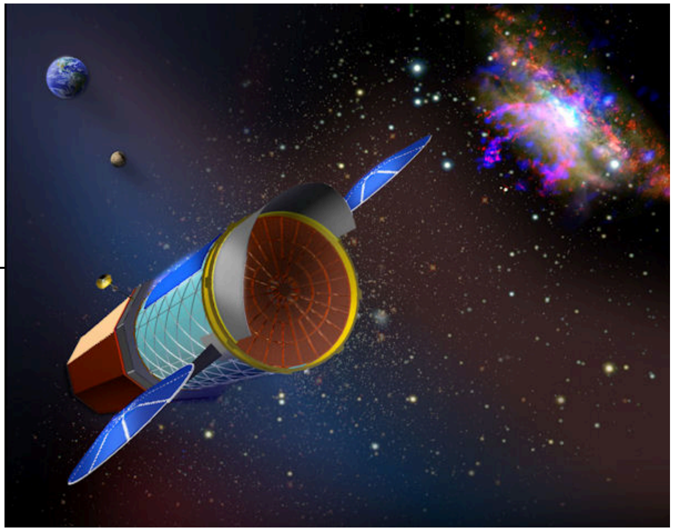
IXO Briefing – Second meeting of the Astro2010 Program Prioritization Panel
June 8, 2009 / Pasadena, California

IXO Response to EOS PPP Questions



Jay Bookbinder

on behalf of the IXO team

IXO Team Members in Attendance

Marcos Bavdaz

Jay Bookbinder

Joel Bregman – SDT Co-chair

Michael Garcia

Jean Grady – NASA - Project Manager

Arvind Parmar - ESA - Project Scientist

Paul Reid

Suzanne Romaine

Randall Smith

Harvey Tananbaum

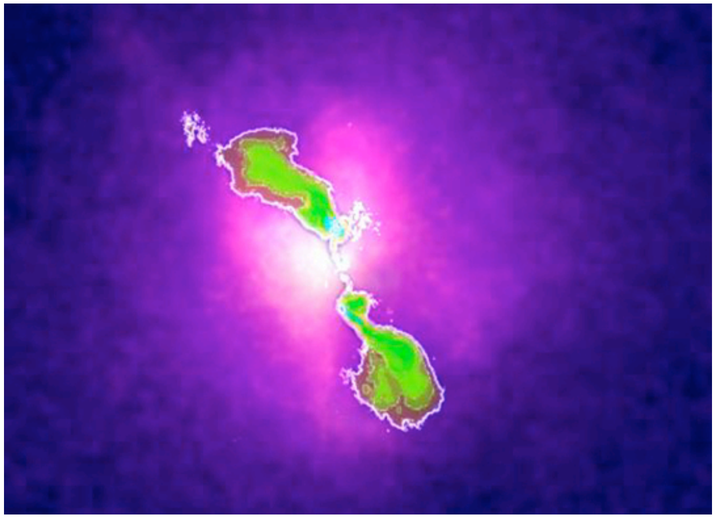
Nicholas White – NASA Project Scientist

Dick Willingale - TWG Co-chair

Will Zhang

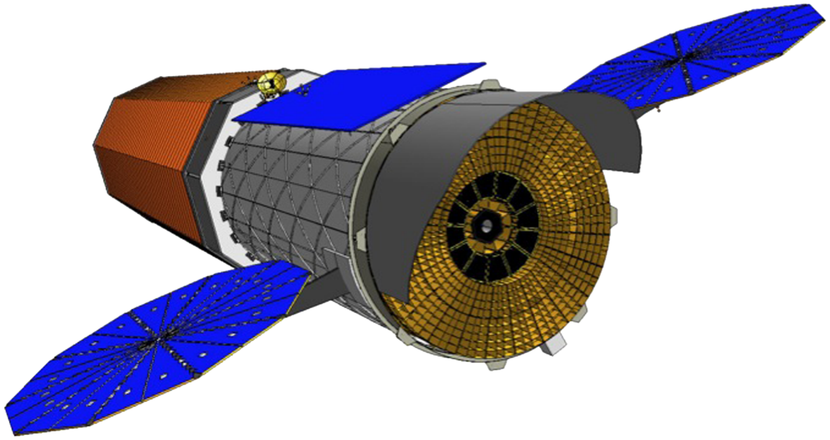
The International X-Ray Observatory

- 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?



Hydra A Galaxy Cluster

A 100-fold increase in effective area for high-resolution spectroscopy, along with wide field of view imaging, polarimetry & timing

