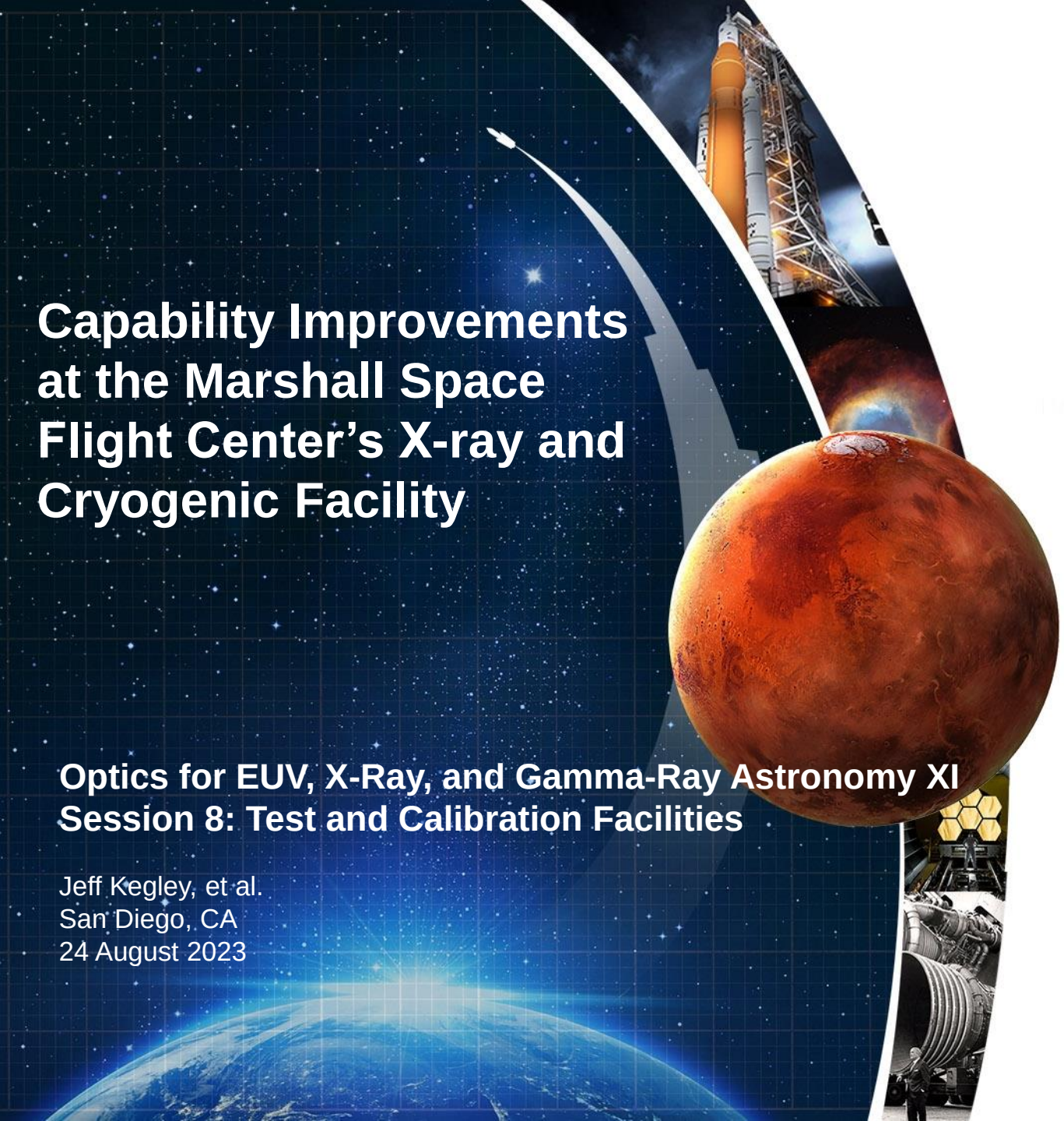
Capability Improvements at the Marshall Space Flight Center's X-ray and Cryogenic Facility



National Aeronautics and Space Administration

NASA



Optics for EUV, X-Ray, and Gamma-Ray Astronomy XI
Session 8: Test and Calibration Facilities

Jeff Kegley, et al.
San Diego, CA
24 August 2023

MARSHALL
SPACE FLIGHT CENTER



Constructed in 1990 to perform ground test & calibration of Chandra optics and instruments

Adaptable, multi-capable space simulation facility

- 6m dia x 19m test volume; P < 10^{-7} mbar; T: -250C to 100C
- 500m^2 ISO6 cleanroom

World's largest grazing-incidence optic test facility

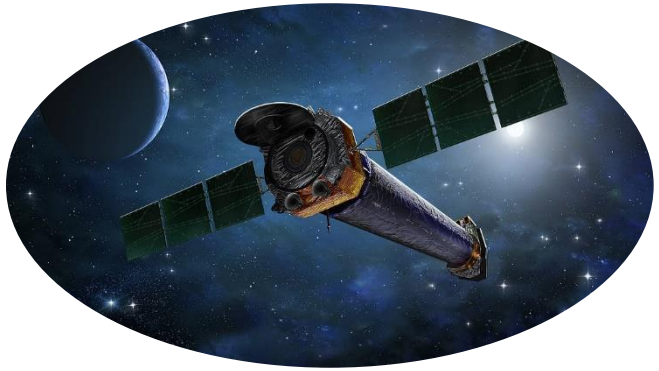
- 518m beamline; 1.46m diameter beam with < 3 mrad divergence

