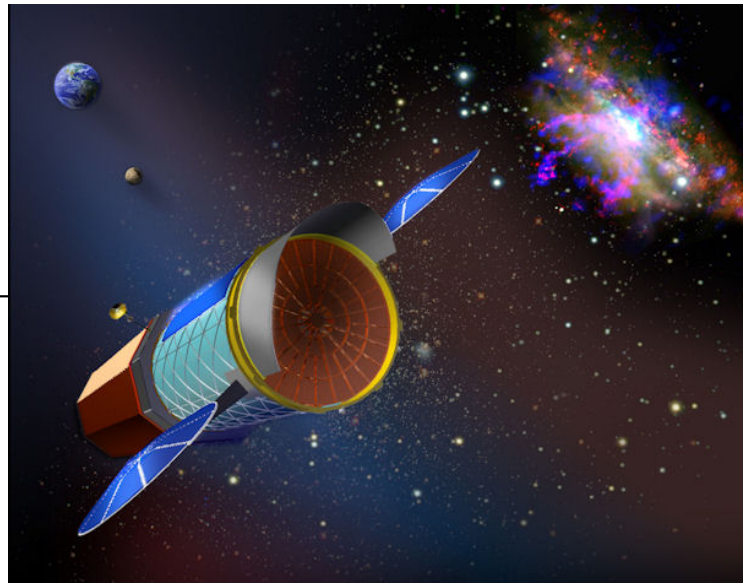
Suzaku/IXO Meeting / June 29 – July 3, 2009
Japan/Hokiado

NASA IXO Mission Concept



Nick White / GSFC
IXO NASA Project Scientist

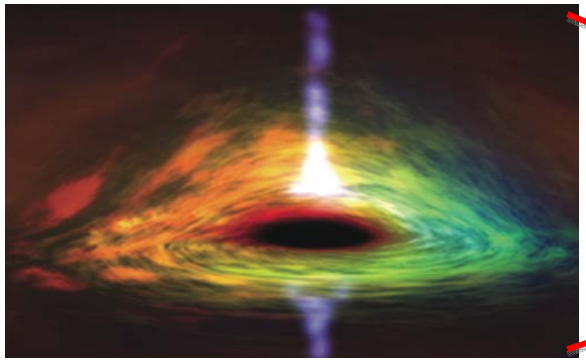
On behalf of

Jean Grady / GSFC

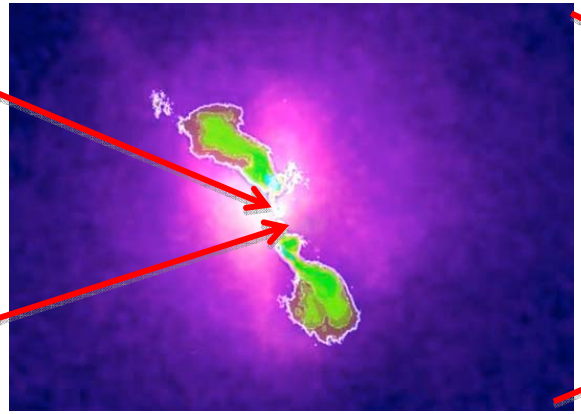
IXO NASA Project Manager

The International X-Ray Observatory (IXO) will address fundamental and timely questions in astrophysics:

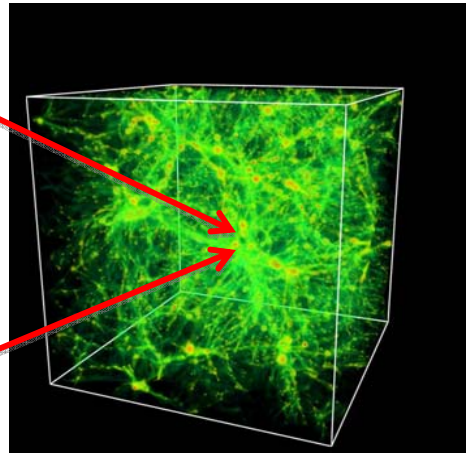
- What happens close to a black hole?
- When and how did super-massive black holes grow?
- How does large scale structure evolve?
- What is the connection between these processes?



Black Hole Accretion

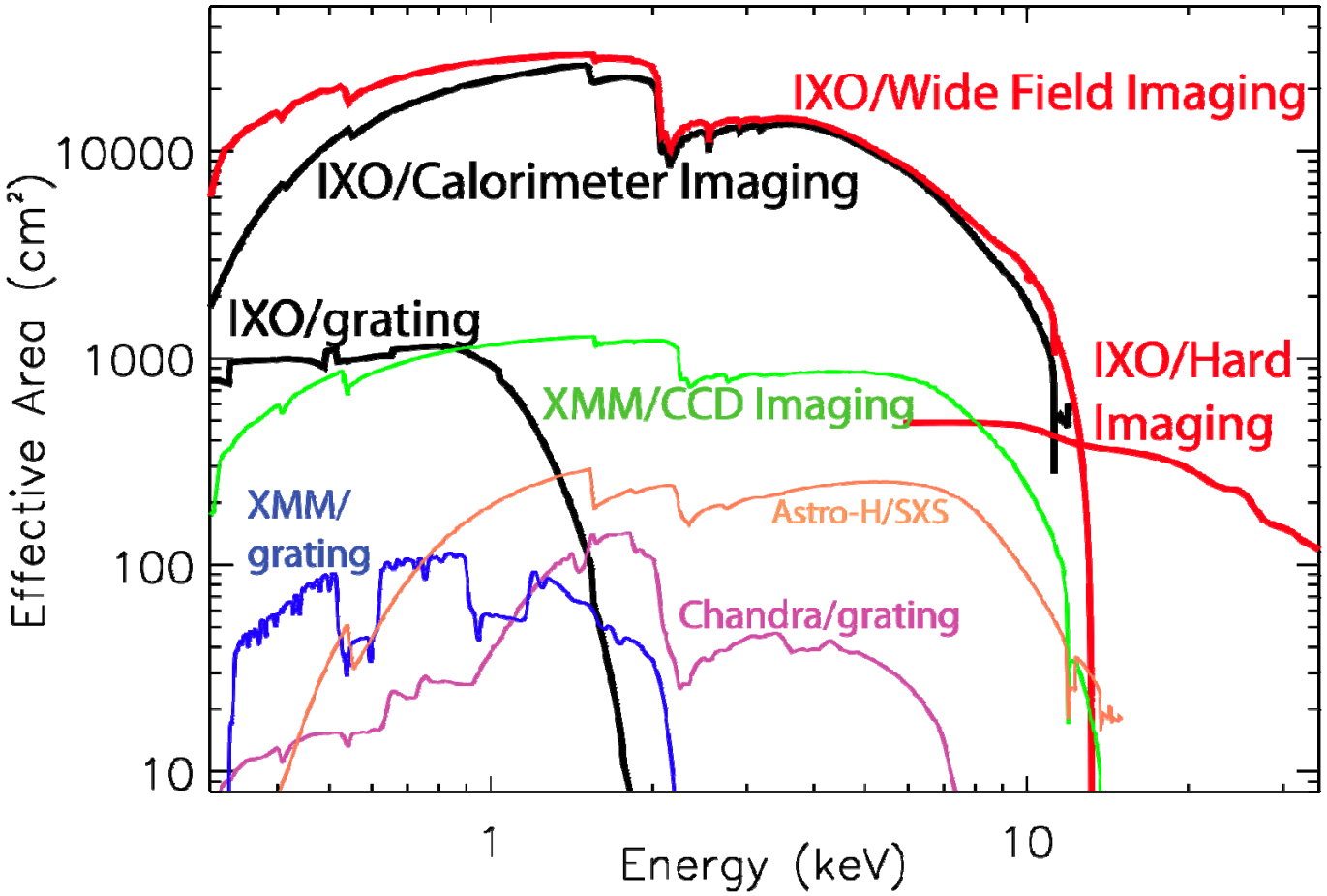


Hydra A Galaxy Cluster



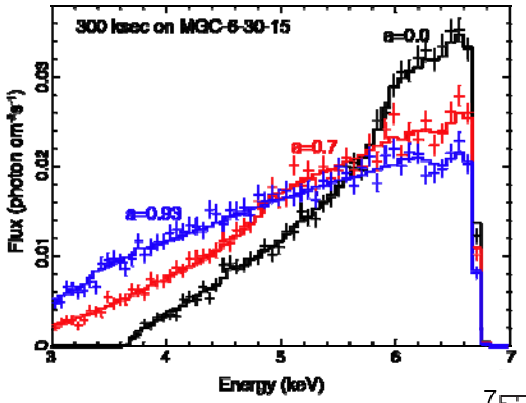
Cosmic Web

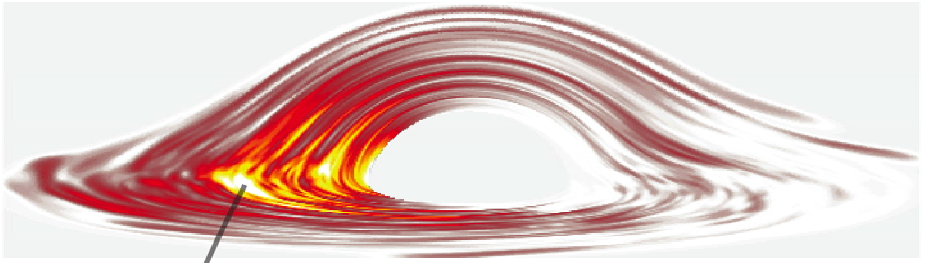
IXO is a Vast Improvement over Existing Missions

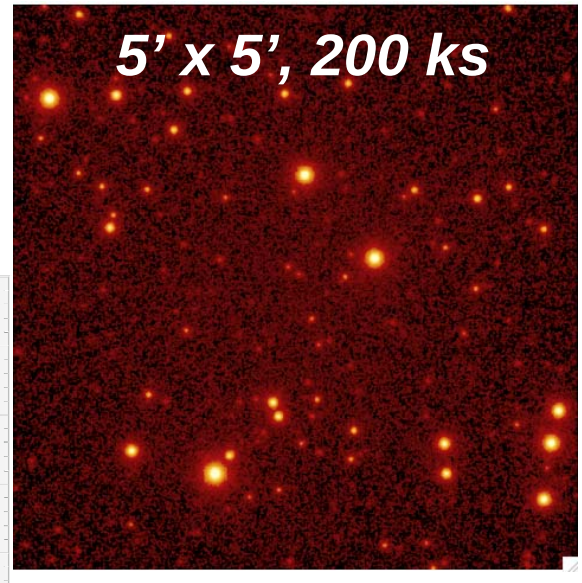


Effective area a factor of >10x of current missions
Spectroscopy capabilities >100x of current missions

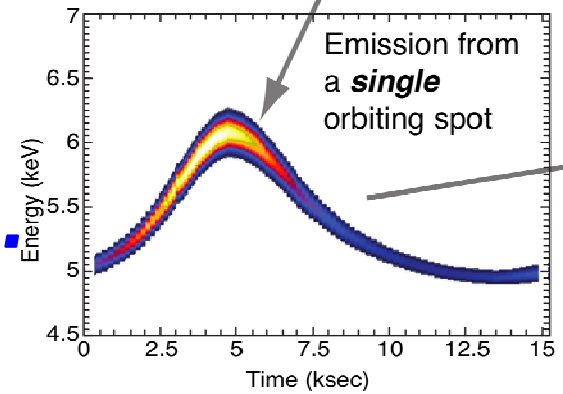
Individual Black Holes…and Black Hole Surveys

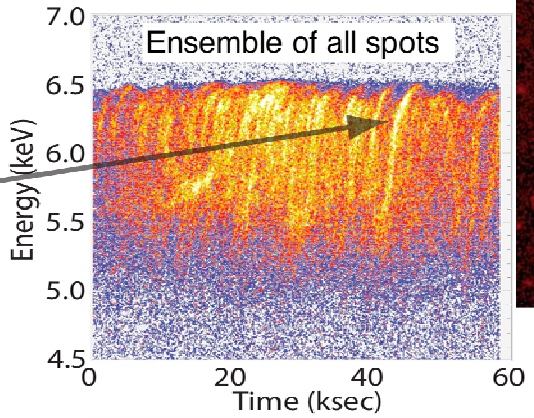




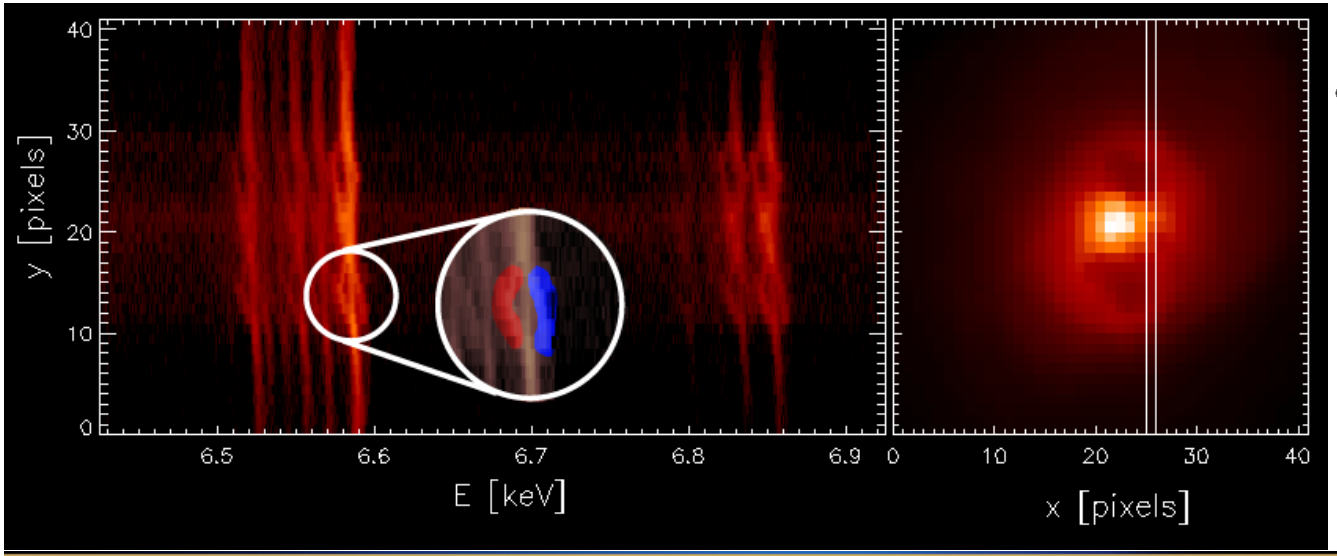


IXO will measure...

