International X-Ray Observatory (IXO)

Outlook

- International X-ray Observatory (IXO) formed by merging concepts from U.S. Constellation-X and European XEUS; IXO supersedes these two programs
- IXO will not be ready for launch until the early 2020s, well beyond the 10-year forecast period
- NASA and JAXA could drop out of the program, with ESA taking the lead role

Orientation

Description. The International X-ray Observatory (formerly Constellation-X) is a follow-on to the Chandra X-ray Observatory (CXO) program.

Sponsor. NASA's Goddard Space Flight Center is directing the IXO study effort. The Smithsonian Astrophysical Observatory was a key partner with GSFC in the IXO mission's development. ESA and JAXA are also involved with the program.

Status. The IXO is currently in pre-formulation doing low-level technology development. It is a joint X-ray observatory with participation from NASA, the European Space Agency (ESA), and the Japanese Aerospace Exploration Agency (JAXA), though ESA may assume a larger role in the future.

Total Produced. None

Application. The IXO is a next-generation X-ray observatory that will enable high-fidelity investigations to validate Einstein's theory of general relativity. This will be done through observations of galactic X-rays, black holes, galaxy formations, and dark matter.

Price Range. IXO is expected to cost approximately $1.74 billion in FY07 dollars.

Contractors

Prime

Goddard Space Flight Center, GSFC	http://www.nasa.gov/centers/goddard/home/index.html, NASA Bldg 03 Rm S22 M/S 6, Greenbelt, MD 20771-0001 United States, Tel: + 1 (301) 286-8955, Prime

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Technical Data

Design Features. The NASA Goddard Space Flight Center is involved in preformulation studies centered on a follow-on mission to the Chandra spacecraft. Previously called the Constellation X-ray Mission, or Constellation-X, the program, now called the International X-ray Observatory, is derived from merging two previous mission concepts: the Next-Generation X-ray Observatory and the Large Area X-ray Spectroscopy Mission. The following technical data is from NASA Goddard Space Flight Center IXO documentation:

The IXO will make observations at high spectral resolution, 100 times more sensitive than Chandra. The mission will address many fundamental astrophysics questions, such as the origin and distribution of the elements from carbon to zinc, the formation and evolution of clusters of galaxies, the validity of general relativity in the strong gravity limit, the evolution of super-massive black holes in active galactic nuclei, the details of supernova explosions and their aftermath, and the mechanisms involved in the heating of stellar coronae and driving of stellar winds.

As originally conceived, the mission would feature four spacecraft, teamed to produce an unusually large focal plane. The mission was rebaselined in late 2006 as costs were growing on the project.

IXO is now going forward as a single 6,300-kilogram spacecraft consisting of four separate modules: Optics Module, Spacecraft Module, Deployment Module, and Instrument Module.

The Optics Module (OM) includes the flight mirror assembly (FMA), deployable sunshade, and the star tracker/TADS periscope assembly. The Optics Module interfaces the FMA to the fixed metering structure.

The Spacecraft Module accommodates the bulk of the spacecraft subsystems, including the power, propulsion, radio frequency communications, guidance, navigation and control, and avionics. The electronics boxes, reaction wheels, and propulsion tanks mount to a nine-sided honeycomb deck. The 6.6 m × 3.3 m diameter cylindrical composite metering structure accommodates the solar arrays, thrusters, and high-gain antenna.

The Deployment Module (DM) is the portion of the metering structure that is extended on orbit. It consists of three identical ADAM masts, similar to those on NuSTAR. High-precision deployment accuracy and repeatability was proven with the 60-meter ADAM masts used in space on SRTM. As the masts deploy, they pull with them wire harnesses and a pleated Whipple Shield-type shroud assembly that shields the instruments thermally and from stray light, and provides effective protection against the micrometeoroids.

The Instrument Module (IM) accommodates the instruments. All detectors except the XGS camera mount to the Movable Instrument Platform (MIP), which is comparable to moving platforms on Chandra and ROSAT. Focus and translation mechanisms, coupled with a Chandra-heritage Telescope Aspect Determination System (TADS) for flex body metrology, assure the centering of the detectors in the converging X-ray beam and accurate attitude reconstruction.

The following instruments are on the MIP: XMS, WFI, HXI, Xpol, and HTRS.

The X-ray Microcalorimeter Spectrometer (XMS) on IXO features high-spectral resolving power in a large array to provide non-dispersive imaging spectroscopy over a broad energy range. The driving performance requirements are to provide spectral resolution of 2.5 eV over the central 2×2 arcmin in the 0.3-7.0 keV band, and 10 eV over the entire 5×5 arcmin field of view.

