The Marshall 100-Meter X-ray Beamline: Usage and Capability

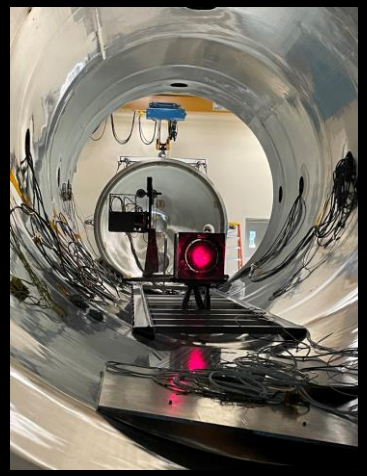
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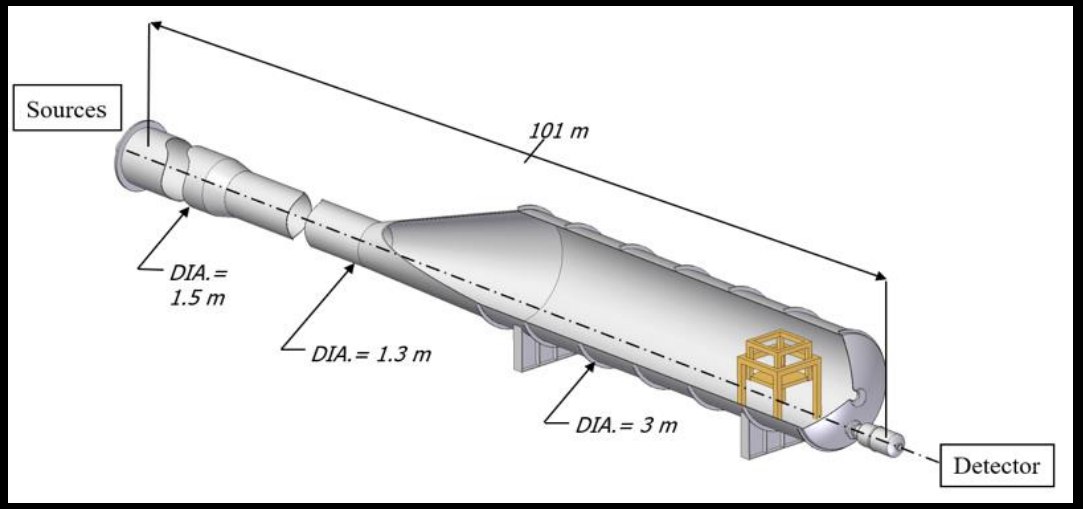
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The Marshall 100-Meter X-ray Beamline







- The *Stray Light Test Facility* was originally constructed in 1963 to validate optical light suppression geometries employed on satellites
- A model of the Hubble Space Telescope/Large Space Telescope was tested at the facility in the 1970's to compare observed light suppression to analytical models.
- The facility's long beam-pipe, along with the recently incorporated vacuum translation stages and instrumentation, now makes the *Marshall-100* ideal for rapidly calibrating X-ray optics.
  - Total facility: 101 meters long
  - Beam pipe: 1.3 meter-wide
  - Detector chamber: 3 meter-wide, 8 meters-long
- Sibling to NASA's *X-ray and Cryogenic Facility (XRCF),* also located at MSFC
- The facility's vacuum capability and cleanroom remain useful for testing and integrating non-x-ray missions and experiments.
- *Marshall-100* is supported by MSFC X-ray ISFM program and made available to Astrophysics Research and Analysis (APRA) projects.

Marshall-100 Vacuum Capabilities

- 3 Rotary piston roughing pumps with blowers
  - Reduces chamber pressure from atmosphere to 10^{-3} Torr in ~ 1.5 hours
- 10” Varian turbo pump
  - Operates from 10^{-3} Torr and can pull the chamber to 10^{-5} Torr
- 3 Cryo pumps
  - 2 cooled by compressed helium
  - 1 cooled by compressed helium and LN2 shroud
  - Normal operation is with two cryo pumps mid-10^{-6} Torr
  - With 3rd cryo we can do 10^{-7} Torr
  - 48 hours of LN2 supply for 3rd cryo pump before refill required.
- If all components are operating nominally chamber can be pumped to:
  - Low 10^{-5} Torr in less than 4 hours
  - 10^{-6} Torr in approx. 4-6 hours
  - 10^{-7} Torr in approx. 6-8 hours
- Beamline repressed with low humidity ‘missile grade’ air





X-ray sources

Tube Brand	Anode	Line (keV)	Max Voltage (kV)	Max Current (mA)
TruFocus 6050/6051	Mo	2.2(l), 17.5(ka)	50	1/2
(Be window)	Rh	2.7(l), 20.2(ka)	50	2
	Ti	4.5(ka)	50	2
	Fe	6.4(ka)	50	1
	Cu	8.1(ka)	50	1
TFX3110EW	W	8.4(l), 59(ka)	110	2.5
TruFocus-10-2-AL	Al	1.49(ka)	8.5	0.5
Manson Source	var	var	10	1

