The IXO- X-ray Grating Spectrometer (XGS)

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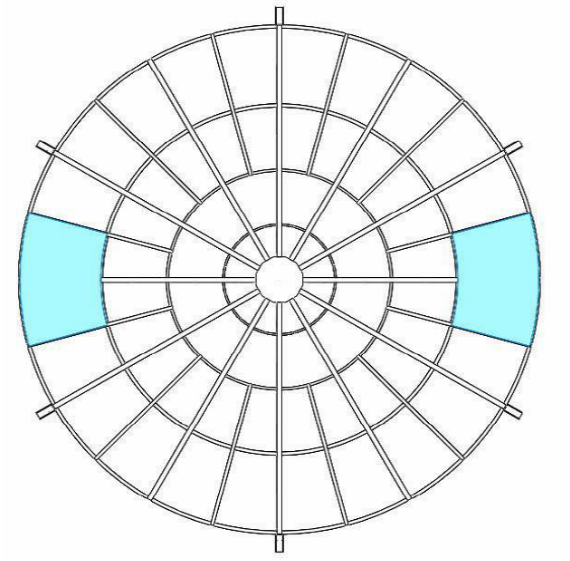
Key Performance Requirements

Mirror Effective Area	3 m^2 @1.25 keV 0.65 m^2 @ 6 keV with a goal of 1 m^2 150 cm^2 @ 30 keV with a goal of 350 cm^2	Black hole evolution, large scale structure, cosmic feedback, EOS Strong gravity, EOS Cosmic acceleration, strong gravity
Spectral Resolution	ΔE = 2.5 eV within 2 x 2 arc min (0.3 – 7 keV) . ΔE = 10 eV within 5 x 5 arc min (0.3 - 7 keV) ΔE < 150 eV @ 6 keV within 18 arc min diameter (0.1 - 15 keV) $E/\Delta E$ = 3000 from 0.3–1 keV with an area of 1,000 cm^2 for point sources ΔE = 1 keV within 8 x 8 arc min (10 – 40 keV)	Black Hole evolution, Large scale structure Missing baryons using tens of background AGN
Mirror Angular Resolution	≤5 arc sec HPD (0.1 – 10 keV) 30 arc sec HPD (10 - 40 keV) with a goal of 5 arc sec	Large scale structure, cosmic feedback, black hole evolution, missing baryons Black hole evolution
Count Rate	1 Crab with >90% throughput. ΔE < 200 eV (0.1 – 15 keV)	Strong gravity, EOS
Polarimetry	1% MDP on 1 mCrab in 100 ksec (2 - 6 keV)	AGN geometry, strong gravity
Astrometry	1 arcsec at 3σ confidence	Black hole evolution
Absolute Timing	50 μsec	Neutron star studies



Grating mirror coverage assumption:

- Selected 1.1m < R < 1.9m; two sectors of 22.5°
- 2.4 kg incl 20% margin each box

XGS camera assumptions:

- Mass ~ 20.4kg incl margins.
- Power ~65 W incl margin + 3W CCD thermal control
- No translation stage needed at 3 σ error level
- Refocusing mechanism needed

Two grating designs under consideration:

CAT – Critical Angle Transmission Grating

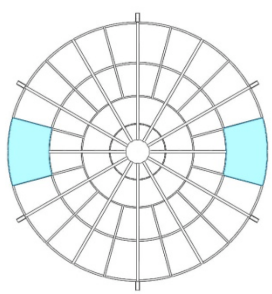
OGS – Off-Plane Grating Spectrometer

Critical-Angle Transmission Grating Spectrometer (CAT-GS)

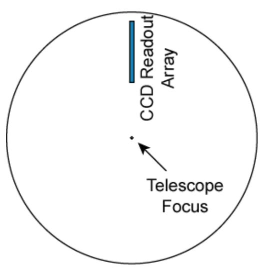
- Based on Chandra TGS heritage
- Similar to Chandra: Low weight, relaxed alignment tolerances
- Improvements:
    - Blazed transmission gratings -> use of higher orders -> higher spectral resolution
    - Broadband high-efficiency gratings -> large effective area
    - Sub-aperturing -> higher spectral resolution