XMS spectroscopic capability will provide extraordinary sensitivity to absorption features, via iron Kα and many other metal species, and will be uniquely powerful at revealing conditions in the immediate vicinity of the supermassive black holes, including black-hole-driven winds. Detection of powerful winds in active galactic nucleus hosts at the major epoch of galaxy formation is the smoking gun of feedback. Complex spectroscopy will reveal the velocity, column density, metallicity, and ionization structure of the outflows for detailed comparison with physical models, which are at present completely unconstrained.

The IXO Wide Field Imager (WFI) is an imaging X-ray spectrometer with a large field of view (18 arcmin × 18 arcmin). It obtains images and spectra in the 0.1-15 keV band, with nearly Fano-limited energy resolution (50 eV at 300 eV; < 150 eV at 5.9 keV). A 100 µm × 100 µm pixel size, corresponding to 1" oversamples the beam, minimizing pile up. The Wide Field Imager and Hard X-ray Imager (HXI) are two detectors incorporated into one instrument, with the HXI mounted directly behind the WFI.

WFI/HXI Layout: The WFI soft X-ray Active Pixel Sensor (APS) is in front of the HXI CdTe detector.

The WFI's key component is the DEPFET (Depleted P-channel Field Effect Transistor) Active Pixel Sensor (APS). Each APS pixel has an integrated amplifier allowing the charge produced by an incident X-ray photon to be read directly from each pixel. This allows on-demand pixel readout, reduces readout noise, and offers radiation hardness against charge transfer inefficiency, all major advantages compared to CCDs.

The HXI extends IXO´s energy coverage to 40 keV, observing simultaneously with the WFI.

Comprising roughly one million pixels on a sensitive area of 10 cm × 10 cm, the WFI will be the world's largest monolithic detector for X-ray imaging and spectroscopy.

The Hard X-ray Imager (HXI) is a 7 cm × 7 cm wide Double-sided Strip Cadmium Telluride detector (DS-CdTe). Its 0.5 mm thickness affords nearly 100 percent detection efficiency for 40 keV X-rays.

The HXI will be mounted beneath the WFI. It will extend the energy coverage up to 40 keV and enable simultaneous observations with both instruments. HXI should have an energy resolution better than 1 keV (FWHM) at 40 keV and cover a field of view (FOV) of 8 arcmin × 8 arcmin.

The IXO X-ray Grating Spectrometer (XGS) is a wavelength-dispersive spectrometer that will provide high spectral resolution in the 0.3-1 keV band. Its key performance requirements are spectral resolution (l/Dl) of 3,000 (FWHM) and effective area larger than 1,000 square centimeters across its operating band. This spectrum in the soft X-ray band can be used to determine the properties of the warm-hot-intergalactic medium, outflows from active galactic nuclei, and plasma emissions from stellar coronae.

The XGS will intercept and disperse a fraction of the beam from the mirror onto a CCD camera. It will operate simultaneously with the observing MIP instrument and collect instrumental background data that can occur when an instrument is not in the focal position.

To achieve high-resolution spectroscopy, the XGS will consist of an array of wavelength-dispersive diffraction gratings with a fine pitch of 5,000 lines/mm or more. This will intercept the converging X-ray beam exiting by the FMA and disperse it to a series of charge-coupled device (CCD) detectors. The CCD energy resolution will then separate the spatially overlapping spectral orders.

The High Time Resolution Spectrometer (HTRS) is proposed as a focal-plane instrument to match the top-level mission requirement to observe a one Crab X-ray source with less than 10 percent deadtime. It will perform high precision timing measurements of bright X-ray sources. It can observe sources with fluxes of 106 counts per second in the 0.3-10 keV band without performance degradation, while providing moderate spectral resolution (200 eV FWHM at 6 keV).

The HTRS science will be focused on the Matter under Extreme Conditions science theme. HTRS targets are galactic compact objects powered by a) accretion, over a wide rage of accretion rates such as X-ray novae and microquasars, b) magnetic energy over a wide range of magnetic fields from millisecond pulsars to magnetars, and c) internal energy over a wide range of ages such as cooling neutron stars.

HTRS is designed as a high-count-rate instrument, capable of dealing with Crab-like count rates (several 100,000 cps) that offer a complementary tool for probing strong gravity – and, more generally, accretion – in the vicinity of accreting black holes and neutron stars, through simultaneous fast X-ray timing and spectroscopy. It also offers a unique tool to probe matter at supra-nuclear densities.

