

# NASA News

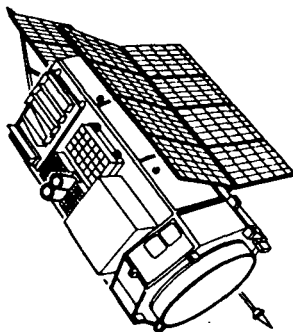
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National Aeronautics and  
Space Administration

Washington, D.C. 20546  
AC 202 755-8370

## Press Kit

For Release 10 a.m., TUESDAY,  
April 5, 1977



Project HEAO-A

RELEASE NO: 77-45

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(NASA-News-Release-77-45) FIRST HIGH ENERGY  
ASTRONOMY OBSERVATORY LAUNCH SET (National  
Aeronautics and Space Administration) 38 p

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For Release:

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(Phone: 202/755-3680)

10 a.m., TUESDAY,  
April 5, 1977

Don Worrell  
Marshall Space Flight Center, Huntsville, Ala.  
(Phone: 205/453-0035)

RELEASE NO: 77-45

## FIRST HIGH ENERGY ASTRONOMY OBSERVATORY LAUNCH SET

NASA's first High Energy Astronomy Observatory, HEAO-A, is scheduled to be launched into Earth orbit about April 15, inaugurating a three-mission program to study some of the most intriguing mysteries of the universe -- pulsars, quasars, exploding galaxies and black holes in space.

Two other unmanned scientific satellites, HEAO-B and HEAO-C, will be launched in 1978 and 1979.

-more-

Mailed:  
March 17, 1977

The observatories -- the heaviest Earth-orbiting satellites ever launched -- will carry scientific instruments capable of detecting, with high sensitivity and resolution, X-rays emitted by stellar sources throughout the universe. Celestial gamma ray and cosmic ray data also will be collected.

These high energy rays cannot be studied through Earth-based telescopes because of the obscuring effects of our atmosphere. The rays were observed initially by instruments on sounding rockets and balloons and by small satellites which did not have the instrumentation capabilities required for high data resolution and sensitivity. These capabilities are now available in the HEAO satellite.

Information returned by HEAO may provide clues to the nature of some of the "newest" and most mysterious celestial objects in the universe. This knowledge, in turn, could lead to a better understanding of the high-energy universe and to new theories about energy production and high-density nuclear matter.

HEAO-A, the first mission, will survey and map X-ray sources throughout the celestial sphere and also measure low energy gamma-ray flux. The spacecraft, rotating end-over-end, will survey the entire sky in six months.

The HEAO-B mission will maneuver and point for long periods at selected X-ray sources mapped by HEAO-A and smaller X-ray spacecraft, while HEAO-C will conduct a survey of gamma-ray emissions and study cosmic ray particles from our galaxy.

HEAO-A and HEAO-C, designed to perform sky surveys, are classified as scanning missions. They will rotate slowly end-over-end, with one revolution about every 30 minutes. Each will use a gas thrust reaction control system to maintain proper sky-scanning orientation so that the solar arrays face the Sun at all times to provide electrical power for the satellite.

For HEAO-B, which must point to specific stars or points in the sky, reaction wheels are added to provide a precise and highly accurate pointing capability of one arc minute or better. HEAO-B is termed a celestial pointing mission.

The HEAO-A and HEAO-C observatories will have a mission lifetime of six months each, which is the time required to map fully the celestial sphere. HEAO-B will have a mission lifetime of one year for pointing at selected, highly interesting X-ray sources.

The observatories, 5.8 meters (19 feet) long and weighing 3,150 kilograms (7,000 pounds), will be placed in low circular orbits, about 420 to 460 kilometers (225 to 245 miles) above Earth. The altitude is far enough above the atmosphere to detect the radiation which cannot reach the ground.

X-ray and gamma rays are composed of photons, which are particles having energy but no mass, as in light rays. Cosmic rays are composed of particles such as electrons and protons, which have both mass and energy. An X-ray has thousands of times the energy of ordinary light and gamma rays millions of times the energy of visible light.

The high-energy X-rays and gamma rays which HEAO will study, traveling through space at the speed of light, are called electromagnetic radiation. Other forms of electromagnetic radiation include ultraviolet and infrared radiation.

For many years man has studied these forms of radiation and their energy mechanism and has transformed them into many practical uses, including electrical applications, holography, radio and television, radar and infrared photography.

In high-energy astronomy, interest is in the extreme short-length waves which are known as X-rays and gamma rays. These rays are produced on Earth in both natural radioactive materials and man-made processes. The X-rays and gamma rays on the Earth are produced from well understood physical processes and they are used routinely in physics, chemistry, engineering, medical and other scientific fields. This type of radiation is produced by mechanisms involving the atomic and nuclear structure of the elements. Little is known, however, about the way in which X-rays and gamma rays are produced and accelerated from deep space toward Earth with such great energy.

It is expected that the radiation data collected by the HEAO observatories, after having been reduced and analyzed, will lead to a better understanding of how the extremely high energies are generated in space, how basic elements are formed, how the universe evolved and the extreme physical processes evident within the universe.

Several hypotheses are being pursued in astrophysics and cosmology that need additional experimental evidence such as may be obtained by HEAO. These hypotheses are related to radio galaxies, neutron stars, pulsars, quasars, star explosions and supernovas, many of which radiate copiously in the X-ray and gamma ray part of the spectrum.

The HEAO project is managed for NASA's Office of Space Science by the Marshall Space Flight Center, Huntsville, Ala. The OSS Program Manager is Richard E. Halpern and the Program Scientist is Dr. Albert G. Opp. At Marshall Center, Dr. Fred A. Speer is the Project Manager. Project Scientist for HEAO-A is Dr. Frank B. McDonald of NASA's Goddard Space Flight Center, Greenbelt, Md. Prime contractor for the program is TRW Systems of Redondo Beach, Calif.

The HEAO observatories will be launched by Atlas Centaur vehicles from NASA's Kennedy Space Center, Fla. KSC will manage the launch operations, including prelaunch checkout, launch and flight through observatory separation in orbit. NASA's Lewis Research Center, Cleveland, Ohio, manages launch vehicle procurement and activities for the HEAO program.

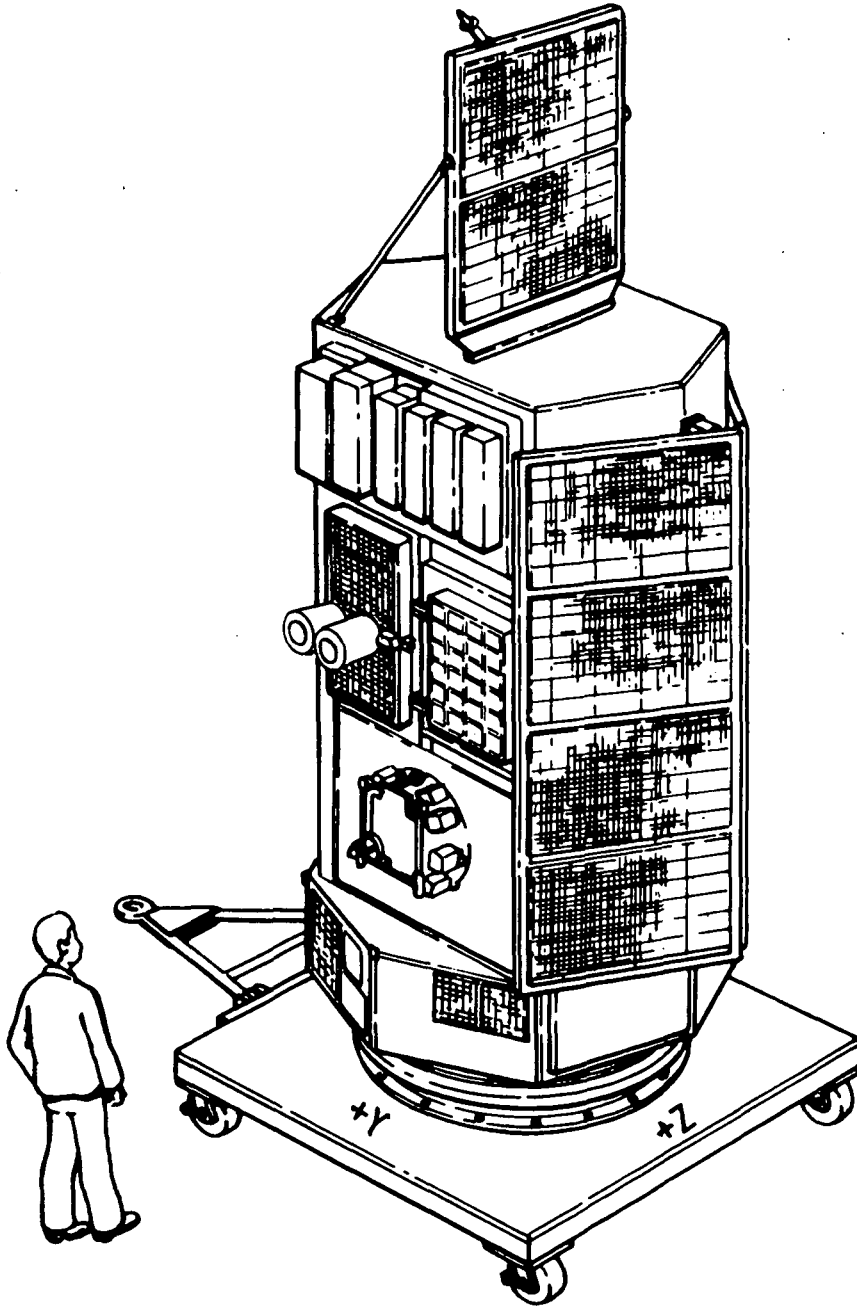
Control of the in-orbit HEAO observatories will be under the direction of Marshall in conjunction with TRW flight control engineers at Goddard.

