The Lynx Mission Concept
Revealing the Invisible Universe

Douglas A. Swartz (Deputy Study Scientist, MSFC)
-Presented On behalf of the Lynx Team
Meet Lynx!

One of 4 large missions under study for the 2020 Astrophysics Decadal, Lynx is an X-ray observatory that will directly observe the dawn of supermassive black holes, reveal the invisible drivers of galaxy and structure formation, and trace the energetic side of stellar evolution and stellar ecosystems.

**Lynx will contribute to nearly every area of astrophysics and provide synergistic observations with future-generation ground-based and space-based observatories, including gravitational wave detectors.**

*Lynx will provide unprecedented X-ray vision into the “Invisible” Universe with leaps in capability over *Chandra* and *ATHENA:*

- 50–100× gain in sensitivity via high throughput with high angular resolution
- 16× field of view for arcsecond or better imaging
- 10–20× higher spectral resolution for point-like and extended sources
Lynx is designed to pursue three science pillars.

There are ample resources for many other programs, including those unexpected today.

It will be a discovery platform for all.

WWW.HIDDENCOSMOS.ORG
Lynx Study Office & STDT Activities

- Lynx Mirror Architecture Trade (LMAT) 01/2018 – 07/2018
  - recommend baseline optics design
  - adopted by STDT – 08/2018
- Large Mission Concept Studies Report Team (LRT) 05/2018 – 06/2018
- Lynx “science” website launched ~07/2018
  - https://www.hiddencosmos.org
- Interim Report submitted 08/2018
- X-ray Grating Spectrometer architecture trade – 08/2018
- Mission Design Lab (at GSFC) – 09/2018
  - system-level independent assessment
- Second Architecture Design Study – 08/2018 – ongoing
  - requested by NASA to provide a less costly option and a range of scientific scope – 06/2018
- Large Mission Concept Independent Assessment Team (LCIT) – ongoing
  - a cost & technical credibility analysis & validation of the technical, cost, and schedule requirements defined by the Lynx study
- Science White Papers submitted to Decadal Survey – 03/2019
<table>
<thead>
<tr>
<th>M1</th>
<th>Comments on Study Requirements and Deliverables</th>
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<tbody>
<tr>
<td></td>
<td>Accept the study requirements/deliverables and submit plan—or</td>
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<td>Provide rationale for modifying requirements/deliverables</td>
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<tr>
<td>O1</td>
<td>Optional: Initial Technology Gap Assessment</td>
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<td>To impact PCOS/COR/ExEP 2016 technology cycle</td>
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<tr>
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<td>June 30, 2016</td>
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<tr>
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<td>Interim Report</td>
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<td>Provide science case and mission concept (use CML 3 as a guide)</td>
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<td>Deliver initial technology roadmaps; estimate technology development cost/schedule</td>
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<td>Update Interim report with LRT comments incorporated (Public Release)</td>
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<td>Required Input Data released by STDTs to HQ</td>
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<td>Support independent cost estimation/validation process</td>
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<td>HQ submits to Large mission studies Cost Assessment Team (slide 35)</td>
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<td>LCIT reconciliation with STDTs</td>
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<td>July 2019</td>
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<tr>
<td>M7</td>
<td>STDTs Final Reports delivered to HQ</td>
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<td>As described in study success criteria chart 15</td>
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<tr>
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<td>HQ Submits final report to Decadal</td>
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### Lynx Study Look Ahead

#### LCIT / HQ Milestones

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#### Conferences

- **3/15**: CxC Prop. Due
- **3/17**: HEAD Mtg.
- **3/21**: Space Astro Landscape for 2020 & Beyond
- **3/29**: SAT/APRA Deadline
- **6/9 - 6/13**: AAS

LCIT Deliverable to include:
- Lynx Report Executive Summary
- Technology Roadmaps
- Cost + BOE (both configurations)
- Schedule (both configurations)
- Final Report outline

#### Tech Roadmap Draft Development

- **3/8**: 1st draft
- **3/25 - 3/29 (TBD)**: Updates
- **4/22**: Aerospace Review
- **4/26**: LCIT Deliverable

#### Science and Tech Team Activities

- **3/11**: Science Whitepaper Submission
- **3/12 - 3/14**: Calibration Workshop
- **3/15**: SAT/CPRA Deadline
- **3/21**: HEAD Mtg.
- **3/29**: Space Astro Landscape for 2020 & Beyond
- **4/1**: 2nd draft
- **4/22**: Aerospace Review

#### ACO Analysis

- **3/6**: 3/11 (TBD)
- **3/25 - 3/29 (TBD)**: Updates
- **4/22**: Aerospace Review

#### Cost Analysis

- **3/6**: Phase 7
- **3/27 (TBD)**: Present to STDT
- **4/22 (TBD)**: Present to STDT
- **5/1 (TBD)**: Report

