



The SuperHERO High-Angular Resolution, Hard-X-Ray Telescope

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The SuperHERO Project Team





SuperHERO

Super – High Energy Replicated Optics



A Balloon-Borne High Resolution Hard X-Ray Telescope

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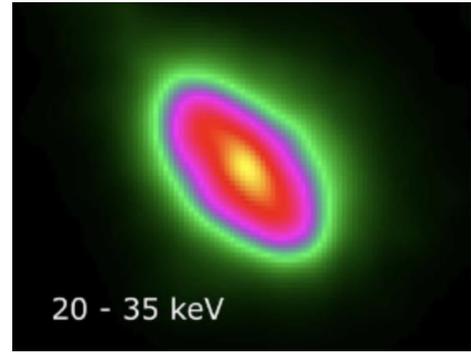


The Hard-X-Ray Universe in High-Resolution

Observations in the hard-x-ray (> 10 keV) provide a unique opportunity to study non-thermal emission in extreme astrophysical environments.

- Open science questions addressed by a high-angular-resolution, hard-x-ray observatory include.
 - What are the physics of supernova?
 - X-ray binary population in Sgr* Complex
 - How do supermassive blackholes grow? How does this influence galaxy evolution?
- Strategy
 - The *SuperHERO* X-ray telescope balloon mission. Inaugural flight in the fall of 2028 from North America.
 - Propose future *SuperHERO* missions for long duration balloon flights with increased technical capabilities.
 - Continued work on the ISFM package and other MSFC's suborbital missions will further progress high angular resolution, replicated NiCo technology.
- MSFC's x-ray optics will provide over an order of magnitude improvement to the state-of-the-art, enabling future space-based mission with increased effective area and high-angular resolution.
 - **High EnERgy Observatory for Imaging X-rays (HEROIX) Mission Concept**

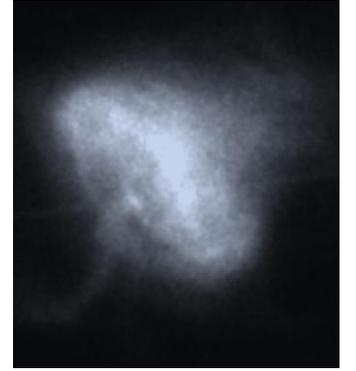
60 arcsec
State-of-art



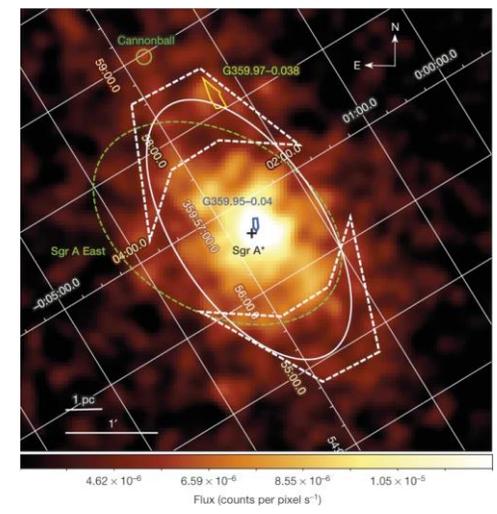
Harrison et al. 2013, Madsen et al. 2015

The Crab Nebula

10 arcsec
Future-mission

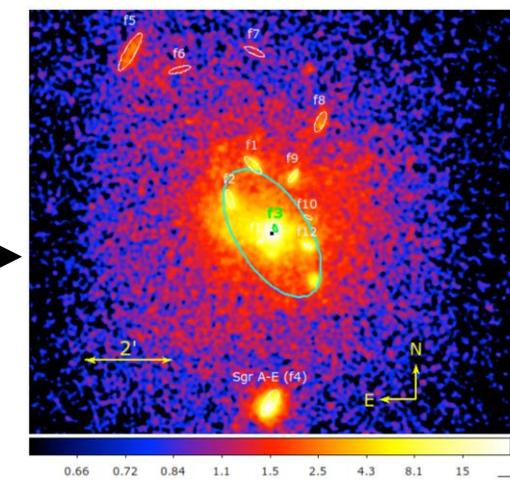


Projected by Chien-Ting Chen Chandra Data Mori et al. 2002, Weisskopf et al. 2012



