The Imaging X-ray Polarimetry Explorer (IXPE): technical overview II

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on behalf of the IXPE Technical Team

Outline

- **Introduction**
- Payload
- Spacecraft
- Calibration
- Operations
- Conclusion

Mission Partners

Marshall Space Flight Center

PI team, project management, SE and S&MA oversight, mirror module fabrication, X-ray calibration, science operations, and data analysis and archiving

Detector system funding, ground station

Spacecraft, payload structure, payload, observatory I&T

Polarization-sensitive imaging detector systems

Mission operations

Scientific theory

Co-Investigator

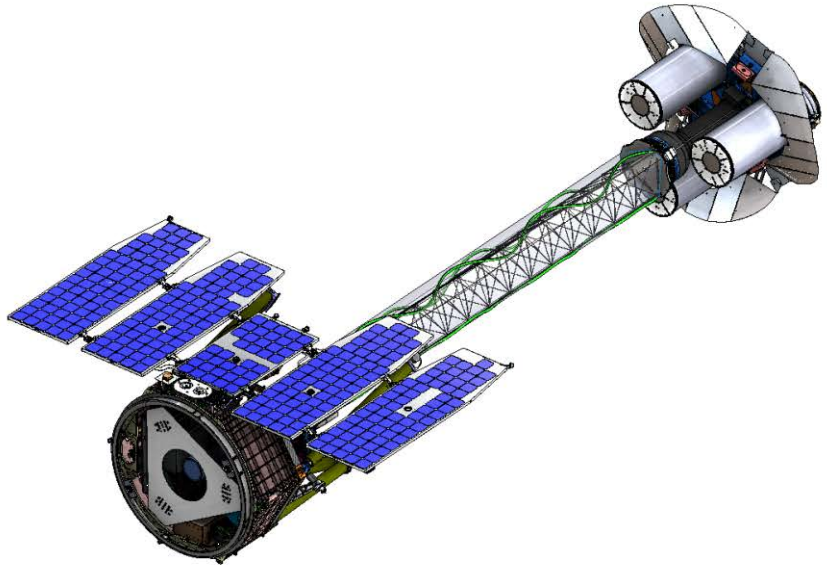
Co-Investigator

Science Advisory Team

Mission Description and Technical Capabilities

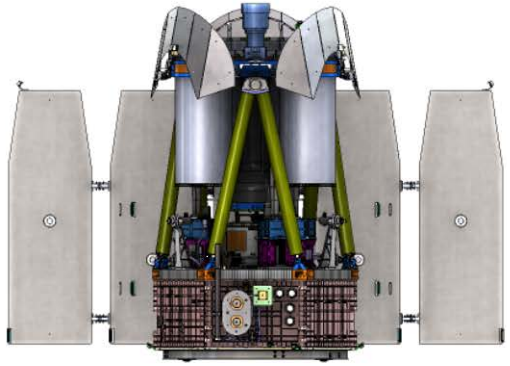
Mission name	Imaging X-ray Polarimetry Explorer (IXPE)
Mission category	NASA Astrophysics Small Explorer (SMEX), with Explorers Program Office (GSFC)
Launch	2021 on Space-X Falcon 9, from Cape Canaveral Air Force Station
Operational phase	2 years following 1 month commissioning; extension of operations possible with General Observer program
Orbital parameters	Circular at 540–620 km altitude, near equatorial (< 3° inclination)
Ground stations	Malindi, Kenya (3°S, ASI contribution) primary; Singapore, Malaysia (1°N, KSAT commercial on NASA NEN) secondary
Spacecraft features	3-axis stabilized pointing (non-propellant) with forward and aft star trackers; dithering selectable
Science payload	3 x-ray telescopes, 4.0-m focal length (deployed), co-aligned to forward star tracker
Telescope optics (3+1)	24 monolithic (primary and secondary) Wolter-1 electroformed shells, coaxially nested in each mirror module assembly (MMA)
Telescope detector (3+1)	Polarization-sensitive gas pixel detector (GPD) to image photo-electron track, in each detector unit (DU)
Polarization sensitivity	Minimum Detectible Polarization (99% confidence) MDP_{99} < 5.5%, for 0.5-mCrab in 10 days
Spurious modulation	< 0.3% systematic error in modulation amplitude for an unpolarized source
Angular resolution	< 30-arcsec system-level half-power diameter (HPD)
Field of view (FOV)	10-arcmin diameter overlapping fields of view for 3 detectors' polarization-sensitive areas
Energy band; resolution	2–8 keV; $(\Delta E/E) \approx 20\%$ @ 5.9 keV
Timing accuracy	20 μs, using GPS pulse-per-second signal and on-board clocks
X-ray calibration	Each MMA and DU separately, at least one MMA-DU together on-ground; DUs on-orbit with radioactive calibration sources

