The International X-ray Observatory (IXO) 
Mission Concept

1 – Introduction

2 – IXO mission requirements and spacecraft configuration
   – Instrument module
   – Service module
   – Mirror assembly

3 – Summary
International X-ray Observatory (IXO): terms of reference

A proposal for a joint ESA/JAXA/NASA study of an International X-ray Observatory was accepted at an ESA-NASA bilateral meeting on 2008, July 14, with JAXA concurrence. Input elements to IXO configuration include:

1 - A single large X-ray mirror assembly compatible with both pore optics and slumped glass technology

2 - An extensible optical bench to reach F=20 to 25m + ways to maximise Aeff above 6 keV

3 - Instruments include a wide field imager, a high resolution non-dispersive spectrometer, an X-ray grating spectrometer + instruments with modest resources

4 - The IXO concept must be compatible with both Ariane 5 and Atlas V 551 launchers.

→ The IXO concept will be the input to the US decadal survey and ESA Cosmic Vision selection process
IXO assessment study overview (preparation for ESA CV selection)

1) Preparation phase: (mid-July 2008 → mid-October 2008)
   - Building of an international ESA-JAXA-NASA collaboration scheme
   - Definition of the preliminary science requirements and draft payload instrumentation
   - IXO mission concept studies by NASA and JAXA

2) IXO Phase 0 study at ESA: (CDF1: Oct. 9th → Nov. 11th 2008; CDF2 :Feb. 4th → Mar. 18th 2009)
   → Definition of a mission concept
   → Consolidated payload definition document + science requirements
   → Input to IXO proposal for NASA decadal survey
   → Preparation of ITT to industry

4) Two parallel Industry Phase A system studies: (Phase A: Q2 2009 → Q2 2010)
   → ITT release on May 5th, proposals received and evaluated, kick-off in July 2009

5) ESA synthesis of the assessment study (Cosmic Vision selection process): (Q3 2010)
   • Mission and payload technical feasibility, technology development status
   • Risks, programmatic and cost
**IXO mission concept summary**

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1 single large aperture X-ray telescope:

6 instruments:
- Wide Field Imager (WFI)
- Hard X-ray Camera (HXI)
- X-ray Imaging Spectrometer (XMS)
- X-ray Grating Spectrometer (XGS)
- High Time Resolution Spectrometer (HTRS)
- X-ray Polarimeter (XPOL)
IXO mission requirements: launcher and orbit

- Launcher: Ariane-5 ECA & Atlas V 551
  - Launcher performance Ariane 5 (excl. adapter) ≈ 6170 Kg
  - Launcher performance Atlas V 551 (excl. adapter) ≈ 6108 Kg

- Target Orbit: direct injection into L2 large halo orbit

- 5 years mission (with consumables sized for 10 years operation)

- Launch ≈ 2020
IXO configuration

- XMS or WFI/HXI or HTRS or XPOL
- Mirror Assembly
- CAT Grating Array
- F = 20 m
- CCD Camera
- Rowland circle
IXO configuration

X-ray telescope with high energy response
  → long telescope focal length
    → deployable optical bench

During science operation,
  - the grating spectrometer is always operating
  - any of the other 5 instruments can be placed at the focus of the X-ray telescope.
    → instrument exchange mechanism

The instruments shall be protected from particle background and stray-light
  → cylindrical baffles and deployable shroud
IXO configuration

- Instrument module
- Optical bench deployment mechanism (+ deployable shroud)
- Service module
- Fixed conical optical bench
- Mirror assembly (+ deployable sun shield)
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## IXO instrument module: resources summary

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<tr>
<th>Instrument</th>
<th>Power</th>
<th>Mass</th>
<th>Data rate</th>
<th>Comment</th>
</tr>
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<tbody>
<tr>
<td>WFI</td>
<td>283 W</td>
<td>83 kg</td>
<td>&lt; 0.5 Mbps</td>
<td></td>
</tr>
<tr>
<td>HXI</td>
<td>61 W</td>
<td>33 kg</td>
<td>&lt; 1 Mbps</td>
<td></td>
</tr>
<tr>
<td>XPOL</td>
<td>61 W</td>
<td>11 kg</td>
<td>MM 128 Gbit</td>
<td></td>
</tr>
<tr>
<td>HTRS</td>
<td>165 W</td>
<td>30 kg</td>
<td>MM TBD</td>
<td></td>
</tr>
<tr>
<td>XMS</td>
<td>1080 W</td>
<td>352 kg</td>
<td>&lt; 0.84 Mbps</td>
<td>Including ESA cryogenics</td>
</tr>
<tr>
<td>XGS</td>
<td>115 W</td>
<td>51 kg</td>
<td>&lt; 1.5 Mbps</td>
<td>CAT option excluding focussing mechanism</td>
</tr>
</tbody>
</table>
IXO instrument module: configuration
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   – **Service module**
   – Mirror assembly

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IXO service module

Power subsystem:
- Max power requirement: 4.5 kW
- 26.4 m² deployable solar array (Ga As cells)
- Li-ion battery (MA temperature control before Sun acquisition – 650 W during 2 h)

Telecommunication:
- 90 Gb/day (8.7 Mbps during 3 hours)
- X bands around 8 GHz (10 MHz band)
- Standard equipment: 10W RF power
  (2 X/X transponder, 2 TWTA, 2 LGA, 1 40cm HGA, 1 RFDU)
- New Norcia 35 m antenna G/S (baseline)
IXO service module

