Replication Technology for Large Segmented Telescopes

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with input and help from:

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and Mike Tupper (CTD)

Adaptive optics primary

Telescope

Initiative for a

Large

Aperture

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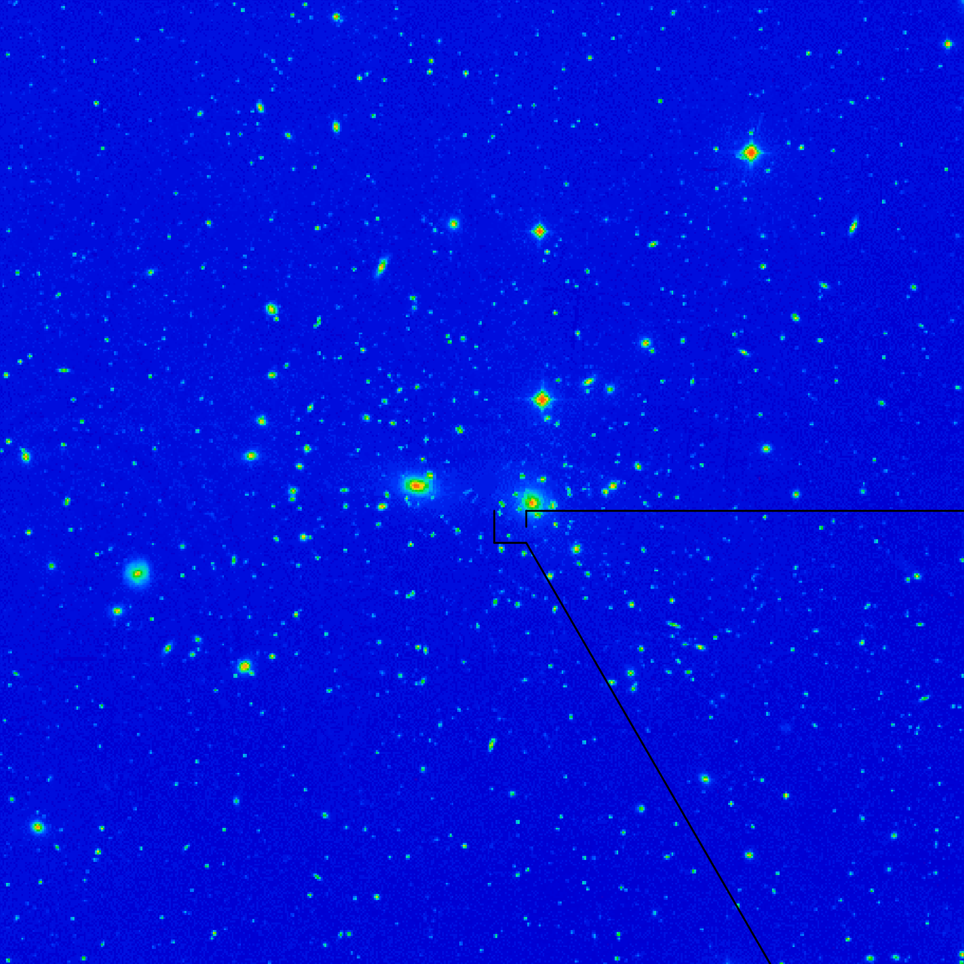
1024TI, KPNO, circa 1991, 7x7 arc min



12k, CFHT, mosaic, circa 2000, 40x30 arc min

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Replication Technology for Large Segmented Telescopes

- Goal: to make light-weight segments

- Requirements:

(1) 20 $kg/m^2 <$ for reduced structure cost AND to allow affordable PRIMARY ADAPTIVE OPTICS

(2) 50 nm or "Strehls" $\approx$ 0.8 for spectroscopy at the sky limit or for planets near stars in IR

(3) Production time and cost significantly less than current classic glass grinding and polishing =>time $\approx$ 5yr/700m^2; cost $\approx \$5000/m^2$

GBT: 100 meters across, our goal for the IR

Sample actuator scheme that is improved with light-weight, can replace those below with low cost speakers