Once HEAO-A achieves orbit, its designation will be changed to HEAO-1.

Cost of the three-mission HEAO program is about \$237 million.

(END OF GENERAL RELEASE. BACKGROUND INFORMATION FOLLOWS.)





HEAO-A Prior to Mating with Launch Vehicle

HEAO SPACECRAFT AND OBSERVATORY

The basic subsystems design of the spacecraft is common for all three HEAO missions with only a few exceptions due to unique experiments or mission requirements. The shape, arrangement and objectives of the experiments on the three spacecraft will be different for each mission.

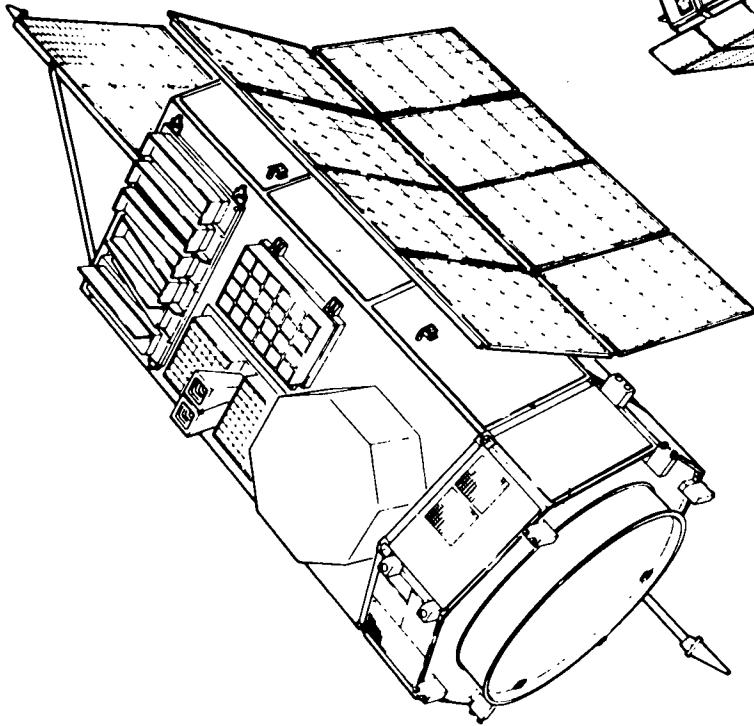
The observatories (i.e., spacecraft plus experiments) each weigh about 3,150 kilograms (7,000 pounds), including 1,350 kg (3,000 lb.) of experiments. Overall observatory length is 5.8 meters (19 feet).

The HEAO spacecraft subsystems take advantage of existing hardware designs developed in other spacecraft programs. About 80 per cent of HEAO spacecraft hardware is "off-the-shelf."

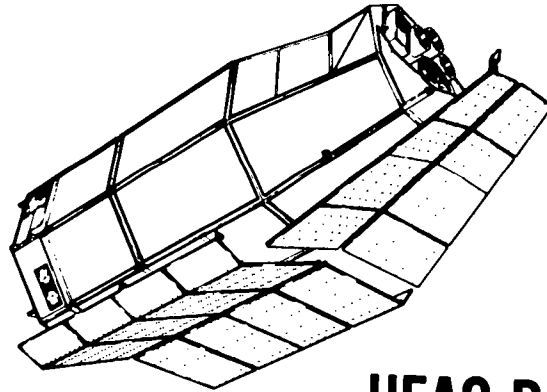
Prime contractor for the HEAO spacecraft is TRW Systems of Redondo Beach, Calif. TRW's role is to design and develop the HEAO spacecraft, integrate the experiments into the observatories, integrate the missions and support launch operations at Kennedy Space Center. TRW will also perform flight operations of the in-orbit observatories in the mission control center at Goddard.

# HEAO

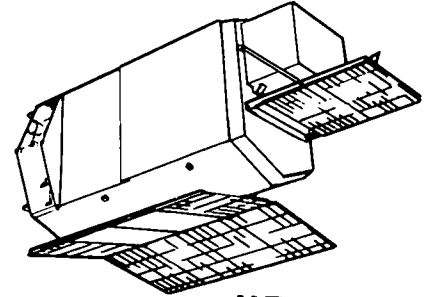
HIGH ENERGY  
ASTRONOMY OBSERVATORY



**HEAO-A  
1977**



**HEAO-B  
1978**



**HEAO-C  
1979**

LAUNCH VEHICLE

Contractor for the Atlas booster stage (SLV-3D) is General Dynamics Convair Aerospace Division. The stage-and-one-half Atlas is powered by three engines -- two Rocketdyne YLR-89-NA-7 engines providing 1,646,500 newtons (370,000 lb.) of thrust and one Rocketdyne YLR-105-NA-7 engine with 267,000 N (60,000 lb.) thrust. All three engines operate on liquid oxygen and RP-1 propellants.

General Dynamics is also contractor for the Centaur upper stage (D-1A), which is powered by two Pratt and Whitney RL10A-3-3 engines with a total thrust of 133,500 N (30,000 lb.). These engines operate on liquid oxygen and liquid hydrogen.

Physical characteristics of the Atlas SLV-3D stage are:

- Length 21.9 m (72 ft.)
- Diameter 3 m (10 ft.)
- Dry weight 5,674 kg (12,512 lb.)
- Launch weight 130,434 kg (287,607 lb.)

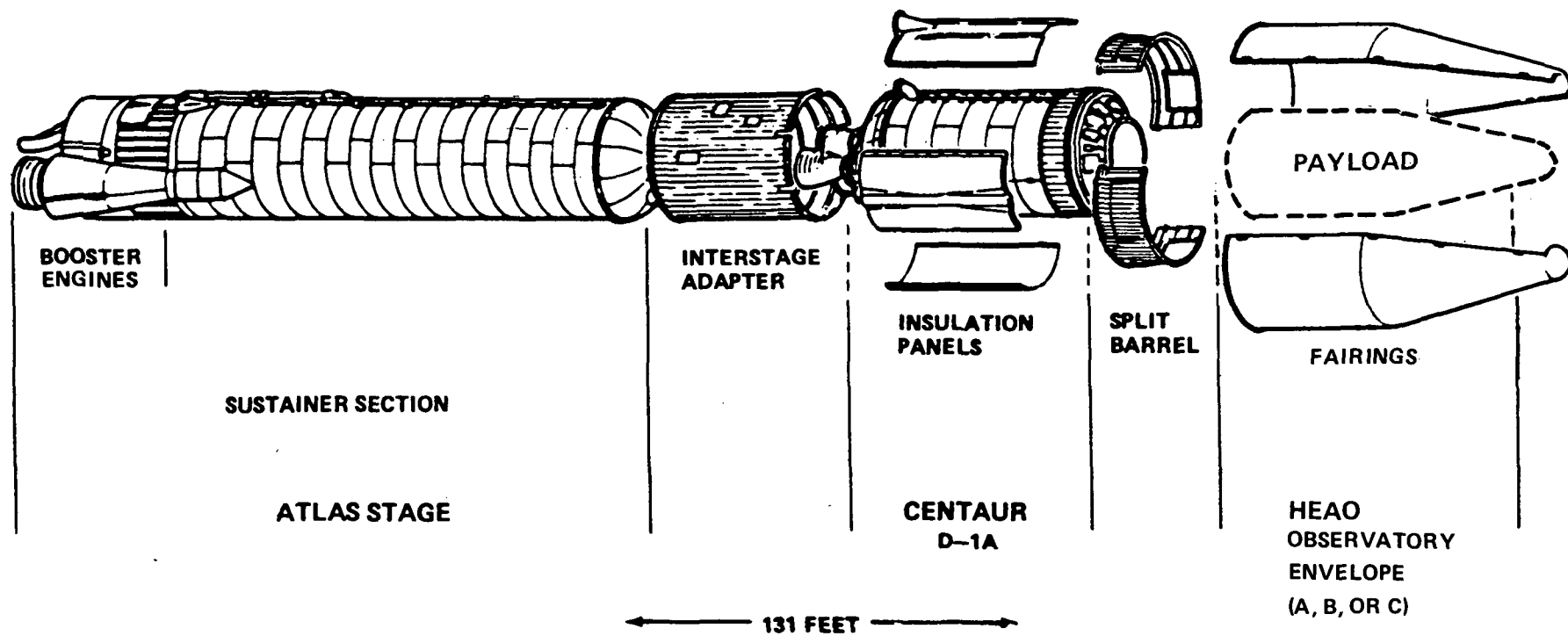
Physical characteristics of the Centaur D-1A upper stage are:

- Length 9 m (30 ft.)
- Diameter 3 m (10 ft.)
- Dry weight 1,754 kg (3,868 lb.), excluding nose fairing.
- Launch weight 17,710 kg (39,051 lb.)

Total height of the HEAO Atlas-Centaur space vehicle ready for launch, is 39.9 m (131 ft.) with a launch weight of about 148,982 kg (328,505 lb.) for HEAO-A.