- X-ray sources range from 0.277 to 110 keV
- 150 µm FWHM source size
- Filters available (Lebow Company, XRCF)



TruFocus 6050/6051 (left) sealed X-ray tube
TruFocucs-10-2-AL (right) open anode X-ray tube

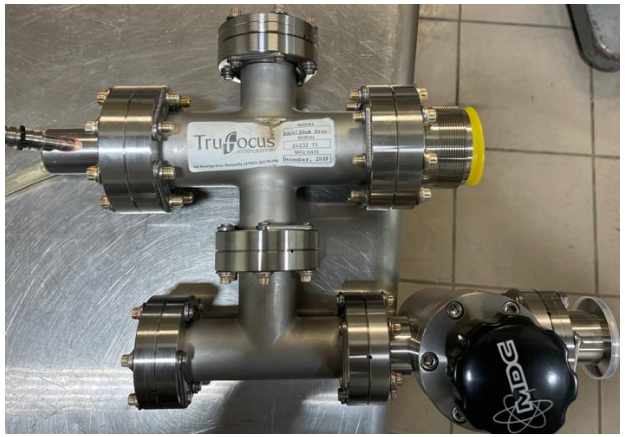


Manson Source

- Open anode X-ray tube
- Exchangeable anode
- Replaceable filament
- Optional inline optical blocking filters-
  - Luxel Company: 520 Å Al deposited on 5372 Å of Polyimide

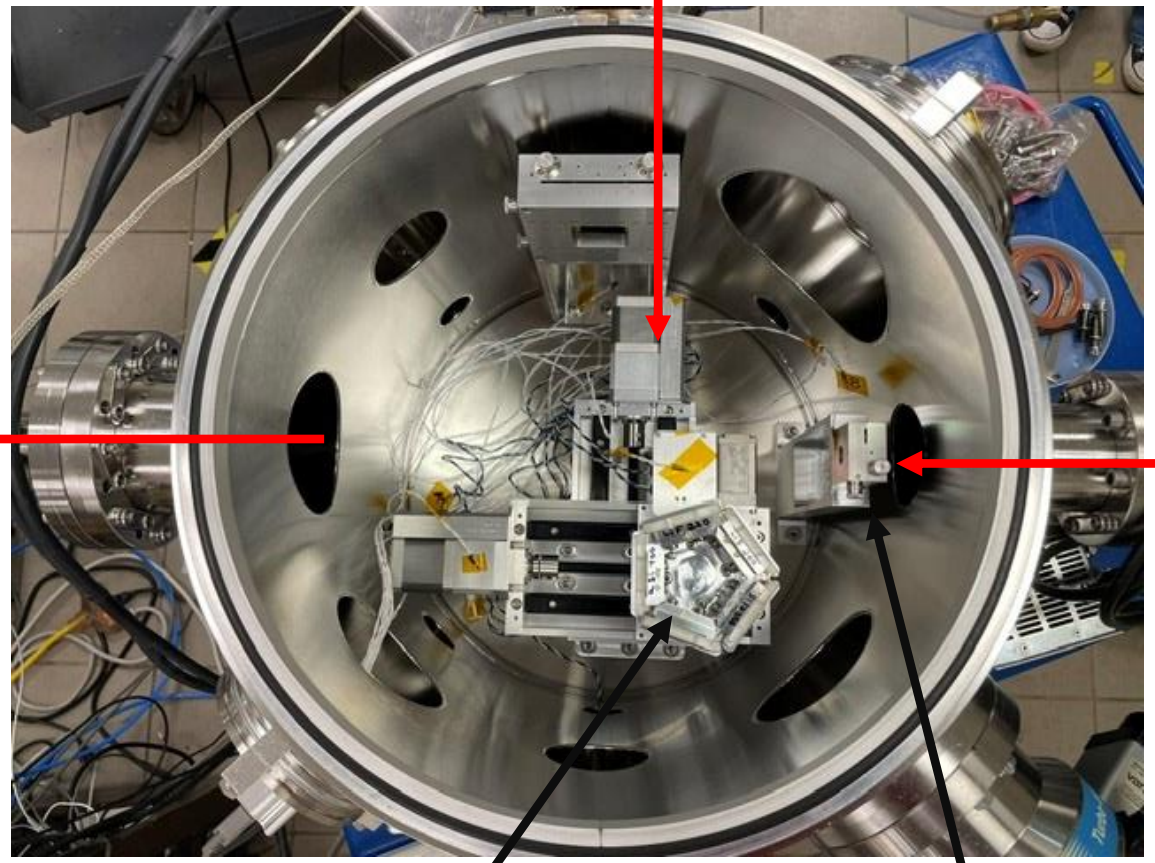
Chrystal Box

- X-ray source to facility alignment
- Polarized X-ray Source



Trufocus 30kV/30mA Source high flux source

Anode	Line (keV)	Max Voltage (kV)	Max Current (mA)	Crystal
Rh	2.7	30	30	Ge(111)
Ti	4.5	30	30	Si(220)
Fe	6.4	30	30	aSi(400)



