Low Cost Very Large Diamond Turned Metal Mirror

Contract No. NNX10CB49C (SBIR 08-2 S2.04-9926) (MSFC)

Mirror Technology SBIR/STTR Workshop

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OUTLINE

- **CONCEPT AND GOALS**
- **MIRROR MFG. PROCESS**
- **PROGRESS TO DATE**
- **SUMMARY**

Concept and Goals

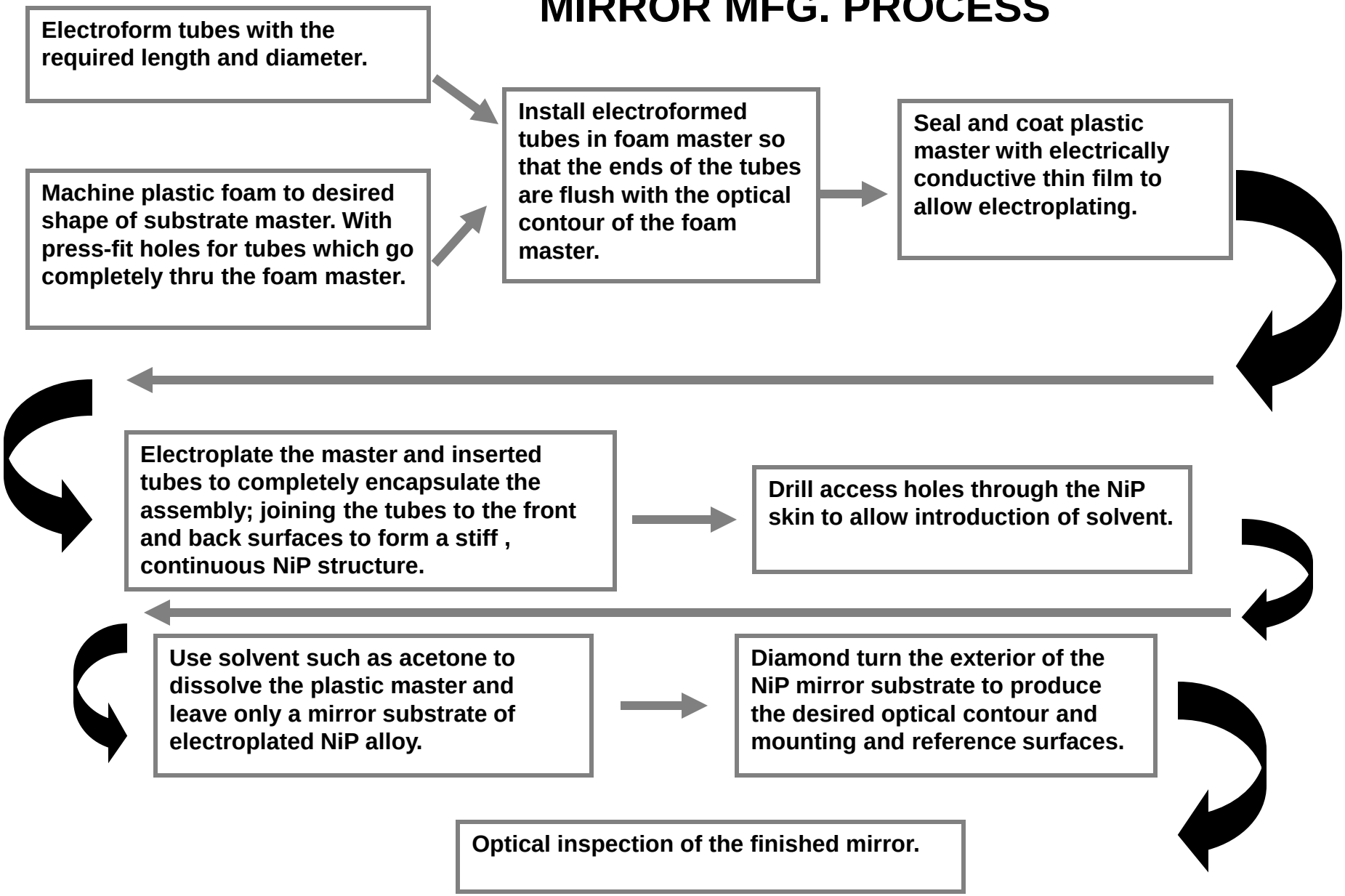
--- Develop and demonstrate a process for producing a light weight, stiff mirror substrate by electroplating a NiP alloy over a plastic foam mandrel which will be removed with solvent after plating.

--- Demonstration of diamond turning as a method of producing a high quality optical surface on the electroplated NiP substrate by producing a 300 mm (12 inch) diameter flat test mirror.

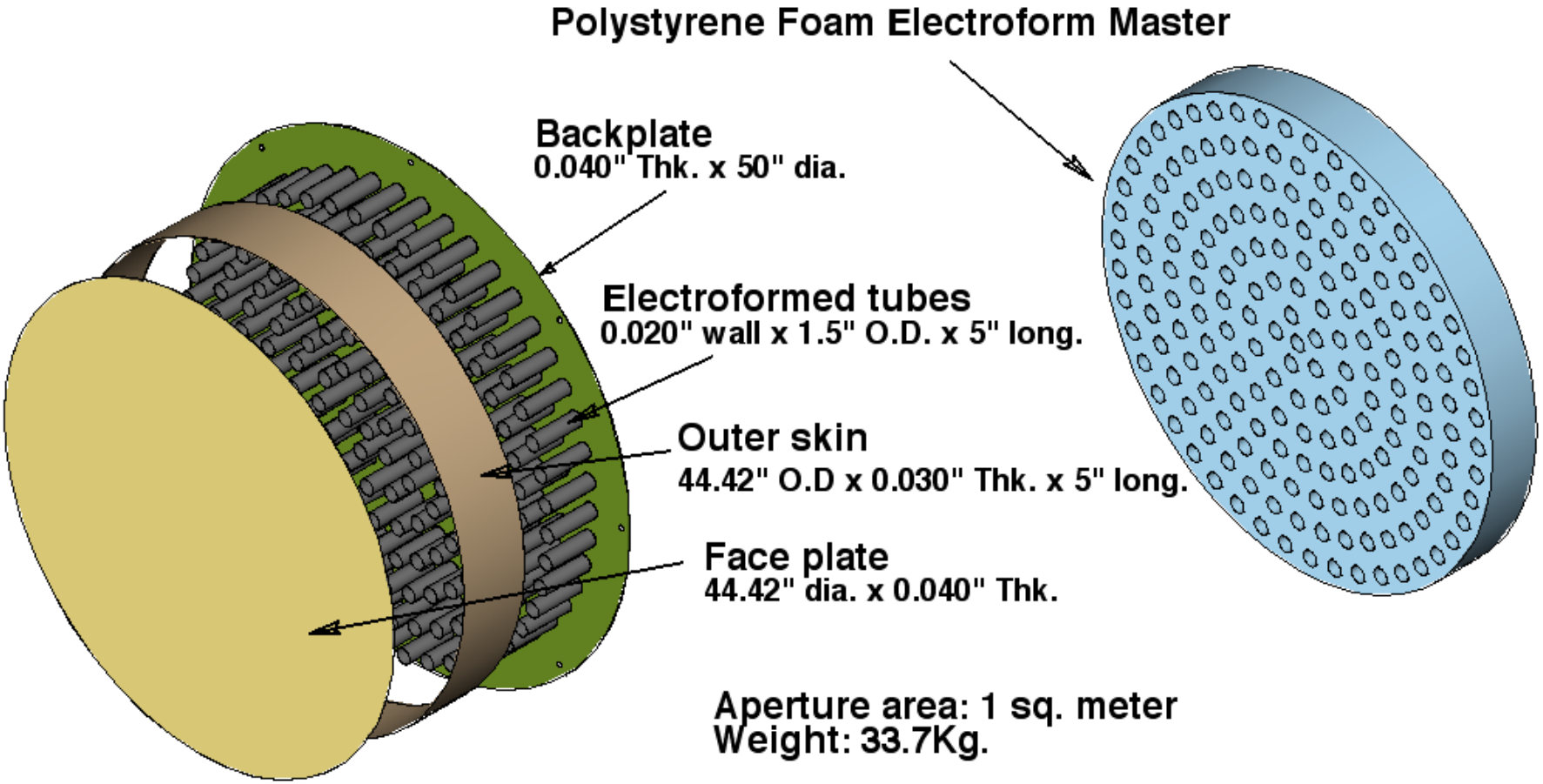
--- Evaluation of mechanical stability and stiffness and the extent of mirror internal structure print through on the finished optical surface as a function of faceplate thickness.