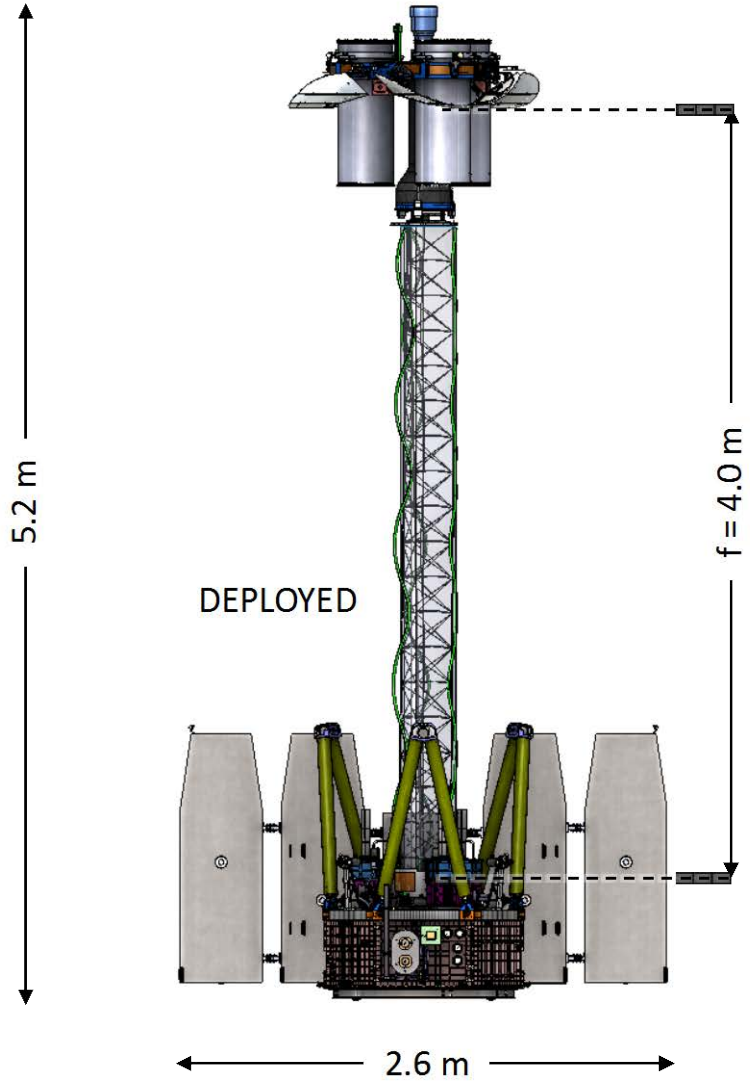
OBSERVATORY CONFIGURATIONS



STOWED

INITIALIZATION





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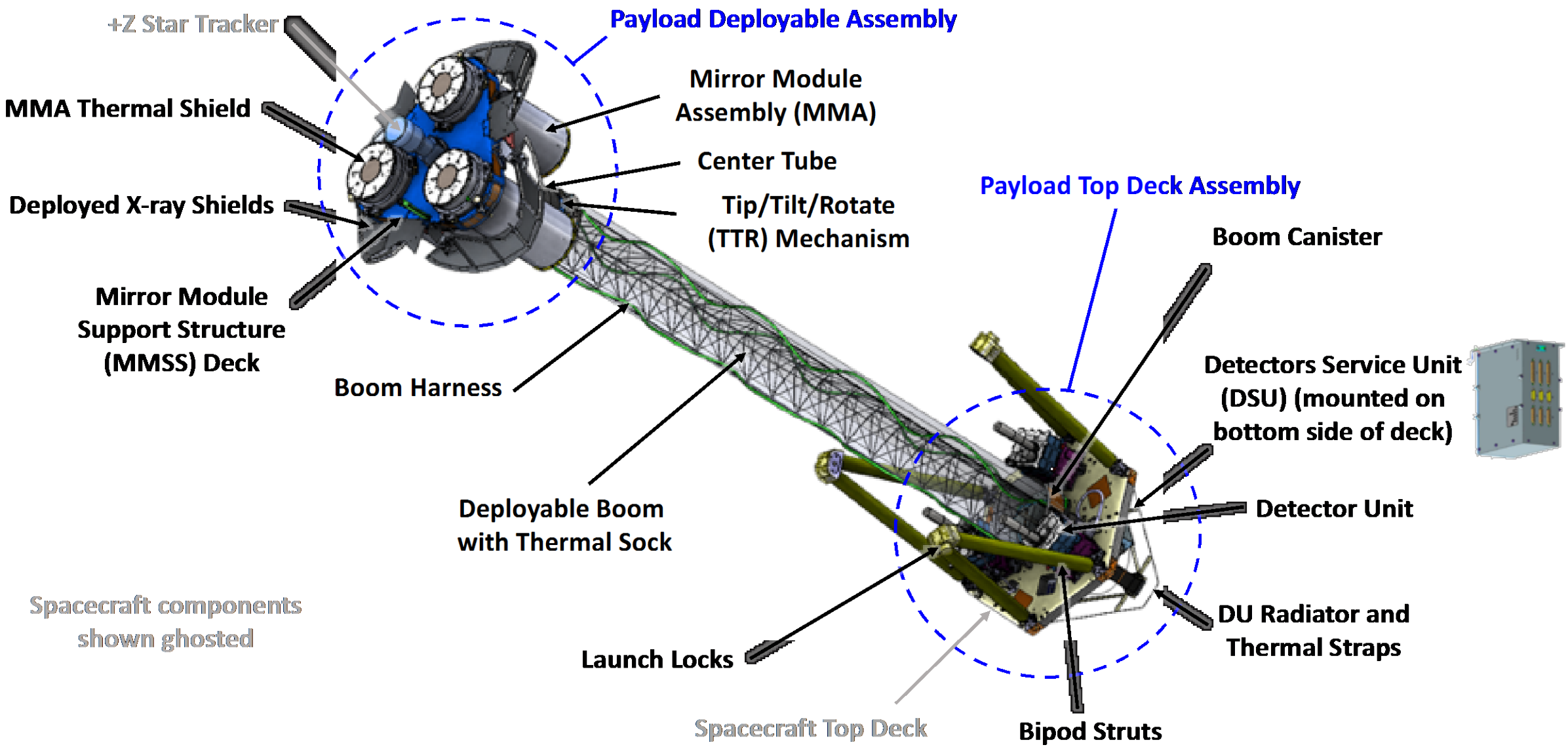
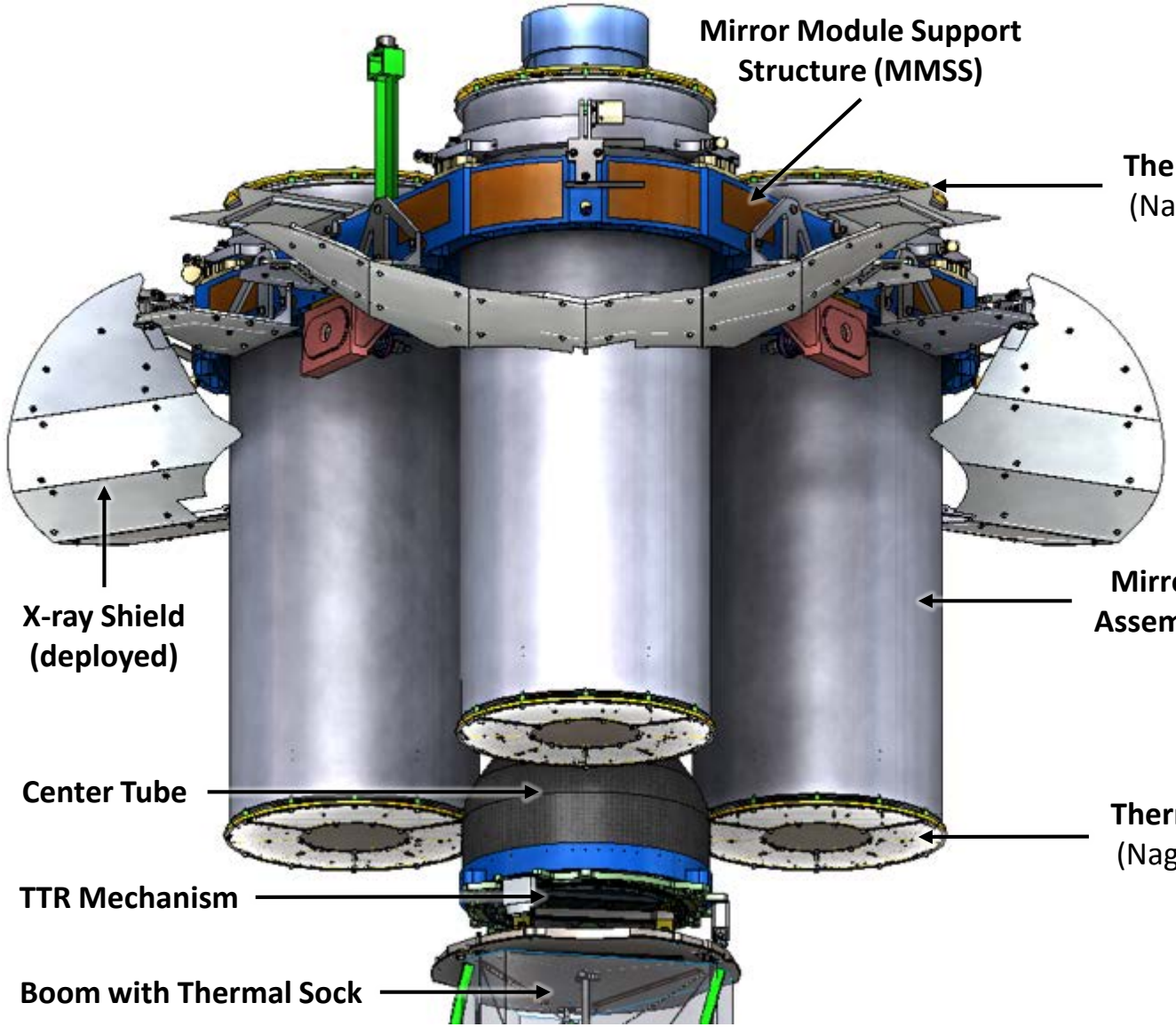
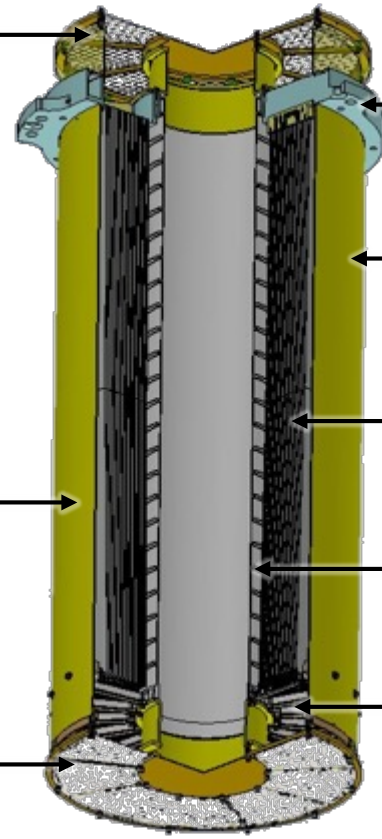
PAYLOAD COMPONENTS



