IXO mission concept

IXO mission terms of reference

-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 - Instrument 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 V and Atlas V 551 launchers.

IXO CDF objectives

1 - Mirror assembly accommodation concept:
- pore optics technology and compatibility with slumped glass technology

2 - Design service module:
- Ariane V and compatibility with ATLAS V launcher

3 - Design instrument support platform:
- WFI+HXI, CSI, XGS (CAT), HTRS, XPOL

4 - Programmatic, organisation and possible ESA contributions (< 650 MEuros):
two main scenarios:

ESA delivers the IXO mirror assembly
NASA delivers the IXO mirror assembly

5 - Options

Focal length extension (> 20 m)
Retractable transmission grating concept
(+ estimate X-ray events time stamping accuracy)

IXO mission concept

IXO mission requirements: scientific performance

Mirror Effective Area	**3 m² @1.25 keV** **~1 m² @ 6 keV** **~350 cm² @ 30 keV**	Black hole evolution, large scale structure, cosmic feedback, EOS Strong gravity, EOS Cosmic acceleration, strong gravity
Spectral Resolution	2.5 eV from 0.3 - 7.0 keV E/ΔE >1250 from 0.3–1 keV with area >1,000 cm² for point sources	Black Hole evolution, Large scale structure Missing baryons using tens of background AGN
Angular Resolution	**≤5 arc sec HPD (0.3 – 10 keV)** ≤15 arc sec HPD (10 - 40 keV)	Large scale structure, cosmic feedback, black hole evolution, missing baryons Black hole evolution
Field of View	**2 x 2 arc min with ΔE < 2.5 eV** 5 x 5 arc min with ΔE < 10 eV **>14 x 14 arc min** with ΔE < 150 eV (18 arcmin at 20 m focal length)	Galaxy Clusters, cosmic feedback Galaxy Clusters Black hole evolution, galaxy clusters
Count Rate	1 Crab with < 10% deadtime ΔE < 200 eV	Strong gravity, EOS

IXO mission requirements: launcher and orbit

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

- Target Orbit: direct launch into L2 (similar ΔV budget for both launchers)

- 5 Year Mission (with consumables sized for a 10 years mission)

- Launch ≈ 2020

Preliminary IXO pointing and optical bench stability requirements

Preliminary image quality error budget (HEW on-axis at 1 keV):

- Mirror module manufacturing errors:	4.30 arcsec
- Optical design (conical approx.~ 3 arcsec)	
- Mirror figuring errors:	
- Mirror mid-frequencies errors & surface roughness:	
- Mirror plate alignment/confocality:	
-Mirror assembly system errors:	1.20 arcsec
- Assembly and integration	
- 1 g release	
- Thermal environment	
- Other (e.g. moisture release)	
- S/C pointing and optical bench distorsions:	2.00 arcsec
- Events relative lateral measurement accuracy	
- Absolute longitudinal displacement errors	
- Margin: (including PSF sampling/detector pixel size)	1.00 arcsec
--	
Total (assuming RSS summation):	5.00 arcsec

Preliminary IXO pointing and optical bench stability requirements

Low f MA pointing requirements (MA ref. frame vs absolute ref. frame):

- Mirror assembly Absolute Pointing Error < 5 arcsec
- Mirror assembly Absolute Pointing Measurement Accuracy < 0.7 arcsec (on ground reconstruction)

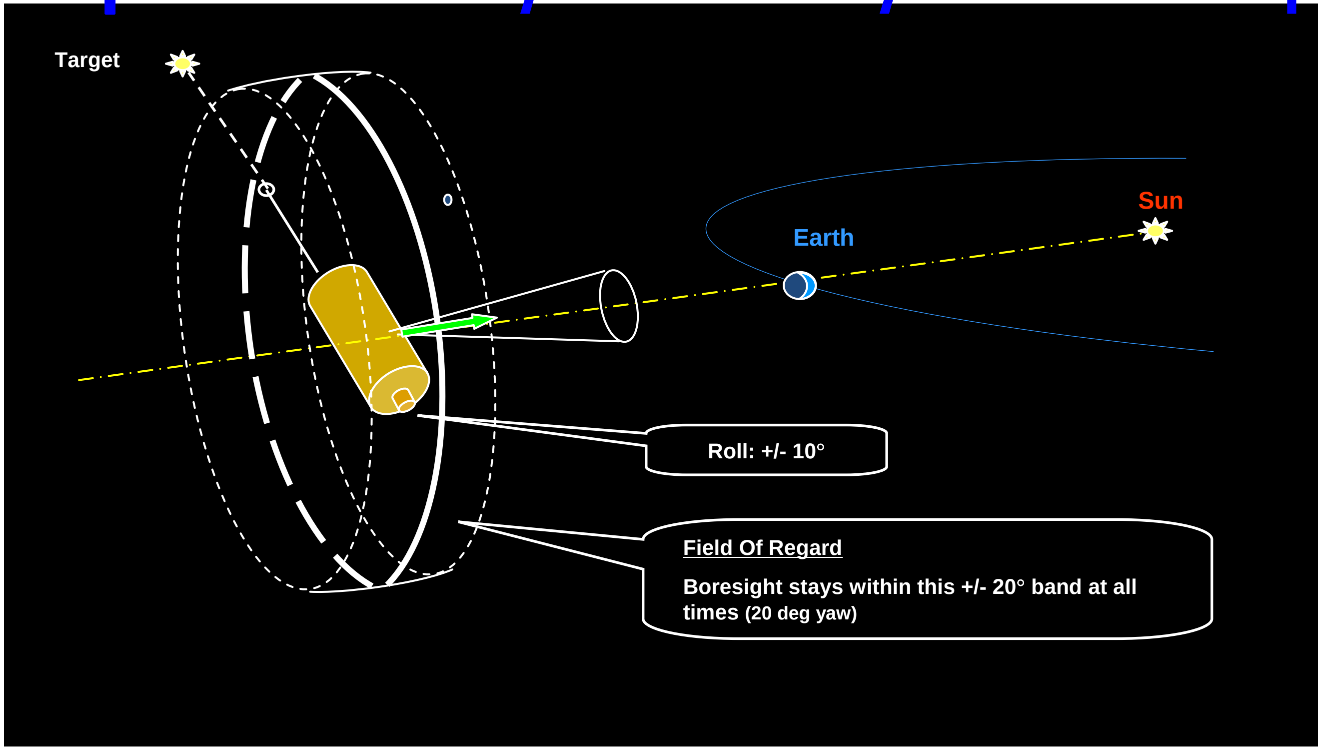
Low f detector positioning errors (detector ref. frame vs MA ref. frame):

- Detector absolute position measurement error (including uncalibrated OB static and low f distorsion) < 0.07 mm
- Detector defocussing < 0.65 mm
- Static and low f optical bench distorsions + detector lateral positioning errors < 0.5 mm (maximum amplitude without pointing correction or calibration accuracy with pointing correction)

High f MA pointing error + high f OB distorsions < 110 μm (or 1.1 arcsec)

Torsional requirements: < 0.05 degree (XGS)

IXO mission requirements: sky accessibility and slew requirements



Field of Regard	• Pitch: +/- 20° off Sunline • Yaw: +/- 180° • Roll: +/- 10° (with a goal of 20°) off Sunline
Slew	• Target Of Opportunity observed in less than 24h

IXO mission requirements: observation scenario

Number of Targets:

- 210 targets in 1 year.
- 77 observations were made of the same target with >3 instruments
- 34 targets required repeated (typically 4) observations spread over time.
- 7 targets needed mosaicing of between 2 x 2 and 10 x 10 pointings to cover 1 sq degree.

Exposure Times

- Minimum Exposure: 10 ks
- Maximum Exposure: 1000 ks
- Mean Exposure: 70.4 ks

Instrument Utilisation

- XGS: assumed to be always operating.
- WFI: 48%
- NFI: 31%
- HTRS: 14%
- XPOL: 5%
- HXC: 1 % (as prime, assumed to be behind WFI)

→183 instrument exchange/year

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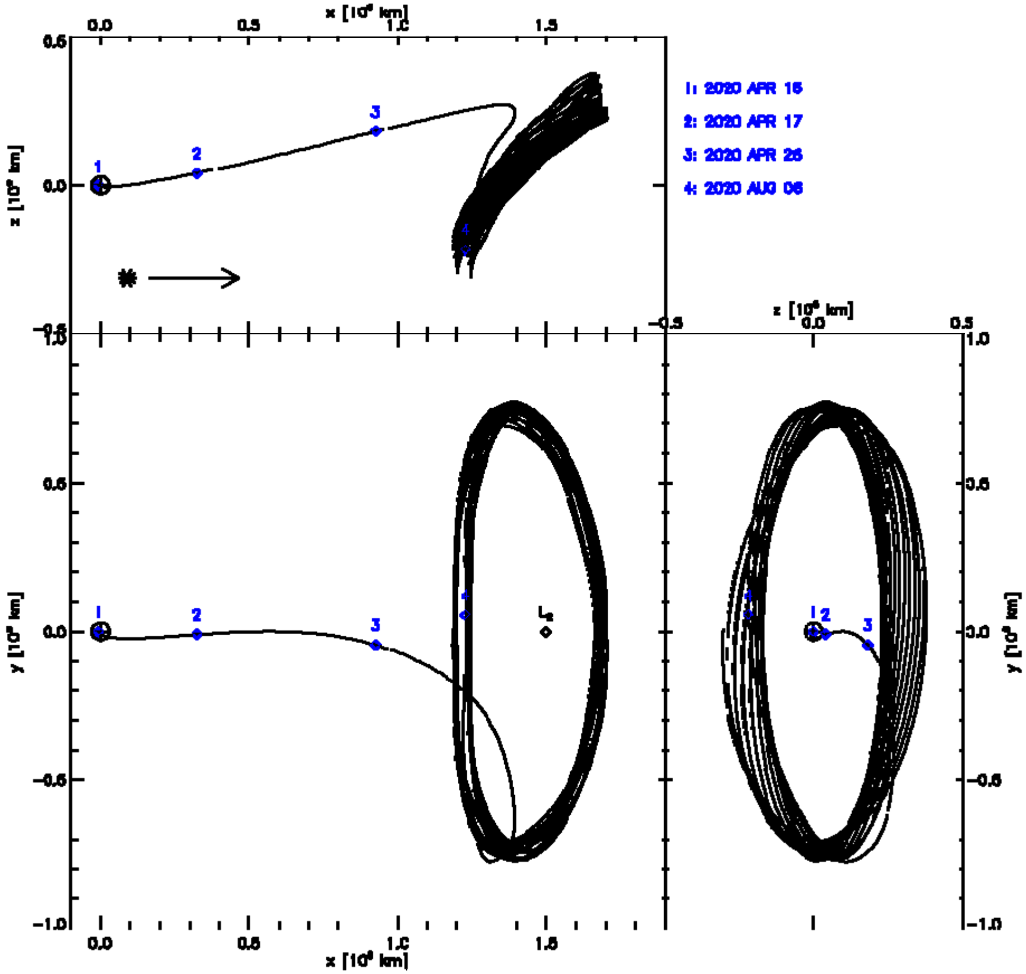
IXO reference trajectory and Δv Budget



manoeuvre	Δv [ms^{-1}]
perigee velocity correction	28.0
launcher dispersion correction	34.0
transfer	3.0
orbit insertion	0.0
station keeping (10y)	20.0
de-orbit	0.0
wheel off-loading correction	7.7
total	85.0
margin (5%)	4.63
thruster mounting 1/cos(28°)	11.7
total Δv budget	**109.4**

L2 particle (protons) environment

- LRAD – now L2CPE: NASA developed statistical model of plasma densities and temperatures in L2 (Solar wind, Plasma sheet, Magnetosheath, Lobe and Mantle)

- Blackwell et al [2000], using LRAD, looked at the effect of L2 halo orbit amplitude on the flux statistics for electrons and protons.

→ No change in flux of protons from 10keV to 100keV depending on halo orbit amplitude,

→ a consideration of Larmor radius for higher energy particles suggests that there should be no dependence on orbit amplitude for the higher energy protons too.

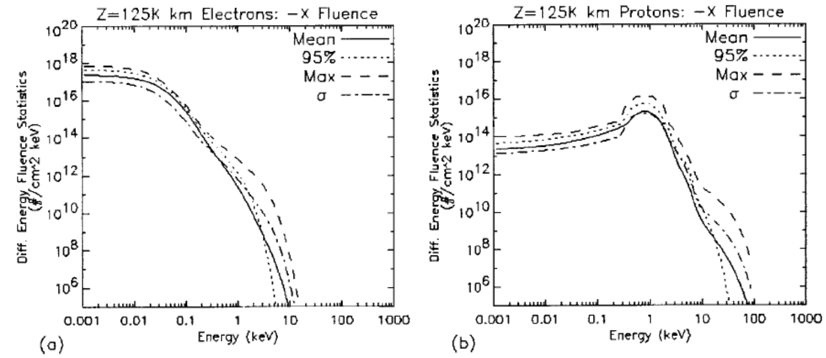


Figure 10. Fluence Statistics for a Single 125,000 km Z-Amplitude Halo Orbit. Solar wind values from 1992 were used to drive the magnetosheath and magnetotail variations for the 6 month orbital period. Fluence is dominated by the bulk flow contribution near 1 keV for the ions.

