NASA TECHNICAL MEMORANDUM

NASA TM X-73396

(NASA-TM-X-73396) HEAO-A OBSERVATORY DESCRIPTION (NASA) 41 p HC A03/MF A01 CSCL 22A

N77-25207

Unclas

G3/12 30430

HEAO-A OBSERVATORY DESCRIPTION

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HEAO Office

April 1977

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

MSFC - Form 3190 (Rev June 1971)

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. NASA TM X-73396	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE HEAO-A Observatory Description		5. REPORT DATE April 1977
		6. PERFORMING ORGANIZATION CODE HA01
7. AUTHOR(S) Carroll Dailey and Thomas A. Parnell		8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812		10. WORK UNIT NO.
		11. CONTRACT OR GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D.C. 20547		13. TYPE OF REPORT & PERIOD COVERED Technical Memorandum
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Prepared by HEAO Office, Space Science Projects Office

16. ABSTRACT

This report presents an abbreviated description of the High Energy Astronomy Observatory (HEAO-A) Program, including spacecraft subsystems, scientific instrumentation, and the mission operations concept. Also, scientific participants such as Principal Investigators and Co-investigators are presented. This report is prepared as an aid to HEAO Guest Observers. Most of the material relating to the scientific instruments has been supplied by the investigators.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
	Unclassified — Unlimited

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	40	NTIS

MSFC - Form 3292 (Rev December 1972)

For sale by National Technical Information Service, Springfield, Virginia 22151

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INTRODUCTION

The purpose of this report is to provide an abbreviated description of the High Energy Astronomy Observatory (HEAO-A) Program, including its missions, observatories, and instrumentation. This information is intended as a guide to those planning to respond with proposals for investigations under the HEAO-A Guest Observer Program; however, it is not expected that this information will be sufficient to prepare a detailed proposal. Contacts with individual HEAO-A principal investigators or other key HEAO Program personnel (presented in the Appendix) will normally be required to discuss specific details and arrangements for desired investigations.

The HEAO Program consists of three observatories carrying experiments in X-ray and gamma ray astronomy and cosmic ray research. The HEAO Program is under the cognizance of the Office of Space Science at NASA Headquarters, and the project management is being carried out by Marshall Space Flight Center in Huntsville, Alabama. The HEAO observatories and experiment integration is being performed by TRW Systems, Inc., of Redondo Beach, California, and the experiments are being developed by the institutions of the scientific investigators. An abbreviated summary of the characteristics of the observatories is shown in Table 1.

HEAO-A is an observatory carrying four experiments covering the disciplines of X-ray and gamma ray astronomy, with the mission of scanning the complete celestial sphere while covering the energy range of 150 eV to 10 MeV with high sensitivity. The combined objectives of the four experiments include discovering new sources, studying temporal variations, providing precise source locations, measuring energy spectra, searching for transient events, and studying the diffuse component of the flux. The scientific participation on HEAO-A is presented in Table 2, and the individual experiments and their objectives are covered in a subsequent section.

TABLE 1. HEAO OBSERVATORY CHARACTERISTICS

	HEAO-A Large Area X-Ray and Gamma Ray	HEAO-B Focusing X-Ray Telescope	HEAO-C Large Area Cosmic Ray and High Resolution Gamma Ray
Normal Operational Mode	Scan	Pointing	Scan
Observatory Spin Rate (±10 percent)	0.03	—	0.03
Spin Axis Directional Accuracy, degrees	±1.0	—	±1.0
Pointing Accuracy, arc min	±60 - 90	±1.0	—
Approximate Target Pointing Frequency	5/week (after first 3 months)	1/orbit (avg)	—
Data Rate, kbs	6.4	6.4	6.4
Housekeeping	1.0	1.0	1.0
Experiments	5.4[a]	5.4	5.4
Tape Recorder Capacity, min	220	220	220
Orbital Inclination	22.75	22.75	44.9
Attitude Determination Accuracy, arc min	±6.0	±1.0	±6.0
Mission Duration, months	6	12	6
Launch Date	June 1977	June 1978	July 1979

a. A-1 special high data rate mode — 128 kbs.

TABLE 2. HEAO-A SCIENTIFIC PARTICIPATION

A-1 — Large Area X-Ray Survey Experiment	
Principal Investigator	
Dr. Herbert Friedman	Naval Research Laboratory (NRL)
Co-investigators	
Dr. Talbot A. Chubb	NRL
Mr. Edward T. Byram	NRL
Dr. Gilbert G. Fritz	NRL
Dr. John F. Meekins	NRL
Dr. James Kurfess	NRL
Dr. Gary Yentis	NRL
Dr. Seth Shulman	NRL
Dr. William Evans	NRL
Dr. William Johnson	NRL
Dr. Jerry Share	NRL
Dr. Robert Kinzer	NRL
Dr. Kent Wood	NRL
Dr. Richard Henry	NASA Headquarters
A-2 — Cosmic X-Ray Experiment	
Principal Investigators	
Dr. Elihu A. Boldt	Goddard Space Flight Center (GSFC)
Dr. Gordon P. Garmire	California Institute of Technology (CIT)
Co-investigators	
Dr. P. C. Agrawal	CIT
Dr. Geunter Riegler	CIT
Dr. C. Stuart Bowyer	University of California, Berkeley (UCB)

TABLE 2. (Continued)

Dr. Ray Cruddace	UCB
Dr. Michael L. Lampton	UCB
Dr. J. I. Silk	UCB
Dr. Stephen S. Holt	GSFC
Dr. Peter J. Serlemitsos	GSFC
Dr. Richard Rothschild	GSFC
A-3 — Scanning Modulation Collimator	
Principal Investigators	
Dr. Herbert Gursky	Smithsonian Astrophysical Observatory (SAO)
Dr. Hale Bradt	Massachusetts Institute of Technology (MIT)
Co-investigators	
Dr. George W. Clark	MIT
Dr. Roger Doxsey	MIT
Dr. Walter H. G. Lewin	MIT
Dr. Sol Rappaport	MIT
Dr. Gianfranco Spada	Labortoria Astrofisica Spaziale, Franscati, Italy
Dr. Riccardo Giacconi	SAO
Dr. Paul Gorenstien	SAO
Dr. Edwin M. Kellogg	SAO
Dr. Harvey Tananbaum	SAO
Dr. Daniel A. Schwartz	SAO

TABLE 2. (Concluded)

A-4 — Hard X-Ray and Low Energy Gamma Ray Experiment	
Principal Investigators	
Dr. Laurence E. Peterson	University of California, San Diego (UCSD)
Dr. Walter H. G. Lewin	MIT
Co-investigators	
Dr. R. M. Pelling	UCSD
Dr. J. L. Matteson	UCSD
Dr. Hale Bradt	MIT
Dr. George W. Clark	MIT
Dr. Sol Rappaport	MIT

In addition to the scanning objective, HEAO-A will be operated periodically in a pointed mode after the first 3 months of scanning. It is anticipated that approximately five pointings per week will be carried out. The actual frequency of pointing and the extent of any maneuvers of the Z axis away from the observatory Sun line will be based on the results of in-orbit operation.

HEAO-A DESCRIPTION

The observatory consists of a spacecraft equipment module (SEM) and an experiment module (EM). The SEM carries most of the spacecraft operational equipment including the attitude control and determination system (ACDS); the hydrazene-fueled reaction control system (RCS); the tape recorders and other components of the command and data management system (CDMS); the batteries, regulators, and other components of the electrical distribution system (EDS). The star trackers of the CDMS are mounted on Experiment A-3, which requires the most accurate attitude determination of all HEAO-A experiments. SEM is a common structural element for all three HEAO's, although the equipment in it varies somewhat for each mission.

The experiment module structure varies considerably for each observatory. In addition to the experiments, the EM carries some elements of the electrical distribution system such as the solar panels and part of the CDMS. Of the latter, the experiment accommodation assemblies (EAA's) are standardized units through which the experiments deliver data and receive commands.

The HEAO-A is shown schematically in Figure 1 with the location of the four experiments indicated. Experiments A-2, A-3, A-4, and one module of A-1 are coaligned in the +Y direction, while the remainder of the A-1 experiment field of view is in the -Y direction.

In the normal scanning mode, the observatory rotates at 0.03 rpm about the Z axis with +Z axis pointing toward the Sun. During "off-set scan" operations and pointing operations, the +Z axis may be varied up to 7° from the Sun line, while maintaining normal electrical power from the solar panels and normal observatory temperatures.

