Development of Light Weight Replicated Integral Optics: An Innovative Approach

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NASA PCOS X-ray SAG
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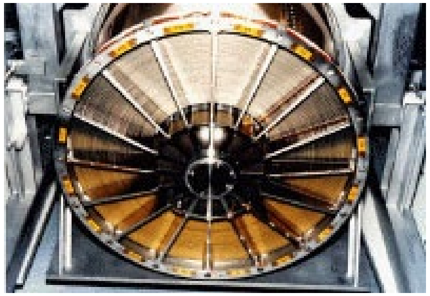
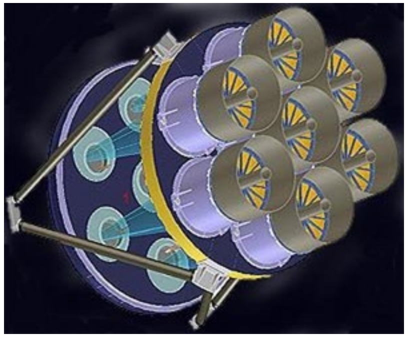
Electroformed Nickel Replicated (ENR) Telescopes

XMM-Newton **(Media Lario)**

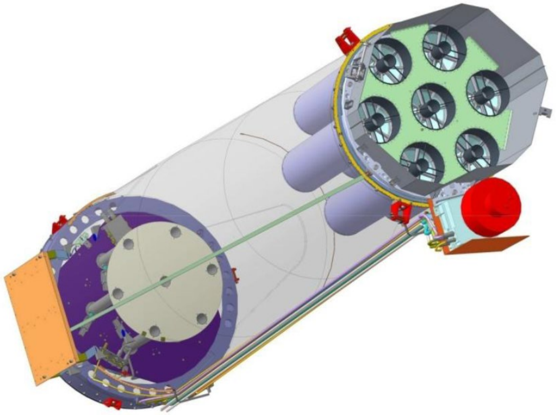


Spectrum-X-Gamma

eROSITA **(Media Lario)**



ART-XC **(MSFC)**



All Integral Optics; All have Multiple Modules (multiple copies)

Focusing optics/ENR/Multiple telescopes

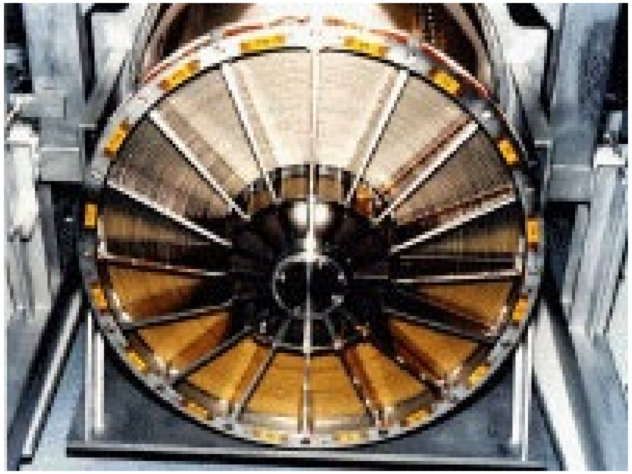
- Nearly all X-ray astronomy missions of the past 25 years have utilized focusing optics.

- Most missions have had multiple X-ray telescopes, e.g. ASCA, Beppo-SAX, Suzaku, XMM-Newton, NuStar, and future missions Astro-H and Spectrum-X-Gamma.

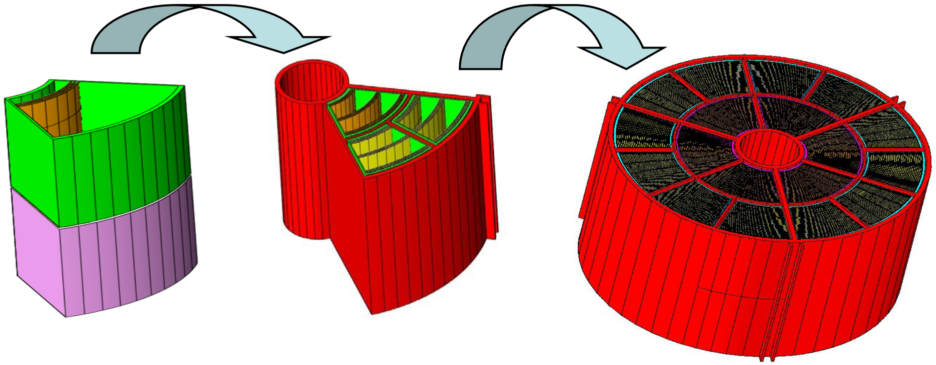
- Multiple telescopes (favor replication) may continue to be the appropriate architecture of future missions.