Table 1. 125,000 km Z-Amplitude Halo Orbit Satellite Location Summary

Number of Monte Carlo Runs = 1000 Total problem duration= 180.00000 days

Fraction of halo orbit spent inside individual regions:

Solar Wind Region	: 12.77 %	(22.99 days)	N/S Lobe Region	: 0.00 %	(0.00 days)
Plasma Sheet Region	: 3.22 %	(5.80 days)	Plasma Mantle Region:	5.91 %	(10.63 days)
Magnetosheath Region:	78.11 %	(140.60 days)			

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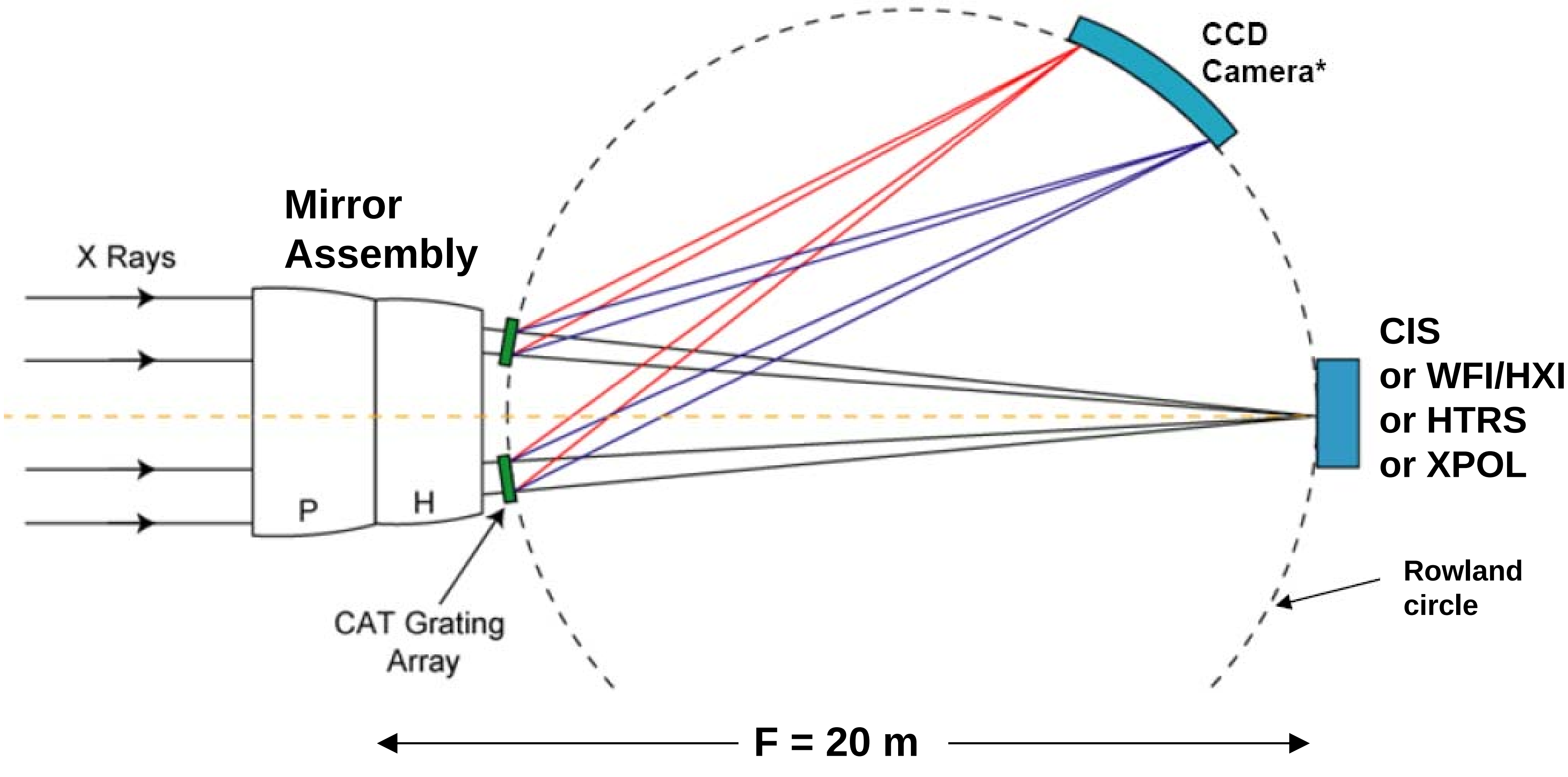
IXO configuration



IXO configuration

X-ray telescope with high energy response

→ large telescope focal length

→ **deployable optical bench**

During science operation,

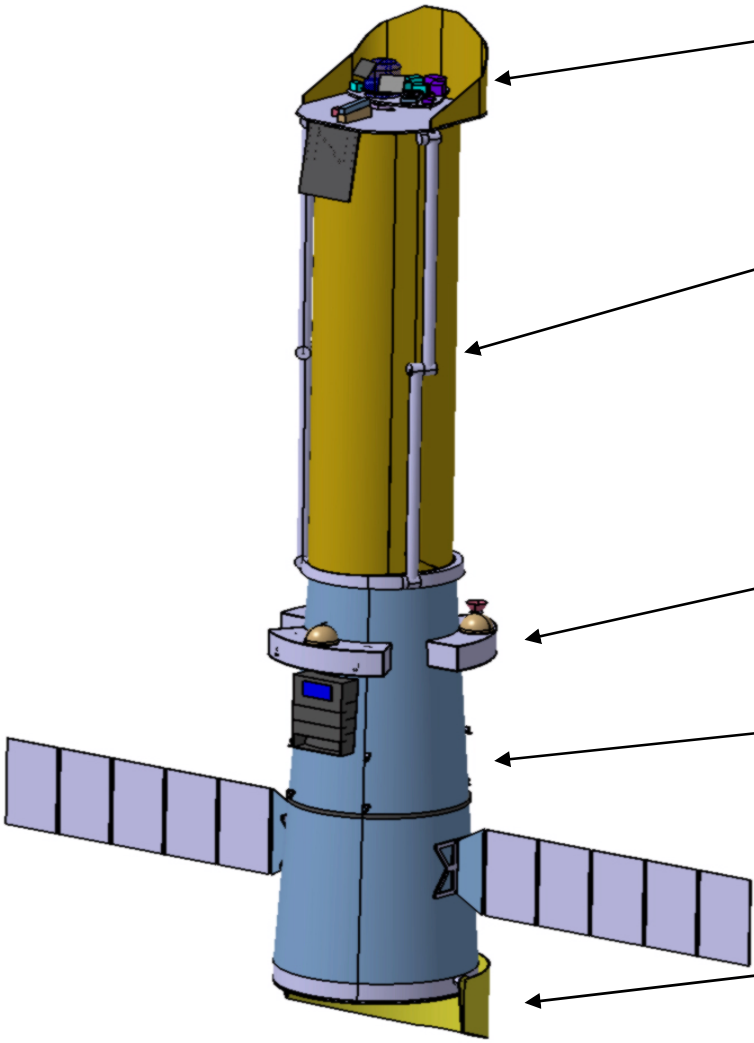
- the grating spectrometer is always operating
- any of the other 4 instruments can be placed at the focus of the X-ray telescope.

→ **instrument exchange mechanism**

The instruments shall be protected from particle background and stray-light

→ **cylindrical baffles and/or (deployable) shroud**

IXO configuration



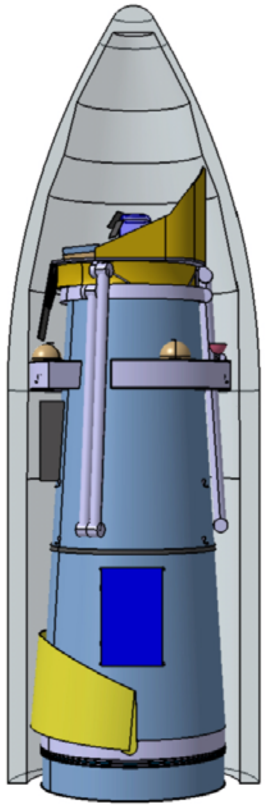
Instrument module

Optical bench deployment mechanism
(+ deployable shroud)

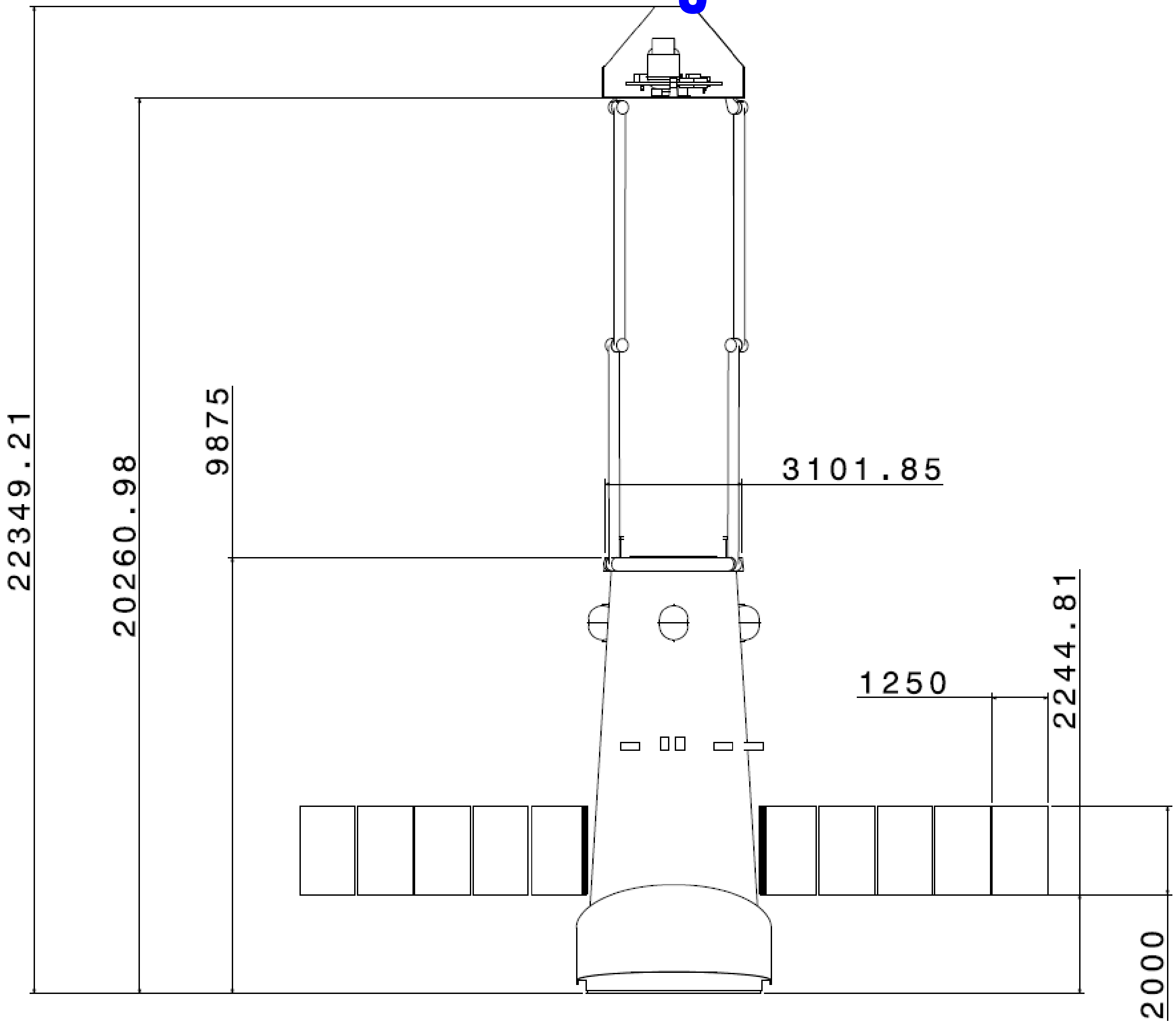
Service module

Fixed conical optical bench

Mirror assembly
(+ deployable sun shield)



IXO configuration



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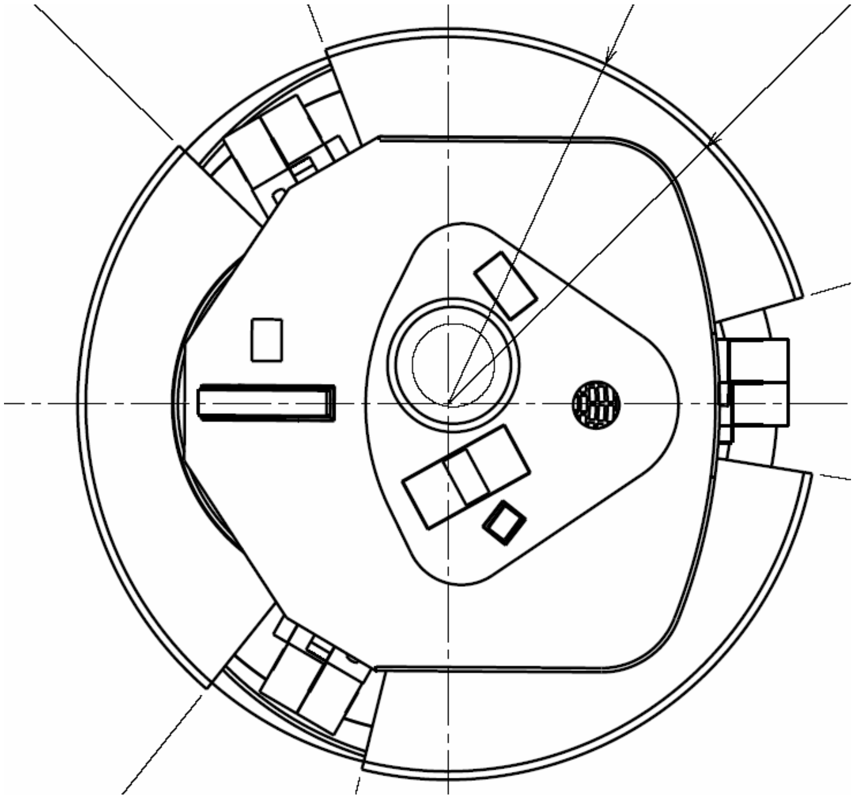
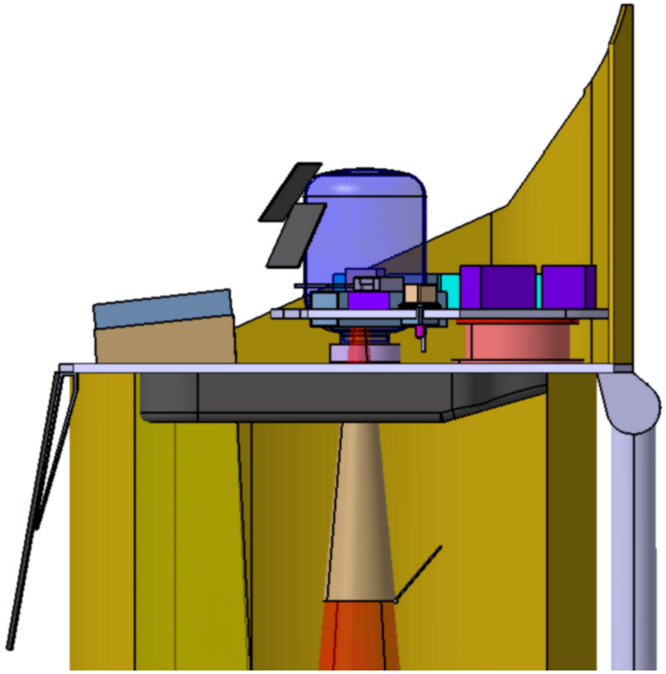
IXO instrument module: configuration

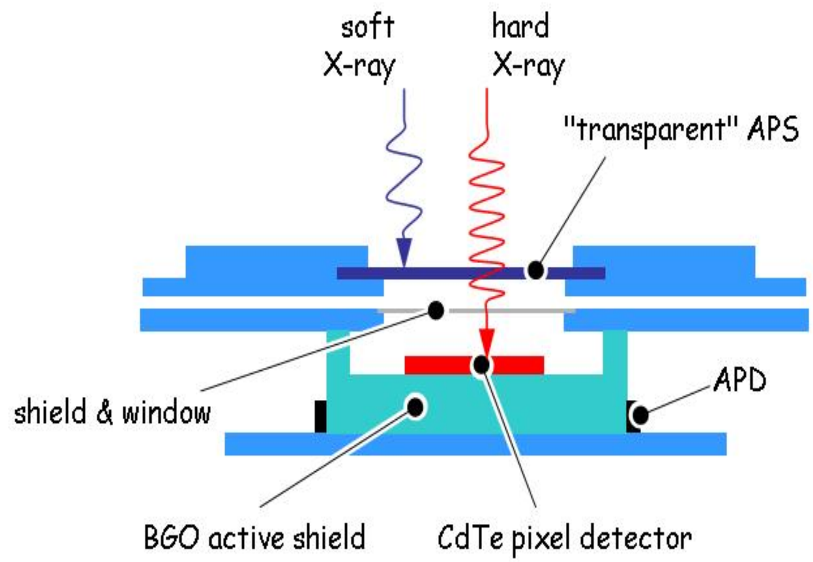




IXO instrument module: WFI+HXI

WFI specifications:

- Imaging spectrometer 0.1-15keV
- Single Si chip array of 1024x1024 active pixels
- Pixel Pitch=100µm
- Area = 102x102mm^2 = 17.5’x17.5’
- 1 detector head (incl FW&FEE) & 2 HPP boxes on MIP
- 3 electronics boxes on FIP

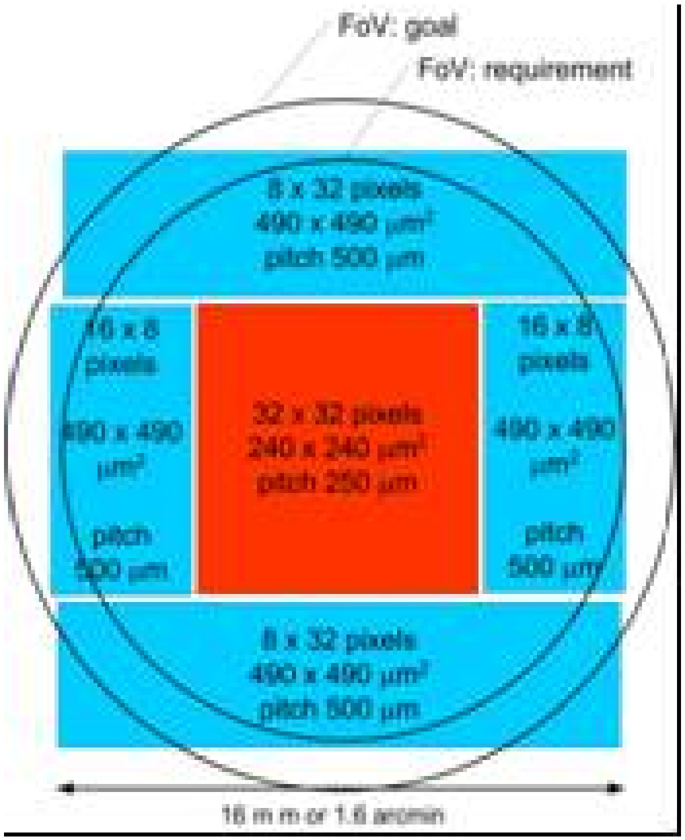


HXI specifications:

- 1 detector head & FEE + Analog electronics on MIP
- 2 Digital unit & PSU electronic boxes on FIP
- FOV = 12’ circular

IXO instrument module: CIS

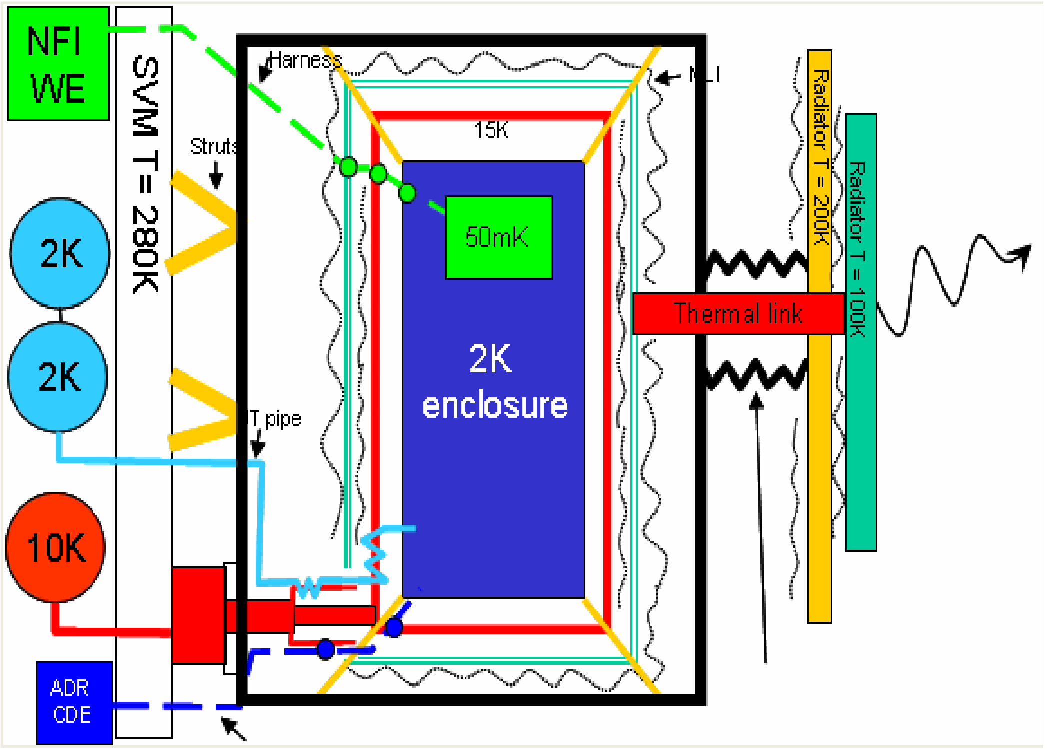
- Cryogenic imaging spectrometer based on TES
- Energy range = 0.1-10keV
- Inner array: 40x40 pixels (300x300 µm^2), ΔE<2.5eV
- Outer array: 52x52 pixels (600x600 µm^2) , ΔE<10eV
- Total 2176 read-out channels
- T_{det} = 100mK ±1µK (50mK cooler I/F)
- FoV = 5.4 x 5 .4 arcmin
- CDF baseline: most demanding combination of European (NFI) and US (XMS) concepts
- Assumed US detector and Europe cooler
- Detector head + SQUIDs @ 50mK
- FEE + DE (RT) close to cryostat (on MIP)
- Event Processor, PSU, cooler controls @ RT on FIP



IXO instrument module: CIS

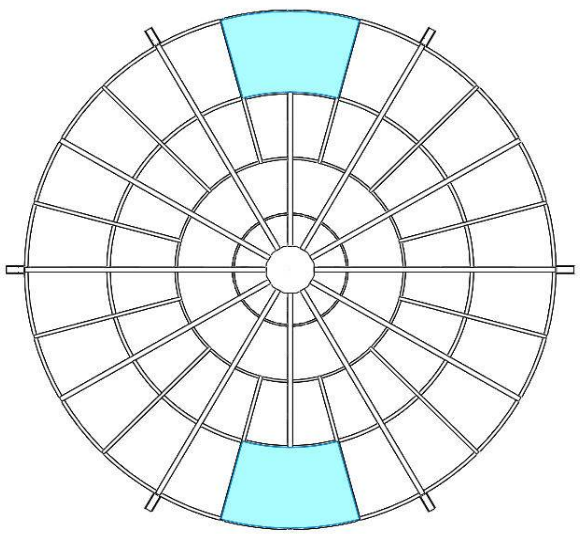
- 280K cryostat + 100K radiator
- 2 stage 10-15K Stirling cooler (2x)
- 2-2.5K JT cooler (4x)
- (300mK sorption cooler
  + 50mK ADR)

- Redundant pre-cooler concept
- Relies on passive shield cooling
- Cryostat @ RT -> simplifies I/F and testing



IXO instrument module: XGS

-> Instrument definition to be improved: PDD shall be updated with an XGS instrument description and interface requirement specification.

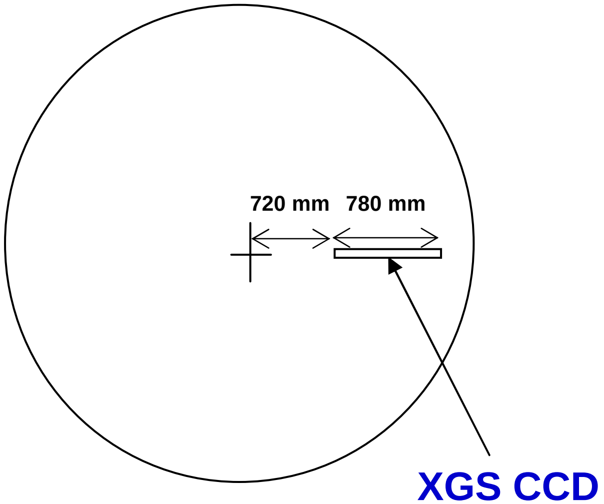


Grating box assumption:

- Selected 1.1m < R < 1.9m and two sectors of 22.5° each.
- Box dimensions ~70 x 80cm structure support Al ~2cm deep (silicon grating only 3 microns thick)
- 2.4 kg incl 20% margin each box
- No attempt to address mounting to mirror, unit calibration, temperature constraints etc . . .

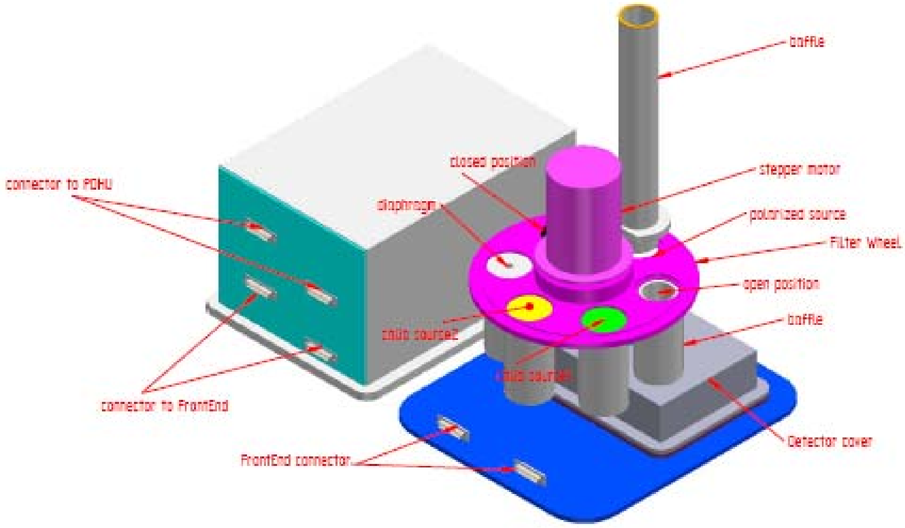
XGS camera assumptions:

- Mass ~ 20.4kg incl margins.
- Power ~65 W incl margin + 3W CCD thermal control
- No translation stage needed at 3 σ error level
- Refocussing mechanism needed



IXO instrument module: XPOL

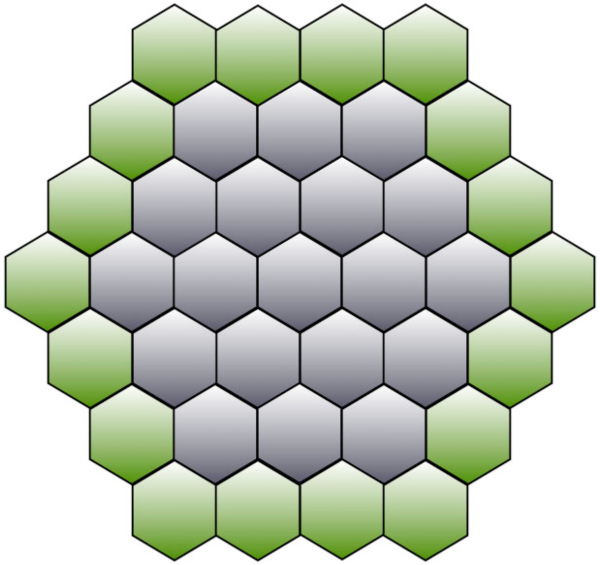
X-ray polarimeter based on scintillating gas cell



- Track detection gives polarization angle
- 300 x 352 pixels (50x43.3μm^2) = 15.24 x 15mm^2
  FOV = 2.6’x2.6’
- E=2-10keV, E/ΔE=6
- T_{det}=283K ±2K
- Room temp electronics
- 1 detector head + FEE & 1 back-end box all on MIP
- Harness: power & SpW

IXO instrument module: HTRS

- High time resolution spectrometer: ~1Mcps, 10us resolution
- 0.5-20keV
- based on 37 Silicon drift detector diodes – placed in defocused beam (182mm)
- T_{det} = 253K ±1K [-40C,+35C]
- 1 detector head + FEE & 1 electronic box on MIP
- Harness: power & SpW
- The instrument is non-imaging
- Multiple pixels are used for distributing the photons and achieving higher count-rate capability



IXO instrument module: resources summary

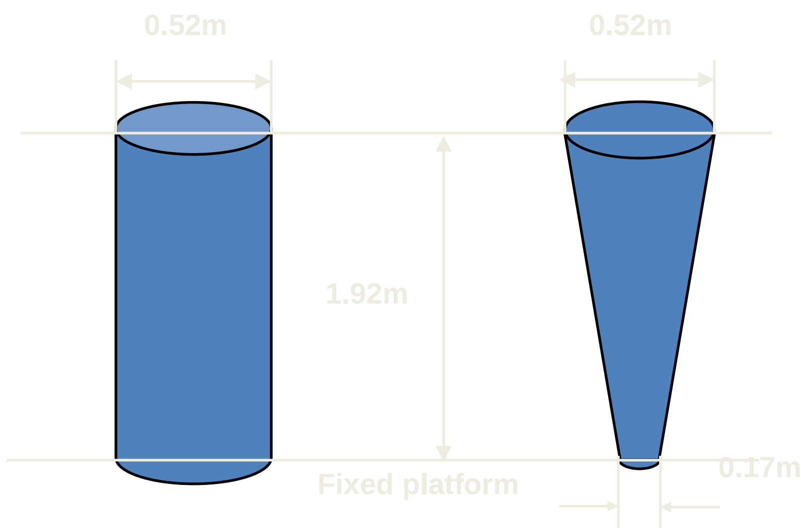
Instrument	Power	Mass	Data rate	Comment
WFI	280 W	90 kg	<1Mbps	
HXI	43 W	31 kg	<1Mbps	
XPOL	44 W	15 kg	<1Mbps	
HTRS	113 W	31 kg	MM	
NFI	521 W 576 W recycling	243 kg	<1.7Mbps	Incl cryogenics & 100K radiator
XGS	68 W	52 kg	158 kbps 1.8Mbps peak	Incl gratings & baffle
Total	993 W	462 kg		Power is worst case scenario

IXO instrument module: baffle

Stray light requirements:

- **visible/IR:**
  - XGS: < 3 x 10^8 ph/s/cm^2 (200-1000nm)
  - CIS: < 1 x 10^8 ph/s/cm^2 (TBC) (<30nm)
  - WFI: < 1 x 10^{12} ph/s/cm^2
- **x-rays:**
  - Baffle should stop (to below particle background):
    - HXI/WFI/CIS: E < 40 keV (baffle+Au coating)
    - XGS: E < 2 keV (shroud is sufficient)

$\rightarrow$ *no direct view to sky other than through mirror*



Mass (2mm CFRP, 200µm LoS Au, 20% mounting)
- cylindrical : 20 kg
- conical: 12 kg