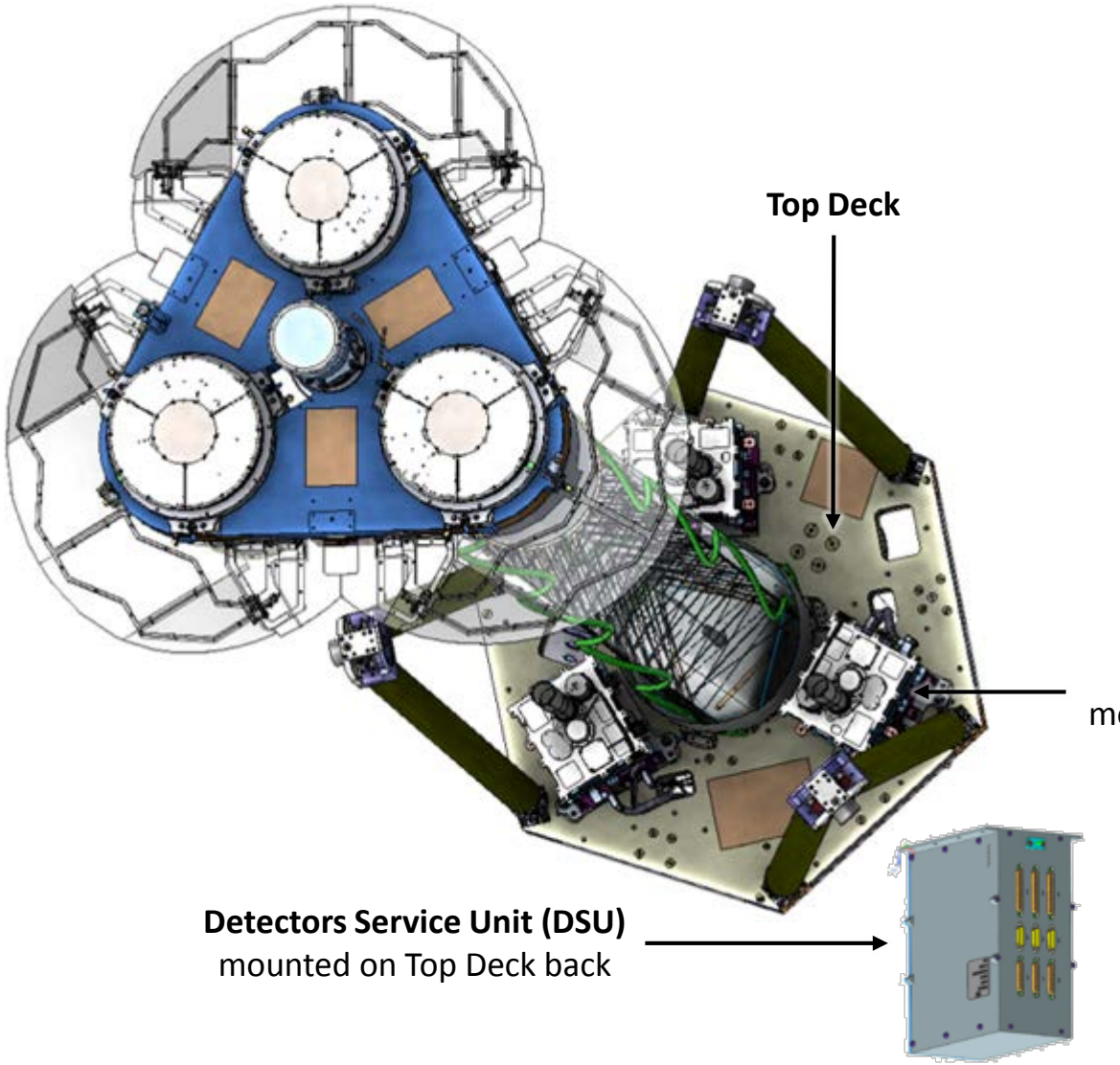
Mirror Module Assemblies (MMAs)

