The Marshall 100-meter X-ray Beamline: description and update (The Stray Light Test Facility)

Nicholas E. Thomas(1)

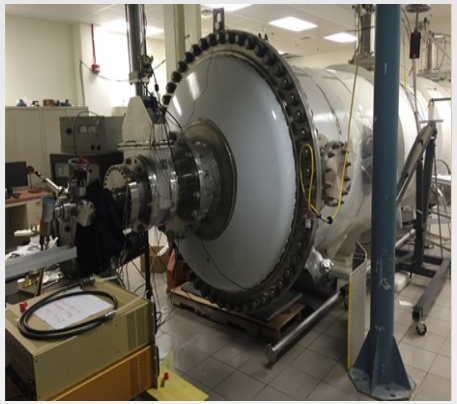
W.H.Baumgartner(1), S.D.Bongiorno(1), P.R.Champey(1), S.P.Cheney(1), C.G.Davis(2), J.A. Gaskin(1), J.Kolodziejczak(1), P.Panini(3), D.D.Smith (1)

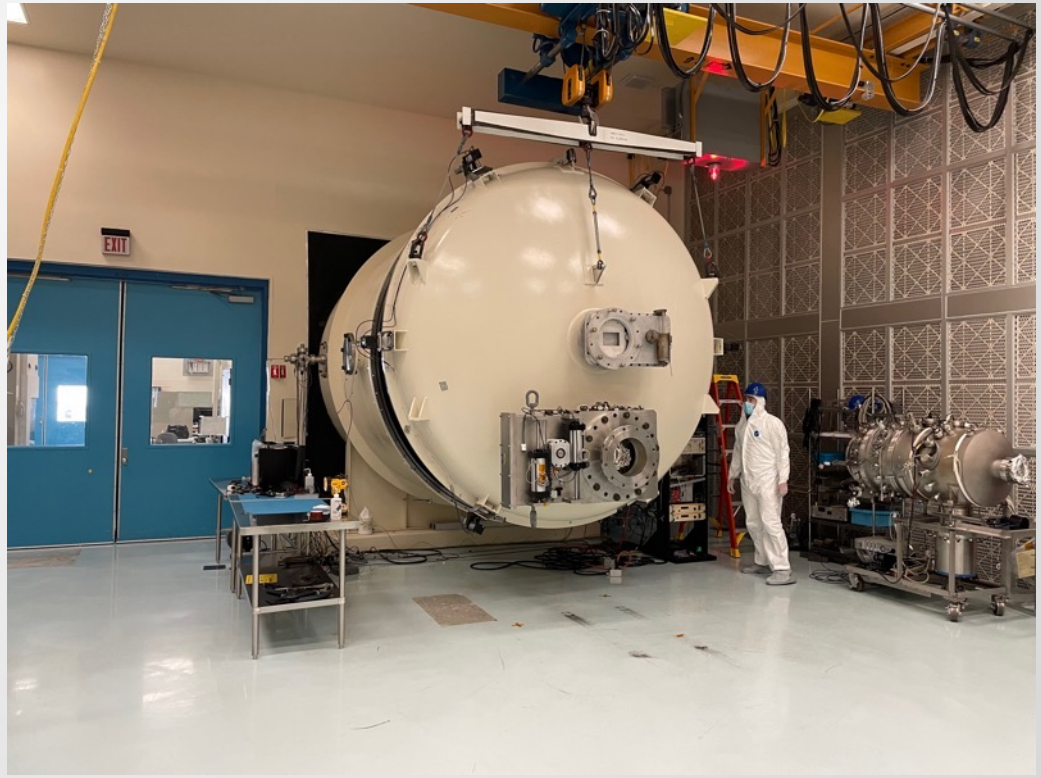
(1)MSFC (2)Polaris Sensor Technologies (3) Oak Ridge Associated Universities

X-ray Beamlines

- Calibrate X-ray Telescopes
  - X-ray optics, collimators, grating spectrometers, and detectors
  - Parallel beam, characterized spectrum, polarized source
  - High vacuum
  - Facility detectors and stages
  - Flexible for small and large projects
  - Cleanroom, laser alignment, lifting
  - Focal length, plate scale/PSF size, and effective area