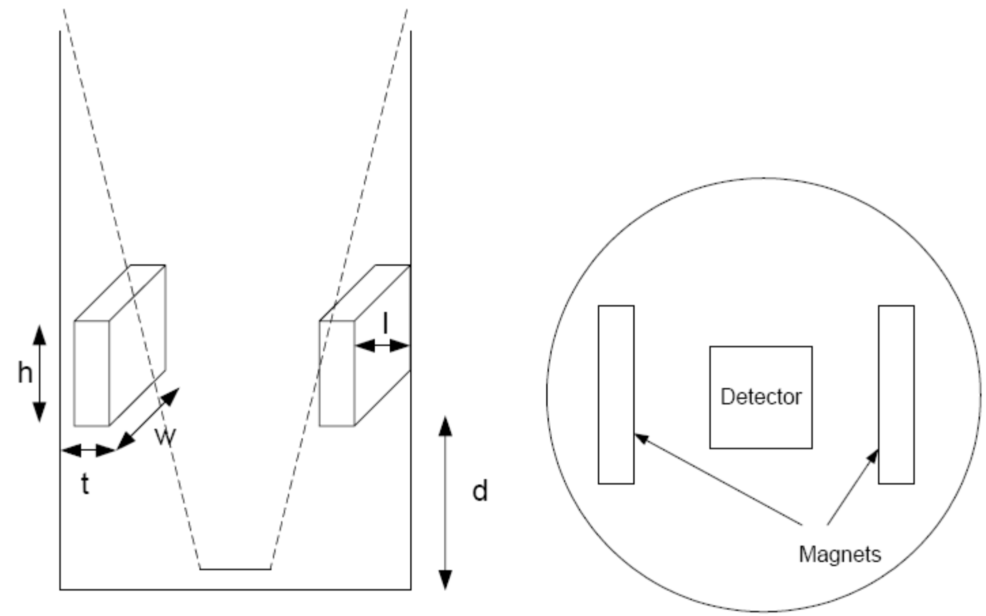
IXO instrument module: magnetic deflector

in instrument baffles (central baffle + XGS baffle)

- Sized for deflection of all protons with in-band energy (after passing fixed filters) outside FOV:

WFI:	E_{max} = 45 keV	FoV = 10 x 10 cm
CIS:	E_{max} = 75 keV	FoV = 3.3 x 3.3 cm
XGS:	E_{max} = 10 keV	FoV = 75 x 3 cm

- On-axis instruments:
  - magnets 10x15x2 cm,
  - Position 0.6m above detector
  - Residual field at detector ~5 Gauss!!
- XGS:
  - magnets 80x6x1 cm,
  - Position ~0.3m above detector



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IXO service module: power

- **Power subsytem:**
  - Max- power requirement: 4.5 kW
  - 28 V unregulated bus
  - 26.4 m2 deployable solar array (Ga As cells)
  - Li-ion battery (MA temperature control before Sun acquisition – 650 W during 2 h)
  - Power Distribution Unit (PDU) dedicated to instruments on the instrument platform

IXO service module: telecommunication

Telecommunication:

- 90 Gbs/day (including protocol over head)
- X bands around 8 GHz (10 MHz band)
- 8.7 Mbps with GMSK and RS (223,255)
- 3 h downlink/day
- 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)
- Cebreros G/S (different hemisphere) used when needed, i.e. elevation too low or weather too bad in New Norcia)

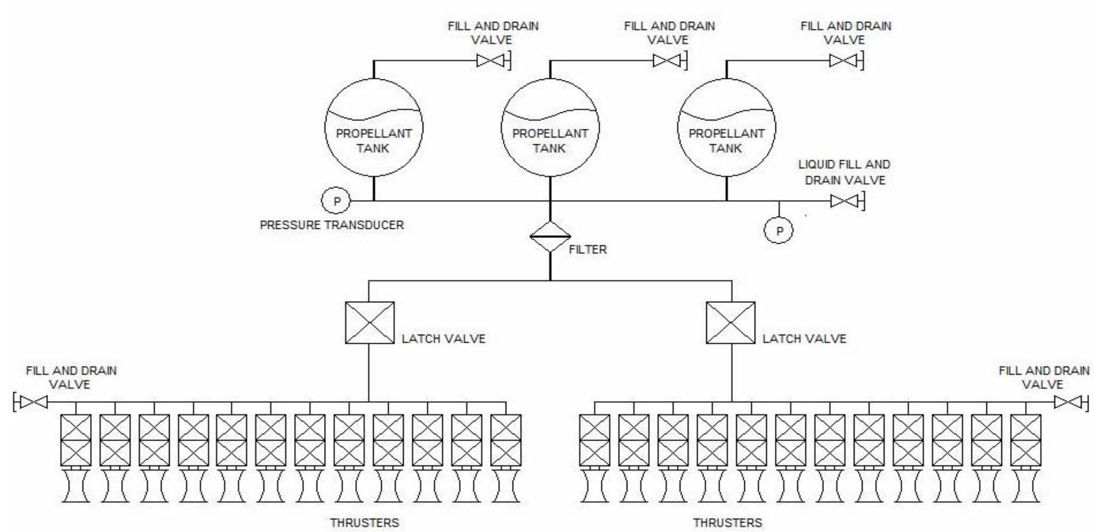
IXO service module: data handling

- **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
  - ICU interface the main S/C bus OBC by means of spacewire

IXO service module: propulsion

A Monopropellant system using Hydrazine (N_2H_4) is selected:

- 24 CHT-20 20N thrusters XMM – HP Astrium (D)
- 3 Titanium diaphragm tanks - Planck mission heritage (D)
- Sofrance filter (F)
- 2 Latch valve Moog (US)
- 2 Pressure transducers - Bradford(NL)
- 5 FDV/FVV Astrium (D)

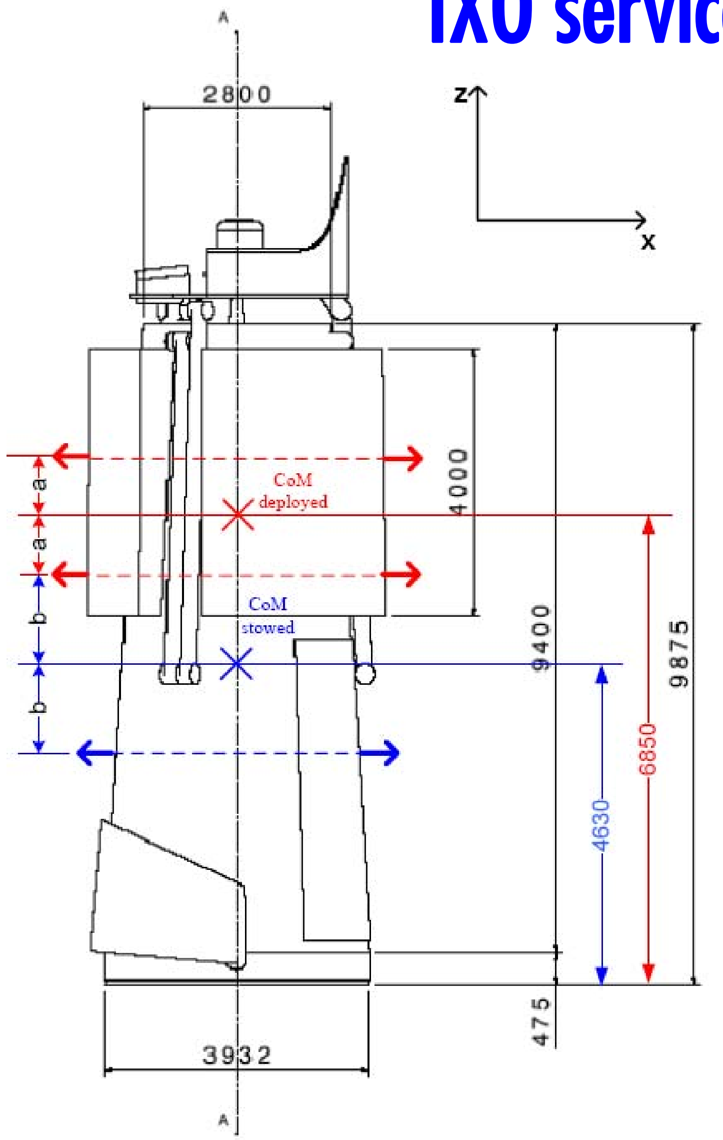


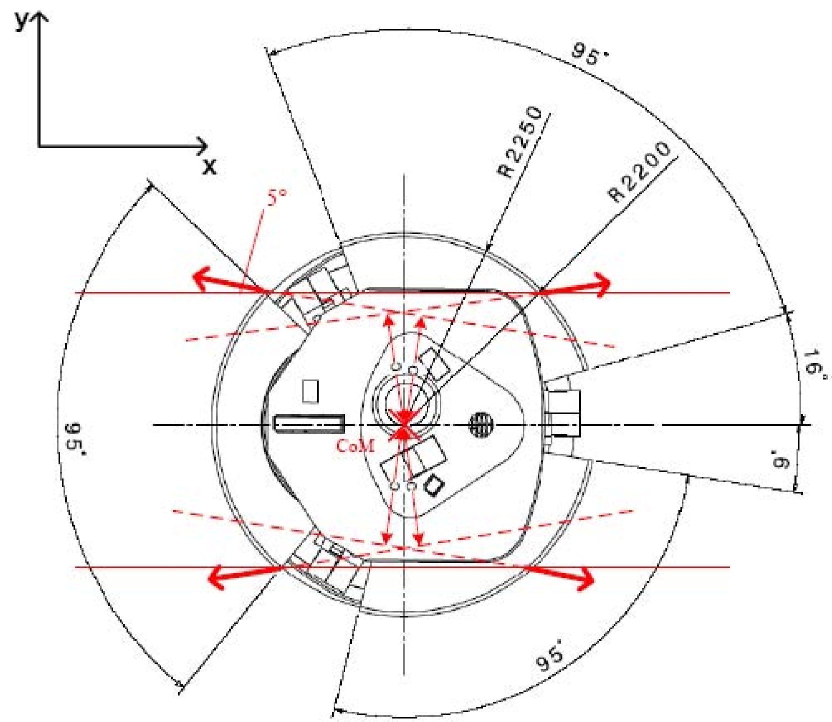
If total Wet Mass = 6090 kg + total ΔV = 100 m/s

then propulsion system =59 kg dry mass + 334 kg propellant = 393 kg

IXO service module: propulsion

SUN





All thrusters are inclined by 5° in the x-y plane with respect to the x-axis.

Assumptions:

a = 1000 mm
b = 1500 mm
c = 800 mm

2 x 12 thrusters with F = 22 N (incl. redundancy)

$\Delta V_x \rightarrow F_{eff} = F \times \cos(5°)$

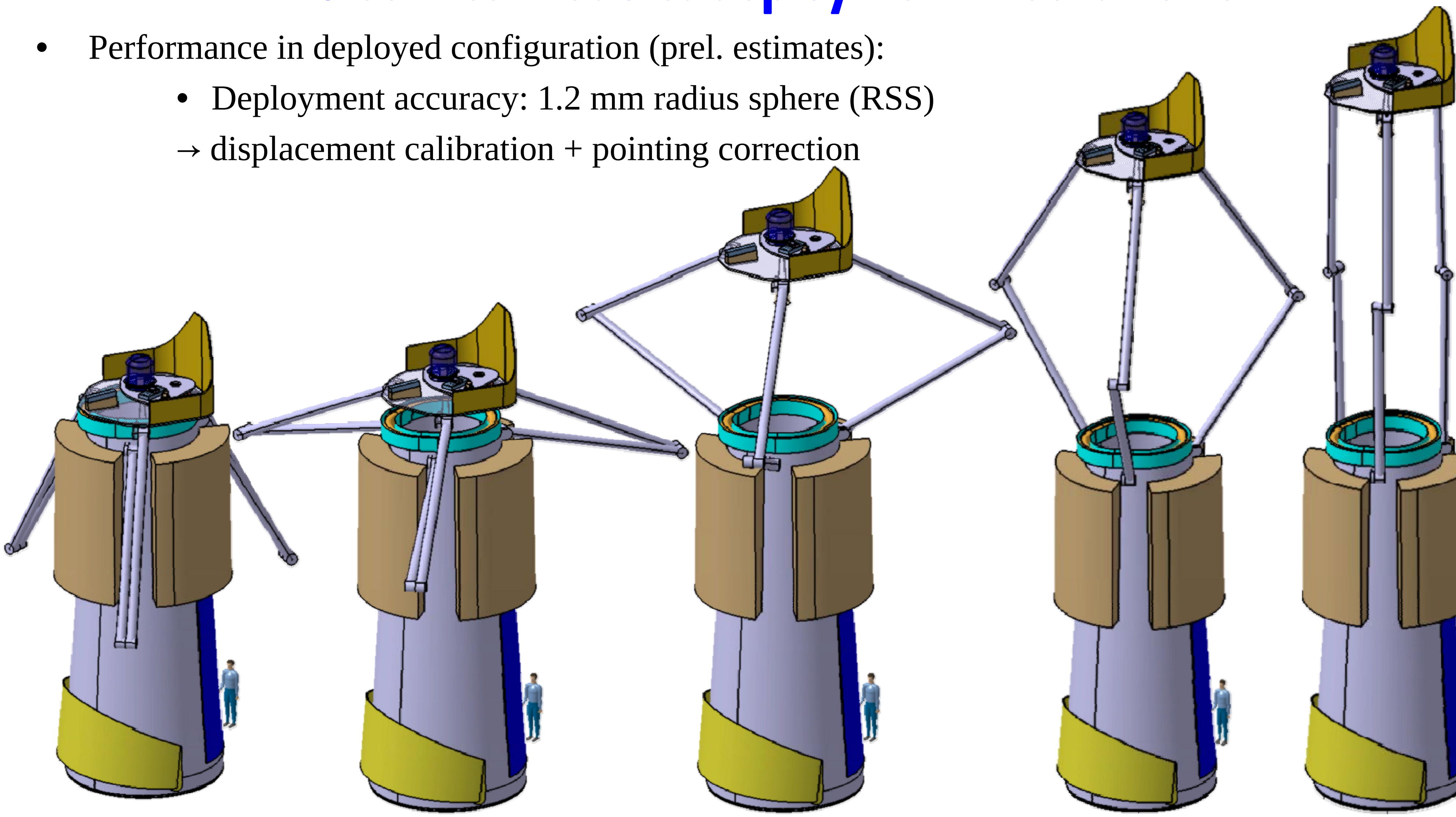
$\Delta V_y \rightarrow F_{eff} = F \times \sin(5°)$

IXO service module: mechanisms

- Optical bench deployment mechanism (articulated boom concept)
- Instrument exchange and refocusing mechanism
- Mirror assembly deployable sun shield
- Inner mirror assembly retractable cover (TBC)
- Outer mirror assembly ejectable cover
- High gain antenna pointing mechanism
- Solar array deployment mechanism