- Electroforming has achieved the best angular resolution (to date) for replicated telescopes

Advantages of integral vs. segmented shells



'One' step mounting/aligning



Multi-step mounting/aligning

•Closed figure of revolution offers maximum rigidity and strength for a cylindrical shell ------ expect **higher resolution**

• Integral cylinders **do not require aligning or assembling segmented optics** into complete shell

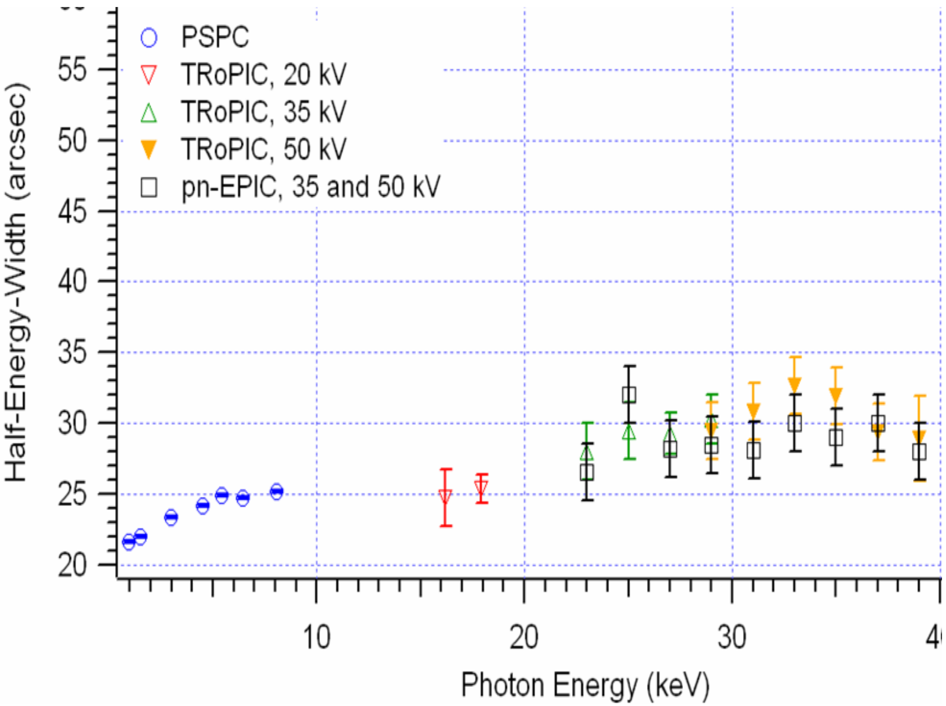
• Each shell provides a complete image, which **greatly simplifies alignment of shells**

New, stronger NiCo alloys developed at MSFC allow the next generation (of ENR) mirror shells to be lower mass

Used NiCo alloy to fabricate and test multilayer coated prototype optics for **hard X-ray telescopes for Con-X with** thickness/diameter ratio of mirror shells ~ 1/3 that of XMM (SAO, NASA/MSFC and Brera Obs.)

