Electroformed Integral Shells for the Con-X HXT: November 2003 Progress Report to the FST

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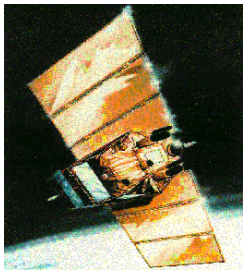
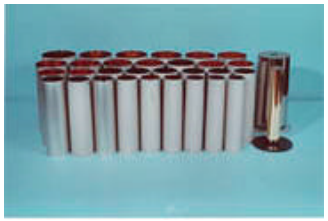
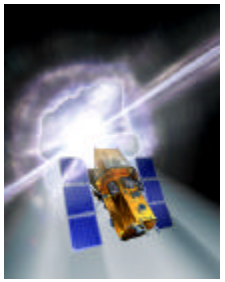
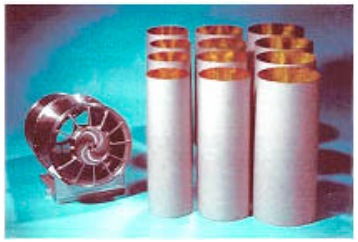
Electroformed Integral Shells for the Con-X HXT

Team Members	Responsibilities
SAO (CfA)	Overall management Delivery of test prototype Deposition of multilayers
OAB	Electroforming larger diameter Ni replica conical shells Integration of shells
NSSTC (MSFC)	Electroforming smaller diameter shells (mostly Ir coated) HERO balloon program testing

Heritage of Electroformed Replica X-ray Optics

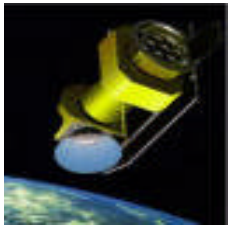



Beppo/SAX

SWIFT/JET-X

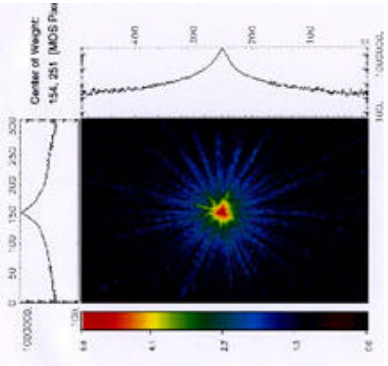
XMM-Newton



ABRIXAS/(DUO)

Advantages compared to segmented mirrors

- **Expect better angular resolution from stiff closed shells** as shown by experience: JET-X/SWIFT 17" HPD, XMM-Newton 15" HPD and recent measurement of thin replica from JET-X (SWIFT) mandrel



HEW_{meas} = 25 arcsec

- **Diam. = 30 cm**
- **Wall thickness = 130 mic**
- 0.29 XMM shell
- 0.12 SWIFT shell

- **Replication well adapted to making 12 or more identical copies**

- **Fewer parts, simpler integration of reflectors into a telescope**, 90 to 112 shells per telescope, total of 1000 to 1340 shells for all four Con-X S/C

Improvements Required for Con-X HXT Over the previous missions

- Smoother surfaces, 7-8 to < 5 Angstroms rms
- Multilayer coatings on interior surfaces
- Lower mass/area, i.e. thinner wall
- Longer length shells, 60cm to 70 - 80cm
- Larger quantity, total of 12 x 80 = 960 shells

Mass of HXT Integral Shell Ni Telescopes

Est. mass of electroformed replica telescope for the Con-X HXT is: 53 kg/unit or 159 kg/SC. **This fits within mass allowance with margin.**

Shell/diameter thickness ratio is **0.12 SWIFT/JET-X, 0.29 XMM**

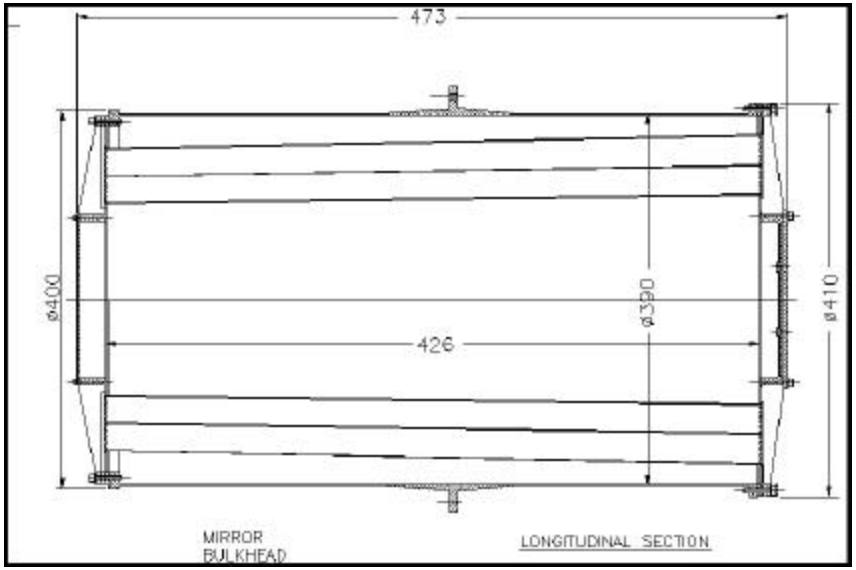
Mean HXT substrate thickness is 105 microns, Ni density is 8.9
Thickness x density = 0.0935 gr/cm^2