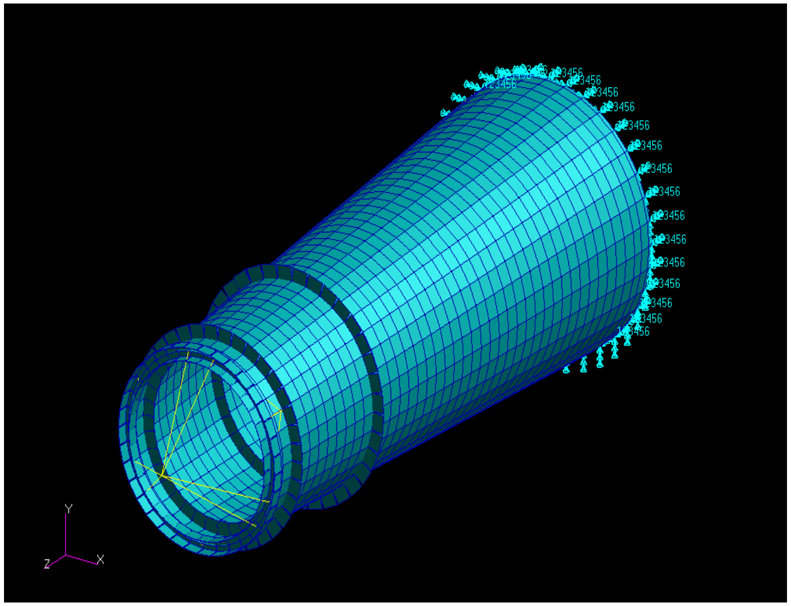
IXO service module: deployment mechanisms

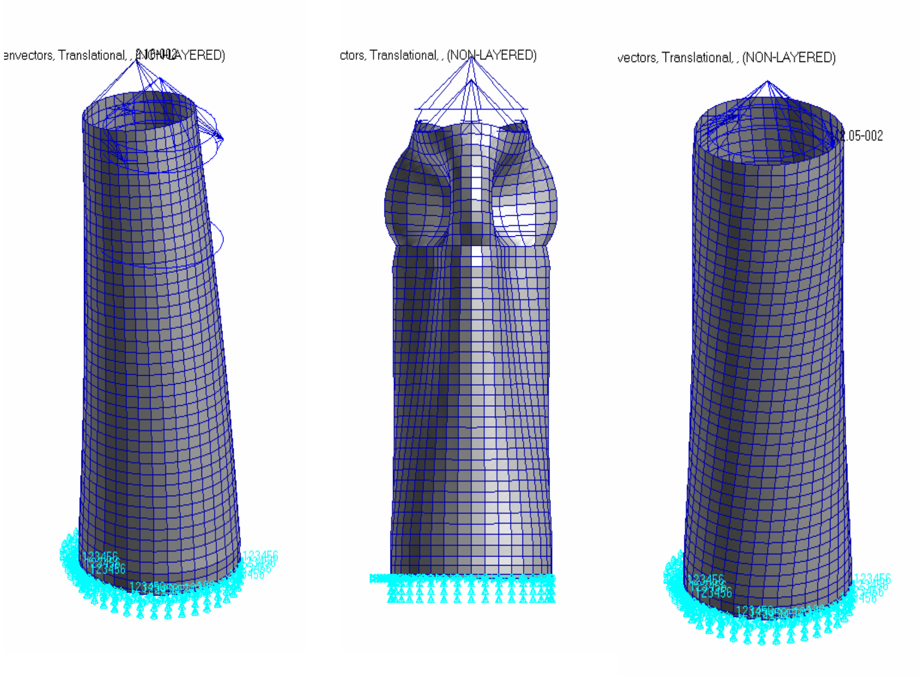
- Performance in deployed configuration (prel. estimates):
  - Deployment accuracy: 1.2 mm radius sphere (RSS)
  - → displacement calibration + pointing correction



IXO service module: deployment mechanisms

	Eigen Frequency (Hz)			
	Requirement			
Direction	Ariane 5	Atlas 5	FEM Target	FEM Result
Lateral	8.50	TBD	9.78	9.72
Longitudinal	27.00	TBD	31.05	44.47

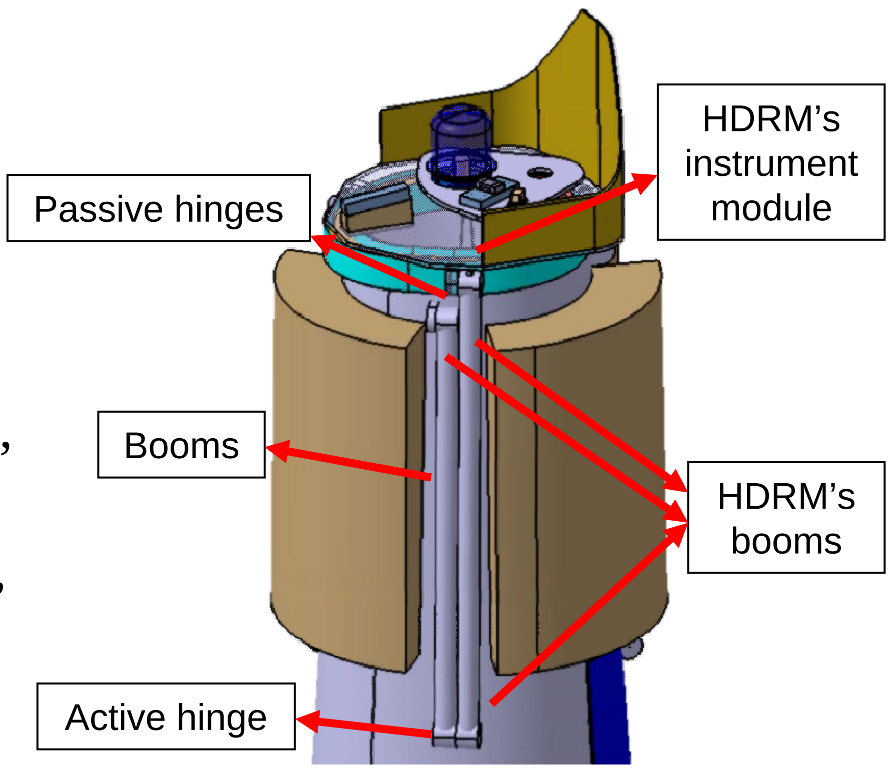




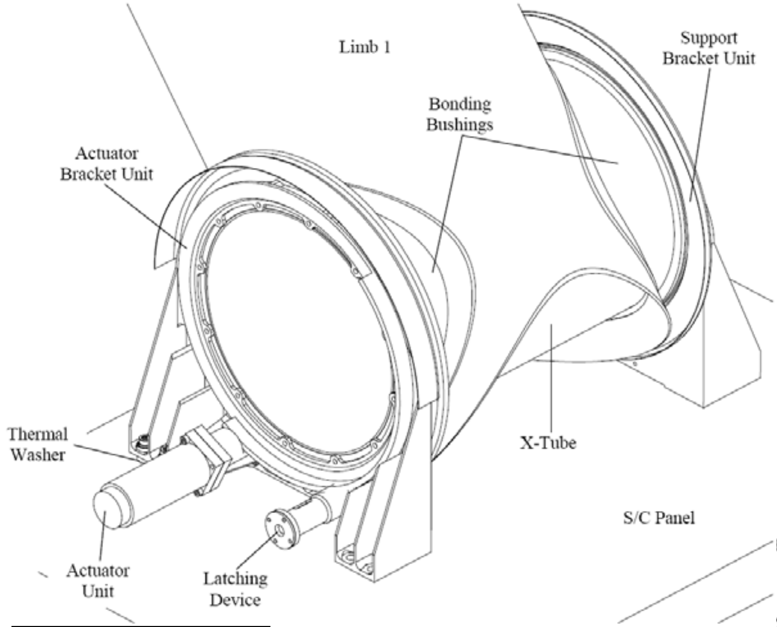
IXO service module: deployment mechanisms

Areas of concern for OB deployment mechanism:

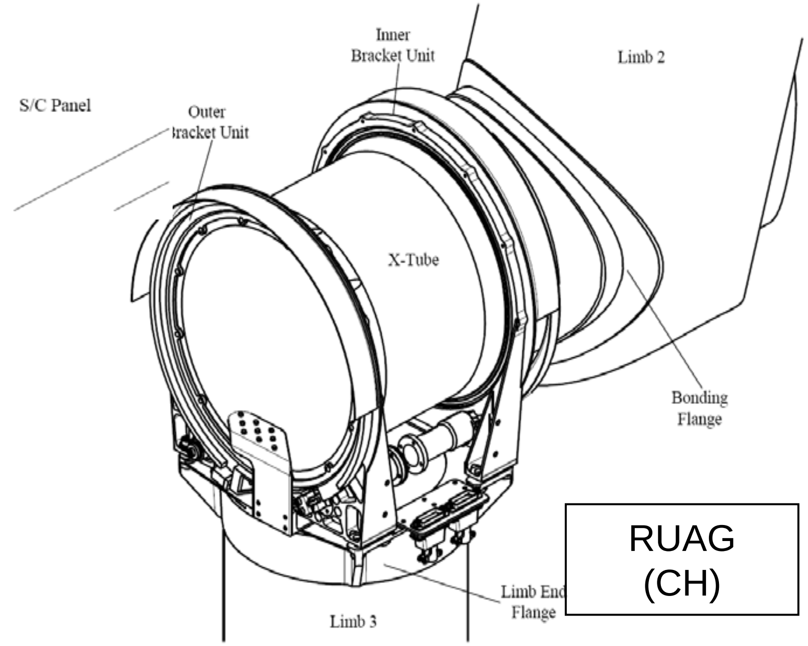
- Stowed configuration:
  - Number / location of hold-down and release mechanisms
- During deployment phase:
  - Adequacy of actuation torque
  - Misalignment / lack of synchronization between arm, thus high stresses, friction, potential jamming, due to :
    - initial alignment errors (on ground),
    - errors during actuation,
    - thermo-elastically induced distortions,
    - dynamic perturbation



IXO service module: deployment mechanisms

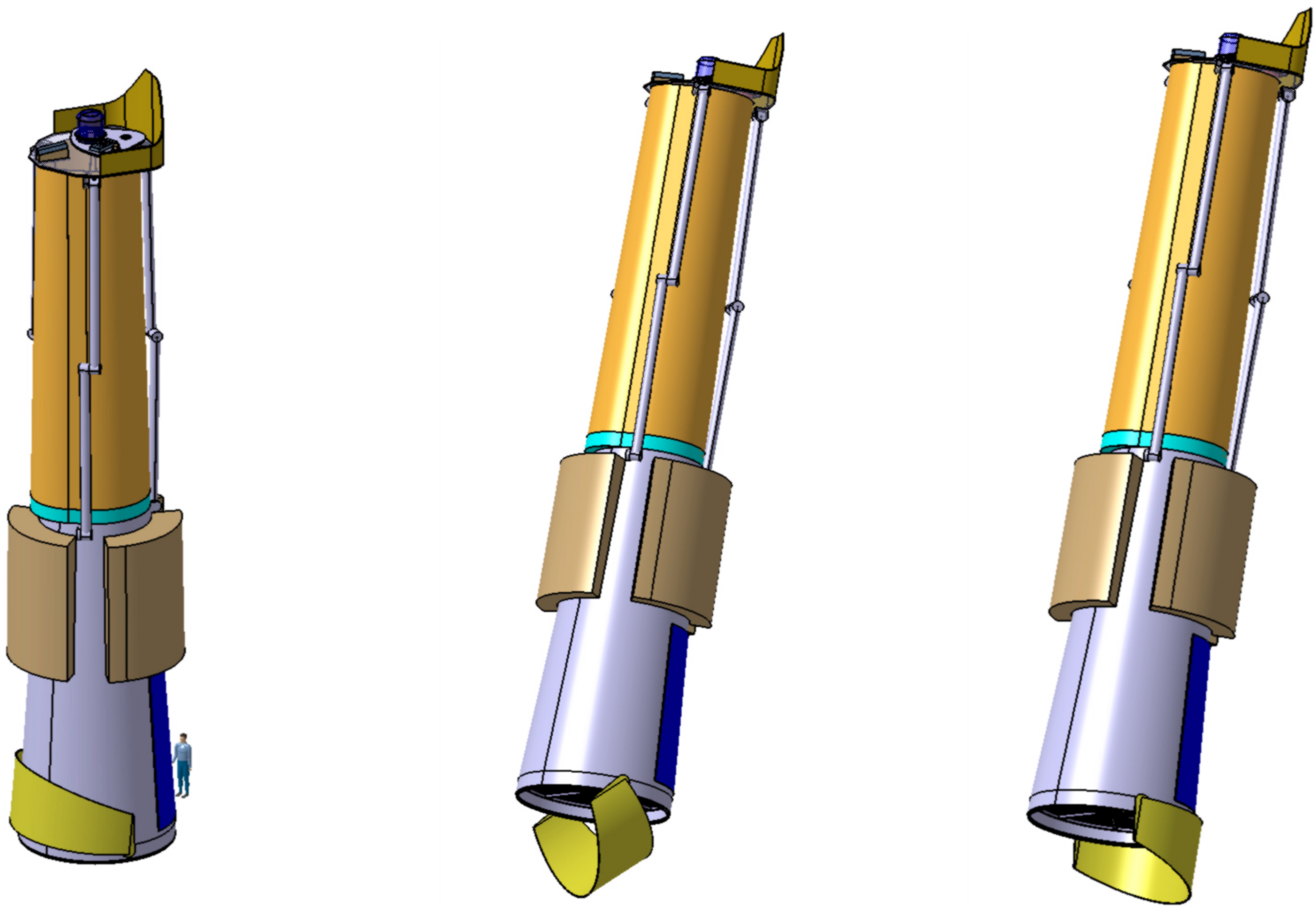


RUAG (CH)



RUAG (CH)

IXO configuration

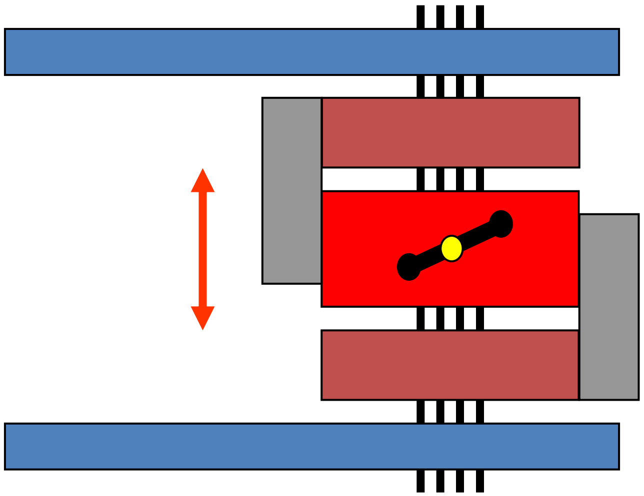


Shroud Scale Model

- The GSFC Blanket shop created this 1/25th scale prototype.
- Stows to 3.5cm with some compression force.
- Extends to 49cm nominally.
  - Can extend to about 65 cm with force, but risks tearing the corner seams.
- Stows to about 7% of nominal extension length. (3.5/49)