--- Optical and dimensional inspection and characterization of the finished mirror for overall optical figure accuracy and surface smoothness achieved by diamond turning.

MIRROR MFG. PROCESS



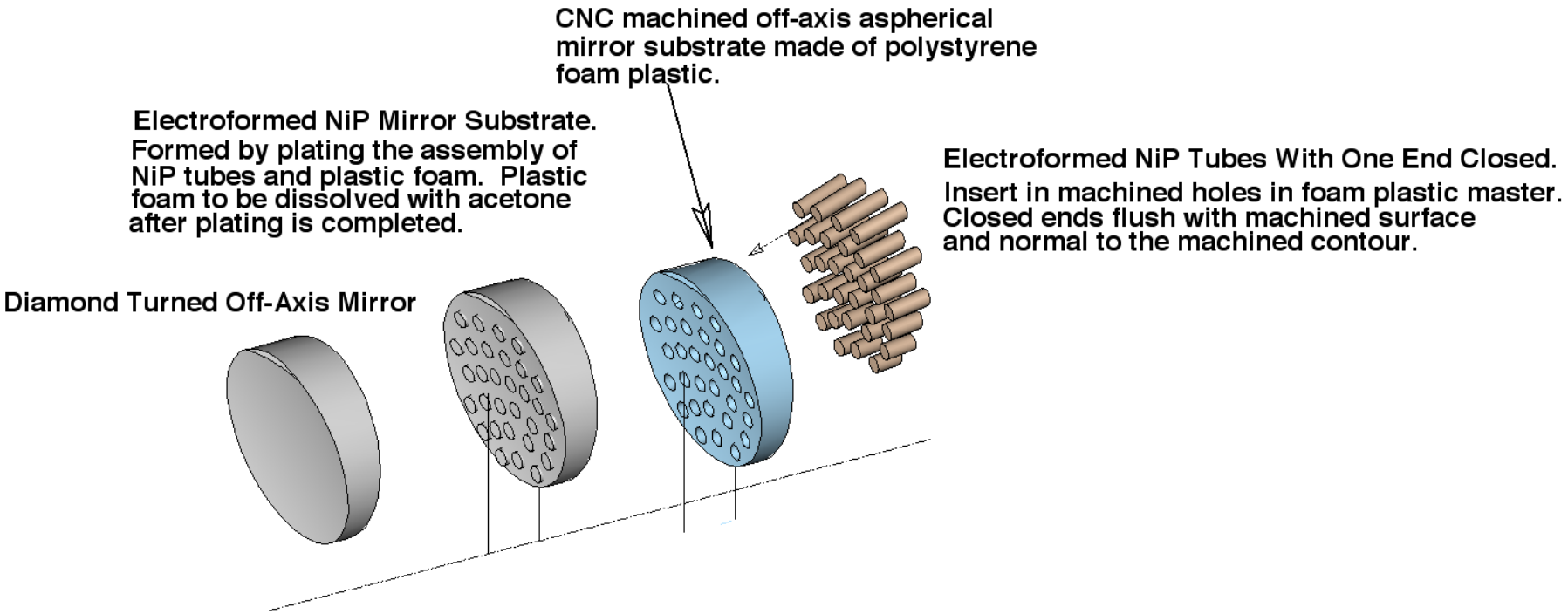
Weight of 1 Sq. Meter Mirror



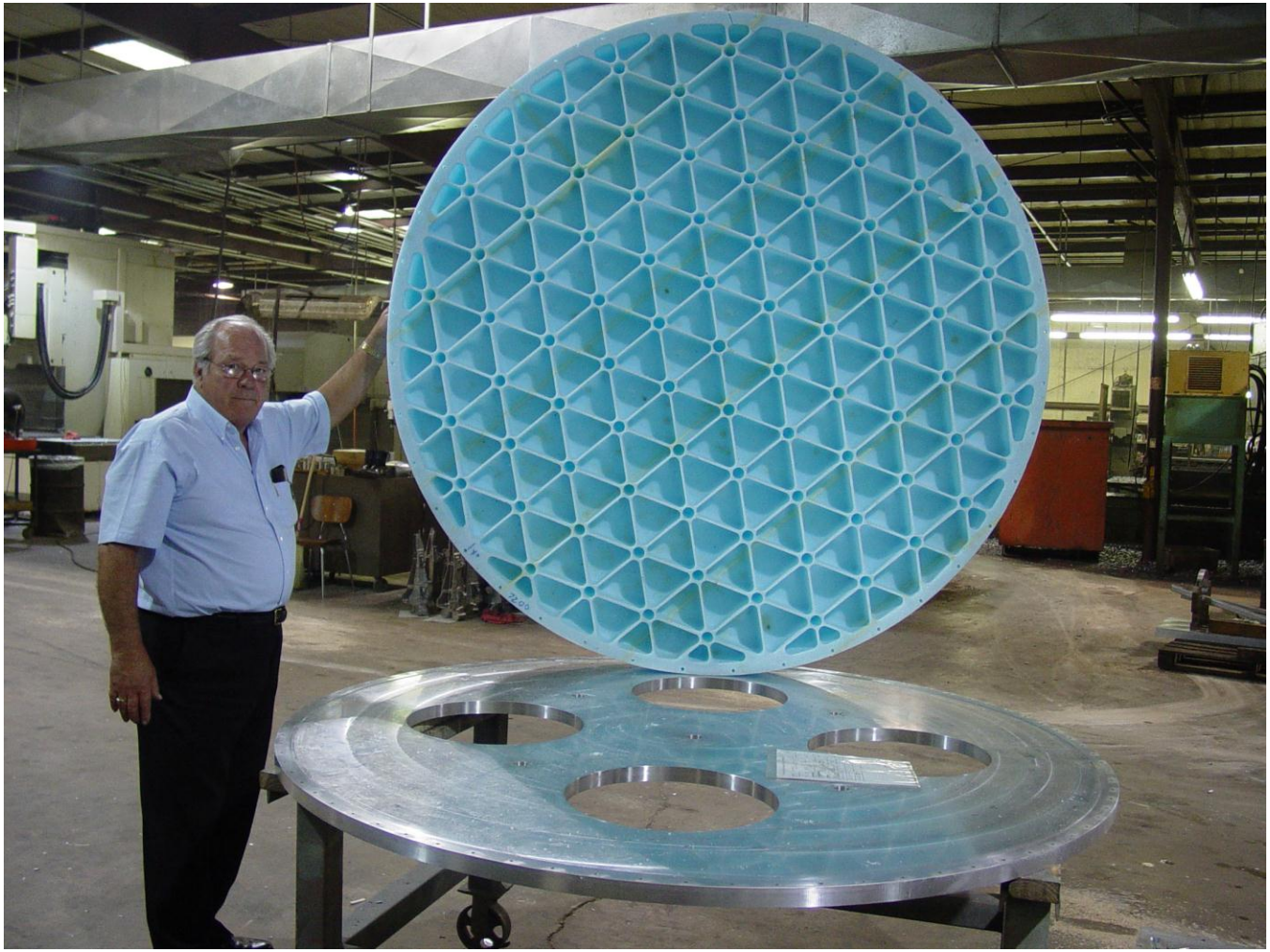
Aperture area: 1 sq. meter
Weight: 33.7Kg.