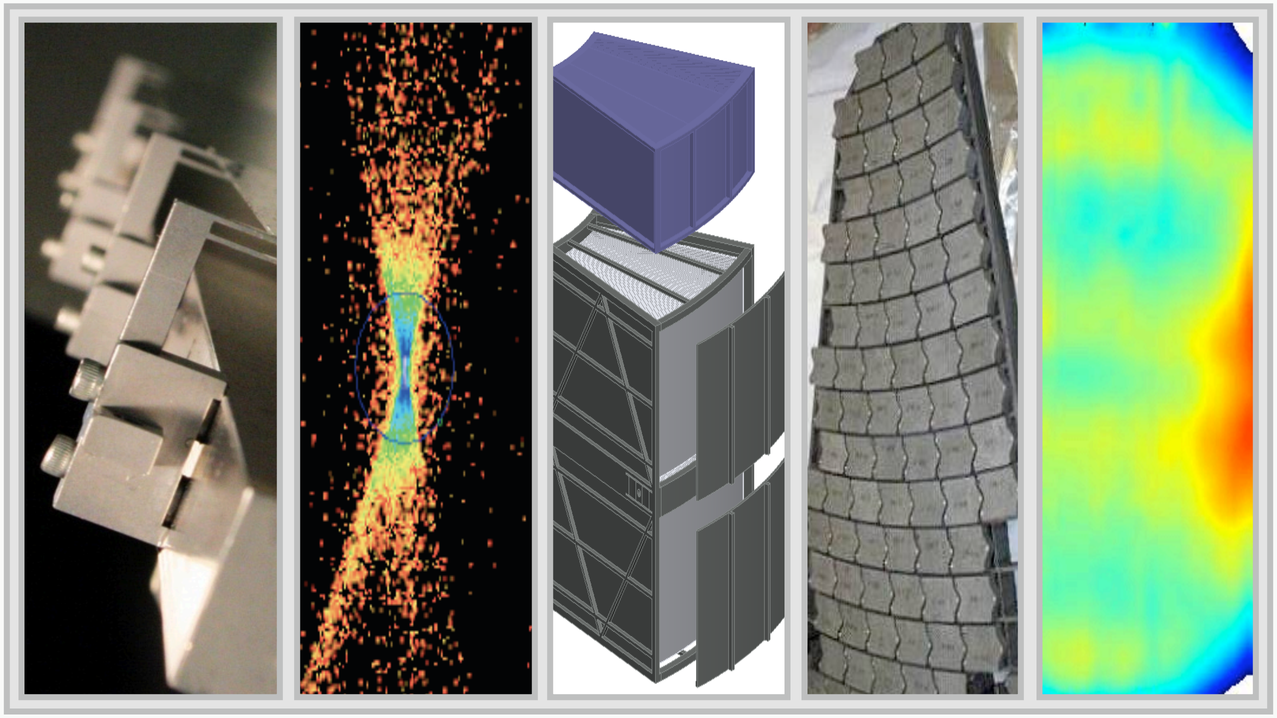


- 20 m focal length
- Mass ~6100 kg (40% margin)
- EELV or Ariane V
- L2 orbit
- 5 year lifetime; 10 year goal

EOS PPP Questions for IXO

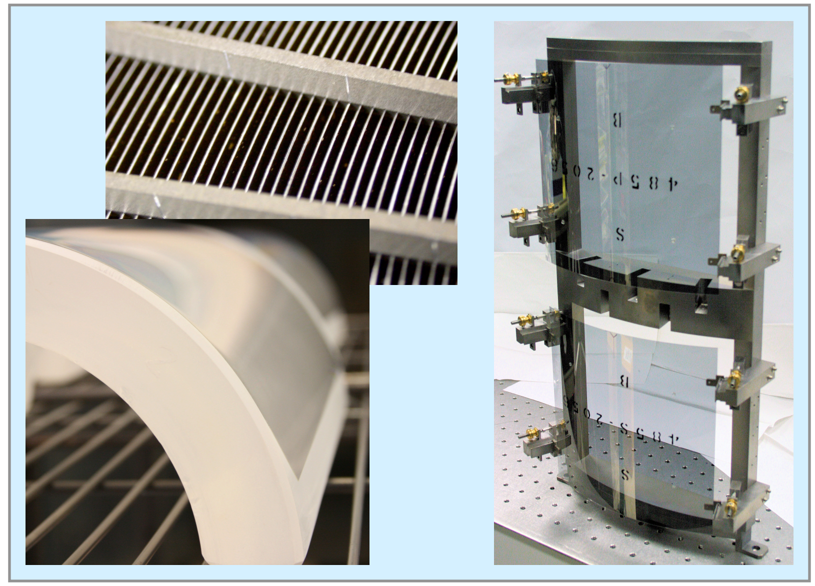
1. ***What is the pathway to developing to TRL 6 the mirrors required for IXO? What are the associated development costs?***
2. ***How does IXO propose to integrate the international consortium required for the project?***
3. ***Does IXO have downscope options and what are those options?***
4. ***Will certain IXO instruments and/or components be competed? If so, which instruments or components and how will they be competed?***

Q1: What is the pathway to developing to TRL 6 the mirrors required for IXO? What are the associated development costs?