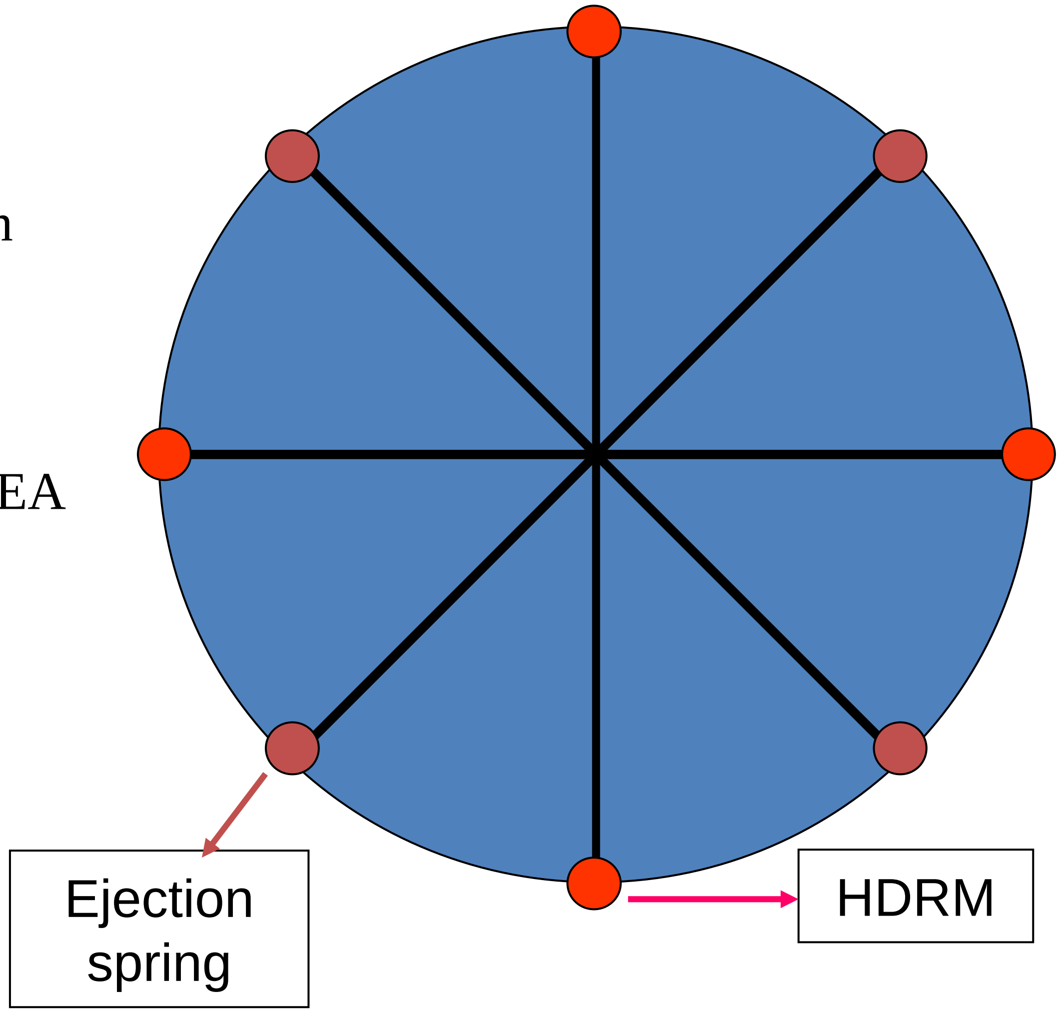
Instrument exchange and refocusing mechanism

- Integrated mechanism for rotational and linear movement
  - Two rotational drives
    - Stepper motors with angular encoders
    - Torque of 90 Nm (TBC-Harness definition missing)
    - Accuracy of 0.01 deg
  - Tilted slots and rolling elements for refocusing
    - Stroke of ±5 mm
    - Accuracy of 0.1 mm
  - Harness routing for minimal torque
  - Temperature controlled
    - > -20˚C operational temperature
  - Life: approx 2000 cycles



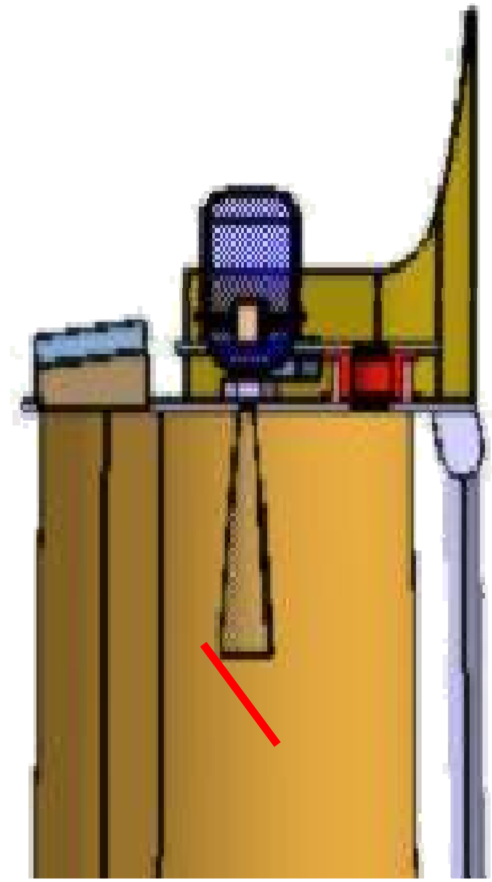
Mirror contamination protection

- Outer mirror assembly protection
  - Outer mirror assembly cover ejection mechanism
    - 4 springs
    - Ejection velocity 0.3-0.5 m/s
  - 4 x Non-explosive separation nut (NEA electronics)
    - Internally redundant
    - Quasi-simultaneous release



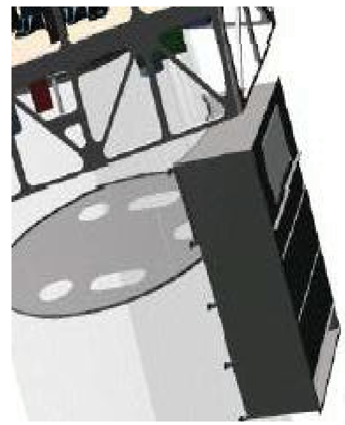
Mirror contamination protection

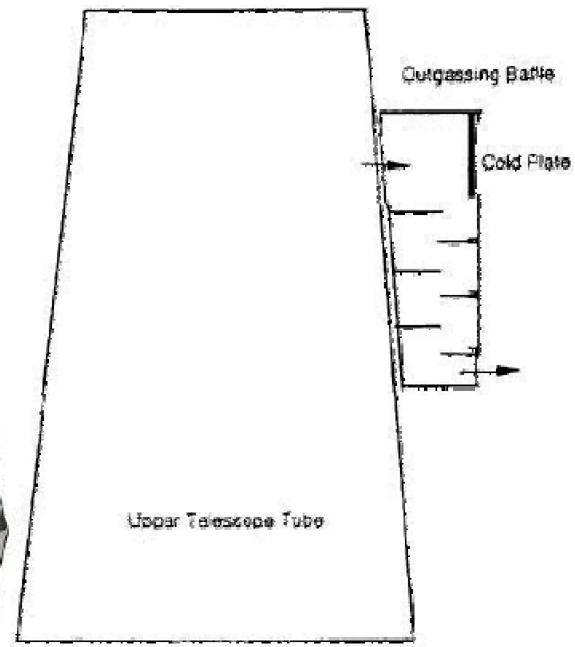
- Inner mirror assembly protection (Baseline)
  - Cover mirror during assembly
  - Eliminate sources of contamination
    - Main source: Electronic boxes on the inside of the instrument module
  - Overpressure telescope inner volume (N_2)
    - Mechanism to close focal point hole on the baffle inside
      - HDRM: Thermal knife
      - Deployment spring

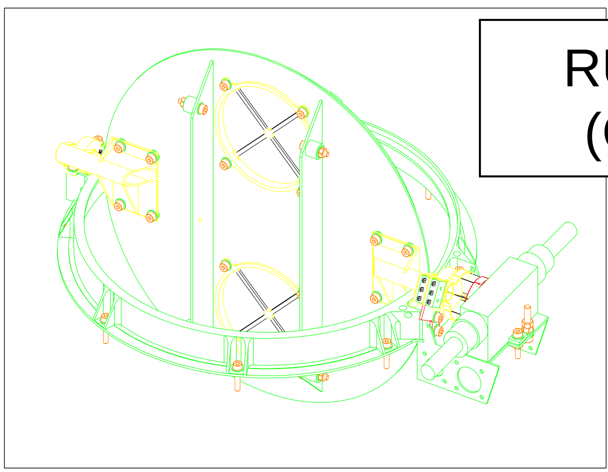


Mirror contamination protection

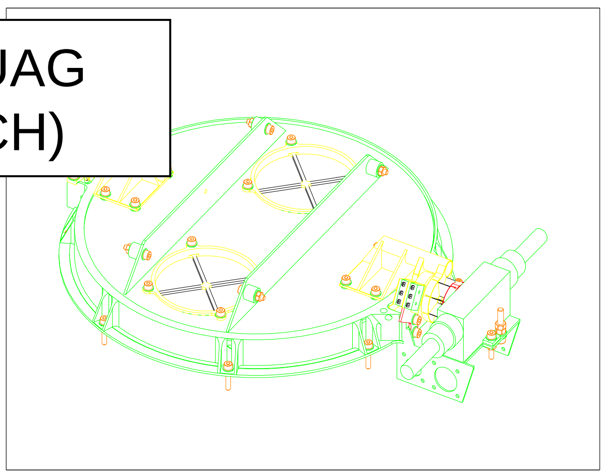
- Inner mirror assembly protection (Baseline)
  - Venting mechanism
    - Two venting and outgassing doors (XMM Newton)
    - Outgassing baffle (XMM Newton)

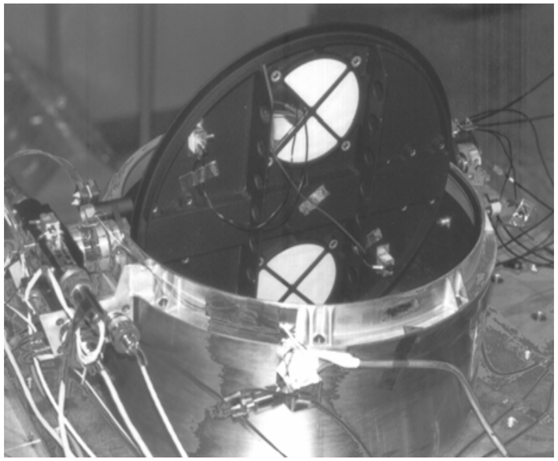






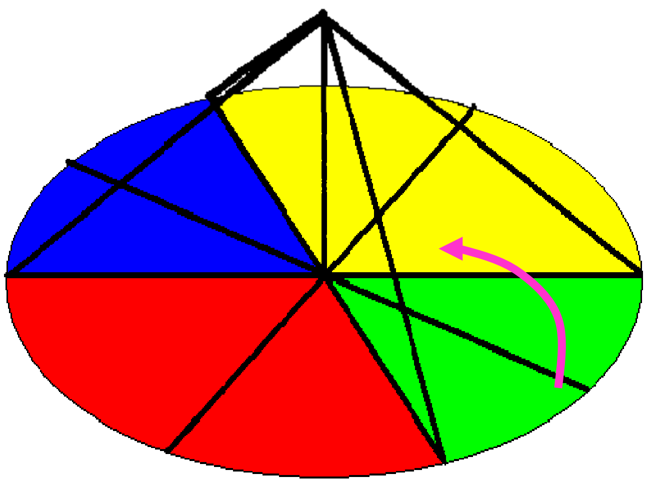
RUAG (CH)

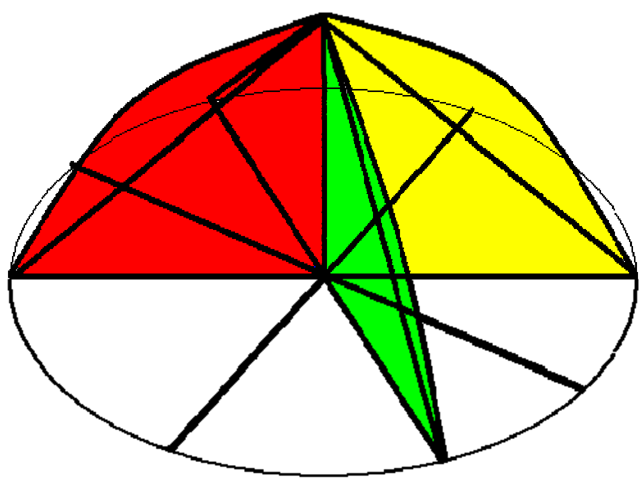


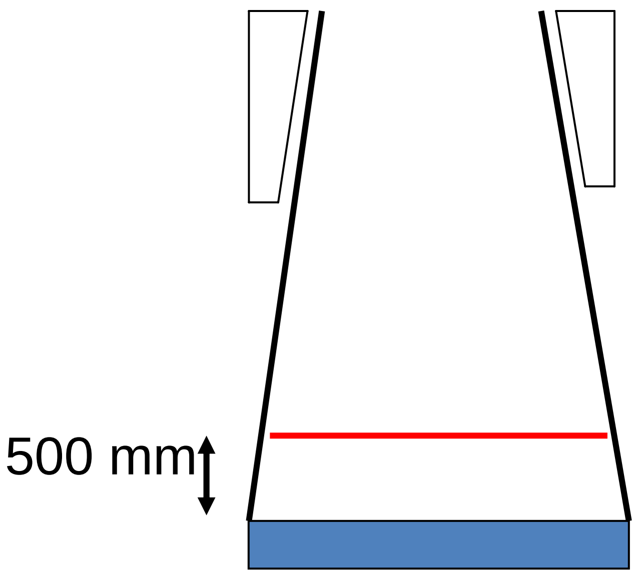


Mirror contamination protection

- Inner mirror assembly protection (Option / addition)
  - Deployment springs
  - 4 x 3 Thermal knives (Dutch space)
  - Dampers
  - Seal ring
  - Feasibility? Interface with XGS?