Agency's premier cryogenic direct-incidence optic test facility

- Mirrors up to 4.25m in diameter with RoC < 22.5m to 20 Kelvin

Facility Background

- Highly utilized throughout 30+ year history for technology development, maturation, and pre-flight verification activities for programs including:

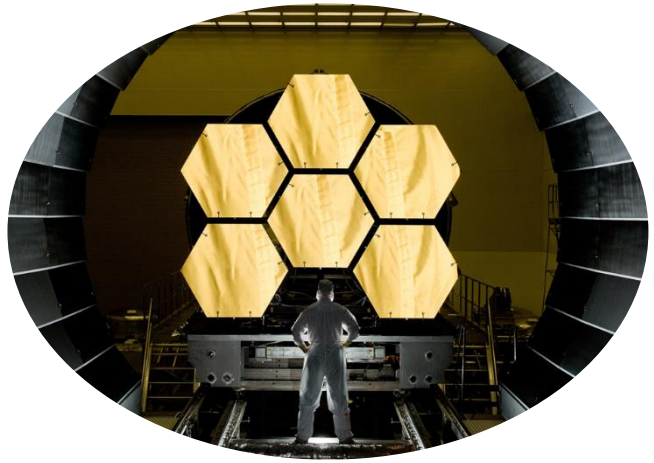


Chandra

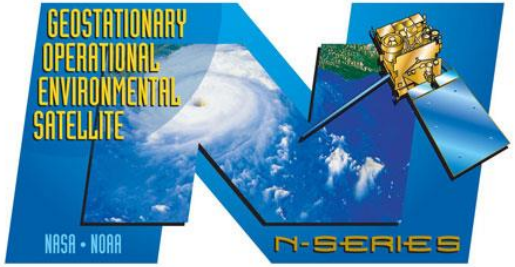