Mean SXT substrate thickness is 440 microns, Glass density is 2.5
Thickness x density = 0.1100 gr/cm^2

Electroformed HXT substrates are less dense than SXT's

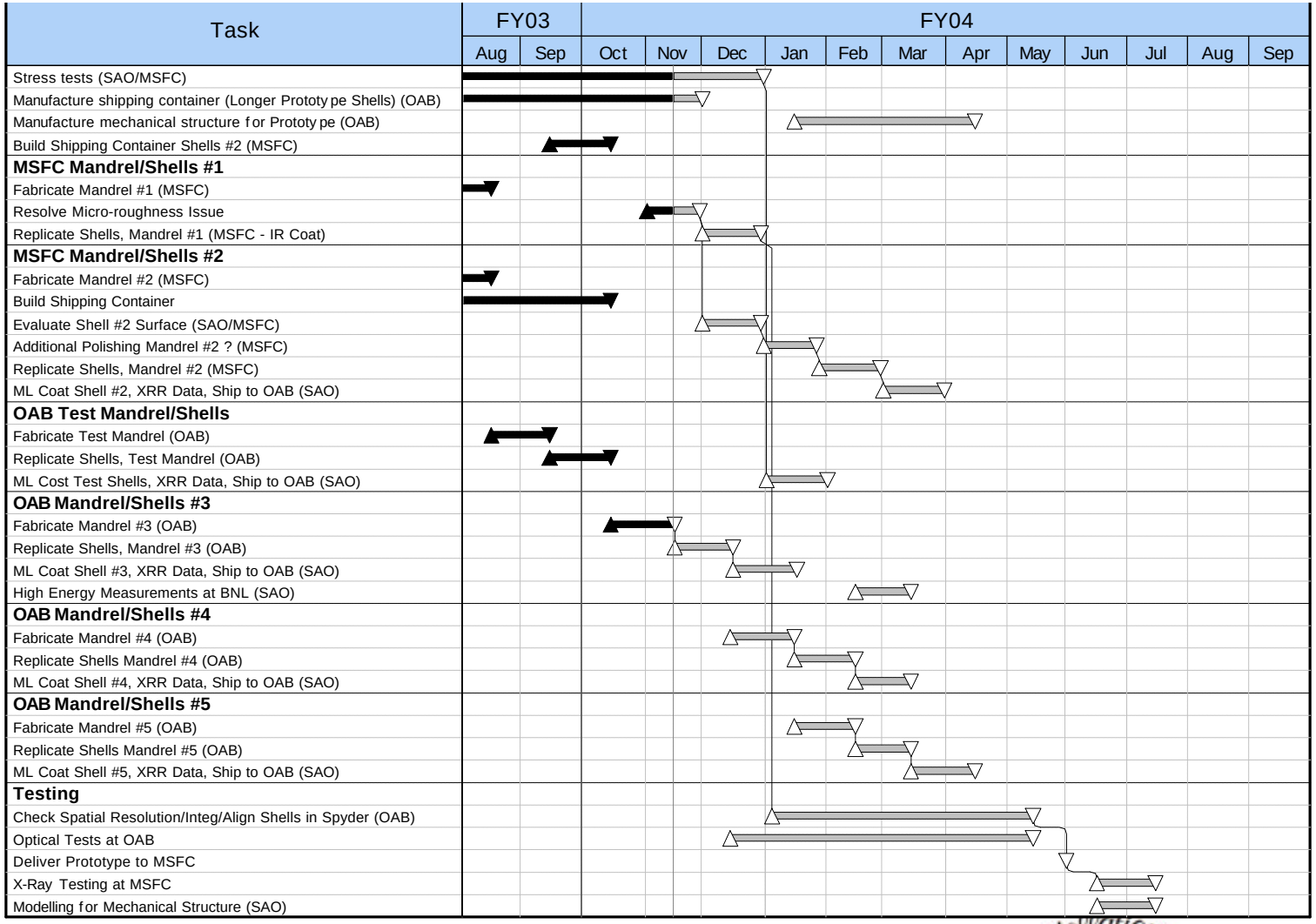
Construction of Prototype for Testing

Focal Length = 10000 mm
Mirror length = 426 mm



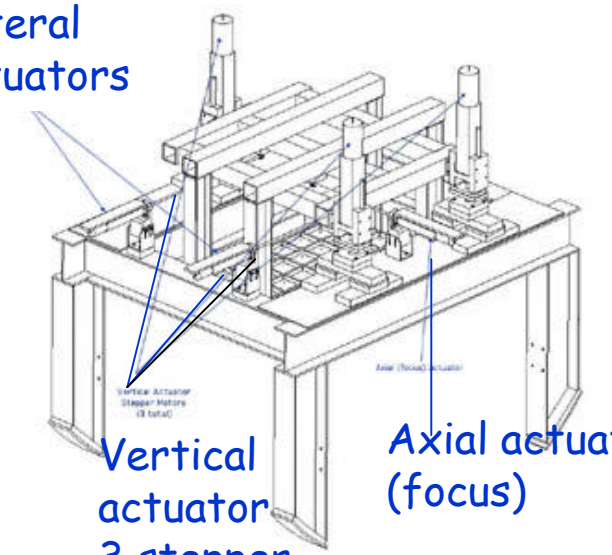
- ✓ **3 shells (Æ = 250, 270, 280 mm) are being provided by OAB;**
- ✓ **deposition of the multilayer films at CfA;**
- ✓ **2 additional shells (Æ = 240 and 150 mm) provided by MSFC. The 150 mm shell will be coated with single layer, Ir;**
- ✓ **integration at OAB;**
- ✓ **full-illumination tests at the 102 m Hard X-ray facility of NASA/MSFC.**