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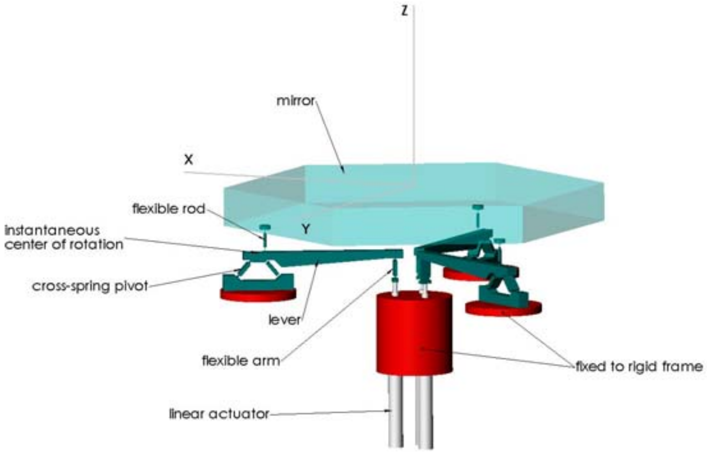
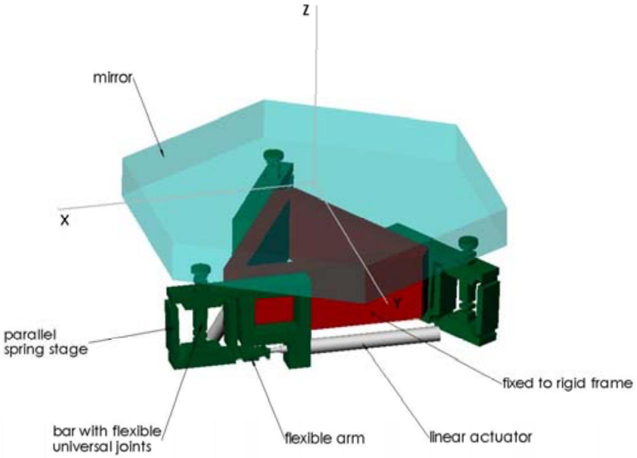
Proposed by CSEM (Dr. Lorenzo Zago)





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Background:

• X-ray astronomers are working on nearly all replication technologies: Composites, CVD SiC, Plasma Spray, Electroforming, Slumped Glass

•=> It is natural for X-ray astronomy to contribute to technology development of segmented mirrors

• Leading contenders to meet our requirements are

• Electroforming and Composites

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Advantages:

- Time and cost requirements can be met:

- 1 day per $1m^2$ or better capital cost of equipment further allows for easy upgrade to production mode; current production cost of a ~ 50 cm long x 10 cm diameter mirror costs $1k => projected cost of $5k/$m^2$ is reasonable.

- Smoothness, or high frequency roughness Strehl requirement can be met = 0.5 nm or better on 100 micron length scale and 1-5 nm on the 1 - 5 mm scale

Advantages cont:

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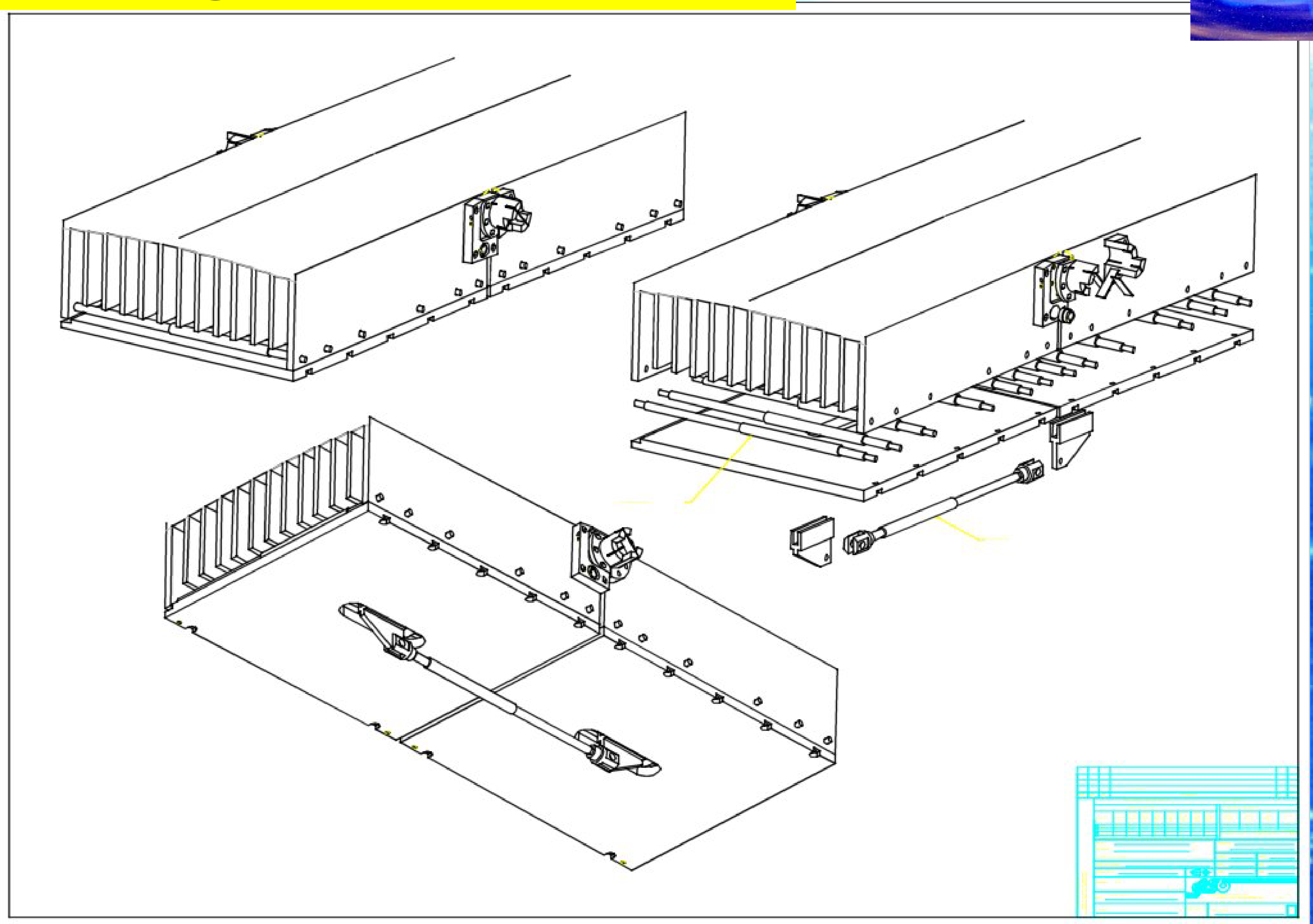
• Since no grinding and polishing of the optic, the optic can be made thin and light-weight

• Using a mask technique, one mandrel can be used to make all the required hexagonal segments at a given radial distance from the mirror center

• Development of bending techniques means one master can be used for more than 5 different radii of curvature =>

• The net number of masters needed versus conventional figuring is reduced by 20-30

SESO@Aix En Provence



Summary:

• Electroforming replication can meet time, cost and light weight requirements right now!

• It is definitely worth pursuing replication technologies.

• And technical expertise developed for X-ray astronomy can and should be migrated to segmented mirror technology.

Mini Review of composite and ceramics (SiC, plasma spray)

- Composites for X-ray astronomy can do no better than 40 arc seconds and the figure has been unstable over months.

- Composites are acceptable for micro-wave applications however.

- Ceramic carriers + epoxy replication has tried, and still does not meet specifications for Constellation X which is about 15 arc seconds

Mini Review of composite and ceramics (SiC, plasma spray)

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- SiC preferred over plasma sprayed alumina at this point, but SiC is very expensive = about \$70k/m^2 Whatever backing is used, this is 2 step process: make ceramic structure , then use this to support the epoxy

- Both SiC and plasma spray are hot ($\geq$ 2000 C) processes. Need a robust master and extreme care with CTE matching between ceramic and mandrel

NU just happens to have a patented fine particle plasma spray machine

Progress to date

- At Northwestern (NU) we are working on electroforming. We are beginning is to make flat and convex pieces and to test them. Ball Aerospace is supplying characterization facilities and expertise.