# ATLAS/CENTAUR D-1A

HEAD SPACE VEHICLE FOR A, B, & C OBSERVATORIES



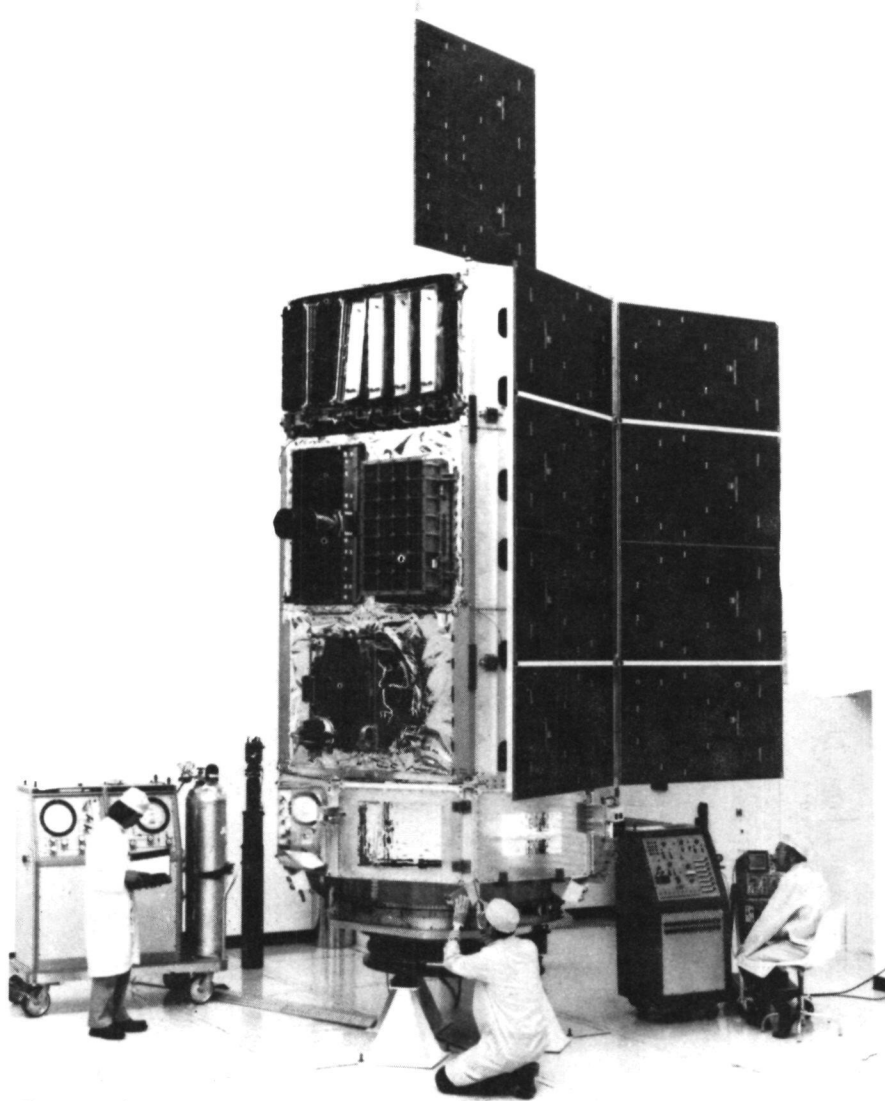
HEAO LAUNCH OPERATIONS

NASA's John F. Kennedy Space Center, Fla., and its Expendable Vehicles Directorate play key roles in the preparation and launch of Atlas-Centaur 45 which will carry HEAO into orbit.

The Atlas booster was erected on Pad B at Launch Complex 36, Cape Canaveral Air Force Station, Jan. 25, and the Centaur upper stage was mated with it Jan. 27.

The HEAO spacecraft arrived at KSC aboard a C-5A aircraft during the week of March 7 and was moved into the Assembly Building in the Explosive Safe Area for prelaunch processing. After a series of systems and subsystems tests and experiments, checkout, culminating in observatory tests in late March, the spacecraft was encapsulated in the Atlas Centaur shroud April 1. It was moved to Pad B and erected on its Atlas-Centaur launch vehicle April 4.

**HEAO-A  
DURING  
SYSTEMS  
CHECKOUT**



HEAO MISSION OPERATIONS

Control of the in-orbit HEAO observatories will be directed by Marshall Center flight control engineers at the Goddard Center.

Flight control operations will be performed by TRW under the direction of the Marshall flight director and supported by experimenters associated with each HEAO mission.

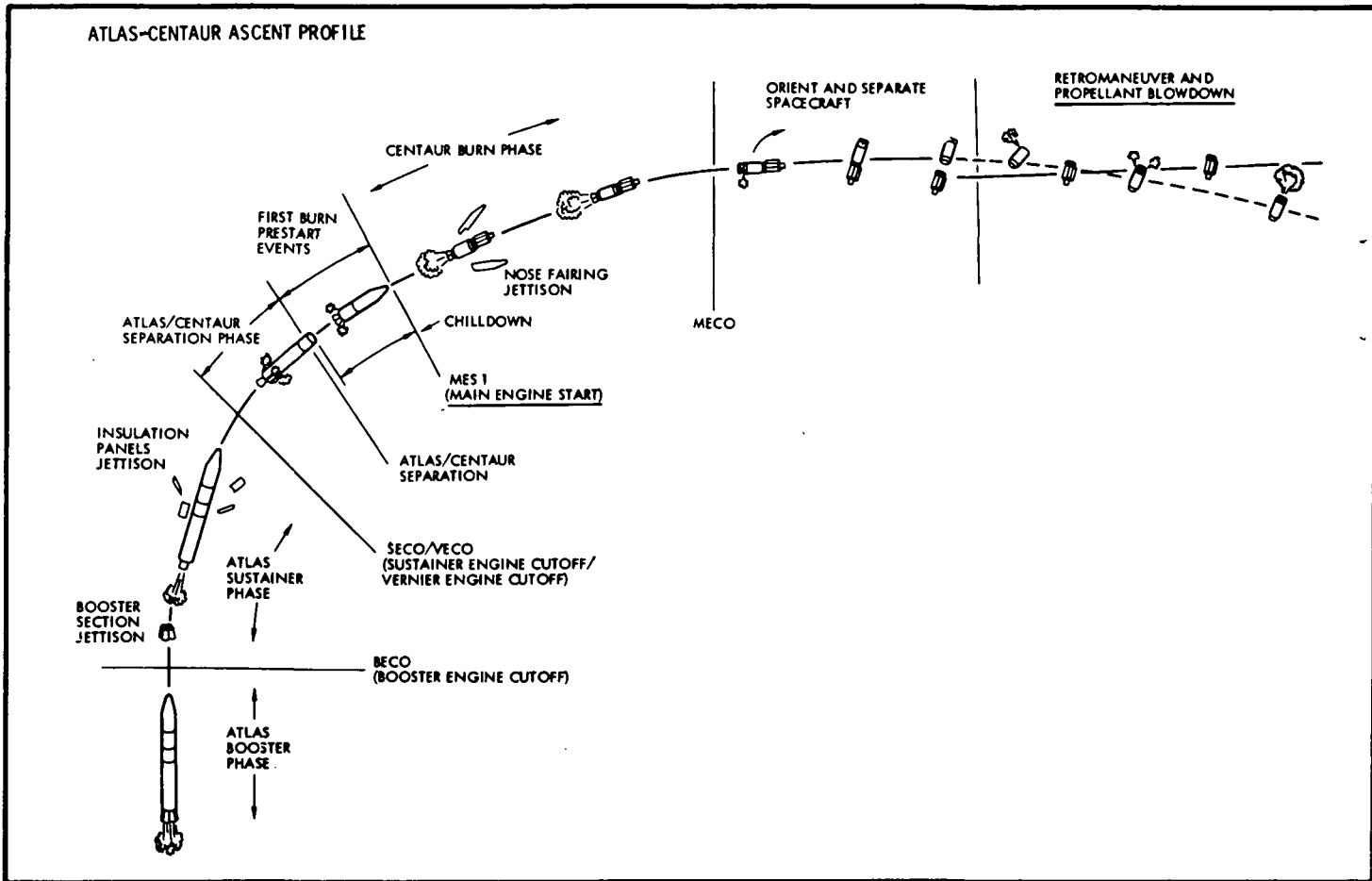
Marshall Center directs the mission planning and establishes the mission support requirements to be met by the worldwide Spaceflight Tracking and Data Network (STDN), the Operations Control Center and Data Processing Center.

Goddard Center will provide and operate these network and mission operations support facilities required by Marshall to control and operate the observatories.

These existing NASA facilities will be prepared and configured as necessary to support the HEAO missions.

The large amounts of data taken by each of the HEAO observatories will be reduced and analyzed by the principal investigators, co-investigators and other scientists from the United States representing various industries, universities and government agencies, as well as other nations. They will report their findings and scientific results in various reports, papers and publications.