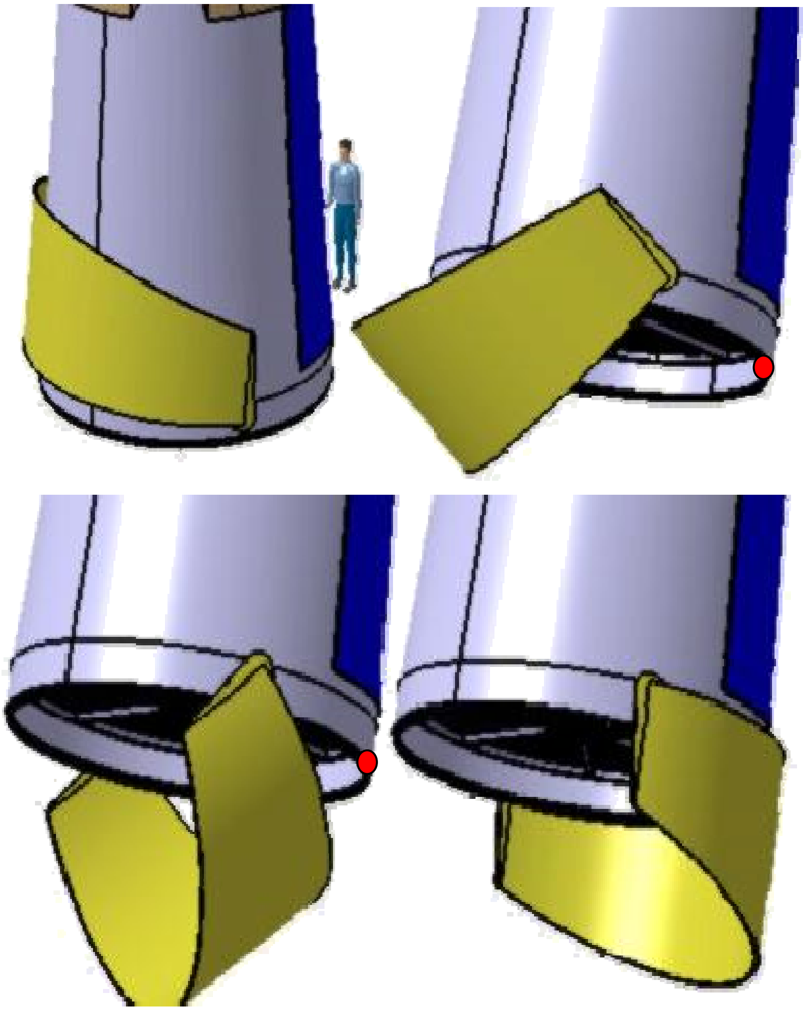






Mirror assembly sunshield

- Rotating mirror baffle (Baseline)
  - Two deployment springs
  - 4 x Thermal knives (Dutch Space)
  - Locking mechanism at the center of baffle half circle
- Inflatable structure (Option)



IXO service module: attitude and orbit control system

- **GNC Architecture : 3 modes**
  - Acquisition and Safe Hold (ASH) mode
    - Acquire Sun on +X axis
  - Fine Pointing and Slew (FPS) mode
    - Hold inertial pointing towards target
    - Target change manoeuvre
    - Note: use also during cruise
  - Thruster Control Maneuver (TCM) mode
    - Trajectory correction, orbit maintenance and wheel off-loading

IXO service module: attitude and orbit control system

- **GNC Equipments**
  - Actuators
    - Honeywell reaction wheel: HR16 (120 Nms) @ 0.2 Nm Note: possible alternative Goodrich TW-125E200
    - 5 reaction wheel (including 1 on Y-axis)
    - EADS monopropellant thruster: 22 N
  - Sensors
    - Sodern autonomous star tracker: Hydra
    - TNO fine sun sensor (calibrated bias error: 0.01^{o})
    - TNO sun acquisition sensor (accuracy < 1^{o})
    - SAE MEMS rate sensor (rate bias drift < 5^{o}/hr)
    - Alignment Monitoring Camera (AMC): Sodern coarse lateral sensor (derived from Hydra star tracker) FoV: 1^{o} – accuracy < 1”

IXO service module: attitude and orbit control system

42° (No. of slews / year: 250)	[day]	40.0	Settling time allocation: 5 min
180° (No. of slews / year: 10)	[day]	5.4	Settling time allocation: 5 min
Momentum management (every 2 days)	[day]	0.05	Settling time allocation: 2 min
L2 orbit maintenance (every month @ 4 hr)	[day]	2.05	Settling time allocation: 3 min
Detector (No. 41 @ 60 s)	[day]	0.03	Settling time allocation: 1 min
TOTAL	**[day]**	**48.3**	
Science	**[day]**	**316.7**	
Operational Efficiency	**%**	**86.8**	

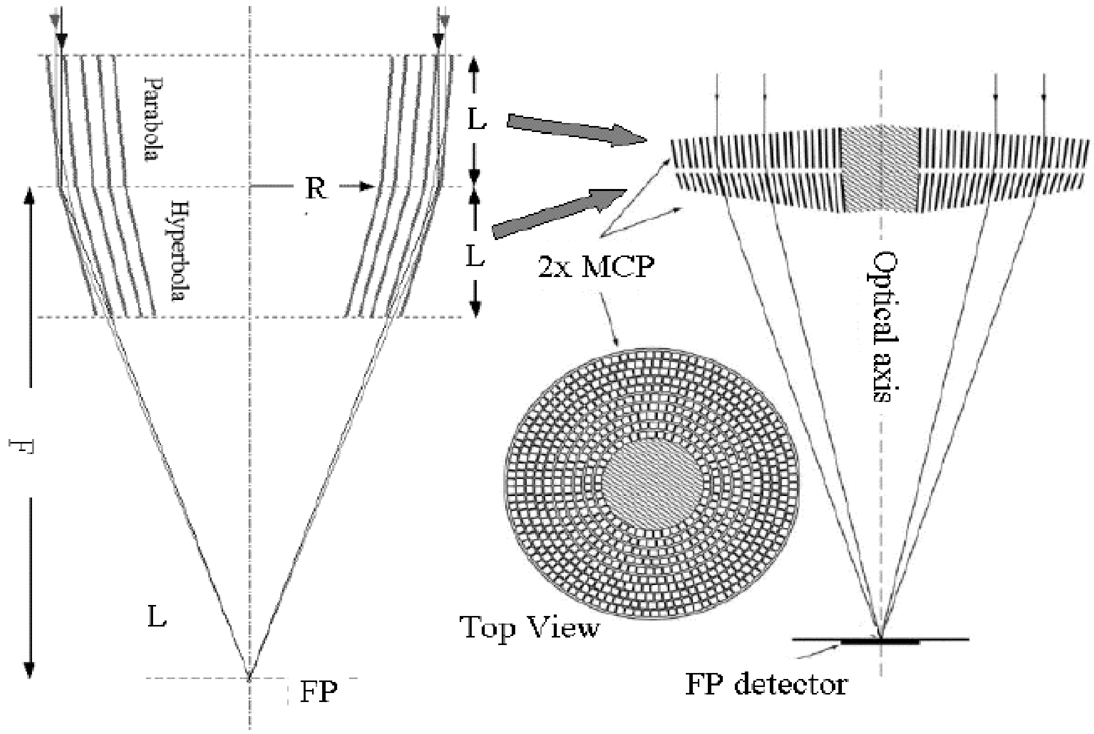
IXO service module: attitude and orbit control system

- Onboard pointing requirements (after stabilization)
  - (LT, MT) STR vs MA alignment 1.0 arcsec
  - (LT, MT, ST) STR measurement errors **4.0 arcsec**
- Preliminary image quality budget
  - (MT) STR vs MA alignment 0.3 arcsec[1]
  - (MT) STR measurement stability **1.0 arcsec**
- Preliminary astrometry budget
  - (MT) STR vs MA alignment 0.3 arcsec[1]
  - (S, LT) STR vs MA alignment 0.3 arcsec[1]
  - (S, ST) STR residual bias **0.5 arcsec**
  - (S, ST) Residual STR measurement noise **0.1 arcsec**

[1] *similar requirements for the Alignment Monitoring Camera*

IXO mission concept

IXO mirror assembly: specification requirements



Pore optics technology

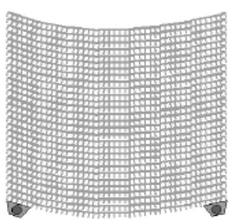
Double-conical approx to Wolter I

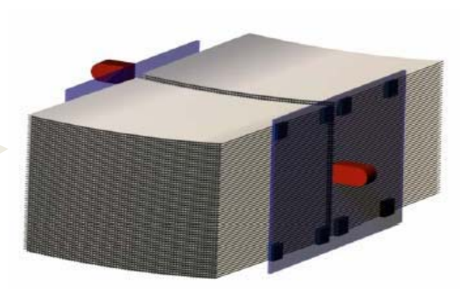
F = 20 m

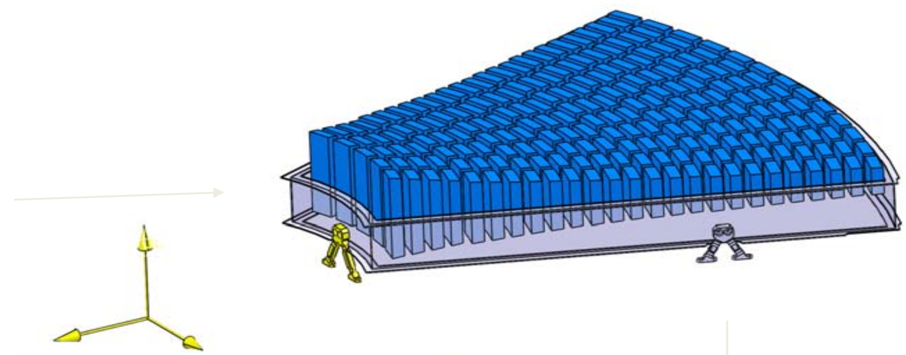
FOV = 17.5 x 17.5 arcmin

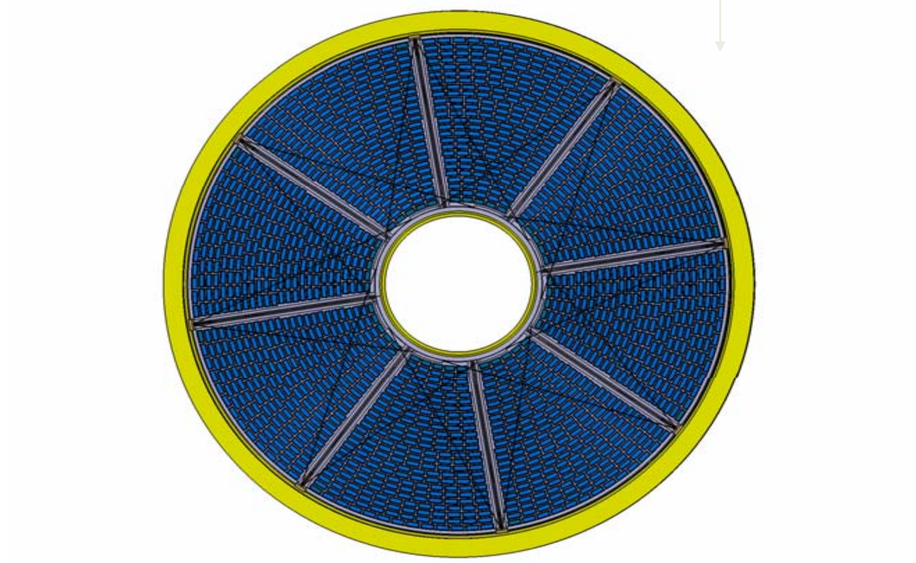
Coating:
- Irridium + C overcoating (outer shells)
- Multilayer coating (inner shells (θ < 0.27°)

IXO mirror assembly: manufacturing concept





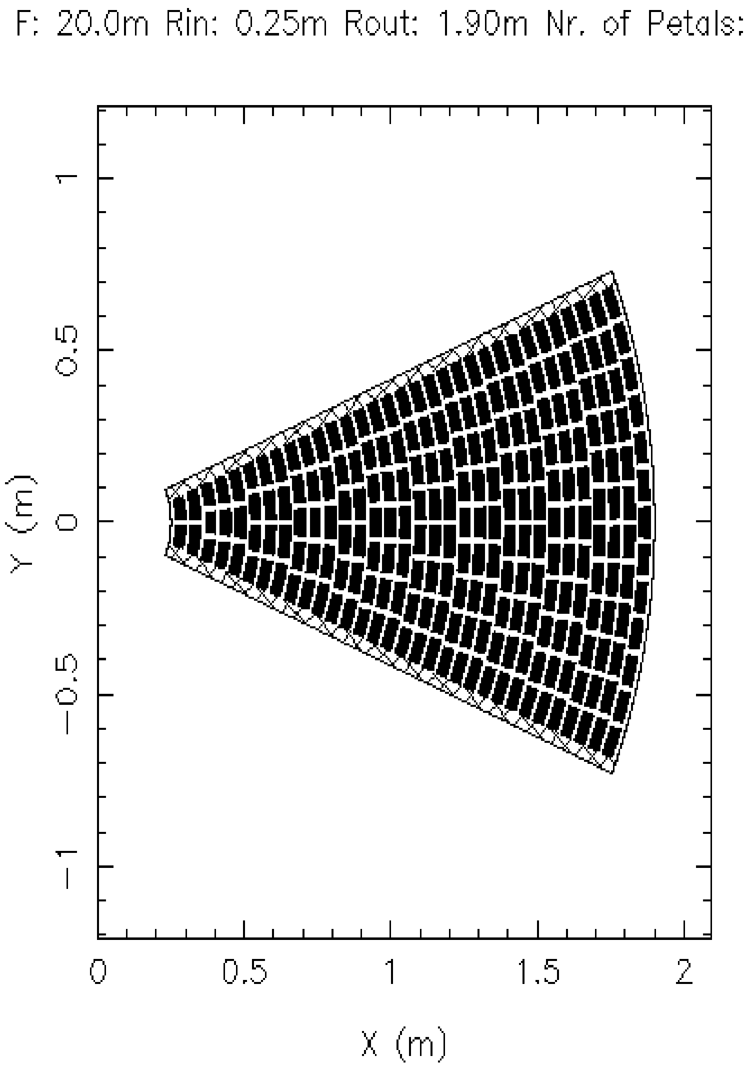




Hierarchical fabrication of mirror assembly

- Mirror stacks
- Mirror module
- Petals
- Optical bench

IXO mirror assembly: optical design



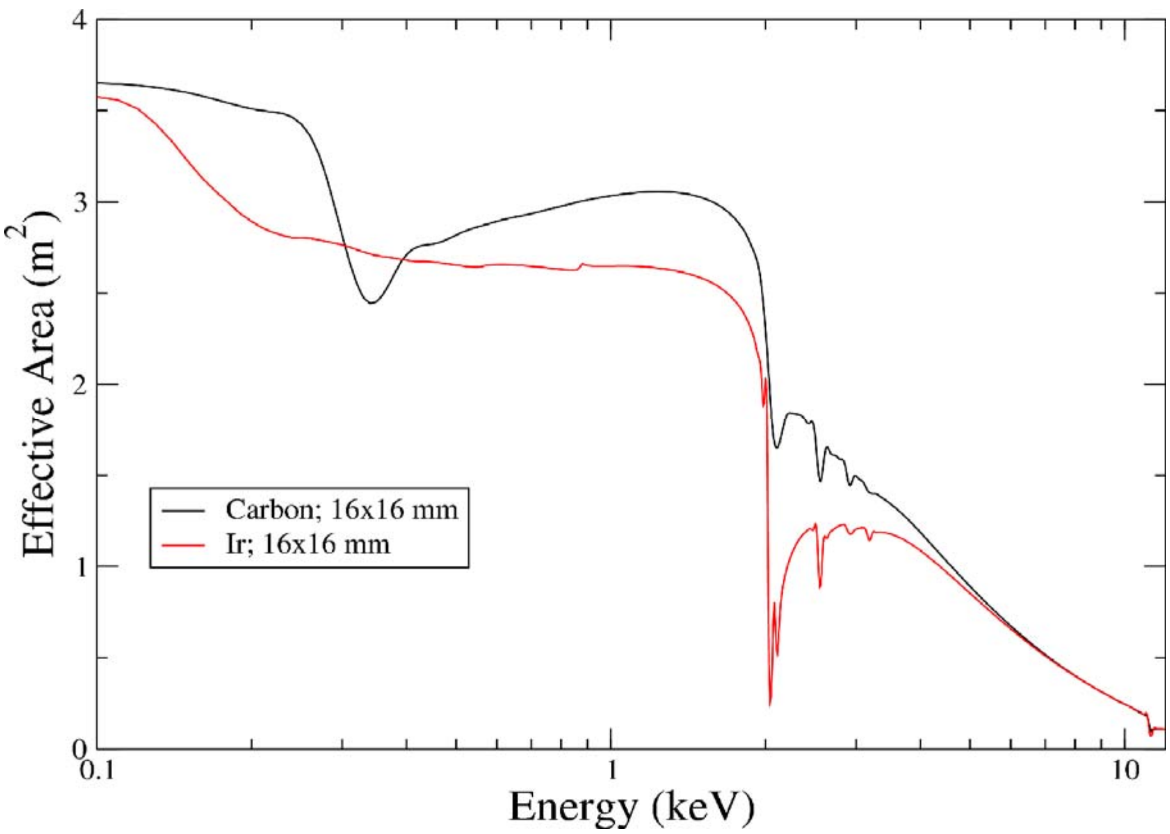
Optical design assumption:

- 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** (22mm assumed for XEUS)

--> The compatibility of the optical bench structure with the allocated mirror module spacing, mass, spoke width and launch loads has to be demonstrated by FEM analysis.

