Precision-Deployable, Stable, Optical Benches for Cost-Effective Space Telescopes

A Key Technology to Accomplish IXO Science

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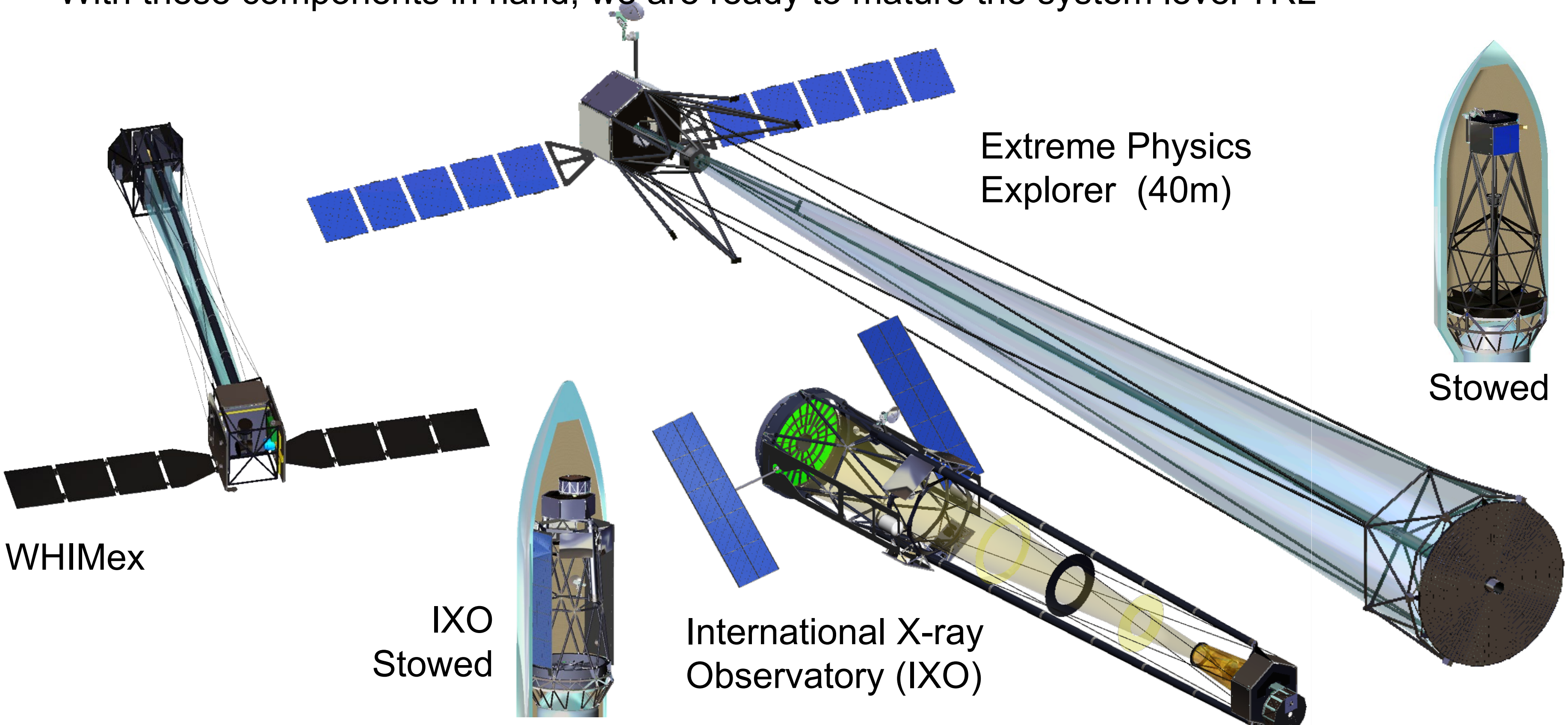
Large Missions in Small Launch Vehicles

- Deployables enable long focal length telescopes to be launched on smaller launch vehicles thus reducing over all mission cost
- Adjustable (more than 10 mm range), precision deployable (micron accuracy), stable structures are possible today due to high TRL components
- With these components in hand, we are ready to mature the system level TRL