Hinode X-ray Telescope

Webb Space Telescope

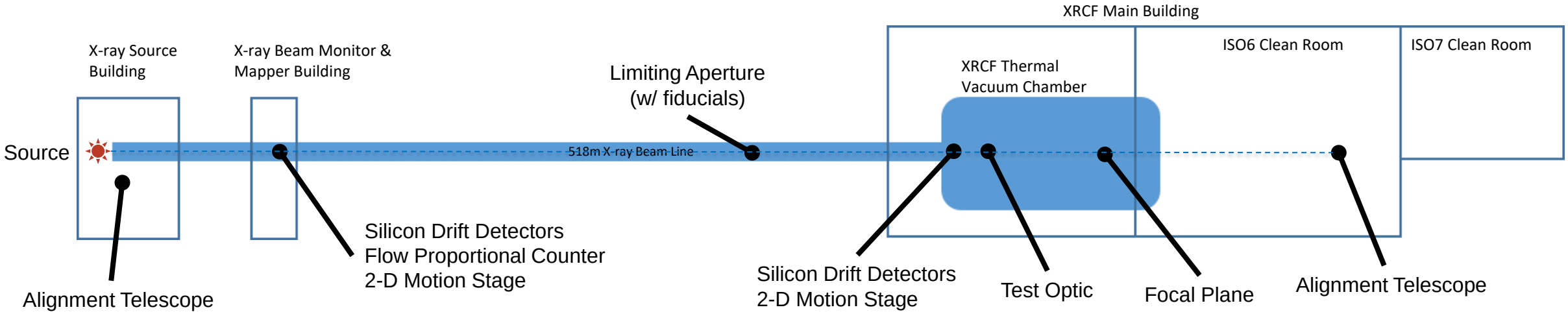


Solar X-ray Imagers

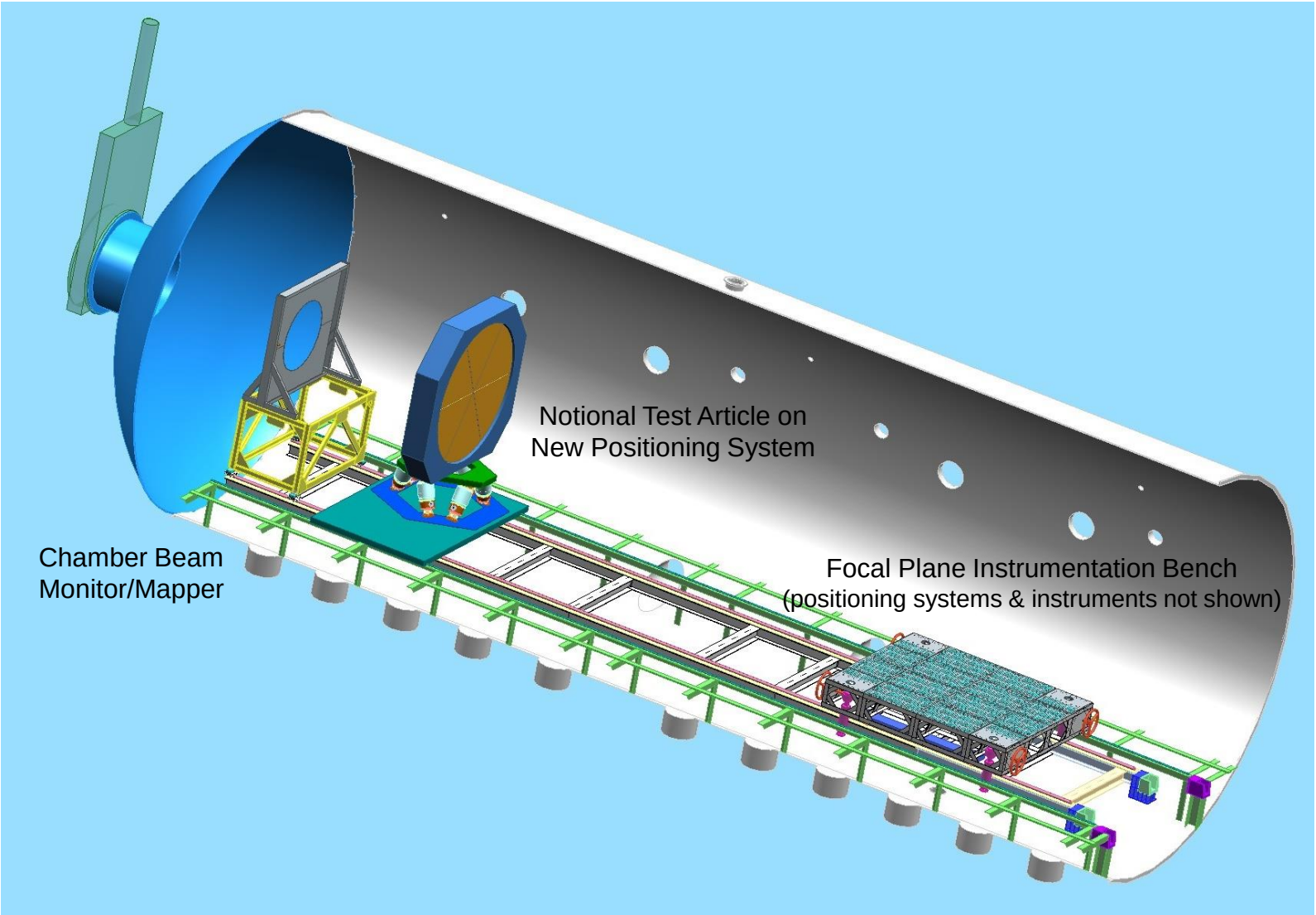


Notable Missions

Images: nasa.gov

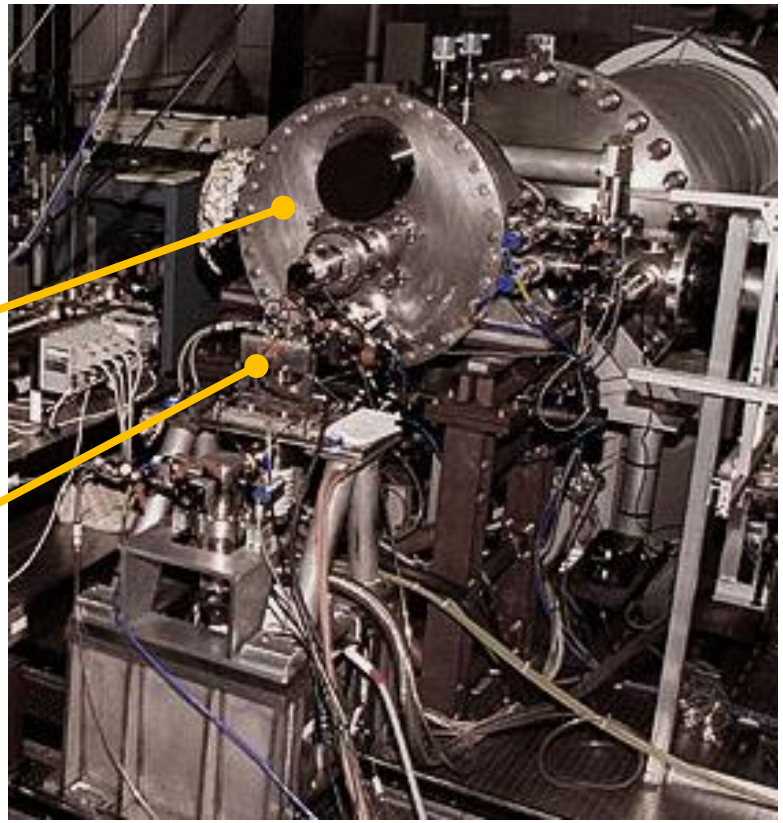


Facility Diagram - overall

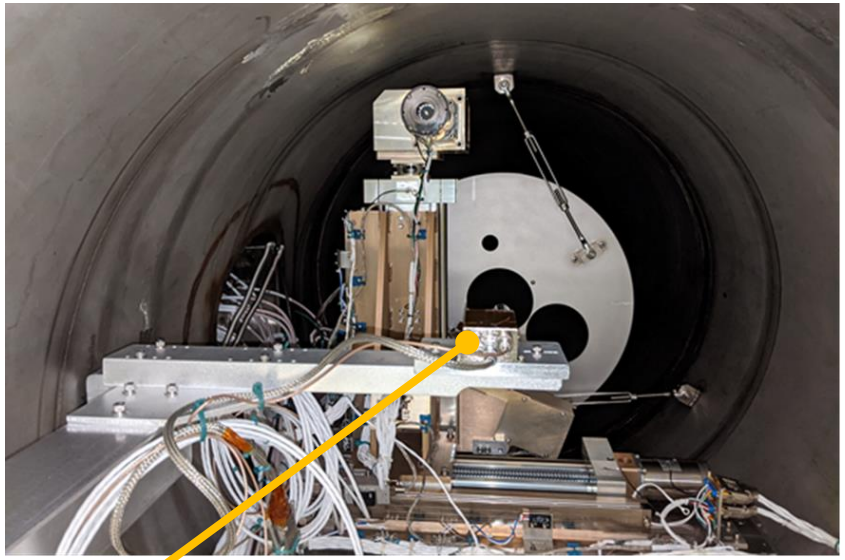


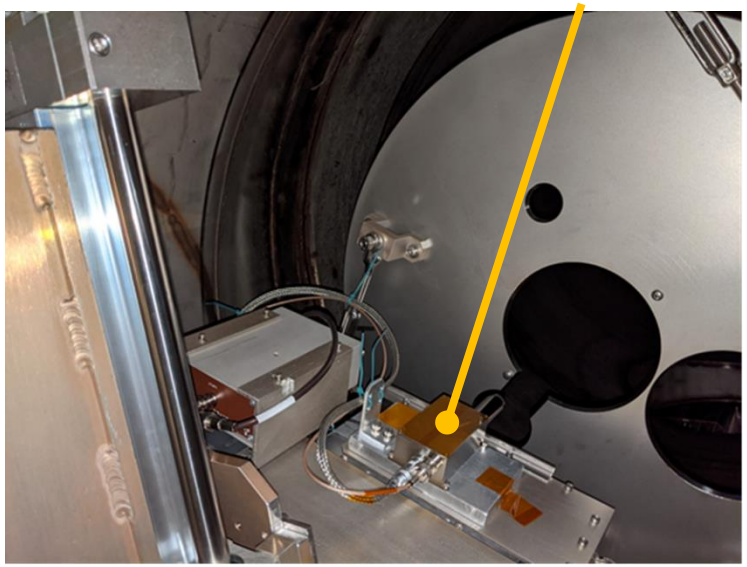
Facility Diagram – inside chamber