Perez et al. 2015

Sgr* Complex

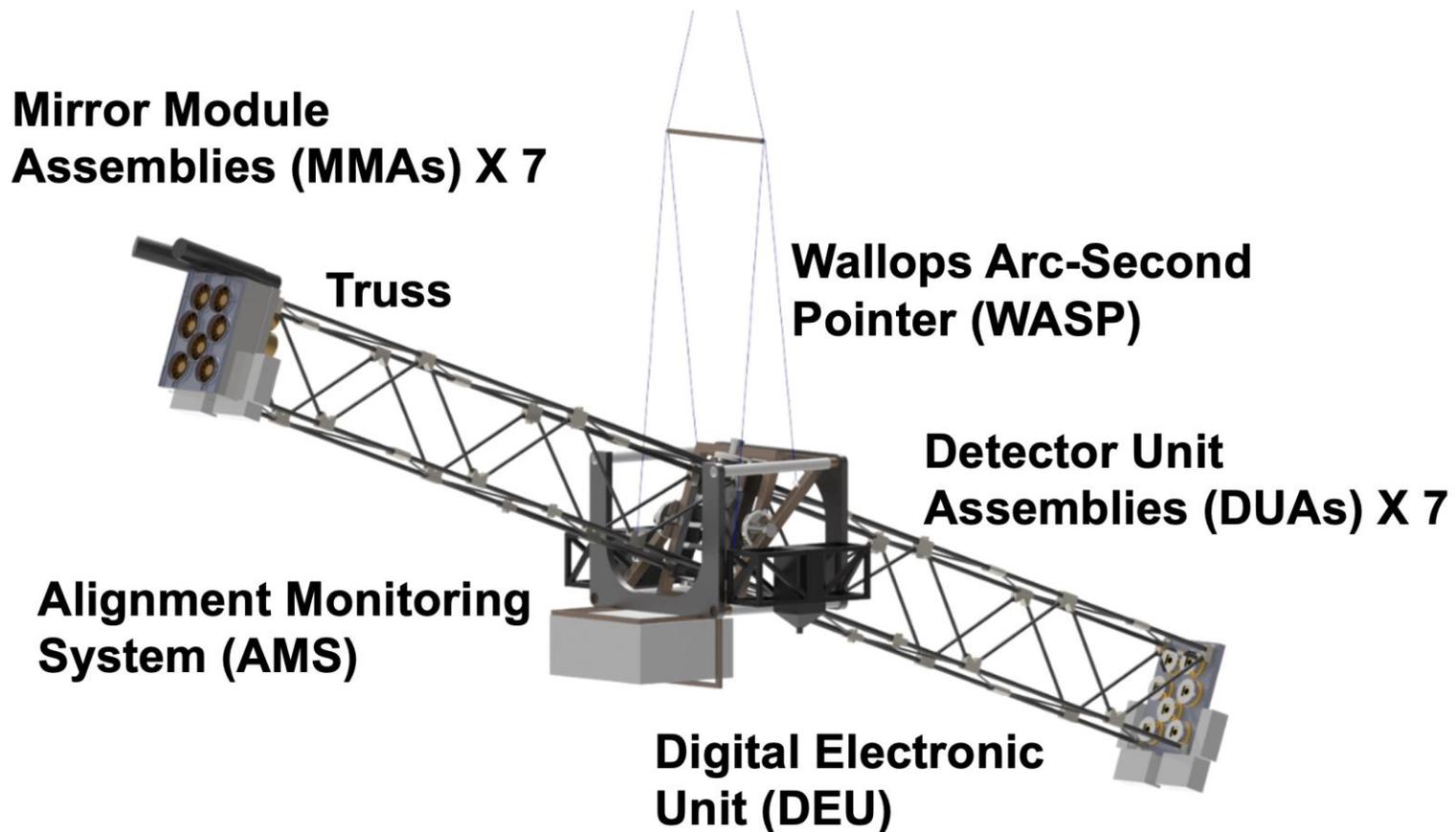


Mori et al. 2023



The *SuperHERO* Hard -X-ray Balloon- Borne Telescope

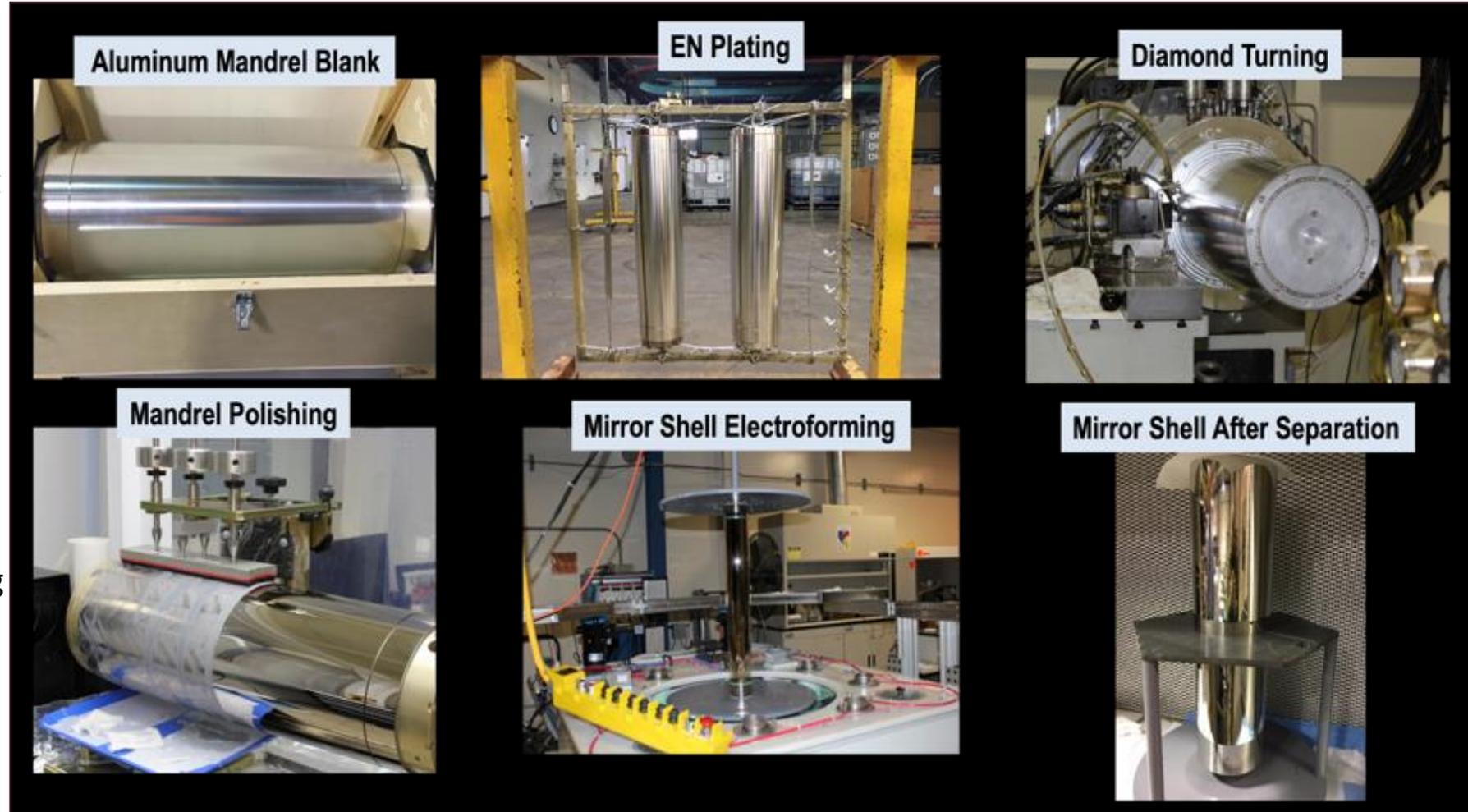
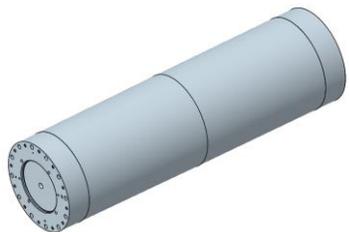
- Successor to the successful *HERO/HEROES* missions
- Incorporates cutting-edge MSFC's NiCo shell x-ray optics