HEAO-A ATLAS/CENTAUR SEQUENCE OF EVENTS

EVENT	BASIS	APPROX. TIME FROM LIFTOFF (SEC.)
LIFTOFF ROLL PROGRAM BECO	2-IN. MOTION LIFTOFF + 2 SEC. 5.49 G	0 2-15 140
BOOSTER PACKAGE JETTISON JETTISON INSULATION PANELS SECO	BECO + 3.1 SEC. BECO + 45 SEC. PROP. DEPLETION	143 185 251
SEPARATION MES 1 JETTISON NOSE FAIRING MECO 1	SECO + 1.9 SEC. SECO + 11.5 SEC. MES 1 + 12 SEC. PARKING ORBIT (GUID.)	253 263 275 707
SEPARATION	MECO 1 + 665 SEC.	1372
START RETROMANEUVER PROPELLANT BLOWDOWN START	MECO 1 + 675 SEC. MECO 1 + 3750 SEC.	1382 4397

DESIGN DESCRIPTION, HEAO-A

The HEAO-A observatory consists of a spacecraft equipment module interfacing with a mission-peculiar experiment module. The majority of the spacecraft components are common to all three HEAO missions. Specific mission requirements are met by simply adding or removing modular electronic equipment from the spacecraft.

The spacecraft equipment module structure has a rigid central cylinder which contains the reaction control system propellant tank assembly. A closed octagonal honeycomb structure, to which electronic components are attached, surrounds the central cylinder. These components, which are readily accessible during integration and test, are distributed to maintain thermal equilibrium and mass balance.

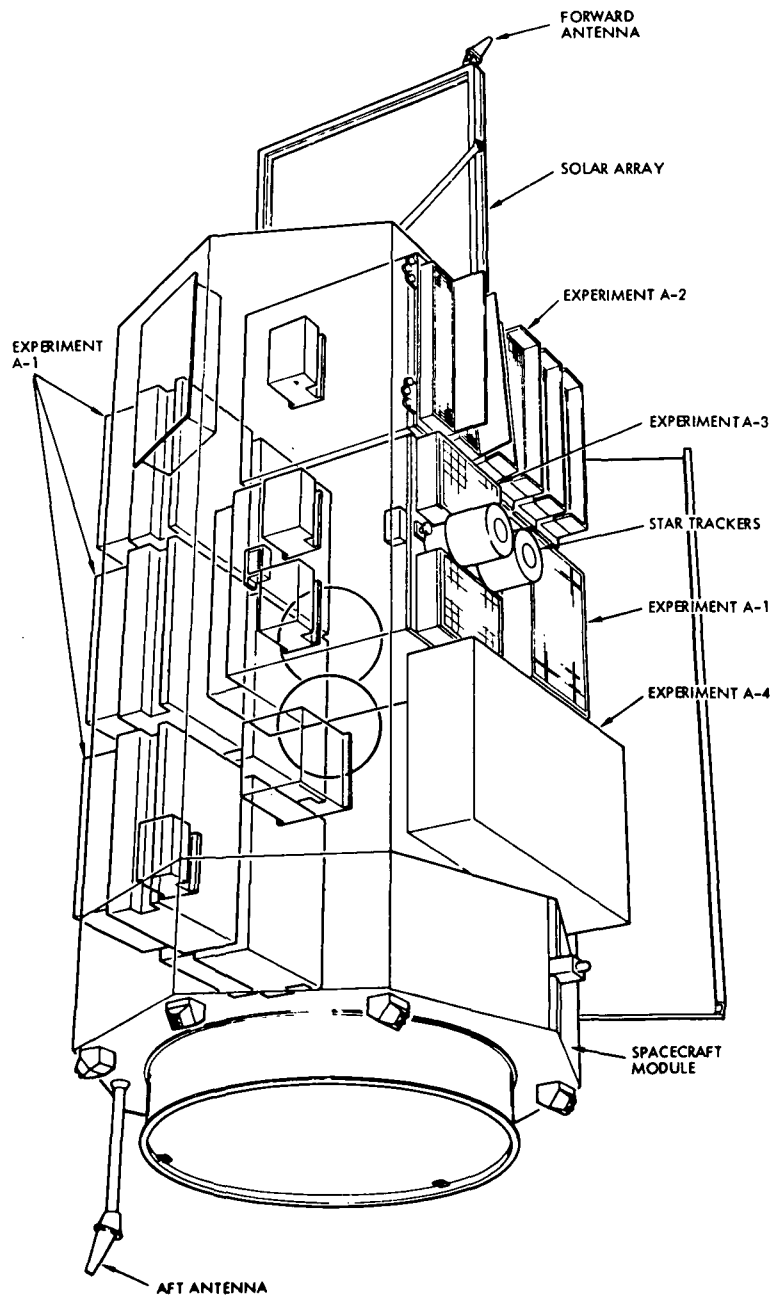
The HEAO-A experiment module structure is six-sided. Two sides are wider than the others to provide for large apertures through which experiments can obtain lateral views of the celestial sphere.

A significant experiment accommodation design feature is experiment independence. Each experiment on HEAO-A is thermally isolated with its own thermostatically controlled heaters. Each has a separate experiment accommodation assembly, which provides power, command and data interfaces without affecting the other experiments. The one exception is the redundant A-3 star tracker, which interfaces through the A-4 experiment accommodation assembly.

To reduce cost and simplify the observatory/launch vehicle interface, Lewis Research Center relaxed certain payload envelope constraints. This permits the use of a single, fixed, aft antenna that extends below the standard envelope and mounting of the reaction control thrusters below the equipment module without cut-outs or other costly structural complexities. It also permits a shorter payload adapter, which lowers the observatory center of gravity and increases allowable payload weight.

The dual-frequency communication system has overlapping hemispherical antenna coverage with a signal-to-noise ratio sufficient to ensure full communications capability under any foreseeable condition during the HEAO missions.

HEAO CONFIGURATION



The command and data handling design satisfies the requirements and provides some growth capacity without system redesign. Use of two existing, flight-qualified tape recorders provides sufficient storage capacity (440 minutes) to accumulate data for more than four orbits without dumping if ground stations are not available when desired.

An onboard digital processor, common to all three observatories, provides extensive, automatic, onboard attitude control. HEAO-A and -C have Sun acquisition and celestial scan modes and HEAO-B has Sun acquisition and celestial point modes. (See following page for description of these modes.) In the event of a critical power loss, a low-voltage sensor automatically commands the observatory into a contingency mode in which simple, hard-wired logic control laws maintain attitude based on Sun sensor data only. This ensures observatory survival until the specific source of difficulty can be determined by ground control.

Orbital altitude has been considered in relation to mission life, radiation environment, launch vehicle capability and specified orbit inclination. The initial orbital altitude provides a 0.98 probability of at least 12 months orbit lifetime above 370 km (230 mi.) for HEAO-A.

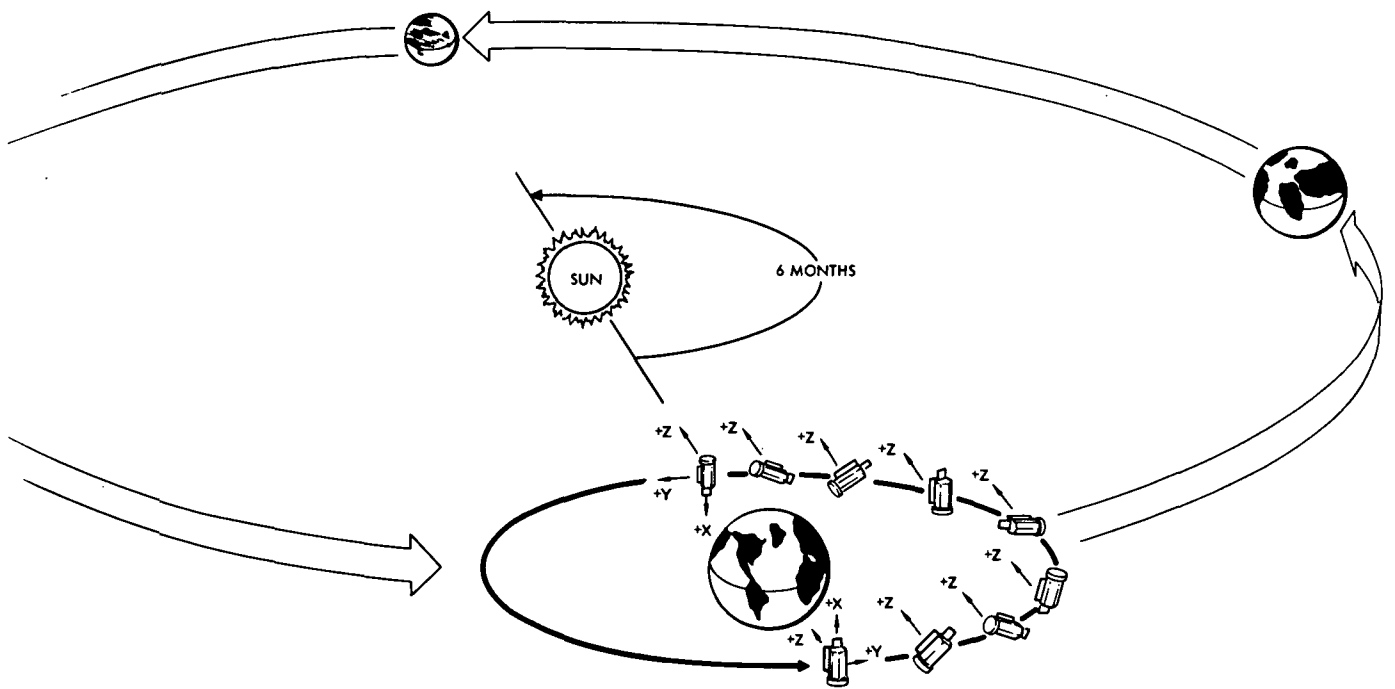
#### MISSION DESCRIPTION, HEAO-A

The HEAO-A will perform an all-sky, X-ray survey from a 22.75-degree inclined, nominally circular 445 km- (275 mi.) orbit.

