Development of Mirror Modules for the ART-XC Instrument

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[1]NASA Marshall Space Flight Ctr., Huntsville, AL 35812, USA
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ABSTRACT

The Marshall Space Flight Center (MSFC) is developing x-ray mirror modules for the ART-XC instrument on board the Spectrum-Roentgen-Gamma Mission under a Reimbursable Agreement between NASA and the Russian Space Research Institute (IKI.) ART-XC will consist of seven co-aligned x-ray mirror modules with seven corresponding CdTe focal plane detectors. Currently, four of the modules are being fabricated by the Marshall Space Flight Center (MSFC.) Each MSFC module provides an effective area of 65 cm^2 at 8 keV, response out to 30 keV, and an angular resolution of 45 arcsec or better HPD. We will present a status of the ART x-ray module development at MSFC.

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SRG overview

✓The Spectrum-Röntgen-Gamma (SRG) mission is a Russian-German X-ray astrophysical observatory that carries two co-aligned X-ray telescope systems.

✓The primary instrument is the German-led **e**xtended **RO**entgen **S**urvey with an **I**maging **T**elescope **A**rray (eROSITA), a 7-module X-ray telescope system that covers the energy range from 0.2-12 keV.

✓The complementary instrument is the Russian-led **A**stronomical **R**oentgen **T**elescope – **X**-ray **C**oncentrator (ART-XC or ART), a 7-module X-ray telescope system that provides higher energy coverage, up to 30 keV.

Parameter	ART	eROSITA
Energy Range	5-30 keV	0.2-12 keV
Effective Area	455 cm^2 at 8 keV	2500 cm^2 at 1 keV
Field of View	32 arcmin	1 deg
System Angular Resolution (on axis)	1 arcmin	15 arcsec
Energy Resolution	1.4 keV at 14 keV	130 eV at 6 keV

ART optics

MSFC has designed and is fabricating four ART x-ray optics modules under an International Reimbursable Agreement between NASA and with IKI.

Deliverables: 1 engineering unit (6 shells + mass simulators) and 4 flight units (28 shells/unit)

Parameter	Value
Number of Mirror Modules	7=4+3
Number of Shells per Module	28
Shell Coating	> 10 nm of iridium (> 90% bulk density)
Shell Total Length, inner and outer diameters	580 mm, 50 mm, 150 mm
Encircled Half Energy Width	Less than 1 mm diameter, center of field of view Less than 2.5 mm diameter, 15 arcmin off axis
Mirror Module Effective Area	≥ 65 cm^2 at 8 keV (on axis)
Module Focal Length	2700±1 mm
Allowable Total Mass per Module	17 kg including thermal control system
Minimal resonance frequency	40 Hz
Operating Temperature Range	17° C to 23° C

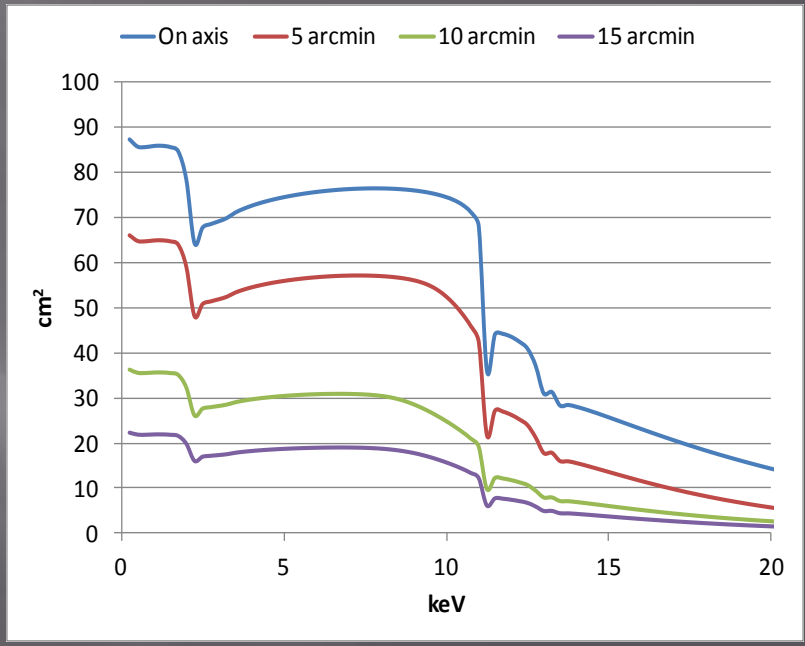
ART optics

MSFC is utilizing electroformed-nickel replication (ENR) to fabricate four ART X-ray mirror modules.