High flux source

Collimated beam projecting 101 meters down the beamline

X-ray source mounted on vacuum flange translation stage

Bragg crystal carousel on translation stage

6 mm by 6 mm tungsten aperture 840 mm from source

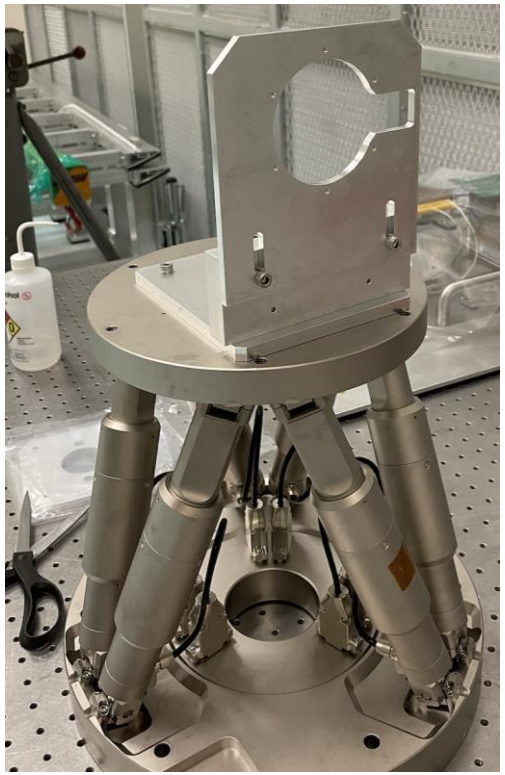
Vacuum Motion Stages

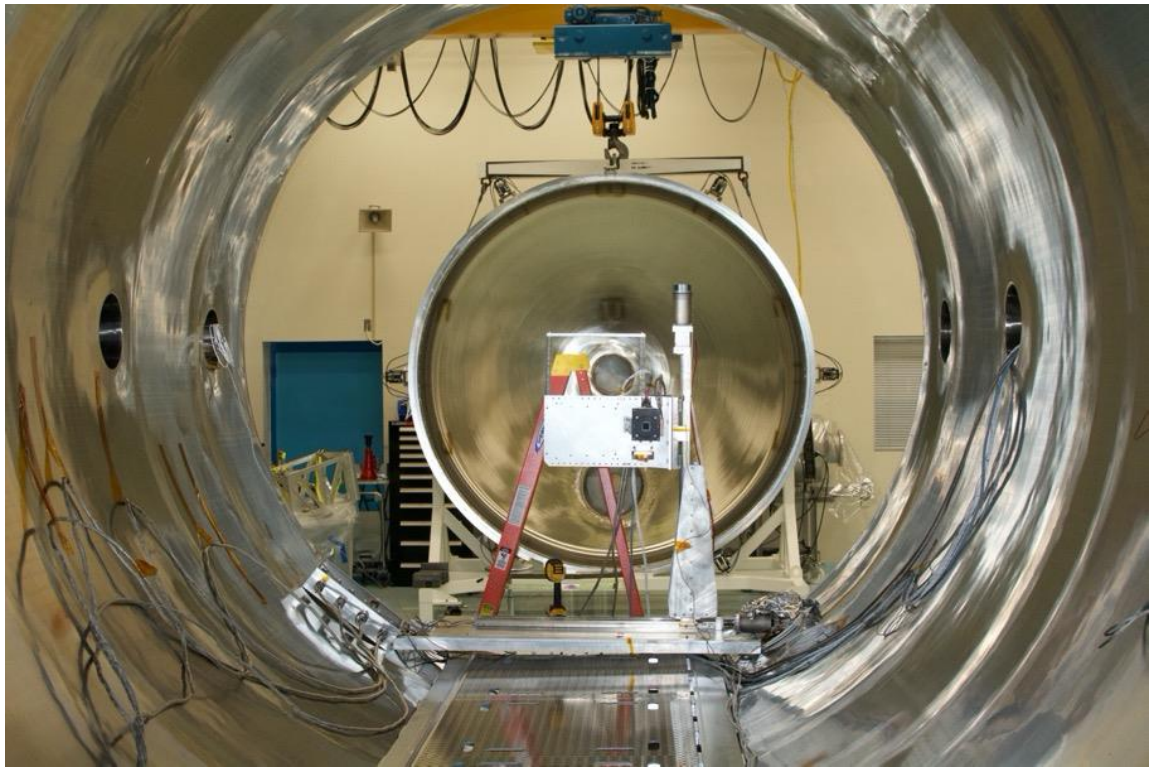
Hexapod (H-850)