Strawman configuration:

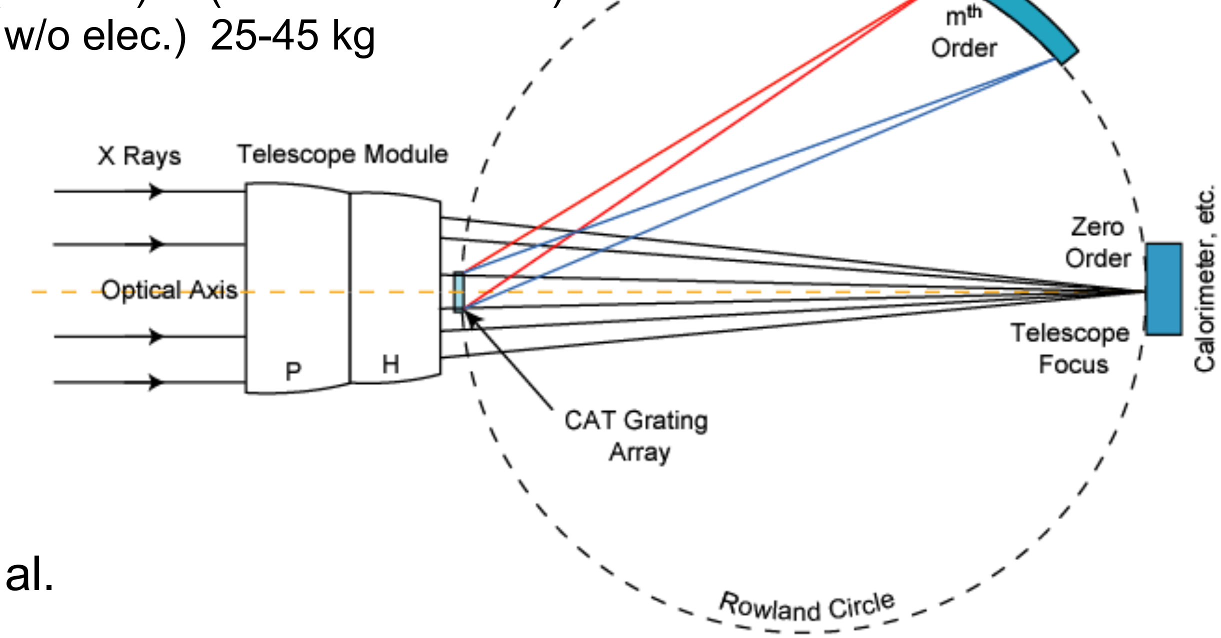
- Cover two opposing pairs of outer mirror modules (2 x 30°)
- Effective area > 1,000 cm^2 (E < 1 keV)
- Resolution E/ΔE > 4500 (FWHM) (E = 0.3 – 1.0 keV)
- Mass (gratings + camera w/o elec.) 25-45 kg



Flight mirror assembly view



Focal Plane



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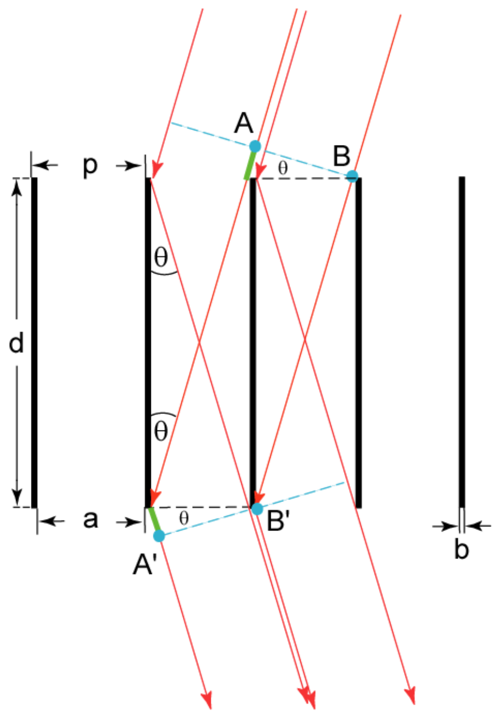
Critical-Angle Transmission Grating Spectrometer: Blazed transmission enabled by the CAT grating

