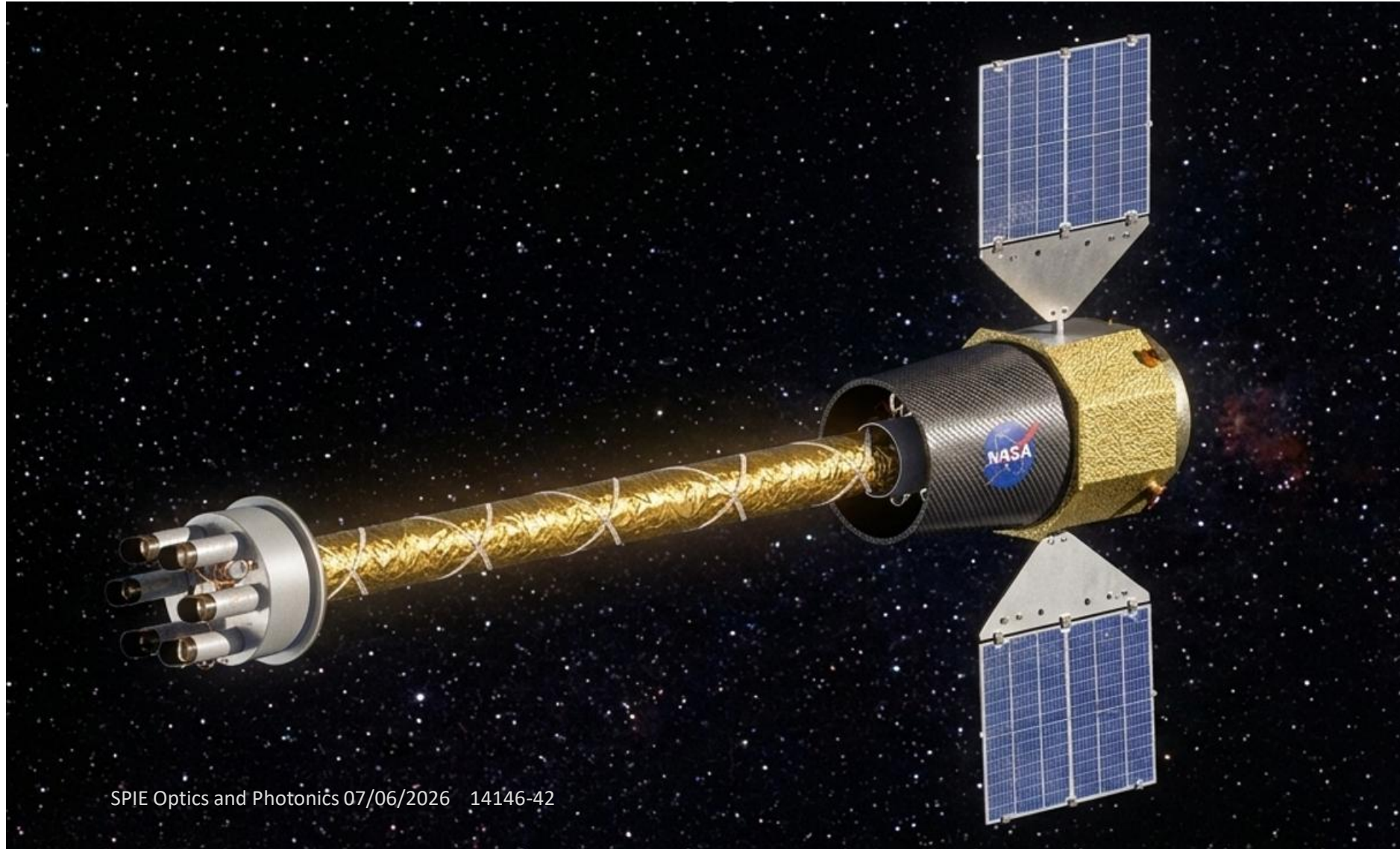


The HEROIX broadband X-ray space telescope mission concept

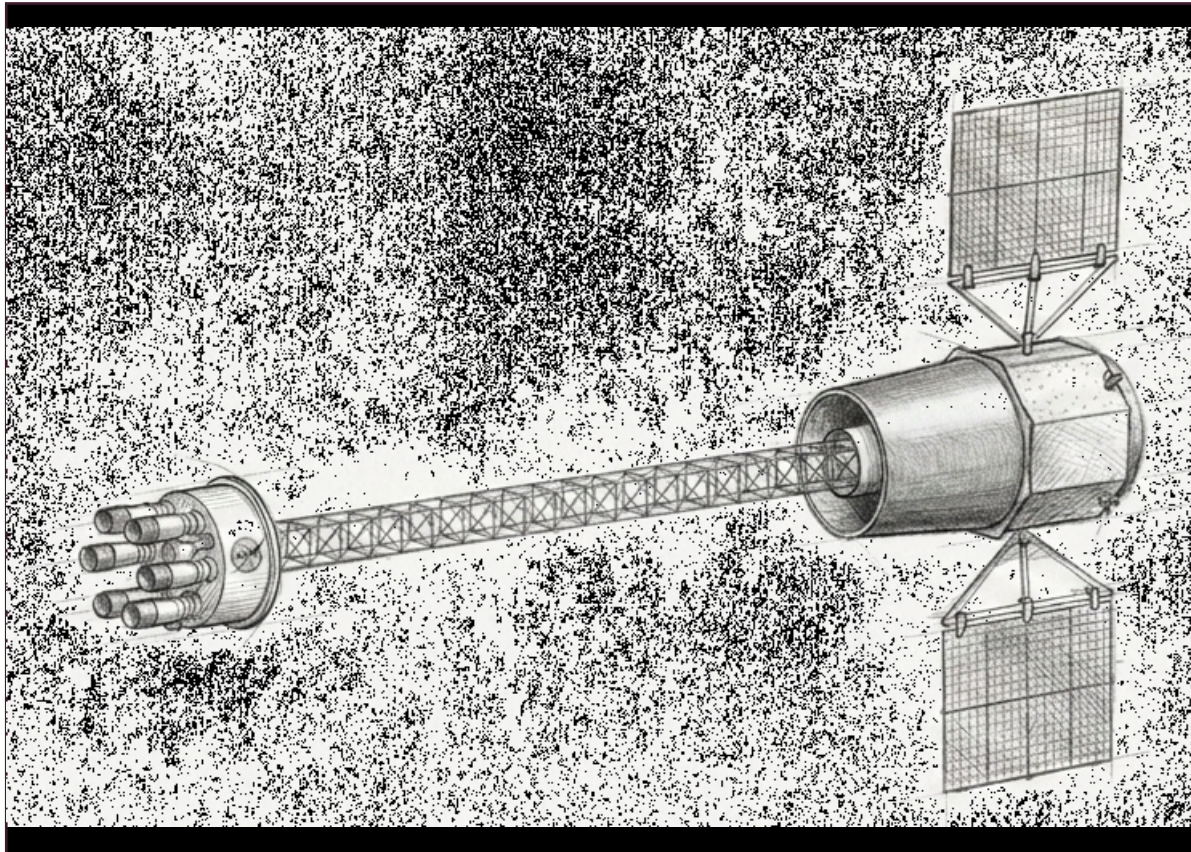
Nick Thomas
NASA MSFC



SPIE Optics and Photonics 07/06/2026 14146-42



The HEROIX Concept Team



Science PI: Chien-Ting Chen

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1 – NASA MSFC, 2 – USRA, 3 – The University of Iowa, 4 – Amentum, 5 – RIKEN, 6 – The University of Osaka, 7 – The University of Miyazaki, 8 – Nagoya University, 9 – Kavli-IPMU, 10 – Fukushima-REI, 11 – Kyoto University, and 12 – JAXA

The High Energy Universe in High-Resolution