Data handling decentralized architecture:
- On Board Computer (OBC) located in the S/C Bus
- Instrument Control Unit (ICU) located on the instrument platform for interfacing the IXO payloads/instruments
- 2 x 250 Gbit memory using SDRAM technology located in the instrument platform

Propulsion:
- A bipropellant system (using monomethyl hydrazine and mixed oxydes of nitrogen) is selected:
- 24 20N thrusters
- 6 titanium tanks for propellant (3 fuel and 3 oxidiser) and 1 titanium tank for He pressurant
IXO service module: deployment mechanisms

- Performance in deployed configuration (preliminary estimates):
  - Deployment accuracy: 1.2 mm radius sphere (RSS)
  - \( \rightarrow \) displacement calibration + pointing correction
Shroud Scale Model

The GSFC Blanket shop created a 1/25\textsuperscript{th} scale prototype that stows to about 7\% of nominal extension length. (3.5/49)
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IXO mission concept

IXO mirror assembly: requirements

Effective area: 3 m² at 1.25 keV
Image quality: 4.5 arcsec at 1.25 keV
Design: double-conical approx to Wolter I
F = 20 m (accommodation constraints)
FOV = 18 arcmin diameter (WFI)
Technology: pore optics
IXO mirror assembly: manufacturing concept

Hierarchical fabrication of mirror assembly
- Mirror stacks
- Mirror module
- Petals
- Optical bench
IXO mirror assembly: optical design

Optical design assumption:
- Inner radius 0.25 m, outer radius 1.90 m
- 32 rows
- 236 mirror modules/petal
- spoke width (7cm)

→ To achieve the 3m² Aeff requirements, the azimuthal/radial spacing of the mirror modules shall be ≤16 mm
IXO mirror assembly: performance estimate

Without C overcoating:
- $A_{\text{eff}} (1.25 \text{ keV}) \sim 2.6 \text{ m}^2$
- $A_{\text{eff}} (6.00 \text{ keV}) \sim 0.65 \text{ m}^2$

With 90 Angstrom C overcoating:
- $A_{\text{eff}} (1.25 \text{ keV}) \sim 3.0 \text{ m}^2$
- $A_{\text{eff}} (6.00 \text{ keV}) \sim 0.65 \text{ m}^2$

To achieve the $3 \text{ m}^2 \ A_{\text{eff}}$ at 1.25 keV requirements, the mirror modules shall be covered with a C overcoating.
**IXO mirror assembly: performance estimate**

With JAXA/ISAS multilayer design (courtesy H. Kunieda) on mirrors with grazing incidence lower than $0.342^\circ$ ($R < 0.477$ m)

Aeff (30 keV) $\sim 150$ cm$^2$
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<td>IXO workshop - July 2, 2009</td>
<td>International X-ray Observatory [IXO]</td>
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<tr>
<th>Mirror Effective Area</th>
<th>Black hole evolution, large scale structure, cosmic feedback, EOS</th>
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<tbody>
<tr>
<td>3 m² @ 1.25 keV</td>
<td>Strong gravity, EOS</td>
</tr>
<tr>
<td>0.65 m² @ 6 keV with a goal of 1 m²</td>
<td>Cosmic acceleration, strong gravity</td>
</tr>
<tr>
<td>150 cm² @ 30 keV with a goal of 350 cm²</td>
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<tr>
<th>Spectral Resolution</th>
<th>Black Hole evolution, Large scale structure, Missing baryons using tens of background AGN</th>
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<tr>
<td>ΔE = 2.5 eV within 2 x 2 arc min (0.3 – 7 keV) . ΔE = 10 eV within 5 x 5 arc min (0.3 - 7 keV)</td>
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<tr>
<td>ΔE &lt; 150 eV @ 6 keV within 18 arc min diameter (0.1 - 15 keV)</td>
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<tr>
<td>E/ΔE = 3000 from 0.3–1 keV with an area of 1,000 cm² for point sources</td>
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<tr>
<td>ΔE = 1 keV within 8 x 8 arc min (10 – 40 keV)</td>
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<th>Mirror Angular Resolution</th>
<th>Black hole evolution, missing baryons</th>
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<tr>
<td>≤5 arc sec HPD (0.1 – 10 keV)</td>
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<tr>
<td>30 arc sec HPD (10 - 40 keV) with a goal of 5 arc sec</td>
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<th>Count Rate</th>
<th>Strong gravity, EOS</th>
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<tr>
<td>1 Crab with &gt;90% throughput. ΔE &lt; 200 eV (0.1 – 15 keV)</td>
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<tr>
<th>Polarimetry</th>
<th>AGN geometry, strong gravity</th>
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<tr>
<td>1% MDP on 1 mCrab in 100 ksec (2 - 6 keV)</td>
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<tr>
<th>Astrometry</th>
<th>Black hole evolution</th>
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<tr>
<td>1 arcsec at 3σ confidence</td>
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<th>Absolute Timing</th>
<th>Neutron star studies</th>
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<td>50 μsec</td>
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IXO mission concept: conclusion

An IXO mission concept has been identified that is:
- compatible with IXO science performance requirements
- technically promising (no show-stopper identified)
- modular and well-suited to an International collaboration

Highest technical risk areas include:
- mirror technology and overall mirror assembly,
- X-ray microcalorimeter spectrometer including cryogenic chain,

► a technology development program is running at ESA that includes the development of pore optics mirrors and cryo-coolers for IXO