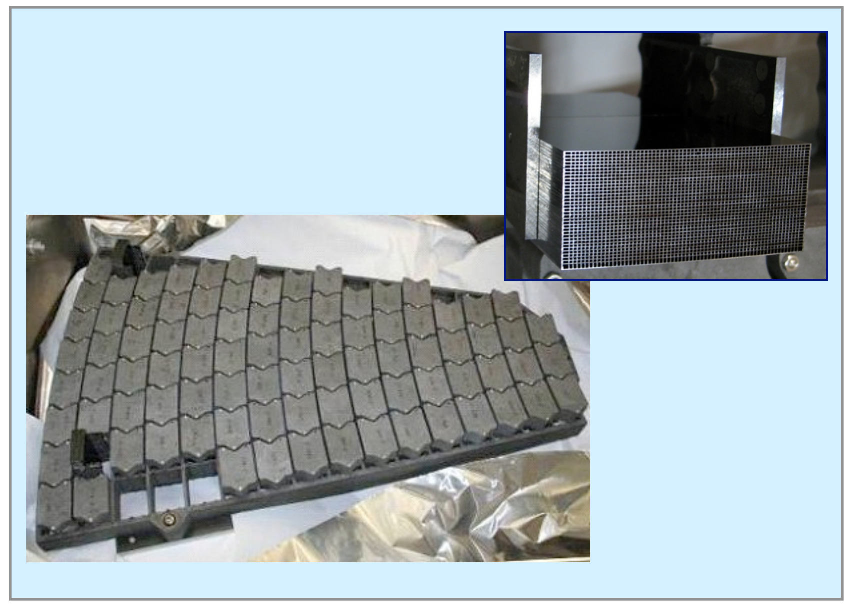


Mirror Technology Approach

- 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

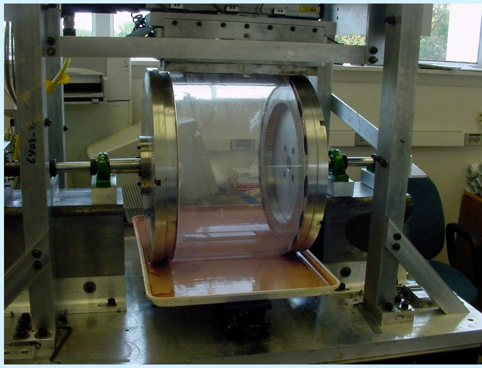


Silicon Pore Optic Petal

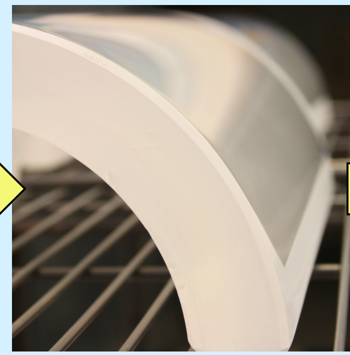
Segmented Glass Mirror Overview

Mirror Segment Fabrication

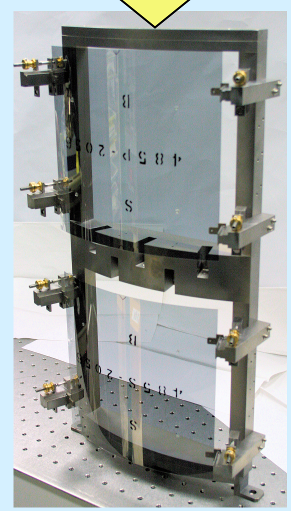
Mandrel manufacture



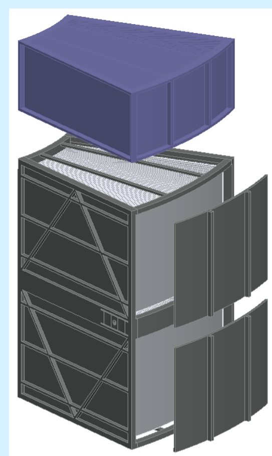
Slumping



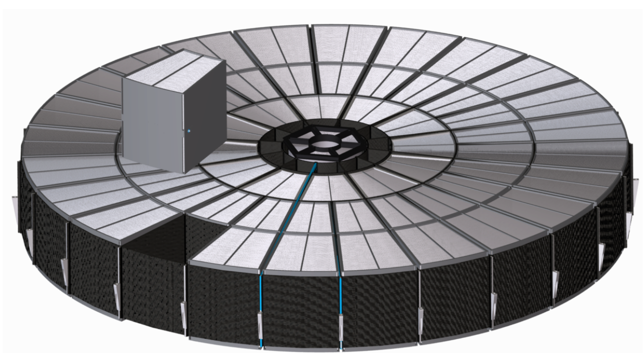
Cutting and Coating



Alignment and Mount



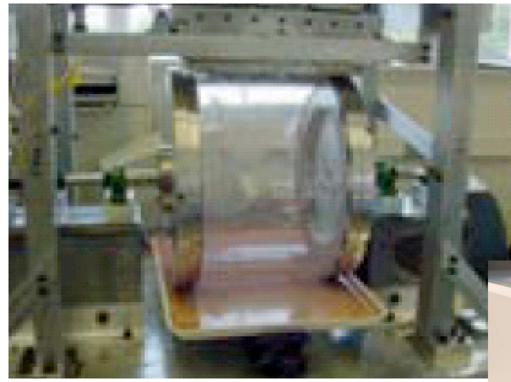
Module



Flight Mirror Assembly

Glass Mirror Segment Technology Development

- Process and tools for segment fabrication and metrology have been established
  - Allows identification, analysis and resolution of remaining error sources
- Principal remaining error sources
  - Low frequency figure ⇒ improve mandrel figure
    - New mandrel reduces term from 7 to 2.5 arcsec
  - Mid-freq. figure ⇒ smooth mandrel release layer
    - Reduces error from 8 to 2 arcsec
  - Sag error ⇒ reduce Ir coating stress
    - Reduces error from 4 to 1 arcsec
- To be achieved by early 2011 to demonstrate TRL 5 on mirror segments