Schedule for construction and testing of HXT prototype (prior to budget reduction)



X-ray of Testing Prototype

Were scheduling X-ray tests of prototype at MSFC for June 2004



Recently announced cuts in Con-X HXT funding will probably cause testing to be delayed.

Current Activities and Issues

- Construction of the prototype
- Study of effect of stress in multilayer coatings upon figure
- Study of adhesion of multilayer coatings to gold coated Ni replica substrates

Activities at OAB, Current Status

OAB is contributing 3 shells to the prototype,
250, 270, 280 mm diam.

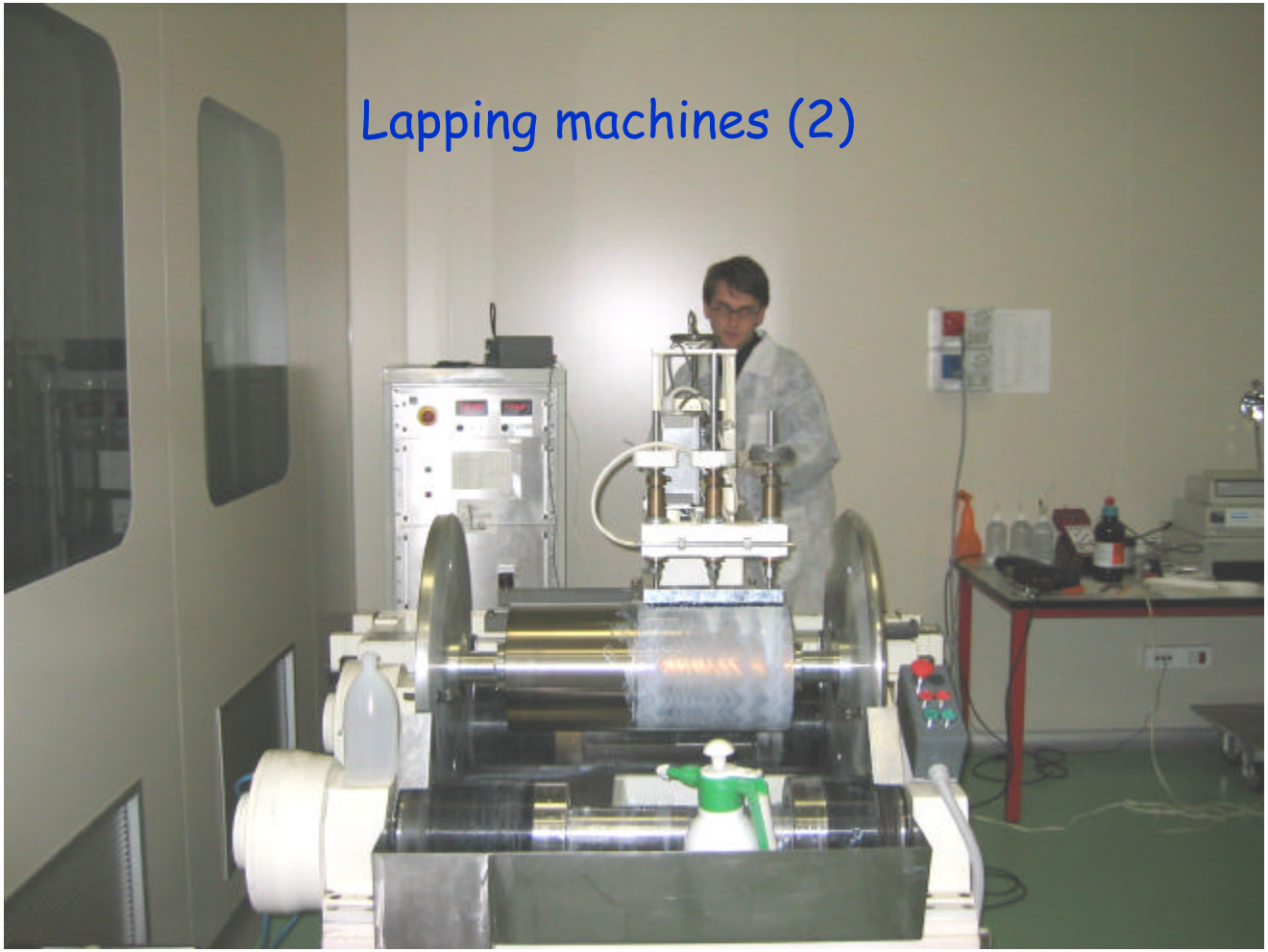
All 3 mandrels to be produced by OAB have been machined and ground to rough finish