The Concept (simplified):

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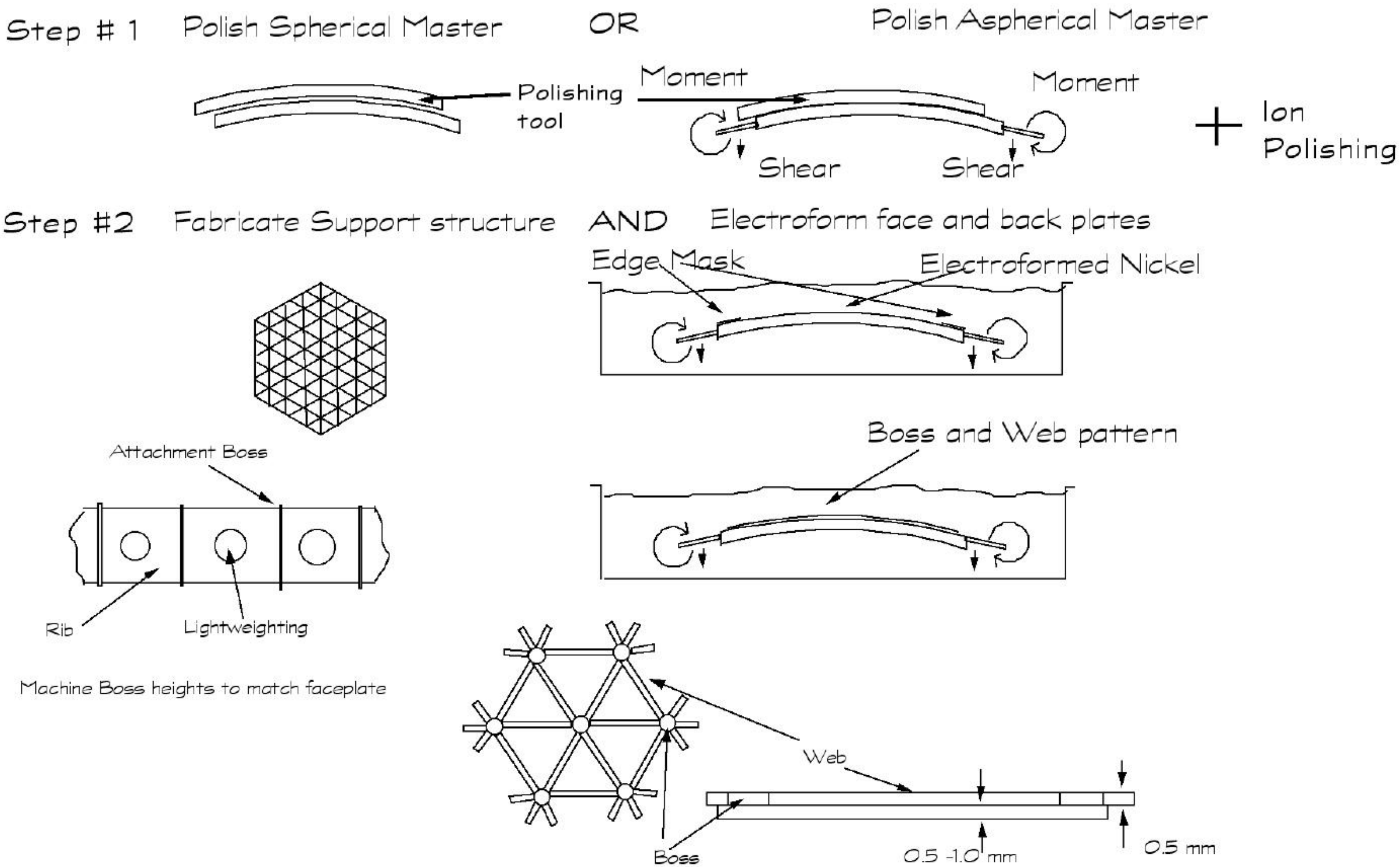
Coat mandrel