After diamond turning mirror surface and back plate.
Weight: 27 Kg.

Off-Axis Aspheric Mirror

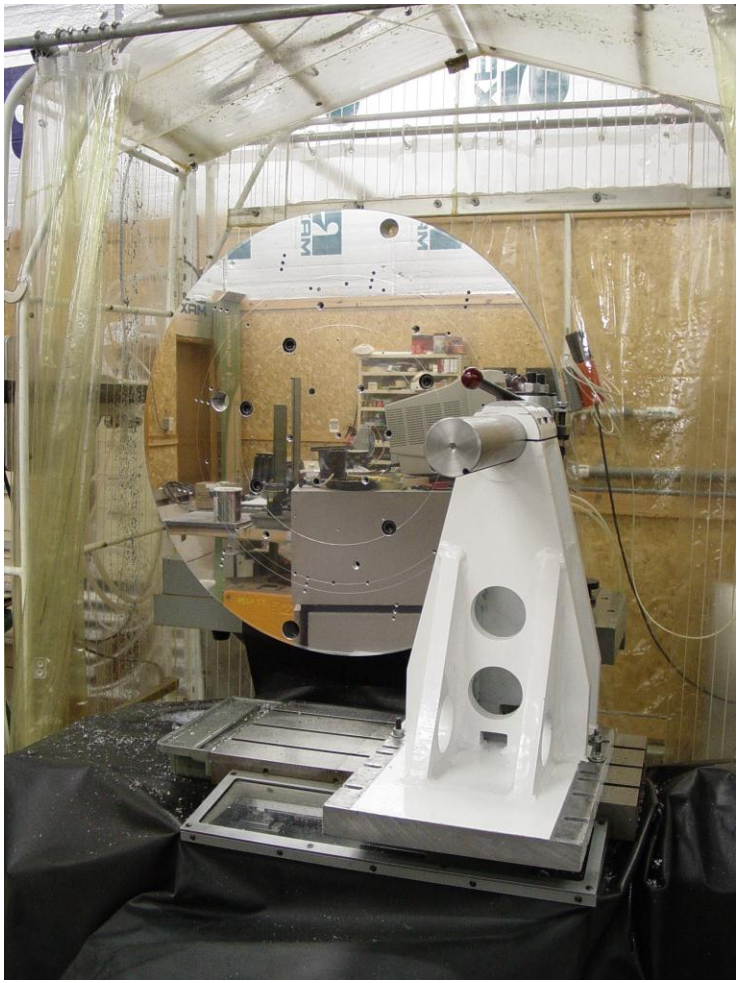


1.8 Meter Diameter Foam Plastic Mirror Substrate



2.48 Meter Aluminum Mirror

Large Part Diamond Turning Experience



Technology

- **A very important process for electroplating high phosphorus nickel alloys has been developed at the University of Alabama at Huntsville and at Marshall Space Flight Center.**

- **This plating process is capable of producing very low stress NiP deposits of very high quality that allow excellent surfaces to be diamond turned on the material.**

- **The electrolytic NiP plating process is not limited in plating thickness. Thick wall, structurally robust mirror substrates can be built up with this electroplating process.**

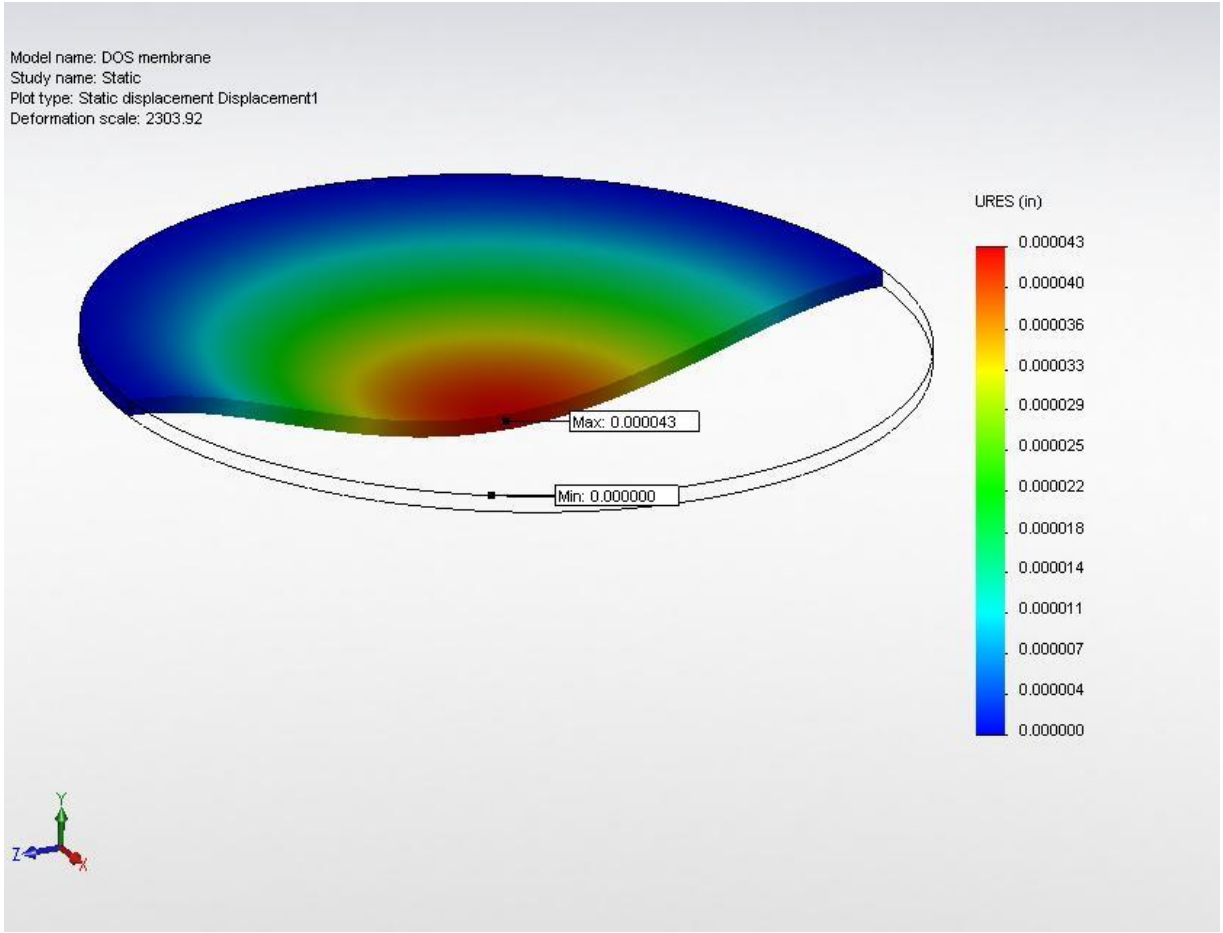
Comparison of Nickel Phosphorus Deposition to Other Processes