- Load: 80 kg
- Range: +/- 30 degrees
- Optic/Collimator stage
- Programable motion

Parker X-Y Stage

- Load: 100 kg
- XY Travel: 36 in by 30 in (Res 0.1 micron)
- Area for additional detectors
- Connected to external chiller (5 C, Water/Ethylene glycol)





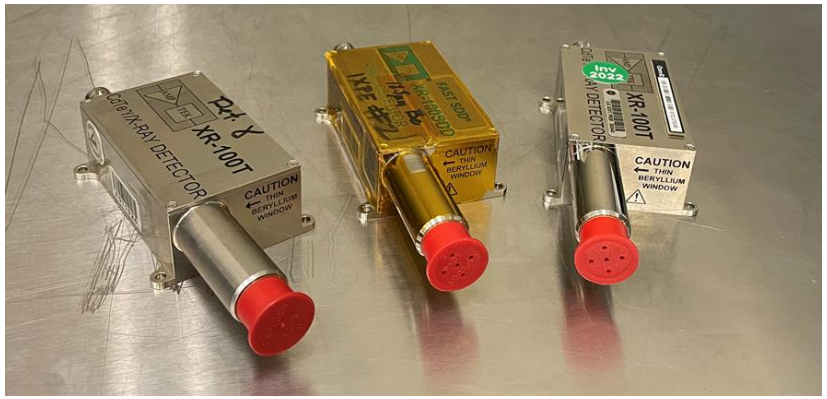
Additional Zaber translational and rotational stage available

Facility Detectors

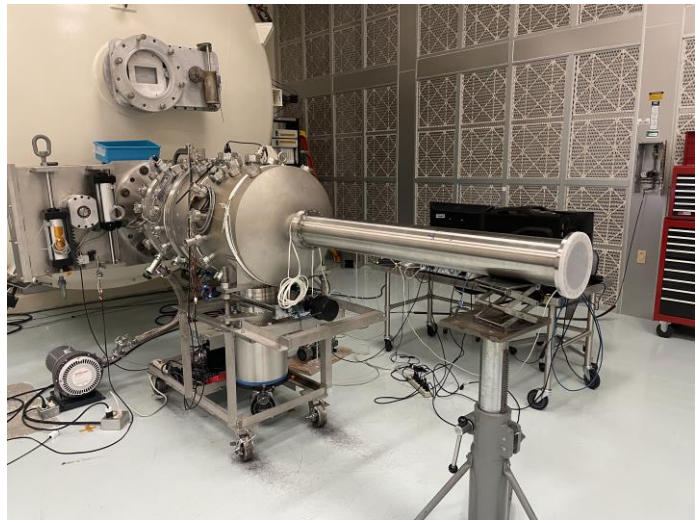
- CCD
  - Andor DW436, SN 10513
  - 2048 X 2048 array of 13.5 μ m pixel
  - Optical blocking filter and shutter
  - Operates at -45 deg C
  - Characterize point spread function of beam.
- SDD
  - Amptek Fast-SDD (50 mm^2)
  - 12.5 μm Be window
  - Si3N4 ‘C-I’ window (50 mm^2)
  - Fast count rate/low deadtime
  - Effective Area

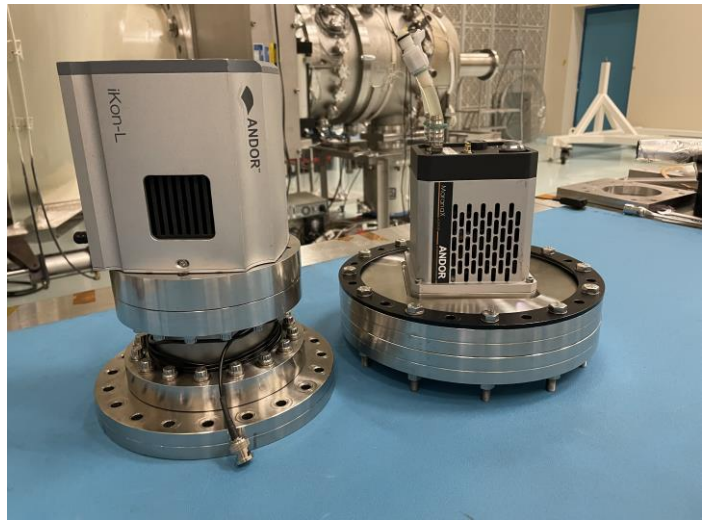
    Two detectors mounted both on focal plane and near optical node
- CdTe
  - Amptek XR-100 CdTe (25 mm^2)
  - For hard X-ray experiments