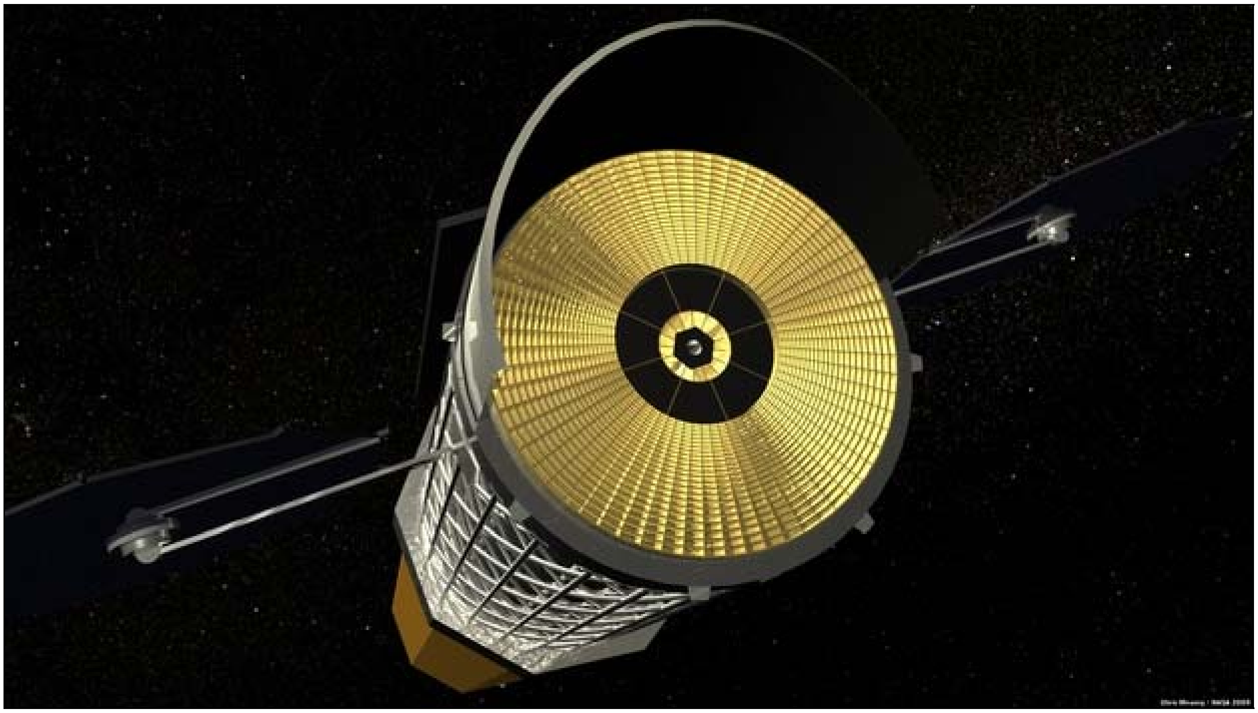
The X-ray Polarimeter (XPOL) is an imaging polarimeter, with polarization sensitivity of 1 percent for a source with a 2-10 keV flux of 1mCrab in a 105 s exposure. XPOL utilizes a fine grid Gas Pixel Detector to image the tracks of photoelectrons produced by incident X-rays and determine the direction of the primary photoelectron, which conveys information about the polarization of the incoming radiation. XPOL also has spectrographic capabilities with a resolution of $E/\Delta E$ of ~5 at 6 keV and timing information at few ms level. The FOV is of 2.6 arcmin × 2.6 arcmin and the spatial resolution is a good match to the point spread function (PSF) of the mirrors.

Data collected by the XPOL will mainly contribute to high-energy astrophysics such as the study of matter under extreme conditions, structure and physics of jets, and also to test theories of quantum gravity.

The unique observatory is to be deployed at the second Lagrange Point, or L2 – one of five areas in our solar system where an object experiences equal gravitational attractions from the Sun and Earth.

Variants/Upgrades

The International X-ray Observatory is being modeled after the Keck Observatory (two optical telescopes positioned high atop Mauna Kea in Hawaii). Each Keck telescope is 10 meters wide and can be used in unison to observe the same light. Both Keck and the International X-ray Observatory have superior collecting areas, or apertures, for analyzing the components of light. Both serve as complements to the Hubble Space Telescope and the Chandra X-ray Observatory.