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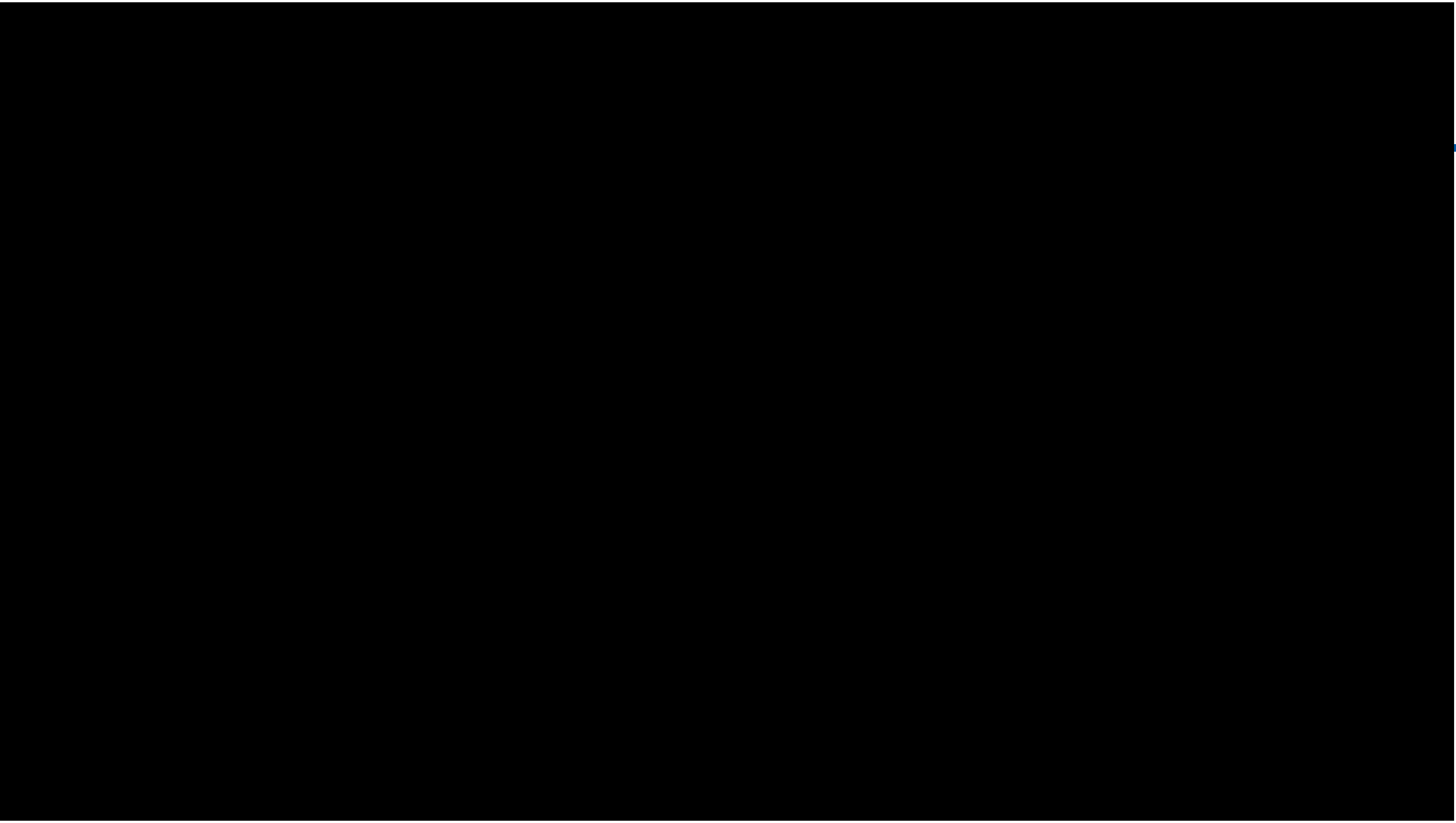

Flight Quality Components Available

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Deployable Optical Bench Concept

