

THE MARSHALL SPACE FLIGHT CENTER DEVELOPMENT OF MIRROR MODULES FOR THE ART- XC INSTRUMENT ABOARD THE SPECTRUM-ROENTGEN-GAMMA MISSION

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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 and complementary X-ray telescope systems. The primary instrument is the German-led extended **ROentgen Survey with an Imaging Telescope Array (eROSITA)**¹, a 7-module X-ray telescope system that covers the energy range from 0.2-12 keV. The complementary instrument is the Russian-led **Astronomical Roentgen Telescope - X-ray Concentrator (ART-XC or ART)**, a 7-module X-ray telescope system that provides higher energy coverage, up to 30 keV (with limited sensitivity above 12 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

The SRG observatory will be launched into an approximately low-Earth orbit from Baikonur and then delivered to a 6-month-period halo orbit around the outer Lagrange point (L2) via a Zenit rocket and Fregat booster.

ART optics

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

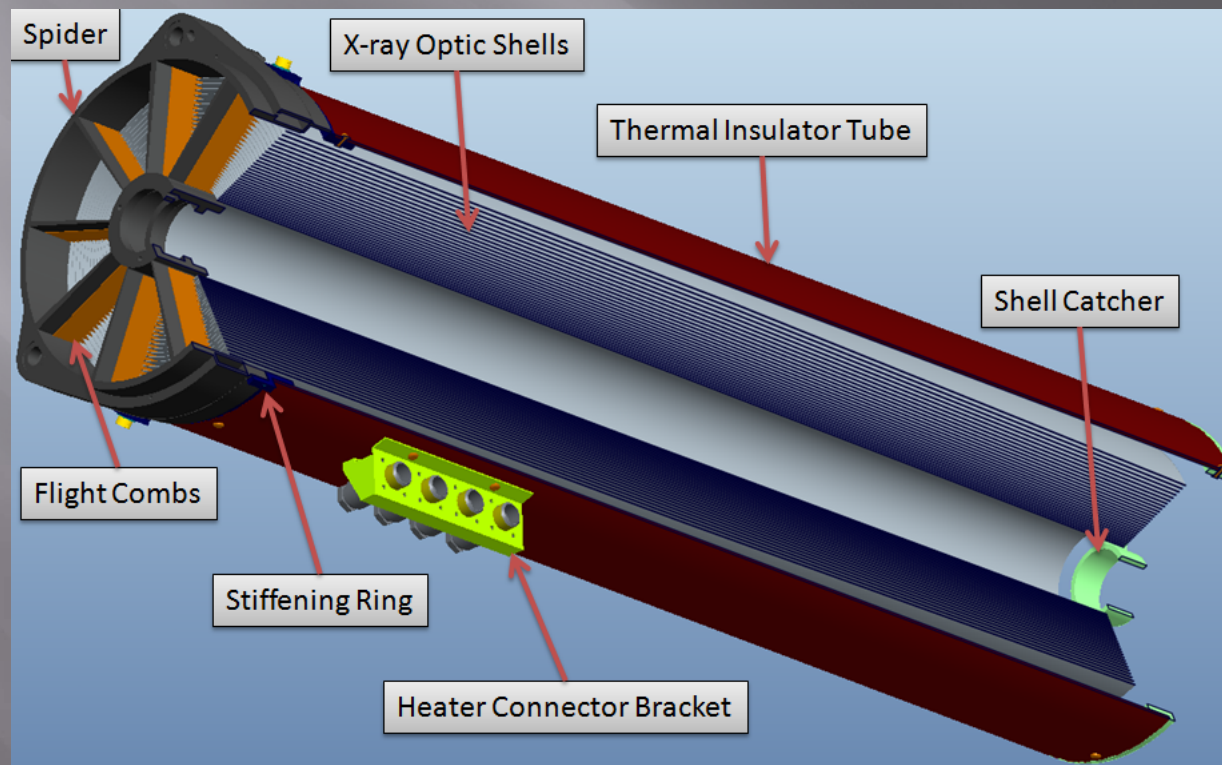
Requirements

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	580 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	$\geq 65 \text{ cm}^2$ at 8 keV (on axis)
Module Focal Length	2700 \pm 1 mm
Allowable Total Mass per Module	17 kg including thermal control system
Operating Temperature Range	17° C to 23° C

1 engineering unit (6 shells plus dummy masses) and 4 flight units (28 shells/unit)

Mechanical design

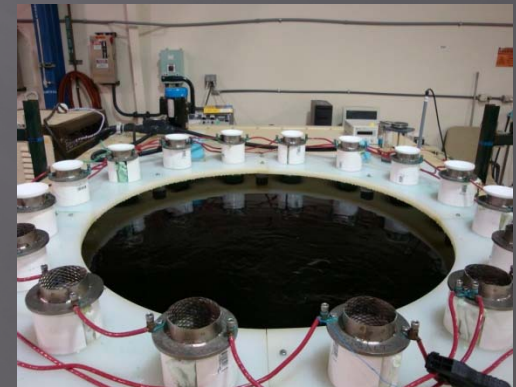
- The current design meets stated design requirements.
- Lowest calculated resonance frequency is 52.44Hz
- Estimated weight margin is 1kg
- The mechanical stress estimates are conservative



Infrastructure

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

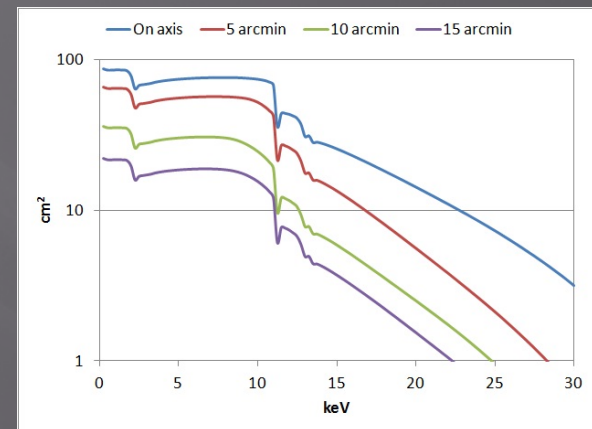


Process

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. One attraction of this ENR process is that the resulting full-shell mirrors are inherently rigid, fostering good angular resolution.

The science-derived effective area requirement for the optics is $> 65 \text{ cm}^2$ at 8 keV on axis, and thus the current design exceeds that value.

The required angular resolution is approximately 1 arcminute (half energy width) and readily satisfied: MSFC-produced X-ray mirror modules are typically at least a factor of two better than this, so the goal angular resolution for the ART mirror module is 30 arcseconds.



ART-e-facts



- ❑ Optical and opto-mechanical design is completed . The design review was held at the IKI in February
- ❑ All aluminum blanks are coated with the electroless nickel
- ❑ 18 mandrels are diamond turned, 5 completed
- ❑ Testing of the iridium coating chambers is completed;
- ❑ Shell fabrication has been started
- ❑ Spider for the qualification unit is fabricated



Future work

- ▣ Qualification unit
- ▣ Mandrels to be completed by October
- ▣ Mirror shell fabrication to be completed by
- ▣ 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. Delivery of these modules to IKI is scheduled for summer 2013 for a scheduled launch in 2014.
- ▣ 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.