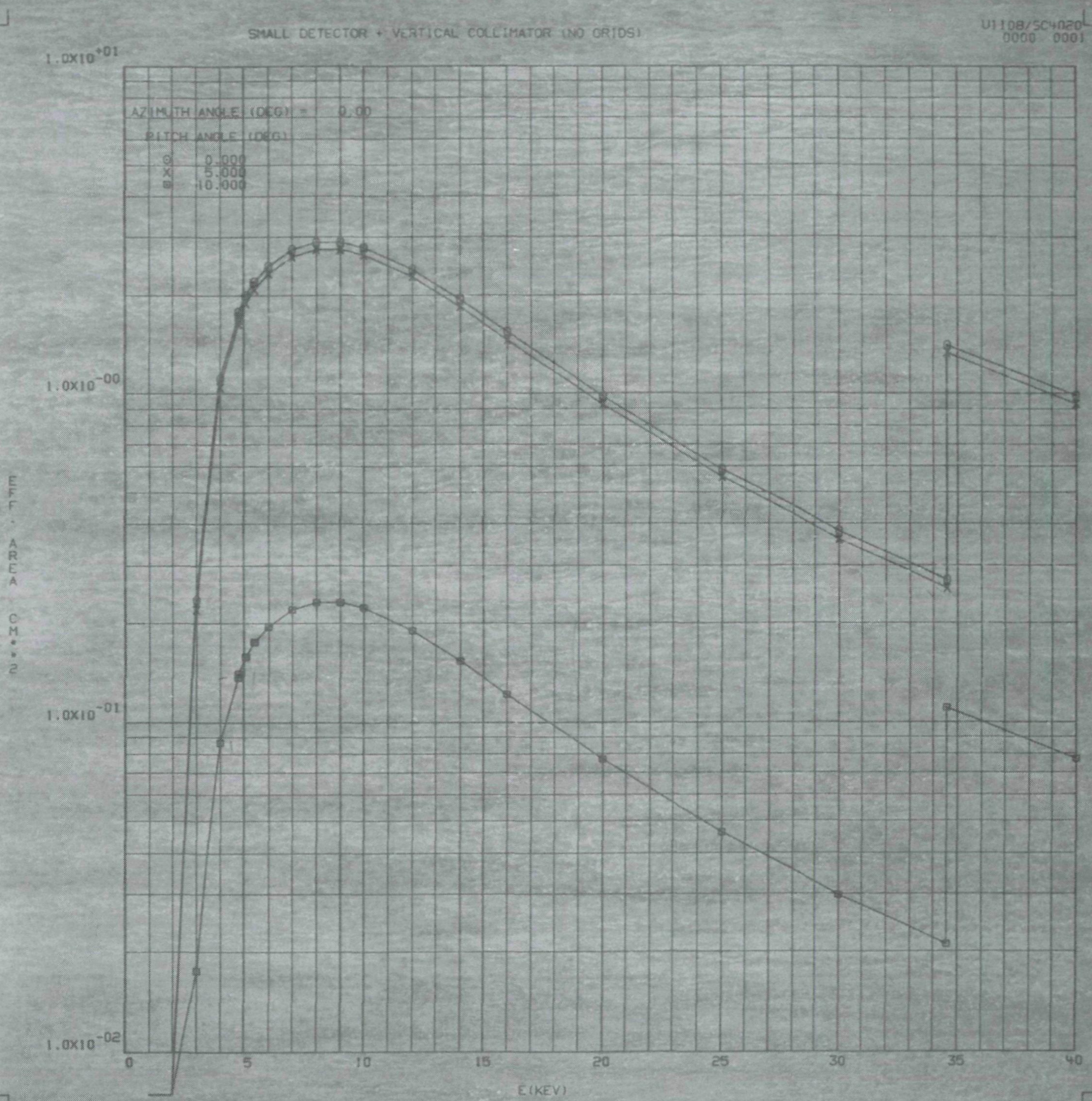

SMALL DETECTOR + VERTICAL COLLIMATOR (NO GRIDS)
U1108/SC4020
0000 0001
AZIMUTH ANGLE (DEG) = 0.00
PITCH ANGLE (DEG)
⊙ 0.000
X 5.000
⊞ 10.000
1.0X10+01
1.0X10-00
1.0X10-01
1.0X10-02
EFF. AREA CM**2
0
5
10
15
20
25
30
35
40
E(KEV)