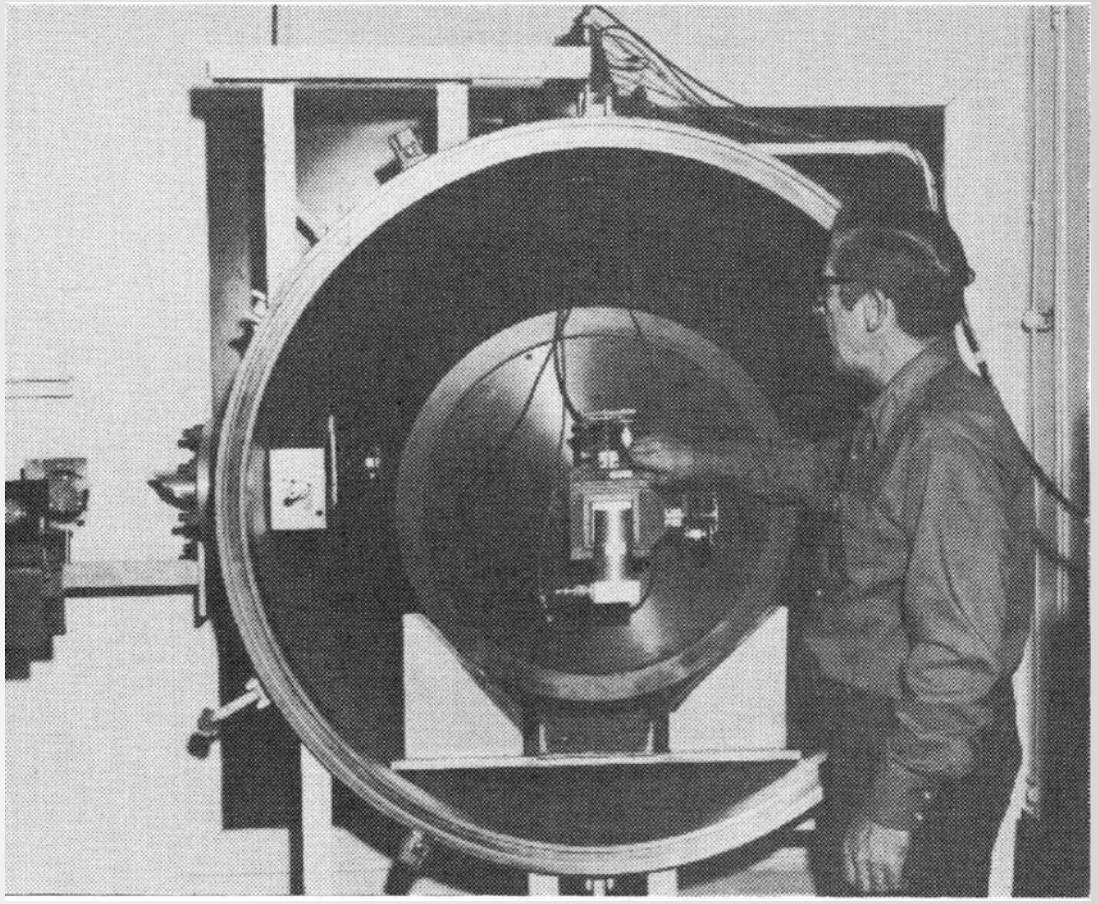
The Marshall 100 Meter



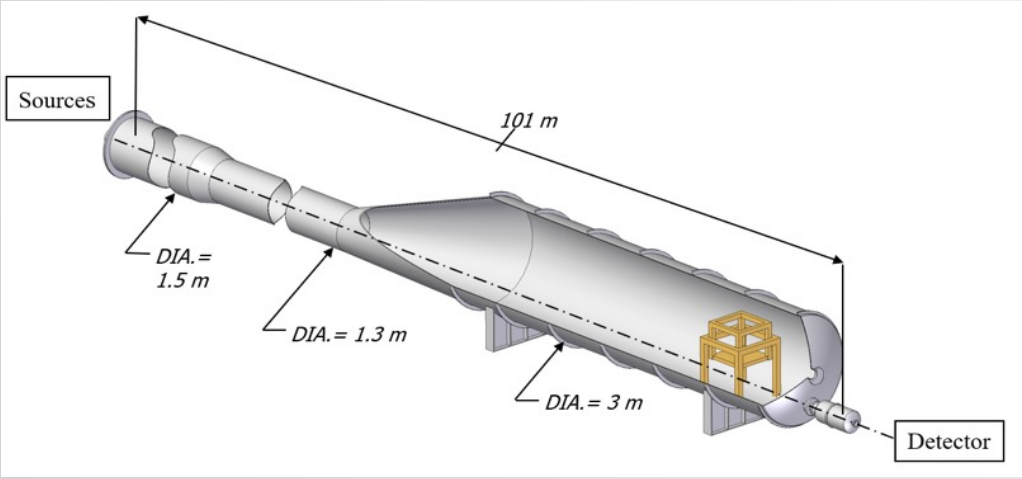


The Stray Light Test Facility

- Constructed in 1963 to test stray light suppression
- Large Space Telescope (Hubble) Stray Light Suppression System designs compared to analytical models (1970s)
- Remains useful for optical testing



C. L. Wyman, et al. "Analysis and Experimental Measurement of Straylight Suppression Systems for the Large Space Telescope," Optical Engineering 14(6), pp. 528 – 532, 1975.



- Total facility: 101 meters long
- Beam pipe: 1.3 meter-wide
- Detector chamber: 3 meter-wide, 8 meters-long

Previous Missions Tested at the Marshall 100-Mete

HERO/HEROES (balloon)

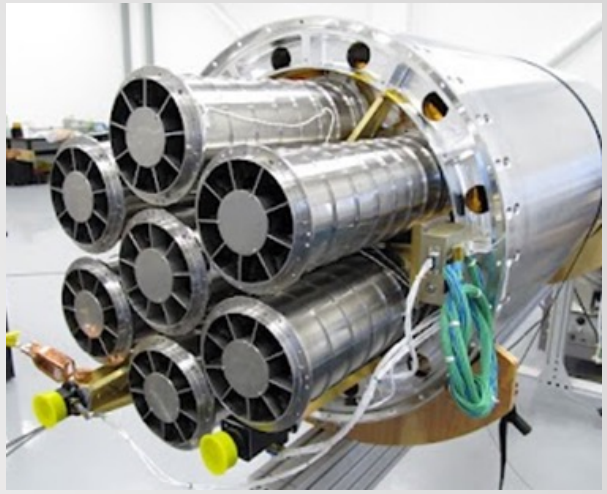
- High Energy Replicated 5 flights, latest Optics/to Explore the Sun
- 8 Mirror Module Assembly (MMA), 13/14 shell
- Last fling in 2013
- Pathfinder for MSFC X-ray optics.

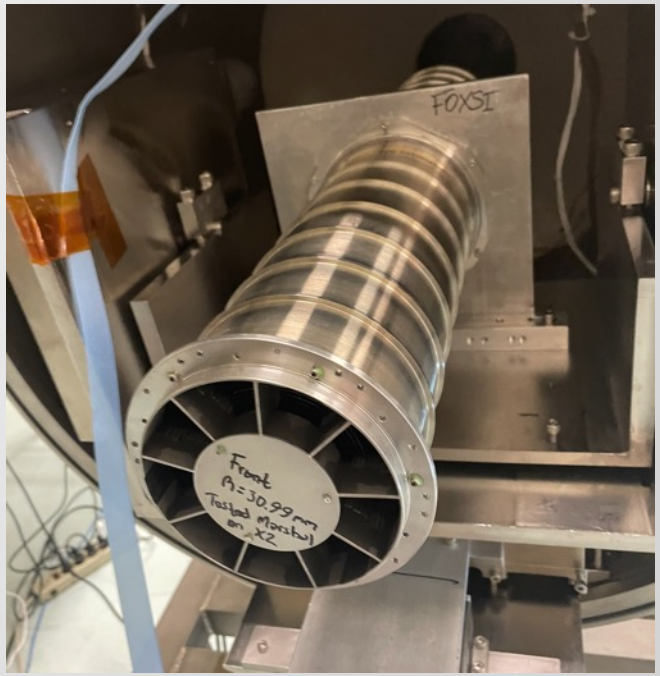
FOXSI (Sounding Rocket)