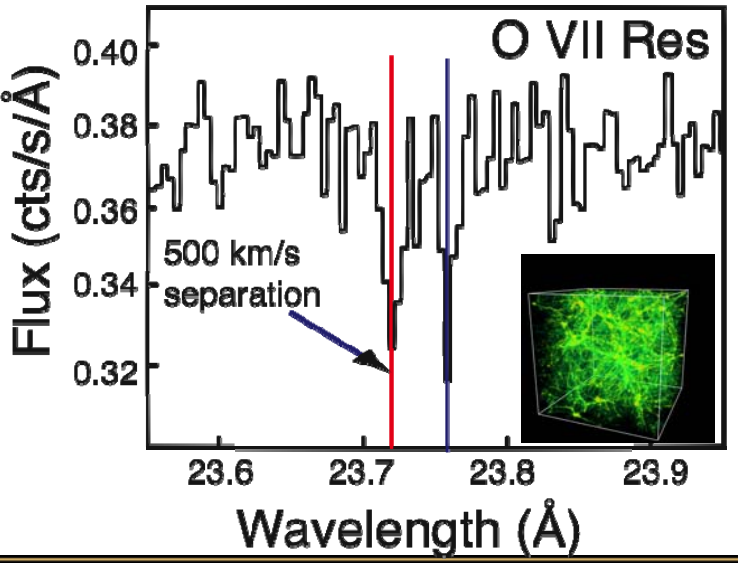




Cluster Gas Motion and Feedback

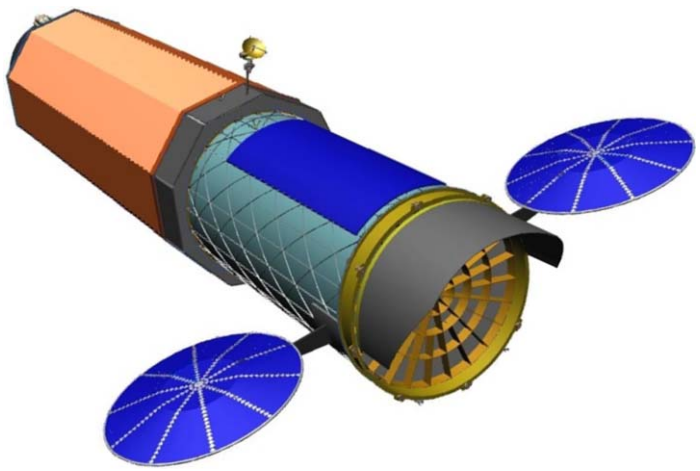


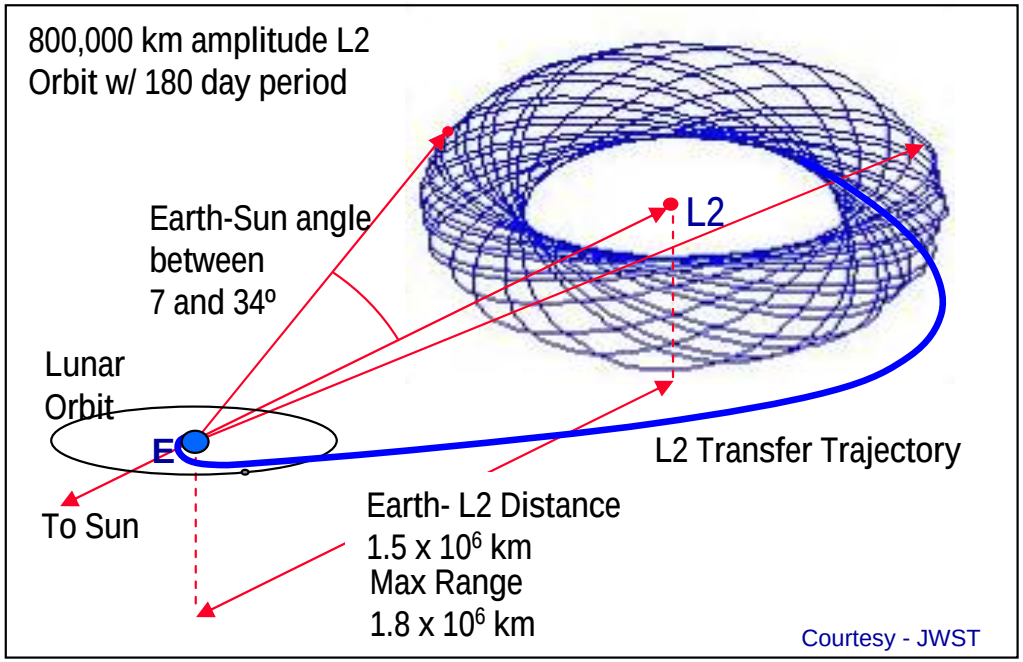
…and the Cosmic Web



IXO Mission

- International Collaboration
  - NASA, ESA, JAXA
- Payload
  - 3.3 m dia X-ray mirror
  - 20 m focal length w/ 12 m extensible metering structure
  - Five science instruments for imaging and spectroscopy
- Mission Class
  - Mission Life: 5 years required, 10 years goal, consumables sized for 10 years
  - Class B : no performance degradation w/ single point failure
- Launch
  - December 2021
  - Atlas V 551 medium fairing or Ariane 5
  - Max Liftoff Mass: 6425
  - Direct launch into “zero Insertion delta-v” L2 orbit
  - 100 day cruise
- Orbit
  - L2 800,000 km semi-major axis halo orbit
  - 0% solar or lunar obscuration throughout 10 years



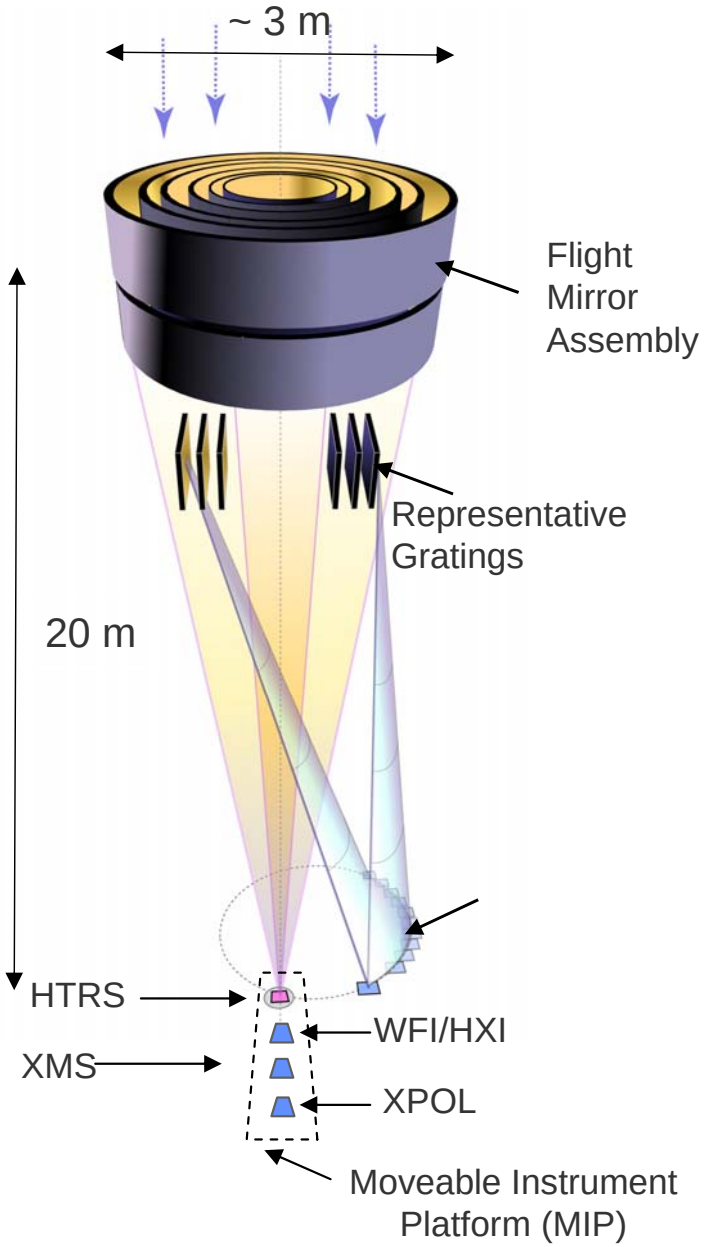


Key Performance Requirements

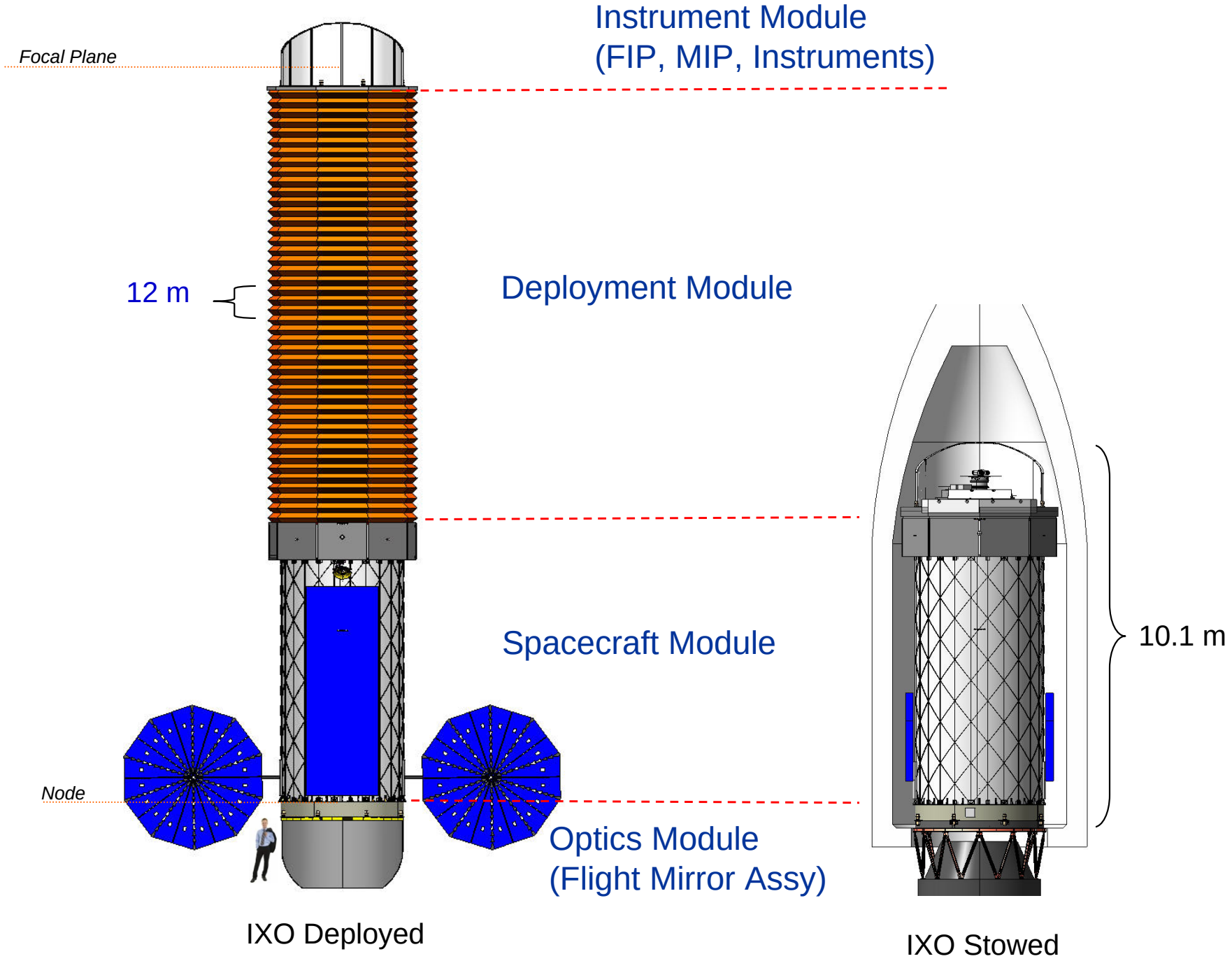
Mirror Effective Area	3 m^2 @1.25 keV 0.65 m^2 @ 6 keV with a goal of 1 m^2 150 cm^2 @ 30 keV with a goal of 350 cm^2	Black hole evolution, large scale structure, cosmic feedback, EOS Strong gravity, EOS Cosmic acceleration, strong gravity
Spectral Resolution	ΔE = 2.5 eV within 2 x 2 arc min (0.3 – 7 keV) . ΔE = 10 eV within 5 x 5 arc min (0.3 - 7 keV) ΔE < 150 eV @ 6 keV within 18 arc min diameter (0.1 - 15 keV) $E/\Delta E$ = 3000 from 0.3–1 keV with an area of 1,000 cm^2 with a goal of 3,000 cm^2 for point sources ΔE = 1 keV within 8 x 8 arc min (10 – 40 keV)	Black Hole evolution, Large scale structure Missing baryons using tens of background AGN
Mirror Angular Resolution	≤5 arc sec HPD (0.1 – 7 keV) ≤30 arc sec HPD (7 - 40 keV) with a goal of 5 arc sec	Large scale structure, cosmic feedback, black hole evolution, missing baryons Black hole evolution
Count Rate	1 Crab with >90% throughput. ΔE < 200 eV (0.1 – 15 keV)	Strong gravity, EOS
Polarimetry	1% MDP (3 sigma) on 1 mCrab in 100 ksec (2 - 6 keV)	AGN geometry, strong gravity
Astrometry	1 arcsec at 3 σ confidence	Black hole evolution
Absolute Timing	50 μ sec	Neutron star studies