Figure 12 c

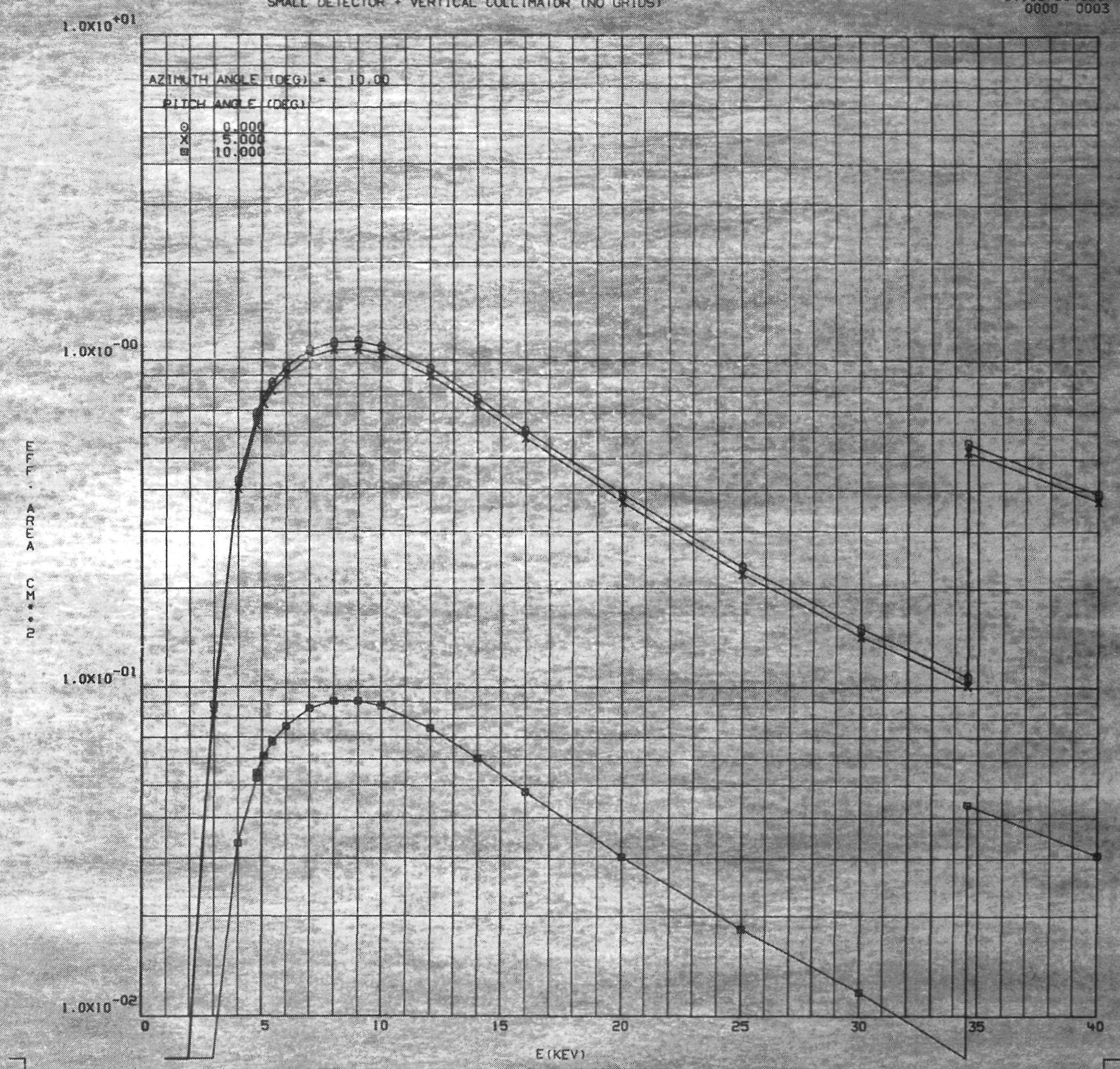