Bellhousing

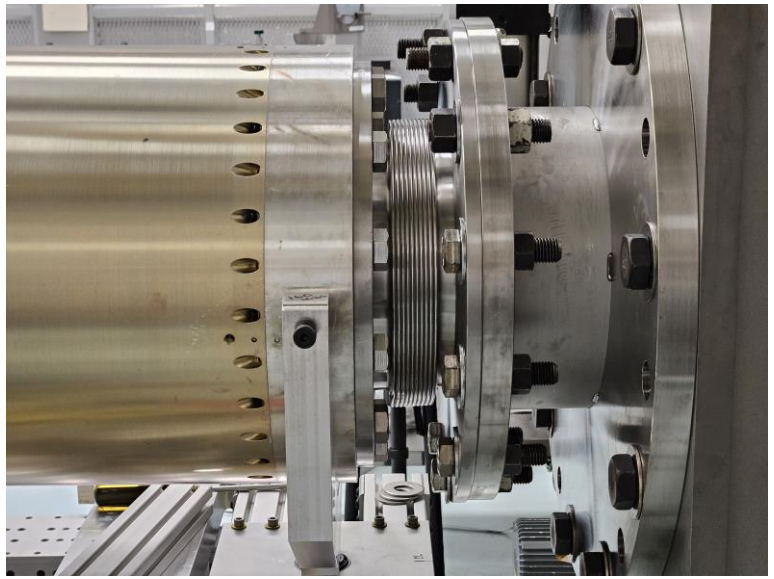




- External vacuum chamber, co-linear to the beamline
- Connects via pneumatic gate valve, internal diameter 292 mm
- Fast turn-around on test optics
- Internal Tip, Pan, and linear Z-stage
  - (Arc minute res/ 0.1 mm res)
- External Andor CCD camera
  - 2048 X 2048 array of 13.5 μm pixel
  - 5 MHz pixel readout speed
  - Air cooled, -45 C
- External Marana-X sCMOS camera
  - 2048 X 2048 array of 6.5 μm pixel
  - 100 MHz pixel readout (high dynamic range 16-bit)
  - 310 MHz pixel readout (fast high dynamic range 16-bit)* (coming soon)
  - Air cooled -25 C, water cooled -45 C
- Be window allows for Amptek SDD/CdTe measurements
- Additional tubing added for longer focal length optics