IXO Payload

- **Flight Mirror Assembly (FMA)**
  - Highly nested grazing incidence optics
- **Instruments**
  - X-ray Micro-calorimeter Spectrometer (XMS)
  - X-ray Grating Spectrometer (XGS)
  - Wide Field Imager (WFI) and Hard X-ray Imager (HXI)
  - X-ray Polarimeter (X-POL)
  - High Time Resolution Spectrometer (HTRS)
- **XMS, WFI/HXI, XPOL and HTRS observe one at a time by being inserted into focal plane via a Moveable Instrument Platform (MIP)**
  - 4 Science Operational Modes
  - XGS always operational



IXO Observatory



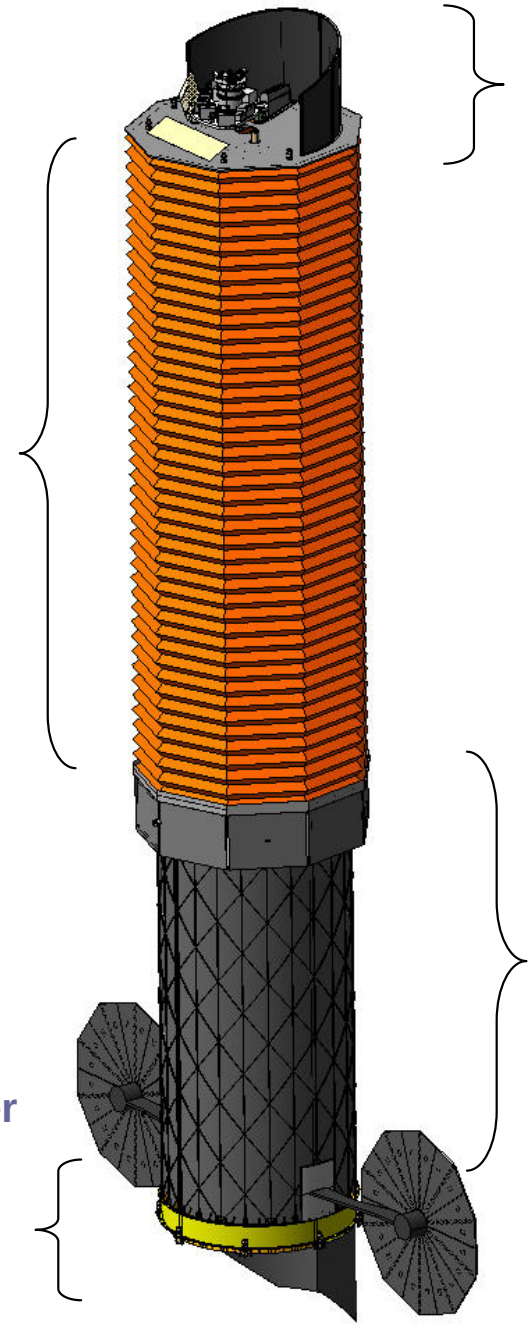
Observatory Modules

Instrument Module

- Fixed Sunshade
- Moveable Instrument Platform (MIP) w/ four Instruments: XMS, WFI/HXI, X-POL, HTRS
- Fixed Instrument Platform (FIP) w/ fifth Instrument: XGS Camera

Deployment Module

- Three extensible ADAM-type masts with harness (not shown)
- 3.9 m diameter shroud, Whipple shield construction for micrometeoroid protection
- Two 3.5 m dia X-ray baffles



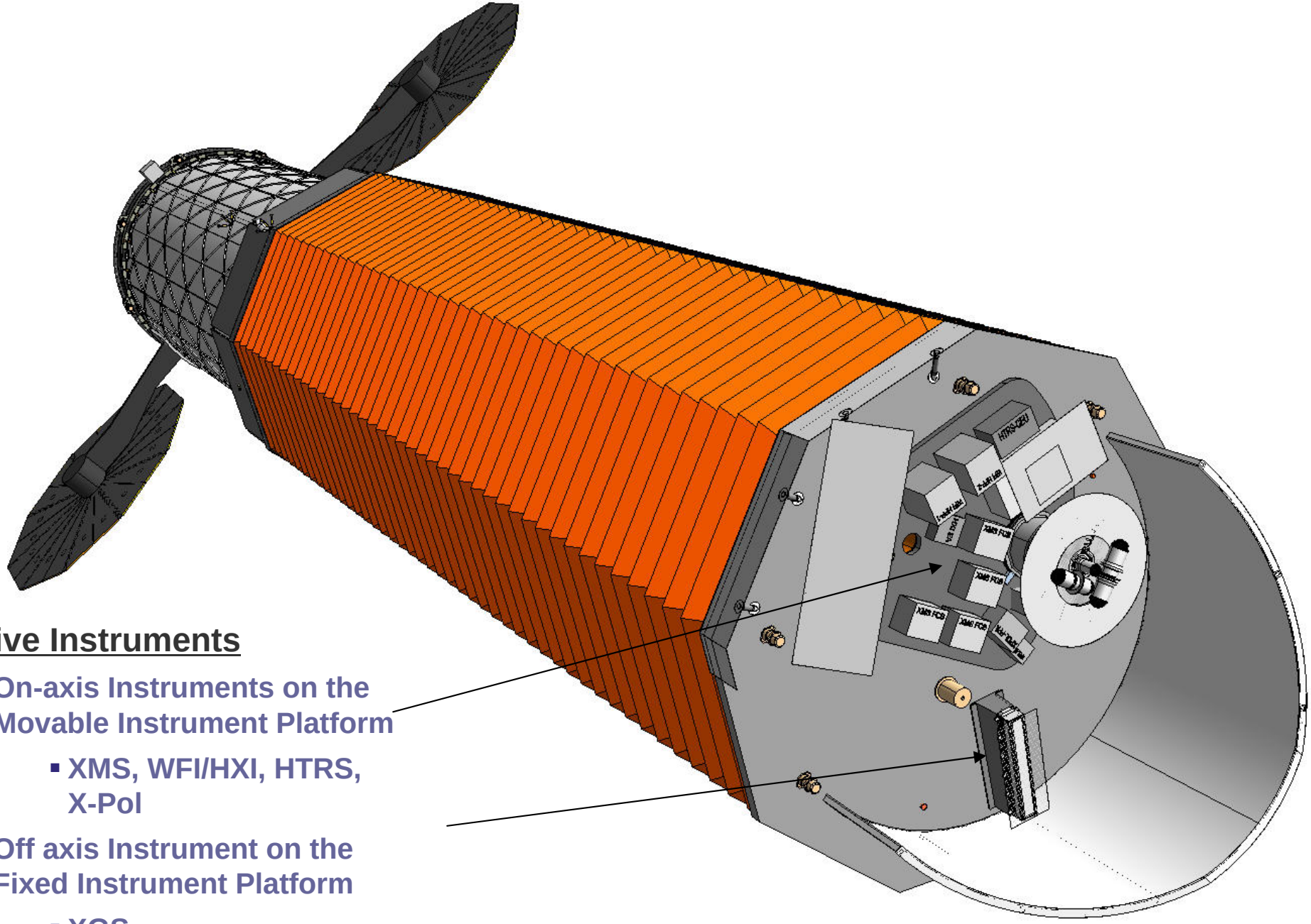
Spacecraft Module

- Nine sided S/C bus structure houses most hardware: avionics, power system electronics, battery, propulsion tanks, reaction wheels, etc.
- Composite isogrid metering structure / thrust tube
- High Gain Antenna
- 25 m^2 total body mounted and deployable non-articulated 3.4 m dia Ultraflex solar arrays
- Biprop and monoprop thrusters (14)

Optics Module

- Flight Mirror Assembly (FMA)
- FMA deployable outer and inner covers
- Deployable Sunshade
- TADS Fore Assy (Periscope)

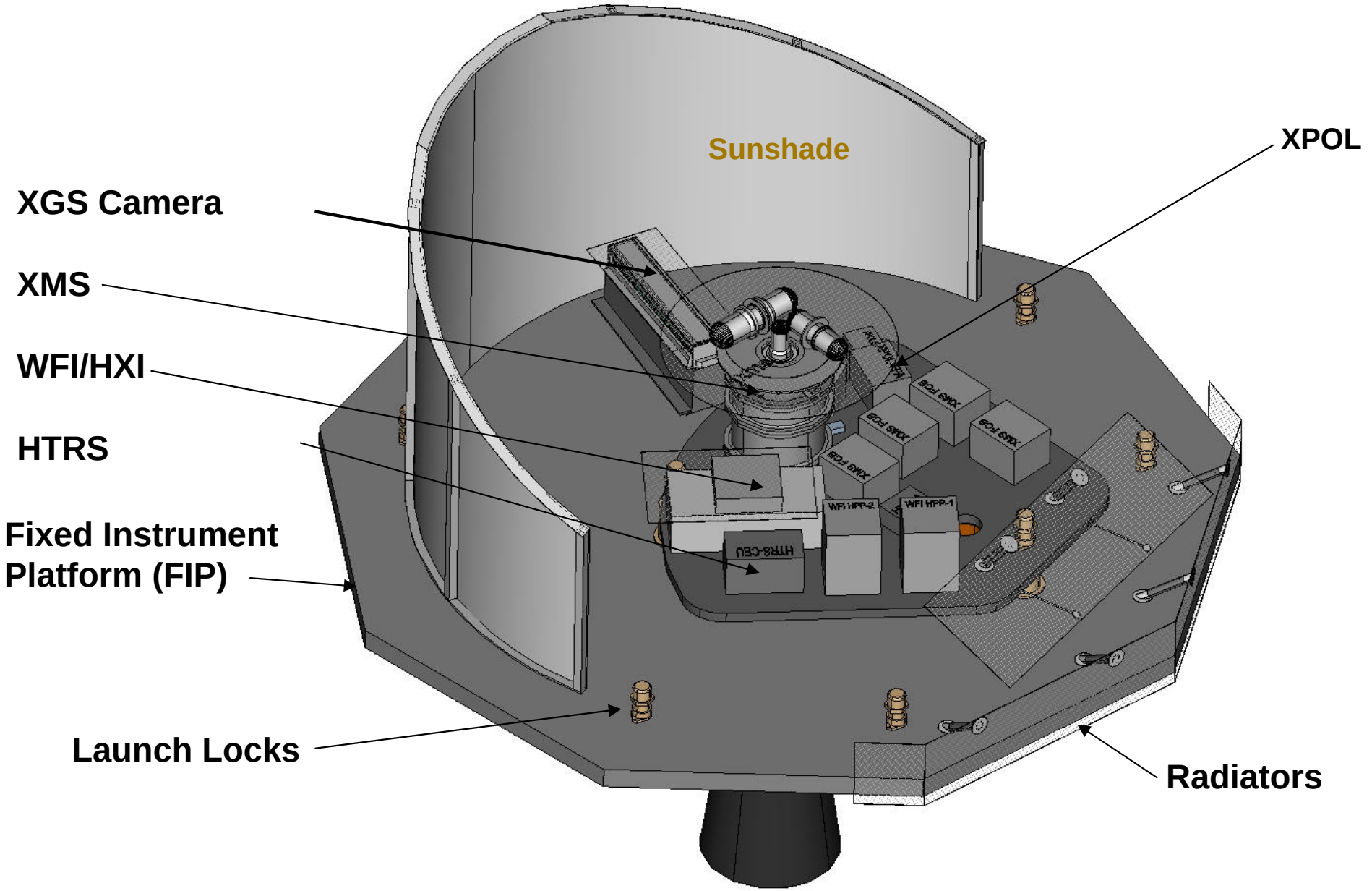
Observatory Aft View



Five Instruments

- On-axis Instruments on the Movable Instrument Platform
  - XMS, WFI/HXI, HTRS, X-Pol
- Off axis Instrument on the Fixed Instrument Platform
  - XGS