- Hard X-ray probes photons generated by physical processes in extreme astrophysical environments, from accreting of stellar mass compact objects to shock waves and jets in galaxy clusters
- *NuSTAR* pioneered this field as the first focusing hard X-ray mission in orbit, albeit limited by its $\sim$ arcmin half power diameter
- An order-of-magnitude improvement in angular resolution will lead to exciting discoveries



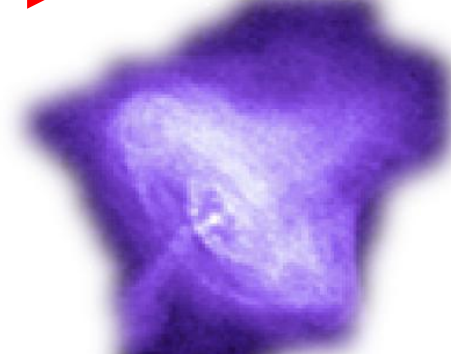
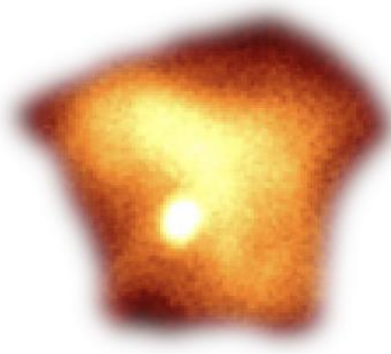
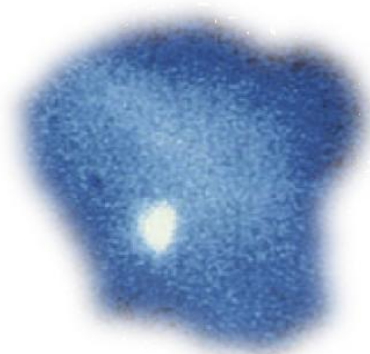
Einstein



ROSAT



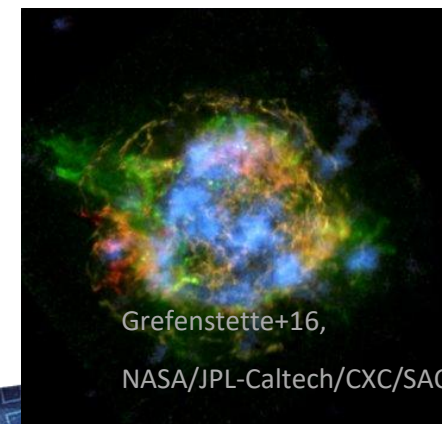
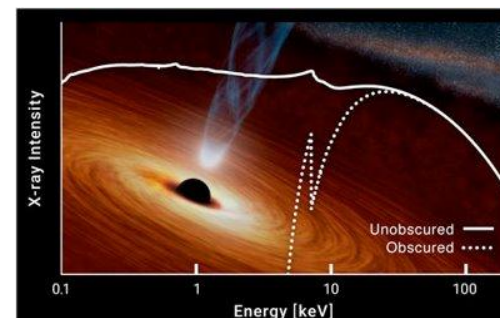
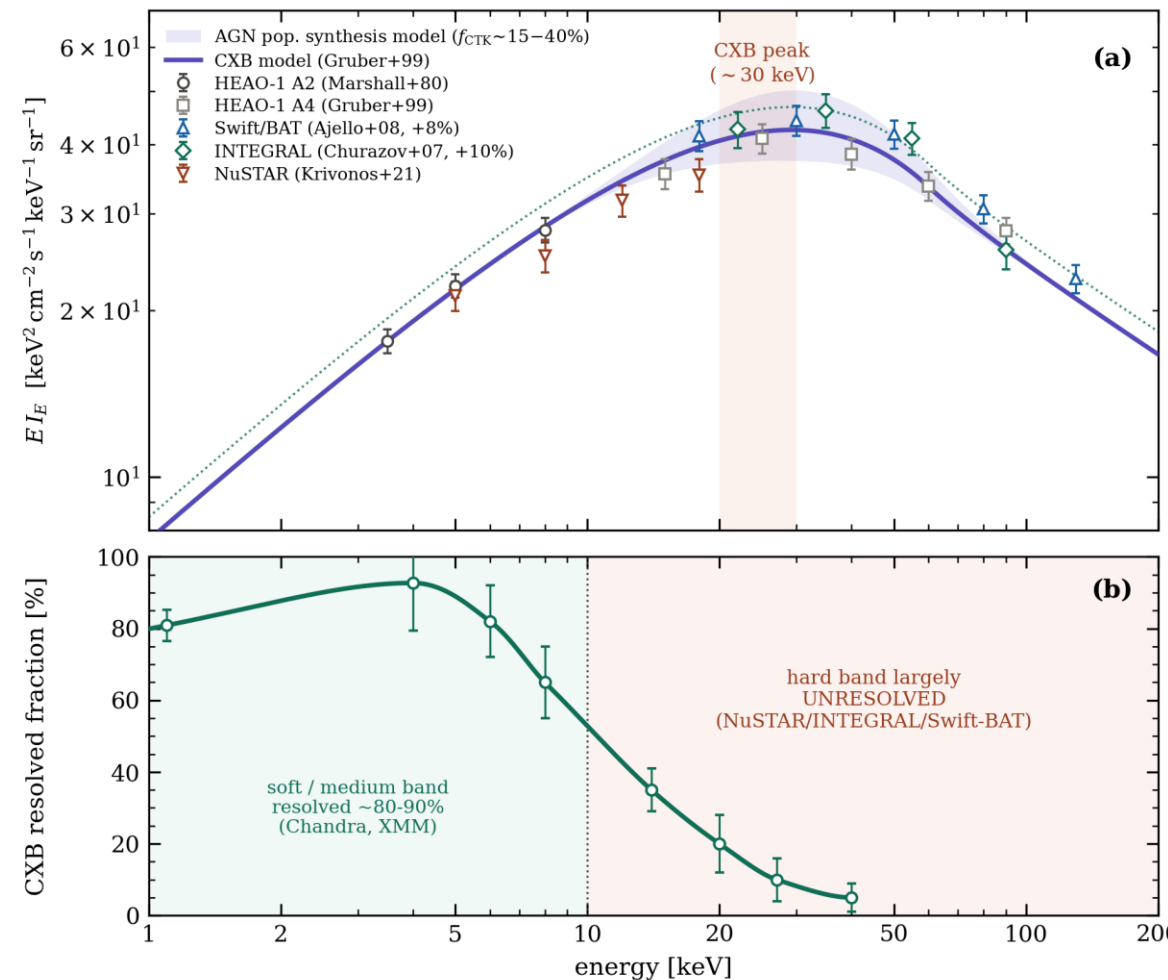
Chandra