Prototype Multilayer Coated Electroformed Hard X-ray Telescope

Met 30” specification for Con-X



Still Ni/Co is high ρ

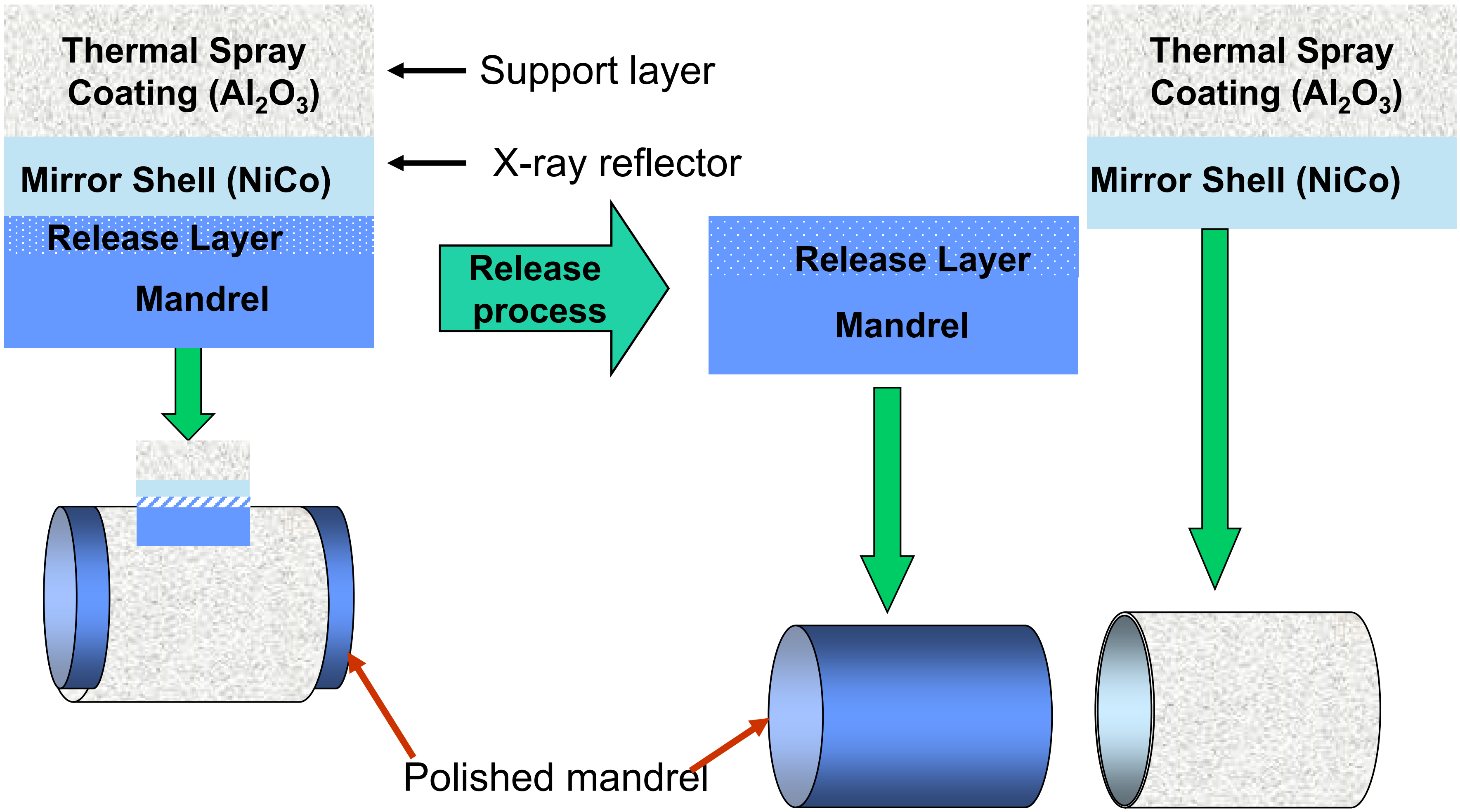
Test mirror shells installed in structure prior to testing at the MPE Panter X-ray test facility.

- NiCo still high density

- We are developing a new technology to replicate mirror shells that are lower density and stiffer than electroformed NiCo. If successful the replicated mirrors will be lower mass and have better angular resolution than present technology.