Instrument Module

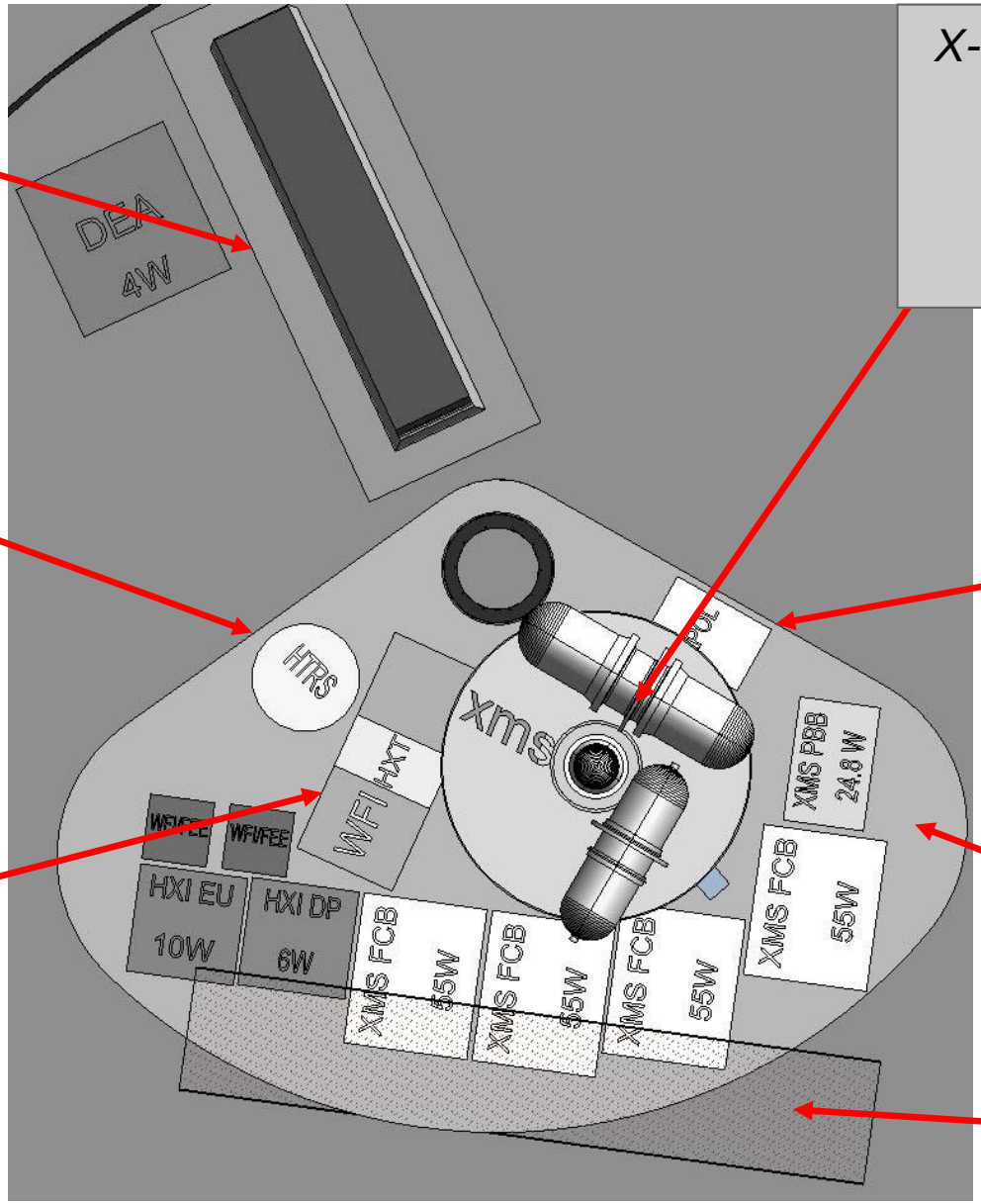


Focal Plane Layout

X-ray Grating Spectrometer Detector 0.3 to 1 keV R = 3000 > 1000 cm²

High Time Resolution Spectrometer 1 Crab > 90% livetime

Wide Field Imager FOV 18 arc min 0.1-15 keV DE < 150 eV + Hard X-ray Imager FOV 8 arc min > 150 cm²@30 keV



X-ray Micro-calorimeter Spectrometer FOV 5 arc min DE = 2.5 eV 0.3-7 keV

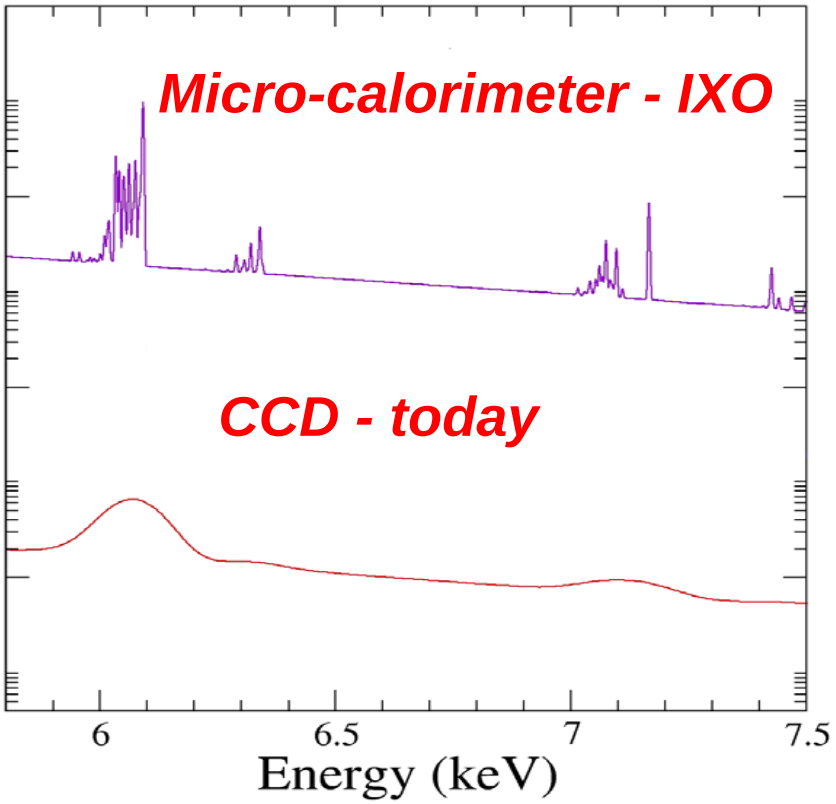
Polarimeter <1% for 1 mCrab in 100ks

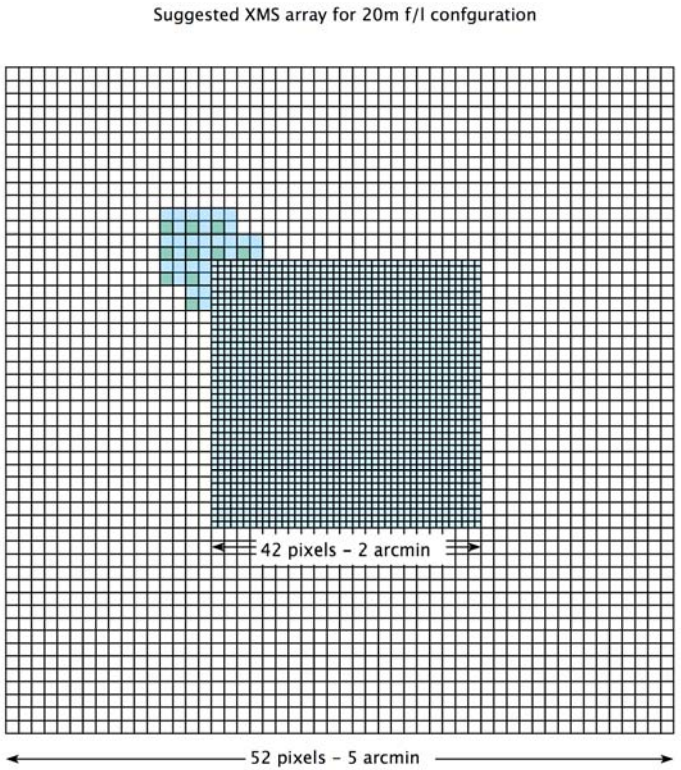
Translation Platform

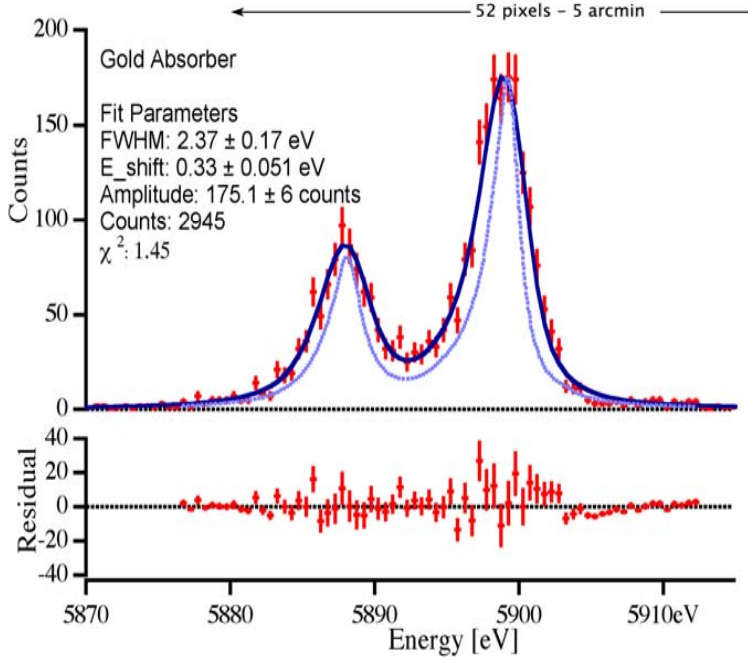
Radiator

Example of Next Generation Instrument Capability
X-ray Micro-calorimeter Spectrometer (XMS)

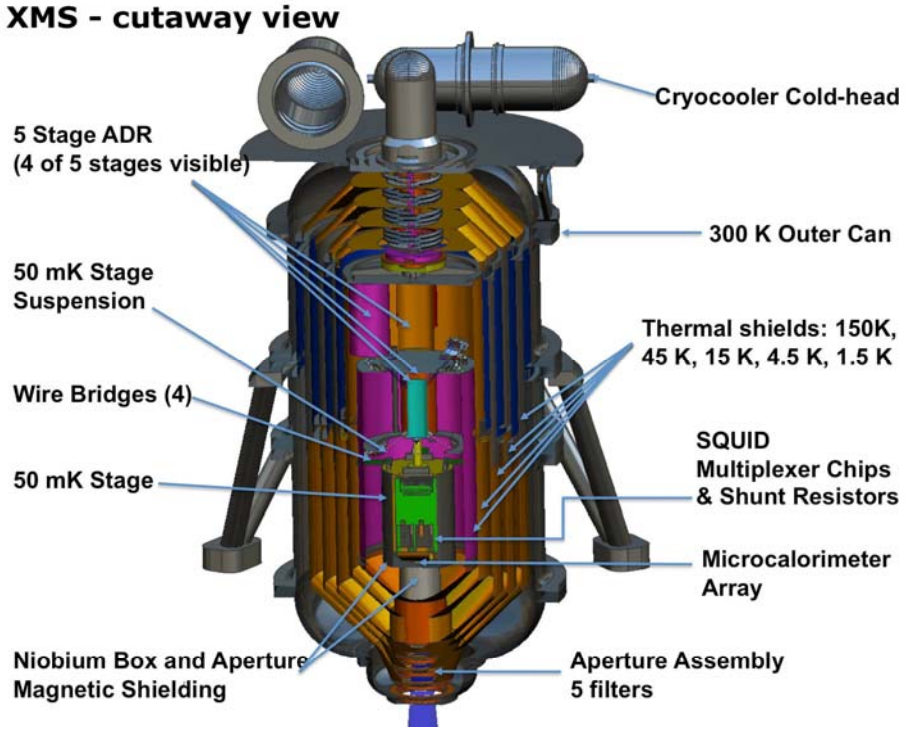
- ***Thermal detection of individual X-ray photons***
  - ***High spectral resolution***
  - ***ΔE very nearly constant with E***
  - ***High intrinsic quantum efficiency***