- Previous Focusing Optics X-ray Solar Imager
- 7 MMA, 7/10 shells
- Three previous flights
- Next flight March 2024

HERO and HEROES

FOSXI





Space Telescope tested at the Marshall 100-Meter

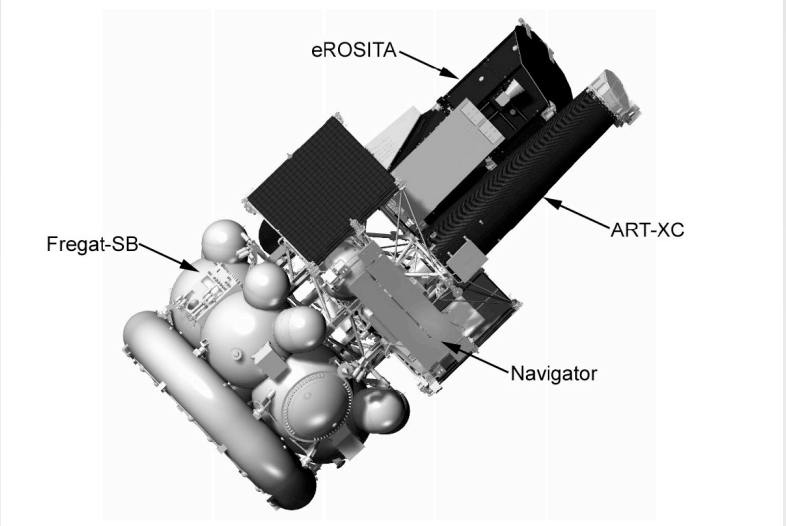
ART-XC

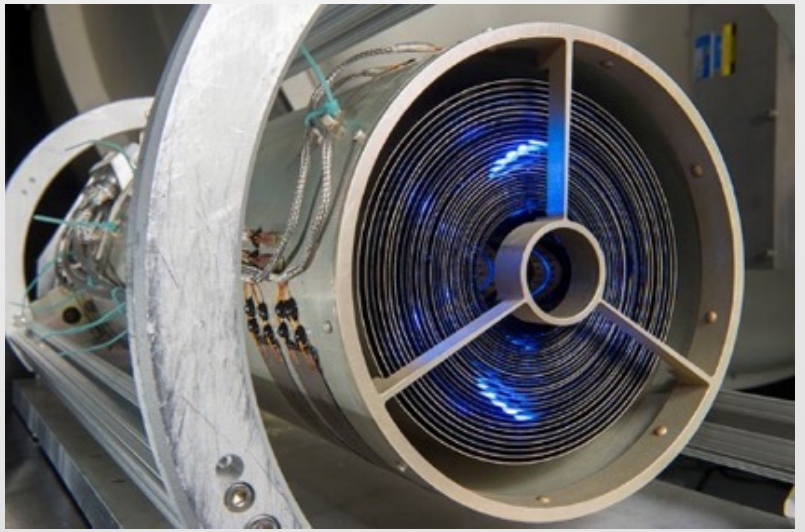
- Astronomical Roentgen Telescope X-ray Concentrator
- 8 MMA qualified, 28 shells, qualified
- Launched with eROSITA on the Spektr-RG (SRG) space observatory in July 2019.
- Hard X-ray observatory 6 to 30 keV

IXPE (SMEX)

- 4 Modules, 24 shells
- Polarization sensitive, 2 to 8 keV
- Launched 12/9/21

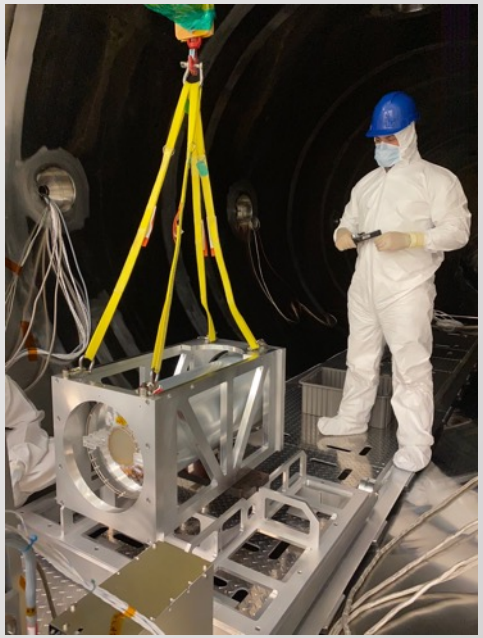
ART-XC





IXPE

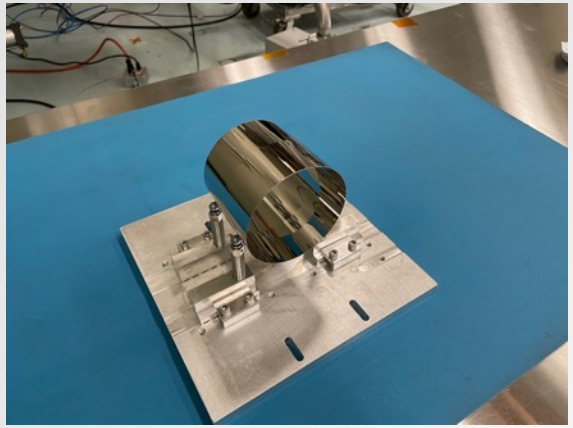
https://ixpe.msfc.nasa.gov/multimedia/images/



