# IXO System Studies and Technology Preparation

European Space Agency





## 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

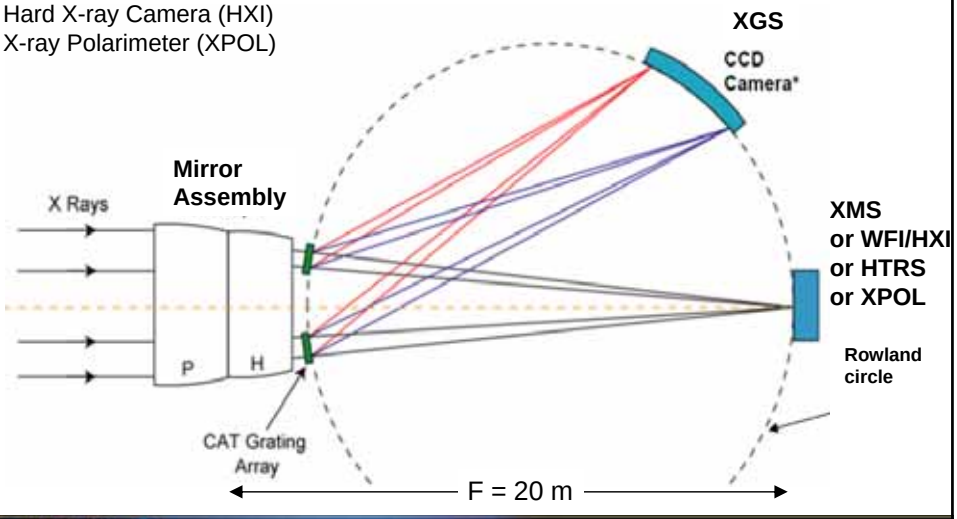
3 - Instruments include a wide field imager, a high resolution non-dispersive spectrometer, an X-ray grating spectrometer + instruments with modest resources

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

→ The IXO concept is subject to the US decadal survey and ESA Cosmic Vision selection process

Wide Field Imager (WFI)
X-ray Imaging Spectrometer (XMS)
X-ray Grating Spectrometer (XGS)
High Time Resolution Spectrometer (HTRS)
Hard X-ray Camera (HXI)
X-ray Polarimeter (XPOL)