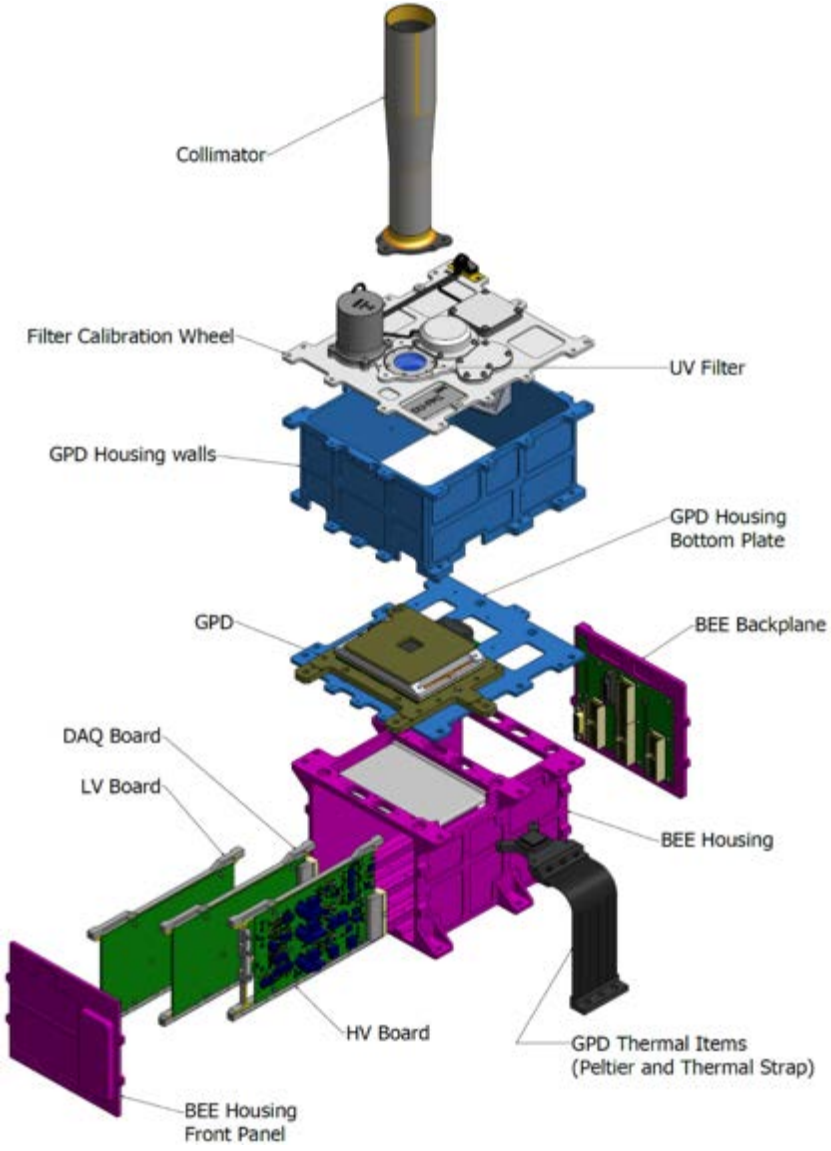




SPIE 11119-2: IXPE mirror module assemblies
Brian Ramsey (MSFC)

DETECTOR UNITS (DUS)

