NASA Facts

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Marshall Space Flight Center
Huntsville, Alabama 35812

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X-ray Calibration Facility

Marshall's X-ray Calibration Facility

The X-ray Calibration Facility at NASA's Marshall Space Flight Center in Huntsville, Ala., is the world's largest, most advanced laboratory for simulating x-ray emissions from distant celestial objects. This facility produces a space-like environment in which components related to x-ray telescope imaging are tested and the quality of their performance in space is predicted.

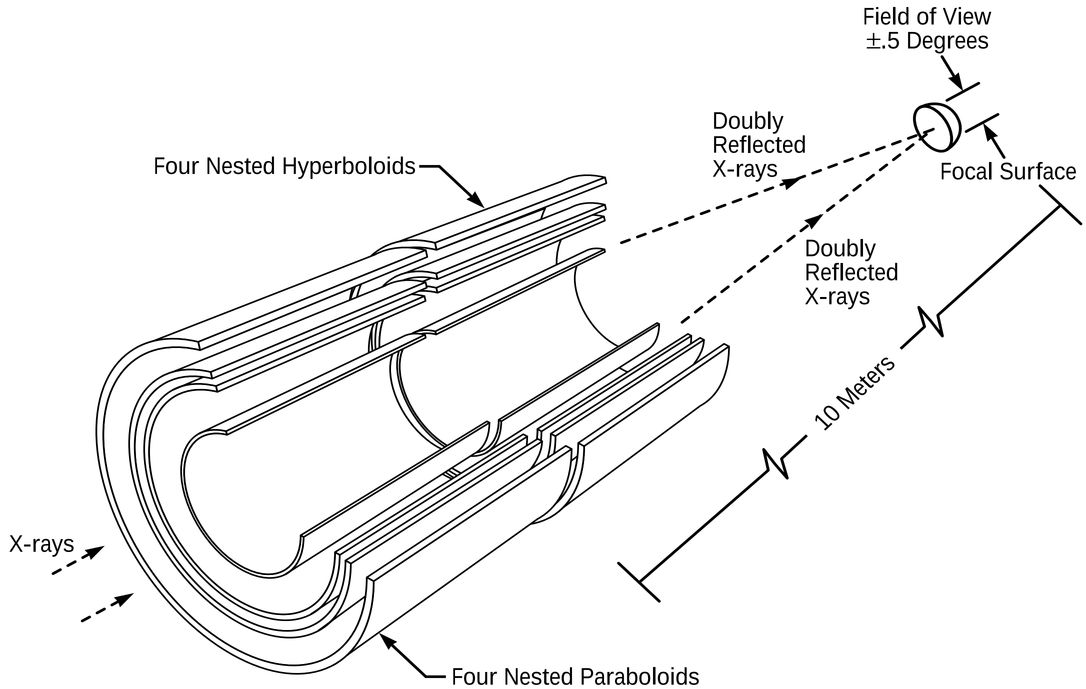
The calibration facility, which includes four buildings located over approximately a one-third square mile area, is presently being used to evaluate optical elements of the Advanced X-ray Astrophysics Facility (AXAF).

The evaluation process will verify that the telescope's mirrors are operating properly and will use familiar x-ray sources to measure the performance of the mirrors under controlled conditions. Measurements obtained during the evaluation process will allow scientists to correctly interpret information received from the orbiting x-ray telescope.

AXAF's Mission

AXAF, a Marshall Center-managed orbiting observatory scheduled for launch in late 1998, will begin a mission of discovery planned to last at least five years. It joins NASA's two other 10,000-pound-plus orbiting observatories—the Hubble Space Telescope and the Compton Gamma-Ray Observatory—examining the wonders of the universe. Newcomer AXAF will scrutinize objects in the invisible energy range of x-ray radiation. It will study the x-ray-producing birth and death of stars and galaxies, as well as investigate some of the most exotic objects in the universe—spinning neutron stars, mighty quasars and mysterious black holes.

AXAF's sister observatory, the Hubble Space Telescope, primarily focuses on visible light range events. Compton examines the invisible portion of the energy range dominated by gamma-ray-producing phenomena.