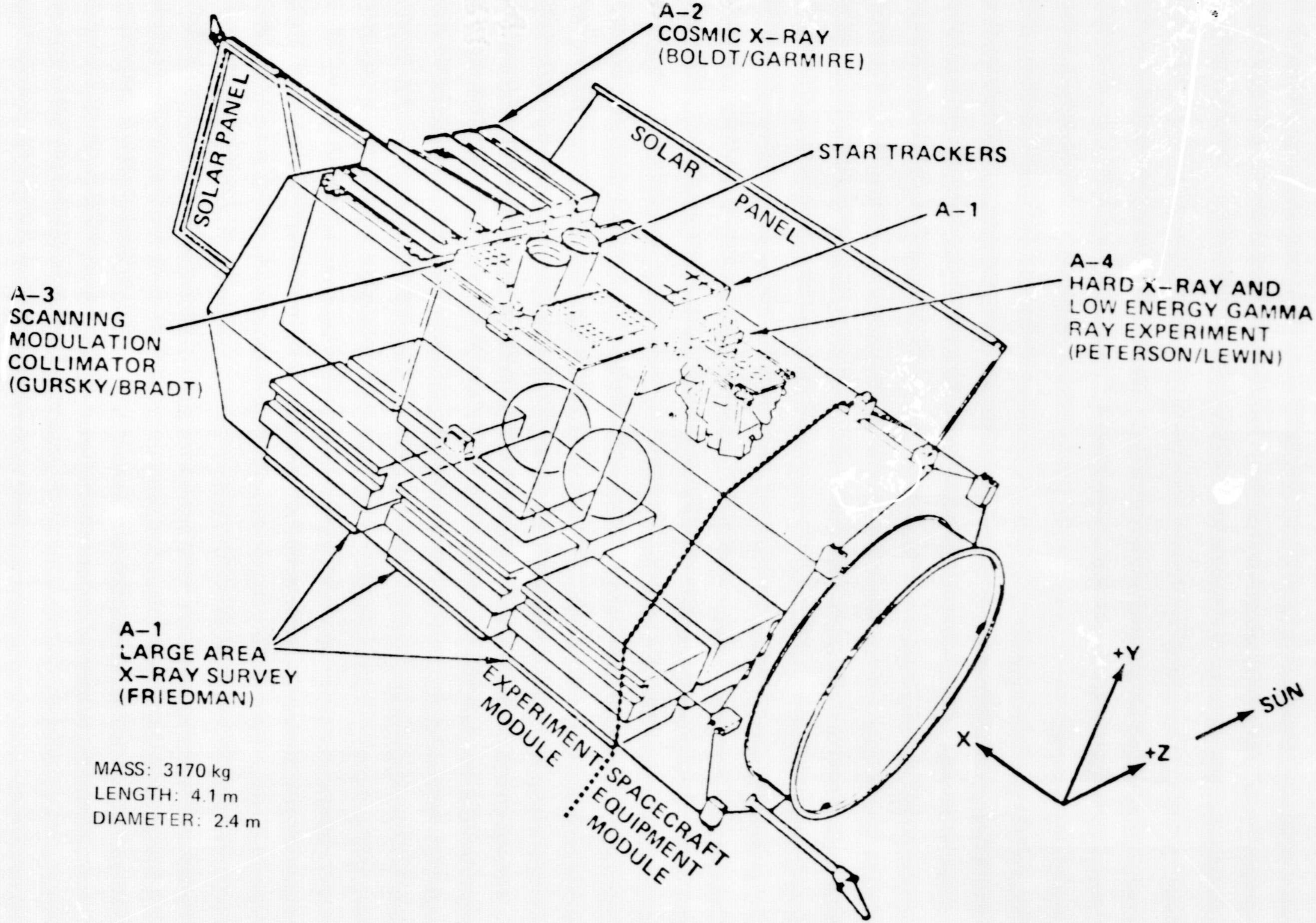


Figure 1. HEAO-A.

In the scanning mode, the viewing axis of the experiments scans a great circle in the sky. The length of time each experiment remains on a discrete source and the number of successive scans of the same source depend upon the field of view of the individual experiment and to a lesser extent on the stability of the spin rate and spin axis. The schedule of observations is governed by such factors as Earth occultation and by instrument cutoff in the South Atlantic Anomaly region of the inner Van Allen Belt.

In the offset scan mode, the observatory continues to rotate at the standard 0.03 rpm, but the spin axis is varied up to 7° from the Sun line. This mode would allow a longer observation of particular objects or regions, but would also somewhat affect the sensitivity of the all-sky survey.

After the first 3 months of scan operation, the observatory will perform up to five pointing operations per week. These pointings will initially be limited to directions that will keep the +Z axis within 7° of the Sun and will be limited in duration.

Although the approved mission is for 6 months orbital operation, observatory consumables are sized for approximately 1 year.

A-1 LARGE AREA X-RAY ARRAY

The NRL A-1 instrument for HEAO-A is a modular assembly of thin window proportional counters which are designed to provide position coordinates and characterization of cosmic X-ray sources (Fig. 2). The instrument consists of seven large area X-ray sensor modules designed to record incident X-ray fluxes, a central electronics module to process data received from the seven sensor modules, a stellar aspect assembly (plus back-up unit) to provide checks and refinements on the spacecraft attitude solution, and a central gas system module used to provide replacement gas to the individual proportional counter sensing elements. A system block diagram is shown in Figure 3.

The A-1 scientific objectives are:

1. To perform all-sky map of discrete X-ray sources in energy range 0.15 to 20 keV

2. To achieve a sensitivity better than 5×10^{-4} Crab Nebula

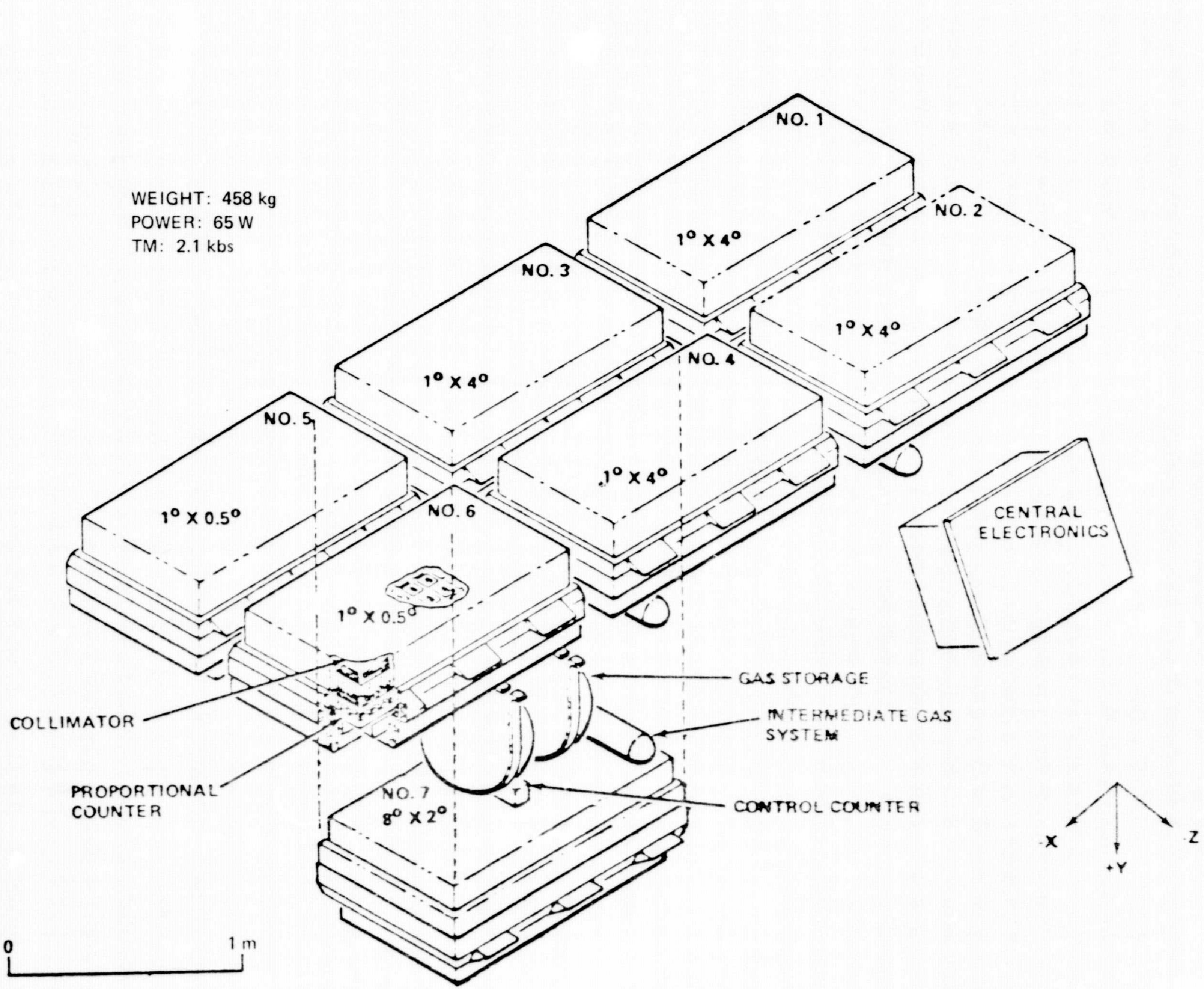


Figure 2. HEAO A-1 Experiment — Large Area X-Ray Survey.