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Source: Chris Meaney/NASA

Program Review

Background. In 1998, NASA's Goddard Space Flight Center awarded cooperative agreements to TRW (now Northrop Grumman) and Ball Aerospace for a five-month study contract involving the Constellation X-ray Mission. NASA contributed about $110,000 to each contractor. The contractors then established mission development teams to participate in defining the mission architecture for Constellation-X.

The space agency also picked seven institutions to share $20 million for technology development projects related to Constellation-X:

- Stanford University, Stanford, California – tungsten transition-edge sensors for soft X-ray detector
- Naval Research Laboratory, Washington – silicon strip detectors for the hard X-ray telescope
- Goddard Space Flight Center, Greenbelt, Maryland – a 2 eV calorimeter spectrometer
- Columbia University, New York, New York – reflection grating spectrometer and CCD camera
- Lawrence Livermore National Laboratory, Livermore, California – closely packed array of X-ray micro-calorimeters with multilayer absorbers
- Northwestern University, Chicago, Illinois – hard X-ray optics
- California Institute of Technology, Pasadena, California – hard X-ray telescope.

Announcing the International X-ray Observatory (IXO)

In May 2008, ESA and NASA established a coordination group involving ESA, NASA, and JAXA, to explore establishing a joint mission merging the ongoing XEUS and Constellation-X efforts. The coordination group met twice, first in May 2008 at ESTEC, then in June 2008 at the Center for Astrophysics. As a result of these meetings, a joint understanding was reached by the coordination group on a proposal to proceed with developing an International X-ray Observatory (IXO). Under the proposal, the coordination group suggested the start of a joint study of IXO. A single merged set of top level science goals and derived key science measurement requirements were also established.

The starting configuration for the IXO study will be a mission featuring a single large X-ray mirror and an extensible optical bench with a 20-25-meter focal length, featuring an interchangeable focal plane. The instruments to be studied for the IXO concept will include an X-ray wide-field imaging spectrometer, a high spectral resolution non-dispersive X-ray spectrometer, and an X-ray grating spectrometer. Also for evaluation is the allocation for further payload elements with modest resource demands. The study will explore how to enhance the response to high-energy X-rays. The IXO study supersedes the ongoing XEUS and Constellation-X activities.

At a bilateral ESA-NASA meeting on July 15 and 16, 2008, in Annapolis, this plan was endorsed by David Southwood, the ESA director for the Science and Robotic Exploration Program, and Ed Weiler, the NASA associate administrator of the Science Mission Directorate. A letter signed by Jon Morse (NASA HQ Astrophysics Division director) and Fabio Favata (ESA coordinator for Astronomy and Fundamental Physics Missions) features the details of the plan.

As part of this plan, the agencies will establish an IXO coordination group (IXO-CG) charged with defining the science requirements for the IXO study, supervising the IXO study activities, and providing input to the agencies.

In April 2011, ESA decided to chart a new way forward with its large-class Cosmic Vision programs. Instead of working closely with NASA and JAXA, ESA will develop scaled-down programs that will cost less and require less help from other countries. This is a result of the budget difficulties that are affecting ESA's partners. ESA will decide the fate of these programs in February 2012.

Timetable

Year	Major Development
2008	IXO announced
2009	Chandra X-ray Observatory design life expiration
2021	Possible launch of IXO

Forecast Rationale

The International X-ray Observatory (IXO) will study a number of critical astrophysical issues such as black holes at the edges of the universe and the origin and content of the universe. New technologies will allow the IXO to accomplish these tasks, which exceeded the capabilities of previous X-ray observatories.

While the scientific value of the IXO has been well established, price and budget restrictions are threatening the program. In August 2010, the U.S. National Research Council recognized the importance of the IXO but fell short of proposing it as a top priority for NASA over the next 10 years. NASA is also faced with a tight budget environment, as Congress looks at ways to reduce spending, while the costs of other programs increase.

In response to the budget issues confronting its partners, ESA has delayed making a decision on whether to proceed with IXO. IXO is one of the programs competing under the Cosmic Vision 2015-2025 L class mission. Instead of relying on NASA and JAXA to fund a large-scale effort, ESA could lead a smaller, and cheaper, effort. The modified IXO would cost about EUR800 million ($1.13 billion), and ESA would provide the majority of the funding. ESA is expected to decide on the future of IXO in February 2012.

At this time, Forecast International is not producing a **Ten-Year Outlook** chart with this report since the IXO is not scheduled for delivery until after the 10-year forecast period. Under current ESA plans, the IXO could launch in the early 2020s.

Ten-Year Outlook

No **Ten-Year Outlook** chart has been provided because the IXO is expected to launch beyond the forecast period.

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