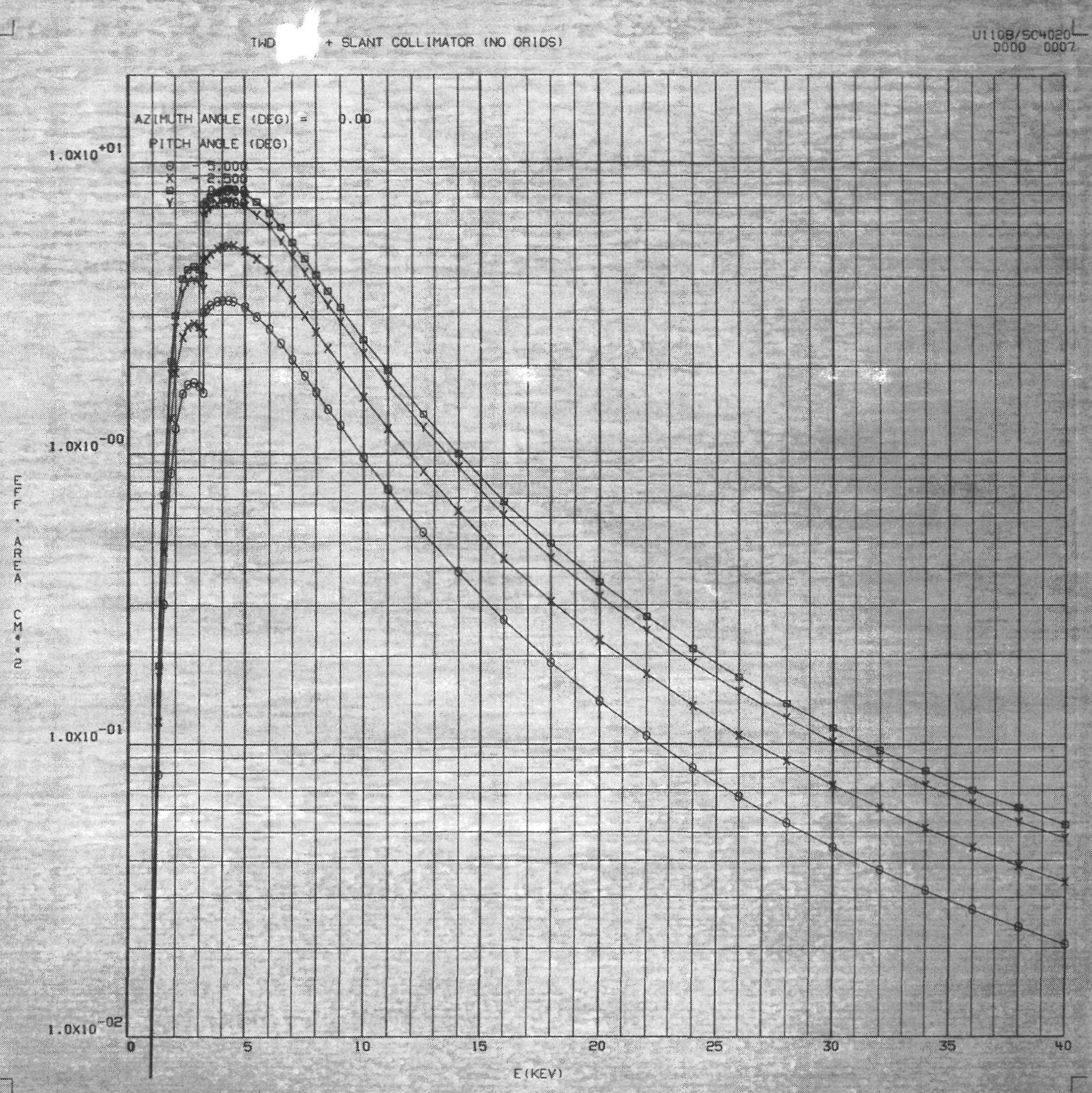