# IXO configuration and Instruments

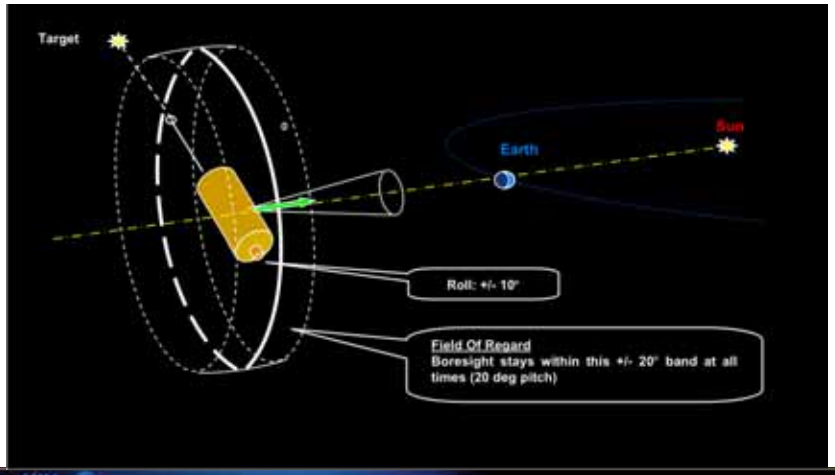




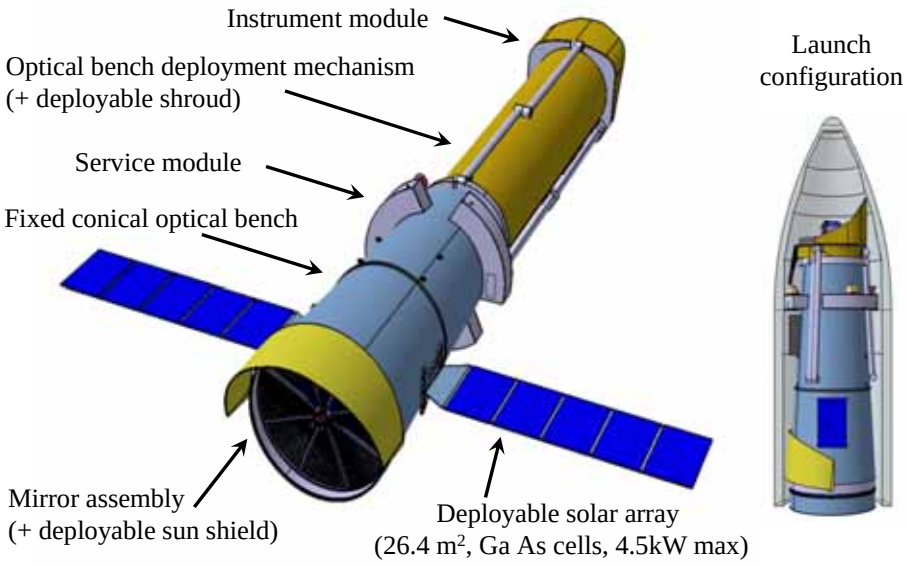



# IXO: launcher, orbit and field of regard

- Launcher to L2 halo orbit (≈ 2020):
  - Ariane 5: ≈ 6170 Kg (excl. adapter), or
  - Atlas V 551: ≈ 6108 Kg (excl. adapter)
- 5 years mission (with consumables sized for 10 years operation)



# IXO configuration (CDF)

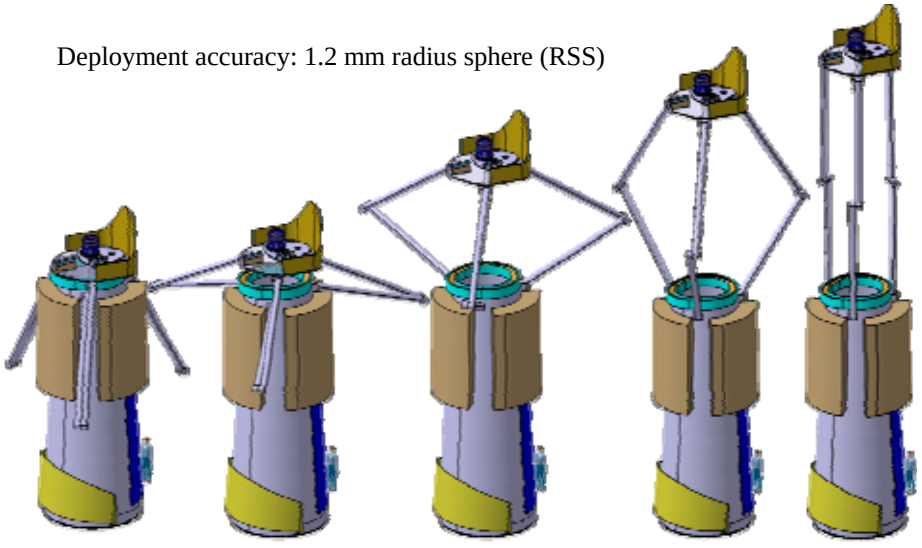






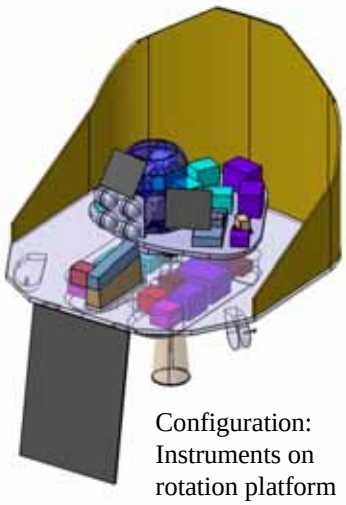

# IXO: deployment sequence

Deployment accuracy: 1.2 mm radius sphere (RSS)



# IXO instrument module

| Instru-ment | Power (W) | Mass (kg) | Data rate | Comment |
|---|---|---|---|---|
| WFI | 283 | 83 | < 0.5 Mbps | |
| HXI | 61 | 33 | < 1Mbps | |
| XPOL | 61 | 11 | MM 128 Gbit | |
| HTRS | 165 | 30 | MM TBD | |
| XMS | 1080 | 352 | < 0.84 Mbps | Including ESA cryogenics |
| XGS | 115 | 51 | < 1.5 Mbps | CAT option, excluding focussing mechanism |