1.5 arcsec forming mandrel

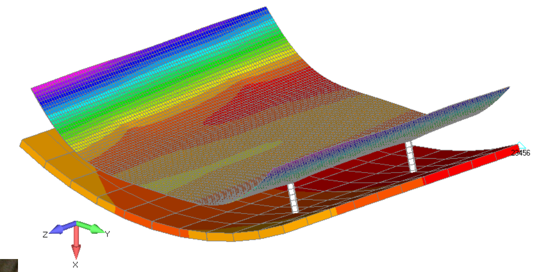
Glass Slumping on Mandrel

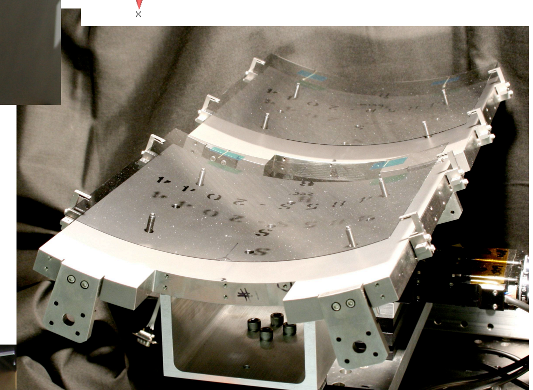
Metrology Mount

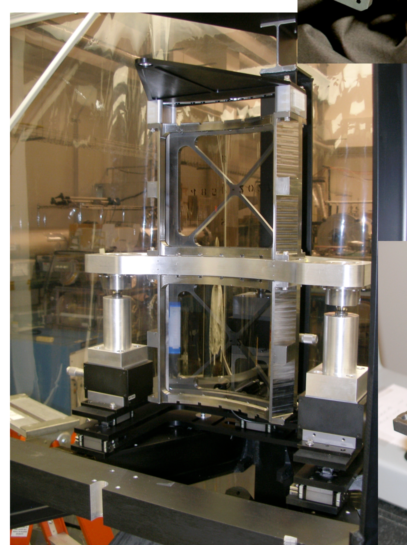
Iridium Coating

Glass Segment Alignment and Mount

- Methodology for Technology Development
  - Systematically identify and minimize every error source.
  - Finite element analysis
  - Small-scale test fixtures to examine error sources in detail.
  - Test at every major TRL milestone
- Two parallel approaches for mirror segment alignment and bonding
  - Passive Mount
  - Active Mount
- For both approaches
  - TRL 4: Align and mount 1 pair of segments
  - TRL 5: Co-align ≥2 mirror pairs
- TRL 6: Prototype Module
  - ~ 3 arc-sec segment pairs with performance and environmental testing
  - 3 segment pairs + segment simulators

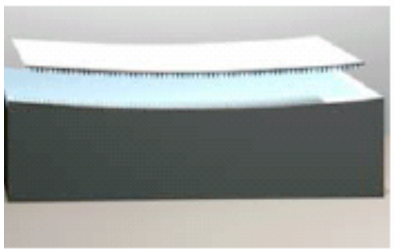


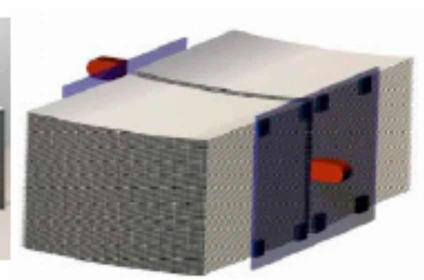


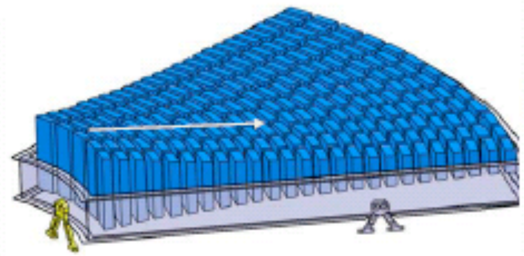


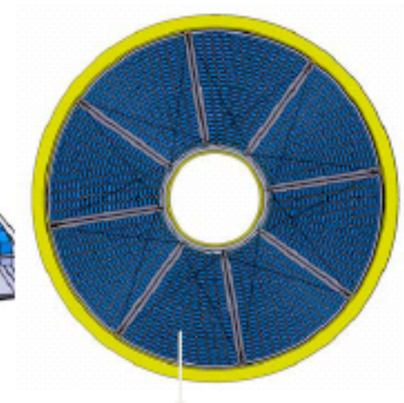
Elements of the Silicon Pore Optics (SPO)

Hierarchical elements







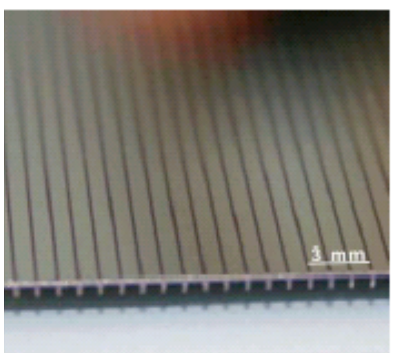


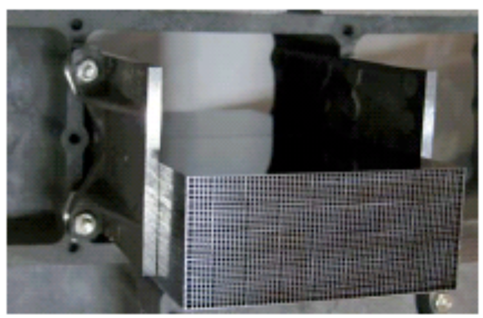
Petals

Mirror plates and stacks

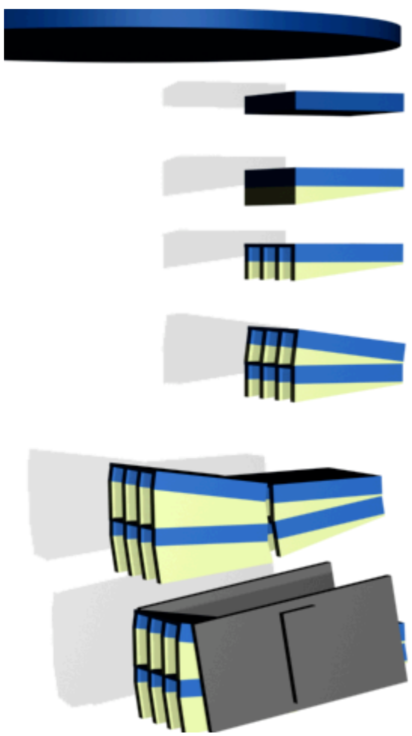
Mirror modules

Optical bench



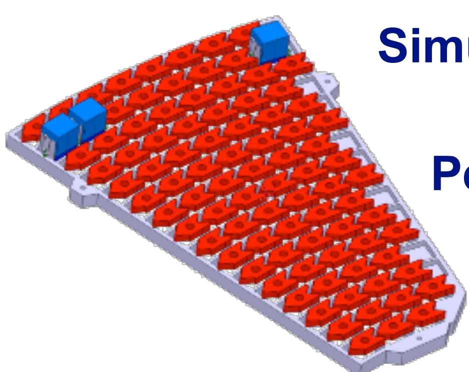


SPO technology: using existing heritage and building on established industrial processes



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)