The scientific objectives of the mission are met by arranging the experiments in the observatory so that the experiment scanning direction is perpendicular to the axis of rotation which is pointed toward the Sun. The movement of this axis as the Earth orbits the Sun provides complete coverage of the celestial sphere in six months.

The observatory will be placed in orbit by an Atlas Centaur D-1A launch vehicle. Diagram on page 20 illustrates an ascent profile requiring a single Centaur firing.

HEAO-A ORBIT/ATTITUDE GEOMETRY

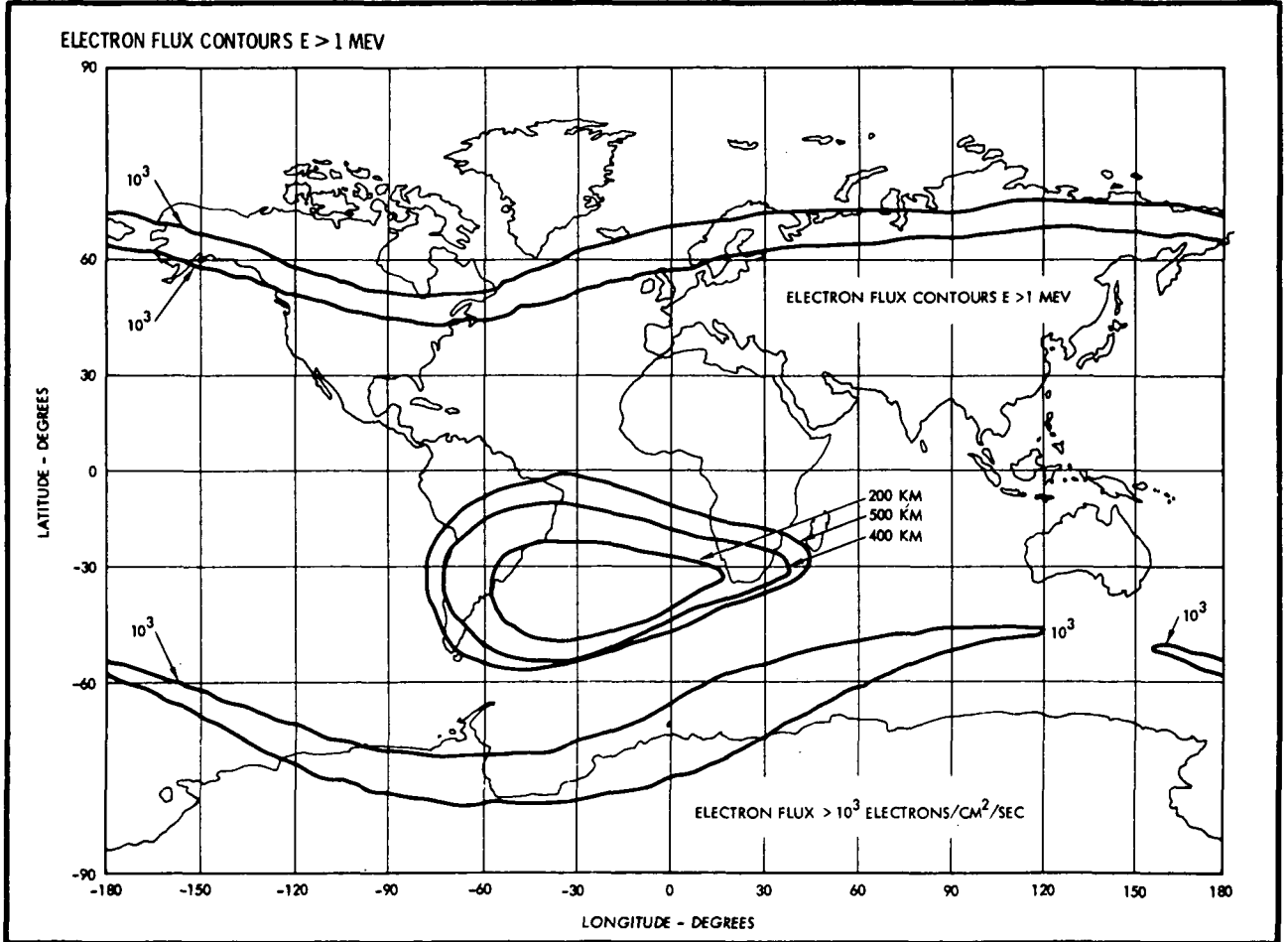


HEAO-A COMPLETES  
A FULL CELESTIAL SCAN  
IN 6 MONTHS

After orbital insertion, the HEAO has three principal phases or modes of operation:

- Activation. This phase includes solar array deployment, removal of separation transients, Sun acquisition and activation of thermal control heaters and standby heaters, if necessary. The observatory subsystems are then activated, calibrated and checked out. During this procedure, the spin axis is held within a seven degree half-cone angle of the Sun line. Experiments are activated and checked out after observatory subsystems are operating properly. The initial data high-voltage turn-on will be an on-off cycle so that experiment operation can be evaluated for corona before final turn-on for routine operation.
  
- Celestial Scan. The scan mode, initiated by ground command, will be the principal operating mode for the six-month mission. The observatory will rotate about the +Z axis. The alignment of the +Z axis toward the Sun will be maintained within a one degree half-cone angle of a chosen reference. Scan rates are selected from 0.03 to 0.1 rpm. The scan rate is maintained with + 10 per cent of the selected values. The observatory can also be placed in the offset scan mode where the +Z axis is offset up to 7 degrees of the Sun line.
  
- Celestial Point. The observatory can be placed in the celestial point mode where three-axis attitude stabilization is provided with attitude sensing derived solely from the gyros. In this mode, the +Z axis of the observatory can be offset up to 7 degrees from the Sun and the scan axis pointed toward specific celestial targets.

The observatory will be controlled in orbit from the HEAO Operations Control Center (HEAO-OCC) at Goddard in Greenbelt, Md. Observatory data stored in the onboard tape recorder will be transmitted to tracking sites at a rate of 128 kbps during realtime station passes. Data from one orbit per day will be relayed to the HEAO-OCC at a reduced data rate and will be used for evaluation by principal investigators.



MISSION INFLUENCE ON DESIGN

The Atlas Centaur D-1A boost vehicle limits the weight and overall size for the HEAO. The environment determines the mechanical design requirements for the observatory and component assemblies.

A basic spacecraft equipment module will be used without significant change for each HEAO. The experiment module, however, will be adapted to the specific requirements of each mission. The HEAO-A configuration is shown on page 18.

HEAO subsystems design and equipment, including experiment interfacing hardware, are similar for all mission. The only exception is the addition of reaction wheels to HEAO-B. The star tracker assembly for HEAO-C is a spacecraft component, whereas on HEAO-A and B it is a component of the experiments. Where possible, equipment designs use modular hardware, so that specific mission requirements can be met by adding or subtracting modules. For example, the command and data handling subsystem (CDHS) hardware is the same for all observatories. Specific mission requirements are satisfied by increasing or decreasing the number of CDHS modules or slices. This approach minimizes development costs and risks.

HEAO-A has a low orbital altitude and inclination to minimize the amount of time spent in trapped radiation zones (see diagram page 22), and thereby increase useful experiment operation time. Minimum initial orbital altitude, approximately 440 km (275 mi.) for HEAO-A, is determined by aerodynamic drag and mission life requirements. The 22.75-degree inclination is the lowest inclination which the Atlas Centaur boost capabilities can accommodate for HEAO.

Orbital altitude affects the aerodynamic and gravity gradient torques imposed upon HEAO, and thus has an influence on the amount of propellant required to perform the mission. The orbit altitude also determines the minimum number of ground stations needed to receive data from the observatory tape recorder. The pattern of recorded data versus time determines the data storage requirements (same as the peak storage requirement).



The low orbit, inclined at 22.75 degrees, produces a nearly constant Sun/eclipse ratio. This in turn fixes the requirements for solar array area and for battery capacity. Battery capacity is also heavily influenced by the large number of eclipse/Sun cycles (5,700 per year) since a low battery depth of discharge will contribute to reliable performance.

The need for scanning while producing electrical power establishes the observatory configuration and the attitude control design. Additionally, the requirement for continuous communications over ground stations while scanning necessitates a dual frequency approach to telecommunications with an antenna at each end of the observatory.

### HEAO-A EXPERIMENTS

The HEAO-A mission includes four scientific instruments as the experiment payload. Three of these (A-1, A-2 and A-3) are designed to study certain attributes of the low to medium energy X-rays from galactic and extragalactic discrete X-ray sources as well as the diffuse X-ray background. The fourth experiment (A-4) extends the observations into the low energy gamma ray region of the spectrum.

These four experiments complement each other for this scanning survey mission. Each is optimized to observe particular features of the radiation in certain energy intervals. Thus, no experiment is compromised by unrealistically broad objectives but rather broad mission objectives are accomplished by these four specialized experiments.