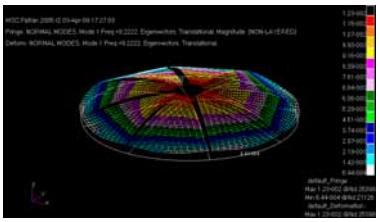


Configuration: Instruments on rotation platform

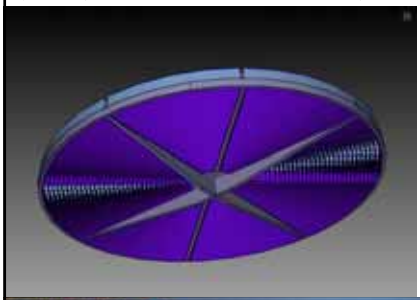


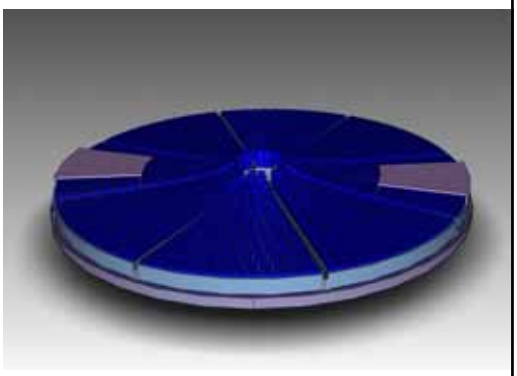


# IXO mirror assembly design and analysis



Cumulative modal mass in longitudinal (lateral) direction < 10% at 31 Hz (9.8 Hz)





- 1 CFRP spoke wheel: 125 kg
- 8 CFRP petals: 1056 kg
- 8 x 236 mirror modules: 568 kg
- 1 Aluminium pre-collimator: 180 kg

# IXO mirror module: performance and environmental constraints

**LAUNCH:**

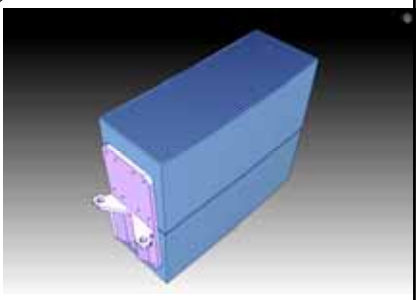
**- Mechanical environment:**

Dynamical behaviour: first eigen f > 200Hz

Quasistatic longitudinal acceleration: ~ 18 g (TBC – innermost MM)

**- Acoustic environment:**

Ariane 5 (~140 db in 20 HZ – 2.8 kHz)



**IN-ORBIT OPERATION:**

**- Thermal environment:**

operation temperature: 268 K – 293 K

axial gradient: < 11 K/m

transverse gradient: < 20 K/m

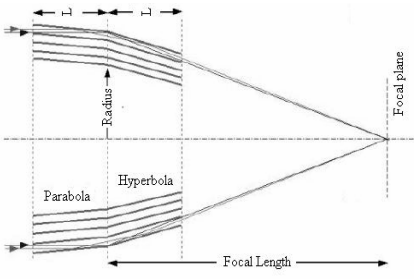
**- Performance requirements:**

HEW < 4.3 arcsec





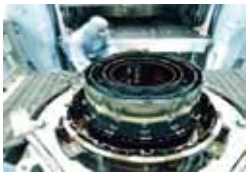
# IXO mirror assembly: performance specification



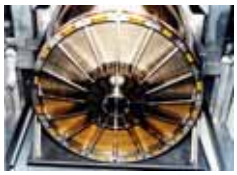

- Effective area: 3 m² at 1.25 keV
- Image quality: 4.5 arcsec at 1.25 keV
- Design: double-conical approx to Wolter I
- F = 20 m (accommodation constraints)
- FOV = 18 arcmin diameter (WFI)
- Mass < 2000 kg

►A mirror technology is needed that can provide large effective area, good image quality and low mass.

# X-ray mirrors technologies: image quality vs mass



CHANDRA
0.5”
18500 kg / m$^2$
$A_{eff}$ @ 1 keV



XMM-NEWTON
14”
2300 kg / m$^2$
$A_{eff}$ @ 1 keV

Si Pore Optics
5”
200 kg / m$^2$
$A_{eff}$ @ 1 keV

- Large effective area, good image quality and low mass not achievable with currently established technology
- A new X-ray mirror technology is needed: Si pore optics or slumped glass

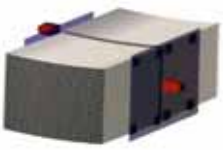




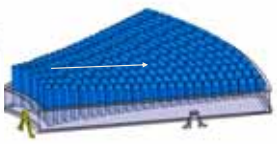
# Elements of the Silicon Pore Optics (SPO)

## Hierarchical elements

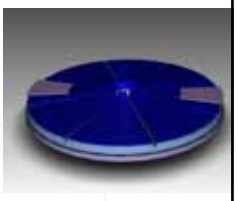
Mirror plates and stacks



Mirror modules



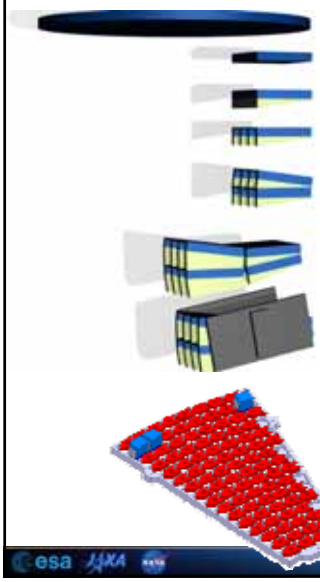
Petals



Optical bench

# SPO Development:

uses existing heritage and builds on established industrial processes



300mm Si wafer (industry standard)
Dicing (adapted chip dicing machine)
Wedging (customised semiconductor process)
Ribbing (adapted chip dicing machine)
Coating (customised semiconductor process)
Stacking (3rd generation stacking robot developed)
XOU assembly (standard optical engineering)