Parameter	Nickel	Electroless Nickel	NiP & NiCoP (Electrolytic)
Plating Temp °C	38 – 50	82 – 90	40 – 50
Control Method	Soluble Anode	Chemical Replenish	Soluble Anode
Yield (0.2%) (MPa)	500	See UTS	See UTS
MicroYield (MPa)	70	500 +	830 +
UTS Max (MPa)	800	850	1800 – 2150
Specific Gravity	8.9	7.8 – 8.0	7.8 – 8.0
Stress Control (Real Time)	Yes	No	Yes
Hardness (Rockwell C)	22 – 24	48 – 52	48 – 52
Diamond Machining	No	Yes	Yes
Thick Deposits	Yes	No	Yes

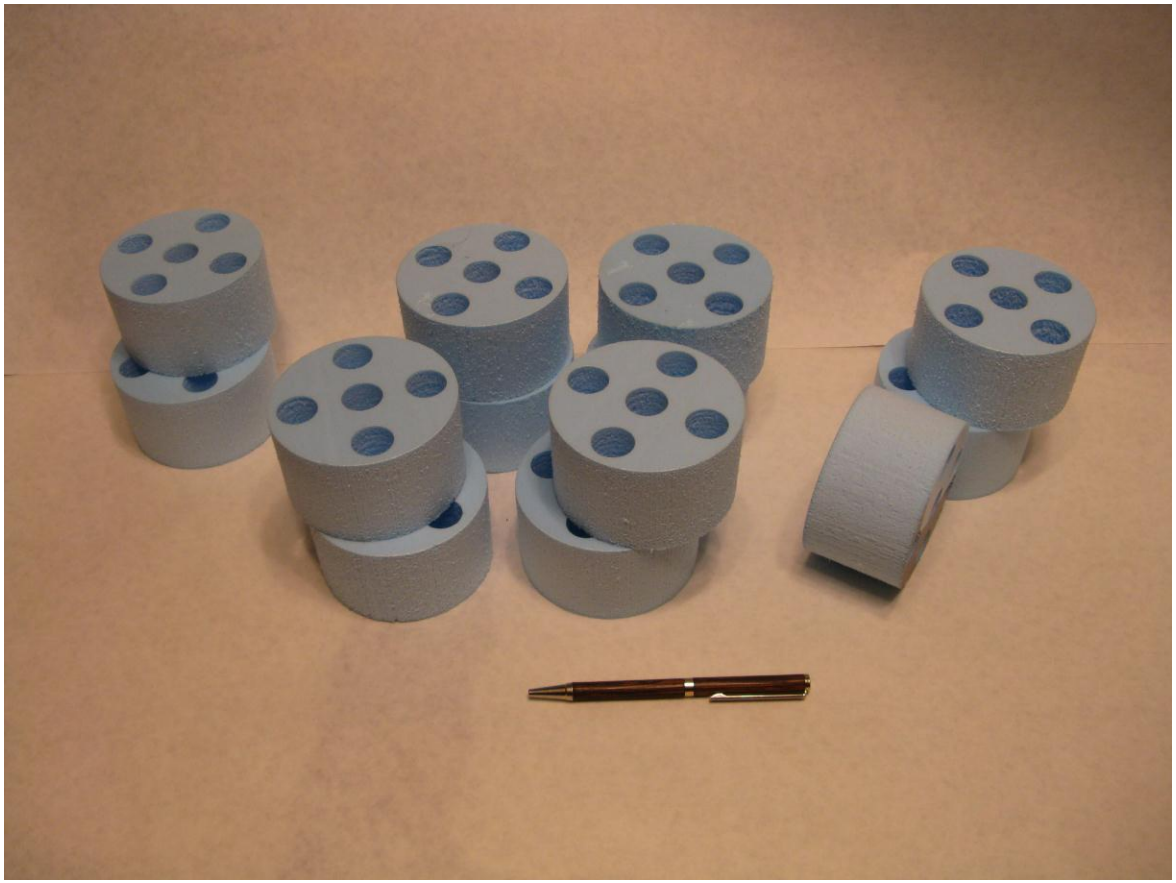
Electroforming Technology Developed by UAH and MSFC for X-Ray Telescope Fabrication