1st mandrel is currently being superpolished. Expect 1st to be completed in about two weeks

2nd and 3rd mandrels will follow

OAB Superpolisher

The Zeiss equipment for the superpolishing and metrology of pseudo-cylindrical mandrels (used for the XMM project) successfully transferred and re-installed at OAB-INAF



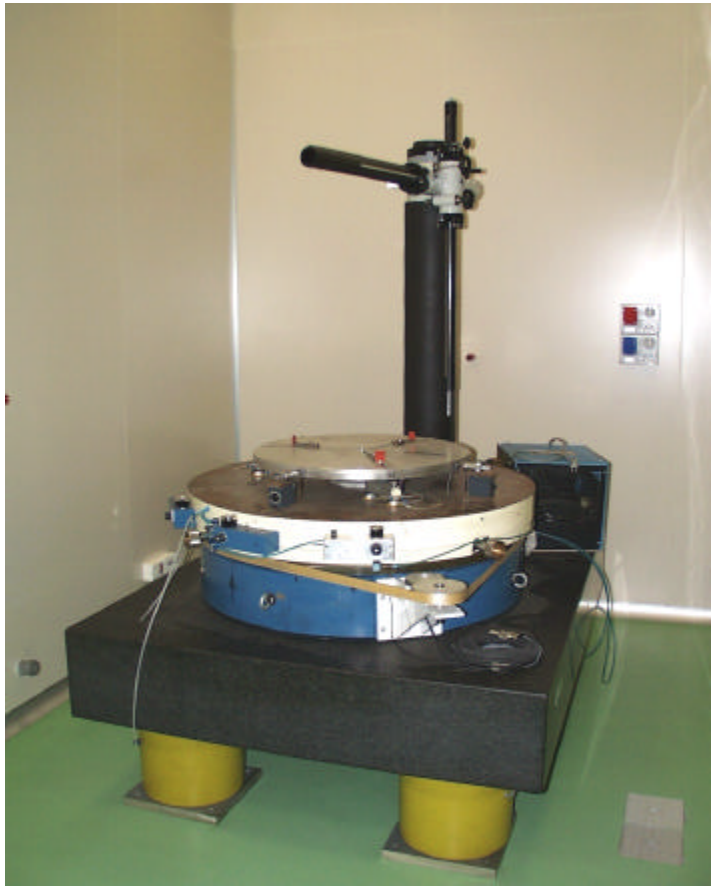
OAB Surface Profilers (1)

Characterization of mandrels by means of the CMD2 contact longitudinal profilometer, Peak-to-Peak error = < 1.5 microns

Zerodur reference flat

OAB Surface Profilers (2)

Optical azimuthal profilometer

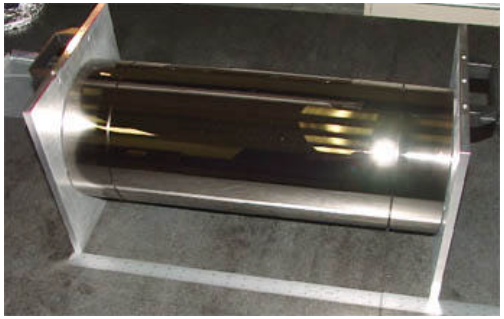


Activities at NSSTC (NASA MSFC)