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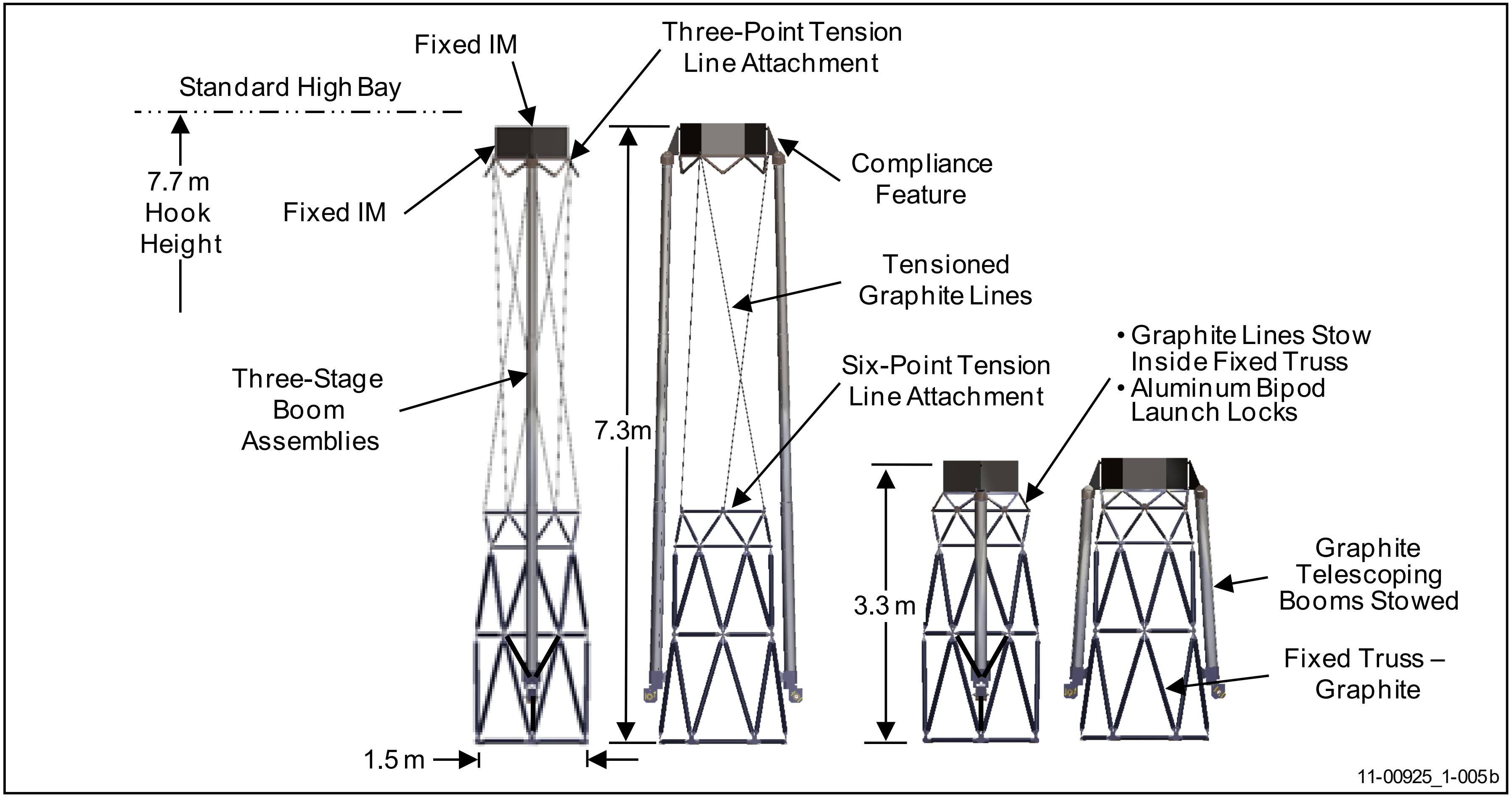
- 2 deployable booms are held in compression by 6 tension lines
- Extendible section is supported by “elephant stool” fixed truss structure
- Results in a stiff, lightweight, tunable structure



