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 Bavadz
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?

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

Hydra A Galaxy Cluster

- 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 Glass Mirror Overview

Mirror Segment Fabrication

- Mandrel manufacture
- Slumping
- Cutting and Coating

Flight Mirror Assembly

Module

Alignment and Mount
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
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

- Mirror plates and stacks
- Mirror modules
- Petals
- 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)
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

<table>
<thead>
<tr>
<th>Steps</th>
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<th>TRL 2008</th>
<th>Next (2011)</th>
<th>TRL</th>
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<td>Plate production</td>
<td>Industrial process</td>
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<td>Reduce cost</td>
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<td>Wedged, coated, non-conical</td>
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<td>Stack production</td>
<td>Automated</td>
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<td>Improve HEW</td>
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<td>Particle inspection, cleaning, bending, interferometry, stacking</td>
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<td>Module production</td>
<td>Design to spec</td>
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<td>Ruggedizing and mass production</td>
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<td>Integration method to spec</td>
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<td>Module validation &amp; qualification</td>
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<td>Focal plane testing</td>
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Q2: How does IXO propose to integrate the international consortium required for the project?
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)
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 Downslope 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](image)
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
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.**