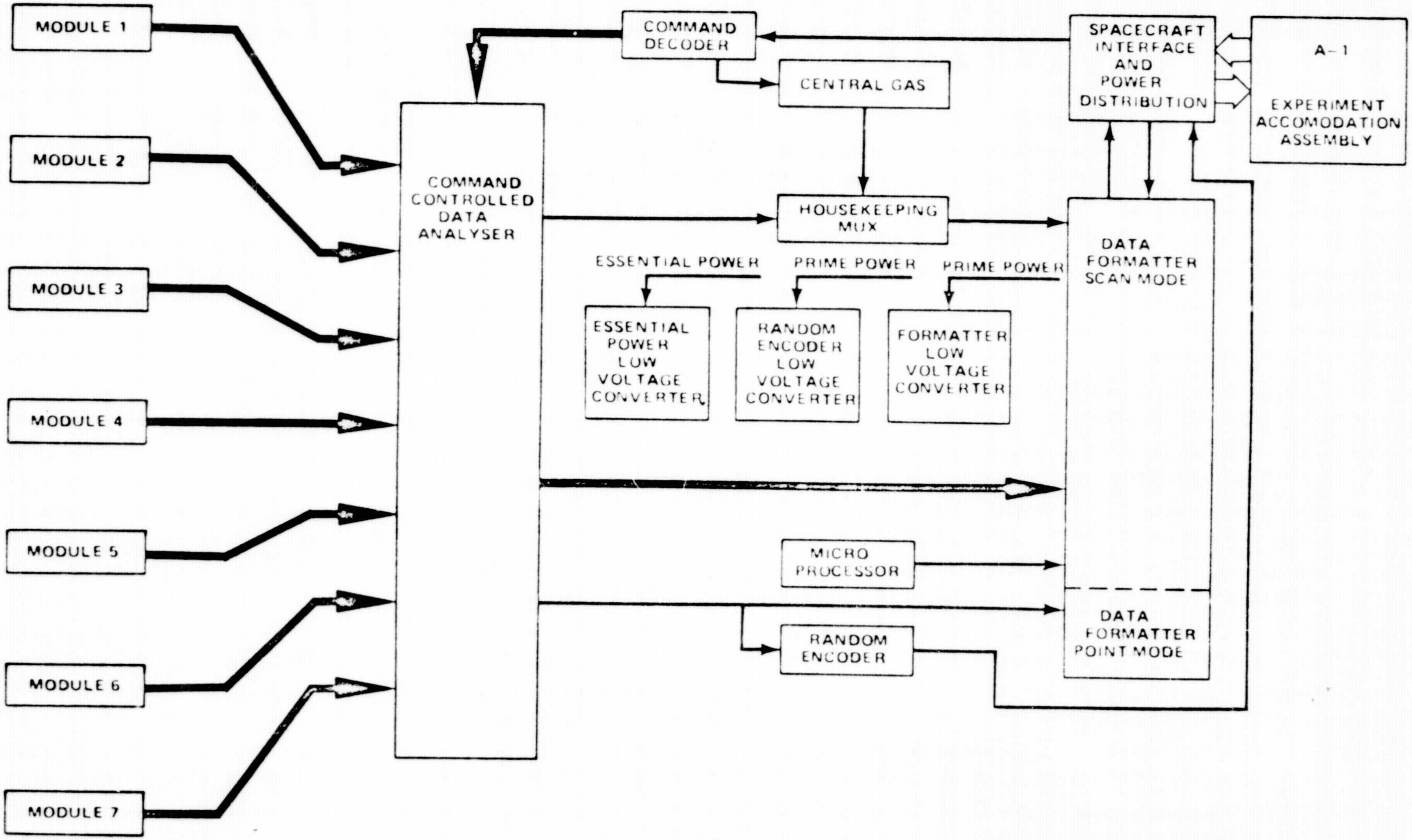


Figure 3. System block diagram.

3. To measure spectra, source locations, and time variations

4. To study extended sources in 0.1° to 1° angular range

5. To study pulsar profiles in the fast timing mode.

The following is a summary of the A-1 instrument features:

1. Seven large area collimated proportional counters

2. All flow counters with 2.0 psia xenon/methane

3. Each counter has three layers of anode wires

4. Bottom two layers primarily for anticoincidence

5. Fields of view

   a. Four counters 1° × 4° (Modules 1 to 4) (1° in scan plane)

   b. Two counters 1° × 0.5° (Modules 5 and 6) (1° in scan plane)

   c. One counter 8° × 2° (Module 7).

6. Magnetic brooms mounted within collimators

7. Two data rates:

   a. 2.1 kbs to the observatory tape recorder in the manual mode

   b. 128 kbs real time direct to the ground station for special high time resolution studies (up to 4 μsec).

8. Energy resolution — approximately 16 percent at 5.9 keV.

Each X-ray sensor module consists of a single proportional counter body frame 24-1/4 × 36-1/4 × 6 in. on which is mounted a window support structure, counter back structure with integral control counter, collimator assembly, and electronic subassemblies. The basic layer of wires is independently metered. Over most of the energy range, the front layer serves as the X-ray sensor, and the back layers provide anticoincidence protection against charged particle events. At higher energies, sensitivity is provided by the top two layers. Anticoincidence protection is also provided on ends and sides by wires strung on 1 in. centers. Ground planes are provided to separate wires where good counter geometry is needed. The counter frame is made from welded aluminum extrusions of special cross-section. The counter gas views space through a gas barrier of $3\,\mu$ mylar M film. Electrical conductivity on the inward surface is provided by a film of vacuum deposited Nichrome approximately 60 Å thick. The gas barrier window is held in place by a photoengraved sheet of stainless steel which, in turn, is supported against the gas pressure within the counter by a stainless steel honeycomb of rectangular cell construction. This honeycomb provides X-ray collimation of $8° \times 4°$ full width half maximum (FWHM).

Each basic counter views space through a collimator made of photoengraved stainless steel plates spaced in register in a collimator frame. The frame plus collimator plates is called the collimator. It is assembled and checked for register before mounting on the front of the counter. The outermost etched plates of each collimator are stacked against each other. The assembly views space through a heat shield made up of a polycarbonate overcoated with 1000 Å of Al and sandwiched between wire grids. This heat shield is the $2\,\mu$ thick exterior surface to the collimator assembly.

The counter back structure provides a gas barrier on the back surface of the counter frame and also contains integrally a small auxiliary proportional counter which shares counting gas with the main counter. This small counter is operated as a control counter. It is excited by an integrally mounted radioactive source containing Fe^{55}. It serves as an electronic component in a feedback loop used to maintain proper operating voltage on the main counter despite density changes in the counter gas or drifts in the high voltage circuitry.

Each X-ray sensor module also includes movable radioactive calibration sources to provide a check on counter operation and channel position, and a magnet assembly to deflect and trap incident low energy radiation belt electrons.

A-2 COSMIC X-RAY BACKGROUND EXPERIMENT

The HEAO A-2 experiment (Fig. 4) is designed to study the diffuse X-ray sky over the band 0.15 to 60 keV. As such, many precautions have been taken to reduce extraneous background, and some novel features have been incorporated

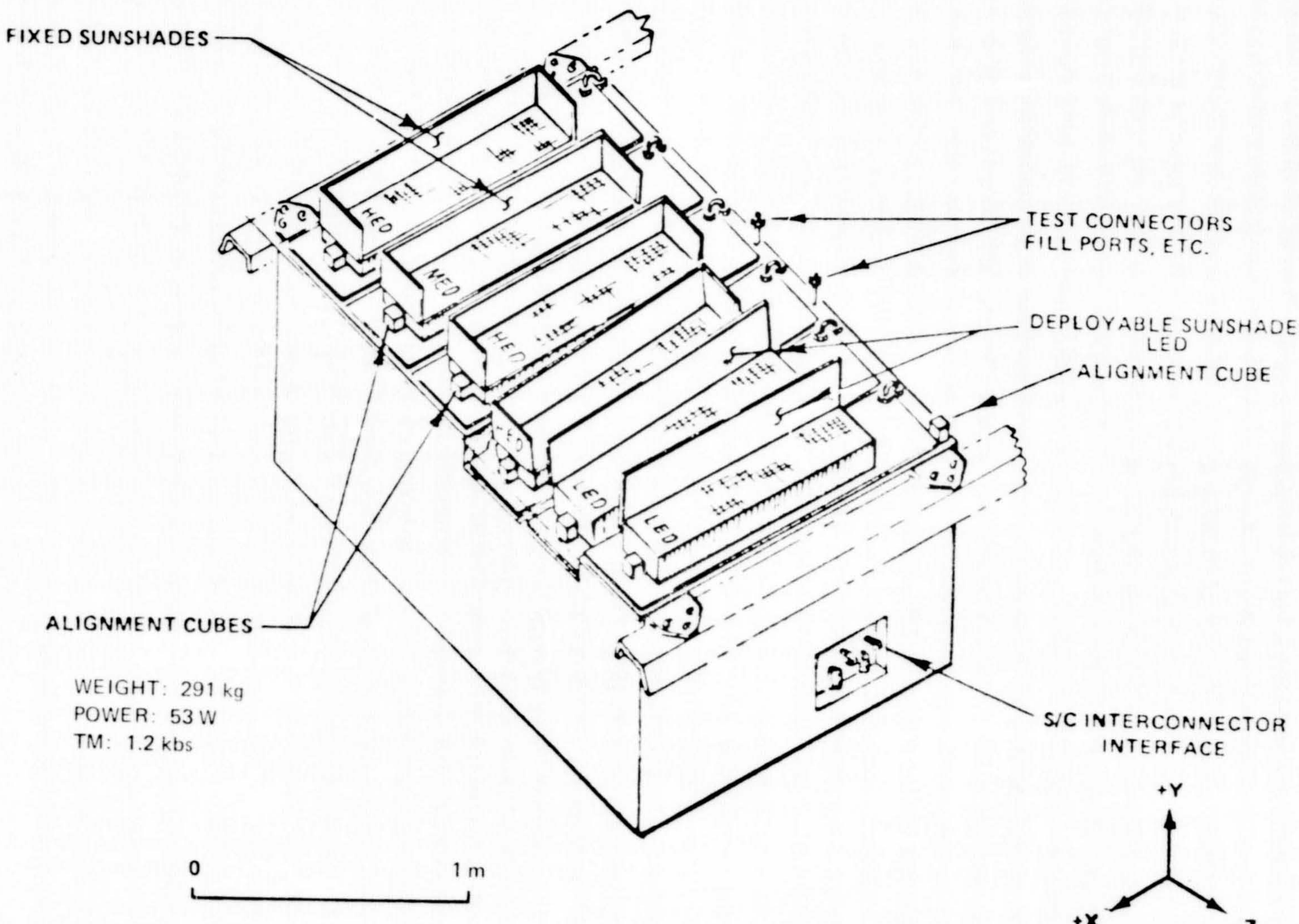


Figure 4. HEAO A-2 Experiment – Cosmic X-Ray.

which permit the unambiguous extraction of sky surface brightness from the total signal (Table 3). In the process, the experiment is also well suited for the examination of discrete sources over an important energy band, and the on-board data system was configured for exploiting this capability. The broad objectives of the experiment are as follows:

1. Measure the relative emission and absorption of diffuse hard and soft X-rays at high galactic latitudes and correlate results with radio and optical studies.

