Marshall Space Flight Center Optics Capabilities

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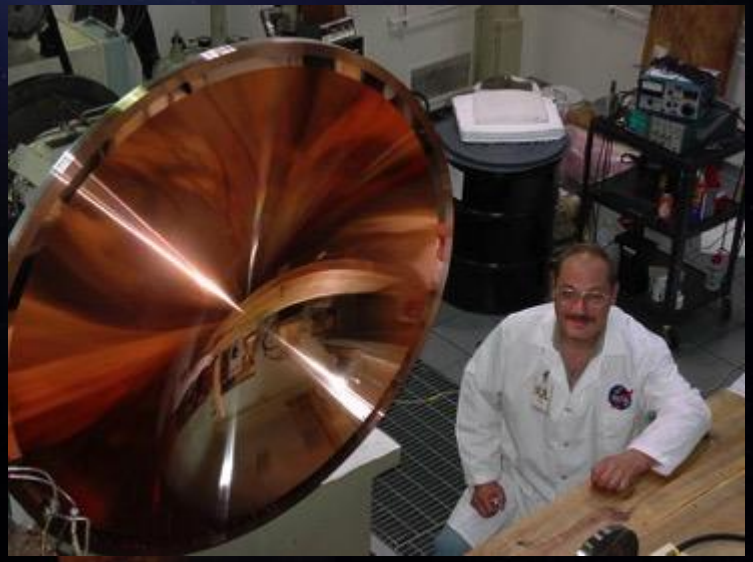
Precision Engineering/Diamond Turning



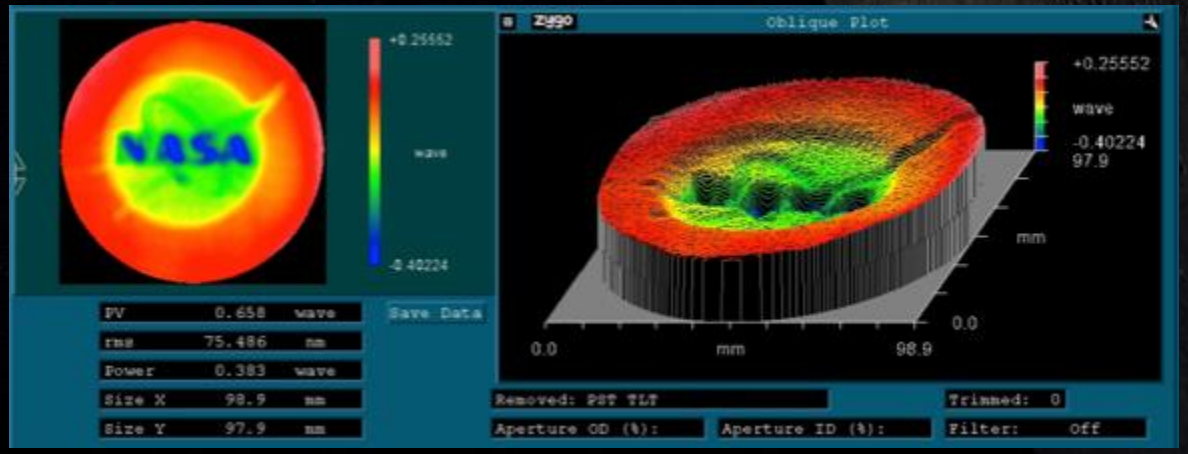
1.5 m copper mold for pressing Fresnel lenses cut under Space Act Agreement

MOORE M-40

Facility currently consist of two ultra high precision diamond turning machines with face turning capabilities of 2 meters and 0.4 meters, cylinder turning to 1 meter, one EDM and two high precision CNC machine tools and conventional machine tools. Extensive metrology support is available.