- Chandra-era Electron Impact Point Source
  - 0.1 and 10 KeV
  - total line and continuum fluxes at the instrument chamber up to 1000 photons/cm2/second/mA using the available anodes and filters

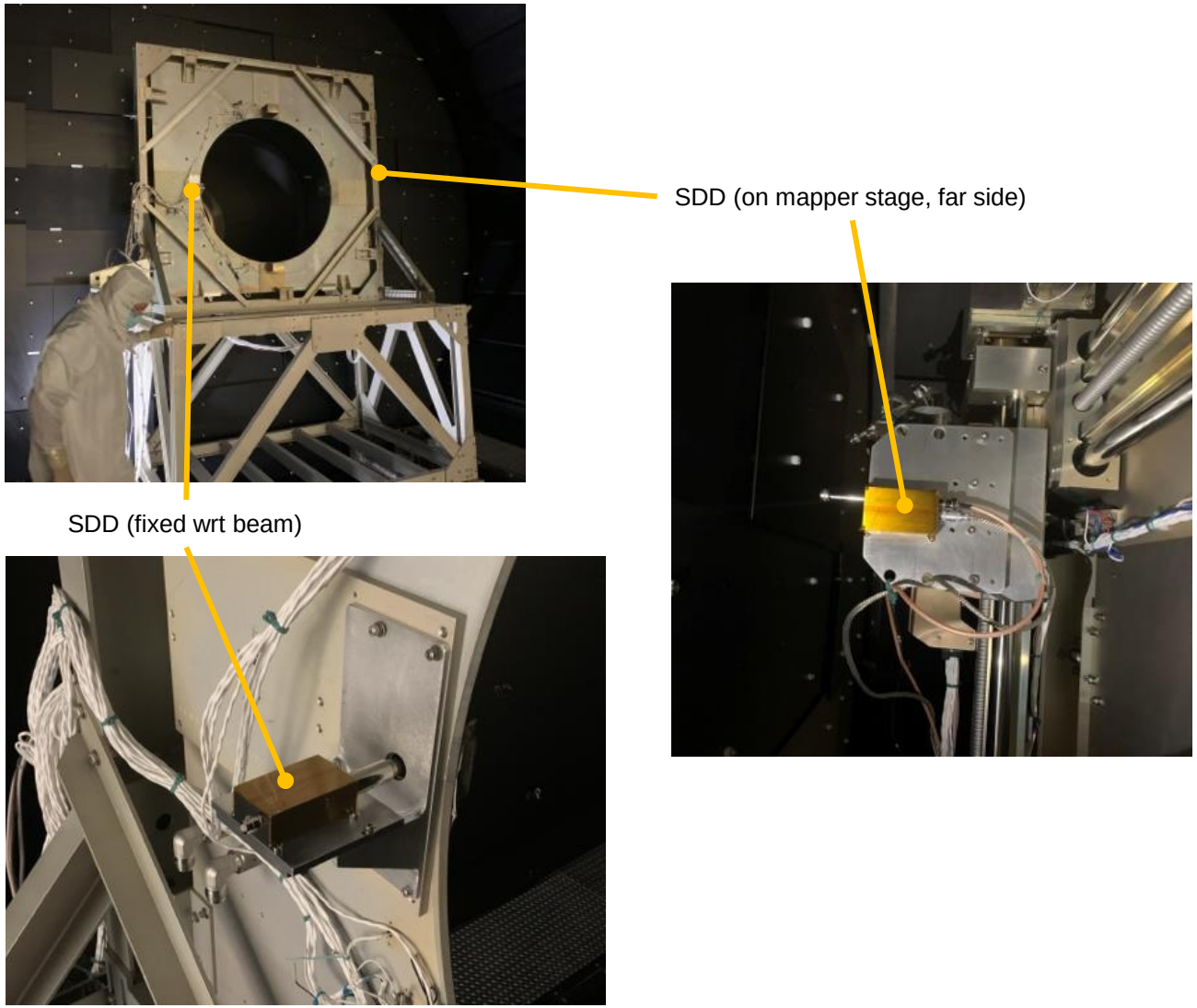


- Beam Monitor – Source
  - 37m from source
  - Fixed and mapping capability
  - New Amptek Silicon Drift Detectors (SDD)
  - Chandra-era Flow Proportional Counter