SMALL DETECTOR + VERTICAL COLLIMATOR (NO GRIDS)
U1108/SC4020
0000 0003
AZIMUTH ANGLE (DEG) = 10.00
PITCH ANGLE (DEG)
0.000
5.000
10.000
1.0X10^{+01}
1.0X10^{-00}
1.0X10^{-01}
1.0X10^{-02}
EFF. AREA CM**2
0
5
10
15
20
25
30
35
40
E(KEV)

Figure 12 d



TWD + SLANT COLLIMATOR (NO GRIDS)
U110B/SC4020
0000 0007
AZIMUTH ANGLE (DEG) = 0.00
PITCH ANGLE (DEG)
1.0X10+01
1.0X10-00
1.0X10-01
1.0X10-02
EFF. AREA CM**2
0
5
10
15
20
25
30
35
40
E(KEV)

Figure 12 e

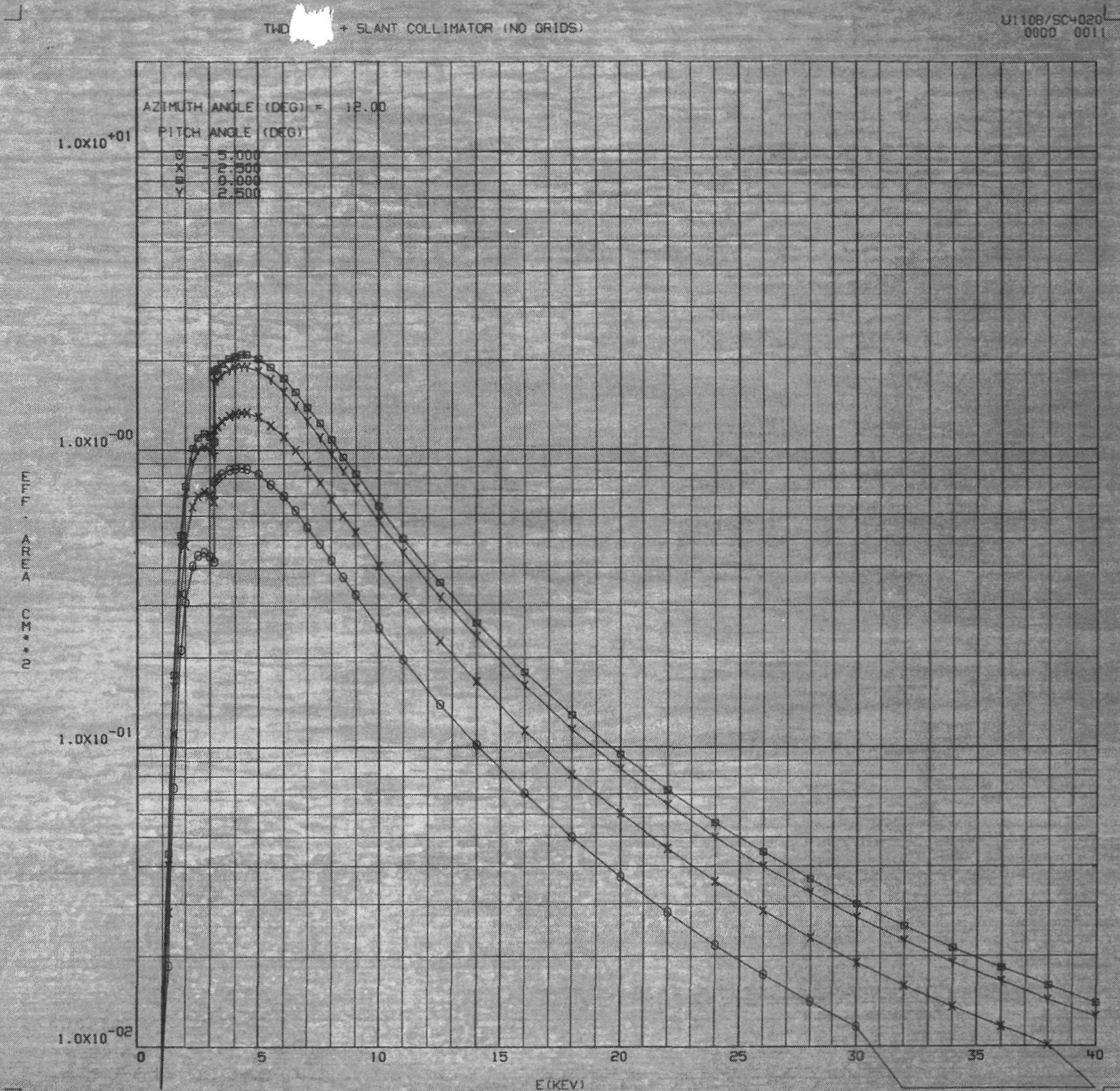

TWD + SLANT COLLIMATOR (NO GRIDS)
U1108/SC4020
0000 0011
AZIMUTH ANGLE (DEG) = 12.00
PITCH ANGLE (DEG)
O -5.000
X -2.500
⊡ 0.000
Y 2.500
1.0X10+01
1.0X10-00
1.0X10-01
1.0X10-02
EFF. AREA CM**2
0
5
10
15
20
25
30
35
40
E(KEV)