The Broadband X-ray Universe

A next-generation, broadband, high resolution X-ray observatory will unlock a new frontier in high-energy astrophysics:

- Resolve the Cosmic X-ray Background at its peak of ~ 30 keV
- Understand dust-enshrouded X-ray population, including X-ray binaries and AGN
- Particle acceleration in extreme environments such as shock waves and jets from celestial objects of all sizes
- Accretion physics with broad-band X-ray spectroscopy
- And many more discoveries



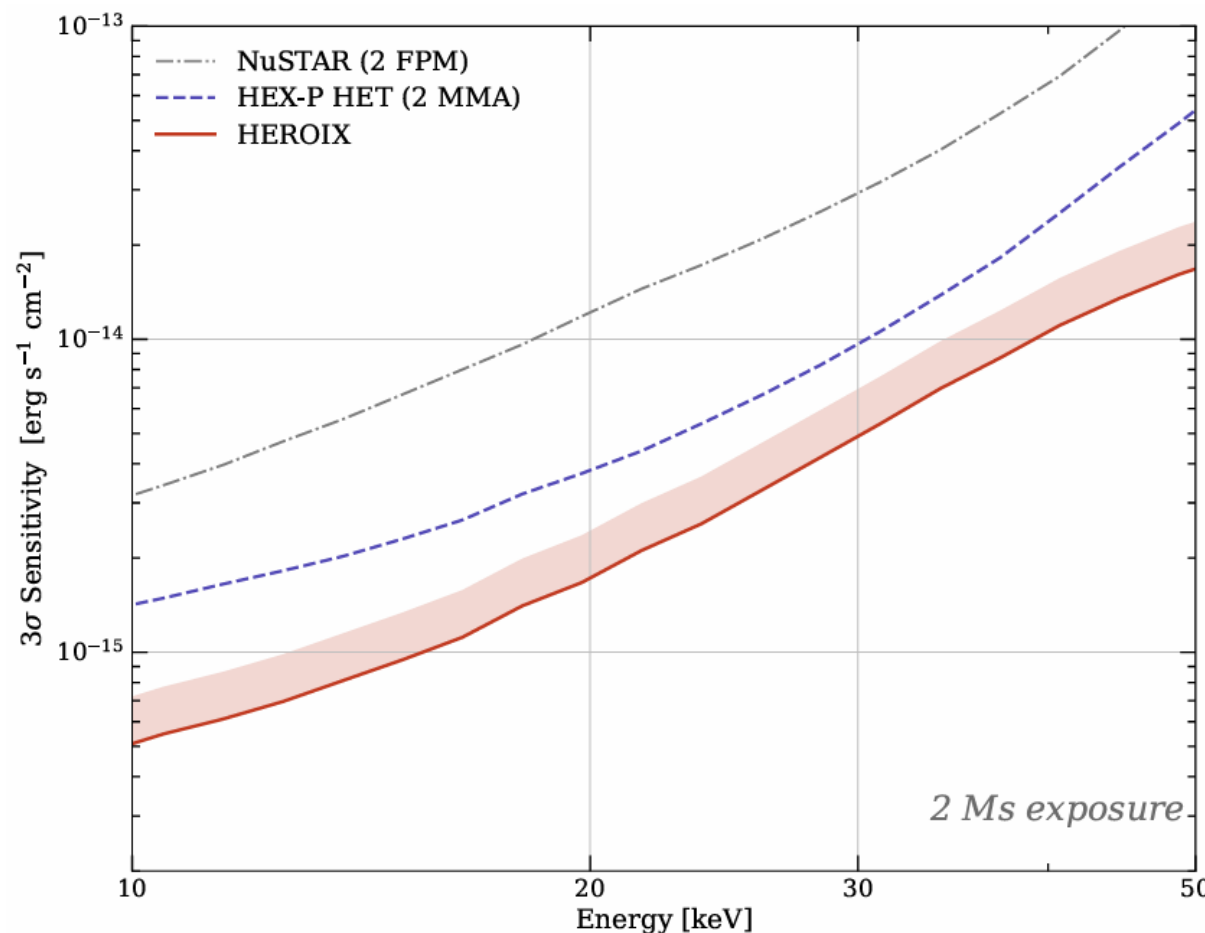
The HEROIX mission concept



- Six co-aligned broadband X-ray telescopes
- 5 arcsecond HPD
- 570 cm² @ 30 keV effective area
- Field of View: 12 arcmin
- Hybrid Focal Plane Assemblies
 - 1 keV to 80 keV
 - Developed for *FORCE* Mission
- 12-meter focal length
- MIDEX class mission

Initial NASA MSFC Advance Concept Office (ACO) study completed in June 2026

HEROIX Sensitivity Curve



Harrison et al, 2013 (*NuSTAR*)

Civano et al, 2025 (*HEX-P*)