Recent Programs

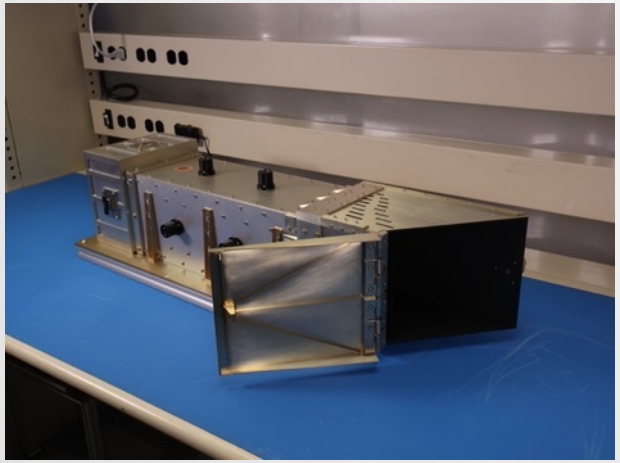
MiXO

- Miniature X-ray Optics
- Center for Astrophysics-Harvard & Smithsonian (PI Romaine- SAO)
- Develop lightweight Wolter-I optics for Small-Sat through PICASSO
- S. Romaine Wed 3:00 RM 17A



LEXI

- Lunar Environment Heliospheric X-ray Imager
- (PI Wash - Boston University) Spring 2022
- Full instrument calibration
- Lunar lander mounted Launched set for 2024

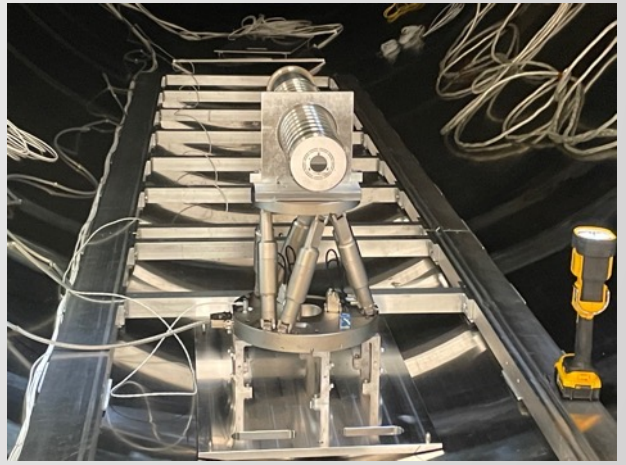


SSAXI

- SmallSat Solar Activity X-ray Imager
- (PI Moore, SAO) Spring 2023
- Flying with Hi-C from Poker Flat, Alaska as a sounding rocket mission in the spring of 2024.

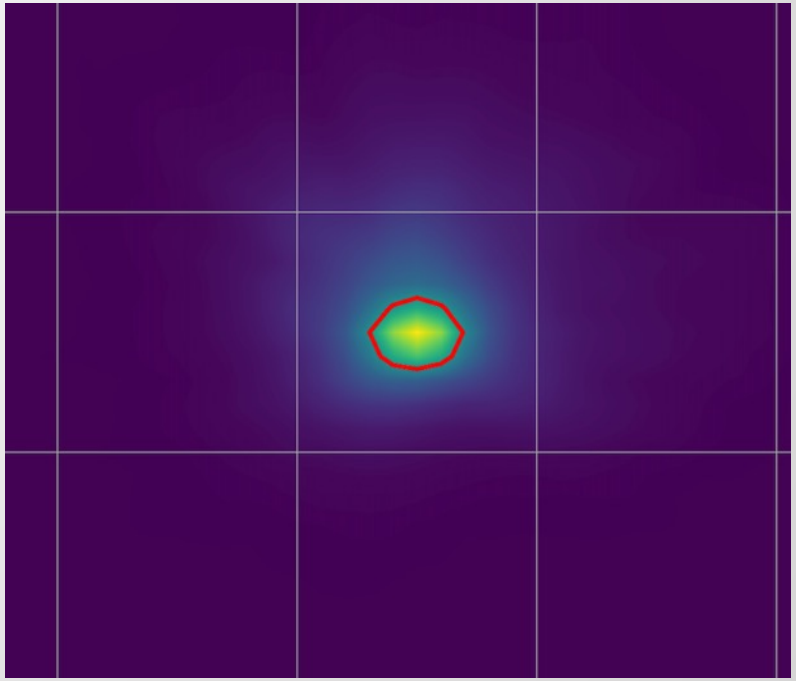
FOXSI-IV

- (PI Glesener - University of Minnesota)
- Extensively calibrated at the over the last year.
- FOXSI-IV will also launch from Poker Flat in the spring of 2024.
- Baumgartner Wednesday 2:20 RM 17A
- S. Bongiorno Wednesday 2:40 RM17A



On Going

Project	Institution	Dates
FOXSI-4 with Nagoya University	Nagoya University	July 2023
Gravity-sag of light-weighted optics	MSFC	July 2023
Facility Maintenance	MSFC Beamline Team	August 2023
Neutron Microscope single shell Concentrator optic	NIST and MSFC	September 2023
MIXO gravity compensation test	SAO and MSFC	September 2023
ISFM high resolution shell	MSFC	October-November 2023
MaGIXS	MSFC	December 2024