Mirror Design

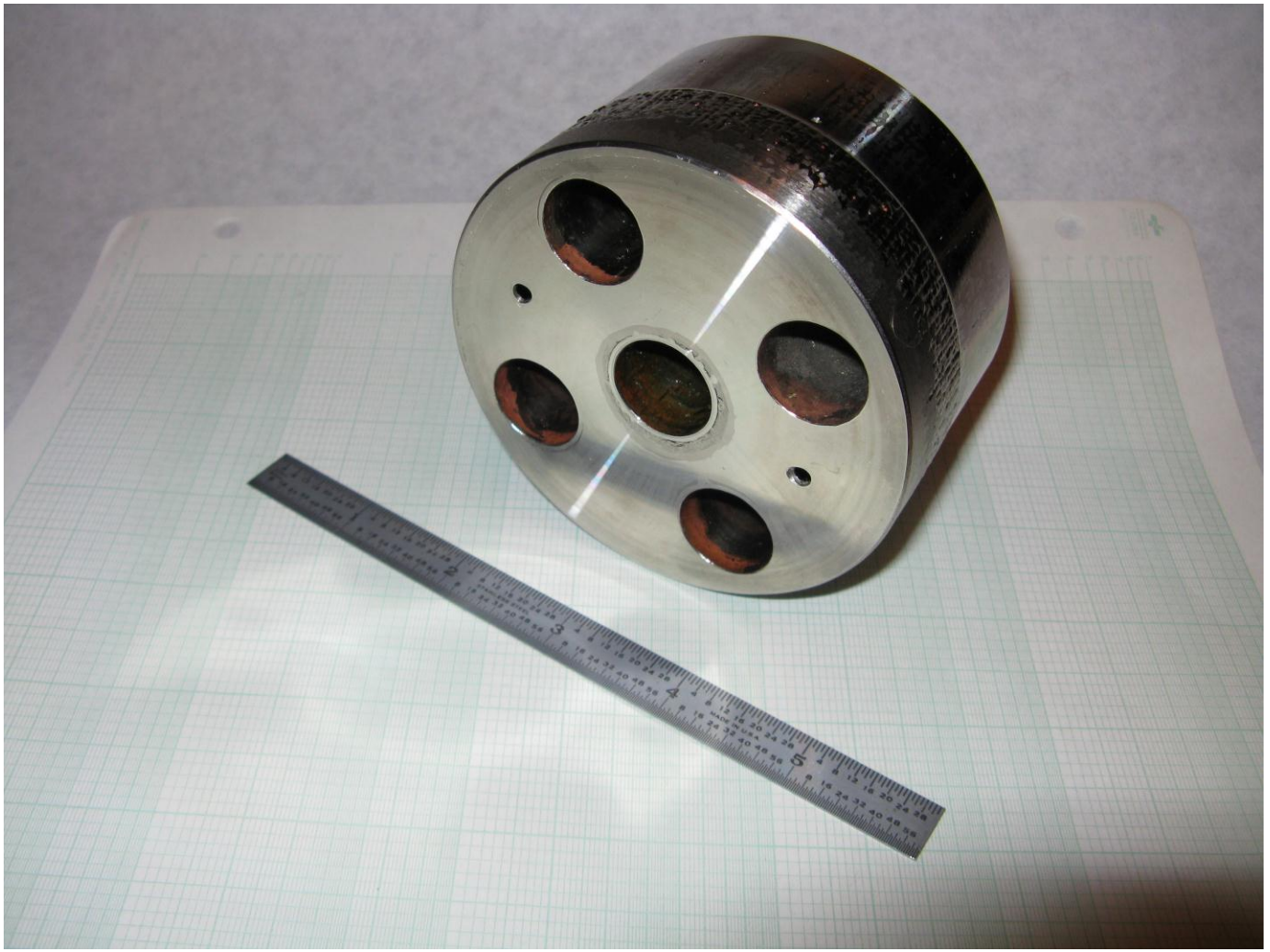
Plating thicknesses and diameter and spacing of tubes optimized for best performance.



89mm Diameter Foam Master Forms



Precision Machined Back of Plated Mirror Assembly



Diamond Turned and Polished NiP Mirror

SBIR Goal Is A *Low Cost Process* For 3 Meter Mirrors

- Large mirrors require production of thousands of tubes.
- Curved mirrors require tubes of different lengths.
- Large production of tubes of many lengths not cost effective.

PRODUCTION FRIENDLY METHOD FOR ELECTROFORMED TUBES

- Electroform long tubes and cut to required lengths.
- Open end tubes allow holes in foam to be parallel to optical axis.
- Inserted electroformed tube assemblies can be matched to contour.

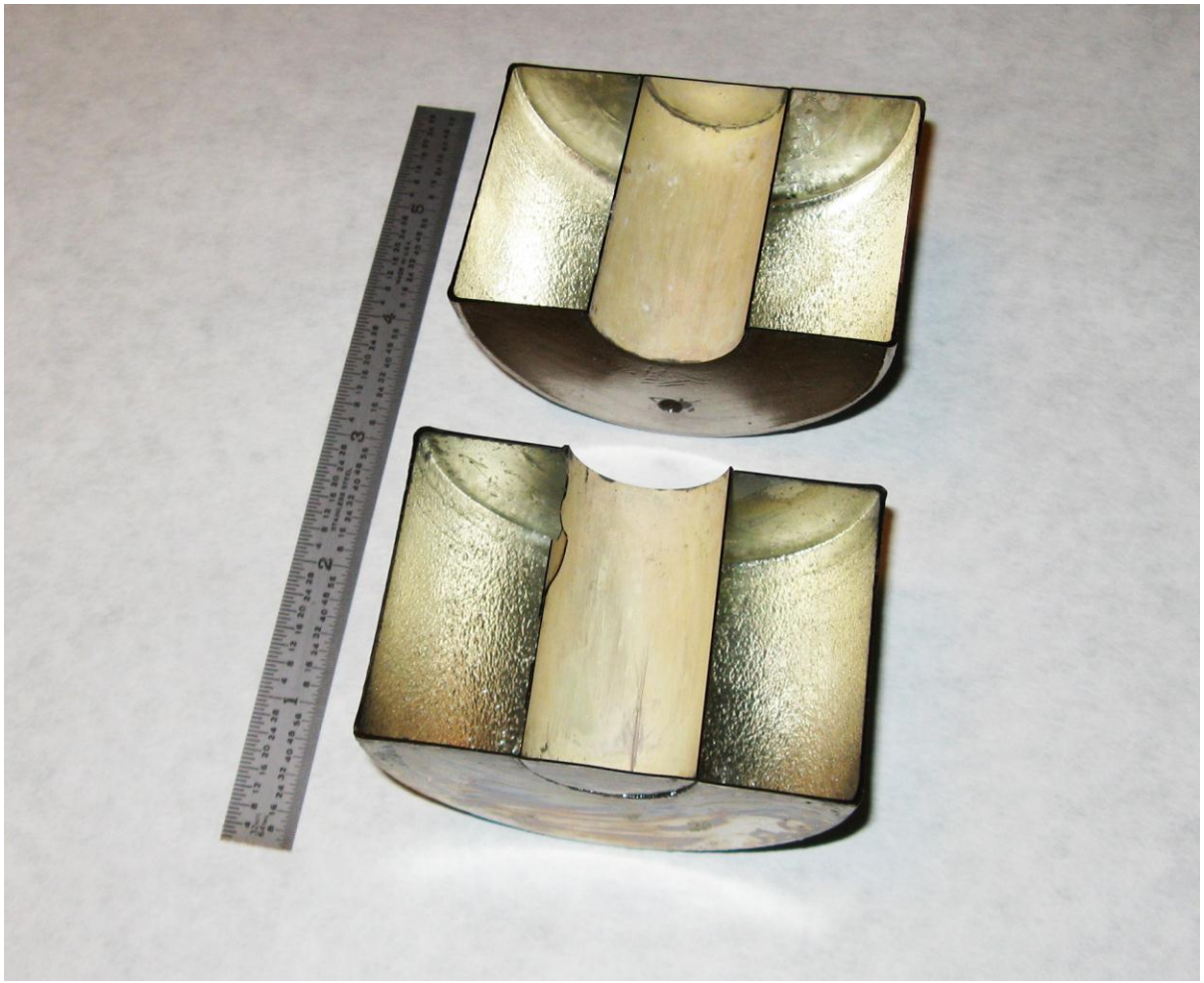
Issues For Electroforming Tubes On Rods

- **Cutting composite of hard nickel on soft rod is difficult.**
- **Mandrel rod must be smooth, round and constant diameter.**
- **Mandrel removal must be a reliable low force process.**
- **Obtaining a reliable continuous bond of every tube to the encapsulation plating at both ends for all tubes is essential.**