NSSTC is contributing 2 shells to prototype, 230 mm and 150 mm diam

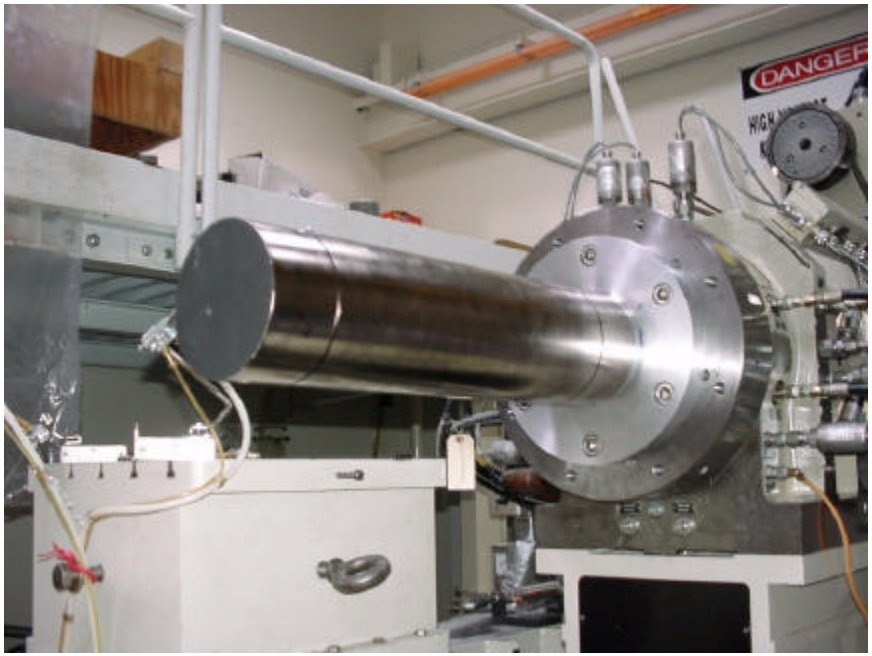
150 mm mandrel is diamond turned at MSFC and polished in house

230 mm mandrel ground by Schmeide Corp. TN and polished in house

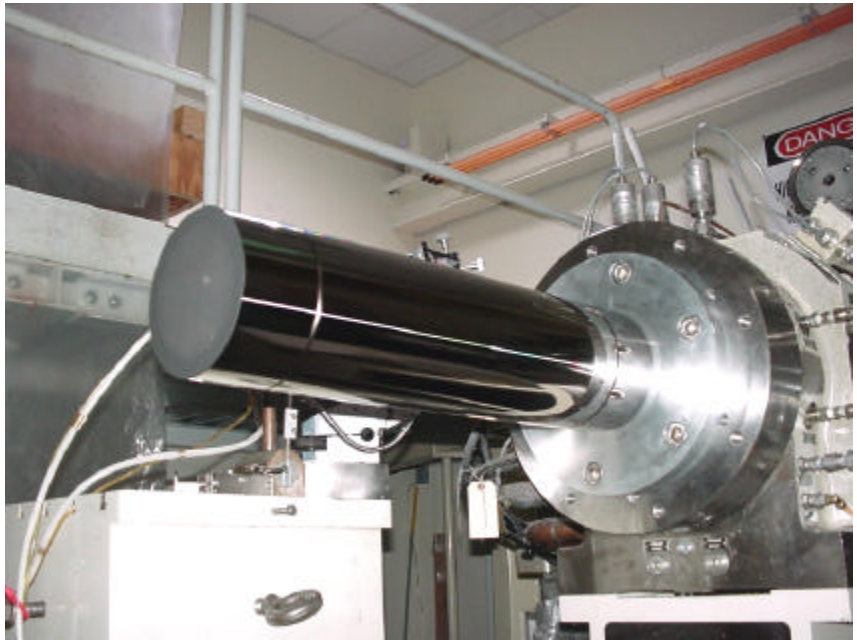


Diamond turning of 150 mm mandrel at MSFC

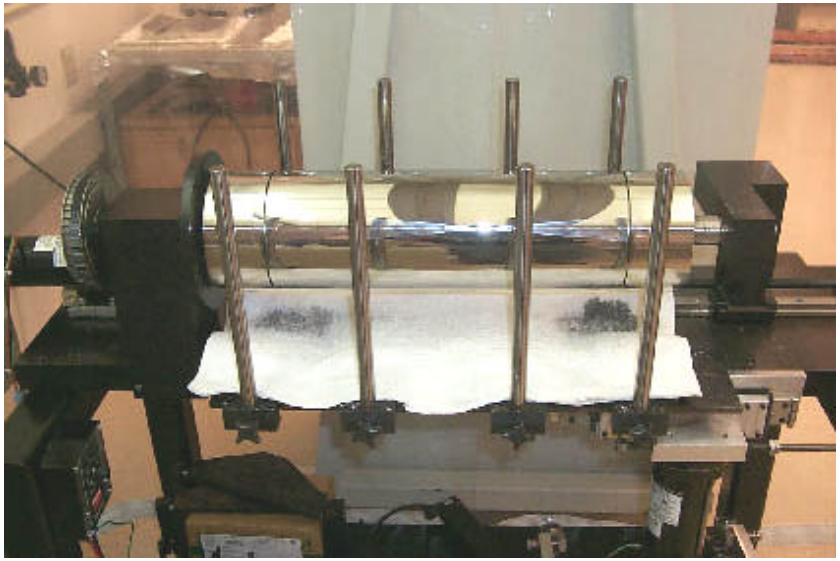
Before



After



Polishing of 150 mm Mandrel at MSFC



Above, being polished
Right, on long-trace profiler

Interior surface of 150 mm shell will be coated with single layer iridium. It does not have to be as smooth as the others coated with W/Si multilayer.