- CAT grating combines advantages of transmission gratings (relaxed alignment, low weight) with high efficiency of blazed reflection gratings.
- Blazing achieved via reflection from grating bar sidewalls at graze angles below the critical angle for total external reflection.
- High energy x rays undergo minimal absorption and contribute to effective area at focus.

CAT grating principle



Grating equation:

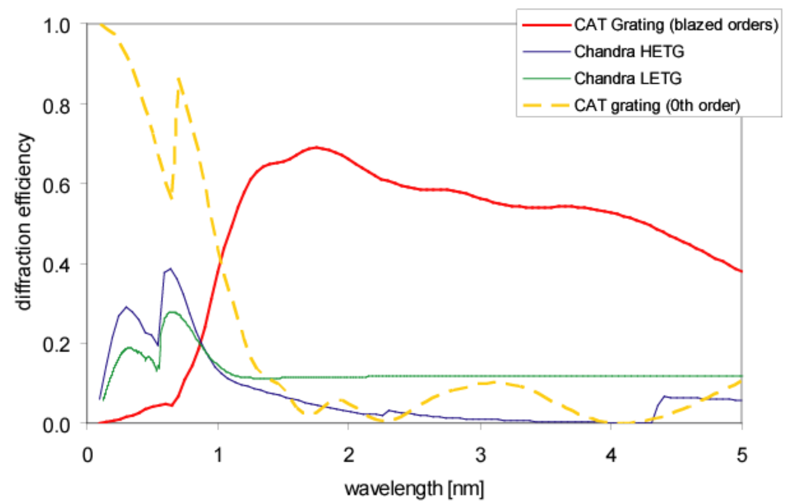
$m\lambda = p(\sin(\theta) + \sin(\beta_m))$,
m = diffraction order

Blazing: $\beta_m \sim \theta$

High reflectivity:
$\theta < \theta_c$ = critical angle of total external reflection

Strawman:
Silicon grating, $\theta = 1.5^{\circ}$
p = 200 nm
b = 40 nm
d = 6 μm
aspect ratio d/b = 150

Efficiency comparison with Chandra gratings



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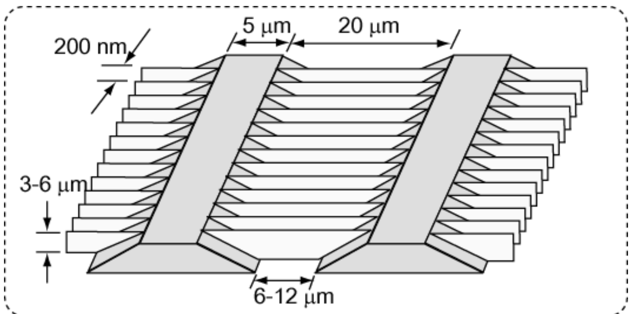
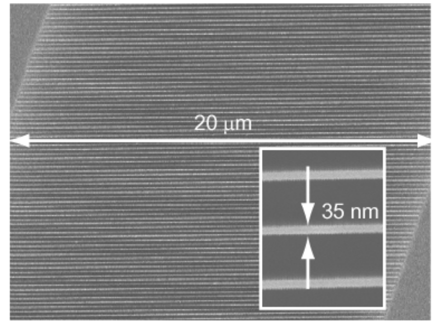
Critical-Angle Transmission Grating Spectrometer: CAT grating fabrication and testing