Optical Shop

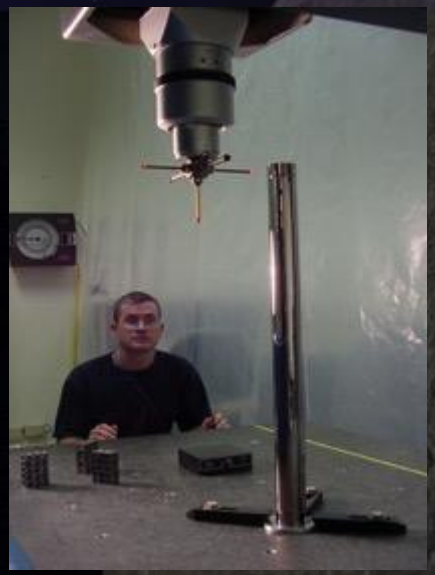
- **Equipment includes curve generators, spindle grinders/polishers, a Blanchard, an edger and a 48 inch continuous polisher.**
- **Custom built polishing machines that are capable of polishing X-ray mirror mandrels 40 - 500 mm in diameter and 305 - 610 mm in length to less than 5 arcsec in figure and less than 4 Å roughness.**
- **Zeeko IRP600 Intelligent Robotic Polisher machine able to grind and polish parts up to 600 mm in diameter to a surface roughness of 5 Å.**
- **OptiPro 300 6-axis Free Form Polisher able to grind and polish parts up to 300 mm in diameter to a surface roughness of 5 Å.**



NASA logo ground into a glass flat in approximately 1 hour on the Zeeko.

Metrology Facilities/Equipment

Zygo GPI with 32 inch beam expander & Mark IV with 18-in beam expander



Coordinate Measuring Machine

- 1 micron accuracy
- parts up up to 1 m

2 Zygo NewView optical profilometers

- Sub Angstrom vertical resolution.
- Sub micron lateral resolution.

Vertical Long-Trace Profilometer

- One of two in existence
- Incorporates rotary air bearing table
- Scan Length: 0.7 m
- Range: 10 m rad.
- Accuracy: 10 nm surface height (theoretical)
- Cylinders/shells up to 0.7-m long x 0.75-m diameter

Stray-light Test Facility

CLASS 10K CLEAN ROOM
AND CHAMBER

OPPOSITE: END OF ROOM TUBE

MAIN CHAMBER AND PREP AREA

3 by12-m test volume for baffle or mirror

1.3-m diameter, 82-m long section

1.5-m diameter, 10-m isolatable section

Pumped with cryo-pump: $<10^{-7}$ torr

Measured baffle rejection ratios up to 10^{15}

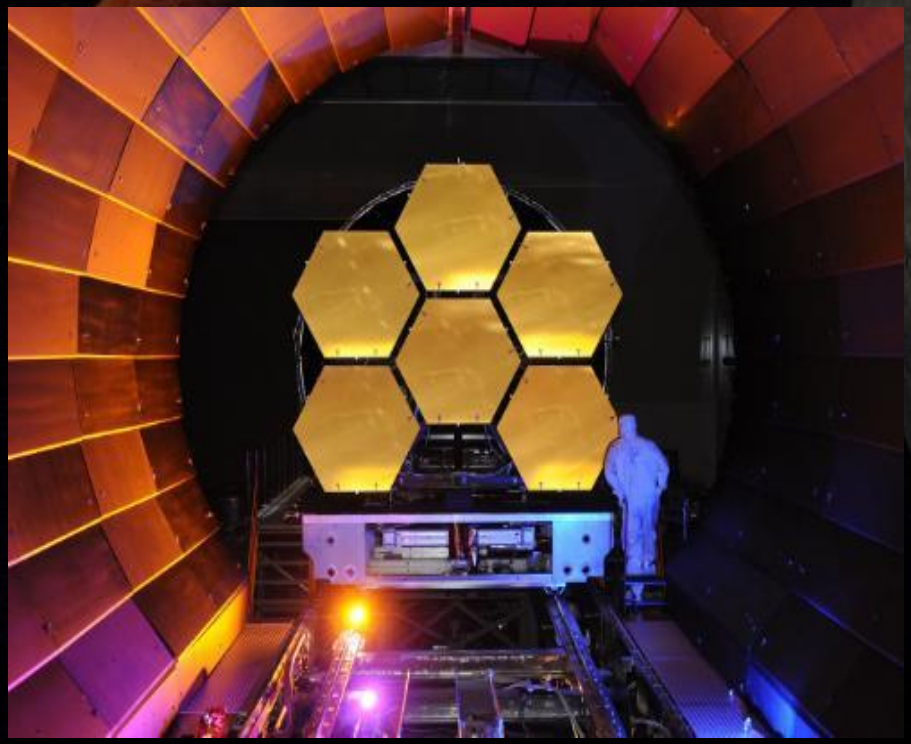
Use to test x-ray optics up to 1-m dia

X-Ray and Cryogenic Facility (XRCF)

James Webb Space Telescope flight mirror segments were tested in the (XRCF), the same facility that tested the Chandra X-ray telescope at MSFC. The test chamber offers the unique capability for simulating a space environment with low temperature and pressure.