2. Determine the contribution to the background by discrete sources.

3. Detect large-scale global anisotropies associated with the solar system motion with respect to distant sources of emission.

4. Make broadband spectral classifications of diffuse and discrete sources.

5. Establish the temporal characteristics of sources with multicomponent spectra.

There are three types of multianode multilayer counters: High Energy Detector (HED) for a xenon filled counter ($\sim$1 atm) to cover the energy range $\sim$3 to 60 keV, Medium Energy Detector (MED) for an argon filled counter to cover the band 1.5 to 15 keV, and Low Energy Detector (LED) for a thin window propane gas flow counter to cover the band 0.15 to 3 keV. The LED counters represent a collaboration between California Institute of Technology and GSFC. The GSFC group is concerned mainly with the HED and MED counters.

The first three months of the mission will be devoted to scanning exclusively. After that, a limited number of targets of opportunity (i.e., sources on or near the nominal scan path) will be considered for extended "pointed" exposures.

There are six detectors (three HED's, two LED's, and one MED) so aligned that a rotation of the spacecraft (every 30 min) provides a complete great circle scan of width 3° FWHM on the sky. The spin axis for this scan is pointed to the Sun. The collimation along the scan direction varies among units from 1.5° to 6° FWHM.

TABLE 3. EXTRACTING THE DIFFUSE X-RAY FLUX FROM THE BACKGROUND

Approach	
Characteristic	Utilization
* Diffuse Flux Increases Linearly with Solid Angle * Electron Contamination Enters Detector via Collimator * Photoelectric Cross-Section Strong Function of Energy * Charged Cosmic Rays and Compton Electrons Produce Longer Ionization Paths than Lower Energy Photoelectrons * 30 min Spin Period Can Involve Wide Range of Geomagnetic Latitudes	* Several Fields of View (2/detector) Along Scan Path * Charged Particle Veto Layer at Entrance Window * Magnetic Broom * C_3H_8, Ar, Xe Gas for Three Energy Regimes * Layer-to-Layer Attenuation versus Photon Energy * Multianode Veto * Observations Repeated in Detectors Offset by 6° (1/2 min time lag)

A. High Energy Detectors

Incident X-rays traverse a collimator covered with 0.2 mil aluminized kapton thermal shields, then a 1 mil mylar window, then the top layer veto (C_3H_8-Ne mixture for rejecting entering charged particles), and then a 1 mil mylar partition separating top veto layer from main xenon (Xe-CH_4 mixture) counter.

The effective area is $\sim 900\ cm^2$. The minimum detectable flux in a 10^3 sec observation is on the order $10^{-4}\ cm^{-2}\ sec^{-1}\ keV^{-1}$ for the bands 3 to 20 keV and 20 to 60 keV. The expected background count rate (diffuse background plus internal) is $\lesssim 10^{-2}\ cm^{-2}\ sec^{-1}$ for each of these bands.

B. Medium Energy Detectors

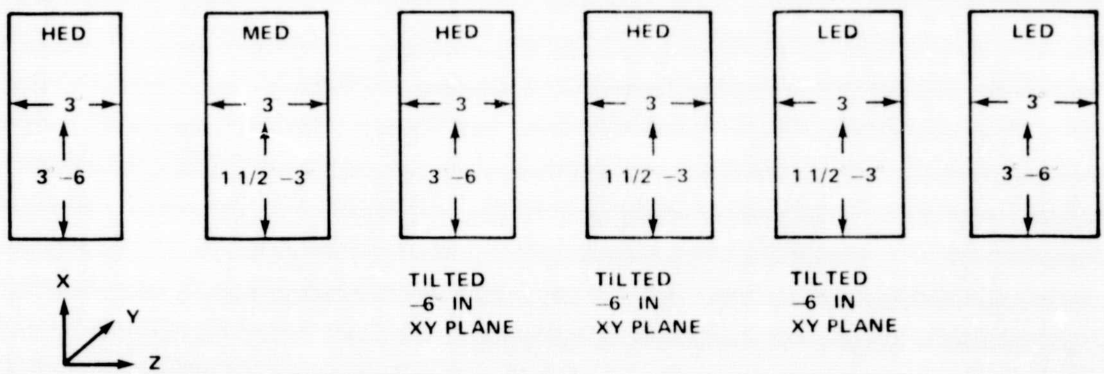
Incident X-rays traverse a collimator covered with 0.2 mil aluminized kapton thermal shield, then a 3 mil Be window, then enter main counter (Ar-CH_4 mixture at ~ 1 atm). The effective area is $\sim 800\ cm^2$. The minimum detectable flux in a 10^3 sec observation is $\sim 10^{-4}\ cm^{-2}\ sec^{-1}\ keV^{-1}$ for the 1.5 to 15 keV band; the total background count rate is $\sim 10^{-2}\ sec^{-1}\ cm^{-2}$.

C. Low Energy Detectors

A thermal precollimator is heater regulated to control heat losses. Permanent magnets are incorporated into the main collimator to prevent incident electrons from reaching the detector window (rejection efficiency >90 percent for electron energies <40 keV). A protective cover (sunshade) is closed over the collimator during the launch phase and whenever direct sunlight is near the field of view. It may also be closed for the evaluation of internal background. After passing through the collimator, incident X-rays traverse 1 to 2 μ polypropylene window (carbon coated) and then enter main counter (propane at ~ 0.3 atm; density regulated by automatic gas replenishment system). The effective area is $\sim 600\ cm^2$. The minimum detectable flux in a 10^3 sec observation is $\sim 10^{-2}\ cm^{-2}\ sec^{-1}\ keV^{-1}$ for the 0.15 to 0.28 keV band and $\sim 10^{-3}\ cm^{-2}\ sec^{-1}\ keV^{-1}$ for the 0.5 to 3 keV. The background count rate (diffuse background plus interval) is expected to be $\sim 10^{-2}\ cm^{-2}\ sec^{-1}$ for each of these bands.

D. Fields of View of Detectors

Collimators provide one field of view for even anodes and another for odd anodes in scan plane.



A-3 SCANNING MODULATION COLLIMATOR

The purpose of the Scanning Modulation Collimator (SMC) instrument (Fig. 5) is to establish accurate information as to location, structure, and size of cosmic X-ray sources.

The instrument views normal to the spin (Z) axis and has the capability of measuring angular structure of detected objects as well as location and size. It will view the entire sky during the HEAO A-3 mission. The SMC will be sensitive to several interesting structural features. If the source is of sufficient strength, the instrument can distinguish between a rather uniform distribution of X-ray emission and a collection of distinct compact objects, as in the case of the blobs in the jet of M-87, which might be resolved in X-rays with this instrument. With sufficient statistical accuracy, it can distinguish between a uniform volume of X-ray emission and a ring structure that resembles the radio emission in the galactic objects Cas A and Tycho's supernova.