Current Status of MSFC Shells

- 23-cm mandrel is completed, 15-cm mandrel is nearng completion

- Recent AFM coupon tests, however, have shown that the current mandrel surface treatment technique, used to ensure that the 100-micron-thick shells release cleanly from the mandrels, is increasing the surface roughness. It is acceptable for 150 mm Ir coated shell but not for the multilayer coated 230 mm shell.

- MSFC is performing coupon tests to derive a release process that will not degrade the microroughness of the mandrels

Effect of stress in multilayer upon shell figure

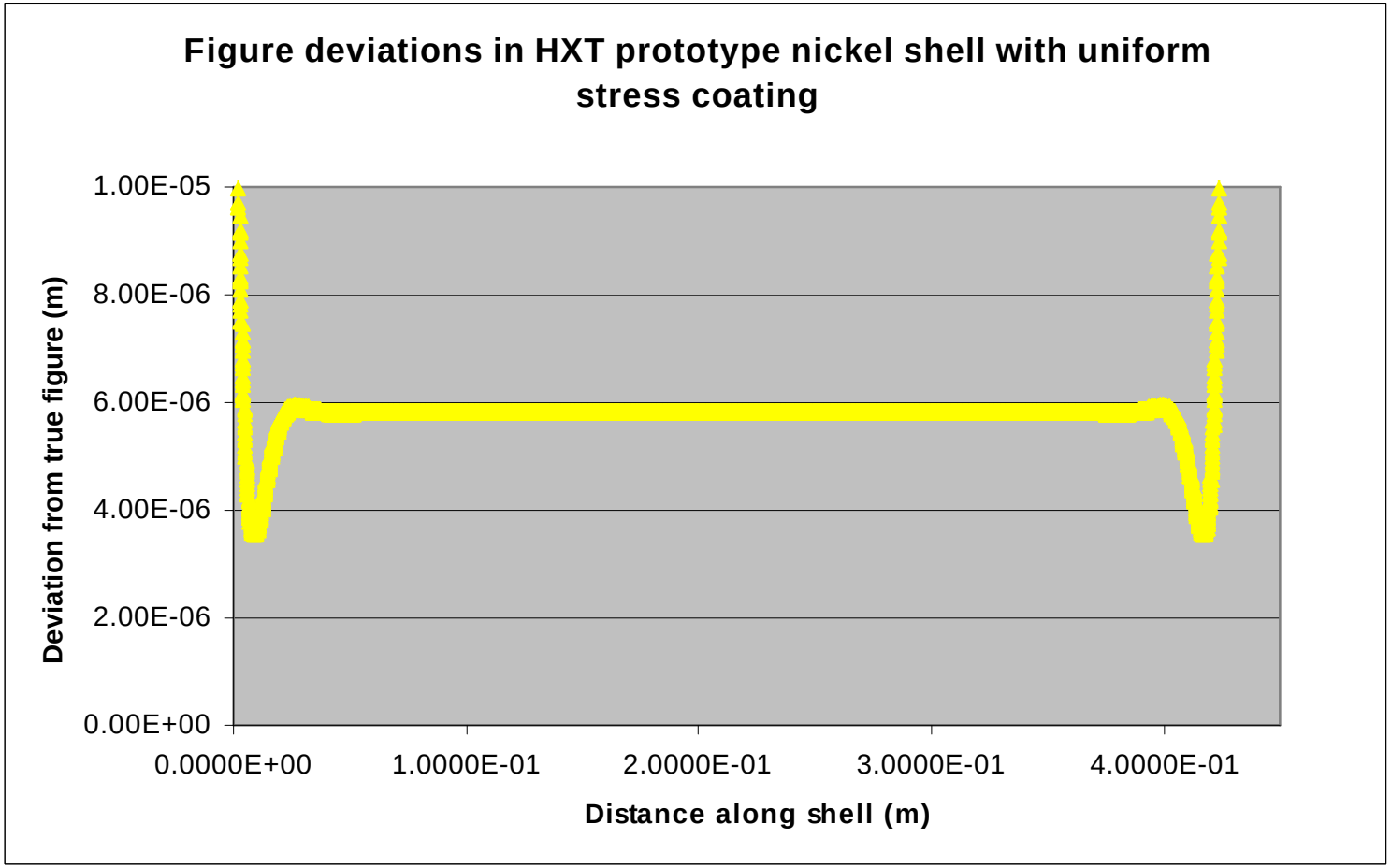
Observed that a thin Ni shell coated with a W/Si multilayer only along part of the 360 deg azimuth became distorted.