- Takes advantage of proven technologies from collaborating institutions (WashU, UNH, WFF, Kavli IPMU, & iMAGINE-X)
- Mission's technical goal: 10 arcsec Half Power Diameter (HPD) in the hard-x-ray band



Electroformed Nickel-Cobalt Replicated Optics Full Shell X-ray Optics

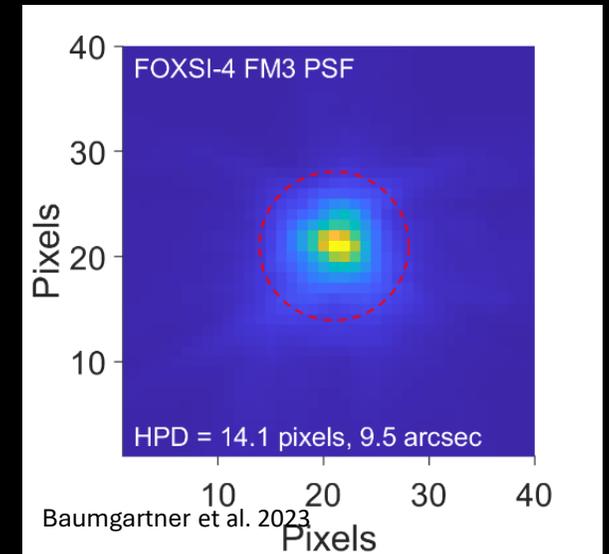
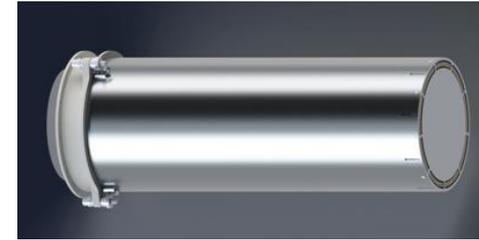
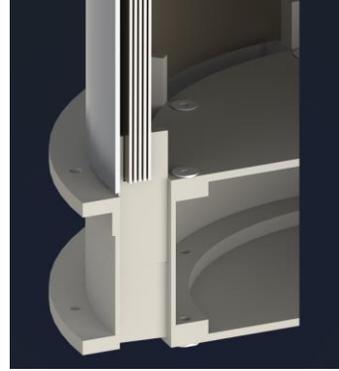