Vacuum Chamber

- **7.3 x 22.8 m Polished Stainless Steel 10-7 Torr Vacuum Chamber**
- **Full 155 to 355K Thermal Shroud – Helium shroud to 20K**
- **Vibration Isolated via Seismic Mass**
- **5DOF Remote Controlled Test Stand**

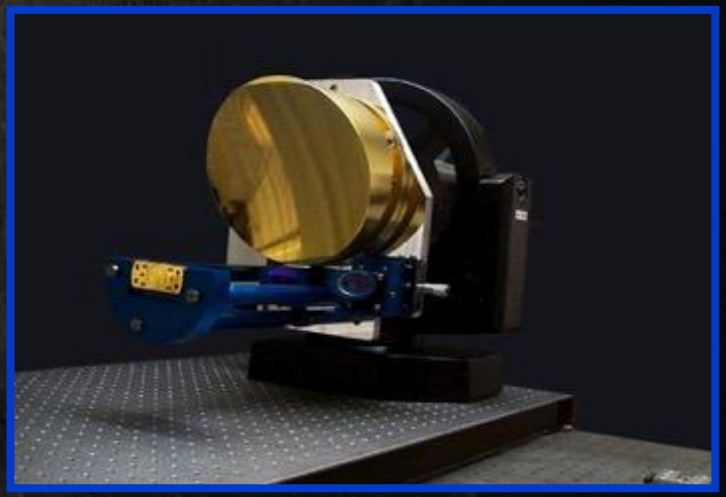


FLIGHT MIRROR DEVELOPMENT

Solar X-ray Imager Mirror on GOES-12 satellite

UV Imager Mirrors on POLAR satellite

Composite Infrared Spectrometer (CIRS) Mirrors on CASSINI



Sparcle Lidar Beam Expander (flight certified but not flown)

Return to Flight Imaging

- Supplied the optical system for the airborne imaging of the Space Shuttle at launch and on portions of the reentry.
- Operates in unpressurized nose ball of a WB-57 aircraft at 60,000 foot altitude
- Visible & NIR, Schmidt-Cassegrain, 28 cm diameter primary mirror, 2.8-meter focal length
- Completed the design using COTS equipment
- Manufactured the optical bench and performed the optical integaration
- Environmentally tested the system prior to flight.
- System continues to be flown in support of Eastern Test Range and KSC launches.

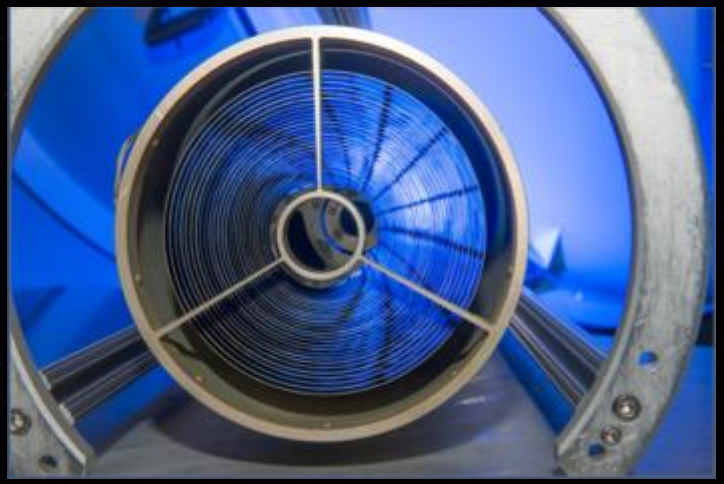
STS-115 – September 9, 2006

Pluto New Horizons – January 19, 2006

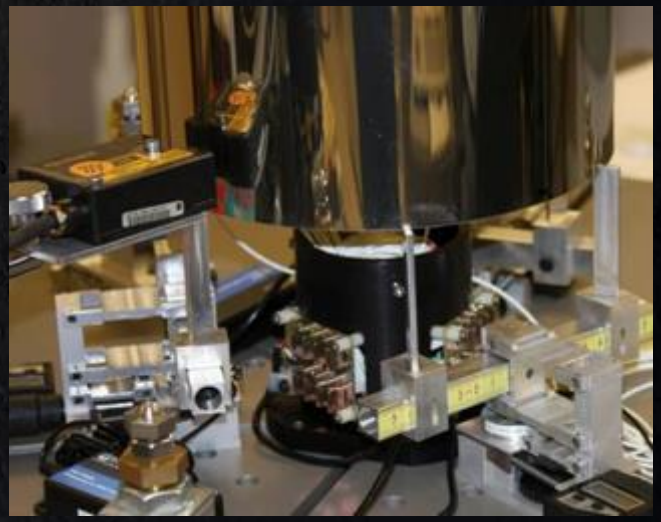
Astronomical Roentgen Telescope X-Ray Concentrator (ART-XC)