We attribute this to stress in the multilayer that is either intrinsic or caused by thermal mismatch between Ni and W/Si

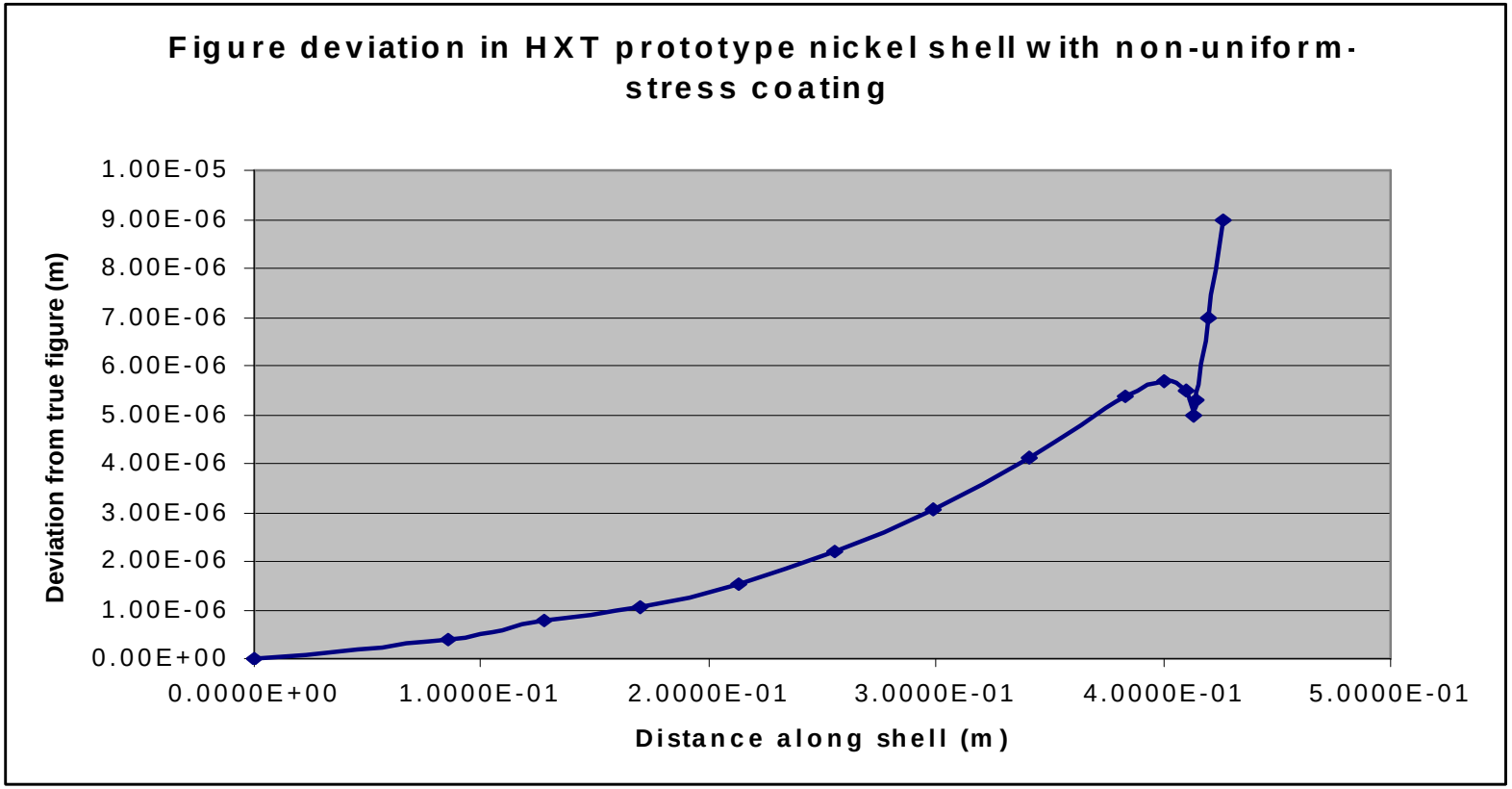
However, it is quite possible that stress would balance when the shell coating is over the entire 360 deg of azimuth.

To test MSFC produced several 23 cm diameter 100 micron thick replica shells. The slope was measured along several azimuths at MSFC before and after SAO applied the W/Si coating