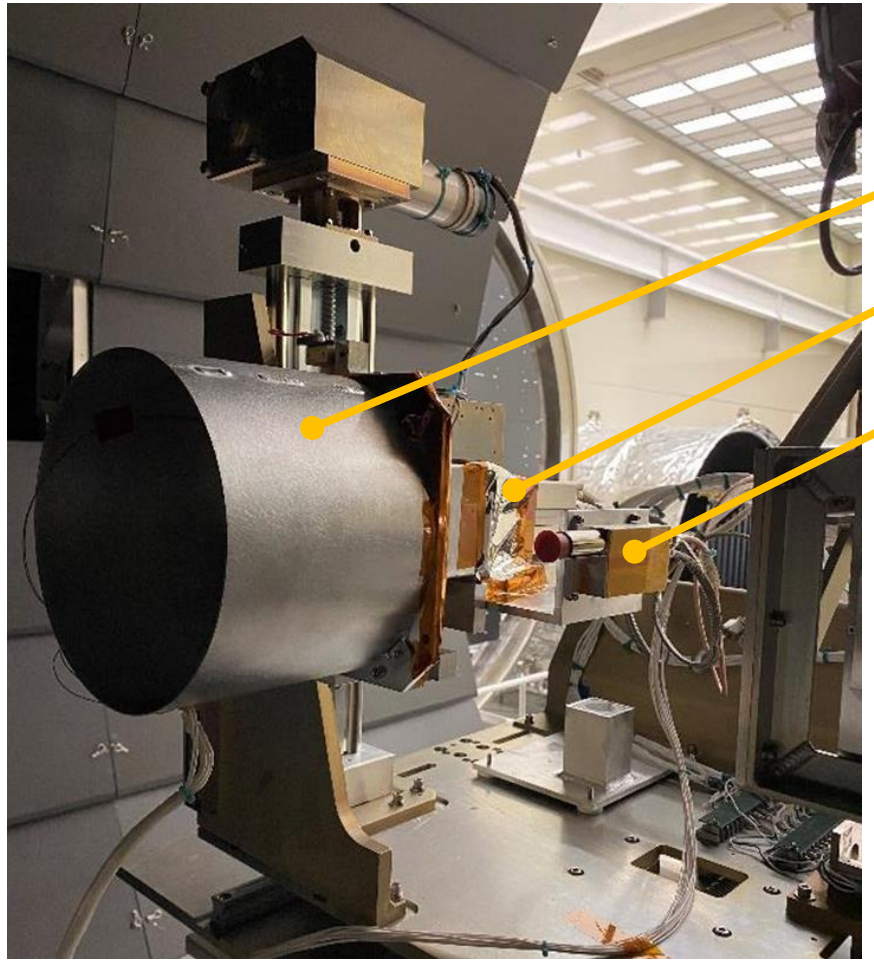




- Beam Monitor – Chamber
  - 524m from source
  - Fixed and mapping capability
  - New Amptek Silicon Drift Detectors (SDD)

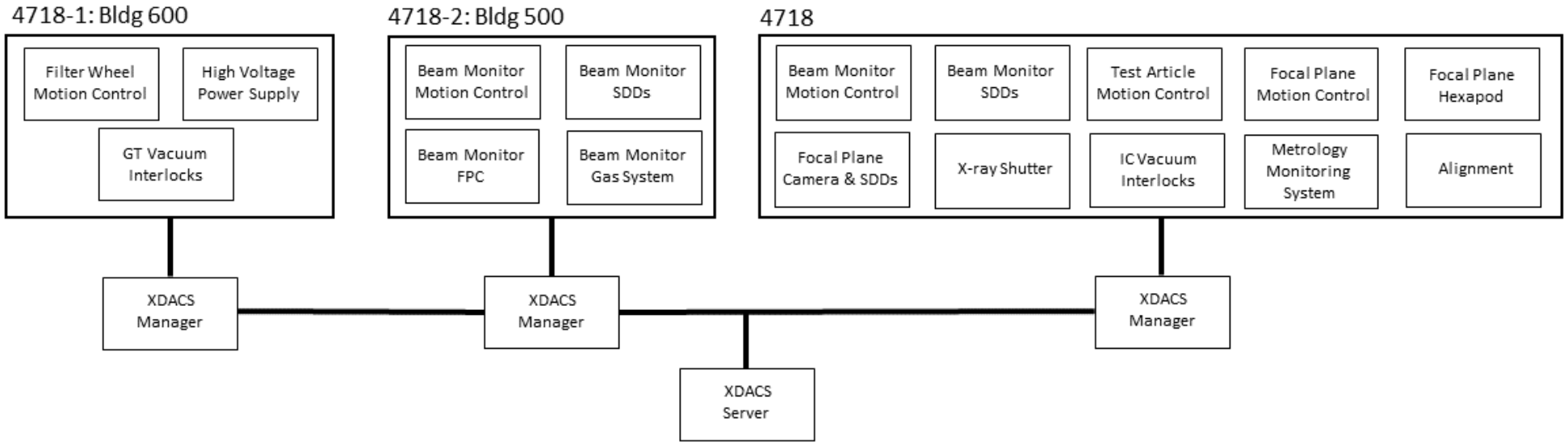


- Focal Plane Instrumentation
  - Chandra-era positioning system
  - Princeton Instruments MTE3 camera
  - Amptek silicon drift detector
  - External beam shutter
  - Stray light baffle/tube