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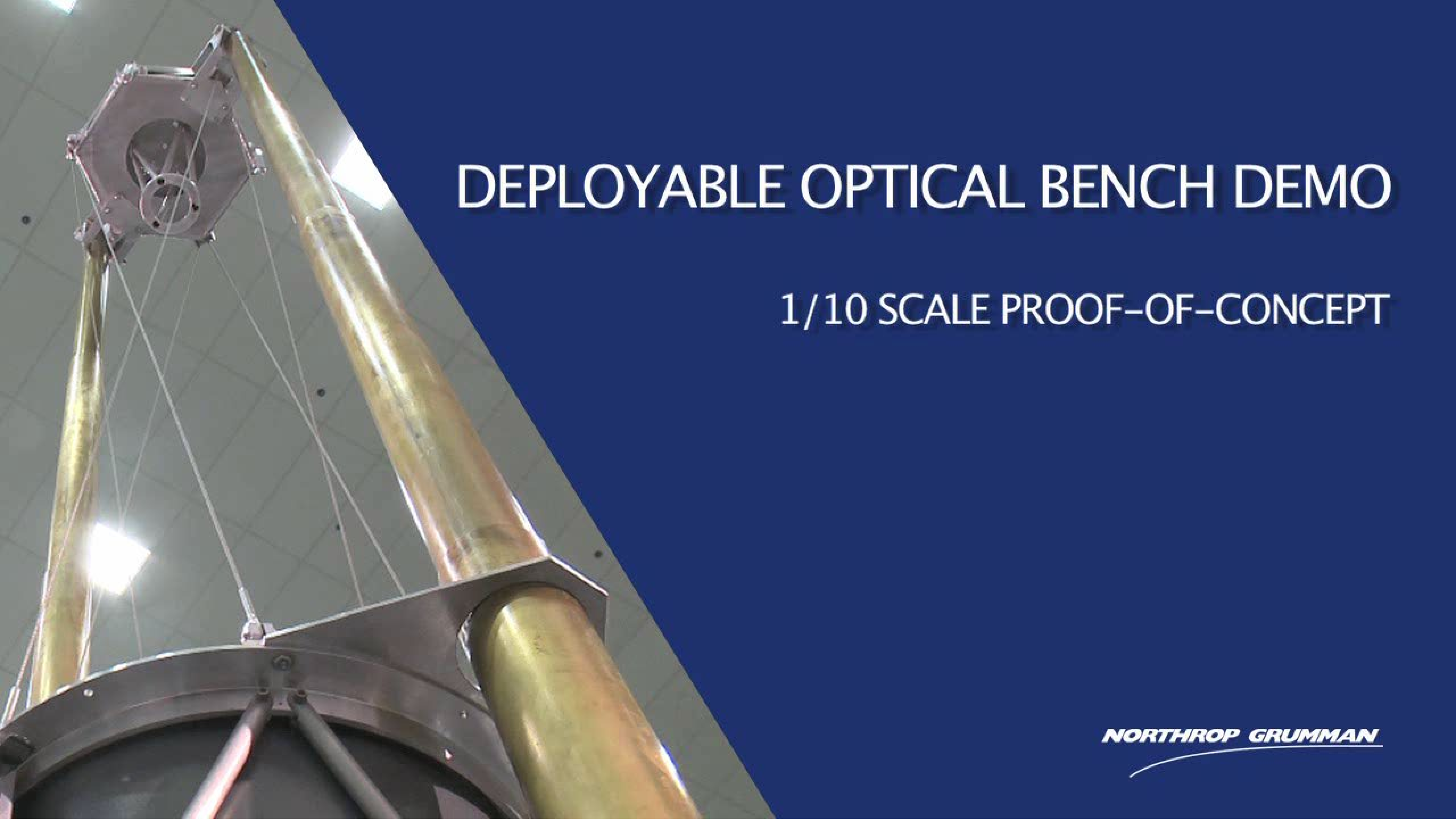

1/10th Scale Model Demonstrates Deployment Concept

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Current TRL Status

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- We have focused on the deployable structure and analysis of the MLI enclosure
- MLI enclosure and deployable harness will need additional development