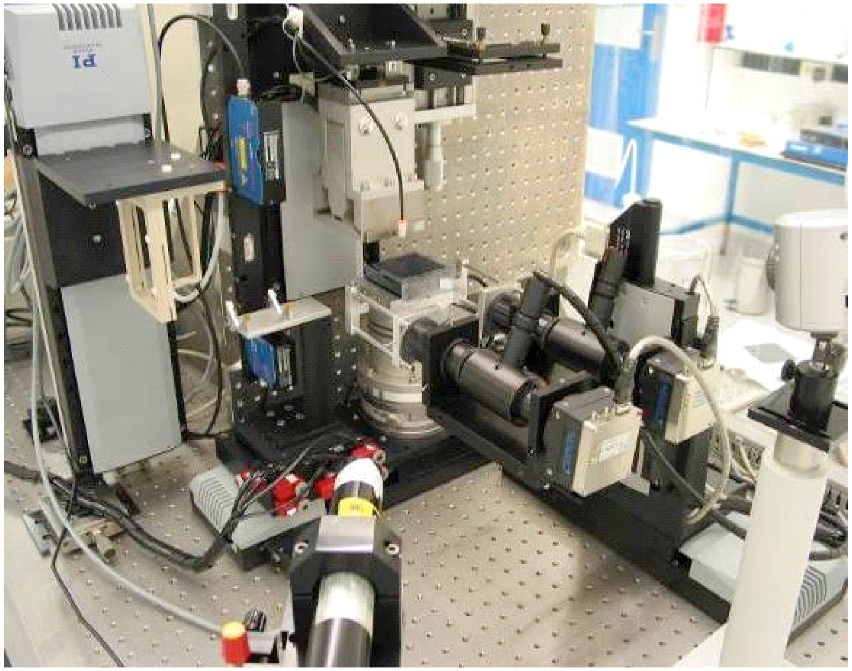
siltronic perfect silicon solutions
infineon Never stop thinking
micronit microfluidics bv
DANISH NATIONAL SPACE CENTER
cosine
ZEISS We make it visible.
PTB
SRON Netherlands Institute for Space Researc
MPE
KAYSER-THREDE

Si Pore Optics Development

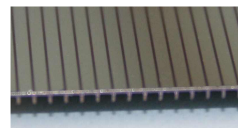
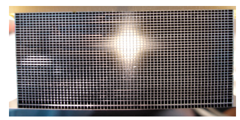
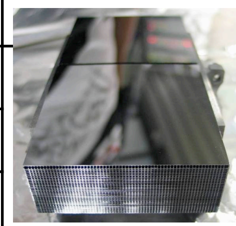
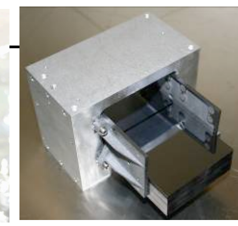
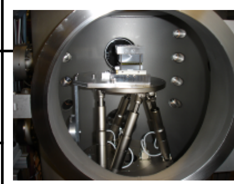
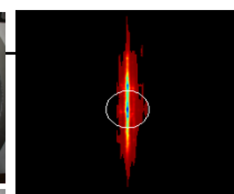
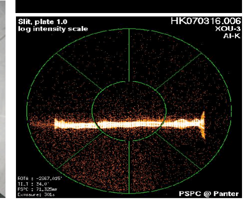
- Achieved 4 arc-sec HEW in X-rays for a single pore
- Achieved 17 arc-sec HEW for a stack of 4 plates

- PSF degrades with illumination of more plates in a stack
  - Caused by contamination during stacking of grooved Si plates
  - Si particles between mating surfaces propagates distortion to reflecting surfaces of many plates

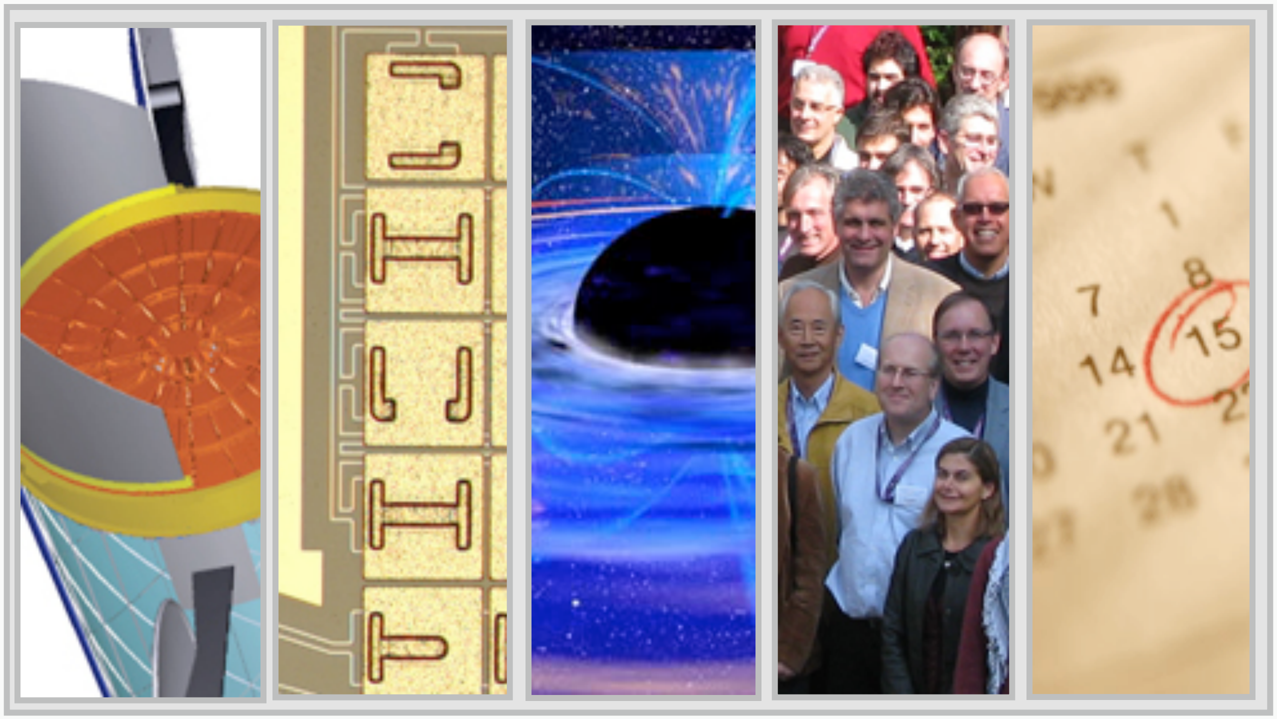
- Solutions being implemented
  - Improved stacking robot (less contamination)
  - Automated particle detection and removal system in close proximity (10s of cm) to stacking robot
  - Improved plate cleaning process
  - Cleaner assembly area