Mandrels (standard optical engineering)
Metrology (standard interferometers, autocollimators etc)
Facilities (dedicated X-ray synchrotron beamline)
FEM analysis (engineering standard)
Simulations (engineering standard)

Petal assembly (SiC breadboard tested 2007)



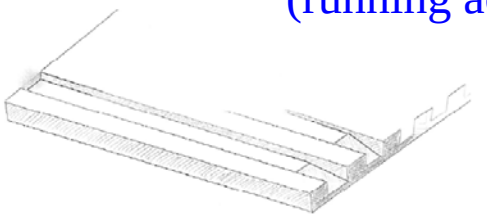


# Development of a stacking robot and test/integration facility

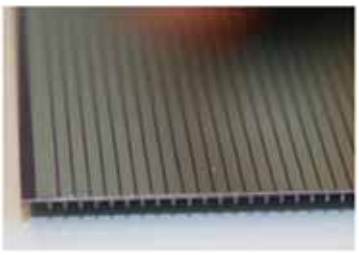
Robotic stacking of ribbed plates
Table-top equipment
Full-area real-time interferometer
Cost-effective commercial parts

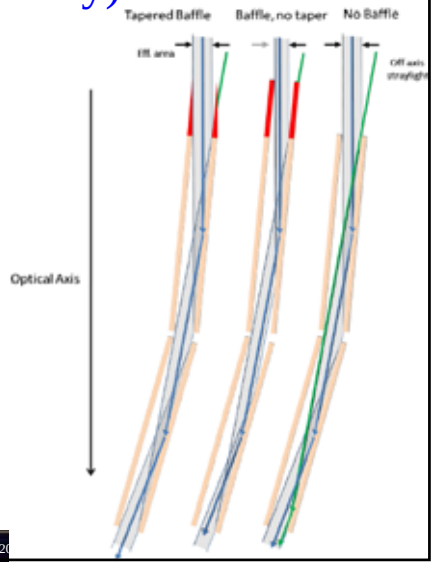
Test chamber at BESSY2 facility
Compact and precise hexapod
3D angle metrology with autocollimators
3D Position metrology

# Mirror module straylight rejection baffle (running activity)



*Artist's impression of tapered baffle*

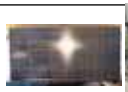
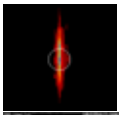









# Silicon Pore Optics – Development & Production

| Steps | Done | TRL 2008 | | Next (2011) | TRL |
|---|---|---|---|---|---|
| **Plate production** | Industrial process |   | 4 | Reduce cost<br>Different sizes | 6 |
| | Wedged, coated | | | | |
| | 500 produced | | | | |
| **Stack production** | Automated |   | 4 | Improve HEW | 6 |
| | Particle inspection, cleaning, bending, interferometry, stacking | | | | |
| | 300 produced | | | | |
| **Module production** | Design to spec |   | 3-4 | Module ruggedising and<br>Industrialisation and mass production | 6 |
| | Integration method to spec | | | | |
| | Mounting method | | | | |
| | 4 produced | | | | |
| **Module validation & qualification** | Synchrotron & beam testing in place |   | 4 | Environmental testing<br>Focal plane testing | 6 |
| | Ruggedness assessment | | | | |
| **Petal production** | Design to spec | | 4 | Production of prototype | 6 |
| | 1 produced | | | | |
| **Petal validation & qualification** | First X-ray testing |   | 4 | Environmental testing<br>Focal plane testing | 6 |

# IXO industrial activities

1) **Two ESA funded parallel Industry Phase A system studies are being conducted:**
   - Started in July 2009
   - Phase A: Q2 2009 → Q2 2010

2) **ESA funded IXO mirror technology development program is being implemented:**
   - High Performance X-ray Optics (running)
   - Pore optics baffle (running)
   - Back-up IXO optics technology (running)
   - IXO mirror module ruggedizing & enviromental testing (running)
   - Development of IXO Si pore optics and mass production processes (KO soon)
   - Bessy X-ray test facilities upgrade plan (running)
   - Panter X-ray test facilities upgrades (Proposal received)