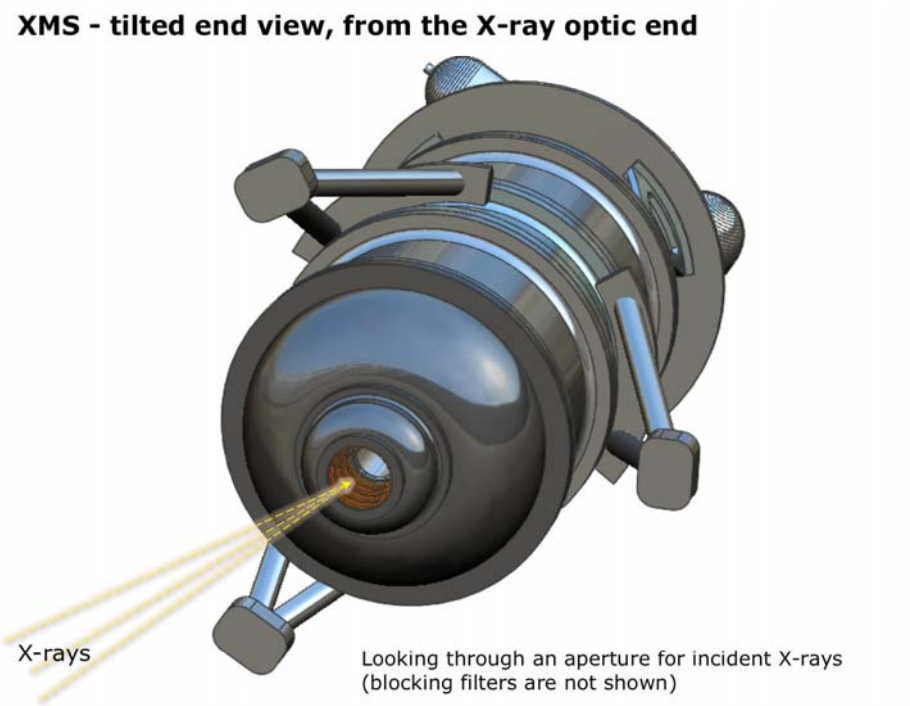






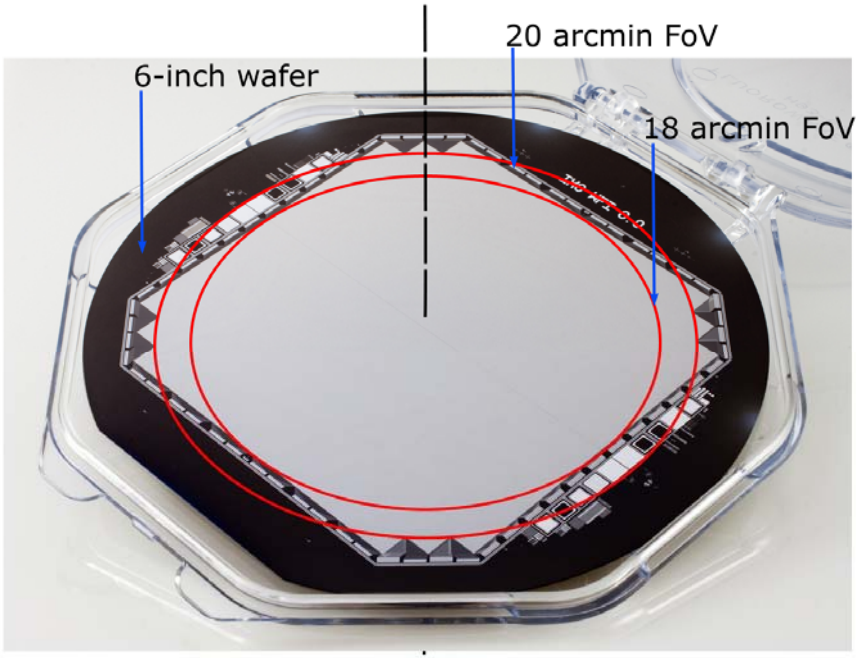
X-ray Micro-calorimeter Spectrometer



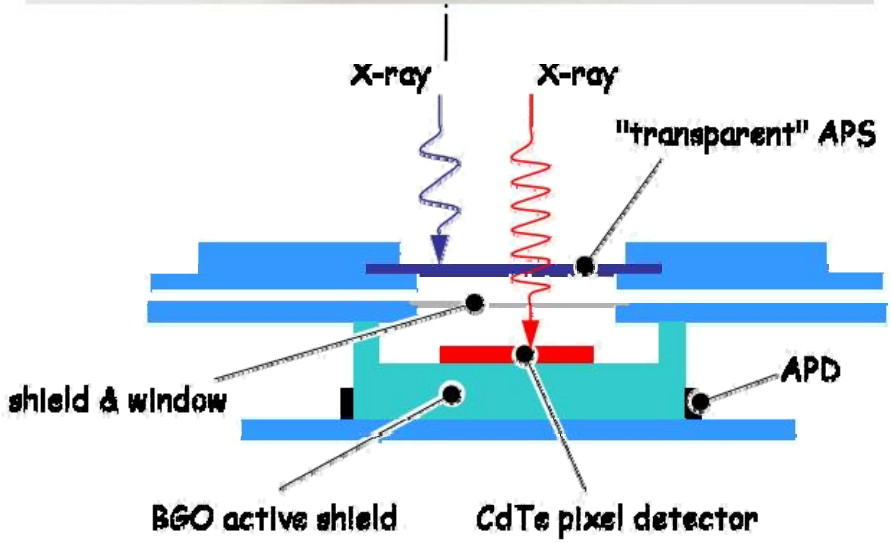


Wide Field and Hard X-ray Imagers

Wide field imager (WFI):
Silicon active pixel sensor
- field of view: 18 arcmin
- energy range: 0.1 to 15 keV
- energy resolution: < 150 eV @ 6 keV

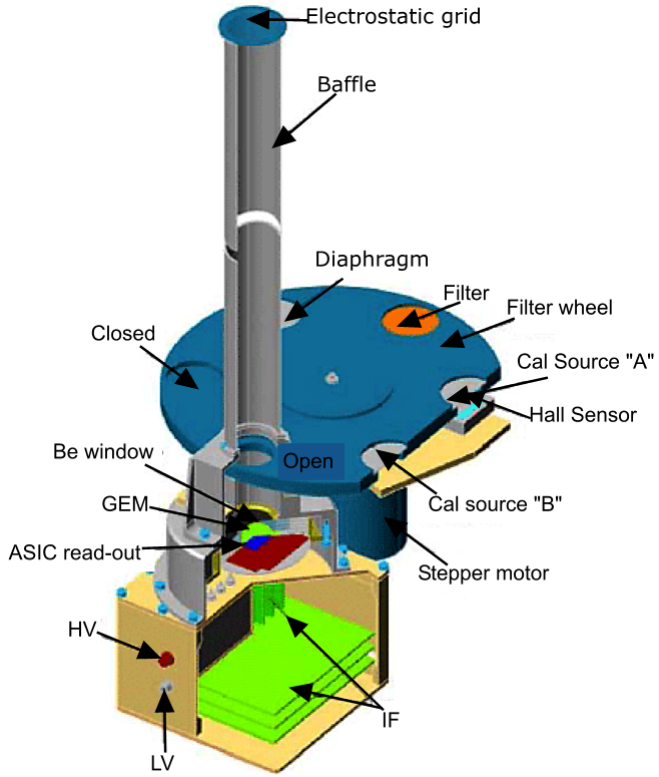


Hard X-ray imager (HXI):
Cd(Zn)Te pixel array located behind WFI
- energy range extension to 40 keV
- field of view: 8 arcmin

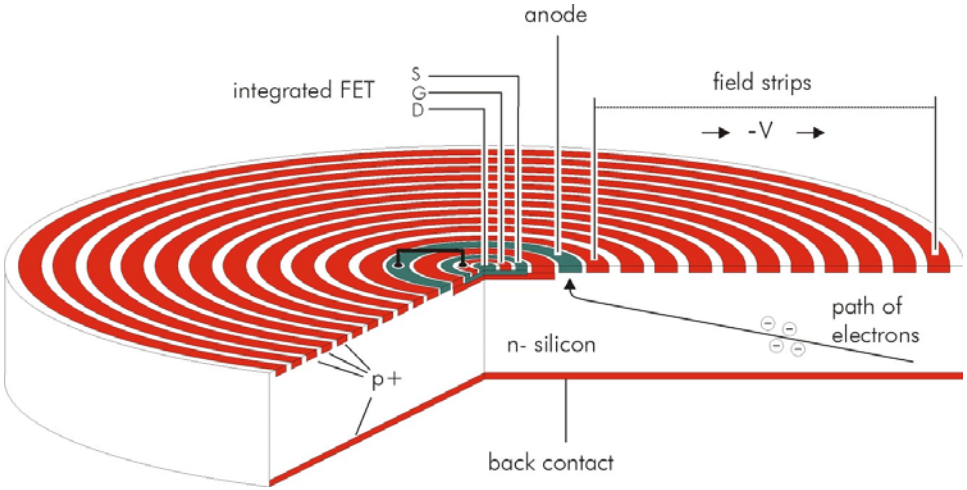


X-POL and HTRS

X-ray Polarimeter
Micropattern Gas Chamber
Imaging Detector
1% polarization



High Time Resolution Spectrometer
37 hexagonal low-capacitance
silicon drift diodes (SDD)
up to 2 M counts/sec, about 6 Crab



X-ray Grating Spectrometer

Two grating technologies are under study:

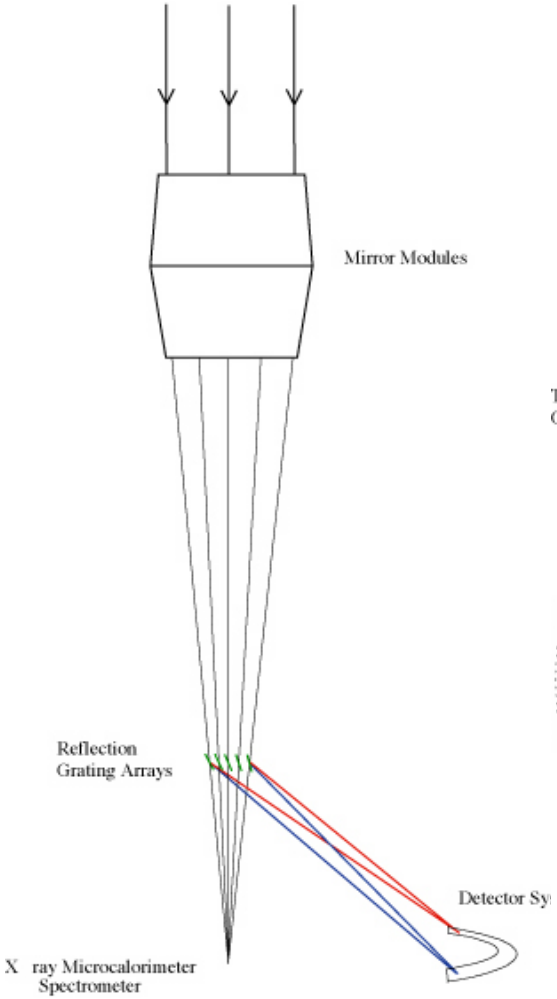
- Critical Angle Transmission (CAT) grating
- Off-plane reflection grating

CCD detectors:

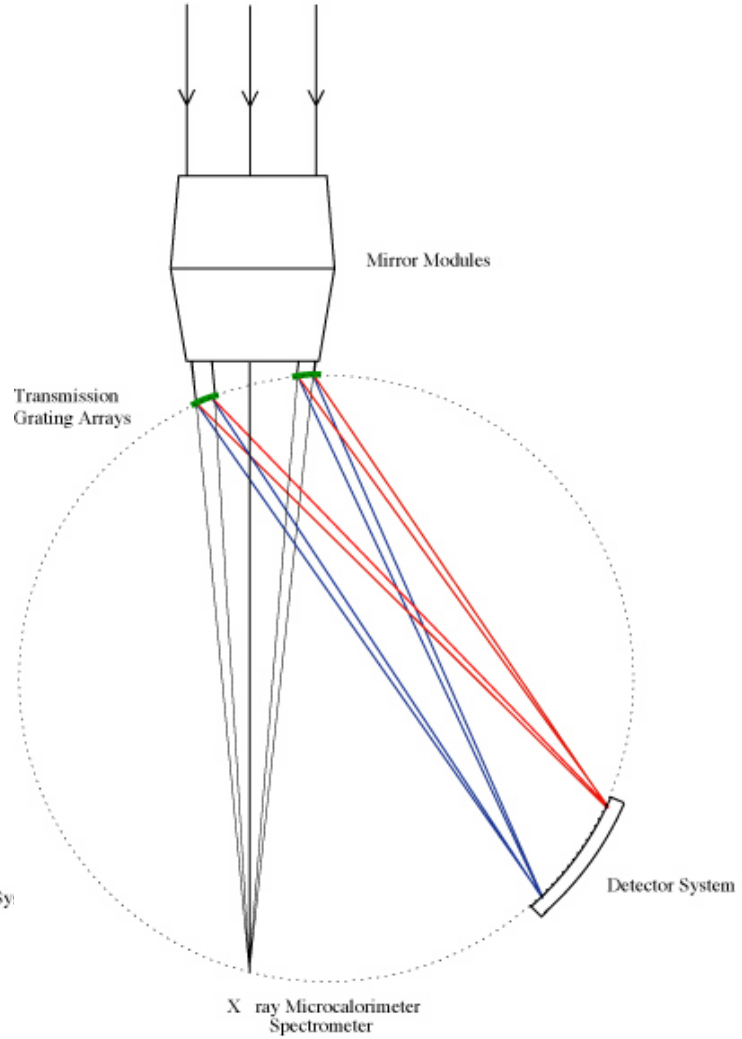
Back-illuminated (high QE below 1 keV),

Fast readout with thin optical blocking filters

Heritage from Chandra, XMM, Suzaku



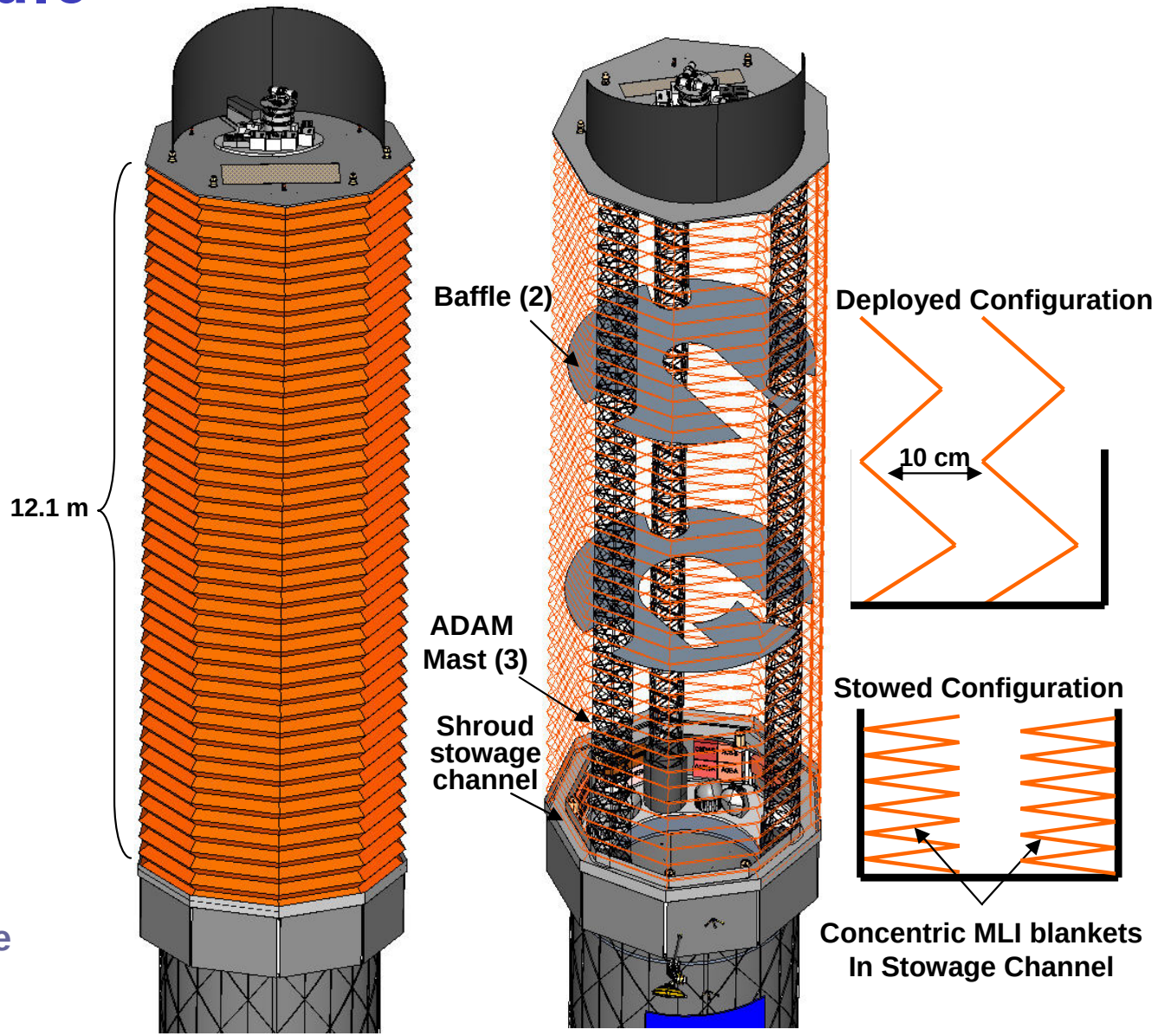
Off-plane



Critical Angle Transmission

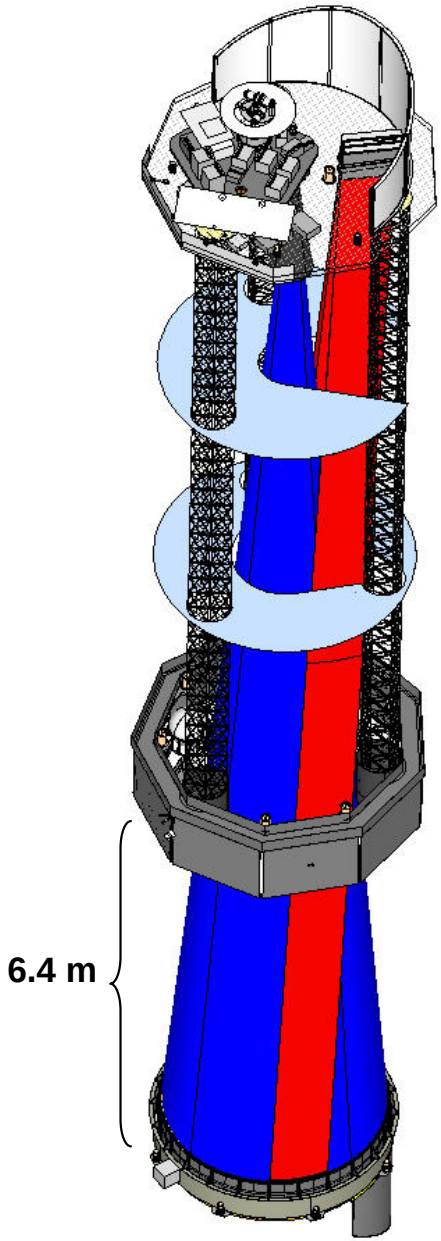
Deployment Module

- 3 ADAM masts deploy the IM, shroud, baffles and harness
  - Provides on-orbit alignment stability between optics and detectors
  - 1.0 torsion and 1.5 bending
  - Proven technology
  - Mast and harness stows into canister
- Shroud blocks light and supports baffles
  - Accordion-pleated multi-layer insulation blanket assemblies
  - Two concentric blanket assemblies form a “Whipple shield” to minimize micrometeorite penetrations
  - Stows in channel on top of the spacecraft bus

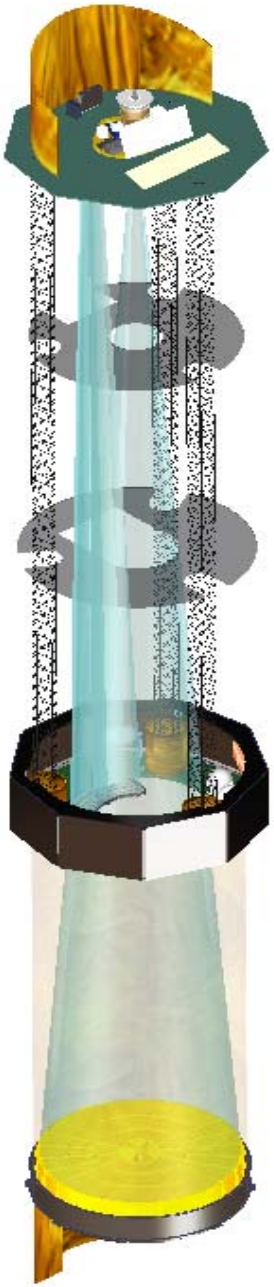


X-ray Trace

- The X-ray traces of the FMA and XGS traverse nearly the entire length of the observatory
- Either Critical Angle Transmission Grating (CATG) or Off-Plane Grating (OPG) XGS can be accommodated
- The x-ray beams drive the size, shape and placement of the spacecraft bus “ring”
  - Needs to be forward of the FMA for sufficient volume for bus components
  - Distance between the bus and the FMA limited to fit in the Atlas V 5 medium fairing
  - (CG, mass propellant lines are additional considerations)