- Mandrel design complete
- IXPE size mandrels requiring the use of the Moore M-40 Diamond Turning Machine
 - 600 mm long (300 mm P / 300 mm H)
 - Diameters: 200 and 203.2 mm
- Axial figure error greatly reduced with reduced deterministic polishing using the Zeeko IRP600X



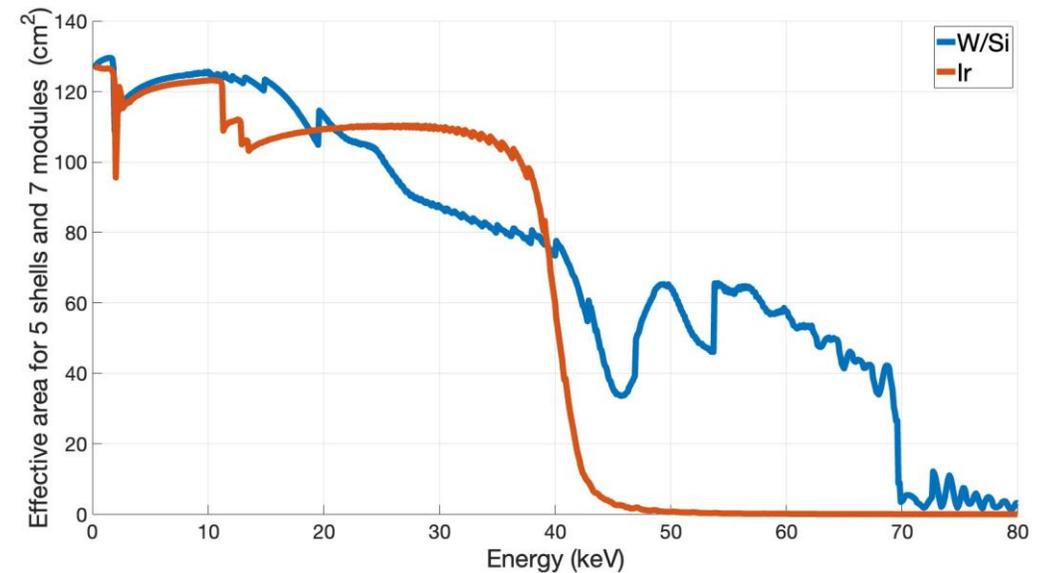
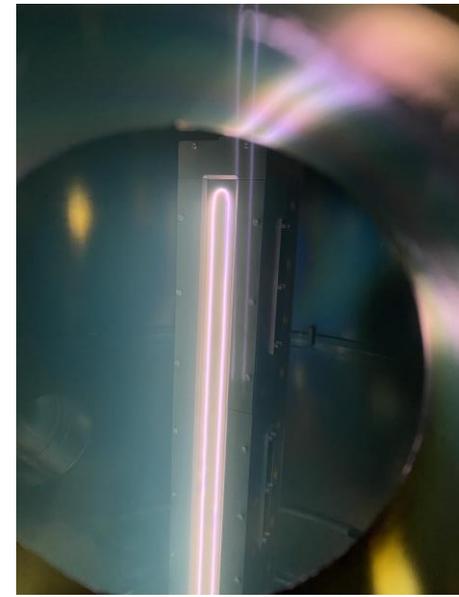
SuperHERO Mirror Module Assembly(MMA)

- Seven MMAs, requiring seven replications off of the two super polished mandrels.
- MMAs to be enhanced for future missions. Designed to accommodate a total of 5 shells each (100 kg to 200 kg)
- Calibration at Marshall 100-meter X-ray Beamline.