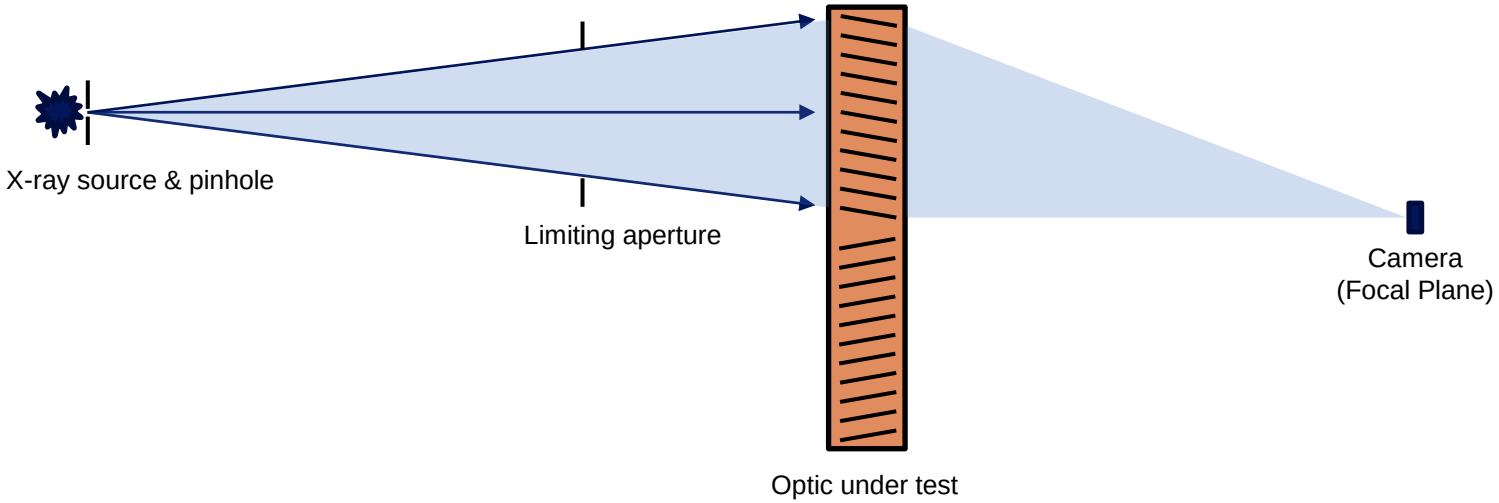
X-ray Source, Beam Monitors, & Focal Plane Instrumentation

- Chandra-era XDACS updated
- Outdated computers replaced
- New architecture

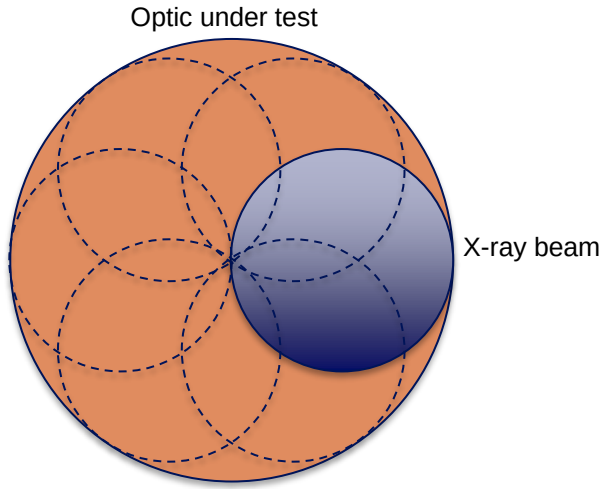


X-ray Data Acquisition and Control System

Sub-aperture illumination testing in a diverging beam (and subsequent data stitching) requires precise knowledge of the optic and detector positions relative to each other and the beam during calibration



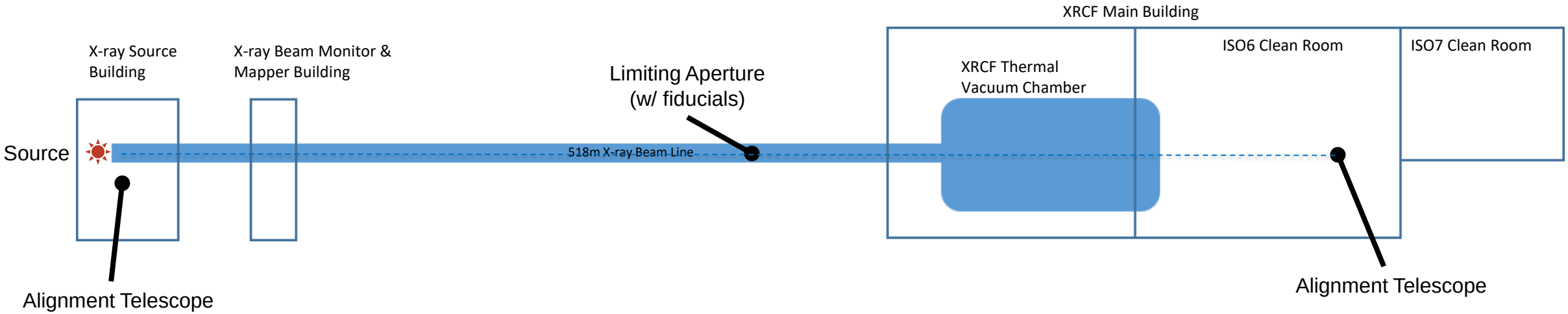
Partial illumination in a diverging beam (2-D)



Notional illumination method.
(Each sub-aperture must be illuminated in the same manner to enable data stitching)