Silicon Pore Optics – Development & Production

Steps	Done	TRL 2008		Next (2011)	TRL
Plate production	**Industrial process** **Wedged, coated, non-conical** **500 produced**	 	4	**Reduce cost** **Different sizes**	6
Stack production	**Automated** **Particle inspection, cleaning, bending, interferometry, stacking** **200 produced**	 	4	**Improve HEW**	6
Module production	**Design to spec** **Integration method to spec** **Mounting method** **4 produced**	 	3-4	**Ruggedizing and mass production**	6
Module validation & qualification	**Synchrotron & beam testing in place** **Ruggedness assessment**	 	4	**Environmental testing** **Focal plane testing**	6
Petal production	**Design to spec** **1 produced**	 	4	**Prototype petal**	6
Petal validation & qualification	**First X-ray testing**		4	**Environmental testing** **Focal plane testing**	6

Q2: How does IXO propose to integrate the international consortium required for the project?



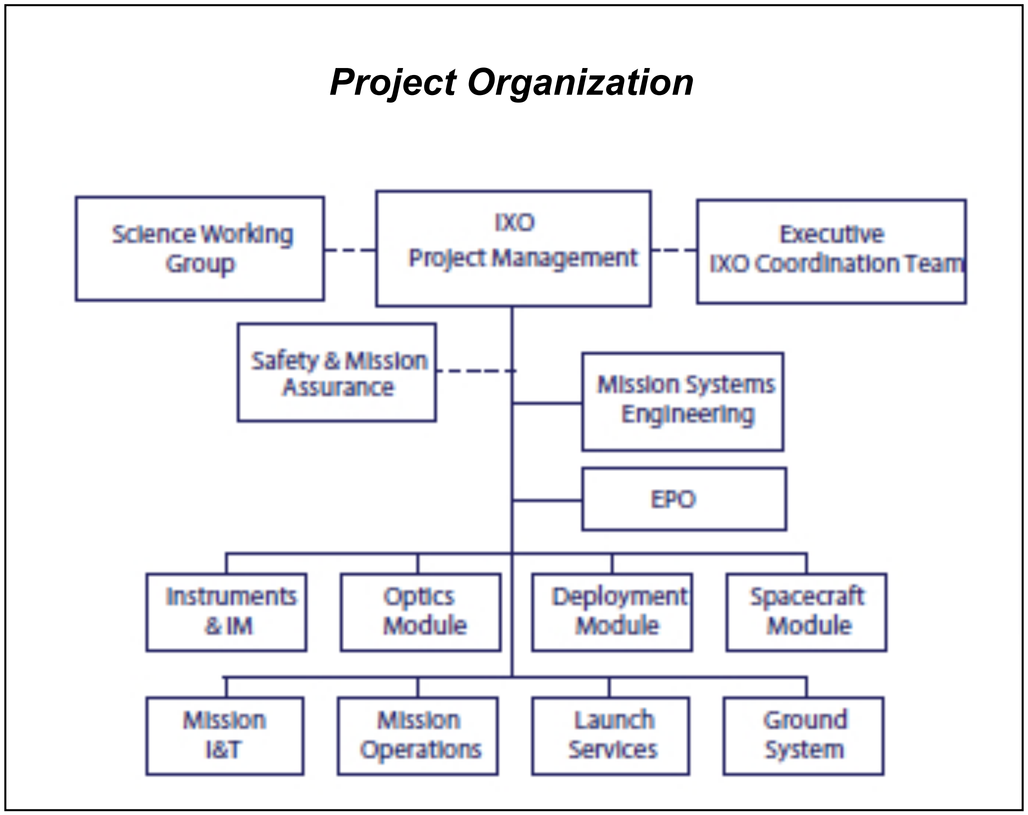
IXO International Consortium

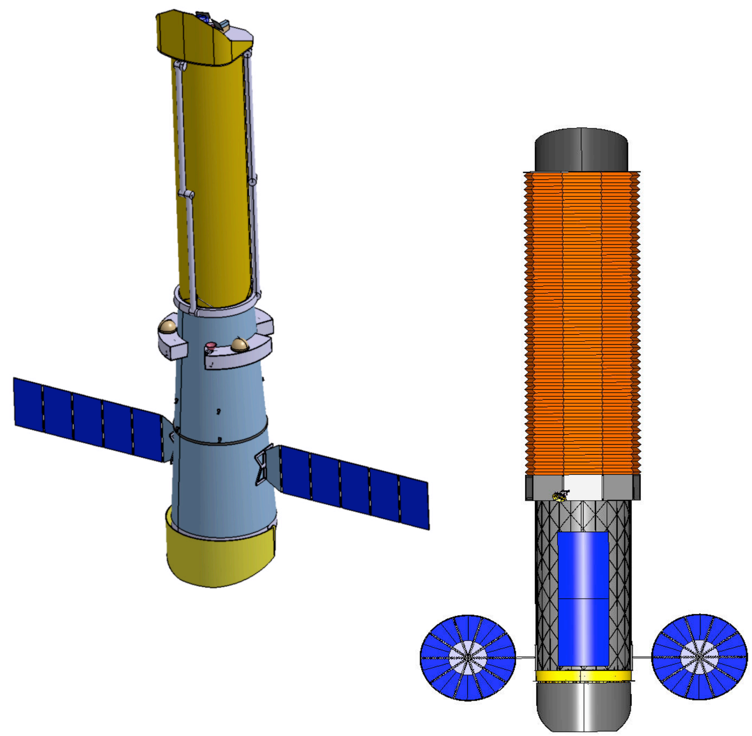
- The IXO project is already well integrated as an International team!
- International structure in place since Spring 2008; will form the basis for integrated international project as mission enters into development
- The US, Europe, and Japan have a successful history partnering on X-ray missions such as *Chandra, XMM-Newton, Suzaku, ASCA, ROSAT*
- Successful interagency projects pave the way (*Herschel, JWST, HST, Hinode*)