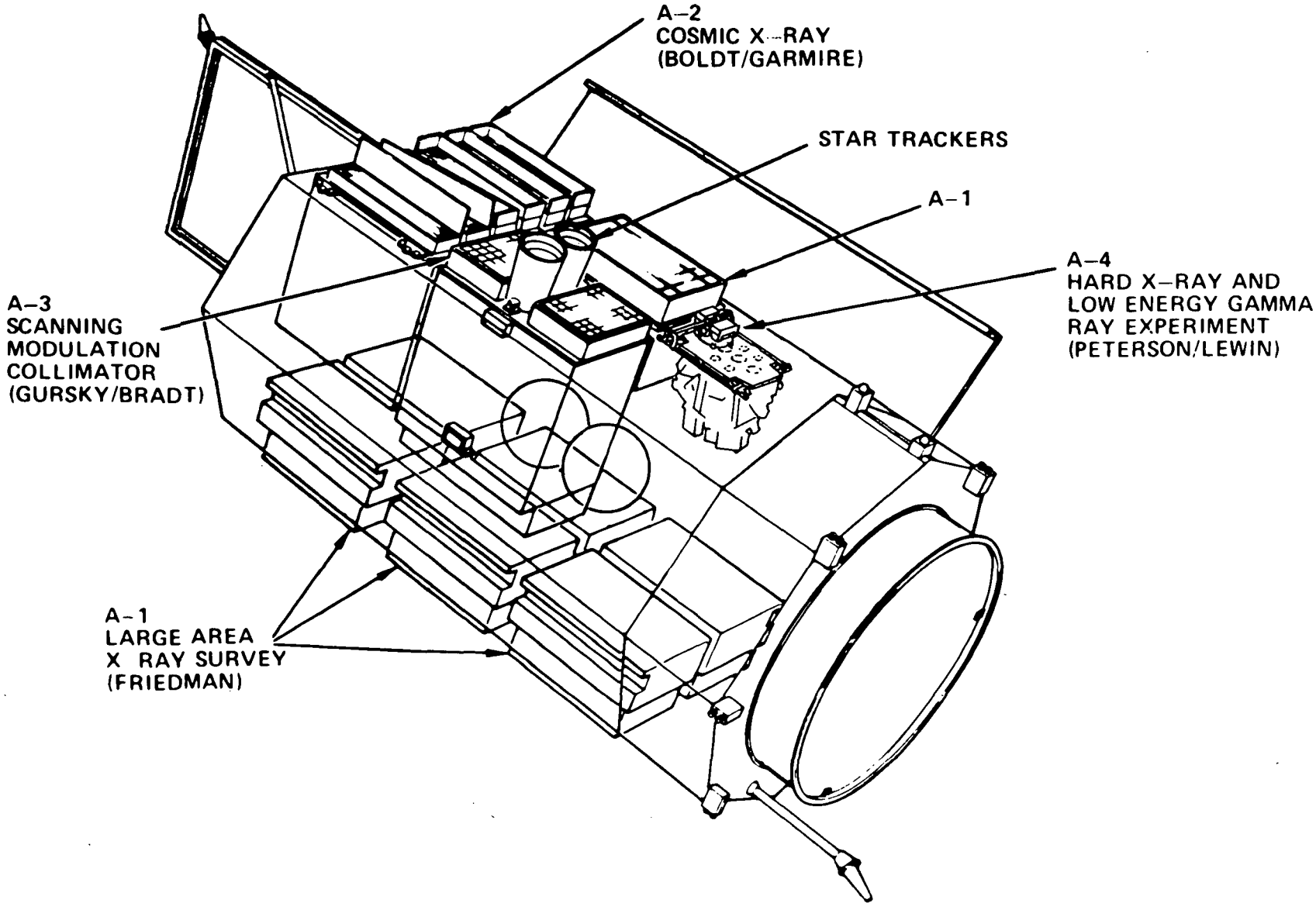
The scope of each HEAO-A experiment is summarized as follows:

#### A-1: The Large X-ray (LAXRAY) Survey Experiment

The principal investigator for A-1 is Dr. Herbert Friedman of the Naval Research Laboratory, Washington, D.C. Hardware was produced by NRL with assistance from New Mexico State University, Las Cruces.

The major purpose of the experiment is to map the celestial sphere for X-ray sources in energy range of 0.15 to 20 keV (thousand electron volts), and to determine energy spectrum, intensity, periodicity or random time structure.

# HEAO-A EXPERIMENTS



The A-1 experiment consists of seven modules of thin window X-ray proportional counters, central electronics, two stellar aspect assemblies and a gas system. It has a data rate of 2.1 kbps and a high data rate of 128 kbps as a spacecraft realtime mode which is operated on command in lieu of tape recorder playback data. It has two fixed telemetry formats which are selectable by ground command.

The multi-module A-1 experiment is the largest of the four instruments being flown on HEAO-A.

#### A-2: Cosmic X-ray Experiment

Principal investigators are Dr. Elihu Boldt of Goddard Space Flight Center and Dr. Gordon Garmire of the California Institute of Technology (CIT), Pasadena. Hardware was produced by Goddard. Assistance on the program was produced by the Bendix Corp., the University of California and CIT.

The major purpose of the experiment is to measure emissions and absorptions of diffuse X-rays in the range of 0.2 to 60 keV and correlate results with radio and visible light ray emission.

The A-2 experiment consists of six collimated detectors of thin window X-ray proportional counters, electronics and a gas system. The A-2 data rate is 1.2 kbps. The telemetry consists of both fixed and programmable formats.

The experiment also measures intensity and energy distribution of discrete X-rays in the same energy range from 0.2 to 60 keV.

#### A-3: Scanning Modulation Collimator Experiment

Principal investigators are Dr. Herbert Gursky of the Smithsonian Astrophysical Observatory at Harvard University and Dr. Hale Bradt of the Massachusetts Institute of Technology. Hardware was provided by American Science and Engineering, Inc.

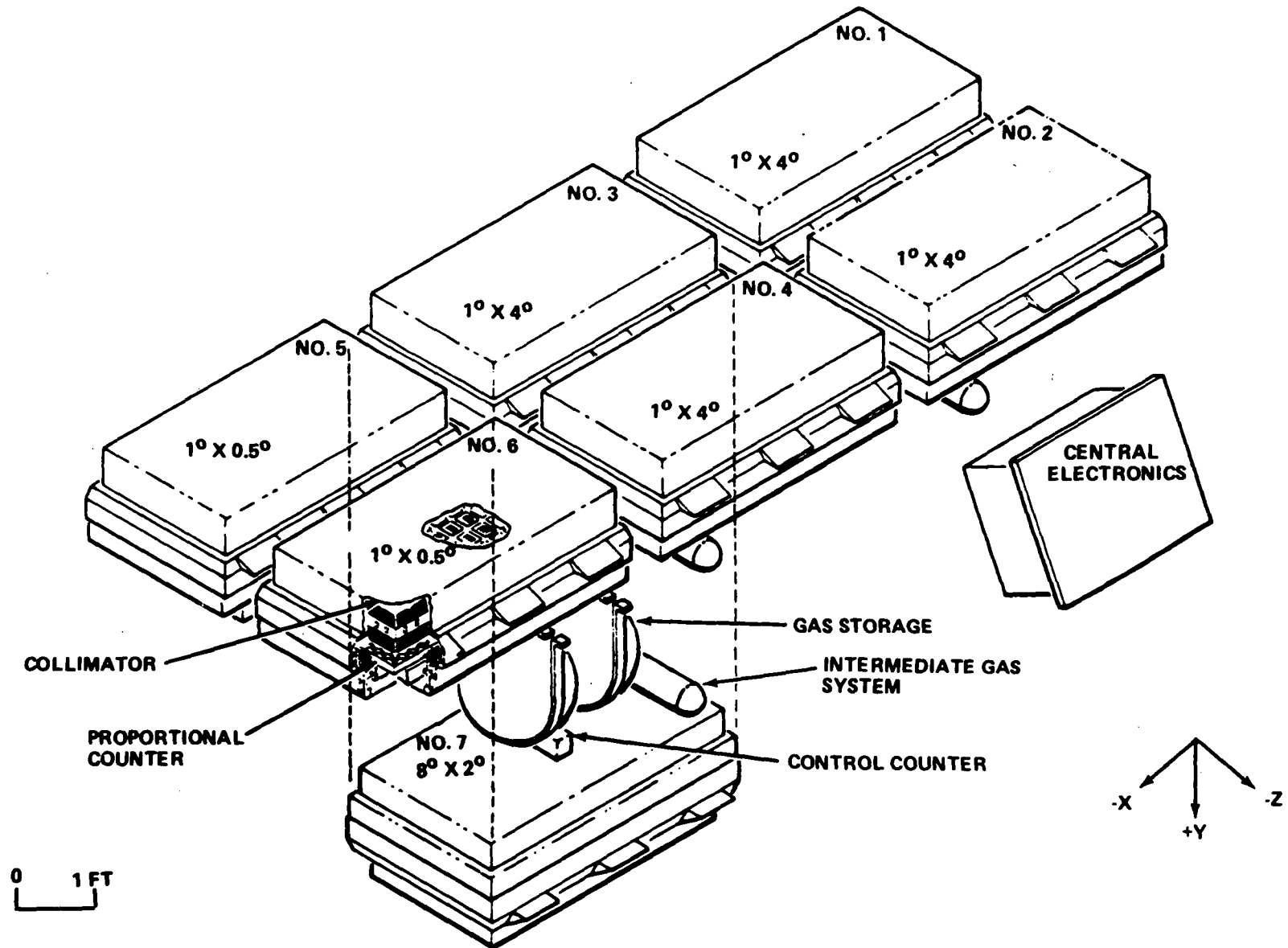
Major purpose of the experiment is to determine precisely the celestial position of selected cosmic X-ray sources in the energy range of 1 to 15 keV and to investigate their size and structure.

