Overview of full-shell approach

Optics for X-ray Surveyor workshop, March 2016

Outline

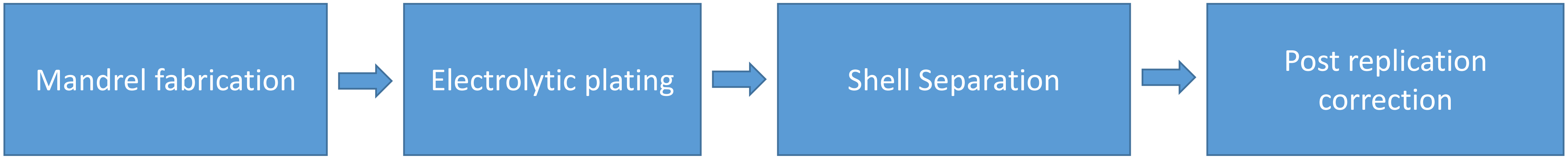
- Error Allocation
- Process flow
- Replication
- Direct Fabrication
- Pros and Cons
- Zeeko experiments
- Post-fabrication correction
- Mounting and Alignment

Error Allocation

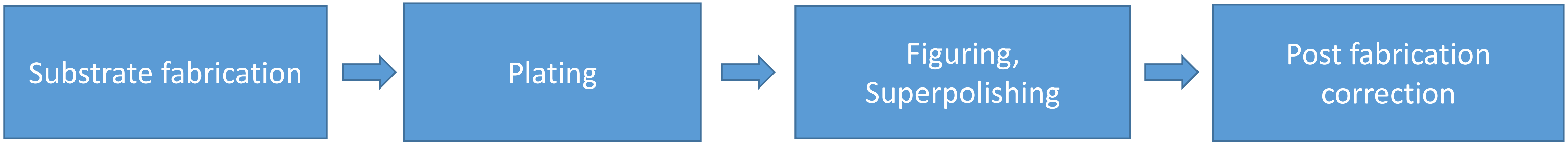
Requirement		0.5
Margin	0.66	0.20
Pointing jitter	0.28	0.14
Vibrational Effects	0.13	0.07
Defocus error	0.01	0.007
Launch shifts	0.13	0.07
Thermal effects	0.15	0.075
Gravity release	0.1	0.05
Epoxy effects	0.13	0.07
Shell-to-shell misalignment	0.24	0.12
Installation errors	0.24	0.12
Reflector pair	0.70	0.38
Surface slope error	0.18	0.10