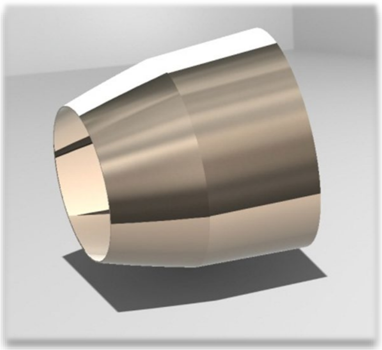
Exploring New Approach

Merging ENR with a Thermal Spray Process to yield Lighter weight, stiffer optics

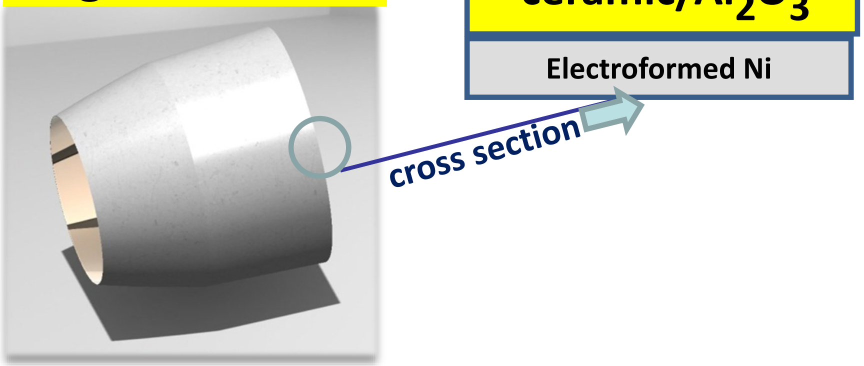


ENR + Thermal Spray Process => Lighter weight, stiffer optics

State of the Art
ENR



New Approach
Lighter, stiffer

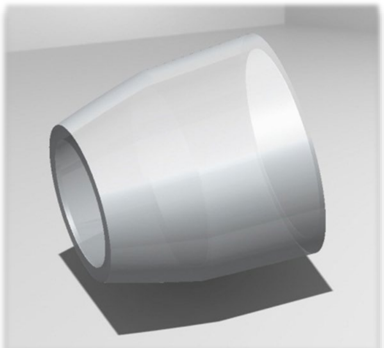
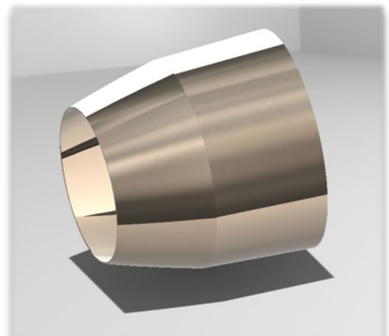
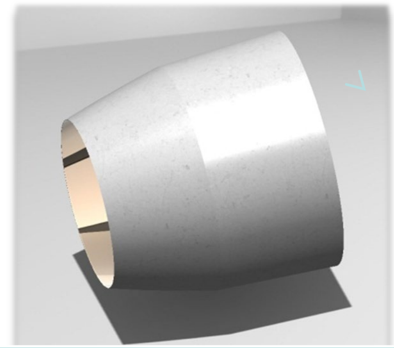


Material	ρ (gm/cc)
Ni	8.9
Al_2O_3	2.7* (as dep)

- stiffness of the alumina is twice that of nickel
- Thinner shells, lower density → significant mass benefit