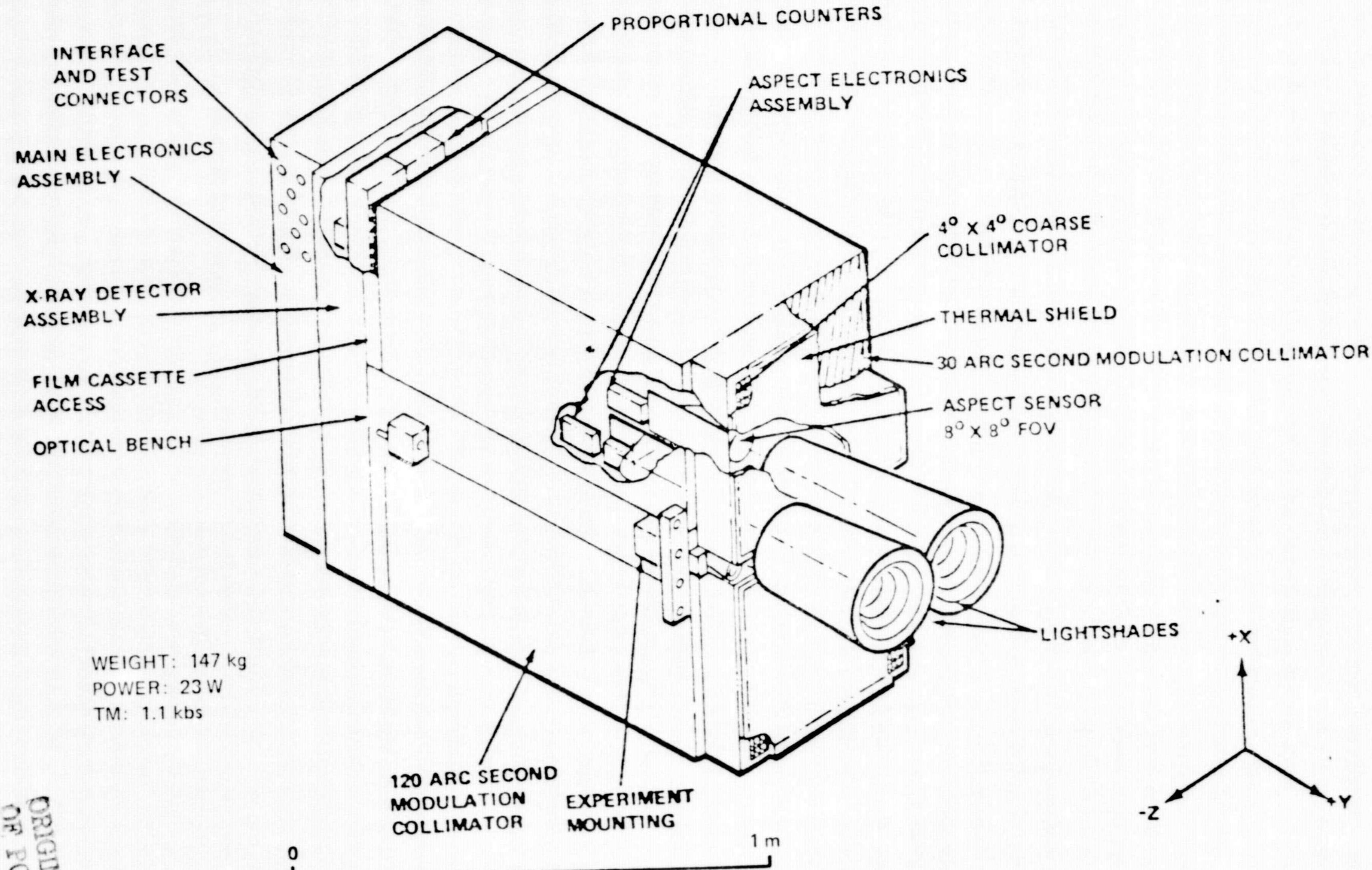


Figure 5. HEAO A-3 Experiment – Scanning Modulation Collimator.

The instrument uses proportional counters to detect X-rays in the energy range 1.5 to 15 keV. The objectives of the SMC are as follows:

a. Determination of the celestial position of selected cosmic X-ray sources to a precision of approximately 5 arc sec.

b. Determination of the angular size of cosmic X-ray sources to a precision of approximately 5 to 10 arc sec in three X-ray energy intervals from 1.5 to 15 keV.

c. Study of the structure of the X-ray emission to a precision of 10 arc sec in three X-ray energy intervals from 1.5 keV.

The details of the instrument hardware are as follows:

a. Eight collimated proportional counters

b. Four behind each of two modulation collimator assemblies

c. Each modulation collimator has four grids

d. Modulation angles are 30 arc sec (SMC-1) and 2 arc min (SMC-2) FWHM

e. Counters sealed with 1.2 atm argon/CO_2

f. 1.5 mil beryllium window

g. 0.1 mylar thermal shield

h. Two anode wires per counter

i. Coarse collimator defines $4° \times 4°$ field of view

j. Two star trackers with on-board calibration lights

k. Net area each collimator = 450 cm^2

l. Gross area each collimator = 1300 cm^2

m. Modulation bands tilted ±10° from scan circle

n. 30 arc sec collimator; each of three energy channels is read out every 40 msec

o. 2 arc sec collimator; each of three energy channels is read out every 160 msec

p. Aspect data every 320 msec

q. High frequency background monitor every 64 msec

r. Auxiliary data; Lower Level Discriminator, Upper Level Discriminator, and Pulse Shape Discriminator rates.

The SMC is comprised of two sections (Fig. 6), each containing four wire grid planes. Each provides a precise location and angular size measurement in one dimension along a "plane of maximum transmission." An additional collimator located forward of the front grid restricts the overall instantaneous field of view to 4° × 4° FWHM for each SMC. The outward view direction of the instrument is perpendicular to the spacecraft spin (Z) axis; thus, for a given spin axis orientation the instrument scans a great circle band on the sky. As the spin axis follows the apparent motion of the Sun, the entire sky is surveyed over a 6 month period.

The two collimators differ by having their plane of maximum transmission inclined +10° and -10° to the scan direction (Fig. 7). Hence, locations and angular sizes are measured along two directions. Precise two-dimensional locations are determined by the interseconds of the locations obtained from each of the two collimators. The collimators also differ by a factor of four in their angular response function (30 and 120 arc sec FWHM with 4 and 16 arc min periodic spacing) to extend the dynamic range up to 16 arc min over which angular size and structure measurements can be made.

The triangular response function of the collimators define the ability for position determination. For a source at the detection threshold, the peak of the triangle can be determined to approximately one-third the FWHM. For stronger sources the peak can be determined to one-tenth the FWHM. The size measurement is made by testing for consistency of the counting rate to a triangular response shape, and any structure is studied by deconvoluting the triangular response from the detailed counting rate pattern.

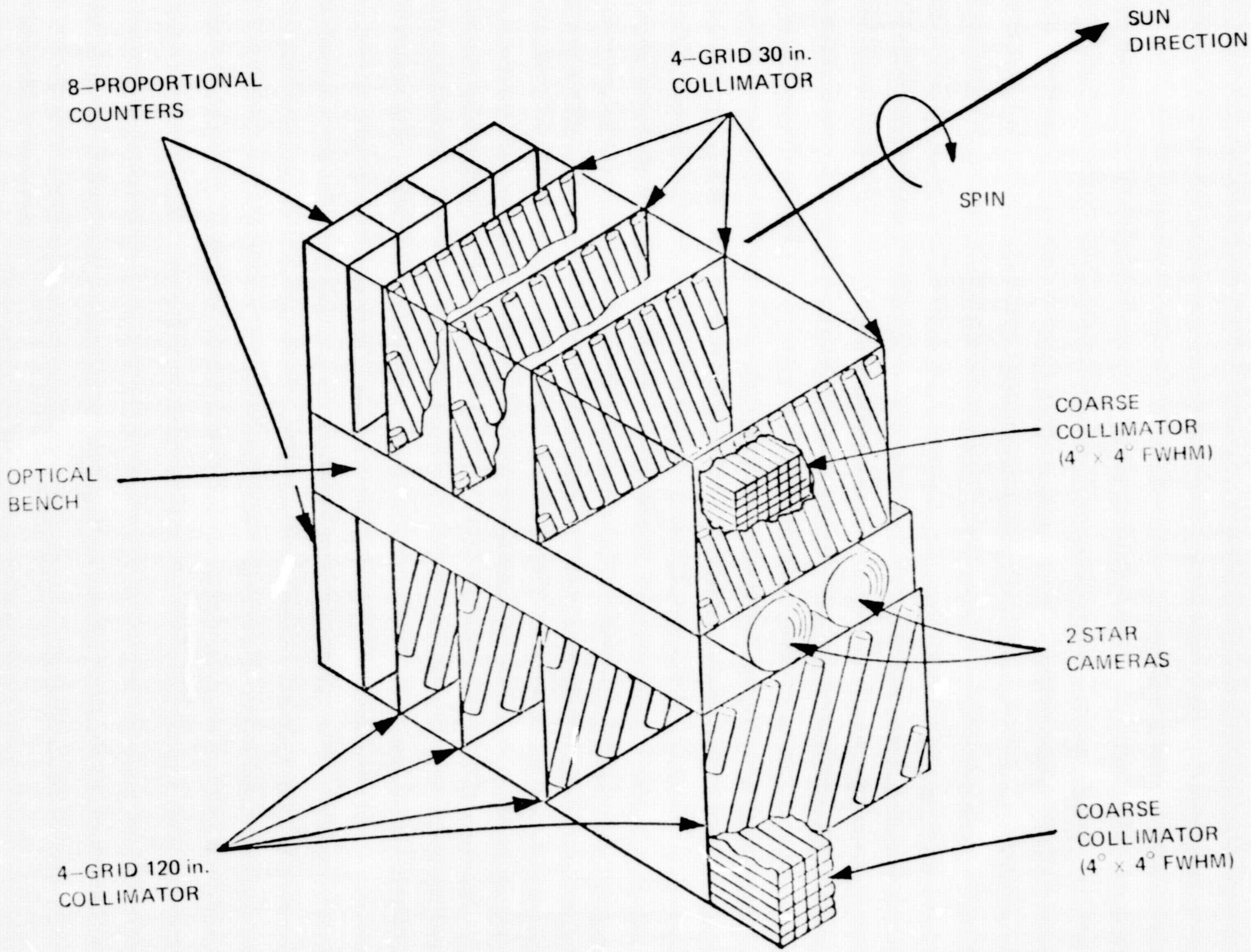


Figure 6. Scanning modulation collimator.