Process flow

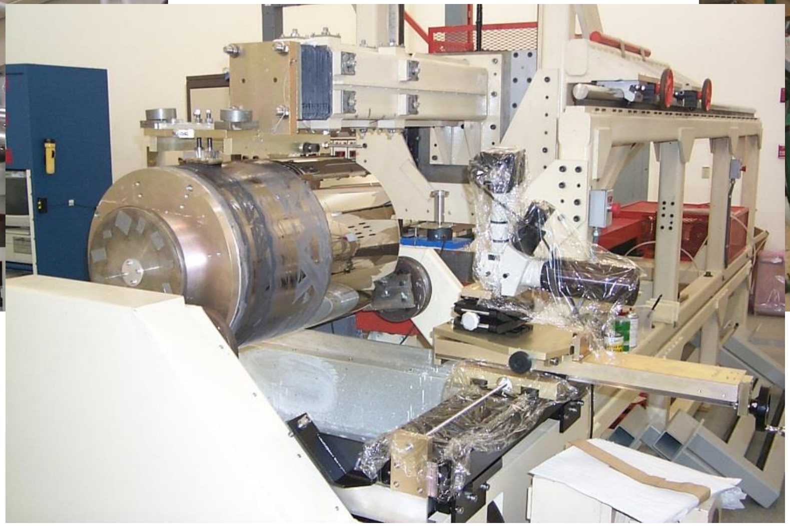
Replication



Direct Fabrication



Replication



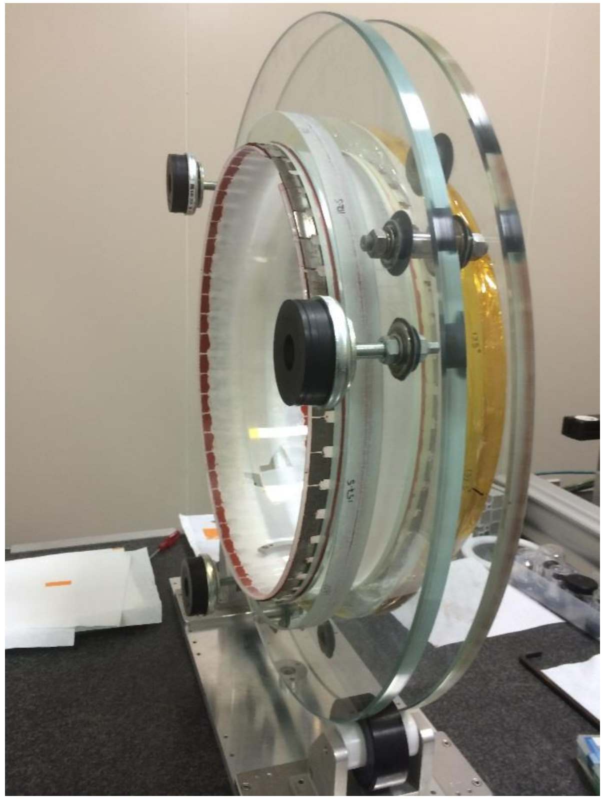
Pros and Cons

	Replication	*Direct fabrication*
Pros:	One mandrel for multiple shells (if multiple modules)	Low density Chandra-like resolution is doable If metal - Taylor the alloy to match CTE, the telescope structure can be done from the same material – simplifying thermal design, less epoxy
	Simplified alignment, especially if the shell has monolithic structure Relatively stiff – less complicated support structure, less obscuration, less weight for support Less susceptible to residual stresses (if any) in coating based corrections	
Cons:	Nickel – higher density Replication process – need for stress	Relatively thick, 1-3 mm
	Limit on diameter ~ 2 meters	