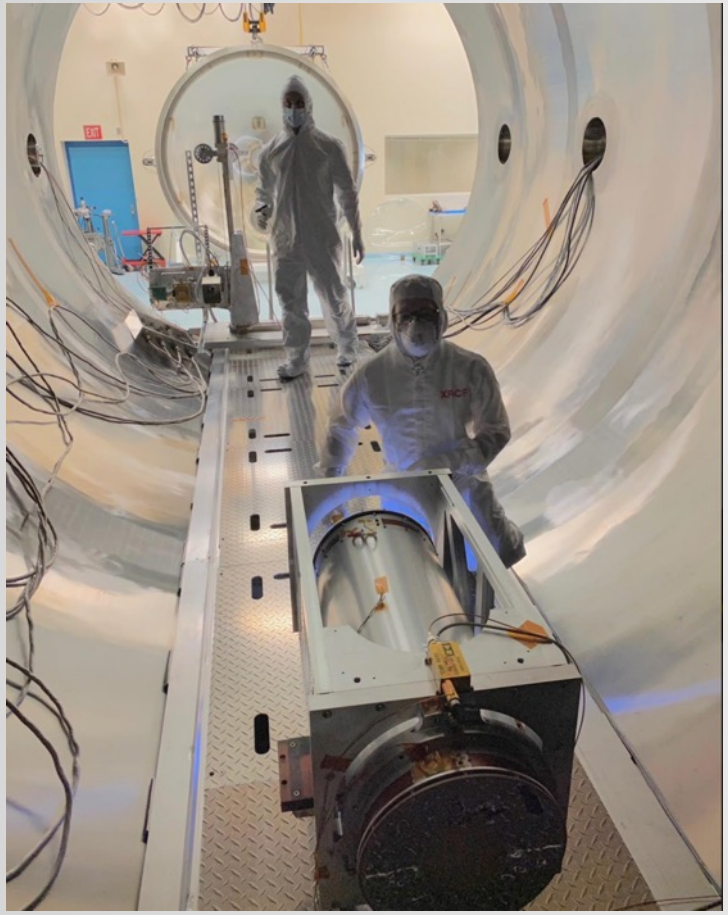
Marshall 100 Meter

General facility information

- 3 Rotary piston roughing pumps with blowers
  - Gets chamber 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 (takes several hours)
  - Not necessary but helps reduce gas load on cryo pumps to allow longer and lower pump downs
- 3 Cryo pumps
  - 2 cooled by compressed helium
  - 1 cooled by compressed helium and LN2 shroud
  - Normal Operation is with two cryo pumps 10^{-6} Torr
  - With 3rd cryo we can do 10^{-7} Torr
  - 48 hours of LN2 supply for 3rd cryo before needing to refill tank (1000 gallons) to keep it within “safety” margins.
- 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

Marshall 100 Meter

General facility information



- Cleanrooms
  - 10 K instrument chamber with flow bench
  - 100 K work/staging area (control room)
  - Gowning facility
  - Hermetic electronic feed through flanges (No Cadmium)
- Loading dock accessible

Marshall 100 Meter

Source Room

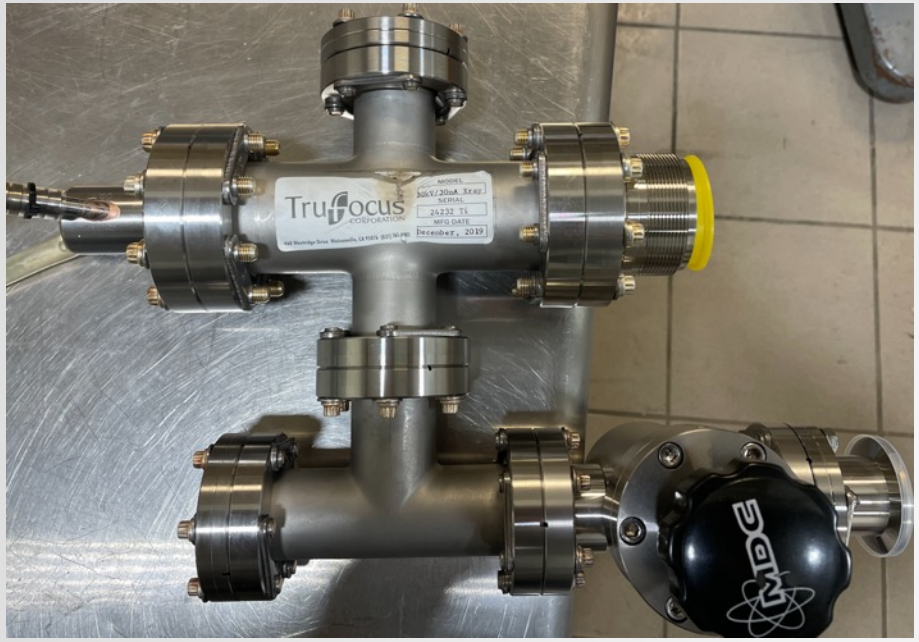
- Sub arcsecond sources
- Flange alignment stage
- Controlled from detector room
- Filters available (Lebow Company, XRCF)

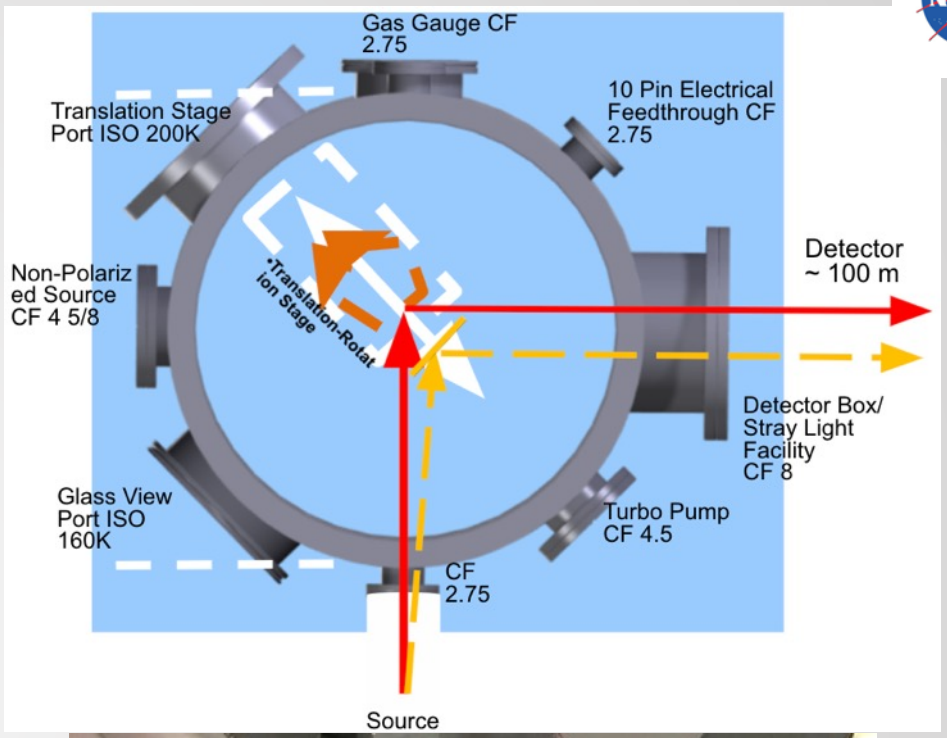
Tube Brand	Anode	Line (keV)	Max Voltage (kV)	Max Current (mA)
TruFocus 6050	Mo	2.2(l), 17.5(ka)	50	1
(Be window)	Rh	2.7(l), 20.2(ka)	50	2
	Ti	4.5(ka)	50	2
	Fe	6.4(ka)	50	1
	Cu	8.1(ka)	50	1
TFX3110EW	W	8.4(l), 59(ka)	110	2.5
TruFocus-10-2-AL	Al	1.49(ka)	8.5	0.5
Manson Source	var	var	10	1