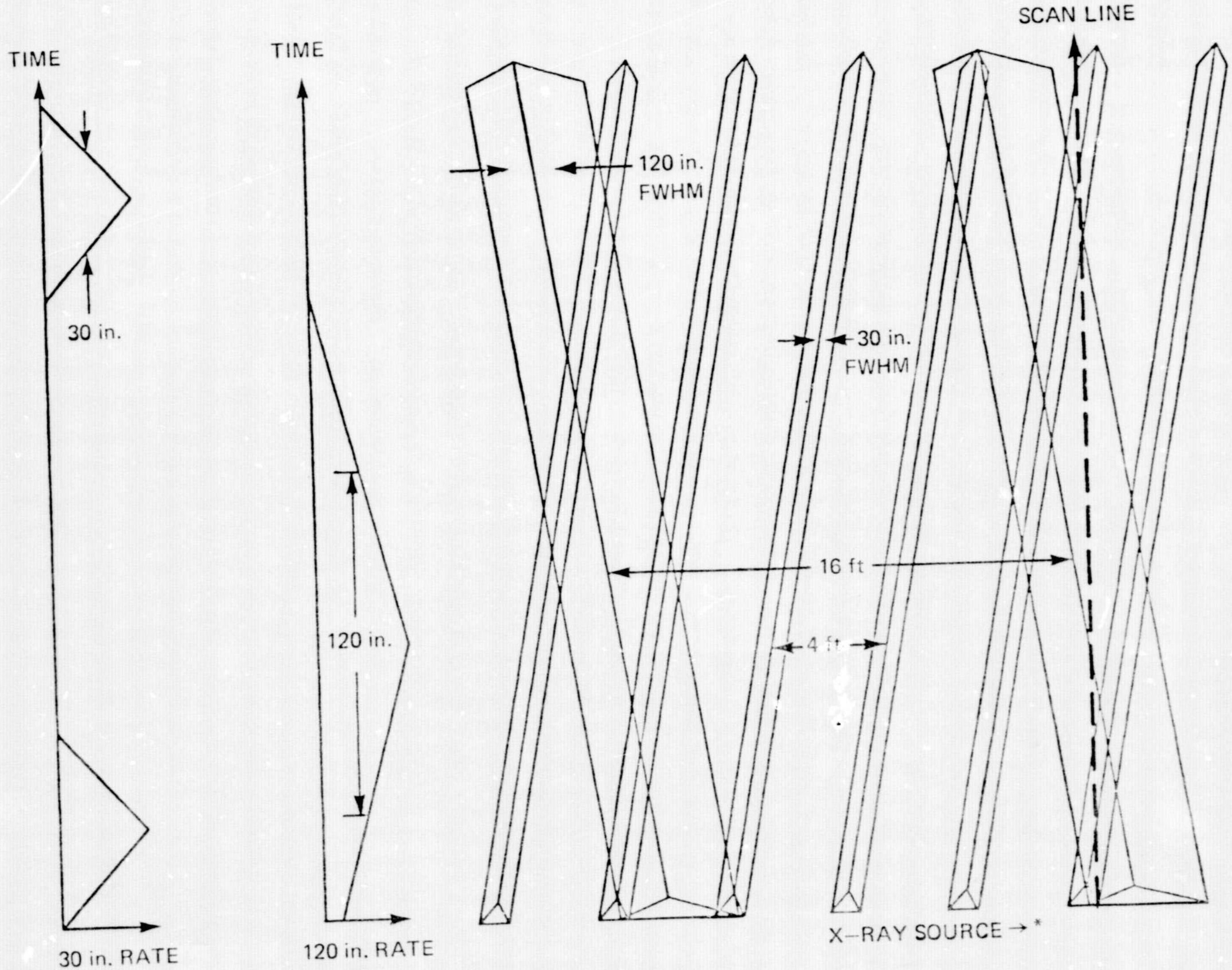


Figure 7. HEAO A-3 fields of view.

A. Instrument Sensitivity

The SMC instrument will be capable of 6 sigma position measurements for X-ray sources having an intensity of 1×10^{-3} Crab, in two orbits of pointing or 4 days of scanning data.

B. Background Rejection

The SMC instrument will utilize pulse shape discrimination (PSD) techniques to reduce the non-X-ray background. Typical PSD performance results in better than 75 percent background rejection with more than 75 percent X-ray event acceptance. We expect residual non-X-ray background in the range 0.005 to 0.02 counts/cm^2/sec (6 to 26 counts/sec, 1 bank).

C. Energy Resolution

Both SMC 1 and SMC 2 perform three channel pulse height analysis covering the 1.5 to 15 keV energy range to provide a minimum energy resolution, consistent with the available data rate, to carry out the scientific objectives of studying source size and source structure versus energy. The three channel pulse height analyzer will cover the following energy ranges (±10 percent one sigma):

Channel No. 1	1.5 to 3 keV
Channel No. 2	3 to 6 keV
Channel No. 3	6 to 15 keV.

The three pulse height analyzer channels are used to select the best signal-to-noise ratio for different X-ray spectral types. A source with a steep exponential spectrum will give a detectable number of counts only in the two lowest channels. A power low type of source will also contribute significantly to the 6 to 15 keV channel. Either spectral type may be cut off so steeply at low energies that the 1.5 keV channel does not give significant counts. The pulse height boundaries are not calibrated.

The A-3 SMC consists of two proportional counter assemblies; two X-ray signal processors; two imaging aspect sensors; and the supporting electronics for power and command distribution, synchronization, and telemetry interfacing.

Instrument operation is monitored via housekeeping circuits which provide command verification, configuration status, and voltage and temperature measurements. A detector block diagram is shown in Figure 6.

There is no South Atlantic anomaly detector as such. Instead, this problem will be circumvented by a signal from the stored command programmer on the observatory that will reduce the high voltage as the anomaly is approached and another signal that will restore the high voltage once the anomaly is passed.

The two aspect sensors will operate entirely independently from one another. Power will be furnished from separate spacecraft electrical accommodation assemblies. No in-flight X-ray calibration will be provided for the proportional counters.

D. Aspect Determination

The experiment must be equipped with aspect sensors (star trackers) to provide data on the stellar orientation of the experiment axes with sufficient accuracy to allow achieving the experiment goal of 5 arc sec position of sources. In addition, the spacecraft rate gyro data are essential to performing the aspect solution. These aspect requirements are consistent with the mechanical alignment tolerances of the collimators. The aspect solution is the limiting factor in determining source location for strong sources (i.e., not limited by counting statistics). It is not required to achieve equal precision around all three axes to achieve this goal. In the case of the SMC, the modulation bands make an angle of 10° with respect to the X axis. Thus, the sensitive direction is rotation around X in which direction precision of 5 arc sec must be achieved. For rotation about Z, 30 arc sec are adequate. Knowledge of aspect around the Y axis is required to approximately 1.0 arc min to perform the SMC data superposition.

The aspect sensor will normally operate with one of the two in a standby redundant mode. Both will be turned on periodically for cross-calibration purposes. The aspect sensors will be aligned with the X-ray collimators as early in the mission as possible using a known source such as CYG X-1, CEN X-3, or HER X-1.

A-4 HARD X-RAY AND LOW ENERGY GAMMA RAY EXPERIMENT

A. Instrument Description

The Hard X-ray and Low Energy Gamma Ray Experiment, also known as A-4, will measure point and diffuse sources of X-rays and gamma rays in the 10 keV to 10 MeV range. (For a more complete description of the experiment, see also "The UCSD/MIT Hard X-Ray and Low Energy Gamma Ray Experiment for HEAO-A," 1974, by J. L. Matteson, R. M. Pelling, and L. E. Peterson, The Context and Status of Gamma Ray Astonomy, ESLAB Symposium.) The instrument is shown in Figure 8. The seven detectors are NaI(Tl)/CsI(Na) phoswich scintillators and are surrounded by eight large CsI(Na) scintillators which provide shielding and define the fields of view. Since the appropriate detector size, field of view, and shield thickness vary greatly through the energy range, the instrument contains three detector types whose details are given in Table 4. All apertures are covered by a thin plastic scintillator to reject charged particle counts. The apertures may also be blocked by a moveable 2 in. thick CsI(Na) "blocking crystal" which will intercept the aperture gamma ray flux to simplify background determination.

The slat collimators of the intermediate energy detectors are positioned at approximately 60° relative to the scan direction (Fig. 9), allowing point source position determination to <1° over the approximately 40° wide band scanned each spacecraft rotation. Sources detected in the point mode detectors will have their positions determined to only less than 20°, but in most cases will be identified with low energy sources by similarity with intermediate energy detector spectral measurements at approximately 100 keV. In the same manner, point sources detected by the diffuse mode detector will be related to those with similar spectra in the point mode detectors.