Direct Fabrication

Technique is pioneered by the Astronomical Observatory of Brera, Italy

Coarse and Fine Grinding → Figuring → Super-polishing → Ion Figuring



X-ray test at PANTER : 17.8" HPD

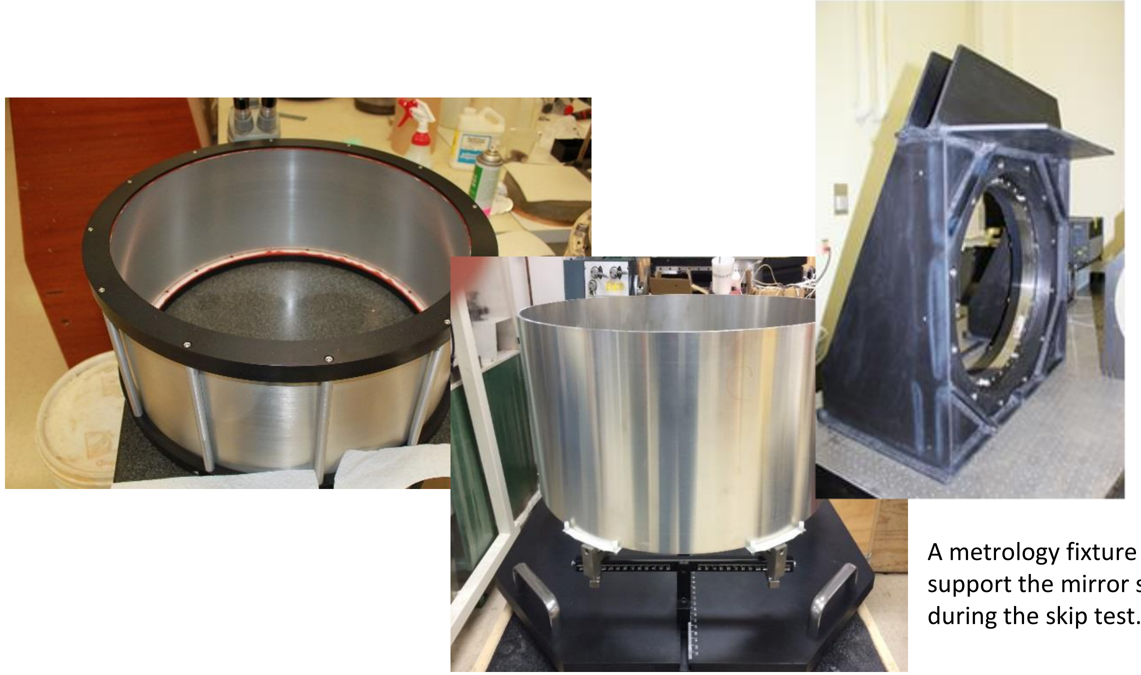
contribution

- low-frequency errors 6″
- mid-frequency errors 13″
- out-of-roundness error 5.3″
- the optical axis tilt between segments 8.9″

Potential

Direct Fabrication

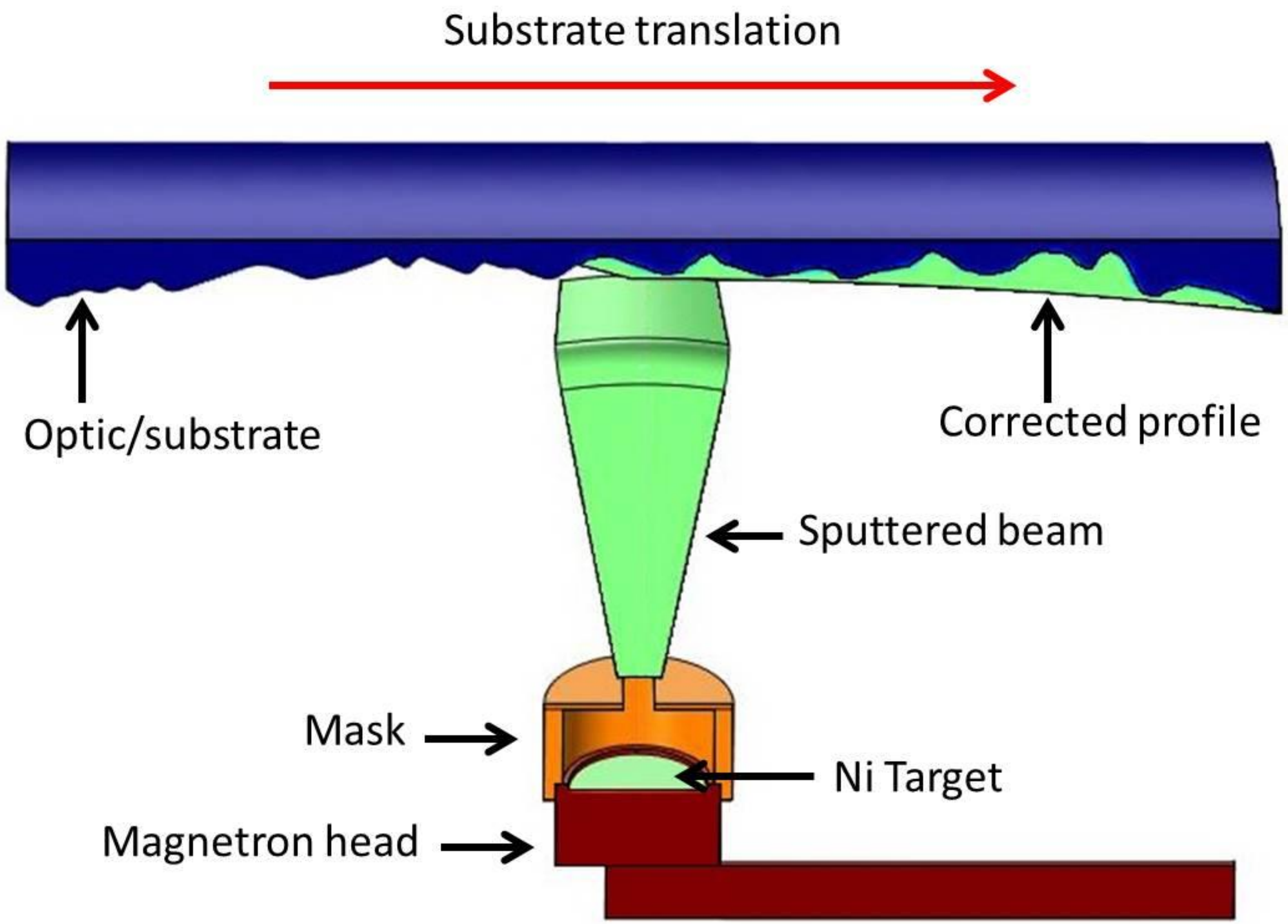
Diamond turning → Figuring → Super-polishing → Differential Deposition