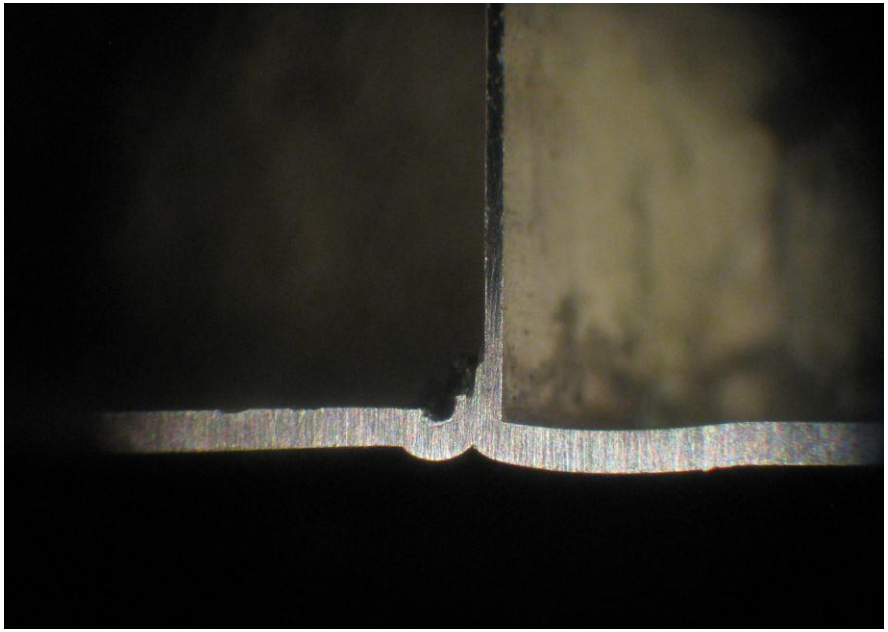
Mandrel Development

- **Castable mandrel material for electroplating meets SBIR goal of very low cost of large mirror substrates.**
- **Castable mandrel material is recycleable low cost and low waste, removable by differential expansion, melting and dissolution.**

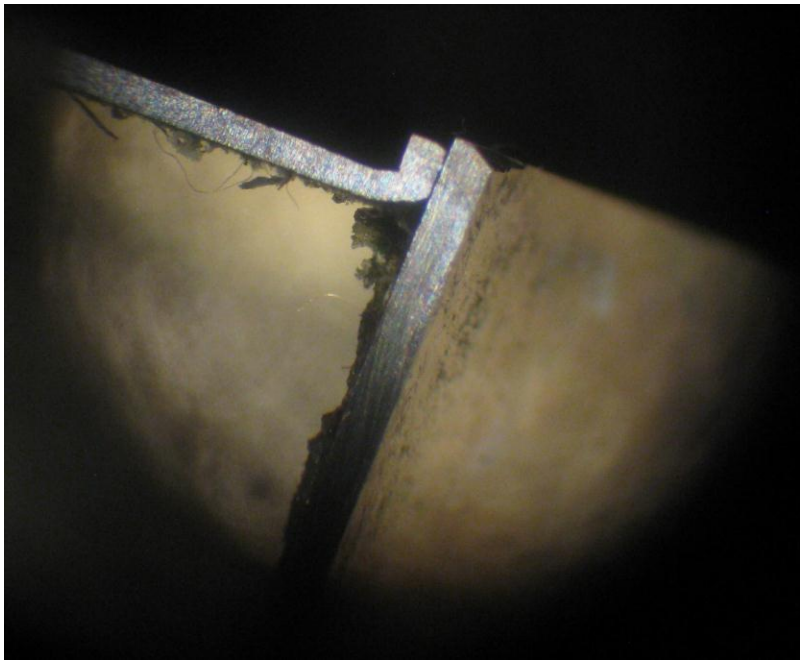
Test Mirror Cut in Half for Evaluation of Joint Quality