Each detector is equipped with a pulse shape analyzer and discriminator which detect and veto CsI(Na) events. In addition, the particular combination of shield upper and lower level discriminators (nominal settings of approximately 5 MeV and 0.1 MeV) used for detector anticoincidence may be selected by command. A unique combination may be selected for each detector, allowing the instrument to be "tuned" for maximum sensitivity. Detector events satisfying the anticoincidence condition are pulse-height-analyzed and telemetered on an

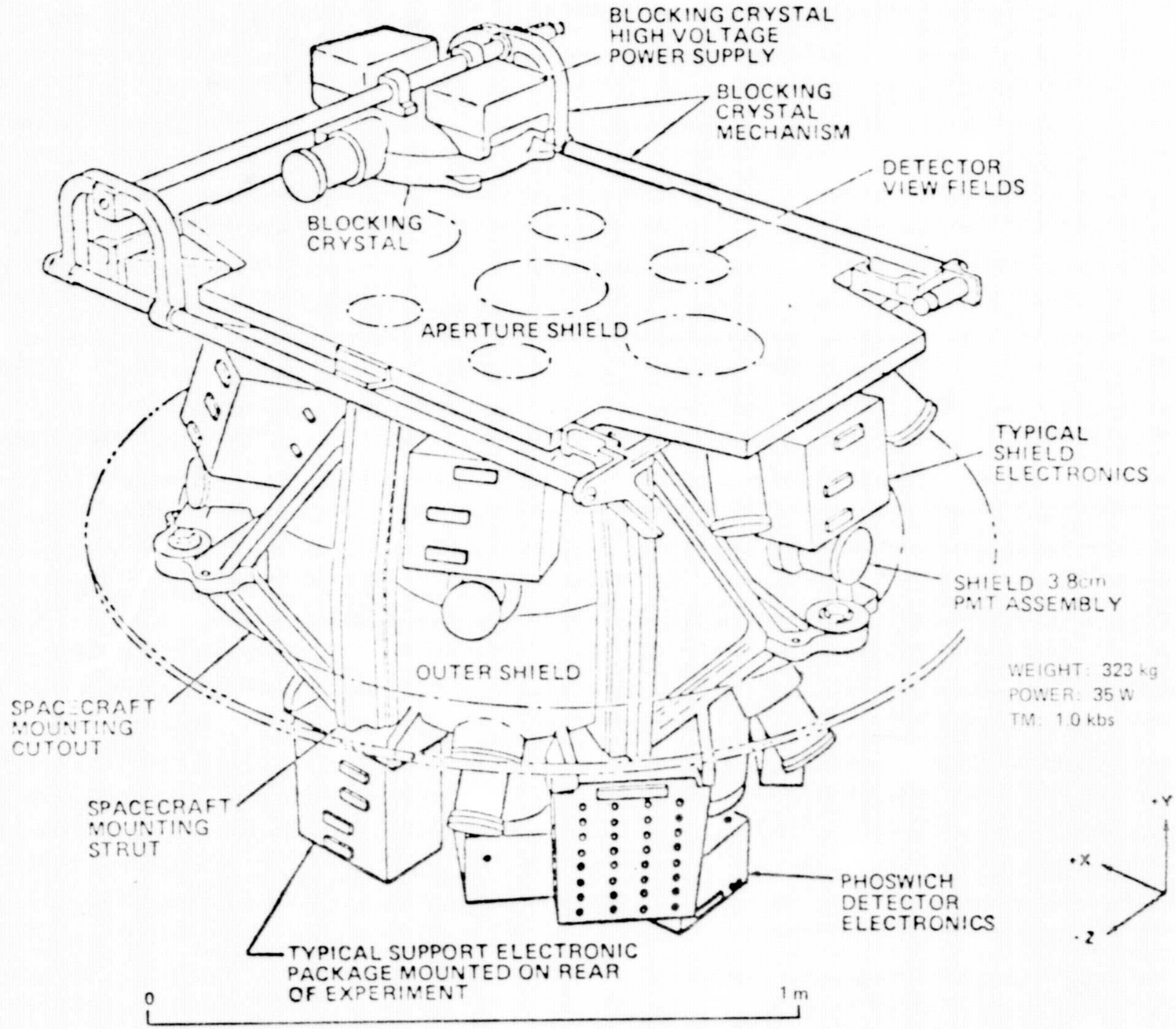


Figure 8. HEAO A-4 Experiment – Hard X-Ray and Low Energy Gamma Ray.

TABLE 4. HARD X-RAY AND LOW-ENERGY GAMMA RAY EXPERIMENT

Detector Characteristics						
Detector Name	NaI Size (in.)	Energy Range	Area (cm^2)	Field of View FWHM (deg)	CsI Shielding (in.)	Point-Source Sensitivity
Intermediate Energy	(2) 5 dia. × 1/8 thick	10 to 200 keV	225	~1 × 20	~2	2×10^{-3} Crab Nebula
Point Mode	(4) 3 dia. × 1 thick	0.1 to 5 MeV	180	~20	~4	10^{-2} Crab Nebula
Diffuse	(1) 5 dia. × 3 thick	0.1 to 5 MeV	125	~40	~6	—

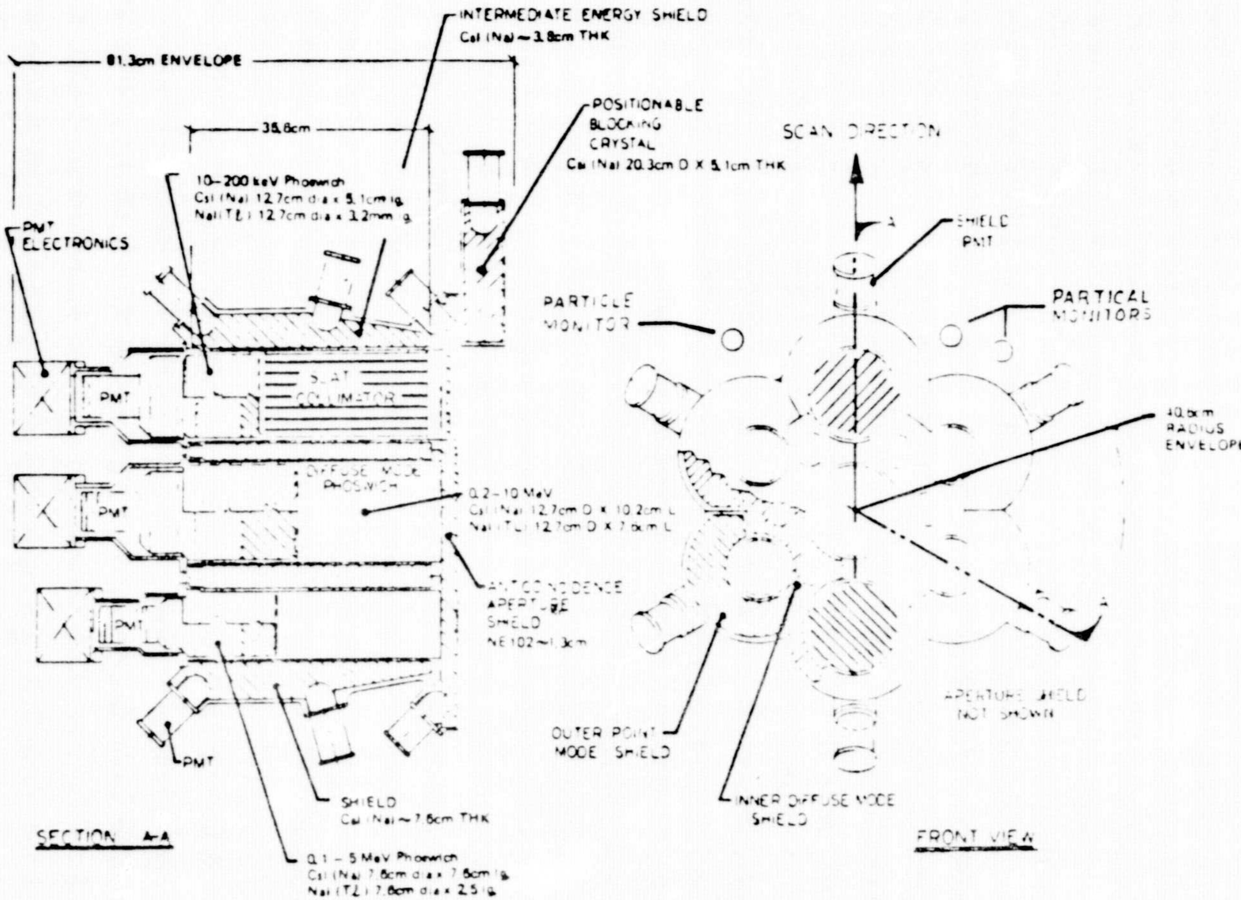


Figure 9. Detailed description of HEAO-4 Experiment – Hard X-Ray and Low Energy Gamma Ray. (The instrument consists of a cluster of seven NaI(Tl) / CsI(Na) phoswich type detectors and eight large CsI(Na) shields. Three detector sizes are used to give efficient operation over the 10 keV to 10 MeV range. The apertures are covered by a thin plastic scintillator to reject charged particle interactions in the detectors. A moveable "blocking crystal" may be positioned over any aperture to simplify background determination.)

event-by-event basis by the Main Pulse Height Analyzer (MPHA) system. Sixty-four pulse-height channels are provided for the intermediate energy detectors and 512 channels for the others. Event time is normally known to 10^{-1} sec accuracy. This may be improved to 5 msec or 20 μsec by commanding an 8 bit or 16 bit time tag to be added to the MPHA word.

An additional data channel is available in the Roving Pulse Height Analyzer (RPHA). This 256 channel PHA selects its input through a 28 input analog multiplexer, which gives it access to all detectors, shields, and pulse shape analyzers in the instrument. The spectrum of a selected input is normally accumulated in a memory for 20 sec and then read out while the next spectrum is accumulated. The input sequence, spectrum accumulation period, number of PHA channels and bit rate dedicated to the RPHA may be changed by command to adapt it to a variety of situations. Normally it will perform energy and pulse shape analyzer calibrations and monitor shield performance, cycling through its inputs every few minutes. In special cases it may dwell on a selected input to study an instrumental effect or to provide an alternate path for prime science data. This will be useful in the study of strong X-ray sources which will exceed the MPHA system's limited readout rate.

The diffuse mode and intermediate energy detectors use 5 in. diameter photomultiplier tubes (PMT) and the point mode detectors use 3 in. PMT. The shields and blocking crystal use 1.5 in. PMT. Each detector and CsI shield contains an Am^{241} doped CsI(Tl) "light pulser" which provides a calibration peak at approximately 2 MeV gamma ray equivalent energy. The calibration peaks will be monitored throughout the mission and gain corrections achieved by commanded PMT high voltage changes.