A metrology fixture to support the mirror shell during the skip test.

Whiffle tree station with an aluminum shell supported at 12 points.

Direct Fabrication Post-fabrication Correction methods



Coating stress and magnetic materials
Melville P. Ulmer (Northwestern University)

Differential Deposition
Kiranmayee Kilaru (USRA, MSFC)
David Windt (Reflective X-ray Optics, LLC)

Ion Figuring (Brera Obervatory, Italy)

Direct Fabrication

Material	Density (g/cm^3)	CTE (10^{-6} / K^{-1})	Elastic Modulus GPa	Yield Strength MPa
Fused Silica	2.2	0.5	72	48*
Beryllium	1.8	12	318	240
BeAL-162MET	2.1	24	69	276
AlSi	2.8	13.9	193	314
Duralcan F3S.30S AlSi+SiC(30% by vol)	2.8	14.6	120	210

Mechanical Properties of Potential Mirror Substrate Materials
*Maximal achievable value. The 'working' value is typically much less and depends on the surface/subsurface condition.

Ideally, the mirror shell has low density, low coefficient of expansion (CTE), high modulus of elasticity and high yield strength. It should also be a material that is not too difficult to figure and polish.

- Be + NiP (CATS-ISS telescope)
- BeAl +NiP
- AlSi + NiP

Additional Benefits of metal substrate:
Less joints – less epoxy error
Thermal design could be simplified

Zeeko machine

- The machine utilizes a “bonnet” technique in which an inflated rubber hemispherical diaphragm supports the polishing medium.
- there are different “bonnet” sizes (20 mm, 40 mm and 80 mm radii of curvature)
- This computer-controlled deterministic polishing processes leads to a high convergence rate.

	before	after
Figure error (St. Dev.)	500 nm	10.7 nm
Slope error (> 2 cm) cm(RMS)	6.32 arcsec	0.30 arcsec
Low frequency (> 7 cm) slope error (RMS)	2.66 arcsec	0.09 arcsec
Mid frequency (2-7 cm) slope error (RMS)	5.73 arcsec	0.29 arcsec