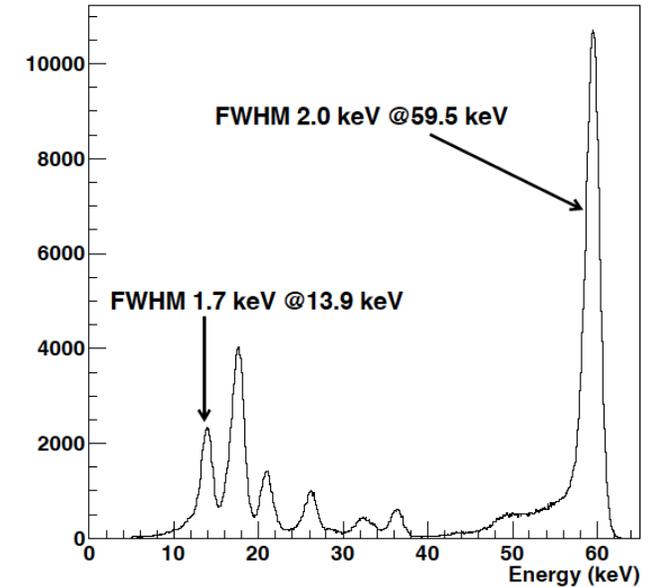
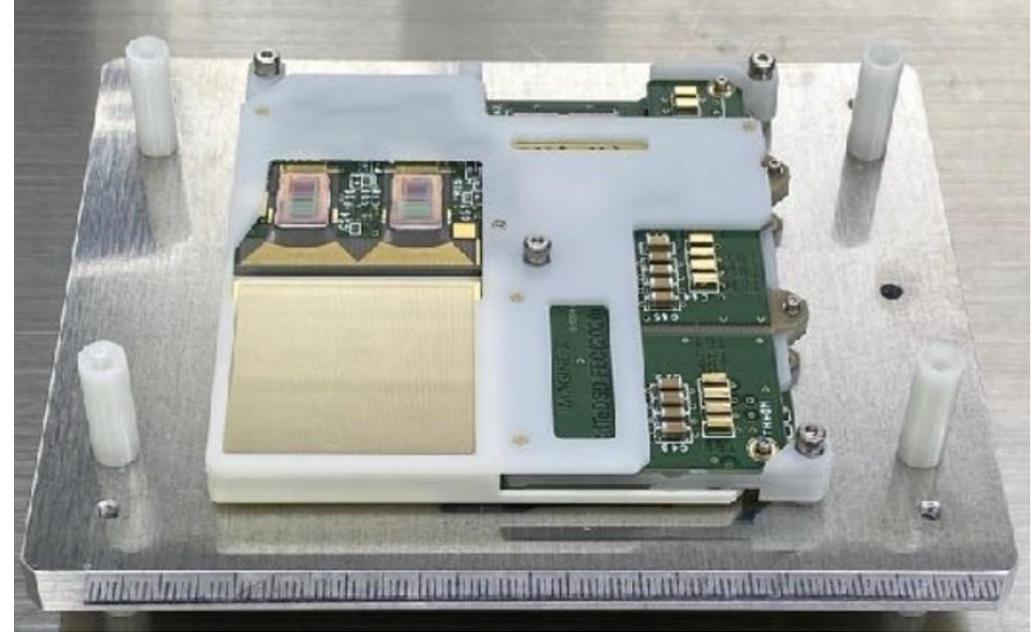
Effective-Area

- To achieve science goals for the 2028 North American flight, the mirrors will be coated with Iridium via RF sputtering.
 - Effective Area of 45 cm² at 30 keV.
- The *SuperHERO* project is designed to improve payload capability over time through technology maturation.
- MSFC X-ray group internally awarded funds to develop a large multilayer (ML) deposition chamber to directly coat full shell optics. (Gurgew, 13626-12)
- Dual Direct-Cooled Linear DC Magnetron (Angstrom Sciences, Inc) integrated with chamber, first plasma July 2025.
- *IXPE* shell (length = 600 mm, dia = 270 mm) will be coated with depth-graded, W/Si multilayer and tested in the hard-x-ray early 2025.

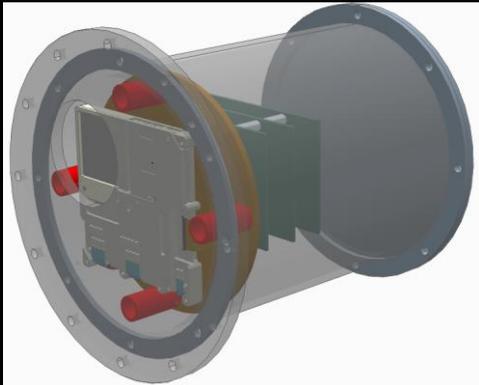


Hard-X-ray Detectors

- Cadmium-Telluride Double-sided Strip Detectors (CdTe-DSD).
- Flown on JAXA/NASA mission *Hitomi* (Takahashi 2012, Kokubun 2012, Nakazawa 2016).
- Available commercially through iMAGINE-X Inc (Takeda 2016).
- Collaborators from Kavli-IPMU and JAXA will provide support.
- Optics and detector plate scale well matched
 - Effective pixel size and calibrated to $\sim 200 \mu\text{m}$ (Hagino et al. 2018)