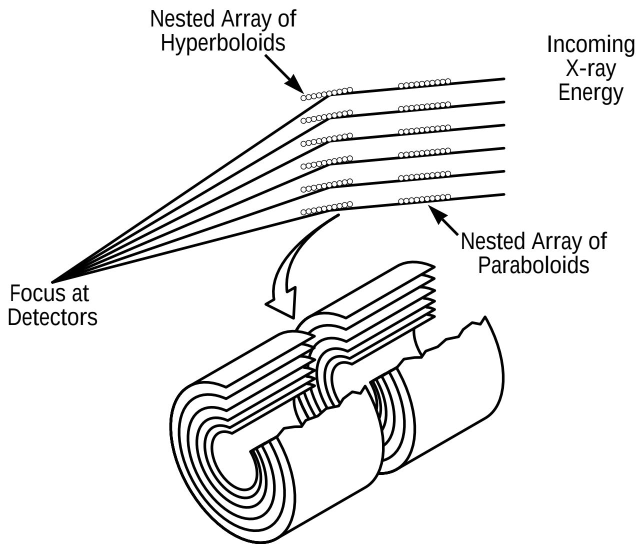


Mirror Elements are 0.8 m long and from 0.6 m to 1.2 m diameter.

When findings compiled from the three observatories are considered together, researchers anticipate being able to answer fundamental questions about the age and size of the universe, the properties of matter under extreme conditions and the fundamental laws of physics.

History

In 1975–1976, the original X-ray Calibration Facility at Marshall was built for testing the Center's High Energy Astronomy Observatory-2 (HEAO-2), also referred to as the Einstein Observatory. At that time, the new x-ray imaging telescope was the most sophisticated ever constructed. Its findings increased the number of known x-ray sources from hundreds to almost 10,000.



Grazing incidence mirrors—Top illustration shows incoming x-ray energy as it is bent by the mirrors toward the focal point; bottom sketch is of nested mirror pairs.

AXAF, with 100-times greater sensitivity than the High-Energy Astronomy Observatory-2, has the power to detect far more x-ray sources than its predecessor.

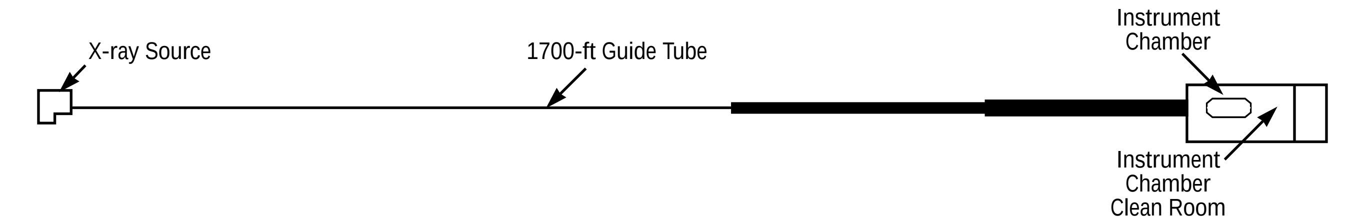
A small-scale, 16-inch prototype of AXAF's mirrors was tested in the original facility in 1989. The demonstration proved that mirrors could be polished to a finish sufficiently smooth to achieve such image precision. In early 1997, NASA will verify that the AXAF mirrors, which are the largest grazing incidence mirrors ever made, have been fabricated just as precisely as the earlier prototype, and the facility will be used to calibrate the telescope for space flight. The largest of the AXAF mirrors is approximately 47.2 inches in diameter.

Soon after completing the 1989 preliminary testing, construction began on improvements to raise the calibration facility to its present standing as a world-class test site. The previous 1,000-foot guide tube, through which x-ray beams are directed from the generation source to the mirrors where the x-rays are focused, was lengthened by 700 feet, with larger diameter tubing. Other facility upgrades included a new building and control room, a much larger instrument chamber and additional x-ray generators.

The Calibration Facility Complex

The complex is composed of four buildings: The x-ray source building where the x-rays are produced; the x-ray detector building in which the intensity and properties of the x-ray beam are monitored; the instrument vacuum chamber building which houses the instrument vacuum chamber, the control room and clean room; and a mid-range building where gas pumping functions are controlled.

In the source building, each of three generators creates x-rays with distinctly different intensities and wavelengths—like those occurring naturally in space—and directs a beam into the guide tube.



Overhead diagram of X-ray Calibration Facility.

As the emissions race through the tube, x-ray scattering is blocked by partitions, or baffles, along the way to the vacuum chamber. X-rays reaching the mirrors inside the test chamber are as nearly parallel as possible, to simulate radiation coming from distant cosmic sources. The rays graze off the mirrors and onto detectors mounted at the focal point. To determine the calibration of the mirror pairs and their focus, the x-ray images produced are analyzed by test engineers and scientists.

X-ray Generators

Test facility x-rays of varying intensities and properties are produced by three generator assemblies in the x-ray source building at the opposite end of the 1,700-foot guide tube from the telescope mirrors in the main building. To simulate rays coming from distant stars, different methods of creating x-rays are used. One method bombards metals such as copper, tin or iron with a stream of high-speed electrons. The test x-rays' exact wavelength is determined by the energy of the electrons and the atomic properties of the specific metal serving as the target.