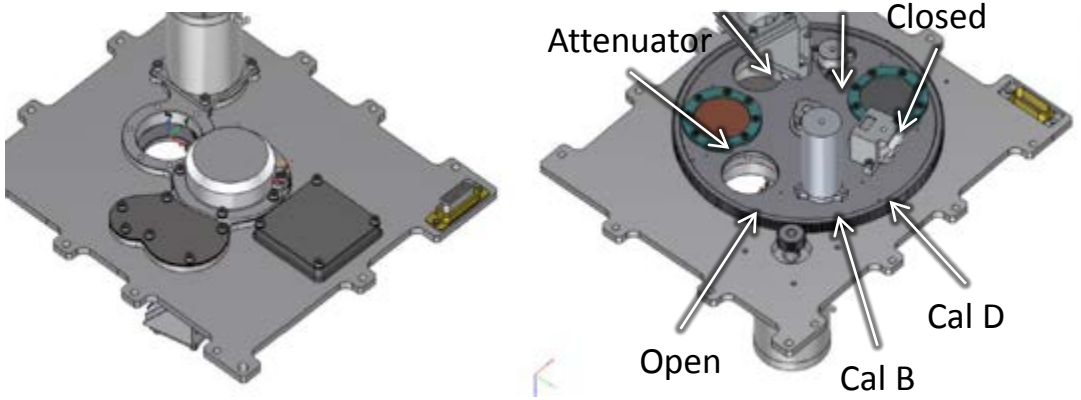




DU Component Details

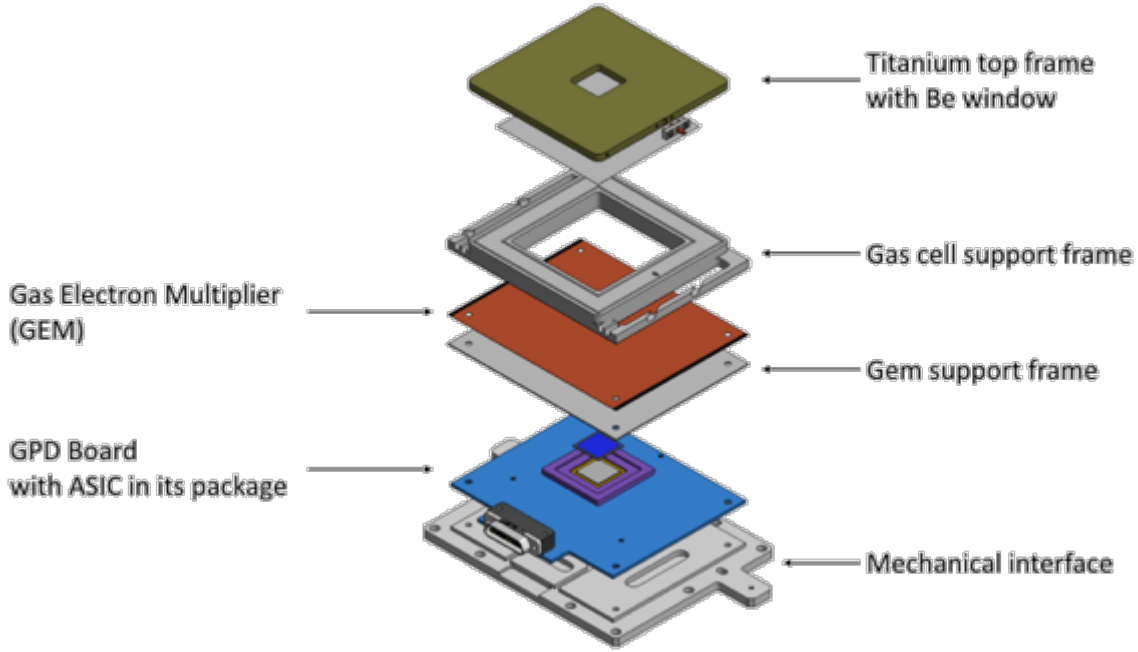
Filter & Calibration Wheel (FCW)

- Open, Attenuator, Closed positions
- Four ^{55}Fe-powered calibration sources
  - Cal A: Polarized 2.98 keV and 5.89 keV
  - Cal B: Unpolarized 5.89 keV (spot)
  - Cal C: Unpolarized 5.89 keV (flood)
  - Cal D: Unpolarized 1.74 keV (flood)



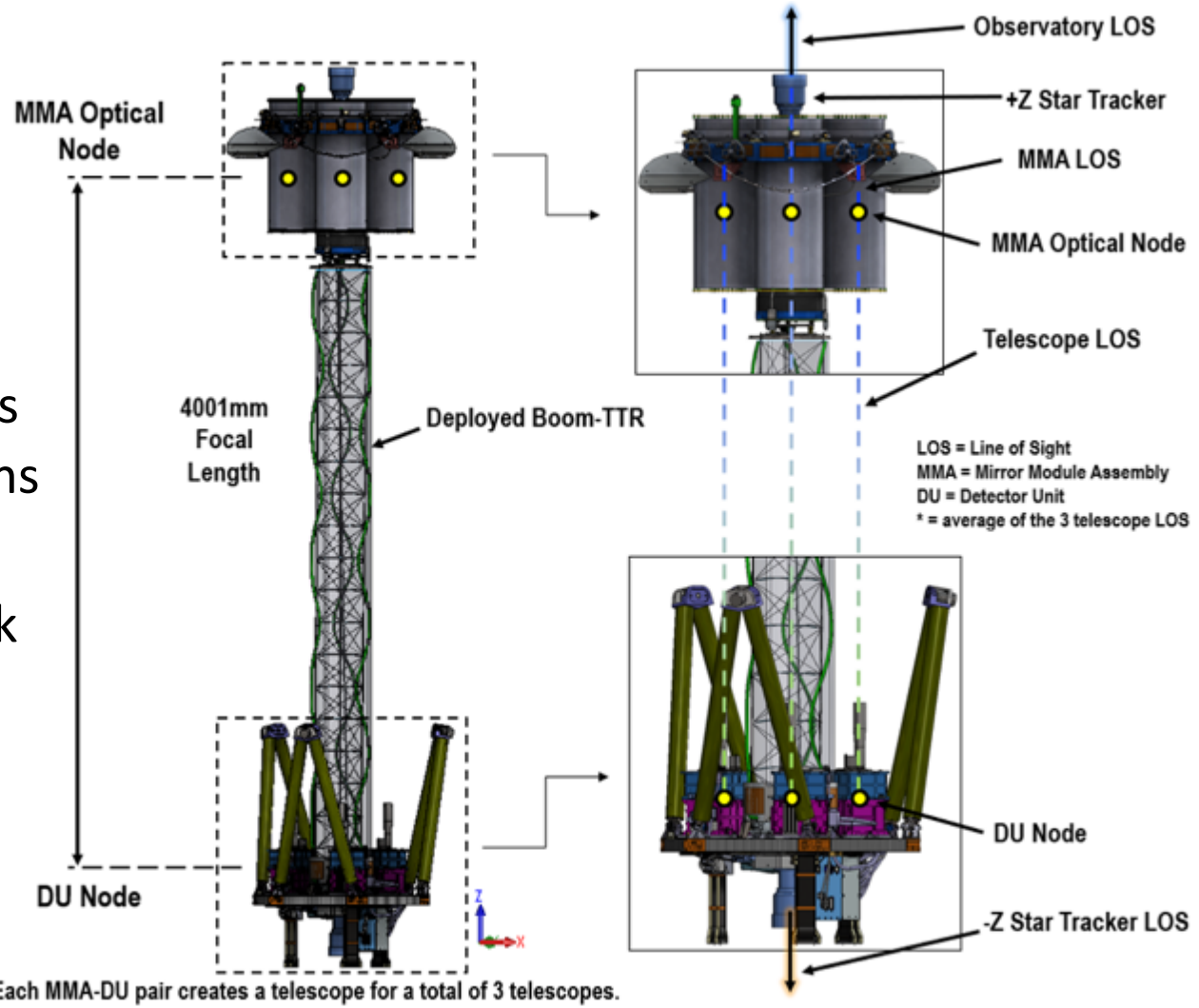
Gas Pixel Detector (GPD)

- DME in gas cell absorbs x-ray photon
  - Photoelectron correlates to polarization
- GEM amplifies ionization track
- ASIC provides pixelated readout



Telescope Alignment

- Star trackers (STs)
  - Orient +Z ST orthogonal to MMSS
  - Orient -Z ST orthogonal to -Z top deck
- Mirror Module Assemblies (MMAs)
  - Orient each MMA parallel to +Z ST
  - Align MMA nodes to nominal positions
  - Precisely measure MMA-node positions
- Detector Units (DUs)
  - Orient each DU orthogonal to top deck
  - Precisely position DUs
    - DU-node triangle must be congruent to MMA-node triangle
- Tip/Tilt/Rotate (TTR) mechanism
  - Translate/rotate DU triangle to align with MMA triangle along +Z ST LOS



- Each MMA-DU pair creates a telescope for a total of 3 telescopes.
- MMA 1 LOS is aligned to STA_+Z LOS, which is aligned to MMSS Datum A. MMA 2 LOS and MMA 3 LOS are aligned with STA_+Z LOS.
- Each DU is aligned to each MMA such that all 3 telescope LOS are parallel to one another and aligned with the STA_+Z LOS.
- There is only knowledge, not alignment, of STA_-Z to STA_+Z.