Initial Alignment Approach

1. An optical reference to the facility's x-ray axis is generated by co-aligning the telescopes with the x-ray pinhole and limiting aperture fiducials



2. Using this optical reference, the focal plane instrumentation is aligned to the facility's x-ray axis
3. The mirror under test is then aligned to the focal plane instrumentation

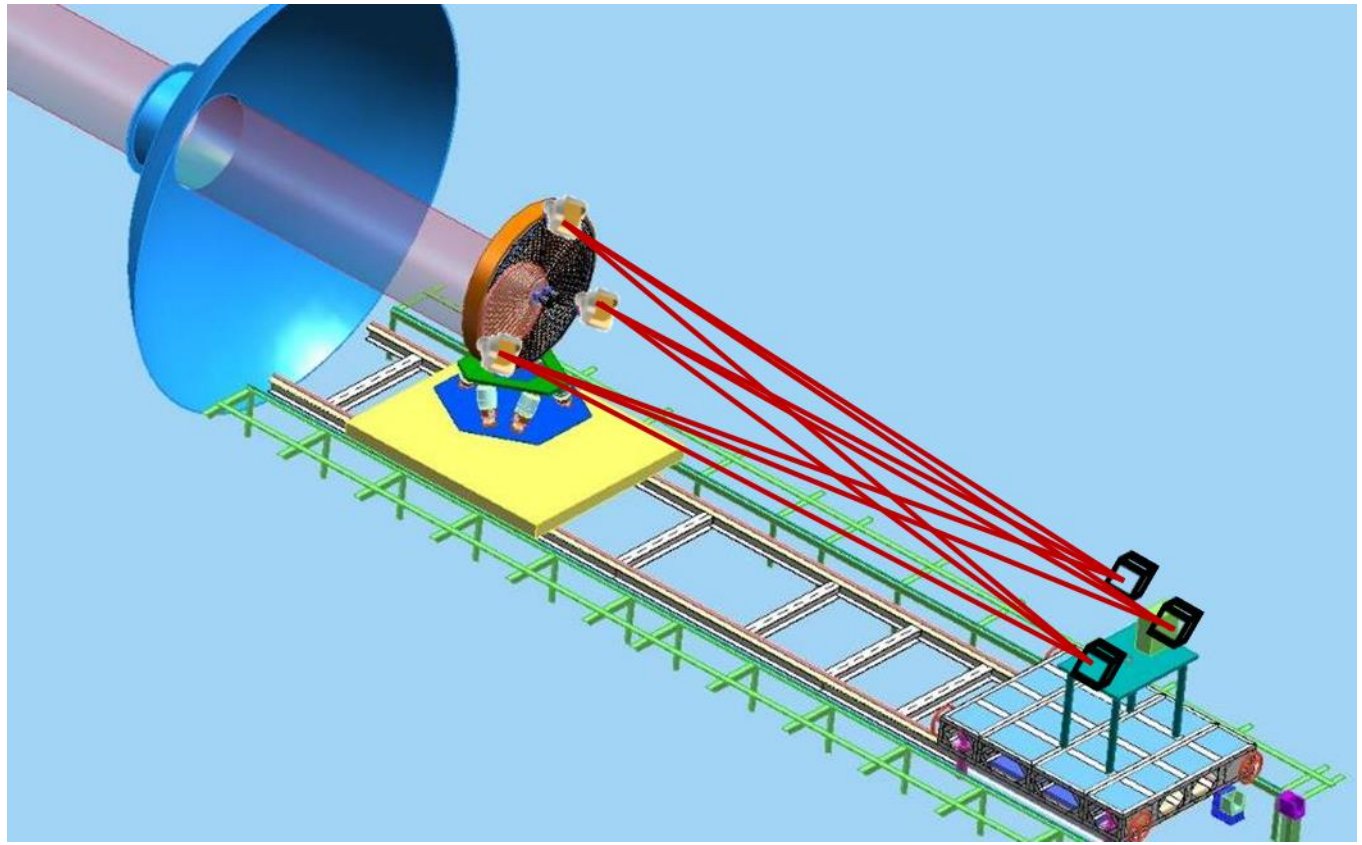
(The Centroid Alignment Tools that enable the shear and rotational alignment of the focal plane and test mirror are described in more detail in the paper)