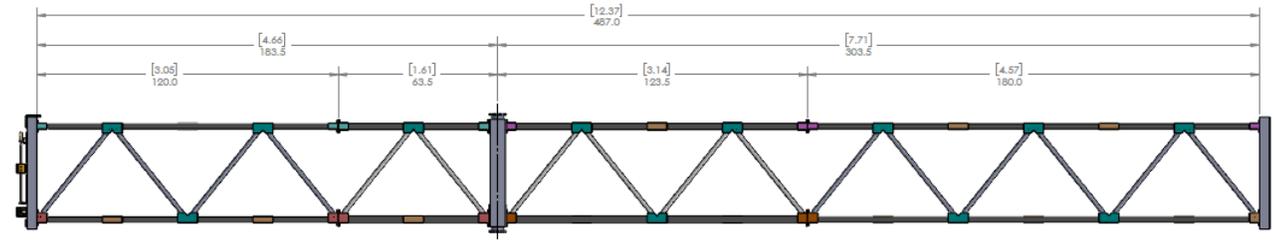
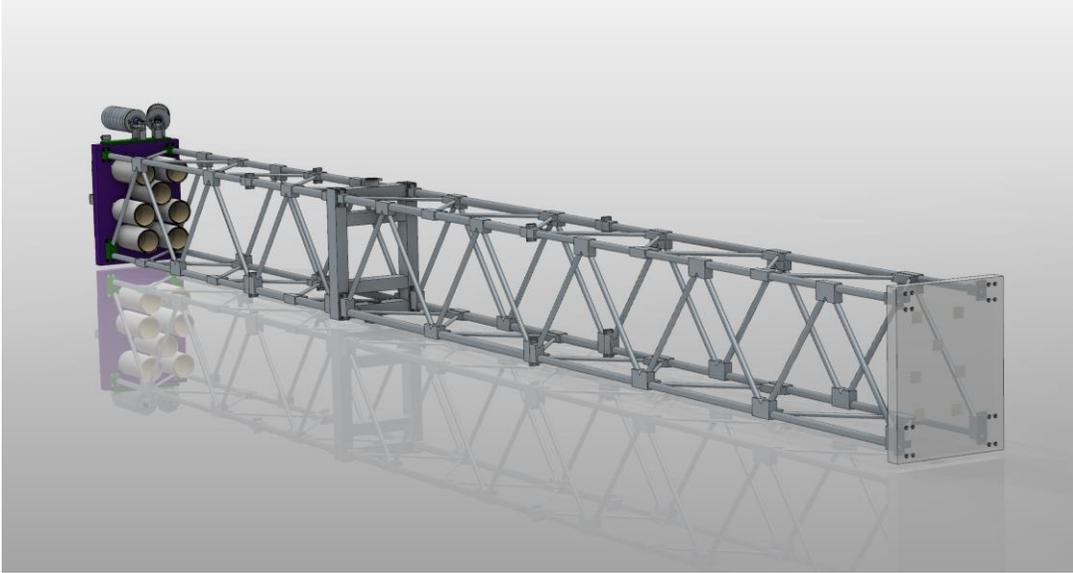
Detector Unit Assembly



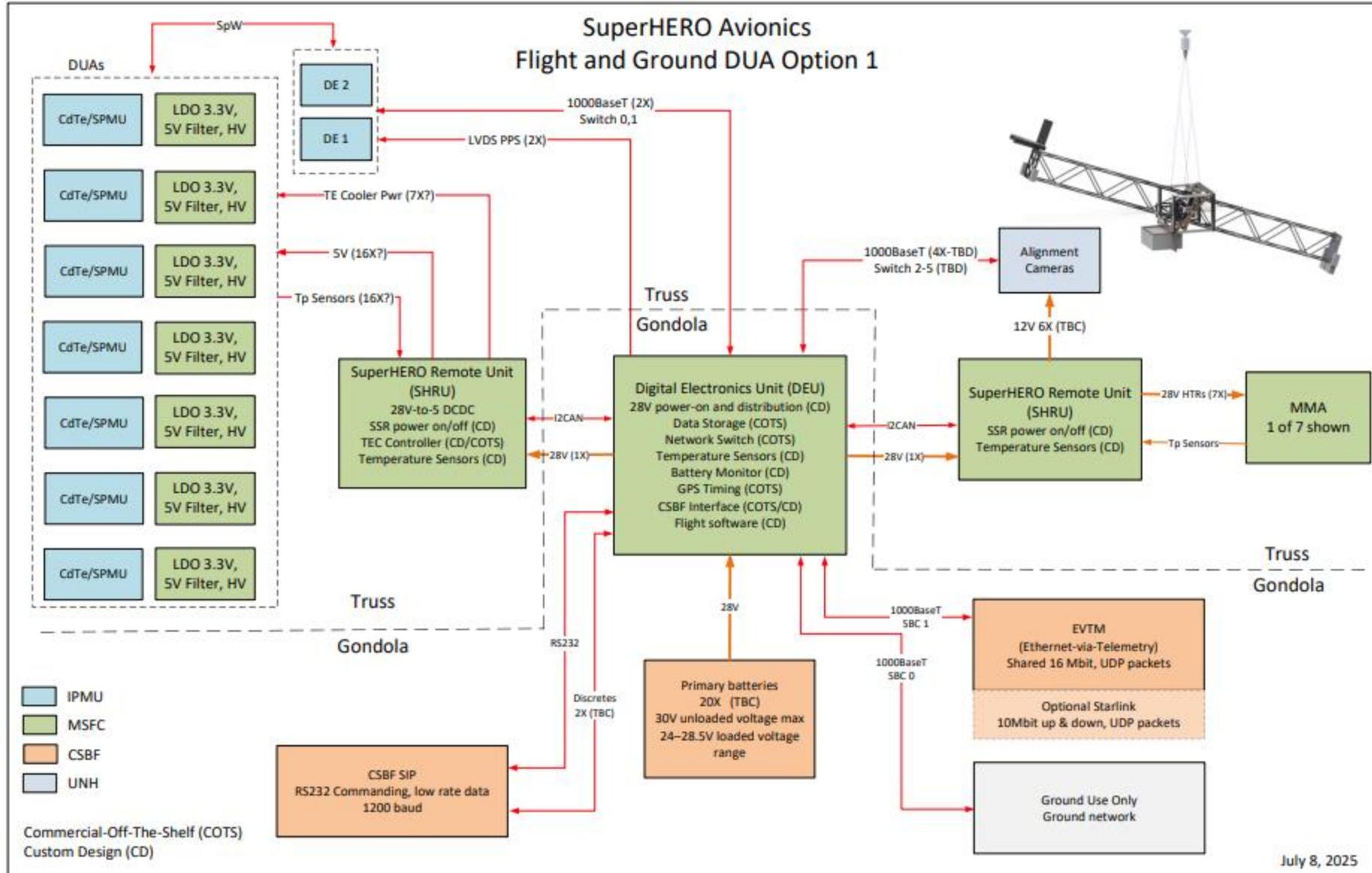
- iMAGINE-X Inc. CdTe-DSDs:
 - Eight detectors purchased and delivered. Additional spare currently being purchased
 - 1 mm thick, $34 \times 34 \text{ mm}^2$ block of CdTe
 - 128 platinum cathode and aluminum anode strips applied to the top and bottom of the CdTe block.
 - 250 μm strip pitch.
 - CdTe-DSD operational temperature and bias voltage is -20° ($\pm 5^\circ$) C and 250 V.
- Currently undergoing 'Aliveness Testing' at MSFC
(Look for A. Appleman's talk at HEAD meeting in October)
- MSFC designing the Detector Unit Assembly (DUA) to house and provide thermal control.
- DUA will be a sealed enclosure kept at 1 atmosphere N₂ to prevent ice build up on detector.