HEROIX Integrated Mission Requirements

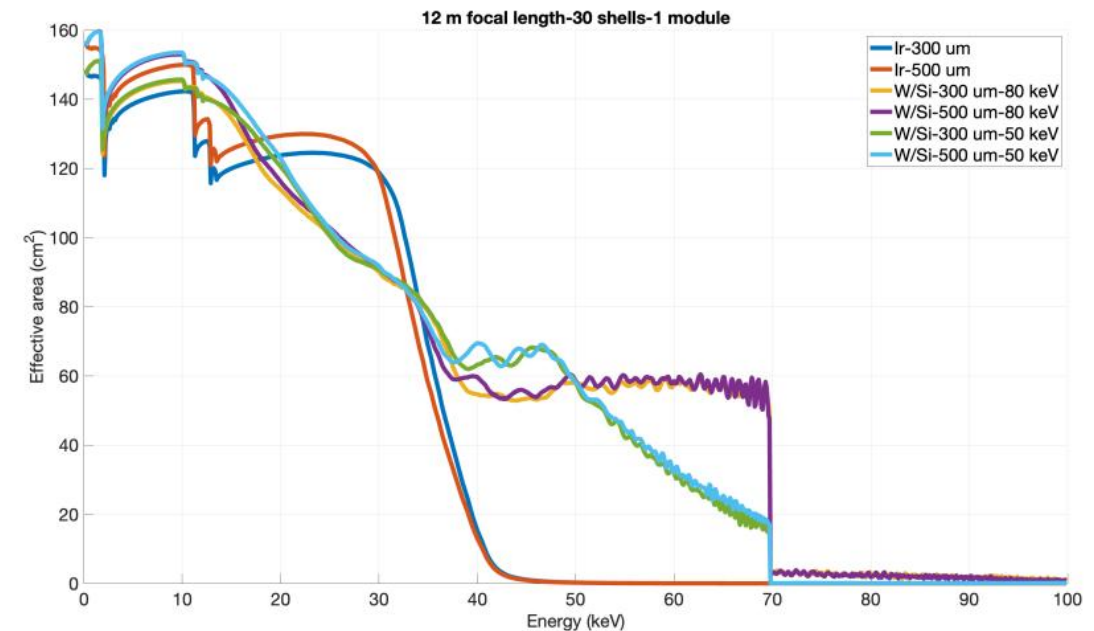
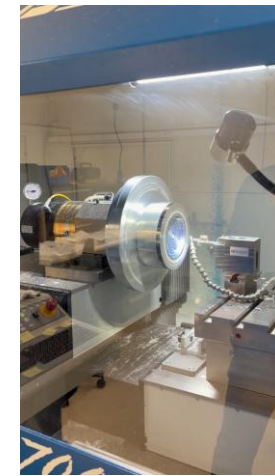
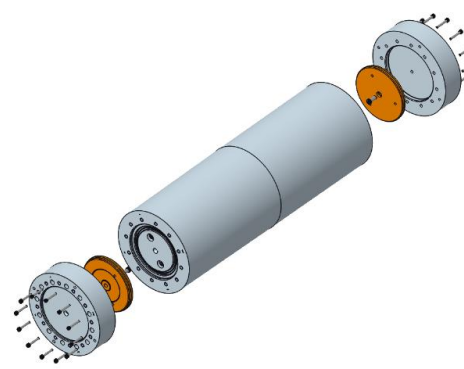


- Launch date: 8 years after selection
 - Telescope delivered by NASA's Launch Service Program
- Mission lifetime: 3 years with option to extend
- Low background
 - Avoid proton activation of focal plane
- Point Knowledge Requirements (Pitch & Yaw):
 - 0.6 arcsec RMS, 0.81 arcsec HPD
- Pointing Target Requirement: 1 arcmin
- Sun Avoidance Angle: 45 deg
 - Thermal baffling
- Slew Rate: 4 degrees a minute
- Data rate: 3 GB/day (10 GB/day Max)
- Download frequency: 4 times a day
- Spacecraft bus and commercially available components meet thermal, mechanical, and electrical requirements for science payload

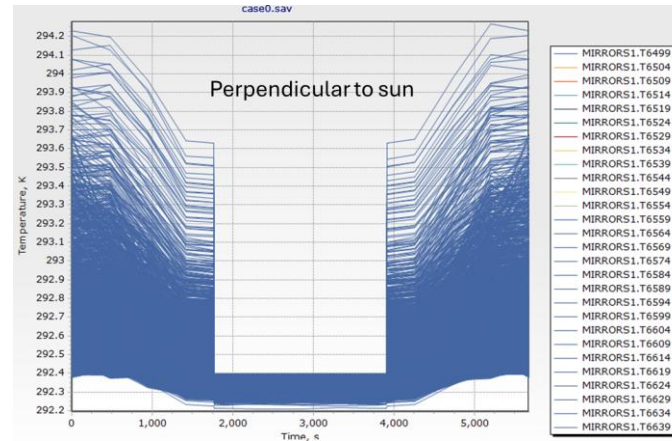
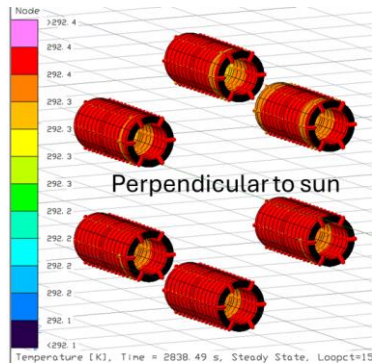
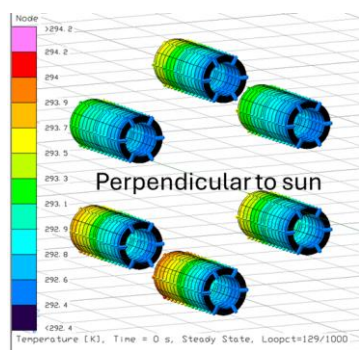
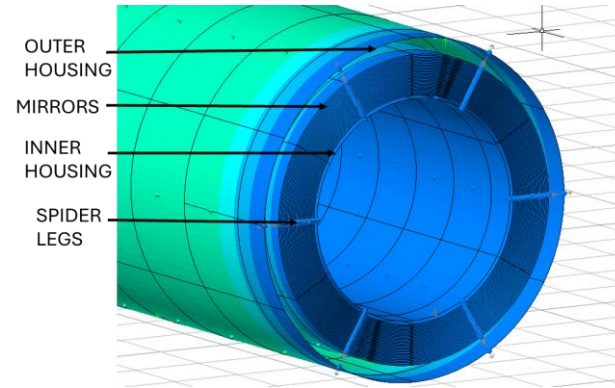
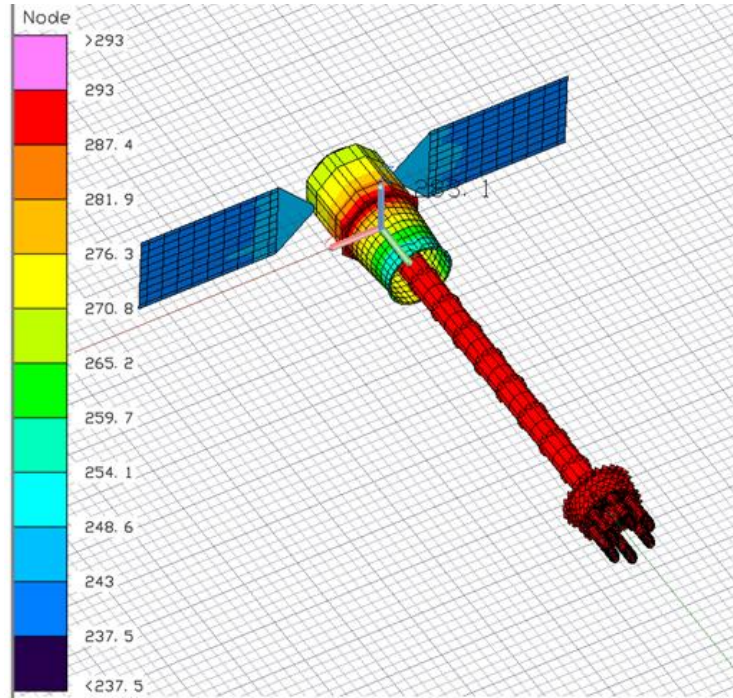