Figure 12 f

TABLE VI

PHA Channel Boundaries For
The Flight Detectors(keV)

OSO Ch.	V_{Lg}	SA_{Lg}	SB_{Lg}	V_{SF}	SA_{TWD}	SB_{TWD}
1	PRD	PRD	PRD	N/A	N/A	N/A
2	1.5 - 2.0	1.6 - 2.3	1.5 - 2.1	1.5 - 2.1	.7 - 1.0	.8 - 1.1
3	2.0 - 2.6	2.3 - 2.9	2.1 - 2.6	2.1 - 2.7	1.0 - 1.2	1.1 - 1.4
4	2.6 - 3.2	2.9 - 3.5	2.6 - 3.2	2.7 - 3.2	1.2 - 1.5	1.4 - 1.8
5	3.2 - 3.7	3.5 - 4.1	3.2 - 3.8	3.2 - 3.8	1.5 - 1.8	1.8 - 2.1
6	3.7 - 4.3	4.1 - 4.8	3.8 - 4.3	3.8 - 4.4	1.8 - 2.0	2.1 - 2.4
7	4.3 - 4.8	4.8 - 5.4	4.3 - 4.9	4.4 - 4.9	2.0 - 2.3	2.4 - 2.7
8	4.8 - 5.9	5.4 - 6.6	4.9 - 6.0	4.9 - 6.1	2.3 - 2.8	2.7 - 3.3
9	5.9 - 6.5	6.6 - 7.2	6.0 - 6.6	6.1 - 6.7	2.8 - 3.1	3.3 - 3.6
10	6.5 - 7.1	7.2 - 7.9	6.6 - 7.2	6.7 - 7.2	3.1 - 3.4	3.6 - 3.9
11	7.1 - 7.6	7.9 - 8.5	7.2 - 7.7	7.2 - 7.8	3.4 - 3.6	3.9 - 4.3
12	7.6 - 8.2	8.5 - 9.1	7.7 - 8.3	7.8 - 8.4	3.6 - 3.9	4.3 - 4.6
13	8.2 - 8.7	9.1 - 9.7	8.3 - 8.9	8.4 - 8.9	3.9 - 4.2	4.6 - 4.9
14	8.7 -10.9	9.7 -12.2	8.9 -11.1	8.9 -11.2	4.2 - 5.2	4.9 - 6.1
15	10.9 -15.4	12.2 -17.2	11.1 -15.7	11.2 -15.8	5.2 - 7.4	6.1 - 8.6
16	> 15.4	> 17.2	> 15.7	> 15.8	> 7.4	> 8.6

APPENDIX VII

Abbreviations Used in Text

ADC	Analog to digital converter
AGP	Analog gate pair
BKG	Background
CTS	Counts
DAC	Digital to analog converter
DC	Discrete commands
FET	Field effect transistor
FLT	Floating
FWHM	Full width at half maximum
HAC	Hughes Aircraft Corporation
HV	High voltage
HVC	High voltage converter
I/O	Input or output
LED	Light emitting diode
LMSC	Lockheed Missiles and Space Company, Inc. Space Astronomy Group of the Radiation Physics Laboratory C.J. Wolfson, Research Scientist- (415) 493-4411, Ext. 45718
LRV	Last reported value
MIP	Master index pulse
MSB	Most significant bit
PDU	Power distribution unit
PCU	Power conversion unit
PCM	Power converter module
MXRH	Mapping X-Ray Heliometer
PHA	Pulse height analyzer
PRD	Pulse Risetime Discriminator
RD	Remote decoder
S/C	Spacecraft
V	Vertical
TTL	Transistor transistor logic
TM	Telemetry

APPENDIX VII

Abbreviations (Cont'd)

SYNC	Syncronization
SM or SMC	Serial magnitude commands
SB	Slant B
SAE	Shaft angle encoder
SA	Slant A

APPENDIX VIII

List of Figures

APPENDIX IX

List of Tables