- Monolithic silicon structure with integrated support bars
- 200 nm period
- achieved design goal of 6 µm tall, 40 nm wide grating bars

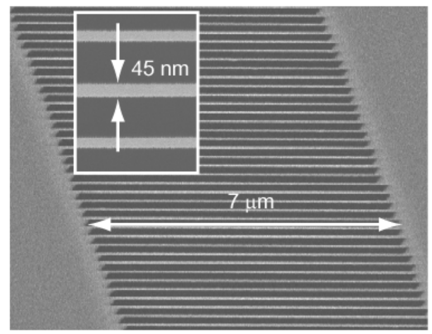


CAT grating schematic

Scanning electron micrographs of 200 nm-period CAT gratings
(a) Top view
(b) Bottom view
(c) Cross section



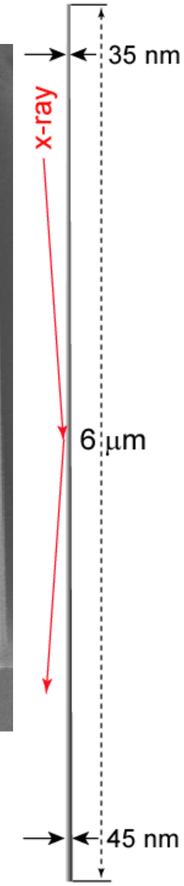
(a)

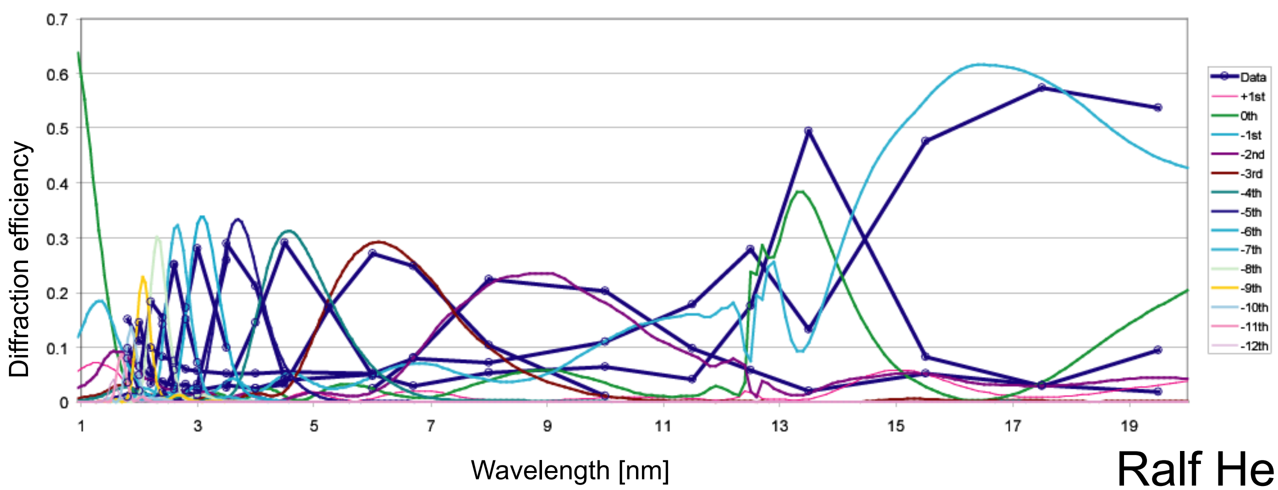


(b)

(c)

Grating bar cross section (drawn to scale)





Comparison between data and theory:
~ 80-100% of theoretical diffraction efficiency