High Resolution Hard X-ray Telescope

- Six Mirror Module Assemblies (MMAs)
- 30 High-Resolution Mandrels
 - Similar scope to *IXPE*, identical prescription to *SuperHERO*
 - CNC deterministic polished
- 12-meter focal length
- Shell diameters range from 200 mm to 271 mm at the node
- Shell wall thickness: 0.5 mm
- Shell P and H each have 300 mm length for a total shell length of 600 mm
- Designed for fabrication on an M-40 DT (diamond-turning) or similar precision diamond-turning machine
- Multilayer reflective coating: Pt/C
- Energy band coverage: 0.1 keV to 79 keV
- Includes thermal baffling for thermal stability
 - Must maintain 20 deg C +/- 1 deg
 - Maintained with zonal heating elements



MMA Thermal Model



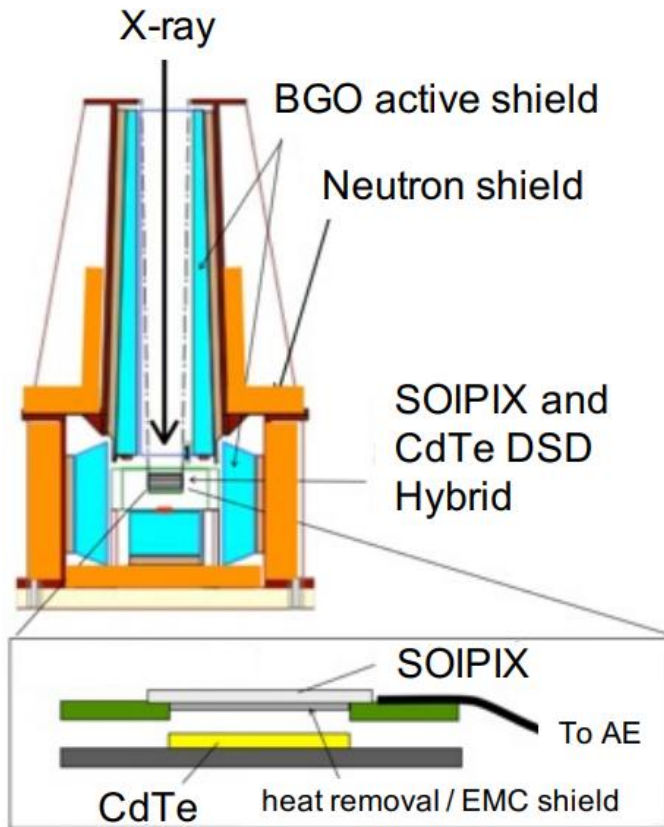
Heating power required is reasonable

Anti-Sun Case Power (W)	Perpendicular- to-Sun (W)	Sun-facing 45° (W)
20.84	24.83	26.91

- Performed a thermal analysis of the *HEROIX* observatory using Thermal Desktop, focusing on the quasi-steady-state behavior of the six MMAs in operational orbital environment.
- MMA thermal requirements applied: 20 ± 1 °C (292.15–294.15 K).
- Developed high-fidelity thermal model of each MMA, including nested shells (30) and supporting structures.
- Evaluated thermal performance across key observatory orientations: anti-sun, perpendicular-to-sun, and 45° sun-facing.
- Dual-layer zonal heater control network (internal and external to the shells) is required for stable thermal regulation.
- Verified that *HEROIX* maintains safe thermal compliance across standard orbital conditions while using minimal heating power.



Hybrid Focal Plane Detector Assembly



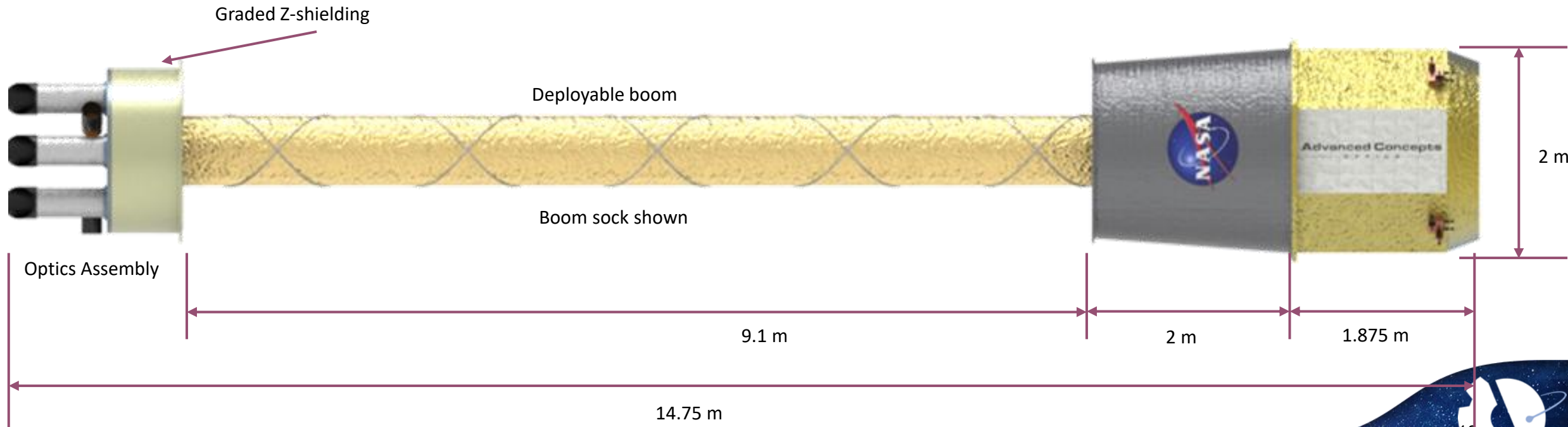
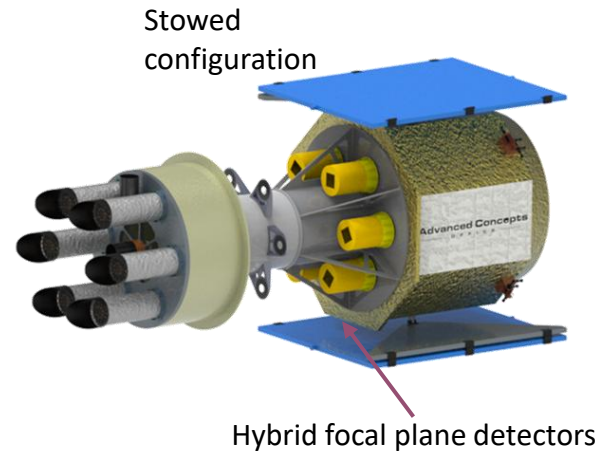
Mori et al, 2022