The A-3 experiment consists of two scanning modulation collimators with proportional counters, aspects sensors (also used as spacecraft star trackers) and electronics. The A-3 data rate is 1.1 kbps. The telemetry is a fixed format.

# HEAO A-1 EXPERIMENT

## LARGE AREA X-RAY SURVEY

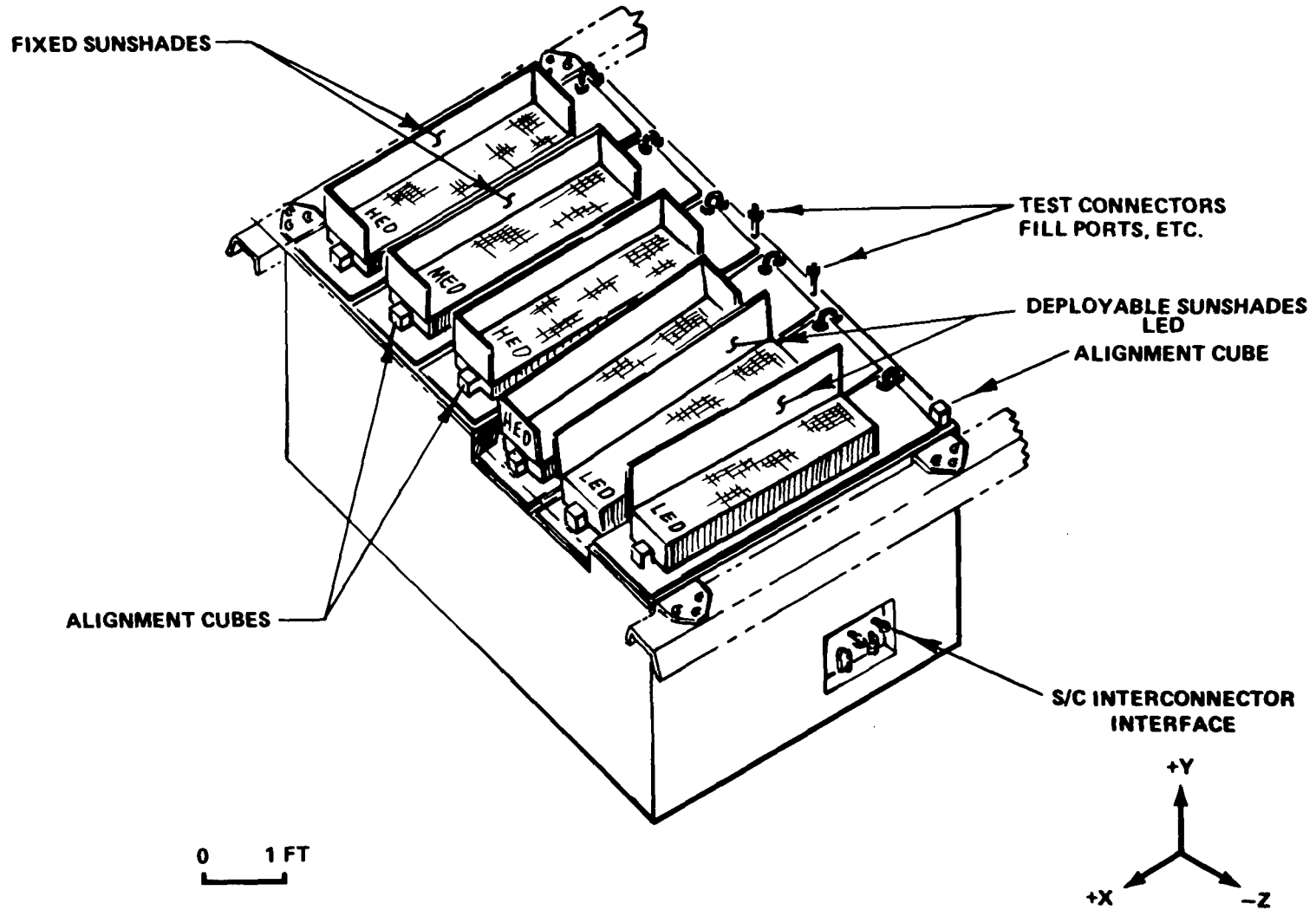
FRIEDMAN



# HEAO A-2 EXPERIMENT

BOLDT/GARMIRE

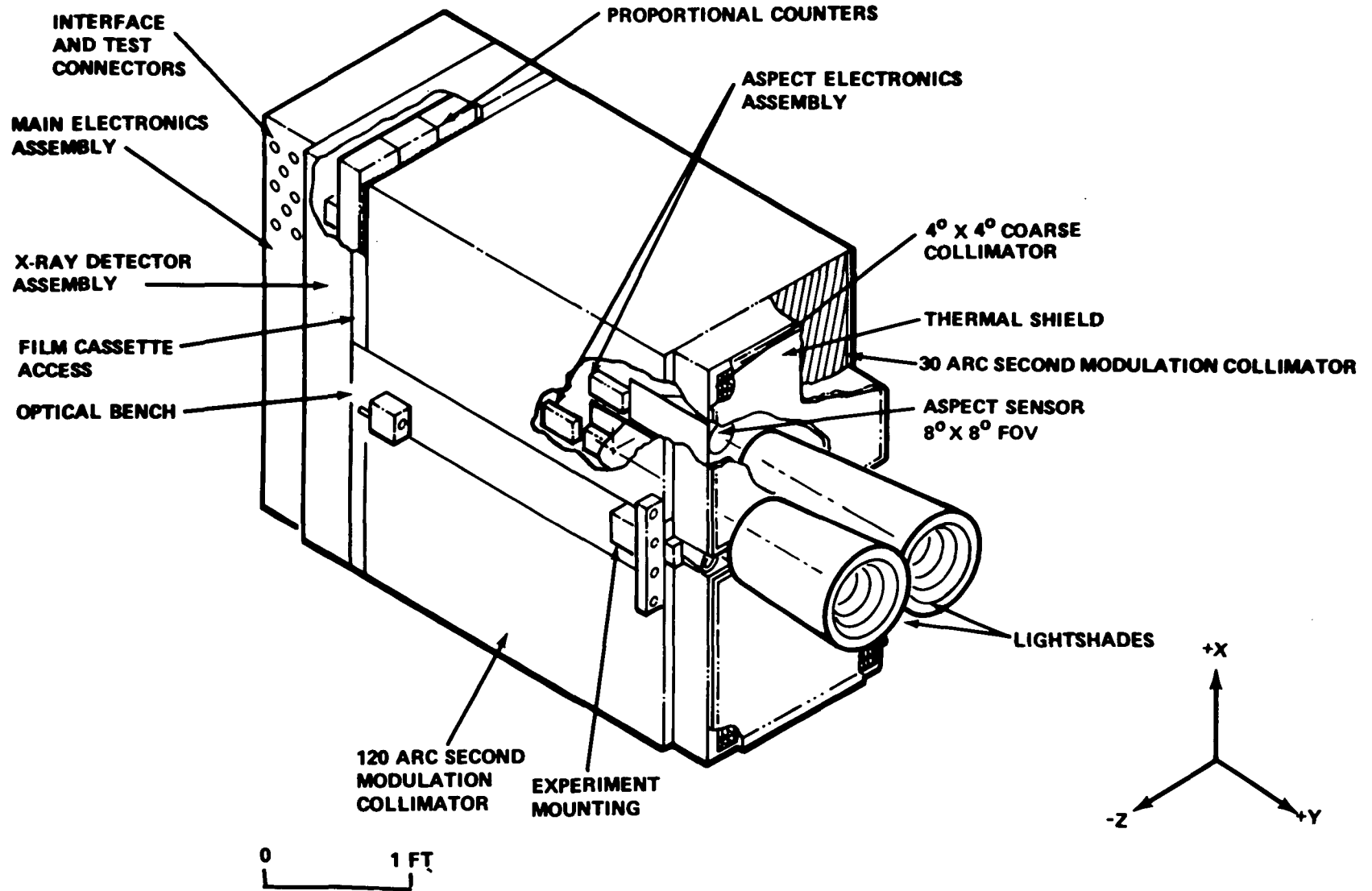
COSMIC X-RAY



# HEAO A-3 EXPERIMENT

## SCANNING MODULATION COLLIMATOR

GURSKY/BRADT



A-4: Hard X-ray and Low Energy Gamma Ray Experiment

Principal investigators are Dr. Laurence Peterson of the University of California at San Diego and Dr. Walter Lewin of MIT. Experiment hardware was provided by UCSD and Time Zero Laboratories of Ball Brothers Research Corp.

The purpose of the experiment is to determine the position, spectrum and time variations, intensity and other properties of certain X-rays and gamma rays in the energy range of 10 keV to 10 meV (million electron volts).

The A-4 experiment consists of a modular array of phoswich scintillator detectors, particle monitors, a digital processor containing power conditioning and data handling electronics. The A-4 data rate is 1.0 kbps. The telemetry consists of both fixed and variable formats.