Micrographs of Unreliable Tube to Mirror Face Joint



FRONT FACE

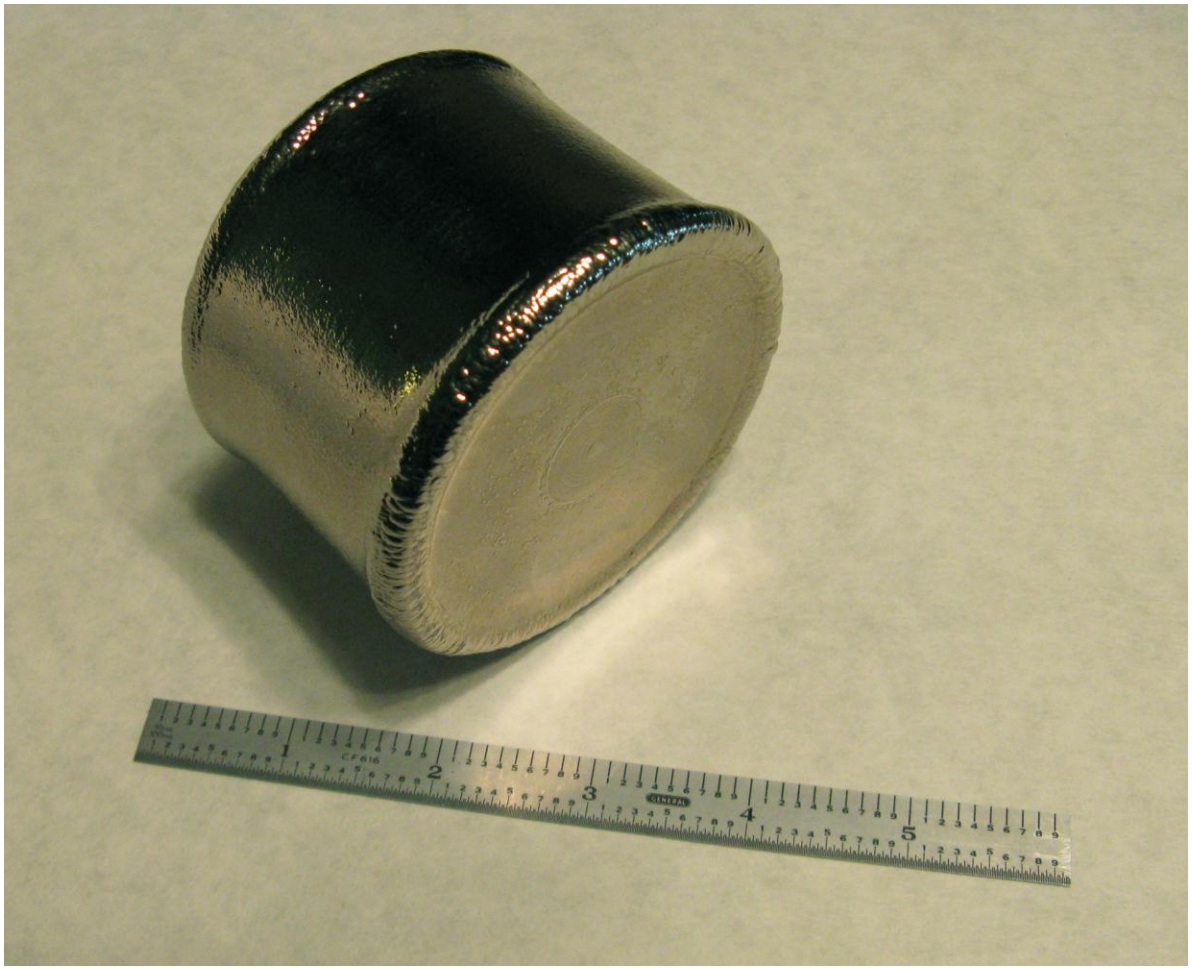


BACK FACE

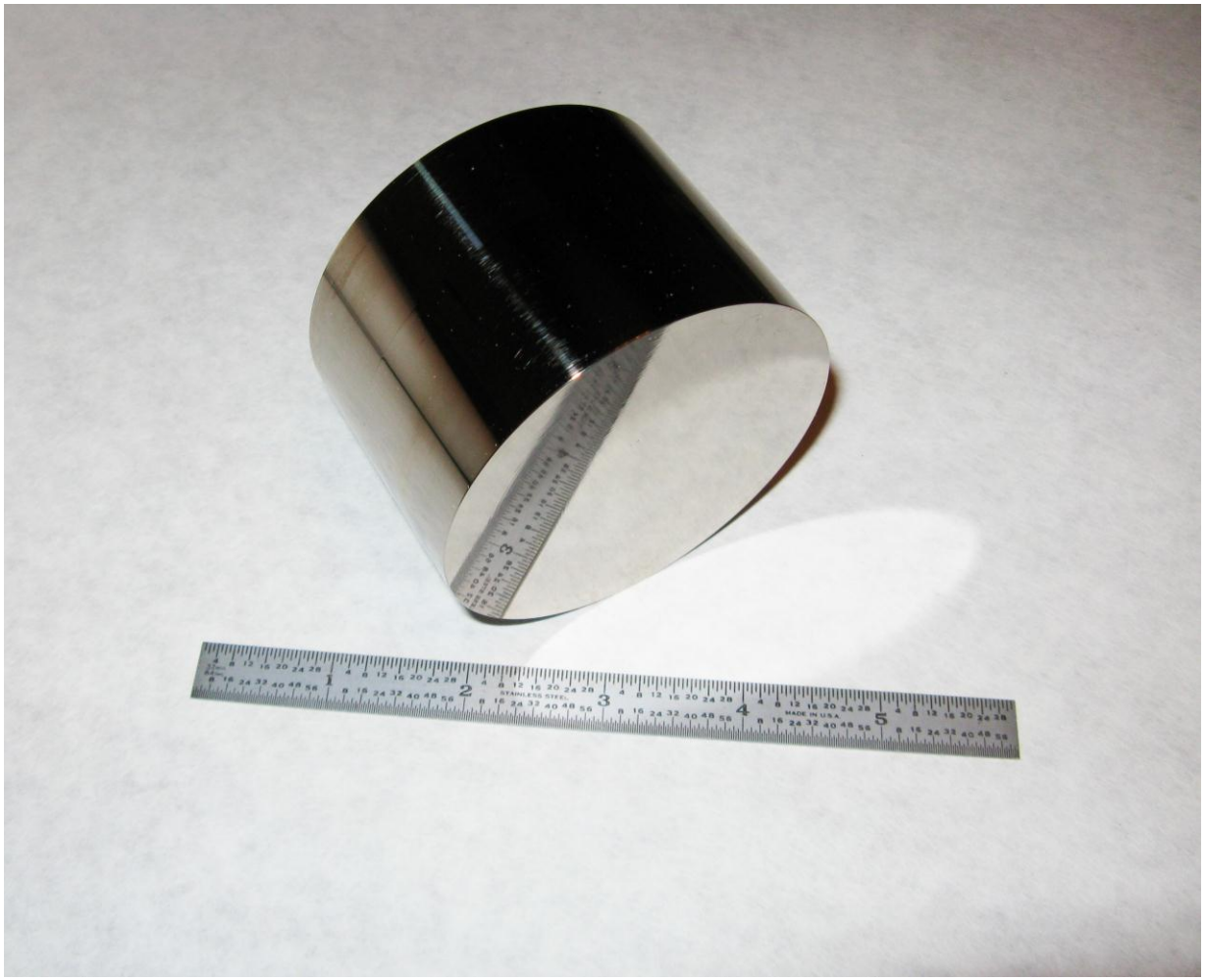
Four Test Mirror Substrates After NiP Plating

- **A method of achieving a reliable bond of tubes to the encapsulating plating has been developed.**

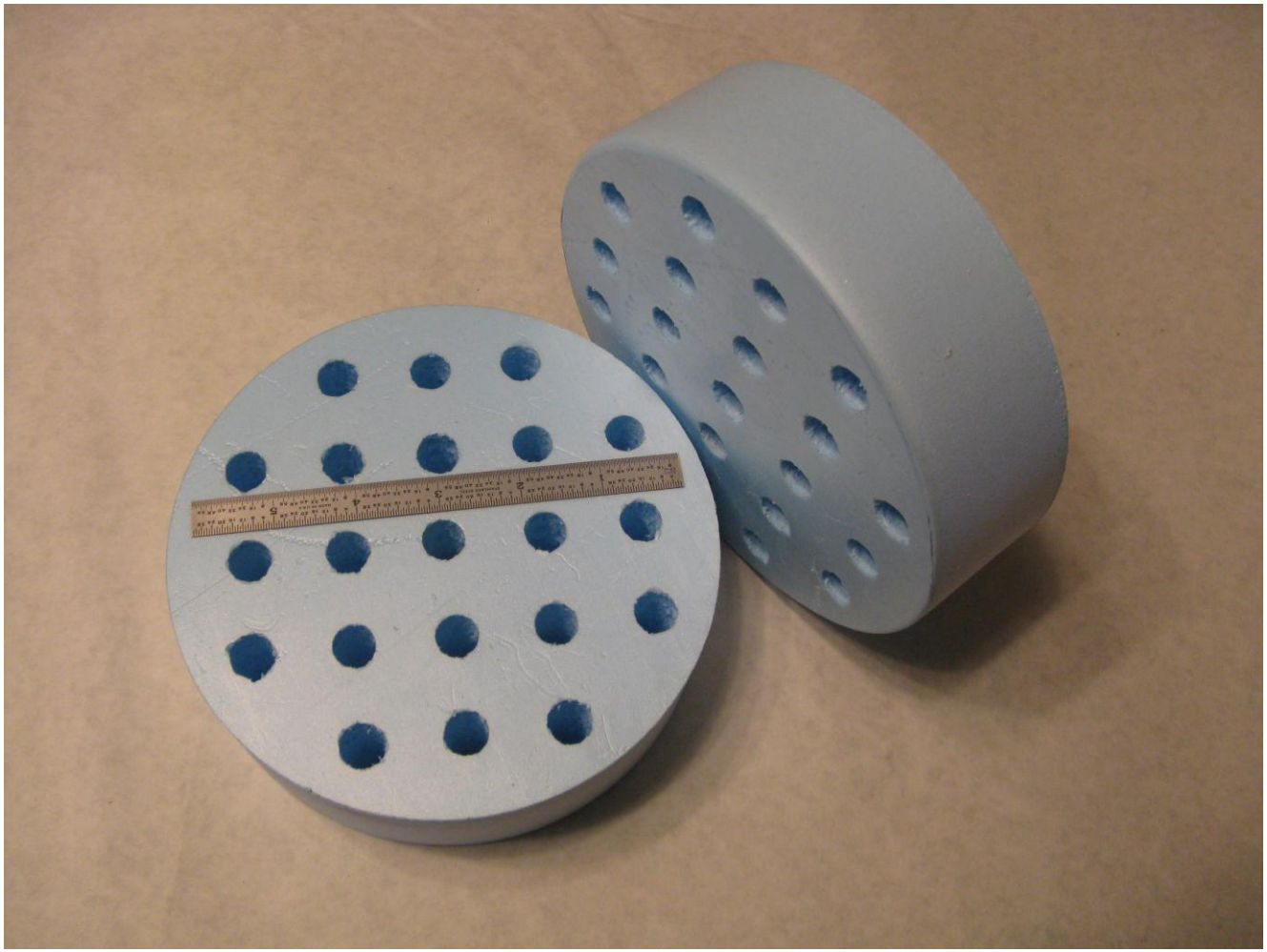
High Quality NiP Plated Test Mirror Substrate