The instrument also contains three particle monitors to measure the proton and electron fluxes encountered in three energy ranges. These monitors will allow data contaminated by excessive particle flux to be identified and provide the proton dose history necessary to determine the build-up of spallation products due to proton interactions in the instrument and spacecraft.

B. Background Predictions

The instrument background properties may be predicted with some confidence since most of the relevant radiations and effects have been measured in the laboratory and/or space experiments. There are four primary background sources: (1) the leakage component is produced by cosmic, Earth albedo and spacecraft-produced gamma rays which penetrate the instrument's shielding, (2) the aperture component is due to cosmic gamma rays which enter the instrument aperture, (3) the spallation component is the result of the decay of unstable spallation products of high energy proton reactions in the instrument, and (4) Earth albedo and spacecraft-produced neutrons may give prompt effects.

C. Instrument Sensitivity

Using the background spectrum estimated from the first three effects from the previous paragraph, Figure 10 shows the 3 sigma instrument's sensitivity to a point source for a 1 year uniform sky scan. Also shown is the Crab Nebula spectrum which is extended to approximately 0.5 MeV. If this spectrum

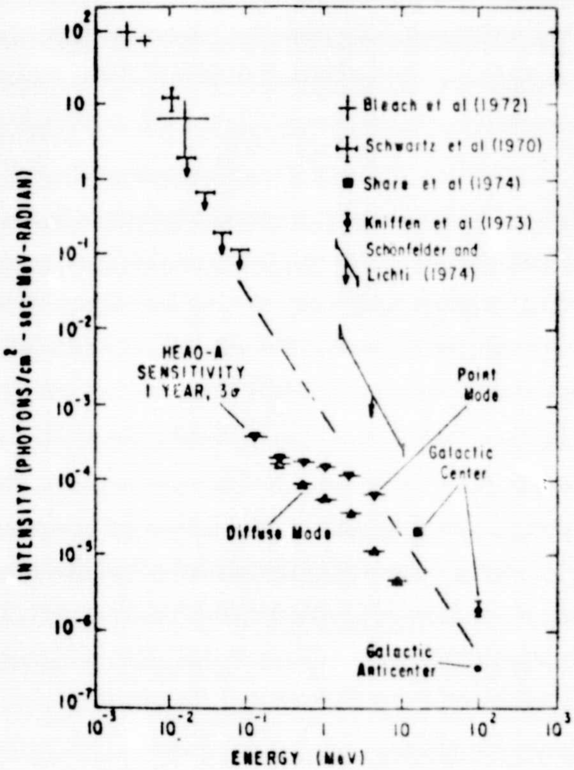


Figure 10. The 3 sigma instrument sensitivity to a point source for a 1 year uniform sky scan. (The instrument should detect the Crab Nebula up to ~5 MeV. 10^{-1} Crab should be detected to ~0.5 MeV and 10^{-2} Crab to ~0.1 MeV.)

extrapolates to higher energy, the Crab should be detected up to approximately 5 MeV by HEAO-A. A source equal to 10^{-1} Crab will be seen to approximately 0.5 MeV and 10^{-2} Crab to approximately 0.1 MeV. The instrument's sensitivity to diffuse emission is shown in Figure 11. This will be achieved, provided the systematic background effects described in Paragraph B can be adequately understood and corrected.

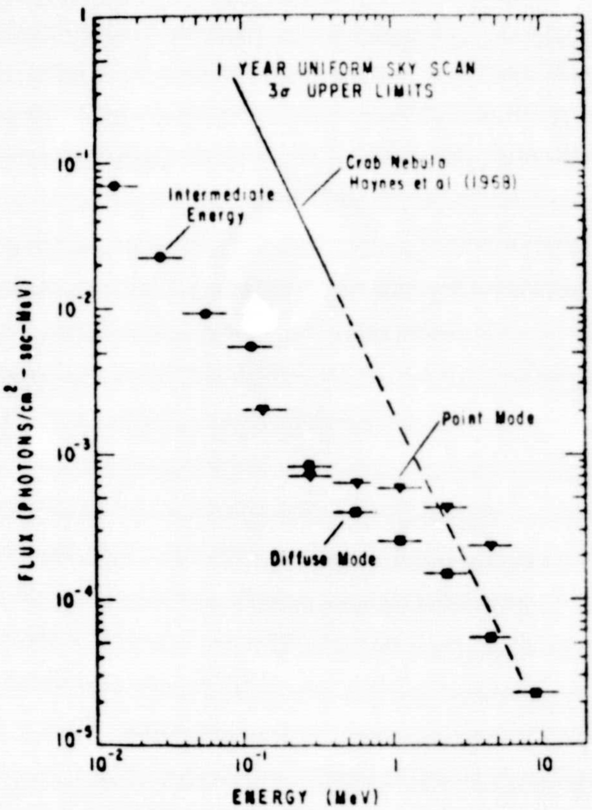


Figure 11. The 3 sigma instrument sensitivity to diffuse emission. (Gamma ray emission from the galactic plane has not been detected in the 0.1 to 10 MeV range. The instrument's sensitivity is well below a simple connection between the 10 keV and 10 to 100 MeV measurements, indicating that the galactic plane should be easily detected and mapped.)

D. Gamma Ray Burst Processor

The instrument also contains a high resolution timing system for the measurement of cosmic gamma ray bursts. The signals of the eight large CsI(Na) shields and the blocking crystal are summed, resulting in an omni-directional collection area of approximately 2400 cm^2. The summed signal is processed by a discriminator system with thresholds of 0.1, 0.2, 0.4, 0.8, and 1.6 MeV. The discriminator outputs are processed by a versatile logic system which recognizes rapid counting rate increases. These trigger a short time scale sampling of the discriminator outputs with the results being stored in a memory which is read out later. Counting rate data of 0.1 to 1.6 MeV are stored on time scales as short as approximately 0.5 msec, and spectral data are stored on time scales as short as approximately 6 msec. The sensitivity for a gamma ray burst with the temporal characteristics of the April 27, 1972, burst will be approximately 3×10^{-6} ergs/cm^2.

MISSION OPERATIONS AND DATA MANAGEMENT

The Operations Control Center (OCC) for HEAO will be at GSFC. A mission operations team consisting of representatives from the scientific groups, TRW, and NASA will plan and direct the observatory operations.

The Flight Control Team at the OCC will have a Flight Director from MSFC who will direct all operations there. His team will consist of GSFC flight control personnel, data net personnel from GSFC, observatory personnel from TRW, and a scientific liaison team from the experiment groups. The OCC team is planned for a 5 day/week, one shift operation after checkout and activation of the observatory, which will require approximately 2 weeks.

During the two work shifts a day when the full OCC team is not present and on weekends, the OCC will be manned by a reduced crew to carry out normal observatory operations. The functions to be performed by the OCC flight control team include:

a. Perform and schedule telemetry ground station passes

b. Generate and transmit commands to the observatory

c. Monitor and evaluate the state of health of the observatory and resolve anomalous behavior

d. Manage observatory subsystems and experiment configuration

e. Integrate experiment operational requirements into the observatory operation plan and execute requirements such as purging gas counters and pointing the observatory.

Data are transmitted to the ground and commands are generated to the spacecraft during passes within range of the stations of the Space Tracking and Data Net (STDN). Commands received by the observatory may be executed in real time or stored on-board to be executed at a preset time. The commands stored on-board are for instrument cutoff in the South Atlantic Anomaly and pointing operations.

At GSFC two facilities are involved in processing experiment data. The Data Reduction Laboratory (DRL) is a facility attached to the OCC. Its purpose is to examine a selected subset of the experiment data to monitor experiment health and to facilitate operations such as the initiation of normal operations, experiment gas purges, etc. Normal scientific data processing will not be performed at the DRL, but rather with data processing facilities at the institution of the scientific investigators.

The Data Reduction Center (DRC) will handle the preprocessing of the bulk of the data before the data are sent to the investigators' facilities. Its function includes stripping out individual experiment data from the main data stream and calculating post factor ephemeris and spacecraft attitude information to be supplied to the experimenters.

During a STDN station pass, the real time data from the observatory at 6.4 kbs are forwarded, unmodified, to the OCC at GSFC. Some of these data are processed and displayed at the OCC and may be used in the DRL for assessing experiment health. The observatory tape dumps received at the tracking stations are abstracted and the abstracted data are forwarded to the OCC within a few minutes. This abstracted data include spacecraft and experiment housekeeping data.

Each day one orbit of data will be designated "quick look" data and the complete data from this orbit will be transmitted from a STDN site to the OCC, delayed only by the transmission time. The scientific data from each experiment will be stripped out at the DRC and transmitted to the individual experimenters' facilities for scientific data analysis. Receipt of the quick look data by the investigators will be within 24 hours of the STDN tape dump.

The bulk of the data will be mailed from the STDN sites to the OCC. After being preprocessed at the OCC, the data from the individual experiments will be forwarded to the investigators' facilities for scientific processing. It is planned that the investigators will receive the data within approximately 6 weeks of the observatory tape dump at the tracking stations.

APPENDIX

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Mr. Carroll C. Dailey Guest Observer Program Project Coordinator	HA01	205/453-1680

APPROVAL

HEAO-A OBSERVATORY DESCRIPTION

By Carroll Dailey and Thomas A. Parnell

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

F. Speer

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