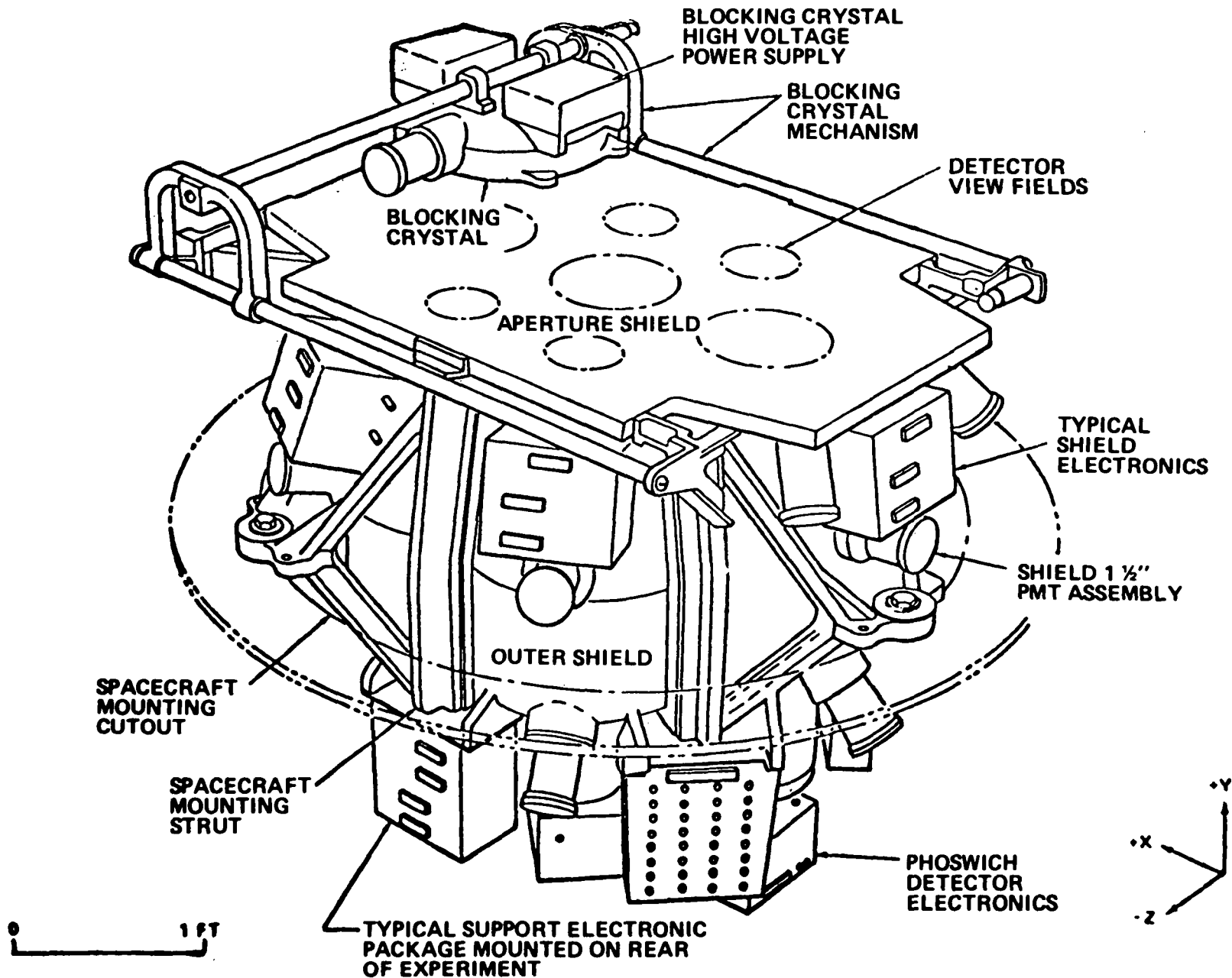
The X-ray detectors themselves for A-1 through A-3 are basically the same, i.e., gas proportional counters. Scintillation counters are the primary detecting elements for the A-4 experiment.

In all four experiments, one is concerned with counting photons of electromagnetic energy. Each experiment, therefore, must provide some means of rejecting the much more intense charged-particle background. This is accomplished by electronic anti-coincidence techniques and/or pulse shape discrimination.

# HEAO A-4 EXPERIMENT

HARD X-RAY AND LOW ENERGY GAMMA-RAY

PETERSON/LEWIN





## ASTROPHYSICAL PHENOMENA

### Pulsars and Neutron Stars

Discovered in 1967, pulsars are stars which emit radio signals in extremely precise pulses. The bulk of available evidence suggests that pulsars may be fast-spinning neutron stars. These are compact bodies of densely packed neutrons (atomic particles having no electric charge), believed to form when a large star burns up much of its fuel and collapses. Containing the mass of a star in a sphere 16 km (10 mi.) in diameter, they are so closely packed that a spoonful of material from the center would weigh a billion tons.

### Black Holes

These are believed to be the final stages in the collapse of a dying star. The star's material is so densely packed -- even more so than a neutron star -- and its gravitational force so great that even light waves are unable to escape from the surface. Black holes have been hypothesized but conclusive observations have not yet been possible.

### Quasars

Astronomers are still baffled by the nature of quasars, but many believe that among observable objects they are the most remote in the universe. They look like stars when viewed through an optical telescope but emit more energy than the most powerful galaxies known. According to calculations, if they are as distant as many astronomers think they are, the total energy emitted by a quasar in one second would supply all of Earth's electrical energy needs for a billion years.

### Radio Galaxies

Located on the fringes of visibility, these emit radio waves millions of times more powerful than the emissions of a normal spiral galaxy. No one knows what these peculiar galaxies are. Several of them broadcast with such power that a sizeable fraction of the nuclear energy locked up in their matter must be going completely into the production of radio waves.

## Supernovae

Supernovae are large stars at their lives' ends whose final collapses are cataclysmic events that generate violent explosions, blowing the surface layers of the stars out into space. There, the materials of the exploded stars mix with other material of the universe (primary hydrogen). Later in the history of the galaxy, other stars are formed out of this mixture. The Sun is one of these stars; it contains the debris of countless others that exploded before the Sun was born.

There is strong evidence that supernovae (exploding stars) and pulsars are X-ray sources at some time in their history and that X-rays have been observed from radio galaxies and quasars.

## BACKGROUND OF HEAO PROGRAM

The Astronomy Missions Board of the National Academy of Sciences has, from the initial concept of HEAO in 1968, been vitally interested in the program. It has been carried as the highest priority program in the astrophysics area.

The HEAO observatory was planned originally as a large satellite 12 m (40 ft.) long, 2 m (7 ft.) in diameter and weighing 9,900 kg (22,000 lb.). The present HEAO is a smaller version weighing some 3,150 kg (7,000 lb.) and being about half the original length.

Among the three HEAO missions, most of the original scientific objectives will be accommodated, although several instruments have been reduced in size.

THE HEAO-A TEAM

NASA Headquarters

Dr. Noel W. Hinners	Associate Administrator for Space Science
Dr. Anthony Calio	Deputy Associate Administrator for Space Science
T. Bland Norris	Director, Astrophysics Programs
Richard E. Halpern	Director, High Energy Astrophysics Payloads
John F. Yardley	Associate Administrator for Space Flight
Joseph B. Mahon	Director, Expendable Launch Vehicles
F. R. Schmidt	Manager, Atlas Centaur Launch Vehicle
Gerald M. Truszynski	Associate Administrator for Tracking and Data Acquisition

Marshall Space Flight Center

Dr. William R. Lucas	Director
Dr. Fred A. Speer	Manager, HEAO Project
Fred S. Wojtalik	Chief Engineer, HEAO Project
Charles H. Meyers	Manager, Spacecraft Office
Joseph B. Jones	HEAO-A Mission Manager

Goddard Space Flight Center

<u>Dr. Robert S. Cooper</u>	Director
Dr. Frank B. McDonald	Project Scientist, HEAO-A Mission
Dr. Elihu A. Boldt	Principal Investigator, Cosmic X-ray Experiment (A-2)
Ronald K. Browning	Manager, Cosmic X-ray Experiment (A-2)
Richard S. Costa	Mission Operations Systems Manager
Tecwyn Roberts	Director of Networks, Tracking and Data Acquisition
Albert G. Ferris	Director, Mission and Data Operations

Kennedy Space Center

Lee R. Scherer	Director
Miles Ross	Deputy Director
Dr. Walter J. Kapryan	Director, Launch Operations
George F. Page	Launch Director, Expendable Vehicles
John Gossett	Chief, Centaur Operation Division
William S. Brosier	HEAO Project Engineer

Lewis Research Center

Dr. Bruce T. Lundin	Director
A. J. Stofan	Director, Launch Vehicles

Other Government Agencies

Naval Research Laboratory

Dr. Herbert Friedman	Principal Investigator, Large Area X-ray Survey Experiment (A-1)
E. T. Byram	Manager, Large Area X-ray Survey Experiment (A-1)

Smithsonian Astrophysical Observatory

Dr. Herbert Gursky	Co-Principal Investigator, Scanning Modulation Collimator (A-3)
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Universities

California Institute of Technology

Dr. Gordon Garmire	Co-Principal Investigator, Cosmic X-ray Experiment (A-2)
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University of California at San Diego

Dr. Laurence Peterson	Co-Principal Investigator, Hard X-ray and Low Energy Gamma Ray Experiment (A-4)
Robert Farnsworth	Manager, Hard X-ray and Low Energy Gamma Ray Experiment (A-4)

Massachusetts Institute of Technology

Dr. Hale Bradt	Co-Principal Investigator, Scanning Modulation Collimator (A-3)
Dr. Walter Lewin	Hard X-ray and Low Energy Gamma Ray Experiment (A-4)

CONTRACTORS

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Scanning Modulation  
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