IXO mirror assembly: performance estimate (TBC)



Without C overcoating:

Aeff (1.25 keV) ~ 2.6 m2

Aeff (6.00 keV) ~ 0.65 m2

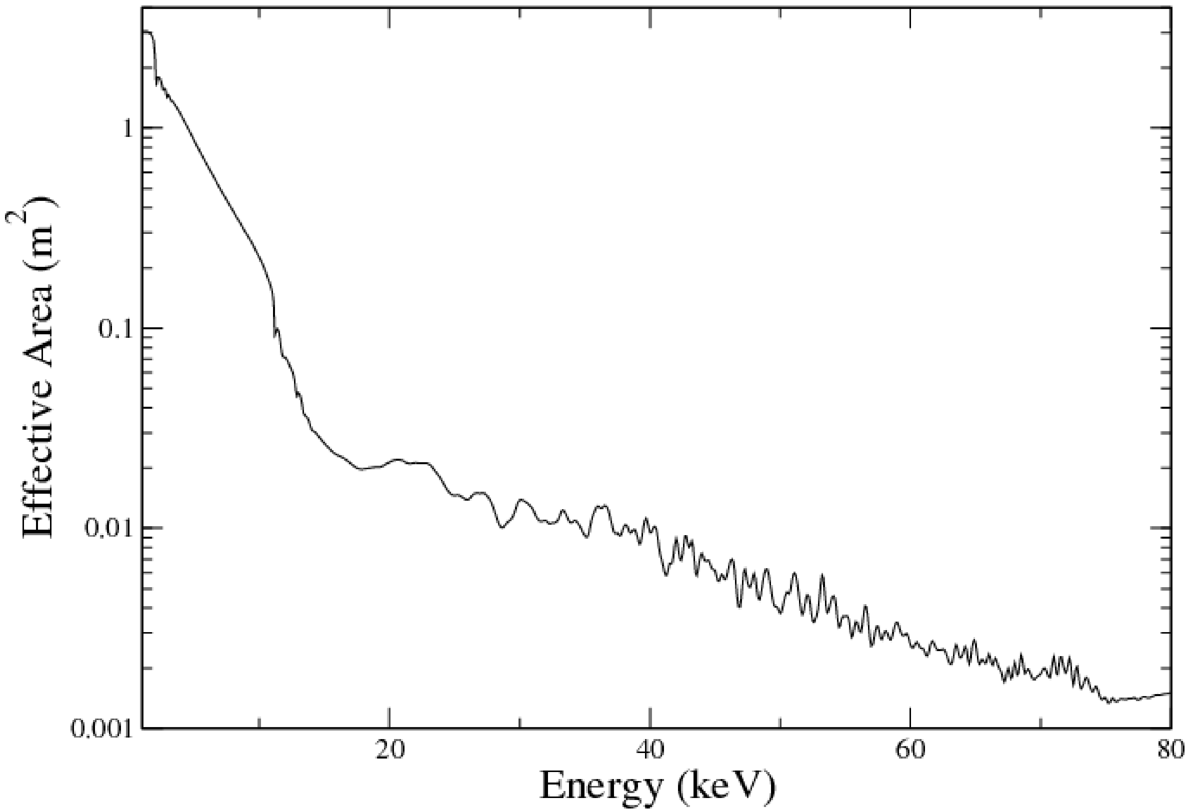
With 90 Angstrom C overcoating:

Aeff (1.25 keV) ~ 3.0 m2

Aeff (6.00 keV) ~ 0.65 m2

To achieve the 3m² Aeff at 1.25 keV requirements, the mirror modules shall be covered with a C overcoating

IXO mirror assembly: performance estimate (TBC)



With JAXA/ISAS multilayer design (courtesy H. Kunieda):

Aeff (30 keV) ~ 150 cm²

Mirror Module Thermal Control

- About 2[kW] heater power needed to operate the mirror assembly at high temperature (feasibility of room temperature operation is TBC for pore optics)
- A pre-collimator is foreseen to control the radiative environment in front of each individual mirror module
- A post collimator is foreseen to control the temperature gradient that will be induced by the inner conical structure.
  - Interface with grating spectrometer? thermal control of grating spectrometer?
- The Sunshield is covered with MLI on external side and SSM on internal side (TBC) for a mass estimated at 10[kg].
- The current thermal control system and configuration allows a slow rate of temperature drop (7.5[K]/hr)

IXO mission concept

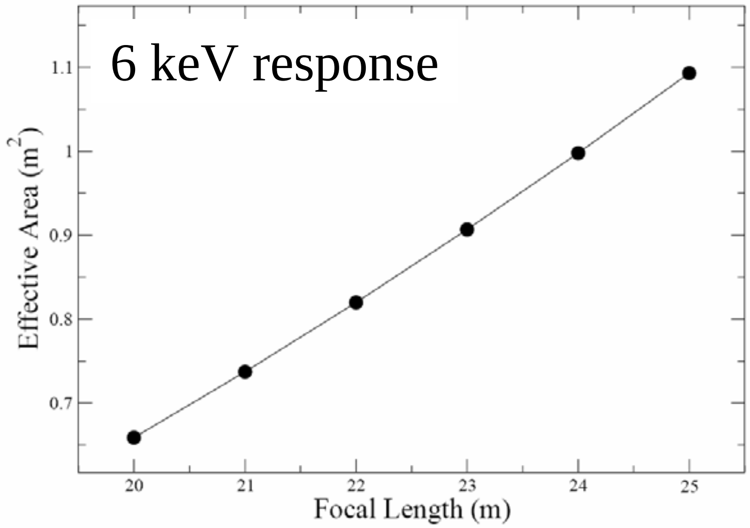
1 – Introduction
2 – IXO mission requirements
3 – IXO mission analysis
4 – IXO configuration
5 – IXO instrument module
6 – IXO service module
7 – IXO mirror assembly
8 – Options
9 – Conclusion

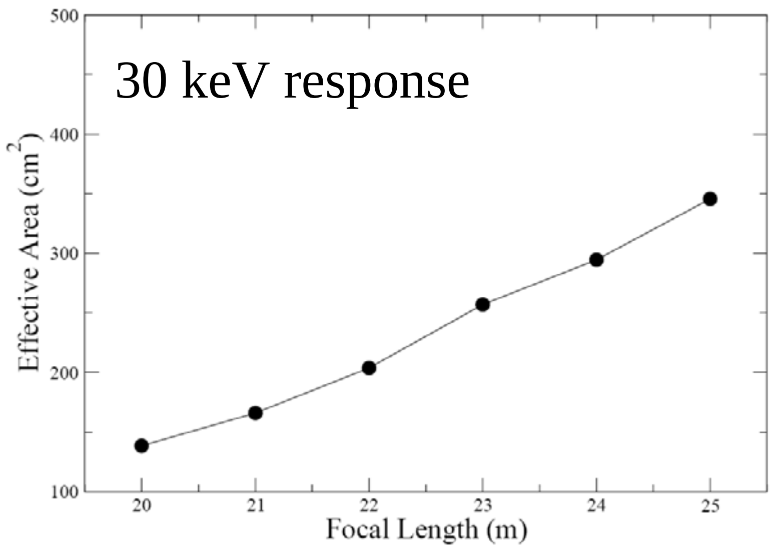
IXO mission concept: increased focal length

Increased focal length → mass increase

→ Mass to be taken on:
- mirror assembly:
- instruments:
  CSI
  or XGS without shroud

→ Large impact on the system





IXO mission concept: retractable grating box

Mirror assembly and CAT grating accommodation still to be studied:

- Mirror assembly optical design **(pore optics)** concept
- Mirror assembly petals and optical bench mechanical concept
- Mirror assembly thermal control (e.g. pre and post collimator, heaters)
- Mirror assembly contamination control (e.g. telescope cover, inner cover if needed)
- Grating box concept and interface requirements (NASA input to PDD)
- Definition of mirror assembly interface with grating spectrometer
- Grating accommodation concept
- Prospective achievable X-ray performance

Retractable grating concept option still to be studied:

- Difficulties anticipated: mechanism concept and reliability, XGS thermal control, accommodation/ interface with post collimator outer cover if needed

→ No solution identified during the CDF

IXO mission concept: X-ray events time stamping accuracy

- The GAIA installations for the pure timing accuracy can be reused:
  1.2 μs timing accuracy (excluding orbital accuracy induced errors)

- Orbital accuracy induced errors:

pass duration* [h]	$\delta\rho$ [km] (1σ)	$\delta\|\mathbf{r}\|$ [km] (1σ)	δt_ρ [μs] (1σ)	δt_r [μs] (1σ)	δv_ρ [mms^{-1}] (1σ)	δv_r [mms^{-1}] (1σ)
8	0.02	0.5	0.07	1.7	0.5	1.5
4	0.02	0.5	0.07	1.7	0.7	1.5
2	0.02	0.7	0.07	2.3	0.9	2.0
0.5	0.02	2.0	0.07	6.7	1.0	2.5

*plus 0.5h ranging

IXO mission concept: X-ray events time stamping accuracy

- 0.5 h pass (0.5h Doppler and 0.5h ranging):

  $$\delta t_{t+\rho+|\mathbf{r}|} = \text{SQRT}\,(1.2^2+0.07^2+6.7^2) = 7\ \mu s$$

- 2 h pass (2h Doppler and 0.5h ranging):

  $$\delta t_{t+\rho+|\mathbf{r}|} = \text{SQRT}\,(1.2^2+0.07^2+2.3^2) = 2.5\ \mu s$$

⇒ 10 μs 1σ achievable even with very short daily passes

⇒ 2h passes allow for higher accuracy (or for coverage gap of up to 2 days)

Time and position reconstitution requires post processing of measurements by Flight Dynamics, i.e. precision data are only available a posteriori (~ week after the fact)

IXO mission concept

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IXO mission concept: conclusion

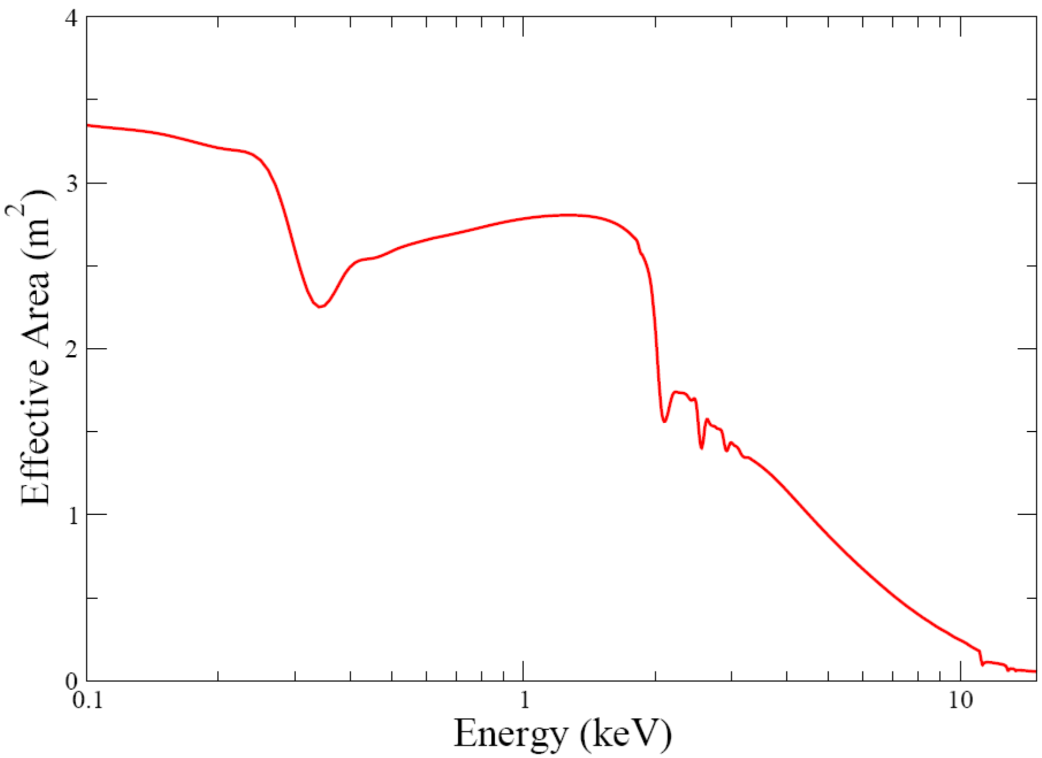
An IXO mission concept has been established that is:
- technically promising (no show-stopper identified)
- modular and well-suited to an International collaboration

The deployable IXO mission concept presents some risks:
- large number of experiments
- large number of deployable mechanisms
- complex collaboration set-up (high cost risk)

Highest technical risk areas include:
- mirror technology and overall mirror assembly (including grating accommodation),
- CSI (including cryogenic chain),
- bench deployment mechanism,
- instrument exchange mechanism,
- shroud (deployment and micrometeorites impact/straylight)
- mirror assembly cover/ front sunshield deployment
- instrument alignment vs mirror assembly/ metrology

IXO mission concept: conclusion

IXO CDF mission concept prospective performance (feasibility to be assessed):



IXO Aeff	Science Objectives	Estimated Performance
1.25 keV	3 m^2	2.8 m^2
6 keV	1 m^2	0.65 m^2
30 keV	350 cm^2	150 cm^2

Assuming:
- Fixed grating assembly with Aeff= 1000 cm2
- MA mass compatible with 1735 kg allocation
- 16 mm MM spacing compatible with launch load
- Carbon overcoating on mirrors
- 50 ppm dust and 1 A microroughness (optimistic)

--> feasibility to be assessed

IXO mission concept: conclusion

IXO open issues:

- Mirror assembly opto-thermo-mechanical design/ performance
- XGS instrument definition and interface requirements (input to PDD)
- XGS grating box accommodation
- Optical bench deployable mechanism → performance/risks/ reliability
- Deployable shroud / micrometeorites impact → stray-light
- Grating box retractable mechanism/ effective area at low X-ray energy

→Post CDF activities:

- Mirror assembly opto-thermo-mechanical design/ performance
- AOCS performance estimate (effect of deployed bench and solar array)
- Deployable mechanism dynamic analysis
- Straylight analysis (TBC)
- L2 particle environment