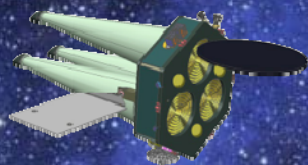
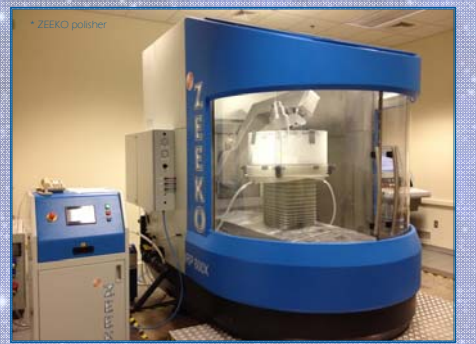


# Direct Polishing of Full-Shell, High-Resolution X-Ray Optics

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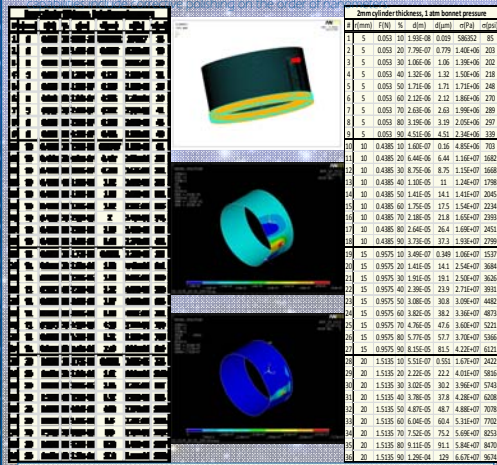


**Abstract:** Future x-ray telescopes will likely require lightweight mirrors to attain the large collecting areas needed to accomplish the science objectives. Understanding and demonstrating processes now is critical to achieving sub-arcsecond performance in the future. Consequently, designs not only of the mirrors but of fixtures for supporting them during fabrication, metrology, handling, assembly, and testing must be adequately modeled and verified. To this end, MSFC is using finite-element modeling to study the effects of mounting on thin, full-shell grazing-incidence mirrors, during all processes leading to a flight-ready report on the results of this study.



## Fabrication

- Fabrication of thin, lightweight, sub-arcsecond optics requires innovative technology
- NASA MSFC procured a Zeeko polisher to aide in technical advancement, its



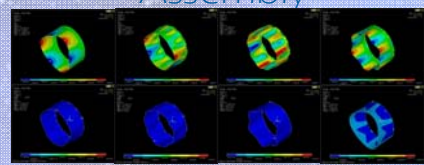
- Top center: finite-element model of cylinder (height=0.300m, diameter=0.610m, thickness= 0.002m and 0.006m) held at base with polishing force applied
- Middle center: displacement results
- Bottom center: von Mises stress results
- Left: stress and displacement results for finite-element model of polishing forces on a 6mm-thick shell, varying the contact area of polisher
- Right: results for finite-element model of 2mm-thick shell, varying contact area



6mm cylinder mounted into hardware to attach to the Zeeko polisher



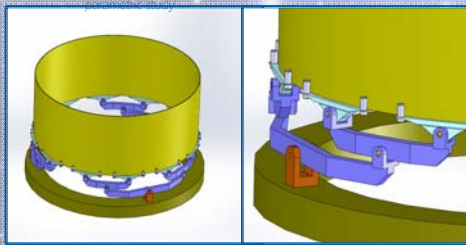
## Assembly



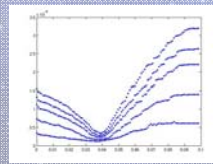
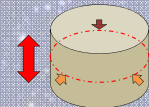
- Top: using FEM shown in Fabrication, distortion due to gravity in the axial direction, mounted at base. Left to right: 3-point, 6-point, 9-point, and 12-point mount.
- Bottom: stress due to gravity in axial direction, mounted at base. Left to right: 3-point, 6-point, 9-point, and 12-point mount.

run#	#pts	displ(mm)	stress(psi)
1	3	8.35	227
2	6	0.16	83
3	9	0.02	54
4	12	0.01	41

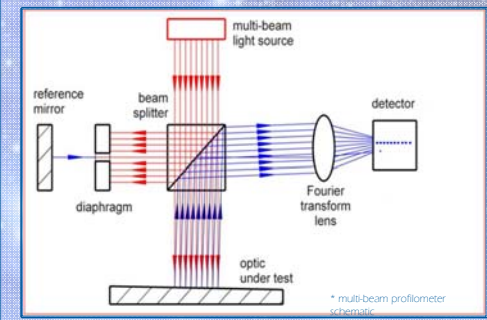
Displacement and stress results from above



Whiffletree design based on parametric study, where 6 points is minimum number of points necessary



- Left: finite-element model (FEM) of thin cylinder (height=0.198m, diameter=0.226m, thickness=10, 30, 50, 70, and 90 microns) with three equidistant mounting points were created to set mounting tolerances. The placement of these points was then varied longitudinally
- Right: imaging half-power diameter is plotted for FEMs described above, varying thicknesses and axial location of mounting points. As the thickness gets smaller, the mounting location becomes more significant. As thicknesses from top of table change

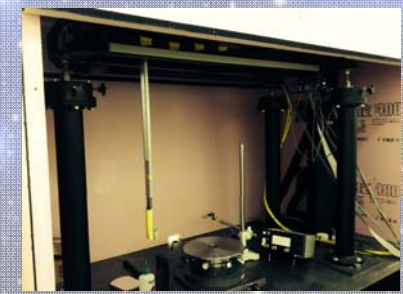


## Metrology

- Because lightweight mirrors are flimsy, they are susceptible to significant distortion due to mounting errors, including gravitational sag, machining errors and assembly distortions
- Blocking fixtures are necessary to fabricate sub-arcsecond grazing-incidence optics on the order of 2mm thick, however, with the added strength comes added error in the optic
- Metrology in a "free form" is required before adding a blocking fixture



- Left: grazing-incidence optic mounted in blocking fixture
- Right: stiffening ring to hold optic for metrology



The Vertical Long-Trace Profilometer (VLT, from Continental Optics) vertically scans the surface under test (sitting on a rotary table) and is best suited for metrology of full-cylinder mirror shells and large-diameter mandrels