Sounding Rocket Adapter Flange and Translation Cart

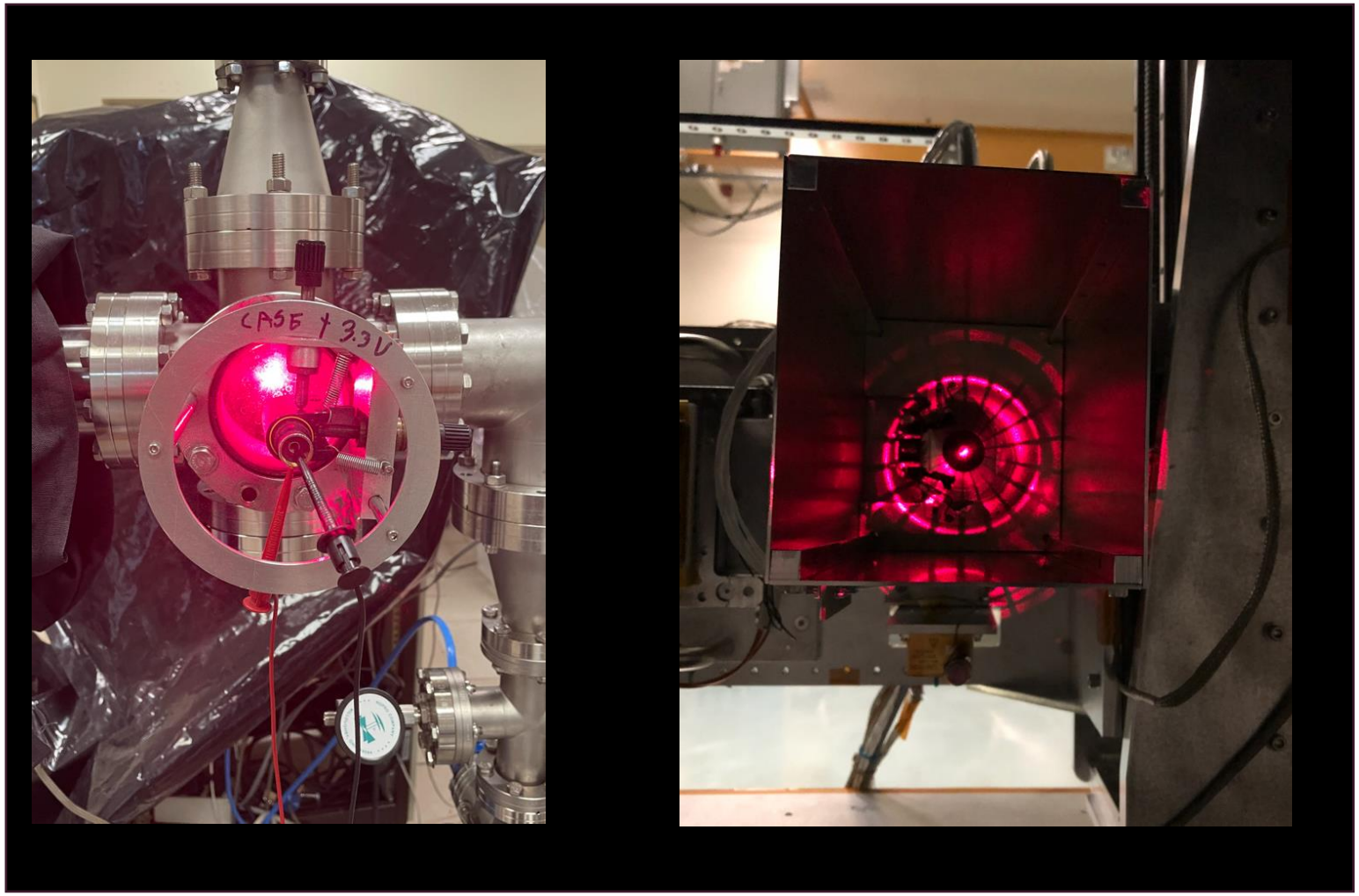




- Attaches vacuum capable sounding rocket skins to the same pneumatic gate valve as the bellhousing (Dia - 292 mm)
- Developed by students at the Alabama School of Cyber Technology and Engineering for the Marshall Grazing Incidence X-ray Spectrometer (MAGIXS) sounding rocket mission
- Sounding rocket translation cart:
  - Accommodates both 17” or 22” standard sounding rocket skin size
  - Max load: 700 lbs. load with factor of 3 safety margin.
  - Max Tip and Pan limited by vacuum bellows: +/- 1 degree
  - Patrick Champey-
    ‘Unfortunately, I don’t have a cool name for it yet…’

Laser alignment and reference

- Laser alignment
  - Laser reflected off retractable mirror at source end
  - Diffuses to ~ 1 m diameter at detector end
  - Allows for rough focus and alignment of X-ray optic
- Laser optical axis reference



Facility Control Room



Control computers recently upgraded

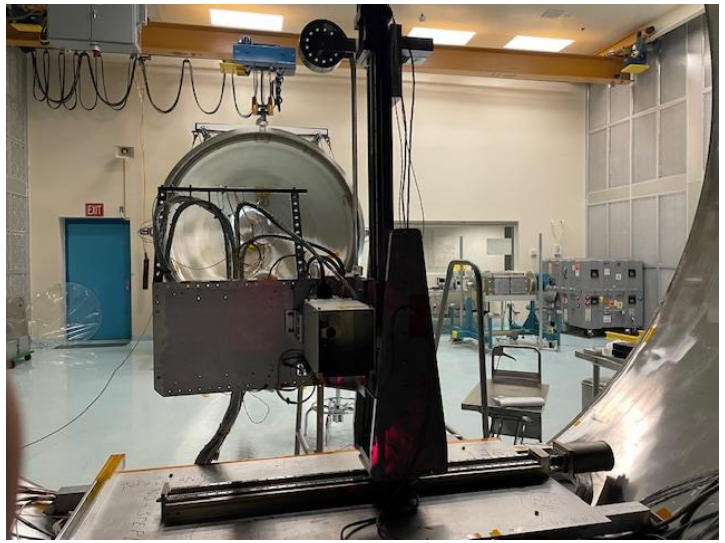


Hermetic D-Sub 37 Connector

- Upgraded computer system provides remote control for:
  - X-ray source flux
  - Translation stage orientation
  - Detector readout
- The facility includes a 100K cleanroom area with:
  - General access for MSFC personnel and visiting experimenters
  - Flow bench for instrumentation setup
  - Adjacent 10K cleanroom with gowning access
  - Loading dock access
- Hermetic electronic feedthrough flanges:
  - D-Sub 37 connectors readily available
  - Visiting experimenters requested to maintain vacuum compatible hygiene, avoiding noncritical components containing zinc and cadmium
- Chilled and cryogenic feedthroughs are available
- Neighboring conference room and visitor office space