In this process a thin nickel or nickel-alloy mirror shell is electroformed onto a figured and super-polished electroless-nickel-plated aluminum mandrel, from which it is subsequently separated in chilled water by differential thermal contraction.

Wolter I prescription for ART mirrors. The goal angular resolution for the ART mirror module is 30 arcseconds HPD.

The science-derived effective area requirement for the optics is > 65 cm^2 at 8 keV on axis



Calculated effective area of ART x-ray optics module

Heritage

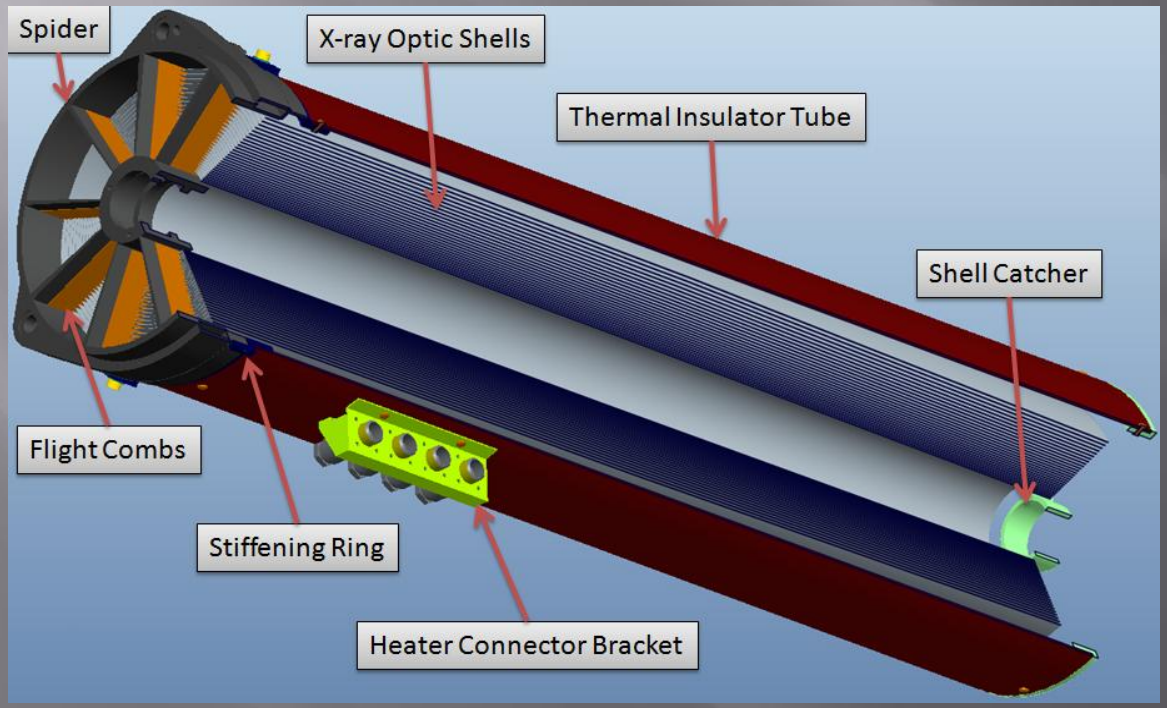
FOXSI : Focusing Optics X-ray Solar Imager

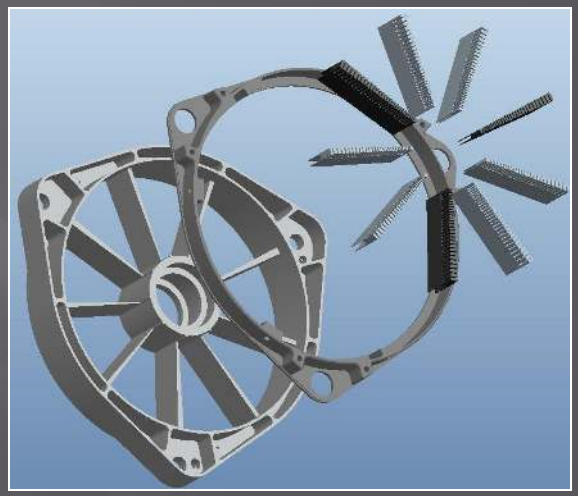
- Focal Length: 2 m
- Number of modules: 7
- Number of shells: 7 (10)
- Optics Type: Wolter I
- Outer shells radius: 51.51 mm
- Inner shell radius: 37.99 mm (32.48 mm)
- Shell length: 60 cm.
- Energy range: 4 – 15 keV