IXO Team Meeting 9/2008 MPE Garching, Germany

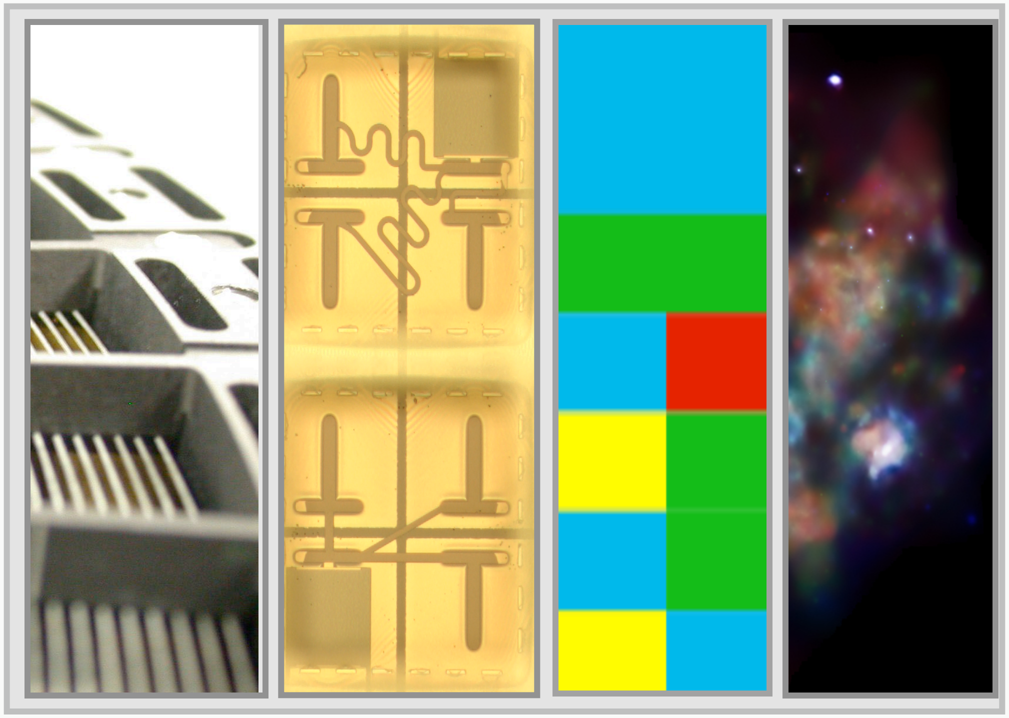
Implementation Responsibilities

- Either NASA or ESA will lead the mission
  - To be decided by NASA, ESA, and JAXA in Phase A
- The modular mission design lends itself to well-defined interfaces and contributions that map to the project WBS





Q3: Does IXO Have Downscope Options And What Are Those Options?