- Mass per unit: 45 kg (2 cm BGO)
- Power per unit: 24 W @ -25 C
- Temp Req: Detector plane: -25 C
- Survival Temp: -30 to 40 C
- Avoid SAA

- Staged design with the soft X-ray focal plane positioned directly in front of the hard X-ray focal plane
- Developed for *FORCE* (Nakazawa et al, 2018)
- Soft X-ray detector: SOIPIX (SOI-CMOS)
 - Energy coverage: 1 to 25 keV
 - Silicon thickness: 0.3 mm
 - Pixel size: 36 μm
 - Energy resolution: 250 eV at 6 keV
 - Focal-plane size: 44 $\times$ 44 mm² ($\approx$ 12.6 arcmin FoV)
 - Time resolution: 10 μs
- Hard X-ray detector: CdTe-DSD
 - Double-sided Strip Detector (CdTe-DSD)
 - Energy coverage: 20 keV to 79 keV (up to $\sim$ 200 keV capability)
 - Detector thickness: 1 mm
 - Strip size: 250 μm
 - Energy resolution: 1 keV at 60 keV
 - Detector tile: 32 mm² ($\approx$ 9.1 arcmin FoV)
 - Time resolution: 25.6 μs per array
- Assembly encased in BGO (Bismuth Germanate) anticoincidence shield

HEROIX Flight Configuration

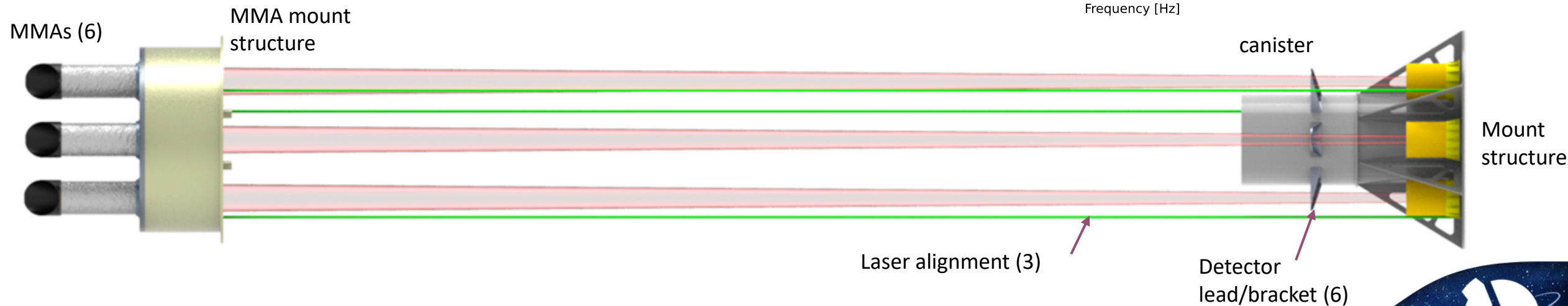
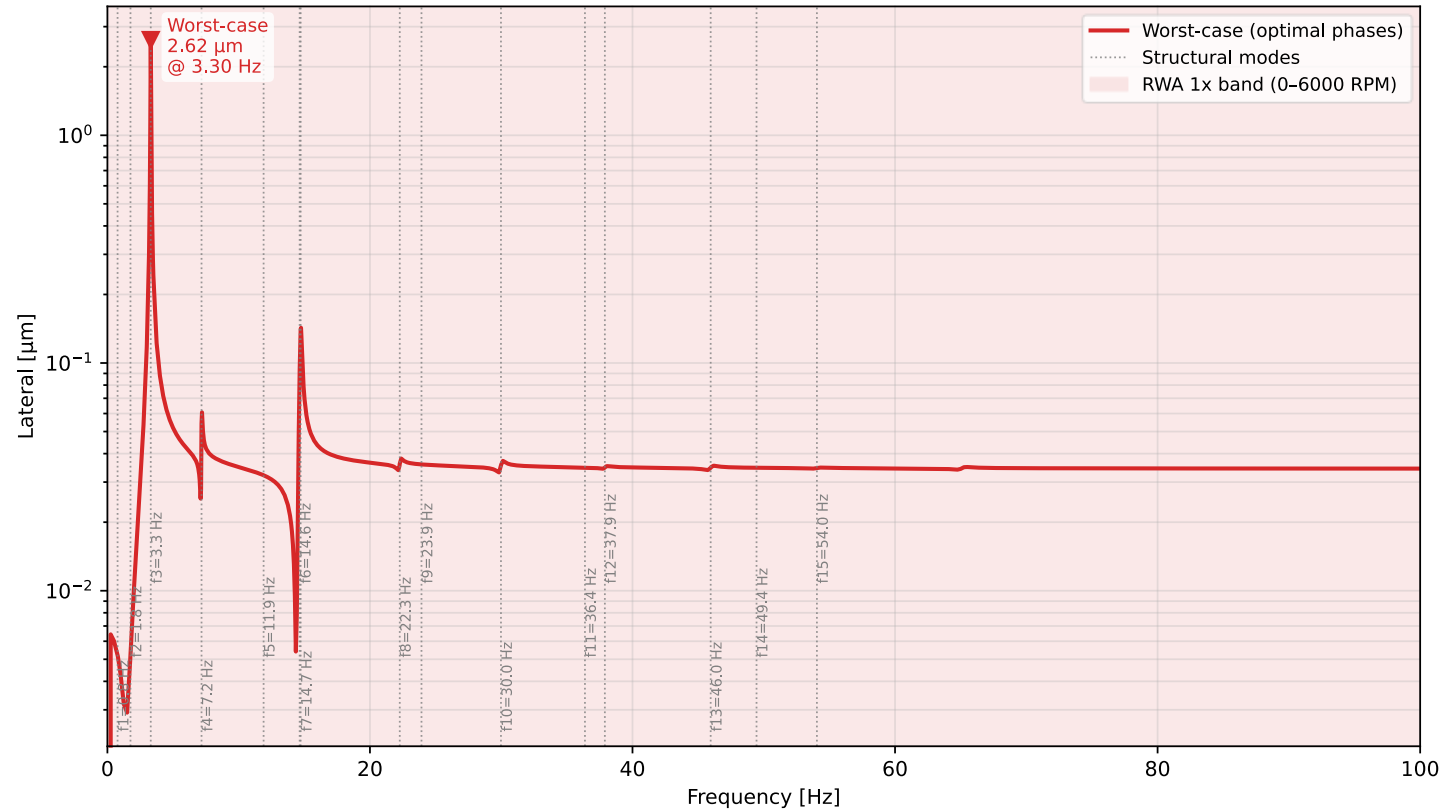
- *HEROIX* utilizes a commercially available spacecraft bus and boom system with integrated avionics, RCS thrusters, fuel tank, attitude-control sensors, reaction wheels, and magnetorquer rods.
- The star camera and gyroscopes are mounted on the optical table, aligned with the tip/tilt/rotation system.