Electroform onto mandrel

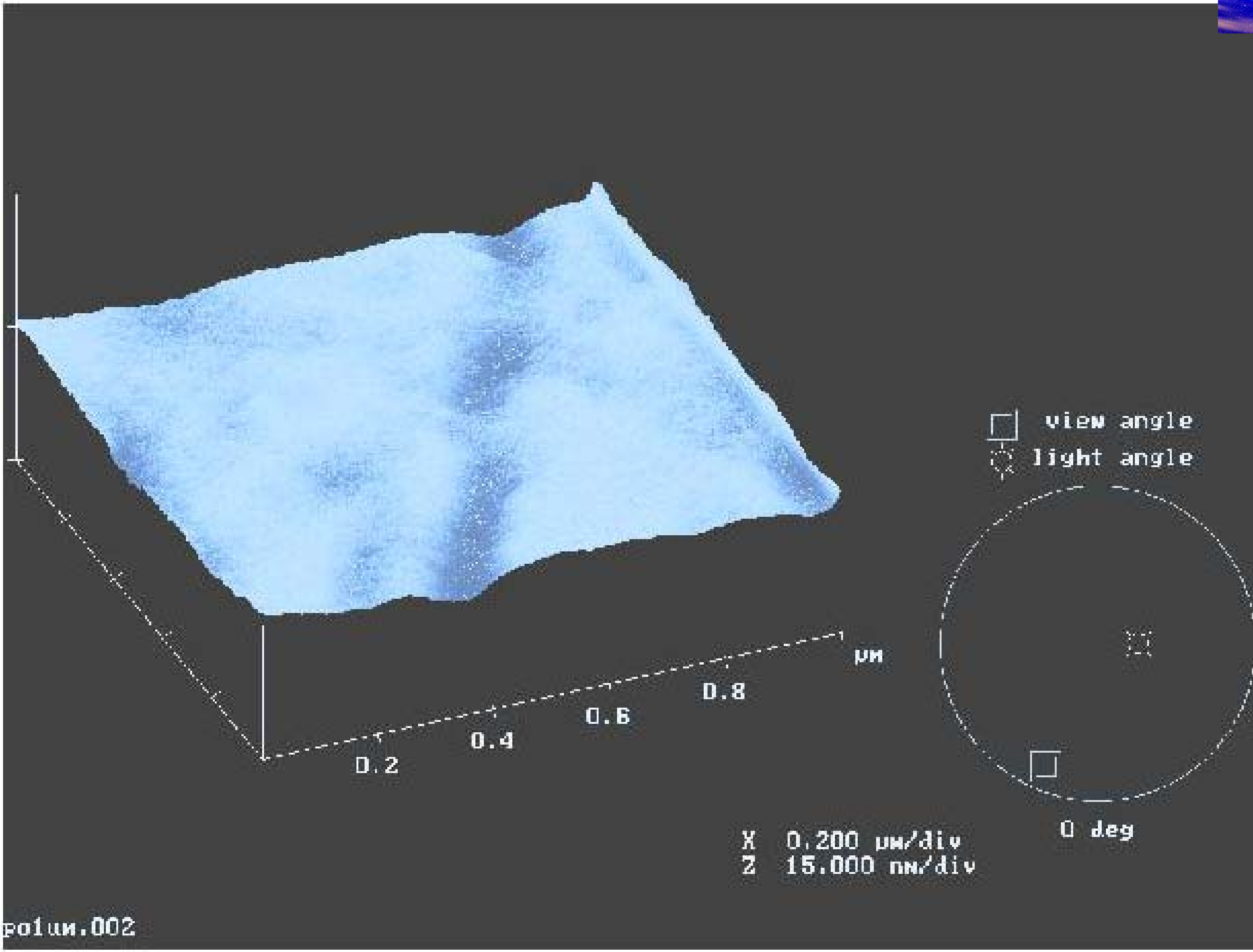
Attach support, if necessary

Remove from mandrel

Segment Fabrication



Step #3 Assemble faceplate, backplate to support structure



view angle
light angle
μm
0.2
0.4
0.6
0.8
0 deg
X 0.200 μm/div
Z 15.000 nm/div
po1um.002

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Sample more complete process:

Coat mandrel with CNx

Coat mandrel with release layer

Coat with refllecting layer

Coat with adhesion layers, if necessary

Electroform

Remove electroform

Remove release layer

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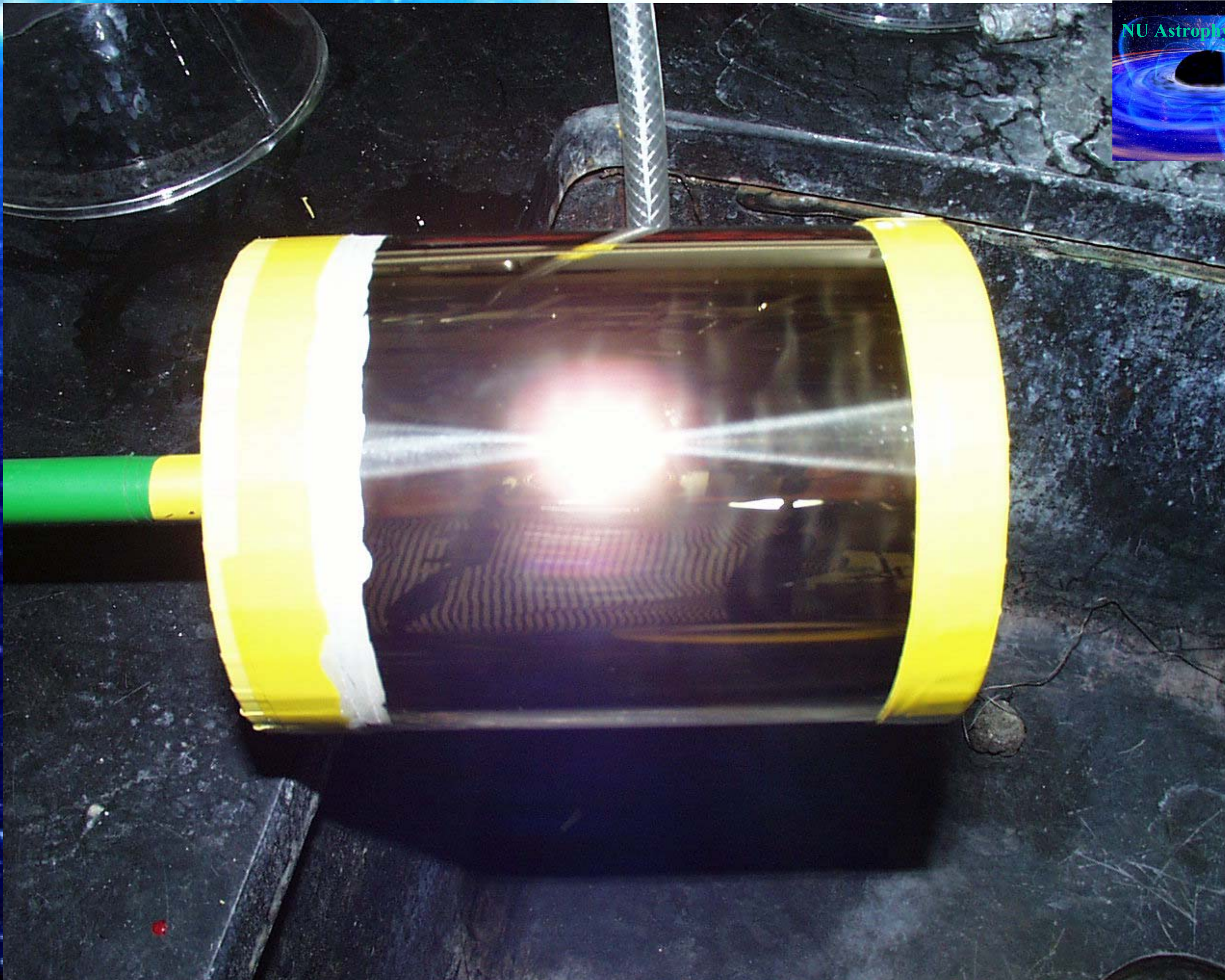
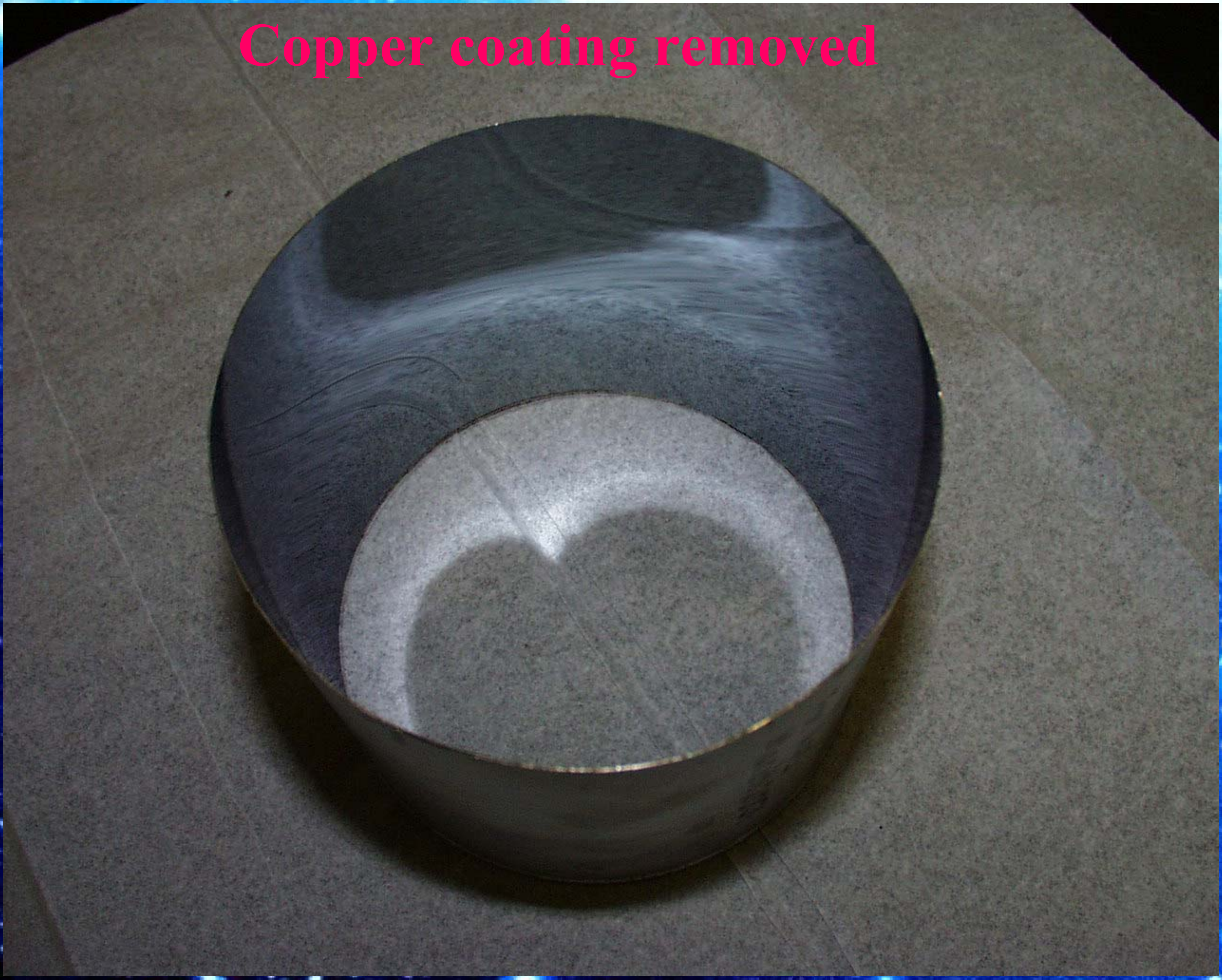