TRL Definition and Hardware Description	Deployable Optical Bench Observatory Assembly - Key Component TRL Exit Criteria		
	DOB Structure	Deployable MLI Enclosure	Deployable Harness
TRL 3: Analytical and experimental critical function and/or characteristic proof-of concept **Hardware:** Analytical studies to set the context and 1/10th scale (2-meter class) mechanical model to physically validate that the analytical predictions are correct.	• **Observatory system level models: solid model, thermal model, FEM, dynamic/ACS model** • **Preliminary mechanical system analysis showing positive margins against requirements** • **1/10th scale proof of concept model: stowed to deployed configuration transition and Tensegrity truss stiffening**	• **Observatory system level models: solid model, thermal model and stray light model** • **Preliminary thermal analysis showing positive margins against requirements, checking FMA gradients and truss temperature stability** • Preliminary stray light analysis showing positive margin against noise background requirement • Minimize complexity of internal stray light baffle and optimize performance of inner MLI layer • 1/10th scale MLI tent & stray light baffle; deploy with 1/10th scale deployable optical bench • Deploy several times to demonstrate integrity of design; visual Inspection only	• Observatory system level electrical block diagram indicating EE architecture and deployable harness requirements • Preliminary EDI assessment of deployable harness capabilities including wire count and shielding • 1/10th scale proof of concept and deploy using 1/10th scale deployable optical bench • Deploy with 1/10th Scale model to demonstrate Integrity of Design, visual inspection only

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Path to TRL 5 & 6

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- The roadmap includes a high fidelity test article at the scale of Explorer class missions
- This would be a subscale test article for larger missions

TRL Definition and Hardware Description	Deployable Optical Bench Observatory Assembly - Key Component TRL Exit Criteria		
	DOB Structure	Deployable MLI Enclosure	Deployable Harness
TRL 5: Component and/or breadboard validation in relevant environment **Hardware:** 7-meter class medium fidelity system brass board is built and operated to demonstrate overall performance in a simulated operational environment with realistic support elements that demonstrates overall performance in critical areas. Performance predictions are made for subsequent development phases.	• Develop high percentage graphite forward and aft truss prototypes • Deployment booms (subset of flight Astro boom assemblies, STEM driven) • Tensegrity truss lines and tensioning system using graphite tension link material and DC brush gear motors • NEA release/HiShear retraction system • Develop secondary equipment modules using aluminum honeycomb panels and aluminum truss and mass simulators • Generate scaled requirements • Visual demonstration of functional deployment, stowed/deployed modal tap, deployment repeatability, sine burst vibe, amplified ambient thermal distortion, focal point adjustment/control, mass properties tracking • Correlate test data to scaled, prototype FEM, verifying positive test margins • Applied scaling to full scale FEM correlation	• Deployable MLI tent prototype with graphite tubing frame and tension linkage, graphite face sheet/aluminum honeycomb end panels and 12-layer MLI blanket complete with "weathered" MLI • Develop internal stray light baffle • Generate requirements for MLI tent • Deploy several times using overhead crane to demonstrate integrity, followed with stowed vibe test, visual demonstration of proper deployment and MLI coatings for scuffs, tears; measure emittance and solar absorptance, transmittance, and deployment drag • Correlate test data to scaled FEM, showing positive test margins • Applied scaling to full-scale FEM correlation as required • Adjust full-scale thermal model as required, showing positive thermal margins • Adjust full-scale stray light model as required, showing positive stray light margins • Applied scaling to full-scale deployment predictions	• Deployable harness to be Installed in Astro Boom Assemblies • Generate requirements for deployable harness • Deployment, followed with stowed vibe test, demonstration of harness deployment, visual inspection for harness scuffs • Deployment followed with stowed vibe test, visual demonstration of harness deployment, visual inspection for harness scuffs, measure resistance change, check for grounding shorts and measure deployment drag • Verify positive electrical resistance change margin and that no shorts or detrimental scuffs detected • Applied scaling to full scale deployment predictions
TRL 6: System model or prototype demonstration in an operational environment **Hardware:** 7-meter class prototype that adequately addresses all critical scaling issues is built and operated in a relevant environment to demonstrate operations under critical environment conditions	• Enhance prototype graphite deployable optical bench assembly, adding graphite rotary instrument module structure including launch locks, rotary position actuator, deployable MLI tent, fixed MLI and harness • Deploy several times to demonstrate integrity of combined assembly, followed with stowed vibe test, visual demonstration deployment, visual inspection of MLI coatings for scuffs and tears. Measure emittance and solar absorptance, transmittance and MLI tent deployment drag • Measure fixed instrument module deployment repeatability • Rotary instrument module release and repeatability precision testing • Thermal vacuum testing for observatory temperature control over 135 degree Sun angle range • Thermal vacuum environment for advanced thermal distortion testing • Add stray light vane mockups at aperture entrance and stray light baffle for ambient stray light testing • Correlate test data to scaled, prototype FEM, verifying positive test margins • Applied scaling to full-scale FEM correlation as required • Adjust full-scale thermal model as required • Adjust full-scale thermal model as required, showing positive thermal margins • Adjust full-scale stray light model as required, showing positive stray light margins • Applied scaling to full-scale deployment predictions		