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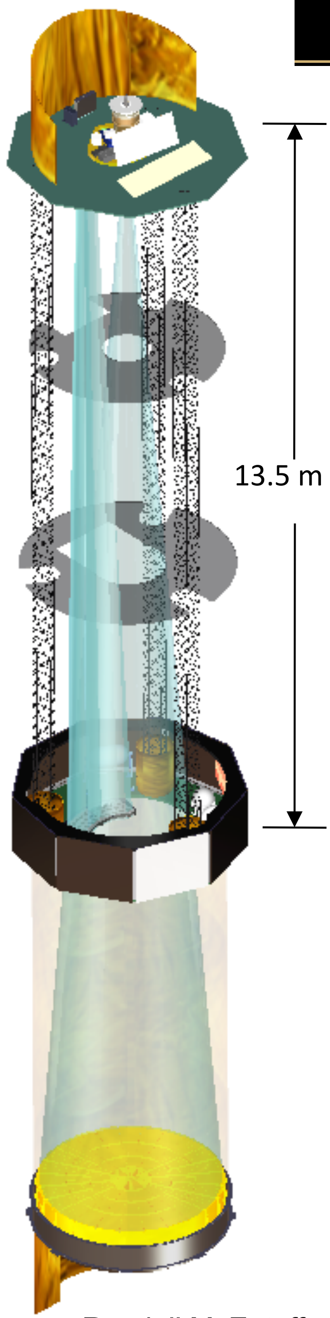
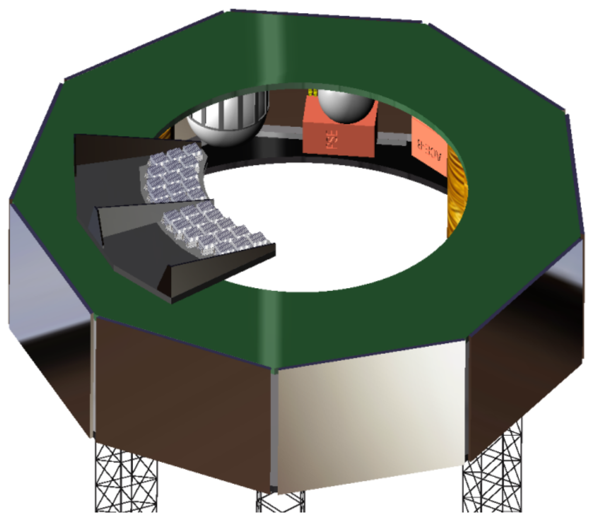
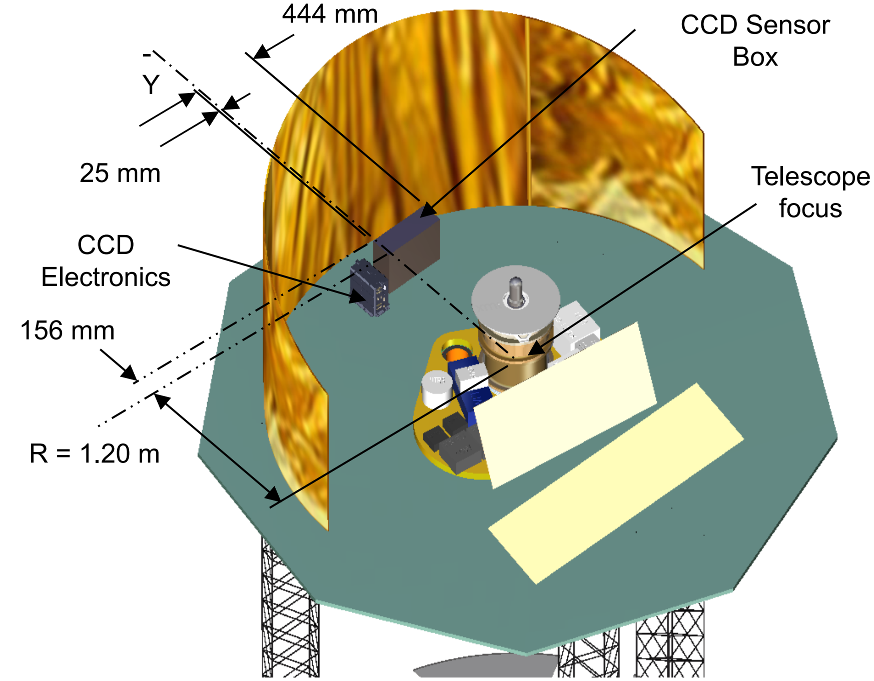
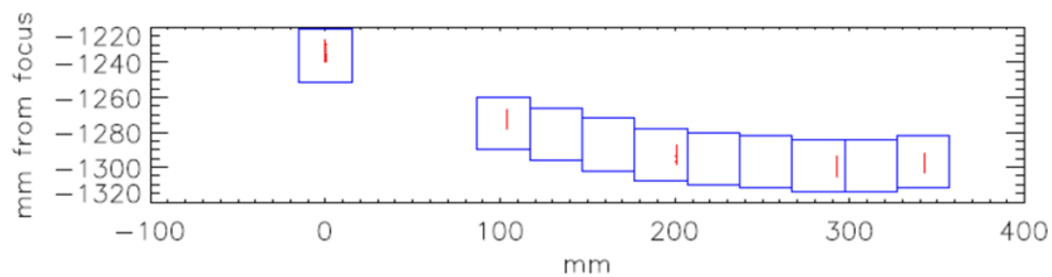