10
cm
10 cm

Copper coating removed



Progress to date, cont.

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• We are well on our way to making 4 inch (10 cm) diameter, and have made 2 in diameter pieces both convex and flat. These were thick enough (100 - 200 μm) to be self- supporting.

• Designs by Ed Kibblewhite, Ball, and NU have been made. We are exploring stiff supports that prevent the electroform from deforming upon removal from the master (based on the assumption that stresses set up in the electroforming of the segment could lead to out of “spec” deformation.)

Other paths to explore:

- Combine composite expertise with electroforming expertise. Send sample to CTD and let them support the electroform with Elastic Memory Composites. Experiment with electroform thickness . Experiment with coating EMC and let EMC be the primary piece. Heating after release to refine the shape?

Other paths to explore:

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• Another possibility is plasma spray and laminates and we (NU) can do this also.

High bay loft at Ball, all ready to go for mirror testing

A smart material consisting of shape memory polymer and fiber reinforcement.

Ball Aerospace & Technologies Corp.

Summary and Conclusions

Replication is such good idea that the basic concept should be explored.

A combination of electroforming or ceramics combined with composites should "win the game"

Our "baby steps," combined with previous work gives support to these ideas.

Summary and Conclusions

The team of NU, Ball and CTD has the necessary skills and facilities to carry out a thorough study of replication technology.

This includes electroforming, plasma spraying at NU, optical alignment testing and control design at Ball, and composite materials development at CTD.

Work is in progress, come to SPIE in Hawaii in August to get an update.

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Summary and Conclusions

Academic institutions such as NU can make significant contributions to address issues related to fabrication of segments and the issue should not be simply treated as problem to be solved by industry.

The ATILA End