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Development Success Criteria Derived from IXO Requirements

- We have developed success criteria for 4 technology miles stones that will bring the system to TRL 5
- The same test article can be used for environmental testing to reach TRL 6

Requirement	IXO Baseline Design (1)	IXO NGAS Design Requirements	Full-Scale Predicted Performance – NGAS	Scaled Requirement for 7-meter Class Test Article	Scaling Method
T1: Focal Point Deployment and Control					
Deployment force margins	See Note 2	>100% static force margin at any point, starting from v = 0			Will comply with NASA-STD-5017
Lateral deployment accuracy (Assumed calibration feedback)	See Note 2	0.60 mm (4)	4 *um*	0.60 mm (4)	Linear actuator error based * (R/F)
Axial deployment accuracy (Assumed Calibration Feedback)	See Note 2	0.112 mm (4)	1 *um*	0.112 mm (4)	Linear-actuator-based
Adjustment range (lateral)	5 mm (3)	5 mm (3)	>10 mm	1.875 mm	Pointing-based lateral delta = angular strain * F
Adjustment range (axial)	5 mm (3)	5 mm (3)	>10 mm	1.875 mm	Linear distortion strain * F
Adjustment resolution (lateral) (4)	0.60 mm (4)	0.60 mm (4)	4 *um*	0.60 mm (4)	Linear actuator error based*(R/F)
Adjustment resolution (axial) (4)	0.112 mm (4)	0.112 mm (4)	1 *um*	0.112 mm (4)	Linear actuator based
T2: Characterization of Deployed Dynamics					
Jitter	**200 mas (3σ) over 200 milliseconds**				**Angle-based – nonscalable**
Tension line and Astro boom modes	N/A	Higher than fundamental optical bench modes			Basic requirement – nonscalable
First optical bench torsion mode (deployed)	1 Hz (unconstrained)	4 Hz (unconstrained) (5)	5 Hz (unconstrained)	7 Hz (UC) Hz (fixed base)	Assumes cantilever beam scaling combined with nonscalable effects
First optical bench bending mode (deployed)	1.6 Hz (unconstrained)	5 Hz (unconstrained) (5)	6 Hz (unconstrained)	10.4 Hz (UC) 4 Hz (fixed base)	
T3: Long-Term Stabililty					
Optical bench temperature delta requirement	10°C (6)	10°C (6)	10°C (6)	10°C (6)	Nonscalable
Long-term slow changing lateral stability (2 weeks)	1.6 mm (3σ)	1.6 mm (3σ)	0.14 mm (3σ)	0.60 mm (3σ)	Pointing-based lateral delta = angular strain * F
Long-term slow changing axial (focus) stability (2 weeks)	0.3 mm (3σ)	0.3 mm (3σ)	0.06 mm (3σ)	0.112 mm (3σ)	Linear distortion strain * F
T4: Stowed Load Verification					
Stowed lateral mode (at separation plane)	8 Hz	8 Hz (fixed base)	8.2 Hz (fixed base)	16 Hz (fixed base)	Assumes cantilever beam scaling combined with nonscalable effects
Stowed loads	Case 1 – 2 G lateral with 3 G axial		TBD following CLA	2.5 G lateral with 10 G axial	Payload planner's guide assuming Taurus 3210 for 3/8th scale
	Case 2 – 1 G lateral with 5 G axial				

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