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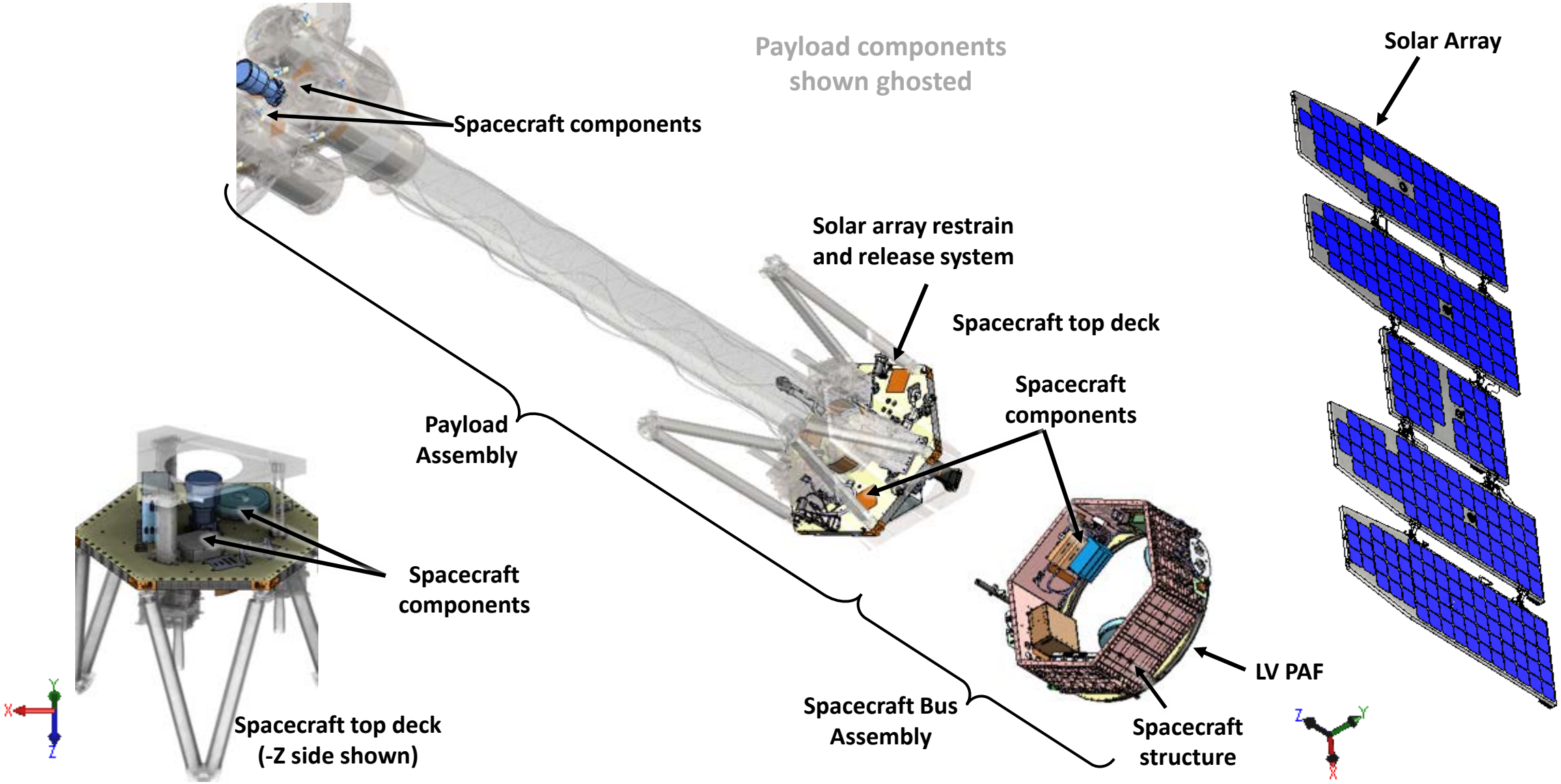
SPACECRAFT COMPONENTS



Spacecraft Subsystems

- Integrated Avionics Unit (IAU)
  - Administers most spacecraft functionality
- Mechanical; Structural; Thermal
- Power; Electrical & Harnessing
- Telecommunications
- Command & Data Handling (CDHS)
  - Functions
    - Computational services
    - Data handling and memory management
    - Telemetry management
    - Time messaging
    - Communication with the Instrument's Detectors Service Unit (DSU)
  - Functionality resides in the IAU
- Attitude Determination & Control (ADCS)
  - Functions
    - 3-axis stabilized pointing, dithering capable
    - Slewing and momentum management
    - Precise timing and position information
  - Components supporting ADCS functions
    - Star trackers (+Z & -Z), shared electronics
    - Coarse sun sensors (12, 4π coverage)
    - Reaction wheels (3, orthogonally oriented)
    - Torque rods (3, orthogonally oriented)
    - Magnetometer (3-axis unit)
    - GPS (1 receiver, 2 antennae)
  - Functionality administered by the IAU

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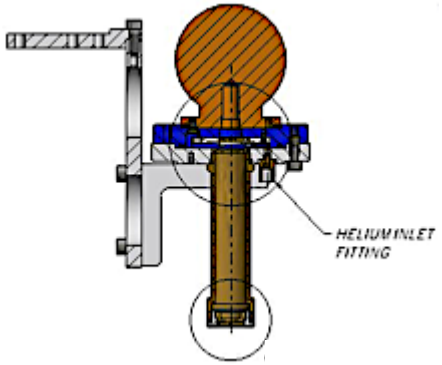
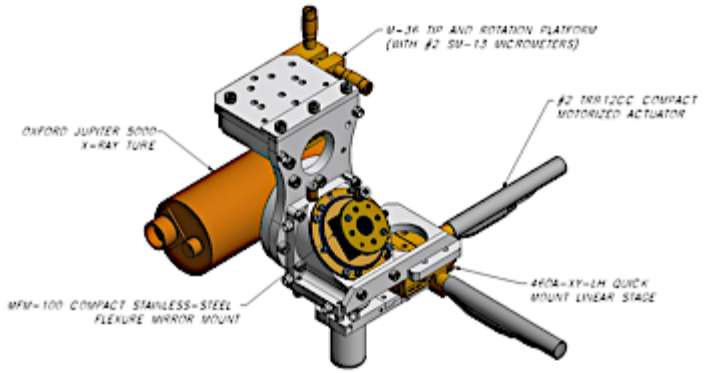
X-RAY CALIBRATION