✓Similar launch loads
✓Shell thickness – 250 microns
✓Two spider support structure
✓The predicted resonance frequency spectrum matches well to measured during vibration tests
✓Two FOXSI outer shells show gravitational sag due to the way they are supported

Mechanical design

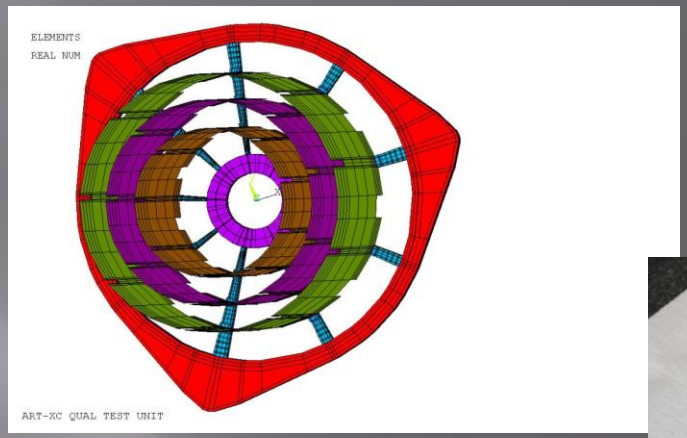
- One spider design allows to increase the thickness of outer shells (250 – 350 micron)
- Lowest calculated resonance frequency is 52.44Hz with requirement of 40 Hz
- Estimated weight margin is 1kg
- The mechanical stress estimates are conservative ; the margin is 1.7 (requirement is 1.5.)





Mechanichal Design – Qual Unit

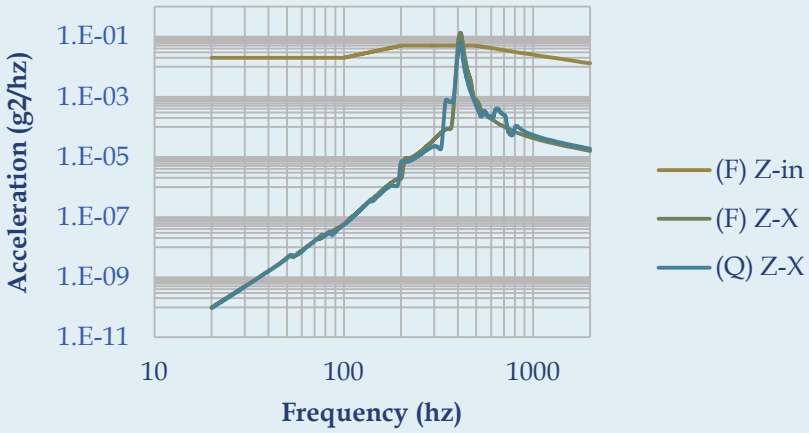
3 mass simulators and 6 shells installed on the spider



Mass simulators installed on the spider

Spider for the qualification unit

PSD Response to Z direction Input



- ✓Three most inner shells
- ✓Three most outer shells
- ✓Three mass simulators to replace missing shells (diameters are 74, 101.3 and 126.4 mm)
- ✓Spider has the same design as for the flight modules
- ✓The clips have the same size grooves for the shells, but the grooves for the simulators are deeper.

Infrastructure

Polishing stations

To support the aggressive ART module fabrication schedule, MSFC has greatly expanded its infrastructure:

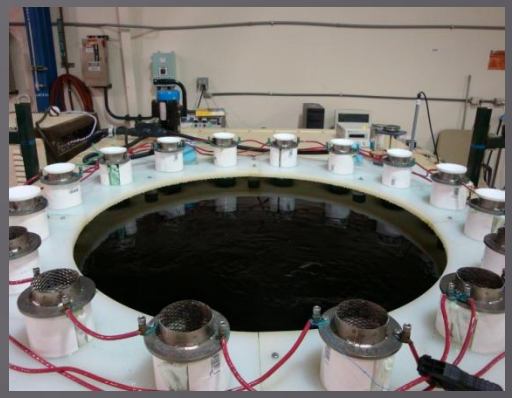
-5 polishing stations dedicated to ART

-Built an additional electroform bath

- five alignment stations (scaled down versions of the FOXSI alignment system) are being built

-two coating chambers are built

-Two optical interferometers and the vertical long trace profilometer are dedicated to the ART project