Off-Plane Grating XGS 13.5 m configuration



Grating Mirror Assembly Platform mounted to S/C Platform 13.5 m from telescope focus

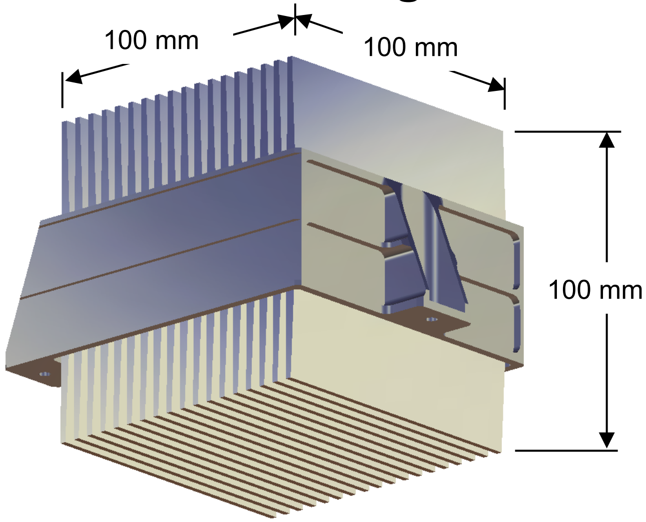


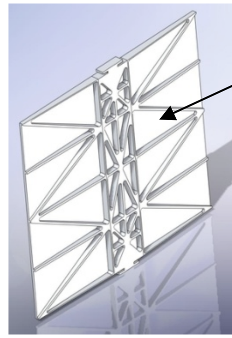


Raytrace determination of CCD position at the focal plane. Blue boxes are 30 mm x 30 mm CCDs (one for zero order camera), red lines are zero order, 12 Å, 24 Å, 36 Å, and 41 Å

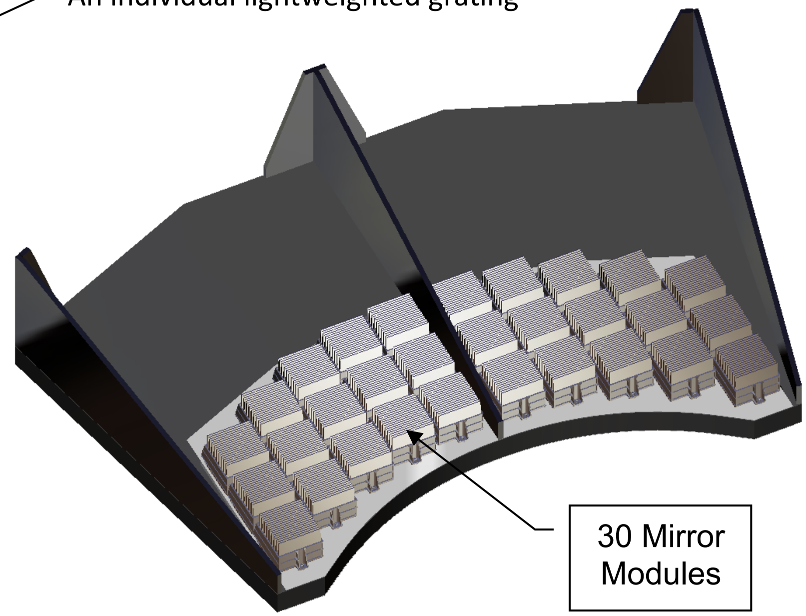
Randall McEntaffer (Iowa), Web Cash, (Colorado), Chuck Lillie, Suzanne Casement, Dean Dailey (Northrop Grumman Space Tech.)