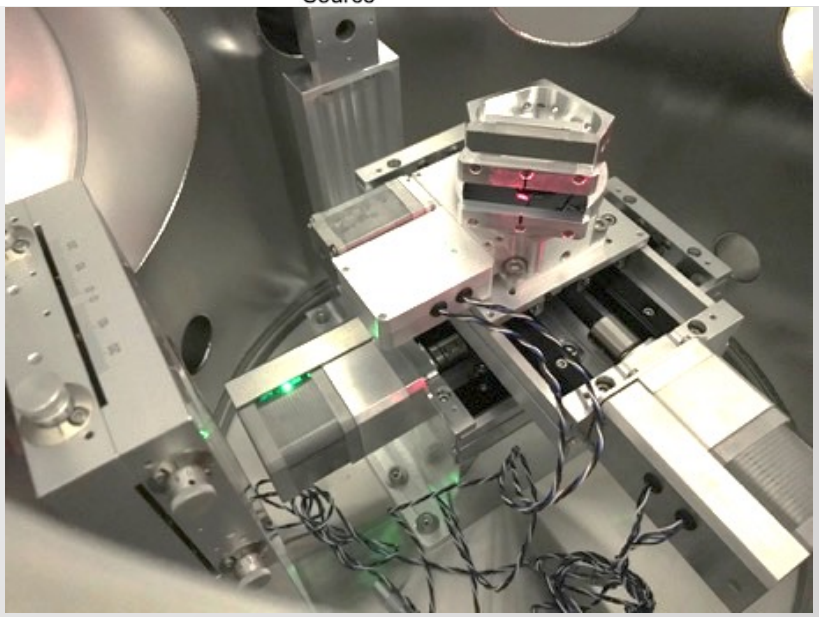
Marshall 100 Meter

Source Room

Trufocus 30kV/30mA Source







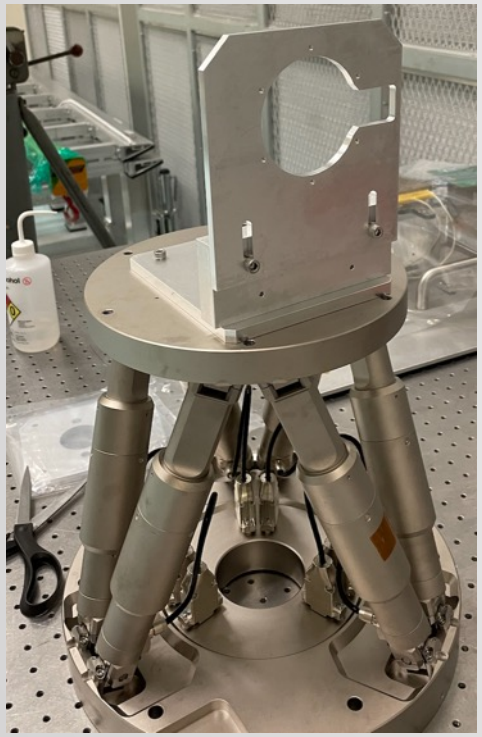
Anode	Line (keV)	Max Voltage (kV)	Max Current (mA)	Crystal
Rh	2.7	30	30	Ge(111)
Ti	4.5	30	30	Si(220)
Fe	6.4	30	30	aSi(400)