Diagnostic equipment gives precise readouts on the x-rays' wavelengths and intensities.

Guide Tube

Most celestial objects AXAF will view are millions—even billions—of light years from Earth. With these originating sites so far away and no atmosphere in space to diffuse the x-ray stream, the emissions appear as a single-point source—with the beams absolutely parallel.

Even though Marshall's generators concentrate the x-rays to stream from nearly a single point, after leaving that source the emissions radiate in all directions. The long guide tube is designed to block out diverging rays, so the beams reaching the instrument chamber are virtually parallel.

The stainless steel guide tube is of three diameters—36, 48 and 60 inches. Attached to the x-ray source building is 1,000 feet of 36-inch-diameter tubing that was part of the original X-ray Calibration Facility. When the X-ray Calibration Facility was upgraded, this part of the guide tube was moved. Four hundred feet of 48-inch diameter and 300 feet of 60-inch diameter tube was added.

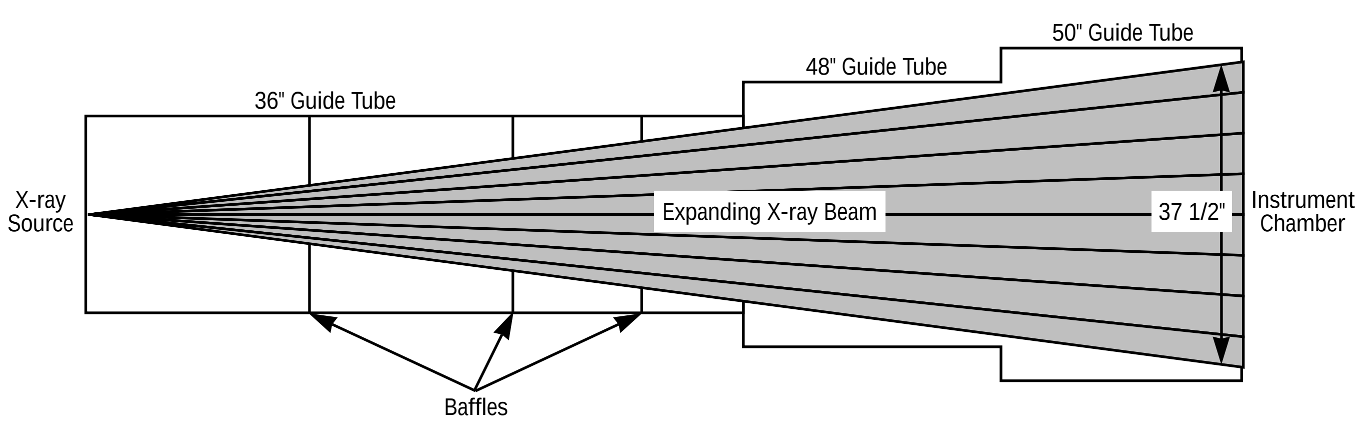
The 1,700 foot guide tube is not level along the Earth's surface. Since the tube is so long, it would actually curve slightly with the Earth's surface if it had been built "level" at all points. So, while it is straight, a level would indicate that the tube is slightly "high" at each end.

The inside of the airtight guide tube must be a vacuum. If even a slight amount of air were present, it would absorb the test x-rays and prevent them from reaching their mirrors.

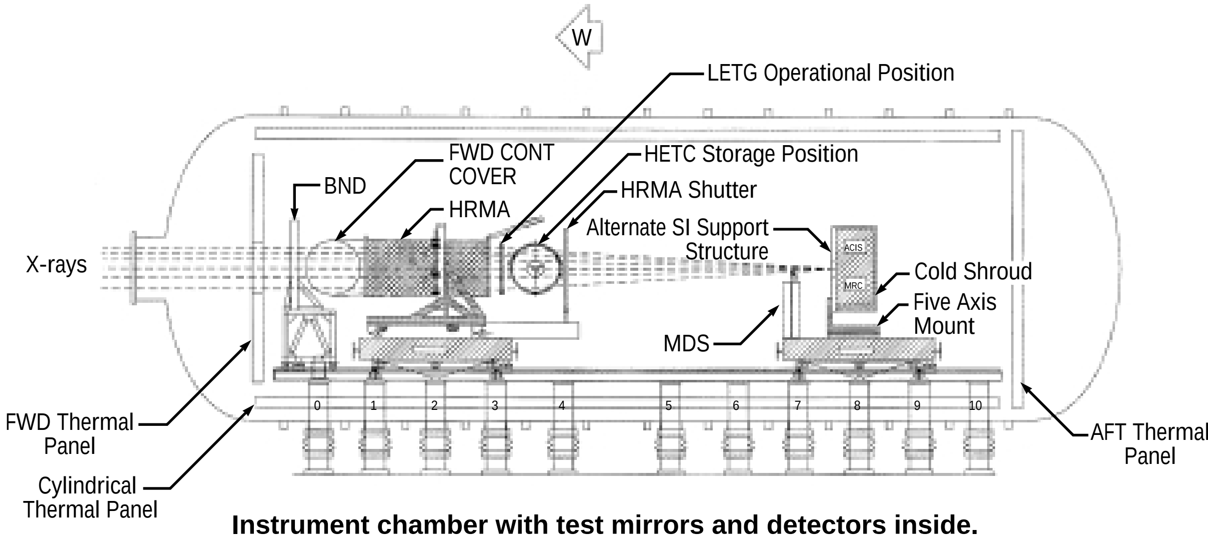
The chamber and guide tube can be isolated by solid gate valves. This allows the guide tube to be used independently of the instrument chamber.