Boom Stability

- The MMA-to-hybrid-detector relative aspect must be known to within $35\text{ }\mu\text{m}$ relative shear (0.6 arcsec)
- NASTRAN model constructed using a candidate commercially available extendable boom and reaction wheels
 - Lateral misalignment displacement: $2.6\text{ }\mu\text{m}$
- Three laser boom-alignment trackers allow monitoring of lateral misalignment and relative angular misalignment.

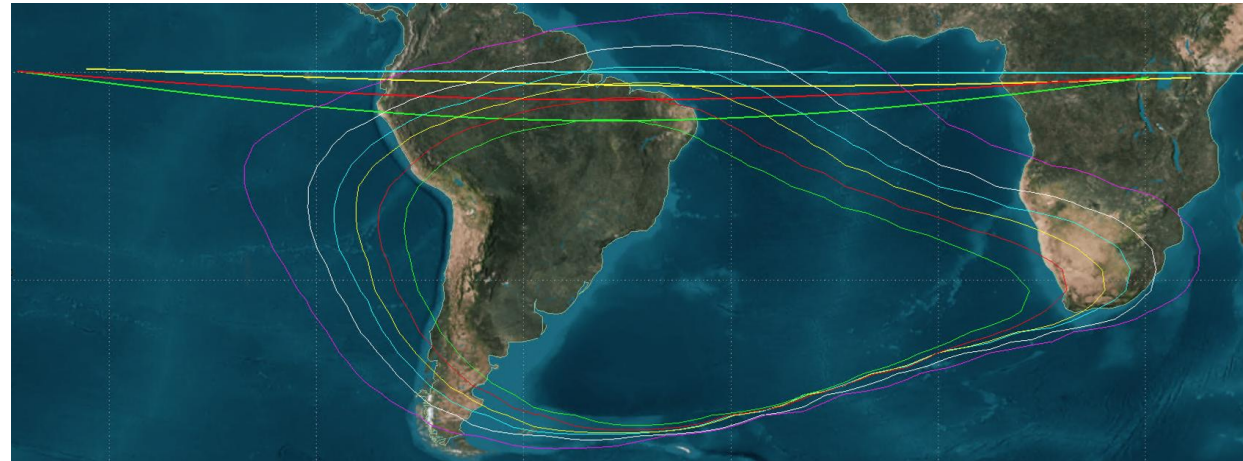
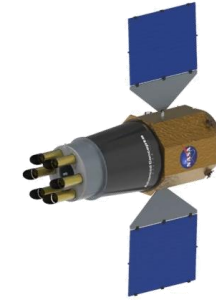
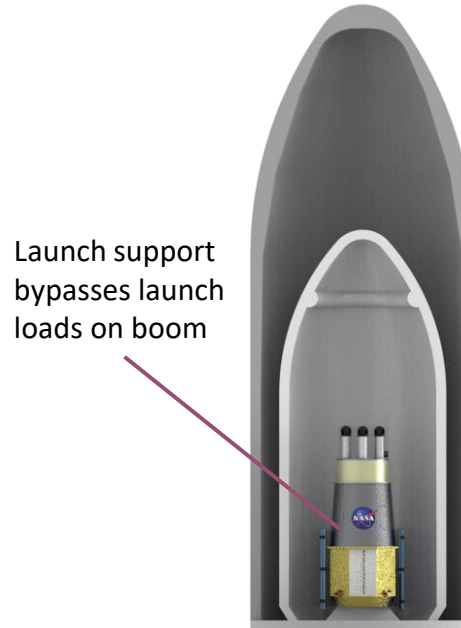
Boom Jitter FRF — Wheels [0, 1, 2, 3] Worst-Case Phase Optimization — Lateral