INAF IAPS

- Instrument calibration equipment (ICE)
  - Unpolarized and polarized x-ray sources
  - Stages for positioning sources over DU
- Calibration requirement
  - All 4 DUs (3 flight + 1 spare)
- Filter & calibration wheel (FCW) sets
  - All 4 DUs, 4 sources (Cal A, B, C, D) per set



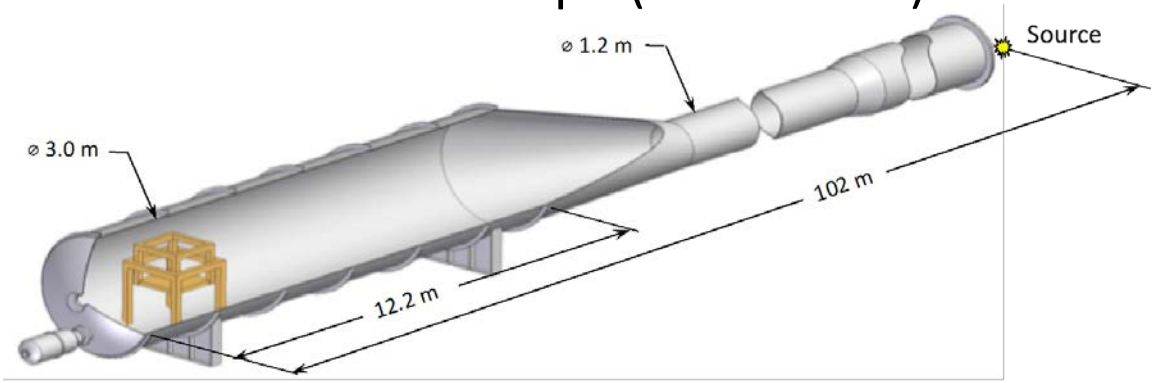
UNPOLARIZED SOURCE



POLARIZED SOURCE

NASA MSFC

- Facility and equipment
  - 100-m x-ray test facility
  - Unpolarized and polarized x-ray sources
  - Hexapod and stages
  - CCD and SDD x-ray detectors
- Calibration requirement
  - All 4 MMAs (3 flight + 1 spare)
  - At least 1 telescope (MMA + DU)