Instrument Vacuum Chamber

The stainless steel, instrument vacuum chamber—the heart of Marshall's X-ray Calibration Facility—is located in the instrument chamber building. It is thermally controlled, capable of simulating widely diverse temperatures within a vacuum. It can be heated to evaporate or "bake-out" contaminated materials or cooled with liquid nitrogen. Researchers can evaluate how hardware will operate under extreme temperature conditions, ranging from –40 to 160 degrees Fahrenheit, in the vacuum environment of space.



Expanding X-ray beam as it travels through guide tube (proportions exaggerated).



Instrument chamber with test mirrors and detectors inside.

The chamber's interior test volume measures 60 by 20 feet (18 by 6 meters)—large enough to hold anything that will fit into the Space Shuttle's cargo bay.

Opening off the chamber is the "clean room," where air is constantly cycled through filters to remove dust and impurities that might contaminate the telescope instruments. It is a Class 2000 clean room. No more than 2,000 dust particles, 0.5 micron or smaller, are contained in a cubic foot of air—a five-fold improvement since the facility was upgraded.

To protect the carefully aligned optics from vibrations, the instrument vacuum chamber is mounted directly to the building's floor. The optical supports inside the chamber are supported independently by 22 stainless steel pillars. The pillars pass through the chamber's wall. Between the building floor and a separate, 5-foot-thick concrete foundation that rests on 2 feet of compact sand, is an isolating air gap. The support pillars, air gap, concrete foundation and compact sand form a seismic isolation pad.

Separating the pillars and chamber are 22 bellows which maintain the vacuum seal and reduce the transmission of any vibration from the chamber to the optics inside.

The evaluation of AXAF's four mirrors and science instruments will begin in December 1996 and be completed in May 1997. The mirrors and detectors used to test them will be assembled in the clean room on mounting platforms, called test benches, and then rolled inside the chamber. Next, the mirrors will be aligned with the x-ray source at the end of the guide tube—one-third of a mile away.

Vacuum Pumps

Using a series of vacuum pumps, the instrument chamber, guide tube and x-ray generator are pumped almost totally free of air molecules. While more traditional mechanical pumps do most of the work, special high-vacuum pumps finish the job. The surfaces of these pumps are chilled to –440 degrees Fahrenheit. They literally attract and trap the remaining molecules of air.

Achieving a hard vacuum in the chamber takes about four hours. However, to bring the temperature to the level and stability desired requires 20 to 24 hours.

After this process, the final vacuum is two ten-billionths of the pressure outside—very similar to the vacuum in space.

For the AXAF optics tests, the chamber's temperature will be about 50 degrees Fahrenheit—slightly below the internal temperature that will be maintained in the telescope as it orbits the Earth.

Once a hard vacuum is achieved, it can be maintained indefinitely by test crews working 24 hours a day.

Test Control

Engineers control and monitor test activities from a control room with a three-part, state-of-the-art graphic panel.

Alarms at critical locations in the facility are available to alert controllers to problems. Near the control panel, information-gathering electronic and computer equipment is set up for scientists evaluating the mirrors and detectors.

During a typical test series, x-rays are generated for specified periods. Then these trials are suspended while scientists analyze their findings, but the vacuum in the chamber is usually maintained. Testing can be resumed if scientists consider further evaluation necessary.

The X-ray Calibration Facility construction was accomplished by Universal Construction Company of Huntsville.

Tests are being conducted by the X-ray Calibration Systems Division of Marshall's Systems Analysis and Integration Laboratory, supported by the contractor teams and other laboratories of the Marshall Science and Engineering Directorate.

After AXAF system testing concludes, the X-ray Calibration Facility will continue to serve as a valuable national resource for evaluating x-ray telescope mirrors, *International Space Station* elements and other NASA flight hardware.