lower mass => higher area/mass ratio

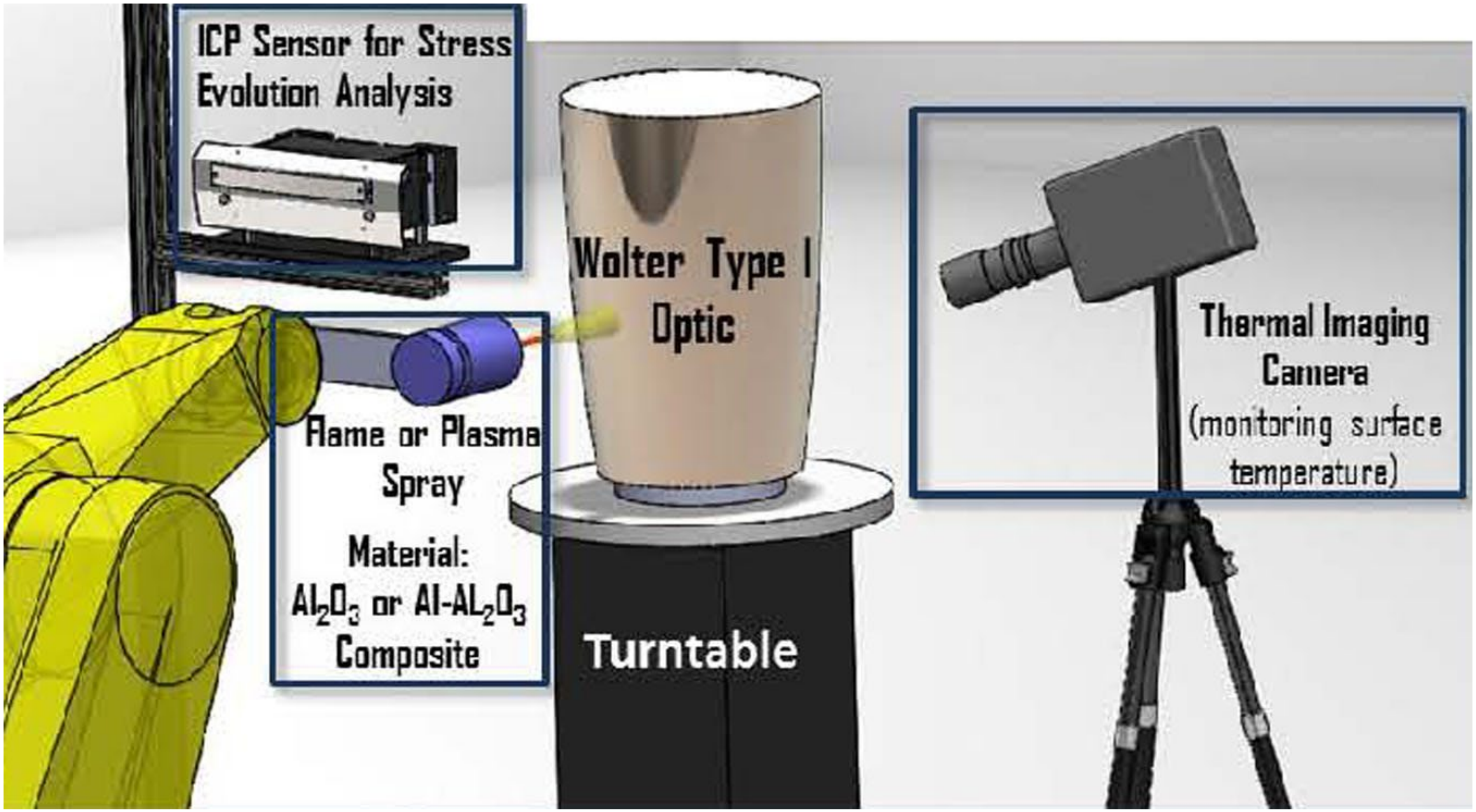
Lighter weight than other integral shell technologies

Chandra	State of the Art XMM	**New Approach**
		
18mm Zerodur	**1mm Ni**	**≤100μm NiCo 200μm Al_2O_3**
~ Mass of 70cm diameter, 60cm long shell		
60.4 kg	**11.8 kg**	**1.9 kg**

Goal: construct and test ceramic-metal, light-weight, full 360 degree prototype mirror shells for a **high throughput, lower mass, low cost mission, ~10-15" X-ray telescope**