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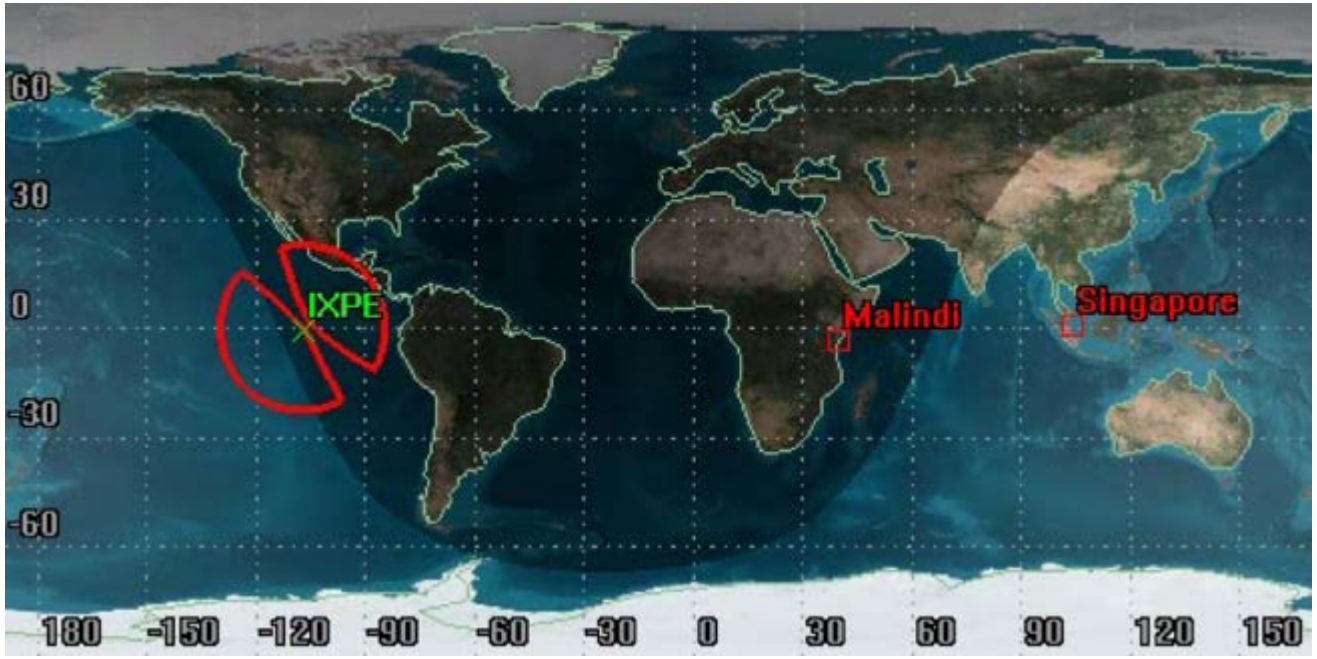
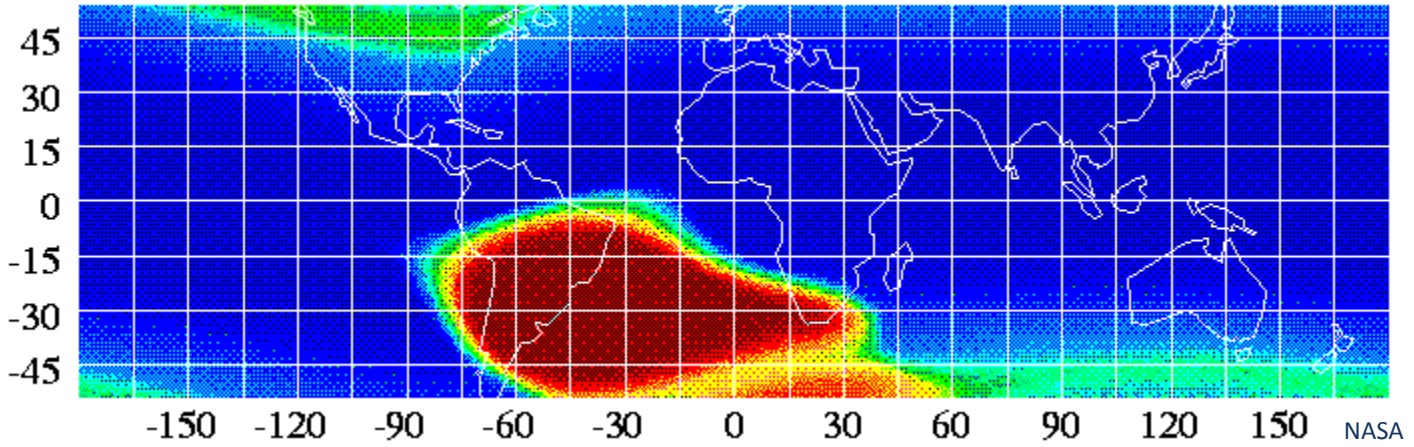
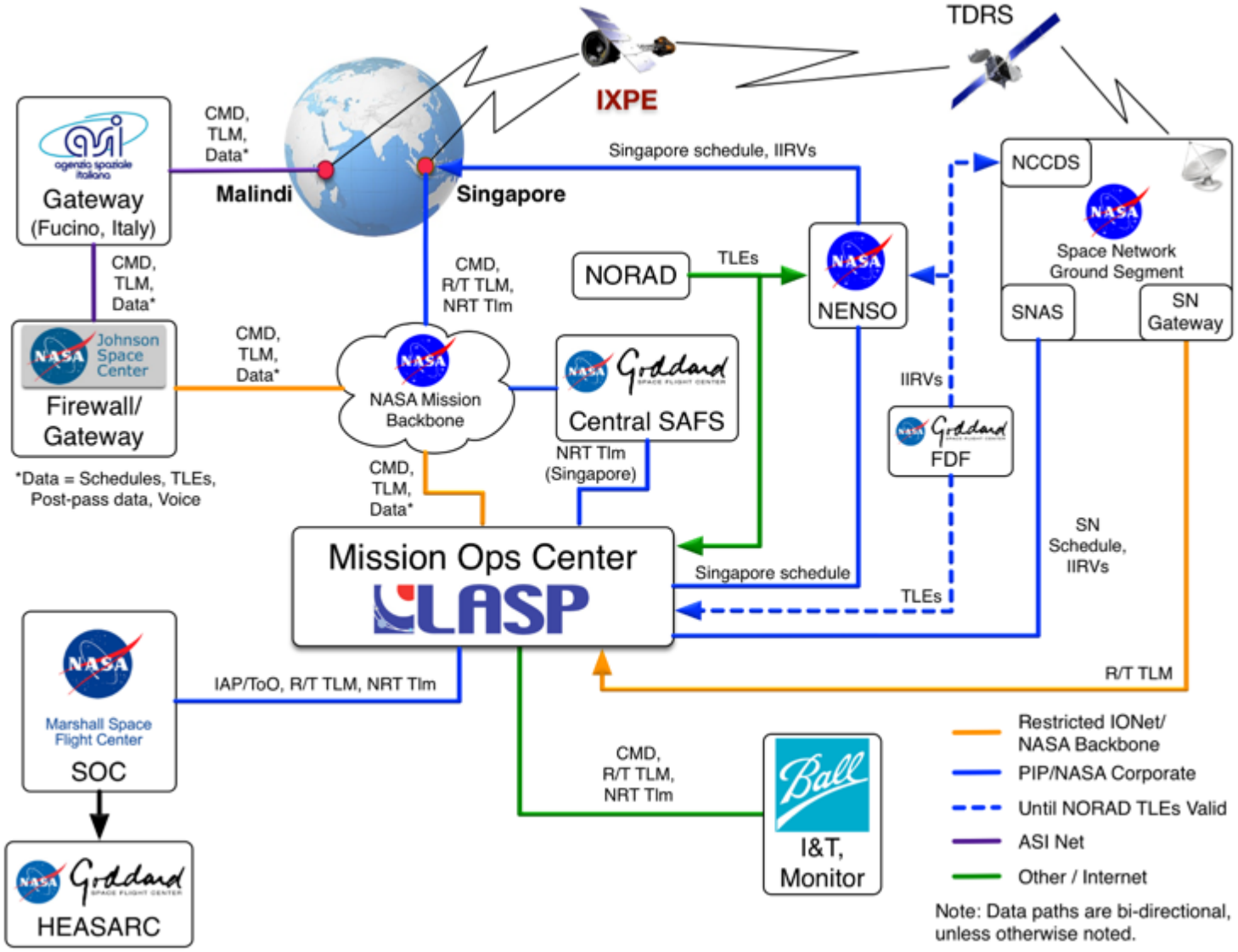
Orbital Considerations

- Inclination near 0°
  - Ground stations
    - Malindi (ASI) at 3° S
    - Singapore (KSAT/NEN) at 1° N
  - South Atlantic Anomaly (SAA)
- Altitude near 600 km
  - Orbital lifetime 10 years or so
  - Re-enters within 25 years
    - Required for uncontrolled re-entry
- Orbital Debris Assessment Report
  - Complicates orbit optimization





GROUND NETWORK



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Mission Milestones

Date	Event	Event description
2015 August	Phase-A selection	Selection by Science Mission Directorate (SMD) for Concept Study Report (1 of 3)
2017 January	Phase-B selection	Down-selection by Science Mission Directorate (SMD) for mission formulation
2017 September	M-SRR	Mission System Requirements Review
2018 June	M-PDR	Mission Preliminary Design Review
2018 November	KDP-C	Key Decision Point – C (Confirmation Review)
2019 March	GS-PDR	Ground System Preliminary Design Review
2019 June	M-CDR	Mission Critical Design Review
2019 November	GS-CDR	Ground System Critical Design Review
2020 April	M-SIR	Mission System Integration Review
2020 May	KDP-D	Key Decision Point – D
2021 March	ORR and MRR	Operational Readiness Review and Mission Readiness Review
2021 April	Launch	Launch on Falcon-9 from Cape Canaveral Air Force Station (CCAFS)
2021 May	Phase-E start	Start of operational phase, to last at least 2 years