Alignment

Shell can be supported from one end

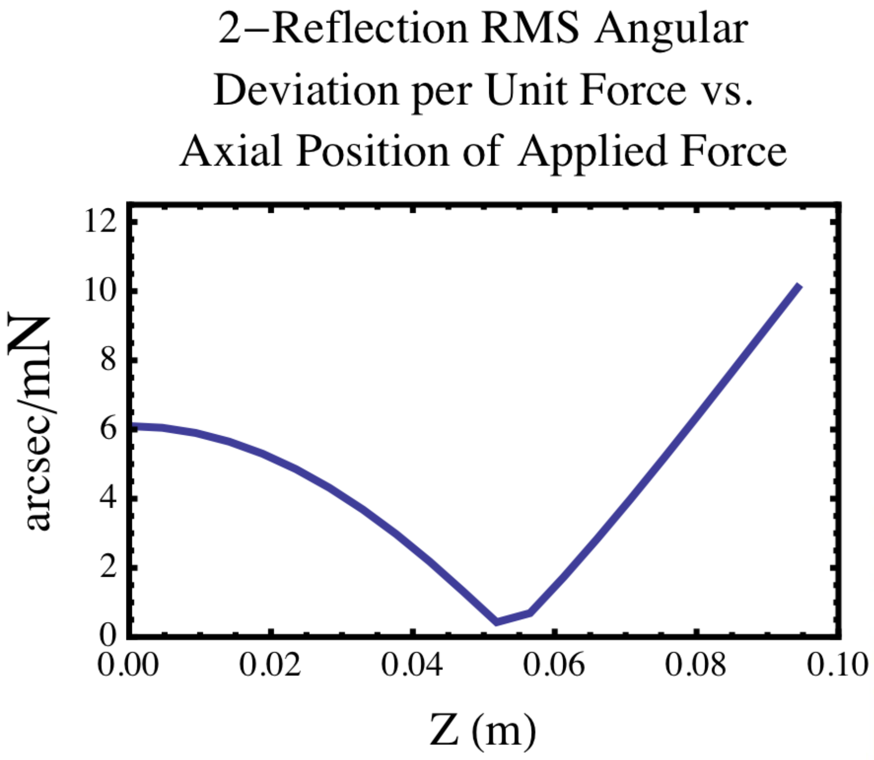
The use of the clips (FOXSI – 2007) minimizes the distortions due to epoxy shrinking

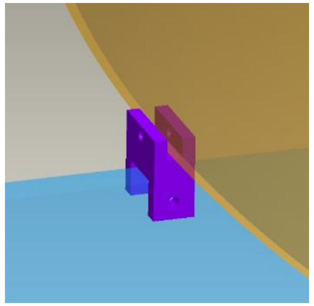
There is a “sweet spot” the influence on the angular resolution performance is minimal

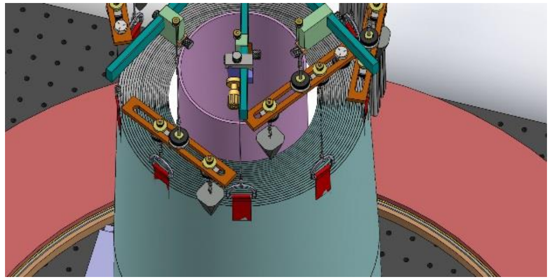
Strings approach – XMM

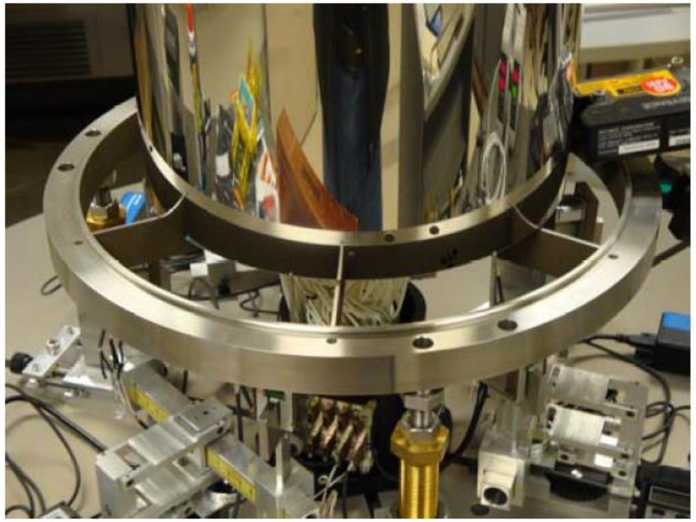
Equalizing the strings tension in azimuthal direction

CDA or UV









Conclusions

- To meet the stringent angular resolution requirements for the X-Ray Surveyor Mission all the error contributors should be addressed;
- Full shell approach could be viable option for inner mirrors of the X-ray Surveyor;
- Direct fabrication technique has potential to meet the angular resolution requirements;
- Post-fabrication and post-assembly figure correction provides an additional venue to meet the requirements.