Plasma Thermal Spray

- Facilitates layered manufacturing
- Is readily scalable

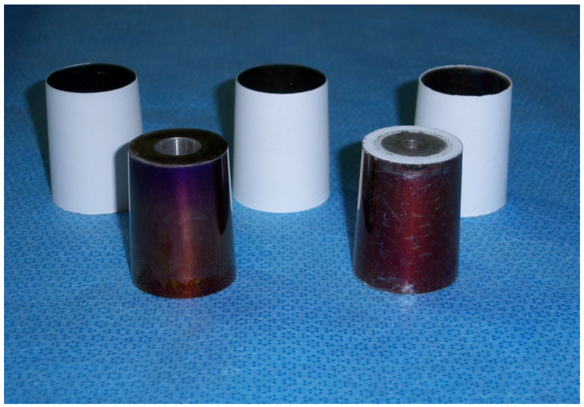


Computer controlled deposition

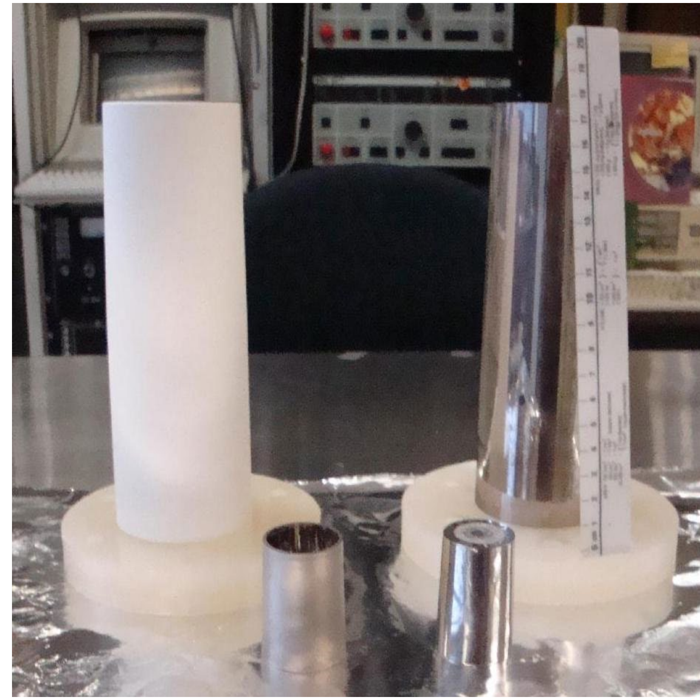
Test mandrels and replicated Al_2O_3 shells

Proof-of-process

3cm diameter x 5cm cones



6cm diameter x 18 cm long Wolter



Accomplishments:

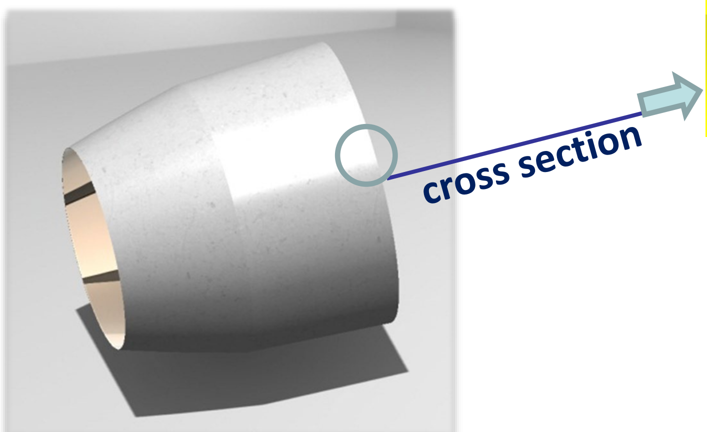
- Shell adheres to mandrel during deposition
- Separation via differential thermal contraction
- Fabricated small conical shells
- Fabricated small wolter-I shell

Optimizing Design

Optimize stiffness and CTE by varying :

- Thickness
- Chemistry
- Density of Al/Al_2O_3

Optimize New Approach



Thermal Spray Al_2O_3	**200μm**
Bond Coat (Ni/Al_2O_3)	**10μm**
TiN barrier Layer	**1-2 μm (sputtter)**
Electroformed NiCo	**20-100μm**

Bond coat (Al) : to enhance adhesion to NiCo
Barrier layer (TiN) : to prevent print through

Plans for the Future

- Minimize stress in deposit and maintain low temp during ceramic coating
  To avoid thermally-induced distortions during cool-down; maintain figure of mandrel

- Material and mechanical characterization of Al_2O_3 coatings

- Optimize coating parameters (e.g. power, deposition rate, thickness, particle size..)

- Metrology and X-ray testing to check figure accuracy – adjust process

- Test even lower density materials

Current TRL :

- NiCo ENR optics = TRL 9 (Ni, NiCo) several flights

- Ceramic optics = TRL 2-3;
  successfully fabricated small conical shells and small Wolter shells

Ceramic Optics TRL plans:

FY13: TRL3: X-ray test small scale Wolter
FY14: TRL 4: fab, X-ray test 15 cm diameter Wolter
FY15: TRL 5: fab, align & X-ray test 2 shell prototype