Alignment & Position Monitoring Metrology

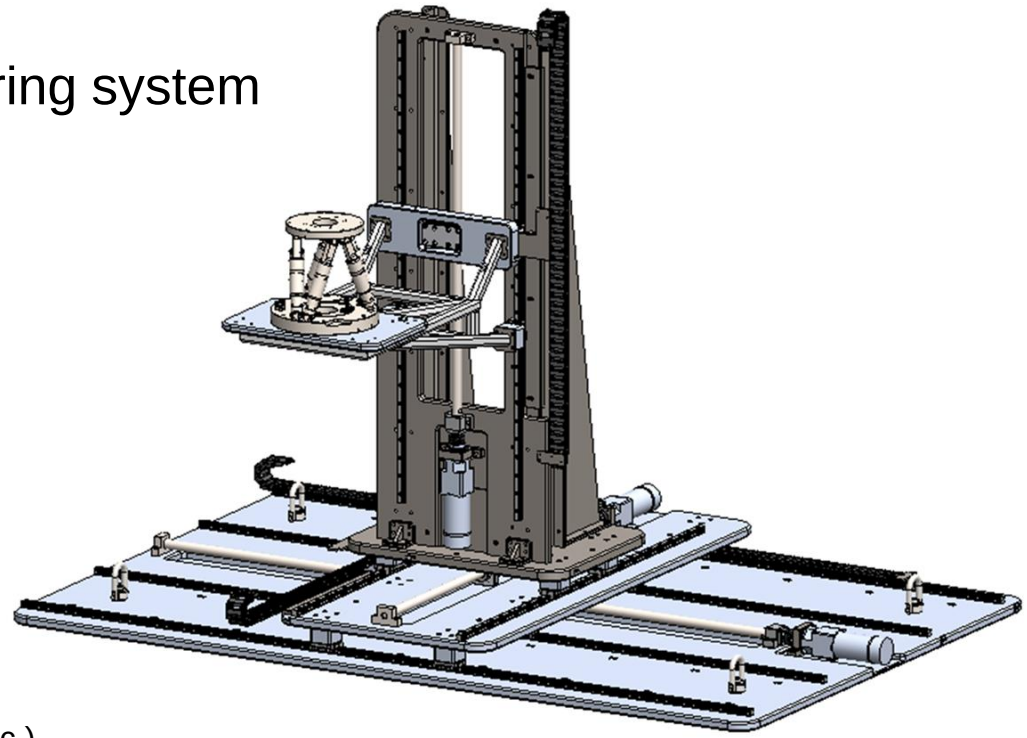
Alignment & Position Monitoring Metrology

Position Monitoring Approach

- Once aligned, monitor
- Monitoring the relative position of the mirror with respect to the focal plane instrumentation
  - six degrees of freedom
  - continual
- “Virtual hexapod” of nine discrete displacement measuring interferometers
- Derived from heritage testing
  - Webb telescope backplane verification at the XRCF
  - position tracking of the Webb Optical Telescope Element for many weeks during optical testing at Johnson Space Center



- 3-axis linear motion stages to accommodate large ranges
- Hexapod for precise positioning
- Focal plane instrumentation + metrology position monitoring system
- (Chandra era sub micron motion stages will be retained)



PI (Physik Instrumente) USA hexapod

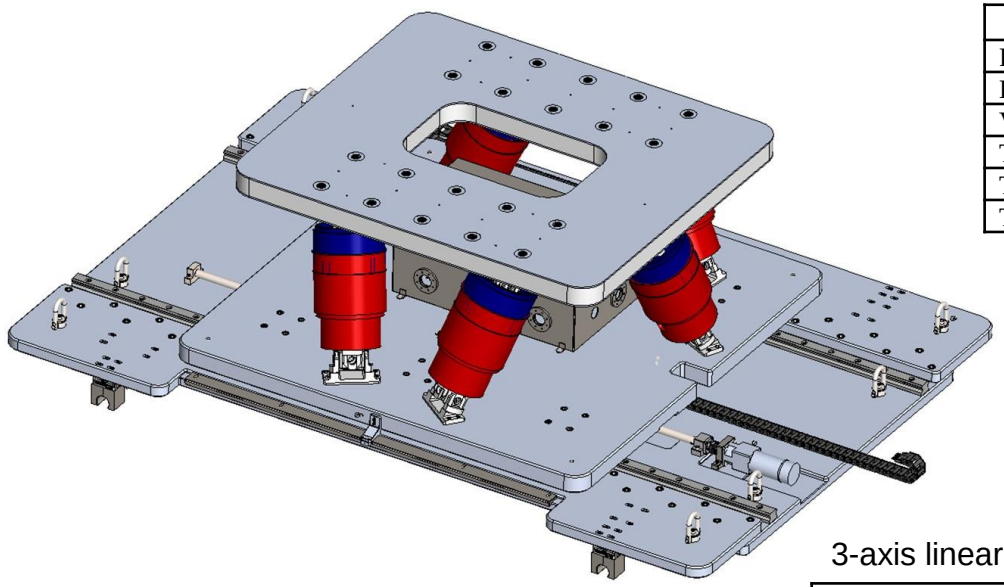
Axis	Range	Minimum Step Size
Focus (X)	100 mm	1 µm
Horizontal (Y)	100 mm	1 µm
Vertical (Z)	50 mm	1 µm
Theta X (roll)	30 deg	5 µrad
Theta Y (pitch)	30 deg	5 µrad
Theta Z (yaw)	60 deg	5 µrad

3-axis linear stage (Moog, Inc.)

Axis	Range	Minimum Step Size
Focus (X)	1 m	500 µm
Horizontal (Y)	2 m	500 µm
Vertical (Z)	1 m	500 µm

Focal Plane Instrumentation Positioning System

- Re-purposing and refurbishment of existing hexapod
- New single axis motion state to accommodate larger range of motion
- 4,000 kg capacity
- (Chandra era motion stages will be retained)



Hexapod (Moog, Inc.)

Axis	Range	Minimum Step Size
Focus (X)	300 mm	1 µm
Horizontal (Y)	300 mm	1 µm
Vertical (Z)	170 mm	1 µm
Theta X (roll)	4 deg	5 µrad
Theta Y (pitch)	4 deg	5 µrad
Theta Z (yaw)	≥ 4 deg	5 µrad

3-axis linear stage (Moog, Inc.)

Axis	Range	Minimum Step Size
Horizontal (Y)	1.5 m	500 µm

Test Article Positioning System

- Many updates and upgrades completed and functionally demonstrated over the past 18 months
- Remaining items include
  - Commissioning new mirror and focal plane positioning systems
  - End-to-End demonstration of full-up alignment & metrology system
- XRCF test capabilities have been fully returned to service, improved, and are now ready to support future large aperture x-ray missions

Conclusion


4718
X-Ray and Cryogenic Facility (XRCF)
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