Grating Mirror Assembly Platform Modular Concept

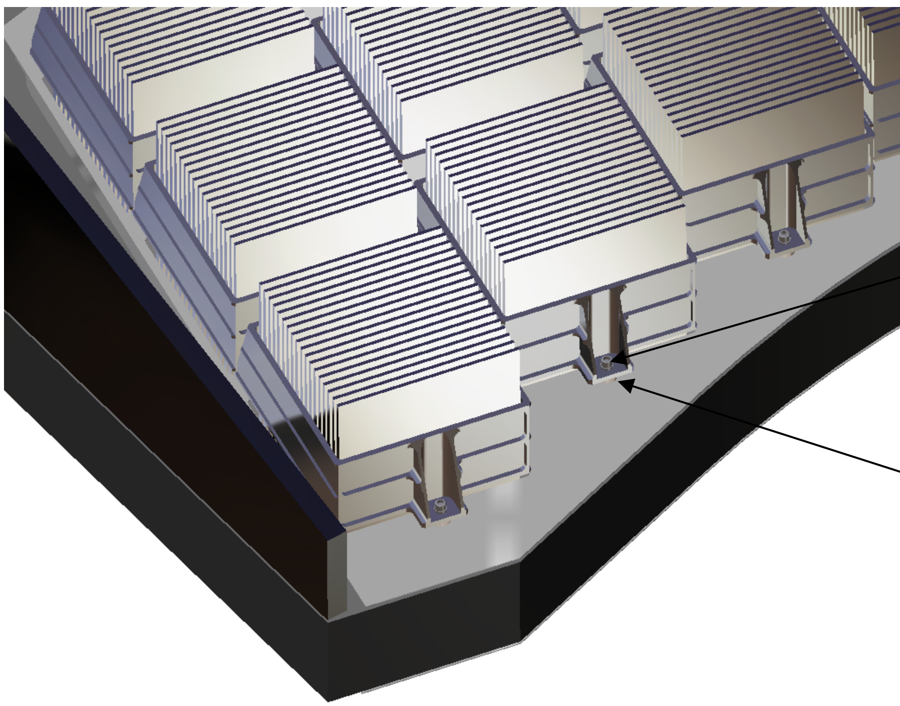




An individual lightweighted grating



30 Mirror Modules



- Mirror Modules Fasten using 3 Point Mount Attachments
- NAS1352 Screw
- MS21043 Nut

Each Module is Adjustable for Tip/Tilt & Piston Adjustment as Needed

OPG-XGS Mass Matrix

Component	Quantity	Mass per (kg)	Total Mass (kg)
Module	30	0.83 (*w/ gratings & fasteners*)	**25**
Grating Thermal	1	5 (*MLI, heaters, temp sensors, harness, and control circuit*)	**5**
Mount Platform	1	19	**19**
CCD camera	1 (*w/ 10x ~3 cm x 3 cm CCDs*)	11 (*head, shielding, TE cooler)*	**11**
CCD electronics	1	15 (*box, wiring & boards*)	**15**
CCD thermal	1	*Included in CCD camera mass*	

Total Mass = 75 kg