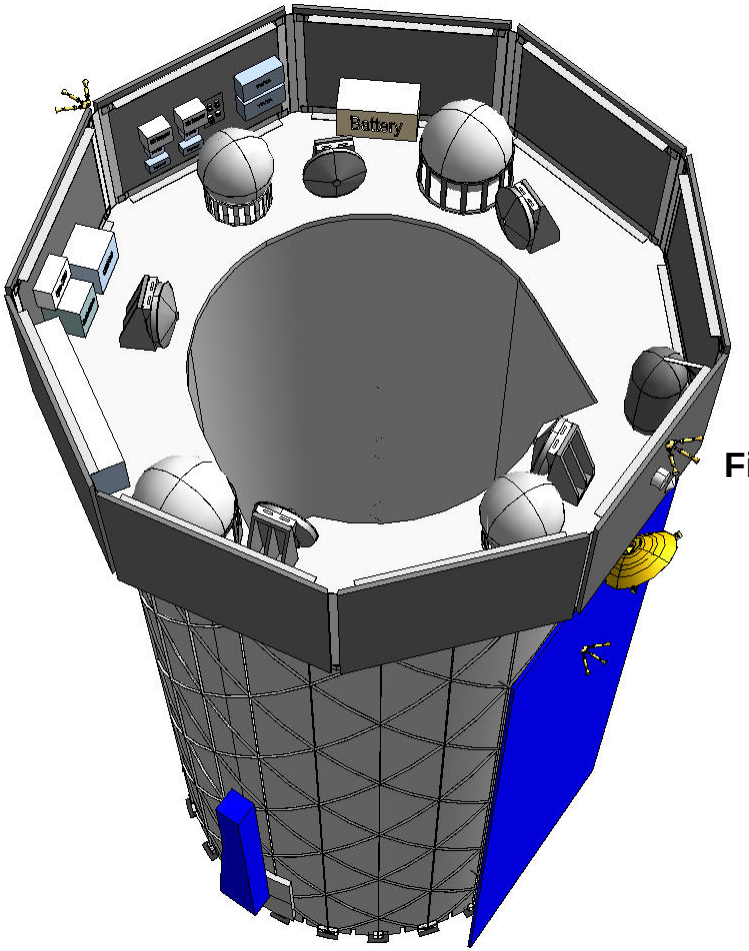


CATG XGS

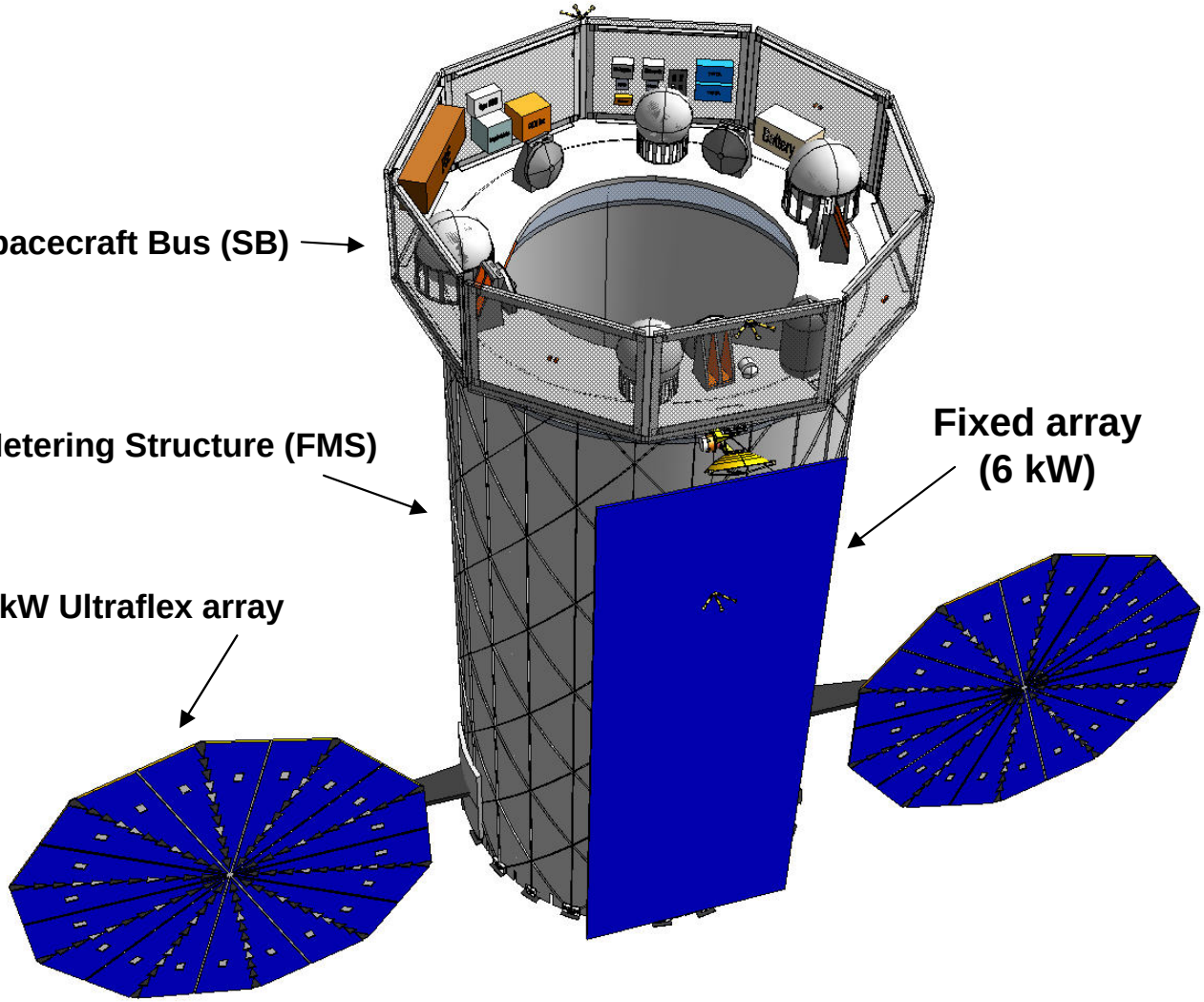


OPG XGS

Spacecraft Module

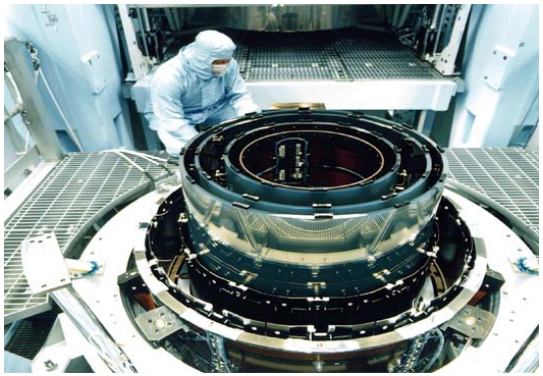


Stowed configuration

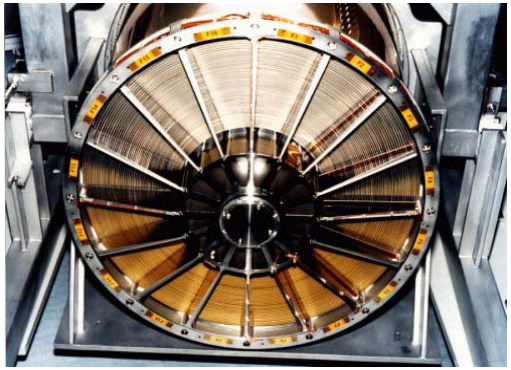


Deployed configuration

The Large Collecting Area Secret: Lightweight Optics

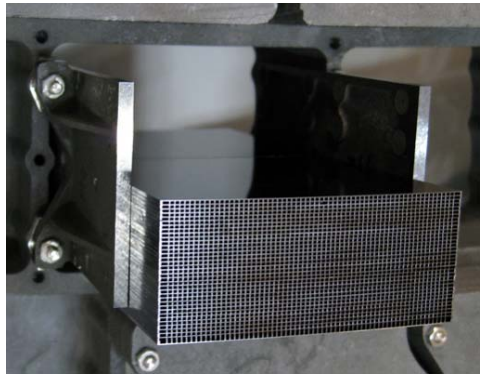


CHANDRA
0.5″ HEW
18500 kg/m²



XMM-NEWTON
14″ HEW
2300 kg/m²

Slumped Glass
5″ HEW
~270 kg/m²

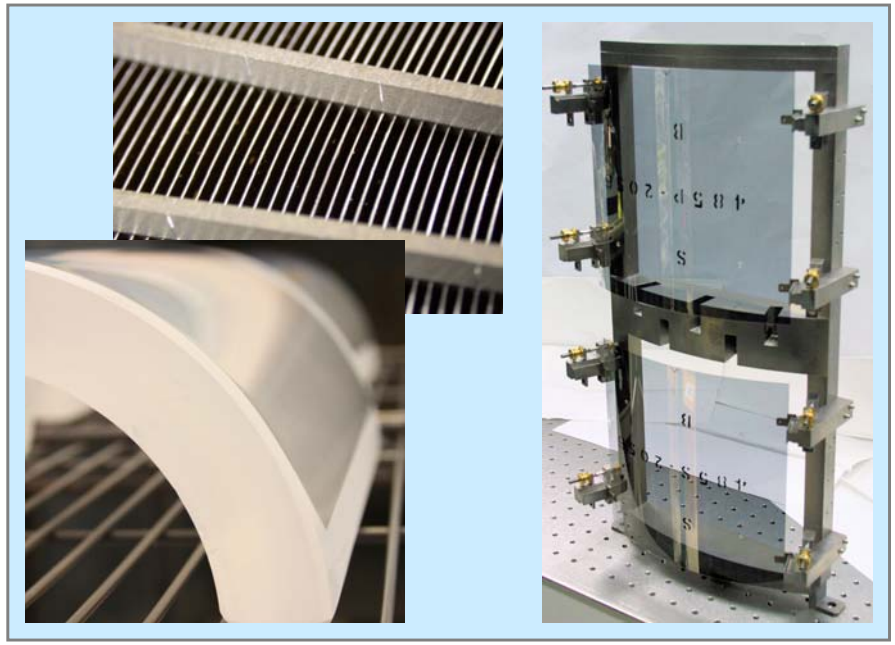


Si-HPO
5″ HEW
~200 kg/m²

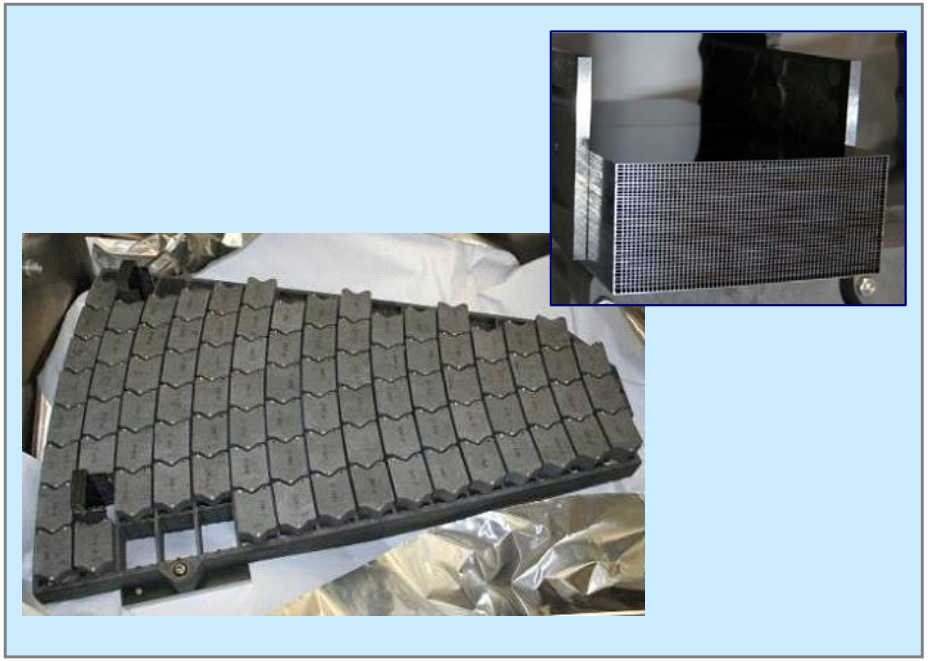
IXO Options

Mirror Technology Approach

- Two fully independent mirror technology paths to TRL **6**
  - Segmented slumped glass
  - Si pore optics
- TRL 6 achieved for both by January 2012
  - 5 months prior to Technology Review
- Technology development roadmaps provided as appendices to written responses
  - Defined milestones for TRL 4 & 5
  - TRL 6 at module/petal level