Marshall 100 Meter

Vacuum motion stages

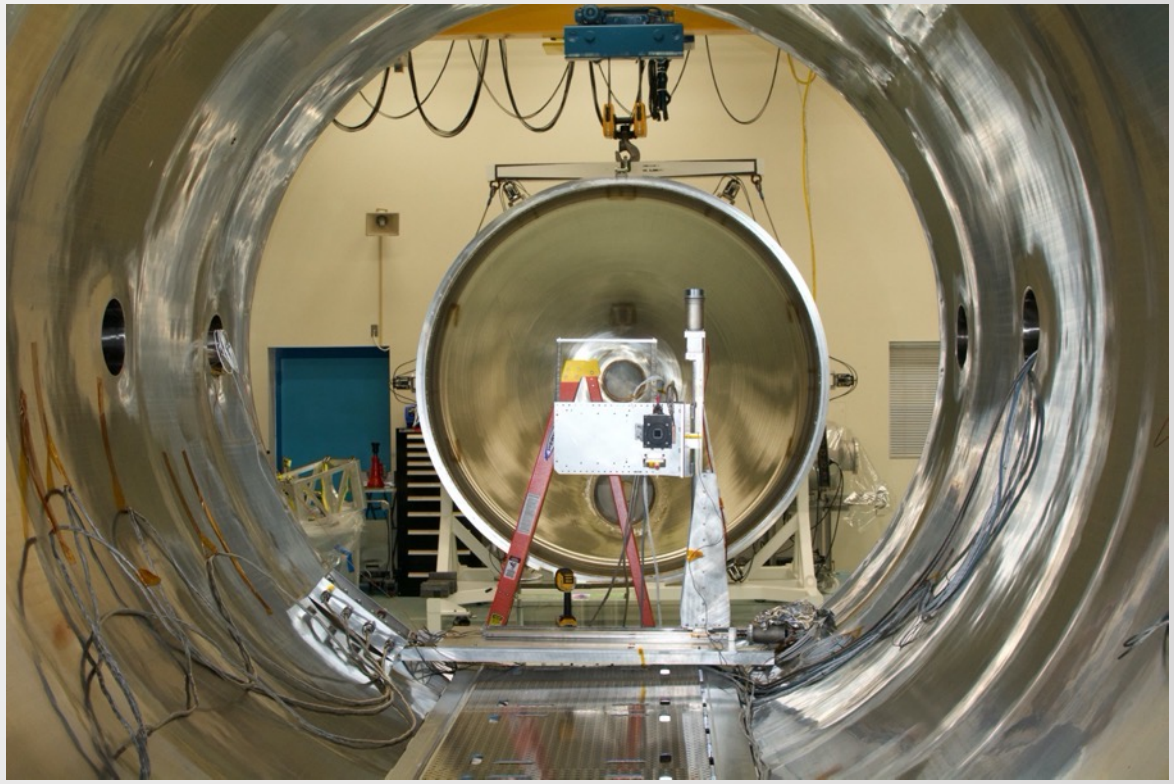
Hexapod (H-850)

- 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

Marshall 100 Meter

Facility Detectors

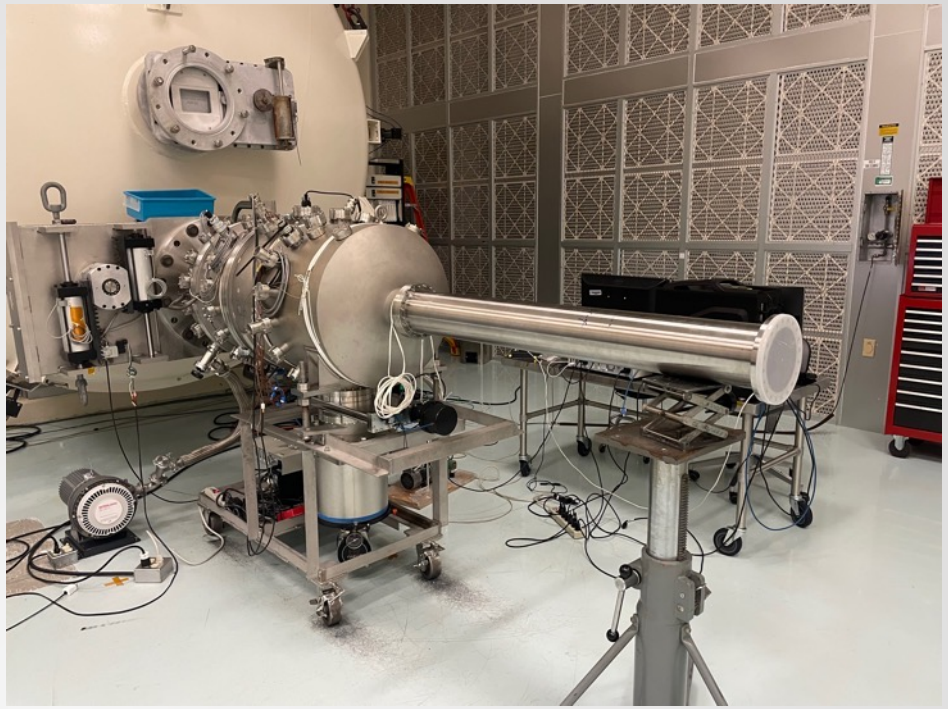
- CCD
  - Andor DW436, SN 10513
  - 2048 X 2048 array of 13.5 μ m pixel
  - Optical blocking filter and shutter
  - Operates at -45 deg C
  - Characterize point spread function of beam.
- SDD
  - Amptek Fast-SDD (50 mm^2)
  - 12.5 μ m Be window
  - Si3N4 ‘C-I’ window (17 mm^2)
  - Fast count rate/low 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