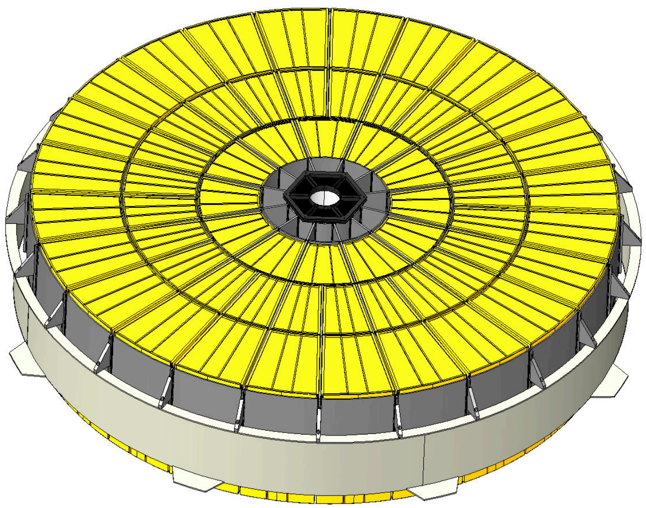


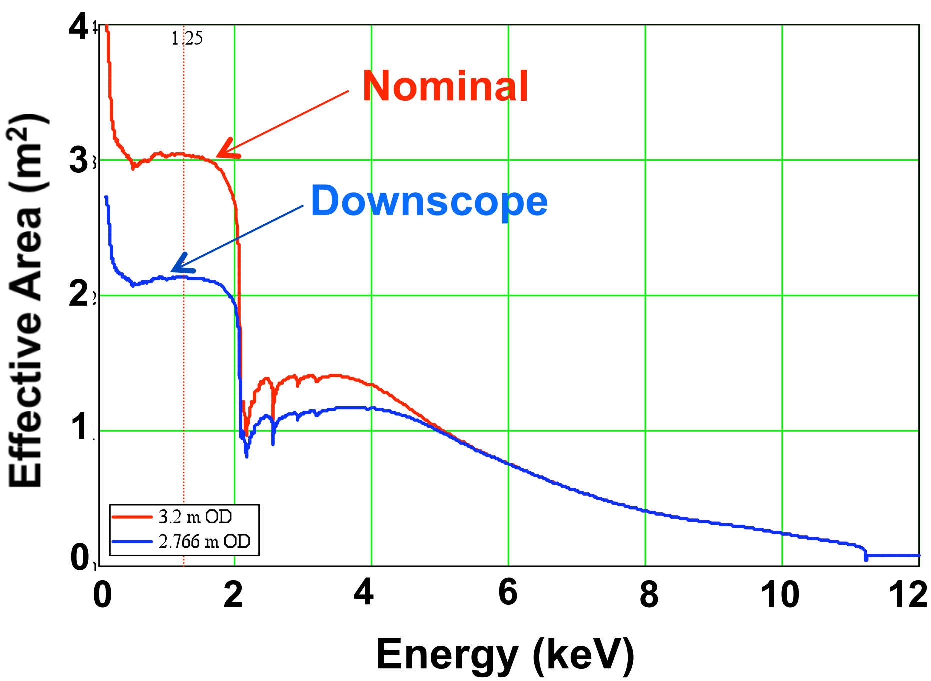
Downscope Methodology

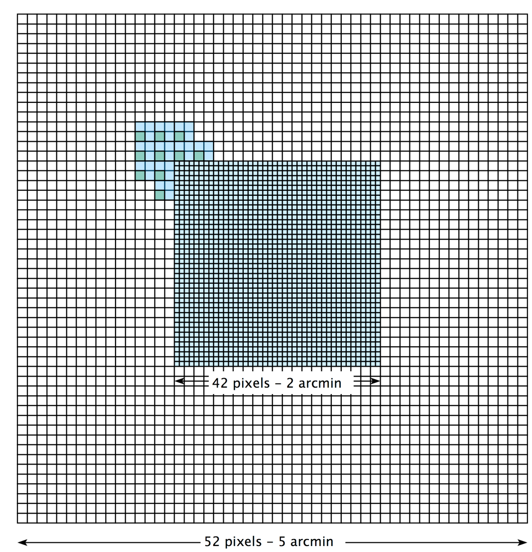
- Downscopes designed to maintain contingency for cost, schedule, mass and power
- Downscopes were developed to address current technical risk areas (in pre-Phase A)
- Science Traceability Matrix used to define science impact of downscope
- Downscope options were
  - Reviewed by IXO Science Definition Team & Science Coordination Group
  - Assessed by project teams
- Additional downscopes will be identified as mission is further developed

Downscope Options

- Two primary downscopes have been identified
  - Mirror area at low X-ray energies
    - Reduction of outer diameter
  - X-ray Microcalorimeter Spectrometer (XMS) field of view







XMS Detector Array – 5.4 x 5.4 arcmin

Science Impact of Downscopes

- Downscopes could:
  - Eliminate science objective
  - Reduce data quality (S/N) or sample size available
  - Eliminate specific techniques without removing all approaches to answering science questions.

- Summary: Downscopes are available, but will seriously compromise science of this facility-class mission

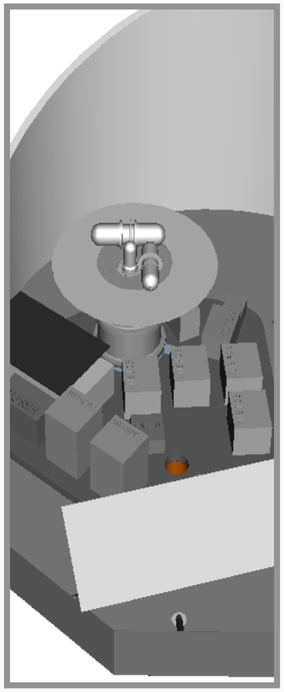
	Downscope Options	
	Mirror Area	XMS FOV
Matter Under Extreme Conditions (nominally 12% of mission)		
Strong Gravity	yellow	green
Neutron Star Equation of State	yellow	green
QED Tests from Magnetars	green	green
Black Hole Evolution (nominally 20%)		
Deep Survey	yellow	green
SMBH Spin Survey	blue	green
Stellar-Mass Spin	yellow	green
Large Scale Structure (nominally 37%)		
Cosmic Feedback from SMBHs	blue	yellow
Galaxy Cluster Evolution	yellow	red
Cosmology	yellow	red
Cosmic Web of Baryons	green	blue
Life Cycles of Matter (nominally 14%)		
Starburst Galaxies	blue	blue
Local Group & ISM Mapping	blue	blue
ISM Gas & Dust - Composition	green	green
Formation of the Elements	blue	red
Stellar flares	yellow	green
Stellar atmospheres	blue	green
Protoplanetary Disks	yellow	blue
Observatory Science (nominally 17%)	red	red

Legend
- green: Minimal or no impact
- blue: Linear impact with time
- yellow: Worse than linear / some science loss inevitable
- red: Major impact / significant science losses inevitable

Q4: Will certain IXO instruments and/or components be competed? If so, which instruments or components and how will they be competed?

Response from NASA HQ:

"Details of the workshare assignments have yet to be agreed to by the agencies. NASA normally competes its instrument and science team shares of international collaboration missions. It is nominally expected that NASA, ESA and JAXA will conduct a coordinated Announcement of Opportunity to solicit and select the competed components of the mission. Details of the process will be defined and agreed to by the partners at the appropriate time. "



- ***IXO addresses key and timely questions confronting Astronomy and Astrophysics***
- ***IXO provides 100-fold increase in effective area for high-resolution spectroscopy, along with wide field of view imaging, polarimetry & timing***
- ***Separate studies by ESA and NASA demonstrate that the mission implementation for a 2021 launch is feasible.***