- **Manufactured for the Russian Spectrum Mission**
- **28 precision mandrels for the replication of ~ 200 mirror shells (15 arcsec figure, 5 Å roughness)**
- **30 keV (0.083 - 1.24 nm), Wolter 1, 5.0 to 14.9 cm mirror diameter, 2.7-meter focal length**
- **Produce 7 flight modules plus 1 spare unit including mirror housings and support spiders**
- **Tested modules in Stray Light Facility**

Mandrel Inspection



Module in Handling Fixture



Shell alignment

Replicated Optics Manufacturing Process

1. CNC machine, mandrel formation from Al Bar

2. Chemical clean and activation & Electroless Nickel (EN) plate

3. Precision turn to sub-micron figure accuracy

4. Polish and superpolish to 3-4 Å finish

5. Metrology – **repeat Step 4 until surface finish met**

6. Ultrasonic clean and passivation to remove surface contaminants

7. Electroform nickel shell onto mandrel

8. Separate optic from mandrel – reuse mandrel for next shell

8. Align shells into module

9. Test module

Sounding Rockets

Solar Ultraviolet Magnetospheric Investigation (SUMI)

- **SUMI flew on a sounding rocket in 2010**
- **λ=155 & 280 nm, Ritchey-Chretein, 30 cm diameter primary**
- **Provided primary and secondary mirrors, heat rejection mirror, four fold mirrors, two off-axis parabolas and two diffraction gratings**

SUMI Integration

High Resolution Coronal Imager (Hi-C)

- **Hi-C launched on a sounding rocket on July 11, 2012 and obtained the highest resolution images of the Sun's corona ever acquired**
- **λ=193 Å, Cassegrain, 22 cm diameter primary mirror, 23.0-meter focal length**
- **Provided the primary and secondary aspheric mirrors to the Smithsonian Astrophysics Observatory (SAO)**
- **The primary was hand polished to a slope error of .09 arcsec and the secondary to .25 arcsec**

Hi-C Primary polishing

MSFC Partnerships Office

Reimbursable SAA - Money coming into NASA

- Permits the partner to use NASA goods, services, facilities, or equipment to advance the partner's own interests
- Primary benefit to partner that is consistent with NASA's mission.

Non-reimbursable SAA - No funds exchanged

- Used to support collaborative technology development, outreach activities and educational partnerships.
- Mutually beneficial activity that furthers NASA's mission
  - Not used to obtain services from partner
- Look for "quid pro quo" contribution between NASA and partner.

Identify opportunity – Could NASA assist me with this?
Evaluate the possibility to partner – Is the opportunity within NASA's authorization
Develop agreement jointly – NASA and the partner agree on scope, schedule and cost
Capture and finalize the agreement – Good coordination ensures a timely review and approval
Execute the agreement – another successful partnership with NASA begins

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Summary of MSFC Unique Capabilities

- ***MSFC has a unique capability to manufacture and test grazing incidence optics.***
  - The capability to develop, fabricate and test electroformed nickel optics at MSFC is unique in the United States; in fact, there are only two such capabilities in the world, the other residing in Italy.
  - MSFC has state of the art metrology capabilities to test and verify that the grazing incidence mirrors meet design requirements.
  - The Stray Light Test Facility (SLTF) is a smaller less expensive and more flexible alternative to the XRCF.
- **MSFC world class optical capabilities include: Moore M-40 Diamond Turning Machine, Vertical Long Trace Profilometer (VLTP), X-Ray Cryogenic Facility (XRCF) and Stray Light Facility**
- **MSFC is a vital participant in manufacturing and testing optics for a range of customers. Partnerships exists with NASA/GSFE, NASA/KSC, Dept. of Energy, National Institute of Health, DARPA, SAO, MIT, UC Berkley, University of Iowa and others.**