#### Independent CATE Analysis

- **3/11 (TBD)**: 4/22 (TBD)
- **4/22**: K/O
- **4/26**: 5/1
- **5/24**: 6/5 (TBD)
- **6/5 (TBD)**: 6/14

#### Final Report Development

- **3/11 (TBD)**: K/O
- **4/22 (TBD)**: Executive Update
- **4/26**: Pens Down For Red Team
- **5/1**: CATE Comments
- **5/24**: Red Team Comments
- **6/3**: Red Team Planning Complete
- **6/12 - 6/14**: F2F & out-brief

#### Red Team Review

- **3/11**: K/O & in-brief
- **4/22**: Red Team Planning Complete
- **5/1**: K/O & F2F
- **6/10**: F2F & out-brief
# Lynx Study Look Ahead

## Milestones

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<th>Task</th>
<th>July 2019</th>
<th>August 2019</th>
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<td>LCIT Report to HQ</td>
<td>Final Qualitative Review</td>
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<td>Final Report</td>
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<td>8/1 - 8/8 (TBD)</td>
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<td>MSFC Mgmt Briefings</td>
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Decadal decision anticipated ~December 2020
Proven Observatory Architecture

3 m OD optical assembly (shown with retractable transmission grating array)

3 Focal Plane Instruments on translation table

10 m focal length rigid Optical Bench

S/C surrounds Optical Assembly (shown w/ sunshade open and solar arrays deployed)
High-Definition X-ray Imager

Ralph Kraft, SAO
Abe Falcone, Penn State University
Mark Bautz, MIT

- Initial instrument design developed by MSFC Advanced Concepts Office (ACO)
- Fully samples Lynx 22’x22’ sub-arcsecond FOV
- >100 frames/s in full frame mode (10^4 in 20px20p window mode); >8000 c/s full field event rate
HDXI: Multiple Sensor Approaches

- Monolithic CMOS Active Pixel Sensor
  - Single Si wafer used for both photon detection and read out electronics
  - SRI/SAO (and MPE)

- Hybrid CMOS Active Pixel Sensor
  - Multiple bonded layers, with detection layer optimized for photon detection and readout circuitry layer optimized independently
  - Teledyne/PSU

- Digital CCD with CMOS readout
  - CCD Si sensor with multiple parallel readout ports and digitization on-chip
  - LL/MIT
Lynx X-ray Microcalorimeter

Main Array
- 1” pixels, 5’ FOV, 50 μm pixels
- ~3 eV, 10 cps/ hydra (5”)
- Up to 7 keV
- 86.4 kpix

Enhanced Main Array
- 0.5” pixels, 1’ FOV, 25 μm pixels
- 1.5 eV, 20 cps/ hydra (2.5”)
- Up to 7 keV
- 12.8 kpix

Simon Bandler
NASA/Goddard Space Flight Center

Ultra-High-Res Array
- 1” pixels, 1’ FOV, 50 μm pixels
- 0.3-0.4 eV (up to ~0.75 keV)
- Count rate ~80 cps/1” (single pixel)
- 3.6 kpix

109.47
R>5000 X-ray Grating Spectrometer

Ralf Heilmann
Space Nanotechnology Lab
MIT Kavli Institute for
Astrophysics and Space Research
X-ray Mirror Assembly

Will Zhang
NASA/Goddard Space Flight Center

109.68

<table>
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<tr>
<td>Outer Diameter:</td>
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<tr>
<td>Effective Area 1 keV:</td>
<td>&gt;2 m²</td>
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<td>Effective Area 6 keV:</td>
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<td>On-Axis HPD:</td>
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<td>FOV w/ 1” HPD:</td>
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Silicon Meta-shell Optics
recommended for DRM by LMAT
Direct-fabrication Mirror Segments

1. Mono-crystalline silicon block
2. Conical form generated
3. Light-weighted substrate
4. Etched substrate
5. Polished mirror substrate
6. Trimmed mirror substrate
The Process of Building a Mirror Module

1. Silicon plate with small silicon spacers that are precisely ground to prescribed radial heights.

2. Mirror segments are placed on spacers, settled by vibrations. The baffle is shown for completeness and has no precision to speak of.

3. Once epoxy cures, another set of spacers are attached to repeat the process for the next layer of mirror segments.

4. The previous steps repeat until a full mirror module is completed. The interim silicon plate is removed at the end of the buildup process.
Steps in Lynx Mirror Assembly Build

- **37,492 Segments**: ~0.01 kg ea.
- **611 Modules**: ~1.5 kg ea.
- **12 Meta-shells**: ~80 kg ea.
- **1 Assembly**: ~1,000 kg

AI&T see 109.45
Full Illumination X-ray Measurement at GSFC and MPE Panter

Effective Area at 4.5 keV (cm²)
- 0.266 predicted
- 0.260 measured

Image at 4.5 keV: 2.2” HPD (logarithmic color scale) approaches TRL 4