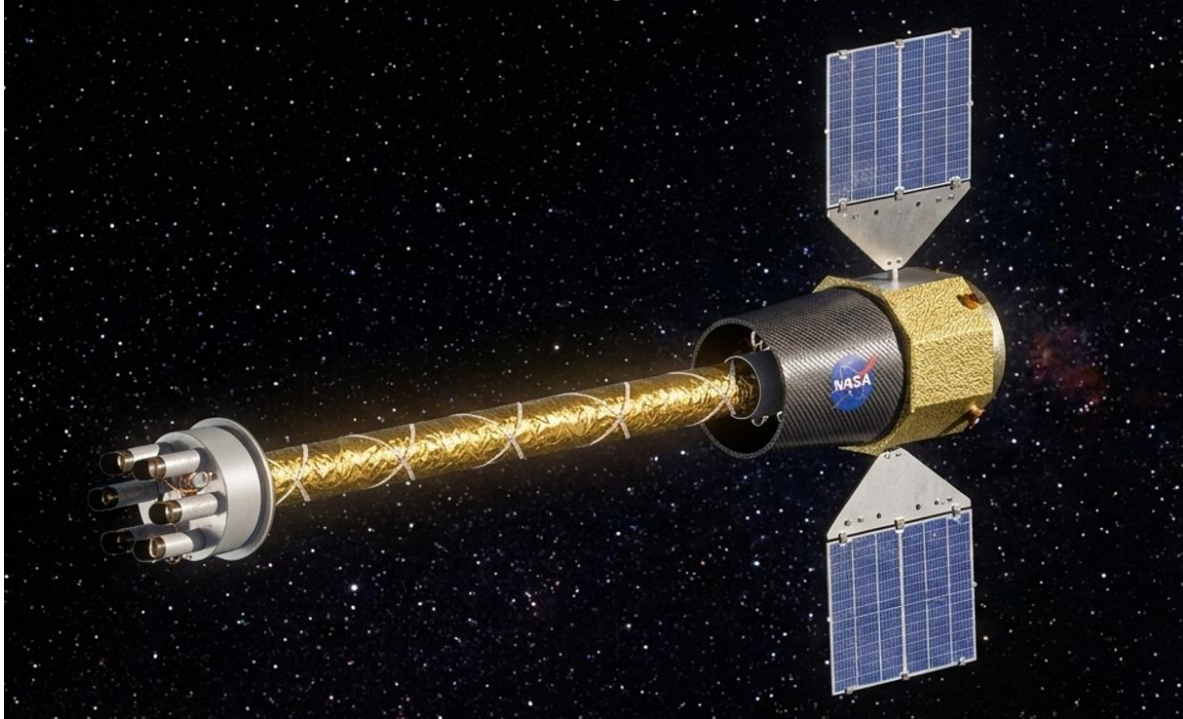
HEROIX Launch Configuration & Orbit



- *HEROIX* incorporates an extendable boom that allows launch in a stowed configuration, enabling compatibility with many launch fairings
- Low-inclination LEO orbit requirement
 - NA launch site
 - 500 km, 1.5 deg inclination
 - Requirements met by NASA's Launch Services Program fleet
- ACS propulsion system added to maintain orbit beneath much of the SAA (428 kg)
- Orbit available

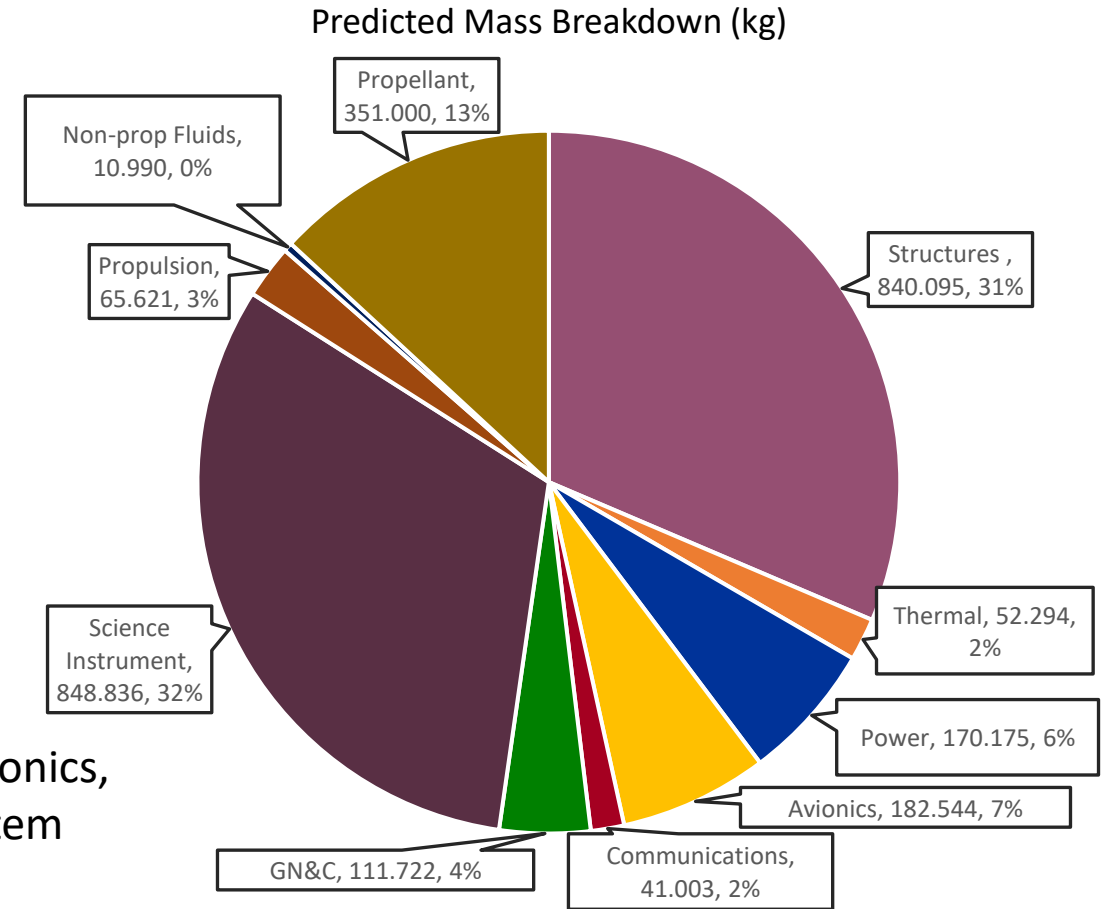


HEROIX Mass Breakdown



- The MSFC ACO study incorporated power, communications, avionics, GN&C, propulsion, the science payload, and the bus/boom system (structure) to generate a comprehensive equipment list
- *HEROIX* mass estimate: 2968 kg*

Well matched for an Astro MDEX



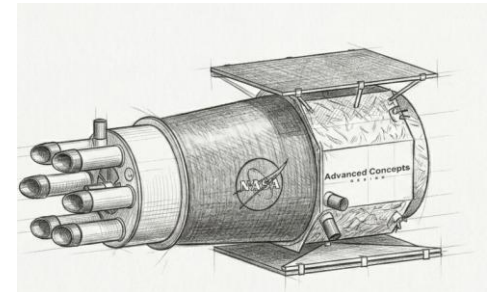
- Mass Growth Allowances based on AIAA Standard Mass Growth Allowance Table (ANSI/AIAA S-120A-2015)
- Detailed Mass Estimate List (MEL) and AIAA Mass Growth Allowance table provided in a separate file.



Summary



- Broadband X-ray observations reveal key physics behind galaxy evolution, the origin of high-energy cosmic rays, and the behavior of matter in extreme accretion environments.
- X-ray NiCo replicated-shell optics and next-generation broadband X-ray detectors are maturing rapidly and make a MIDEX-class NASA mission feasible in the 2030s.
- The *HEROIX* broadband X-ray telescope mission concept is designed to leverage these advances, enabling groundbreaking observations for the astrophysics community in the coming decade.

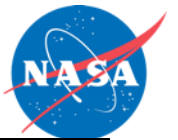


*Please contact me or
Science PI Chien-Ting Chen
to discuss HEROIX!*





Comms & Power



Communication

- Direct-to-Earth via Near Space Network; Singapore (SI-1) is only available station adding operational risk
- NASA transitioning from TDRSS to commercial satcom
- Commercial satellite-to-satellite relay expected to be available in the 2030s

Power System

- Unregulated articulated solar-array / battery system supplying payload and bus for 10-year mission
- Total power requirement: 1236 W
- Predicted mass: 170.2 kg