One of two plating baths

ART alignment station

ART coating chambers

ART-e-facts

- Opto-mechanical design is completed. The design review was held at the IKI in February
- All aluminum blanks are coated with the electroless nickel
- 20 mandrels are diamond turned, 10 are being polished, 5 completed
- Testing of the iridium coating chambers is completed;
- 13 shell mirrors has been plated, 5 mirrors are coated with Ir. The acceptance x-ray tests are under way.
- Spider, clips and mass-simulators for the qualification unit are fabricated
- Spiders for the flight units are fabricated
- Alignment systems are being assembled

Spiders with bafles for 5 (4 + 1 spare) flight and 1 qual units

Mass simulators for qualification unit

Future

- Qualification unit to be tested in September
- Mandrels to be completed by October
- Mirror shell fabrication to be completed by January
- Delivery – June 2013

Conclusions

- MSFC is developing four x-ray mirror modules for the ART-XC instrument on board the SRG Mission under an International Reimbursable Agreement between NASA and the IKI.
- To support the aggressive ART module fabrication schedule, MSFC has greatly expanded its infrastructure to meet the demands of mandrel polishing, shell fabrication, shell coating, and module assembly.
- MSFC is on schedule to deliver flight units in the Summer of 2013.

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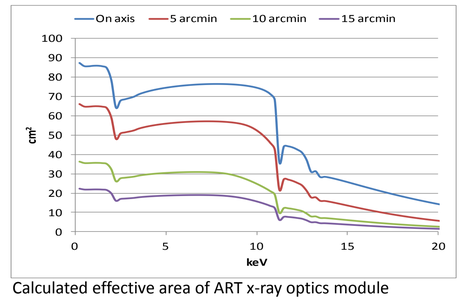
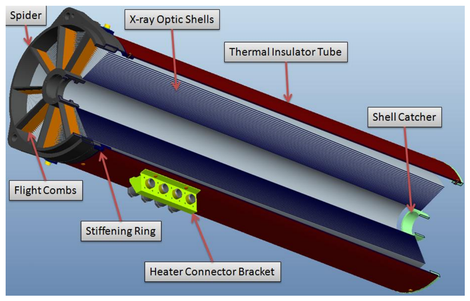


Calculated effective area of ART x-ray optics module



X-ray Optics Module design

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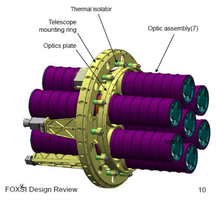
Heritage

Hero

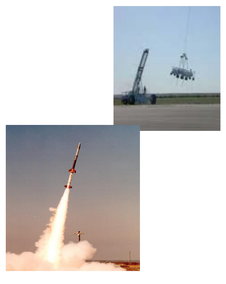
Foxsi



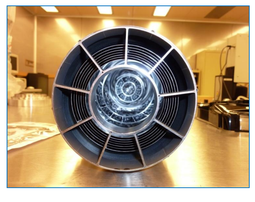

60 cm length – 5 cm diameter - 250 μm thick

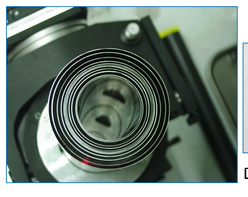

Down to 50 μm thick

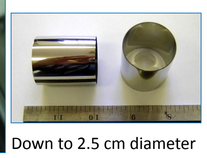

Up to 50 cm diameter



X-ray Optics Projects at MSFC



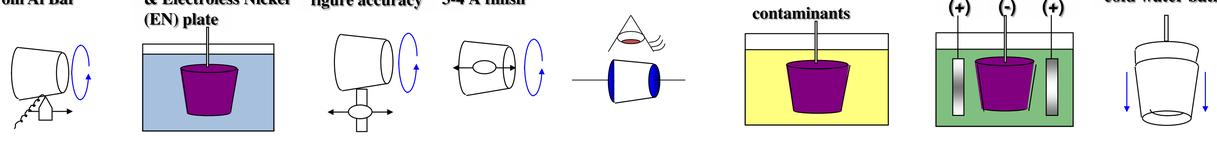


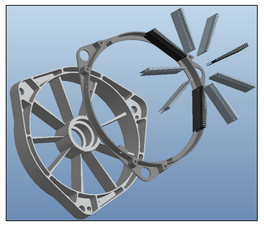

Down to 2.5 cm diameter

Different types of X-ray shells fabricated at MSFC

Electroform Nickel Replication 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 On mandrel
6. Ultrasonic clean and passivation to remove surface contaminants
7. Electroform nickel shell onto mandrel (+) (-) (+)
8. Separate optic from mandrel in cold water bath




Three part design of the ART spider


Spider for the qualification unit


Mass simulators for qualification unit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