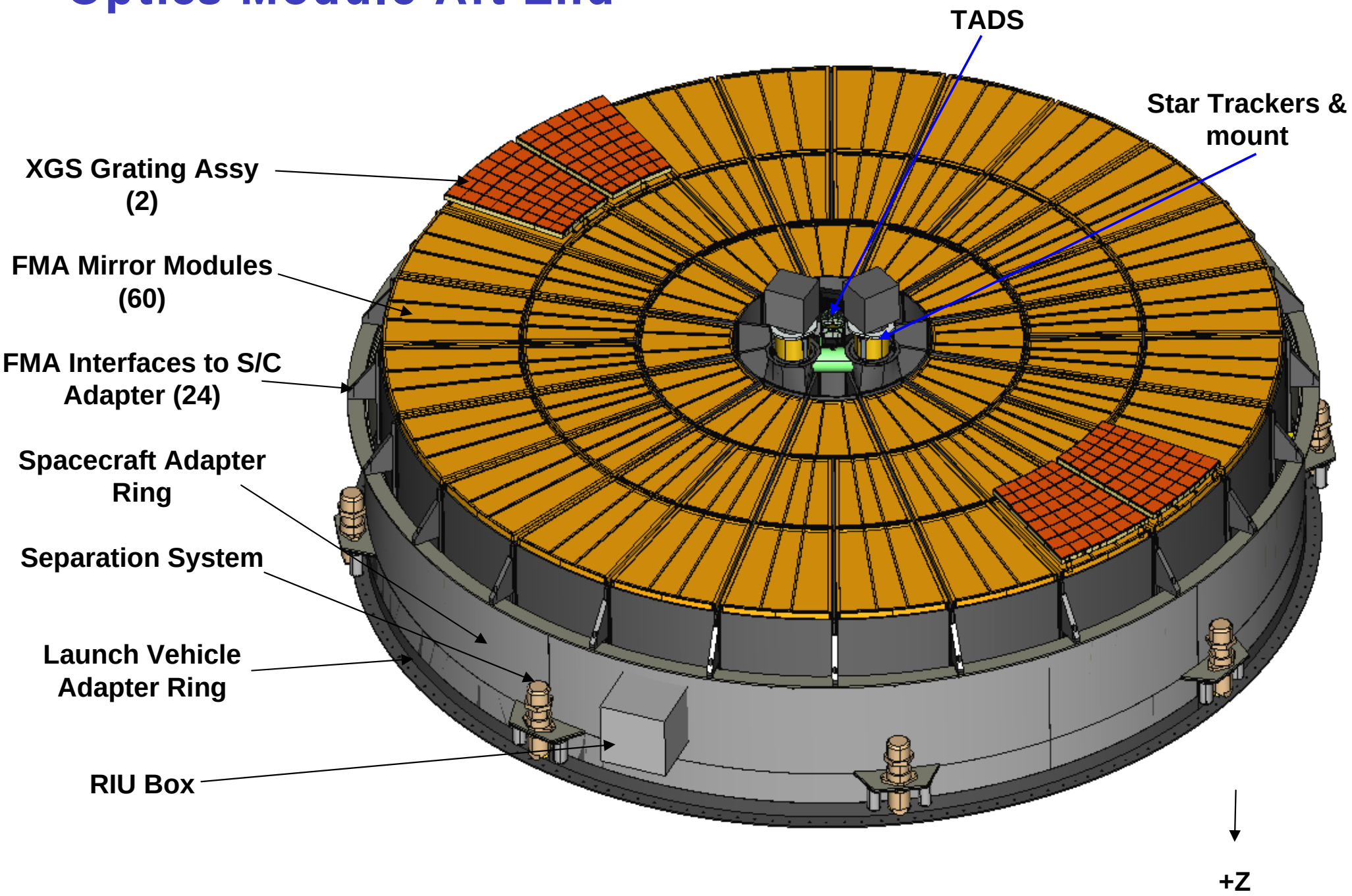


Segmented Slumped Glass



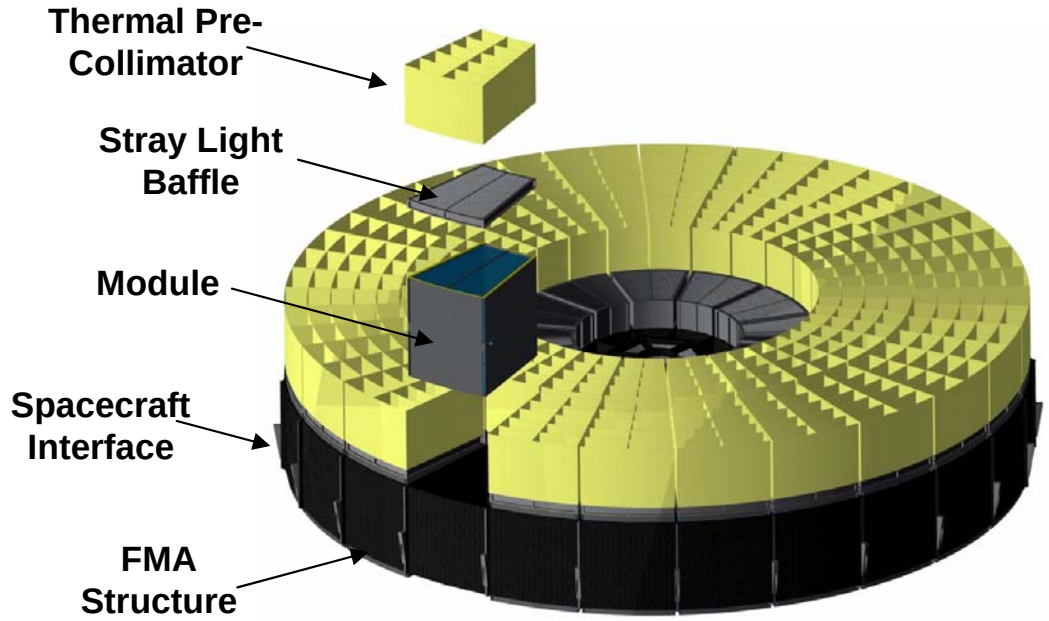
Silicon Pore Optic Petal

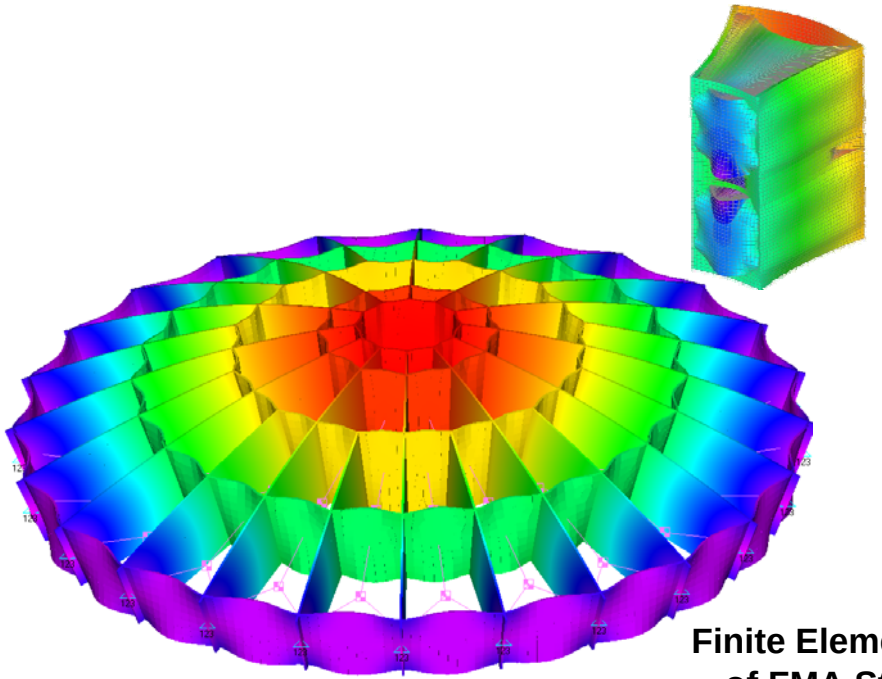
Optics Module Aft End



NASA FMA Concept

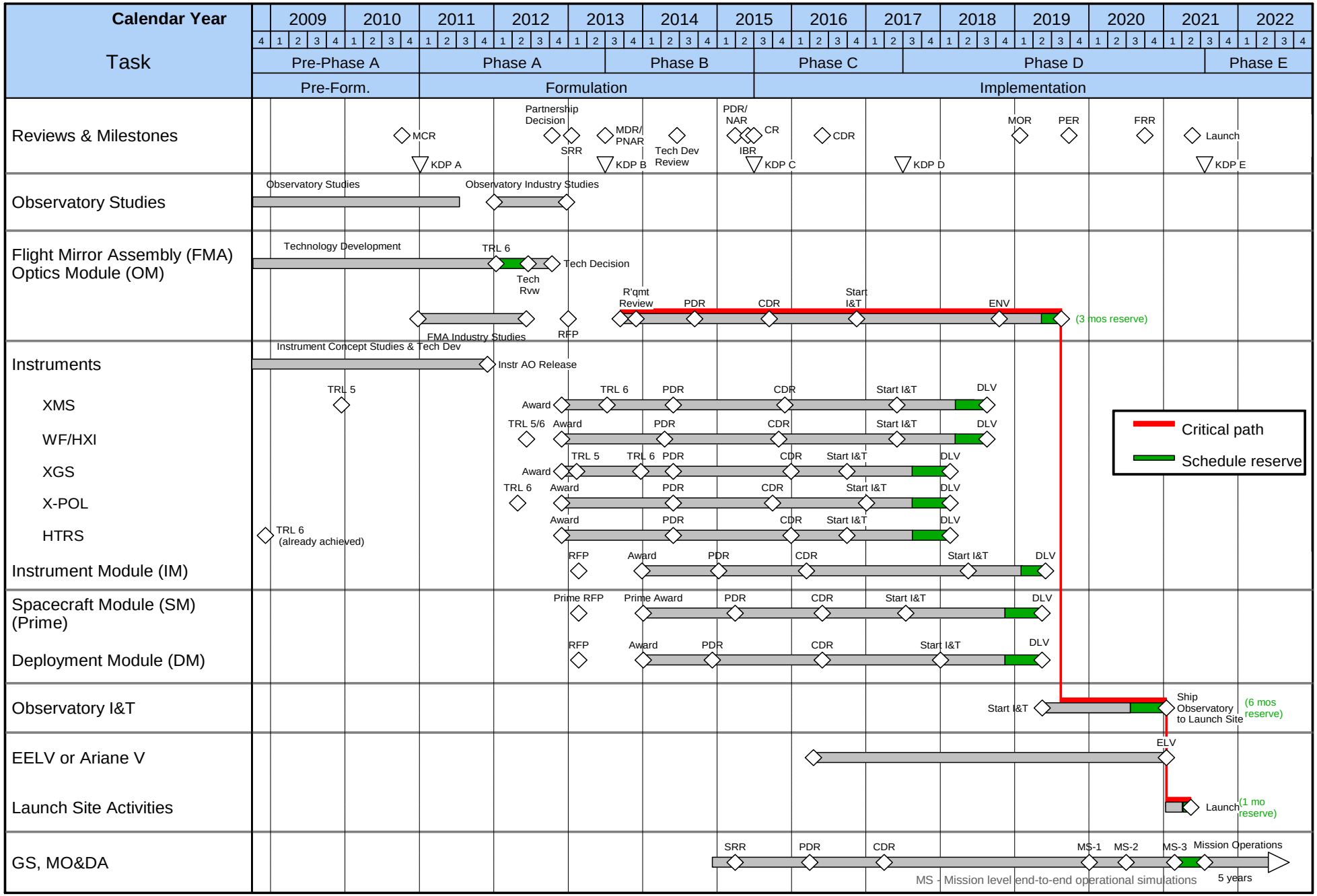
- Key requirements:
  - 3 m^2 @ 1.25 keV
  - 0.65 m^2 @ 6 keV with 5 arcsec angular resolution
  - 150 m^2 @30 keV with 30 arcsec ang. res.
- Overall dimensions: 3.4 m dia x 0.8 m
- Segmented Wolter I optical design
- Slumped glass mirror segments
- 60 modules: 24 outer, 24 middle, 12 inner
- 60 mirror modules each with 200-300 segments
- Hard X-ray mirror module, with multi-layer coated mirrors, in the center provides high energy response
- Total FMA mass is ~1750 kg (current best estimate, no contingency)
- Power is ~1400 W to maintain 20 C
- Finite Element Analyses support design concept
- Structural, thermal, optic integrated analyses supporting design





Finite Element Model of FMA Structure

Top Level Mission Schedule

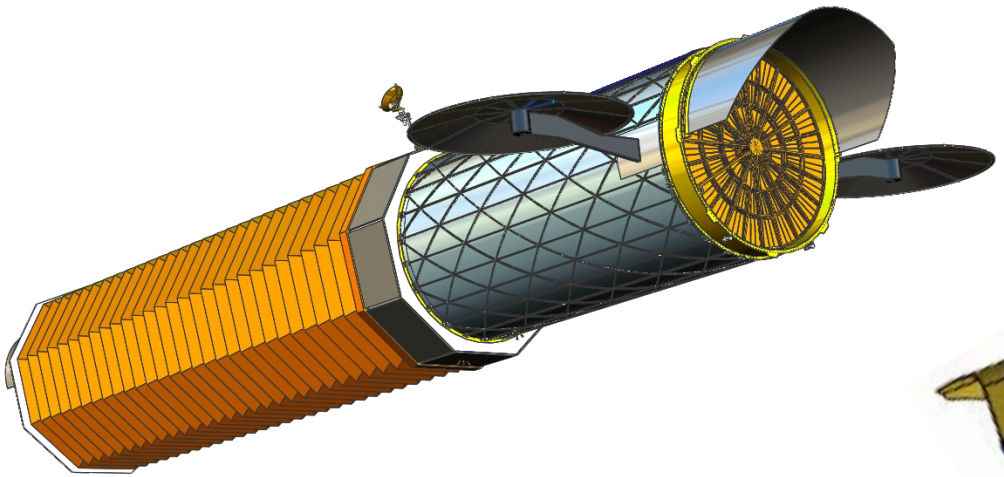


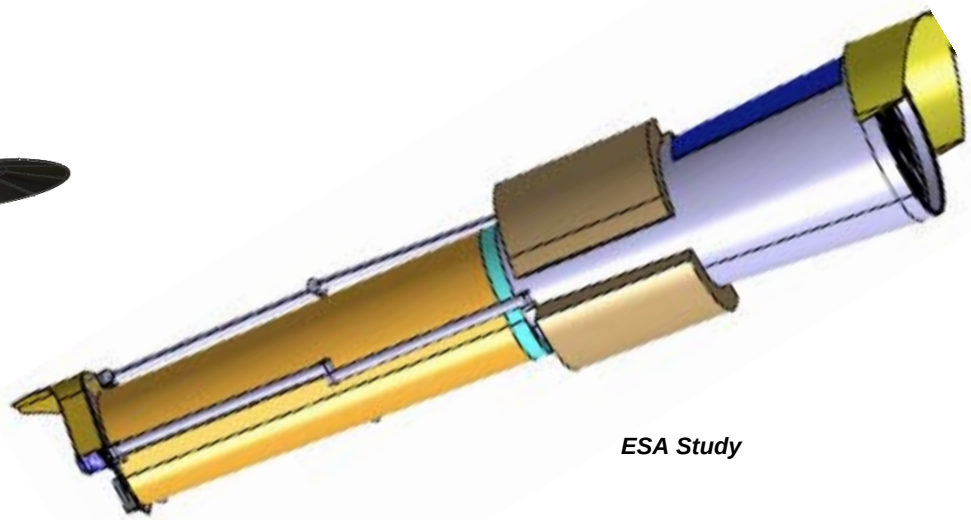
Significant Progress

- **Decadal submittals and presentations**
  - Completed and submitted response to questions from Decadal (June 5)
  - Presentation to Decadal in Pasadena (June 8)
  - Awaiting next set of questions; expected week of June 22
- **Cost estimates**
  - Generating grass roots cost estimate for full Flight Mirror Assembly to further validate existing estimates
- **Communications**
  - Booth at AAS with handouts (brochure, RFI response), technology hardware, new video, etc.
- **ESA proceeding with mission and instrument studies in preparation for Cosmic Visions process**
  - Proposals for industry mission studies have been received. Parallel studies to be awarded in July and will last ~ one year.
  - Declaration of Intent for all instruments (2 for XMS) have been provided to ESA. Studies will start in September 2009 and will go for ~1 year.

IXO Mission Studies

NASA Study





ESA Study

Separate ESA and NASA mission studies demonstrate overall mission feasibility, with no show stoppers