Marshall-100 Cleanroom



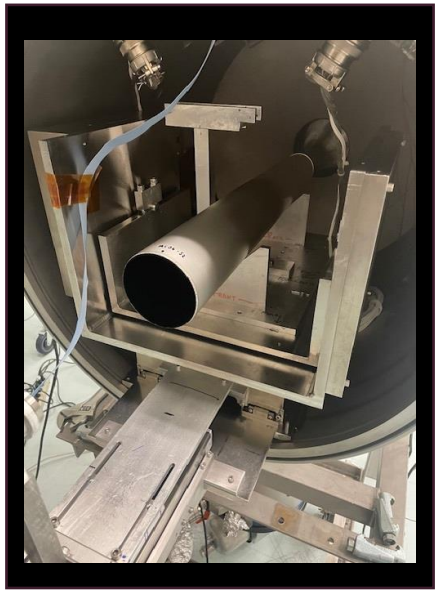


- Provided cleanroom gowning
- ESD mats and optical table
- Humidity controlled
- Overhead 3-tonne lift capacity overhead gantry crane
- Full access to instrument chamber and beam pipe
- Door access to 10K room for ingress of large test articles
- Leica laser range tracker (request in advance)

Recent Programs

MiXO/Merging Technologies

- Center for Astrophysics-Harvard & Smithsonian (PI - Suzanne Romaine)
- Miniature X-ray Optics
- Develop lightweight Wolter-I optics for Small-Sat
- Merging Tech supported through APRA



University of Arizona's Flex Module Segmented Optics

- The Wyant College of Optical Sciences - University of Arizona (PI - Brandon Chalifoux)
- Goal to deliver high-angular resolution through non-contact figuring using Ultrafast Laser Stress Figuring
- Supported through APRA



NIST Neutron Microscope

- NIST PI-Dan Hussey
- Grazing incident optics for imaging thermal neutrons
- Set to be tested at with neutron beamlines (ILL) in Grenoble, France and potentially at the PSI in Switzerland