Marshall 100 Meter

Bell housing

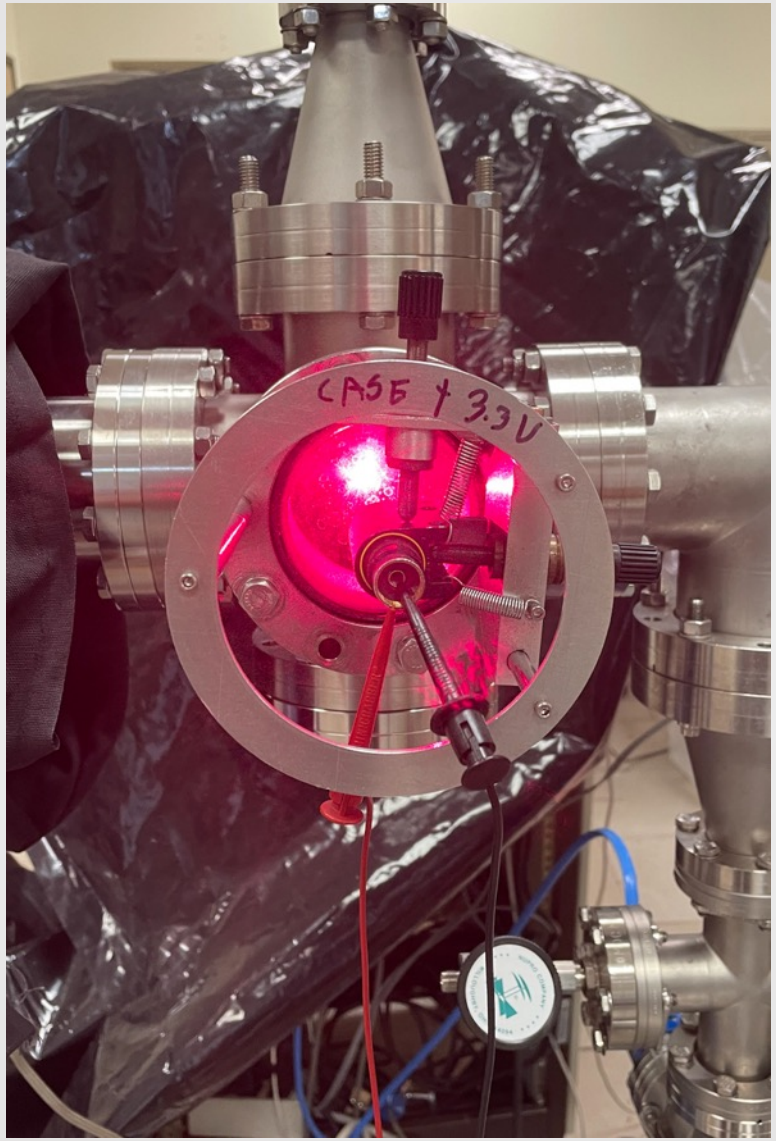
- The Bell Housing
  - External vacuum chamber, co-linear to the beamline
  - Quick turnaround on test optics
  - Internal Tip, Pan, and linear Z-stage
    (Arc minute res/ 0.1 mm res)
  - External Andor CCD camera
    2048 X 2048 array of 13.5 μm pixel
    5 MHz pixel readout speed
    Air cool, -45 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 cool -25 C, water cool -45 C
  - Be window allows for SDD measurements
  - Additional tubing added for longer focal length optics

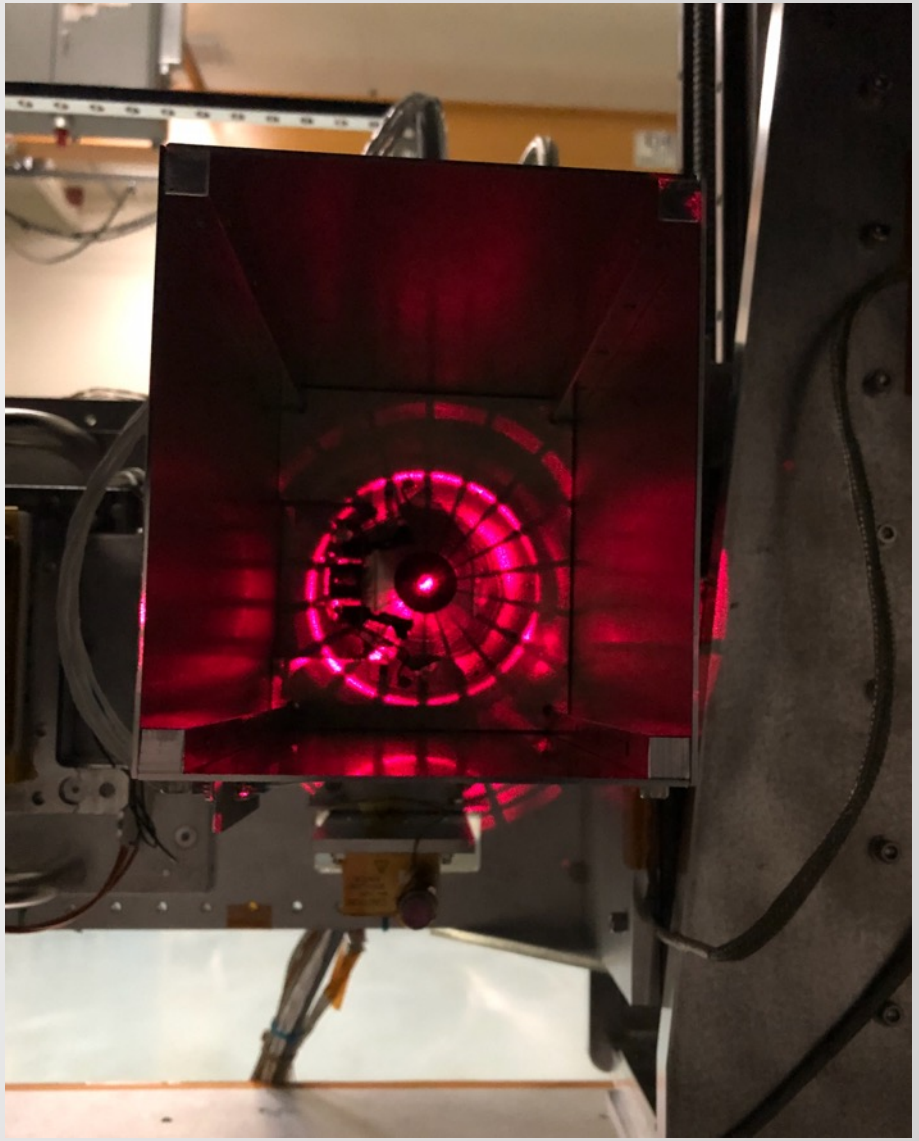


Marshall 100 Meter

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





Marshall 100 Meter

Amenities

- Overhead gantry chain in cleanroom
- Full access to beam-pipe when vented
- Leica laser range tracker
- Temperature housekeeping
- Electronic feed through flanges
- Highly motivated assistance from team of scientist and engineers

Summary

- The Marshall 100 Meter X-ray Beamline (*aka 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 Meter is advertised to all successful APRA funded projects. For additional community support (NASA Centers, Universities, and Industry) please contact:

nicholas.e.thomas@nasa.gov
wayne.baumgartner@nasa.gov
stephen.p.cheney@nasa.gov
jessica.gaskin@nasa.gov

Back-Up filters

- 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

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