Truss, Alignment Monitoring, and WASP Gondola



- *SuperHERO's* open-truss carbon-composite truss design is based on *XL-Calibur*.
 - ❖ Stress analysis and fabrication being conducted by WashU
 - ❖ Asymmetrical design has been selected to accommodate increase weight of optics for future missions
- Alignment monitoring system measures elevation dependent bend with 0.1 mm precision.
 - ❖ Design and implementation by UNH
- The WFF's WASP gondola will provide arcsecond level attitude control system.
 - ❖ WASP kick off meeting September 2024

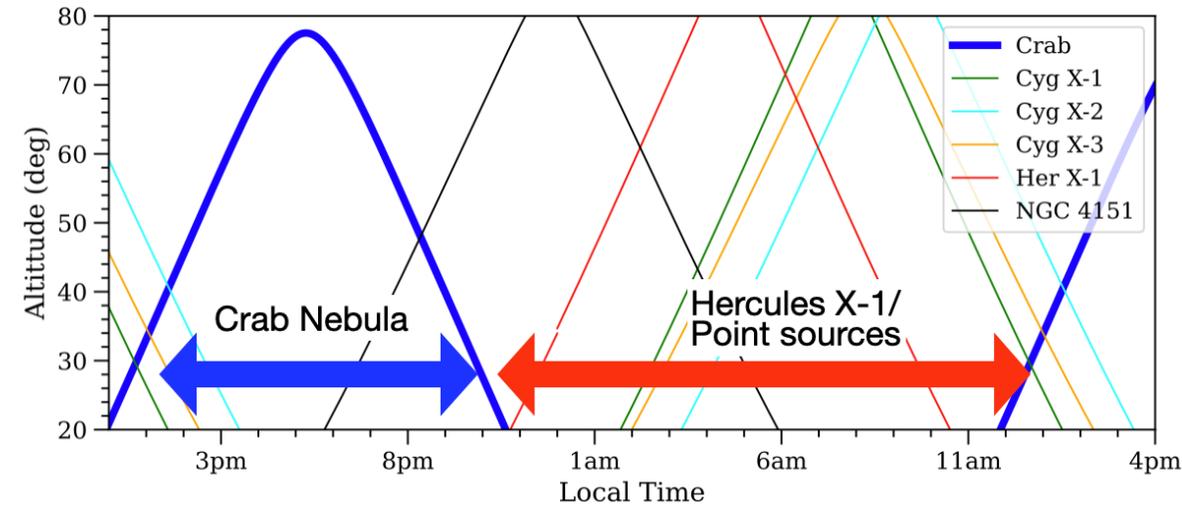


SuperHERO 2028 flight Fort Sumner, NM



- *SuperHERO* will target the Crab Nebula whenever available.
 - 8-hours observation: 70,000 counts
- Hercules X-1 (intermediate-mass x-ray binary) and other point sources will be targeted as calibration sources and to demonstrate *SuperHERO's* angular resolution.
- Alternate observation schedule available to accommodate WASP gondola pointing constraints.