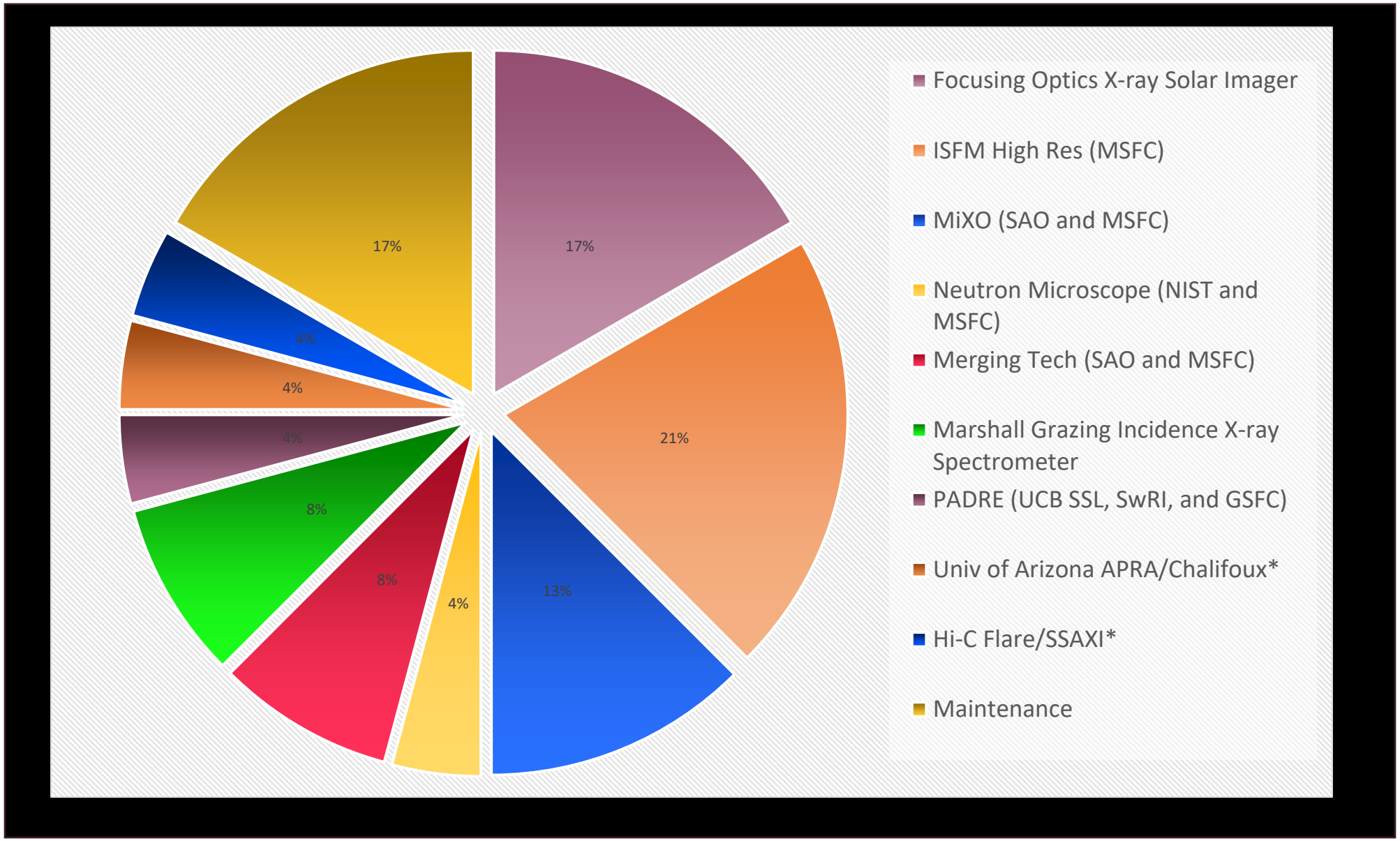


FOXSI-5

- SSL Berkeley PI - Milo Buitrago-Casas)
- Sounding rocket-borne hard-x-ray solar imager
- Extensively recalibrated at the over the last few months (Bongiorno)
- FOXSI-5 will also launch from Poker Flat in late 2025 early 2026



Mashall-100 Beamline Usage FY24 & FY25



- The *Marshall-100* is scheduled to be employed for eight active APRA missions
- *Marshall-100* used extensively in MSFC's High Resolution X-ray optic development program
- Two proposed Pioneer missions have requested beamline time and support
  - 54% External
  - 29% Internal
  - 17% Downtime

Space Telescope tested at the *Marshall-100*

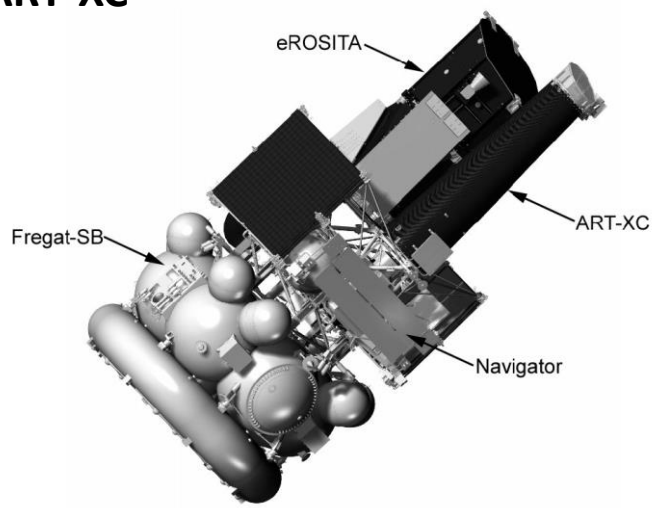
ART-XC

- Astronomical Roentgen Telescope X-ray Concentrator
- 8 MMA qualified, 28 shells, qualified
- Launched with eROSITA on the Spektr-RG (SRG) space observatory in July 2019.
- Hard-X-ray observatory 6 to 30 keV

IXPE (SMEX)

- Imaging X-ray Polarimeter Explorer
- 4 Modules, 24 shells
- Polarization sensitive, 2 to 8 keV
- Launched December 2021

ART-XC

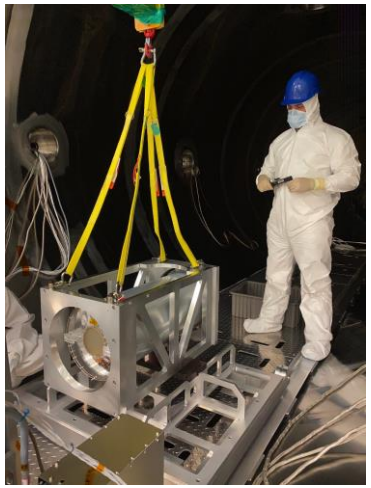


IXPE



https://ixpe.msfc.nasa.gov/multimedia/images/





Summary

- The *Marshall 100-Meter X-ray Beamline/The Stray Light Test Facility* is a world class X-ray optic test facility. It is capable of calibrating projects ranging from student lead experiments, MSFC's ISFM optic development program, going all the way to Explorer size missions.
- The *Marshall-100* is advertised to all successful APRA funded projects. For additional community support (NASA Centers, Universities, and Industry) please contact:

  nicholas.e.thomas@nasa.gov

  stephen.p.cheney@nasa.gov

Extra

Filter Element	Thickness (μm)
Al	18
	38
Co	46
Cu	1.4
	100
Fe	1.2
	2.4
	37
	75
Mg	25
	50
Mo	3
	6
Nb	5
	10
Ni	50
	100
Pb	5.3
Ti	1.2
	2.6
	41
	81



- Filters bought for AXAF Project at XRCF, on loan.
- Johnston, D.D., MSFC memo EL71 (27-95), "Procurement of XSS Point Electron Impact Source (PEIS) Targets and Filters" (11 April 1995).
- Manufactured by the Lebow Company