MSFC Stress Effect Model, Uniform Temperature

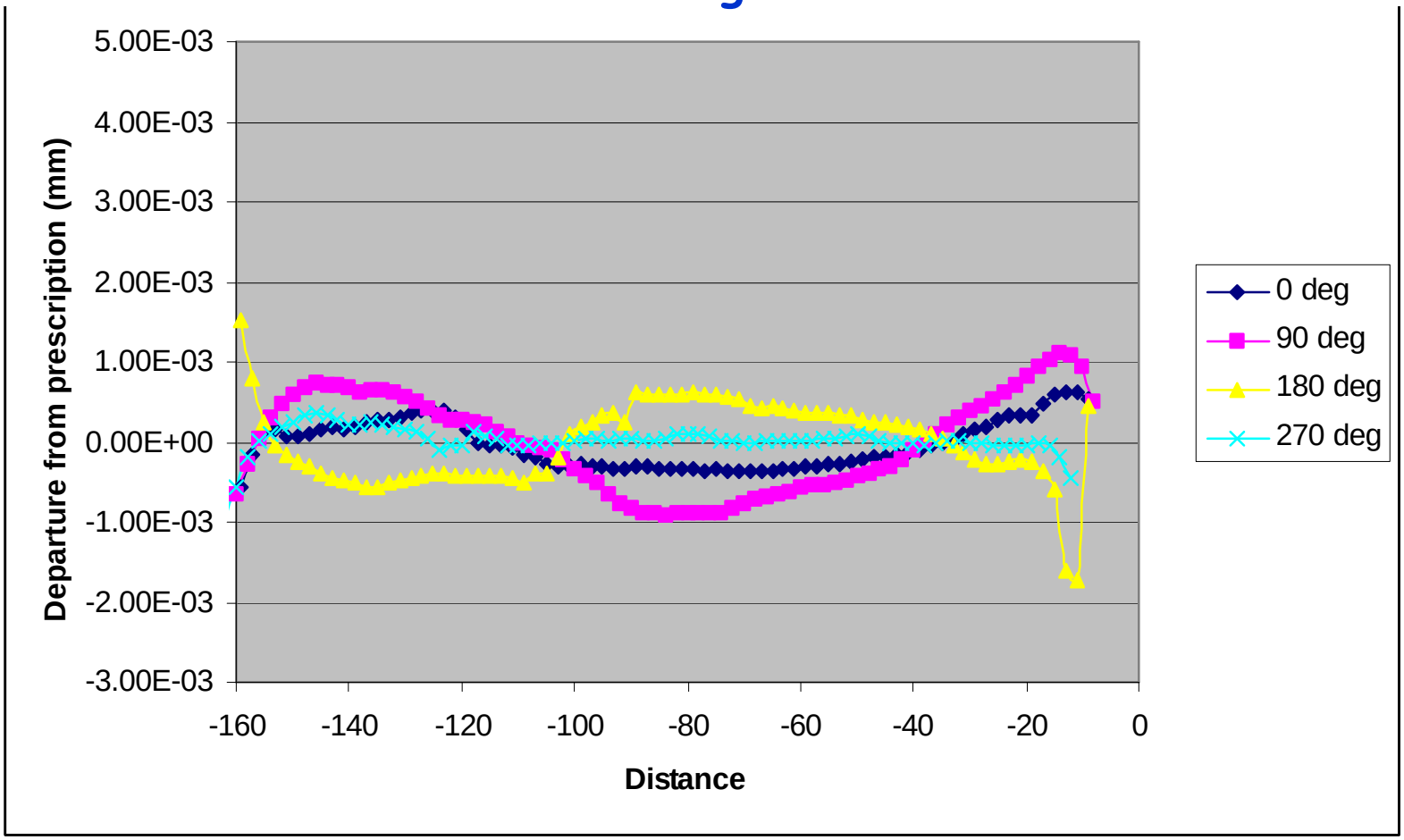


MSFC Stress Effect Model, axial temp. gradient



Maximum deviation of slope from the constant temperature model is only 8 arcsec. With 2 reflections, maximum error would be 32 arcsec but would apply to only a small area near the ends.

Cone 10, measurements before minus after multilayer coating



Effect of coating is changes of a micron over 10 cm, or slopes of less than an arcsecond.

Effect of stress, conclusions

Stress model seems to be generally correct

Coating that is uniform in azimuth will result in an acceptable amount of distortion

Tests will continue

Issue of multilayer's adhesion to gold surface of OAB replica

- Observed several months after a previous deposition that a W/Si coating detached from a shell with a gold surface

- It was possible that the gold surface was not sufficiently clean initially or that W rather than Si should be the first layer deposited upon the gold or that a binder material like chromium is needed to improve adhesion to gold

- To investigate the problem, a gold surface replica Ni shell was divided into several coupons

- The following coatings were deposited upon the coupons: W/Si (Si 1st), W/Si (W 1st), Cr + W/Si (Si 1st) and Cr + W/Si (W 1st)

- The coupons were subjected to a tape pull test. In all cases but one the coatings remained in tact. Visual inspection suggests that the one failure could be due to the initial condition of the gold surface.

- The coupons will be temperature cycled and watched for several months.

Improvements to Multilayer Deposition Chamber/Process

- Developed procedure that dispenses with the use of shutters between changing from depositing Si to depositing W and vice versa. The entire layer of Si (or W) is deposited in a single pass by adjusting the deposition rate to thickness of layer. The deposition time is reduced with no increase in the microroughness

- Last May we reported that collimating the deposition beam to reduce the angular spread as described by Jensen and Christensen improved the microroughness. However, this resulted in longer deposition times

- We found we could obtain essentially the same benefit without increasing the deposition time by keeping the separation between thesputtering source and the substrate within a certain narrow range.