SuperHERO observation schedule



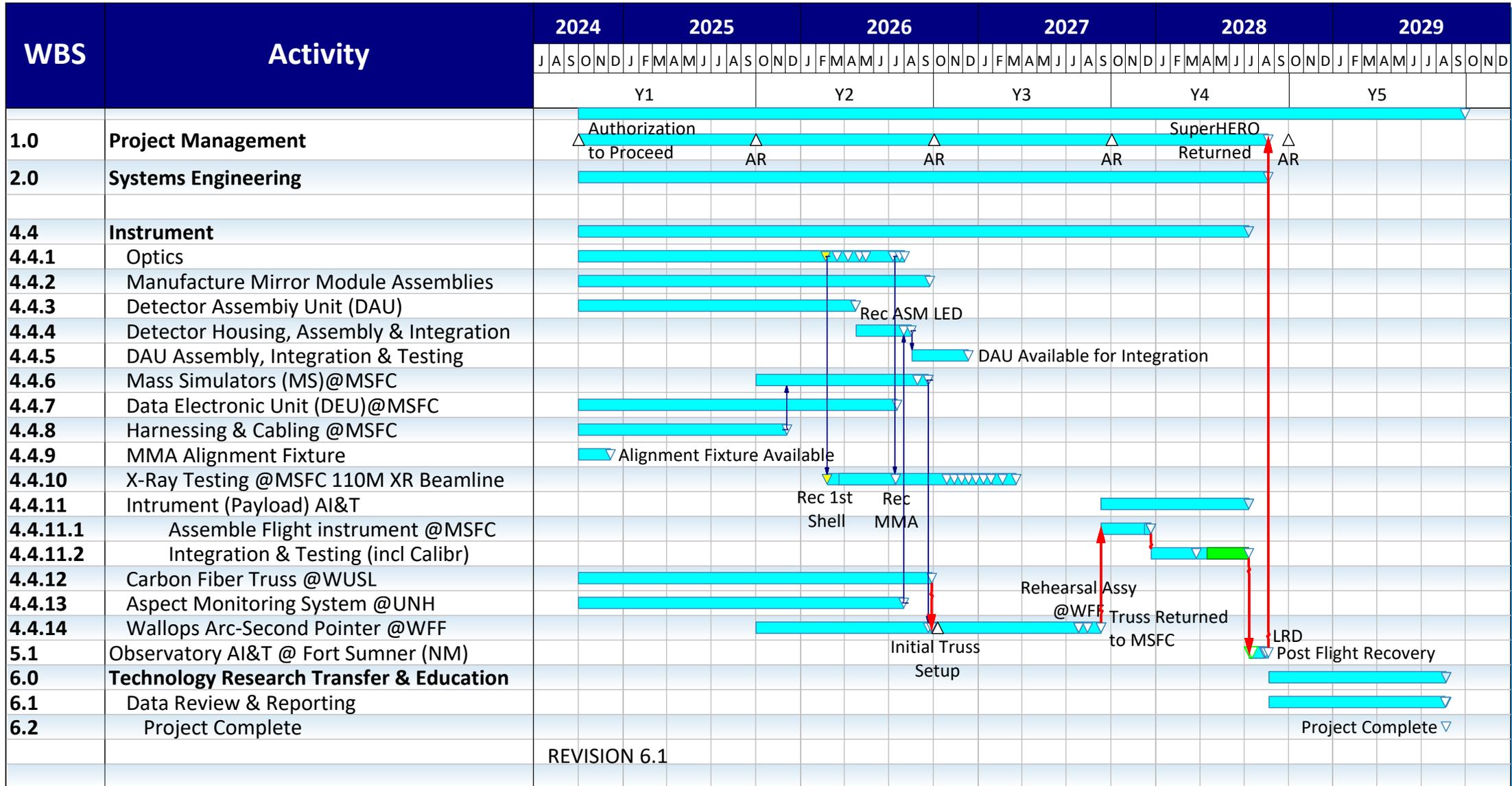
HEROES' GPS track (2013)



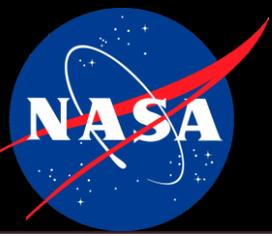
SuperHERO Summary Schedule



1/19/2024



Summary



- ***SuperHERO*** is a hard-x-ray telescope that will demonstrate better than **10 arcsec HPD** imaging on a balloon platform.
- Successor to the *HERO/HEROES* missions that incorporates over 30 years of technology development in MSFC's replicated NiCo shell optics
- Collaborating institutions providing high-heritage technology
 - ❖ Carbon Fiber Truss (WUSL/XL-Calibur)
 - ❖ Alignment Monitoring System (AMS) (UNH/XL-Calibur)
 - ❖ Wallops Arc-Second Pointer (WASP) (NASA WFF)
- North American Flight (2-Day) set for Fall of 2028 and will localize non-thermal emission from structure within the Crab Nebula.
- **Development of *SuperHERO* will enable future long duration balloon flights and space-based missions with increased scientific impact such as the *HEROIX* mission concept**



Join the *HEROIX* science group!



Discussion

Sign up to be a part of the HEROIX team!

<https://forms.gle/62LdpEnwSEZGQBYZ8>



Please contact me or
Science PI Chien-Ting
Chen to discuss science
goals for future
missions!