Diamond Turned and Polished NiP Test Mirror



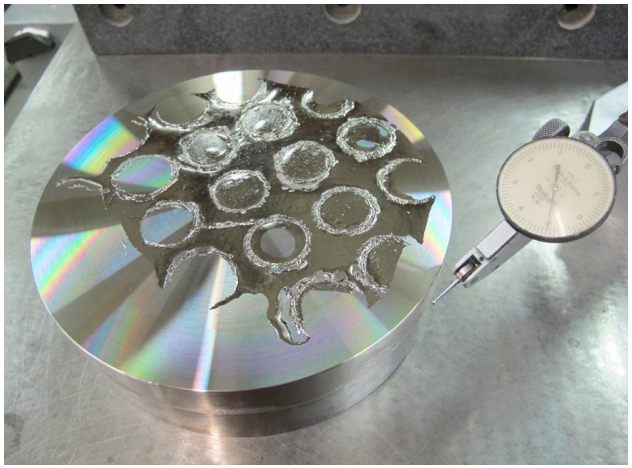
187 mm Diameter Polystyrene Foam Mandrels



187mm Diameter Mirror Assembly Plated with NiP

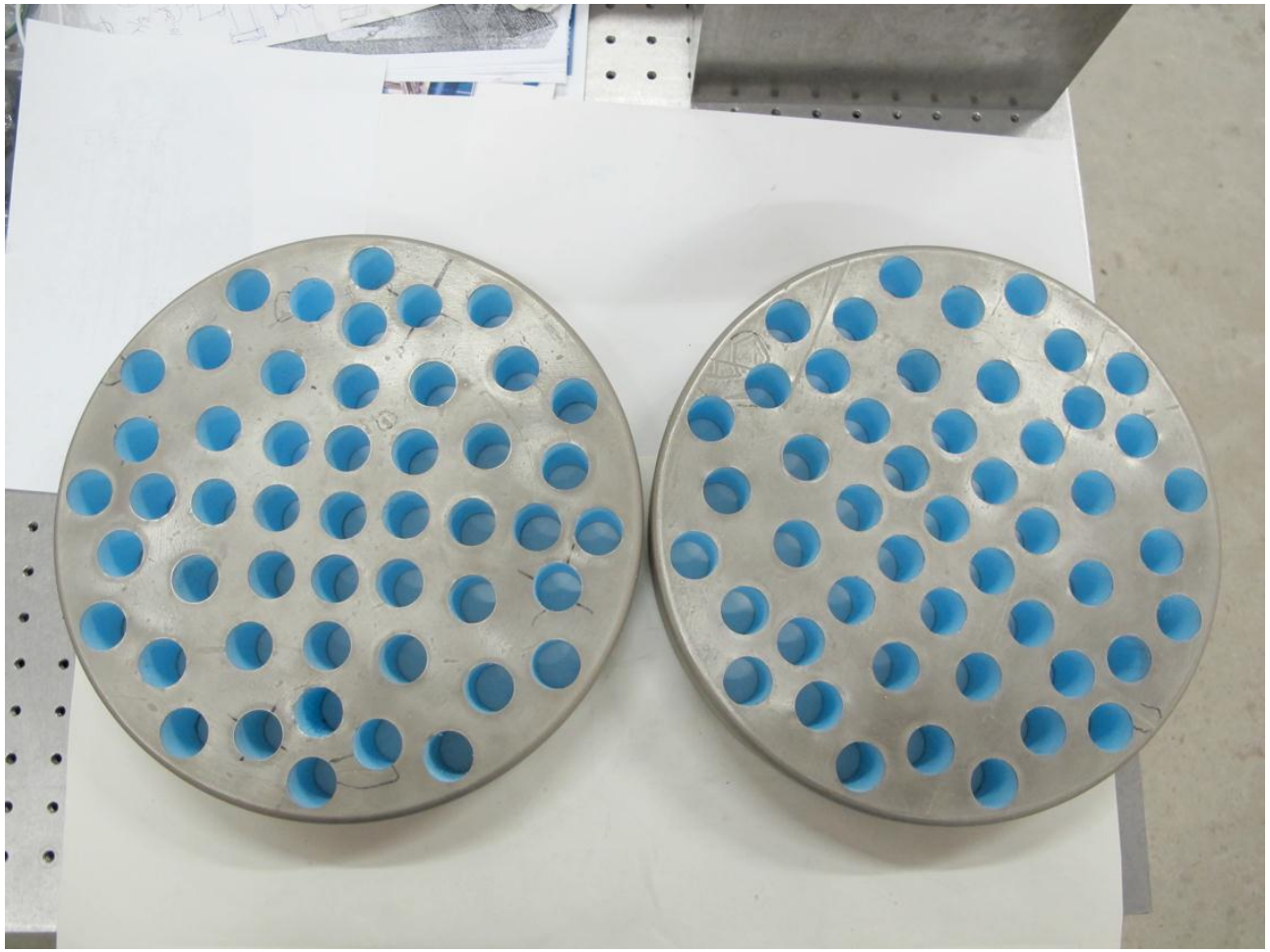
Front of Mirror Substrate

Back of Mirror Substrate



Preliminary PCD Diamond Turning

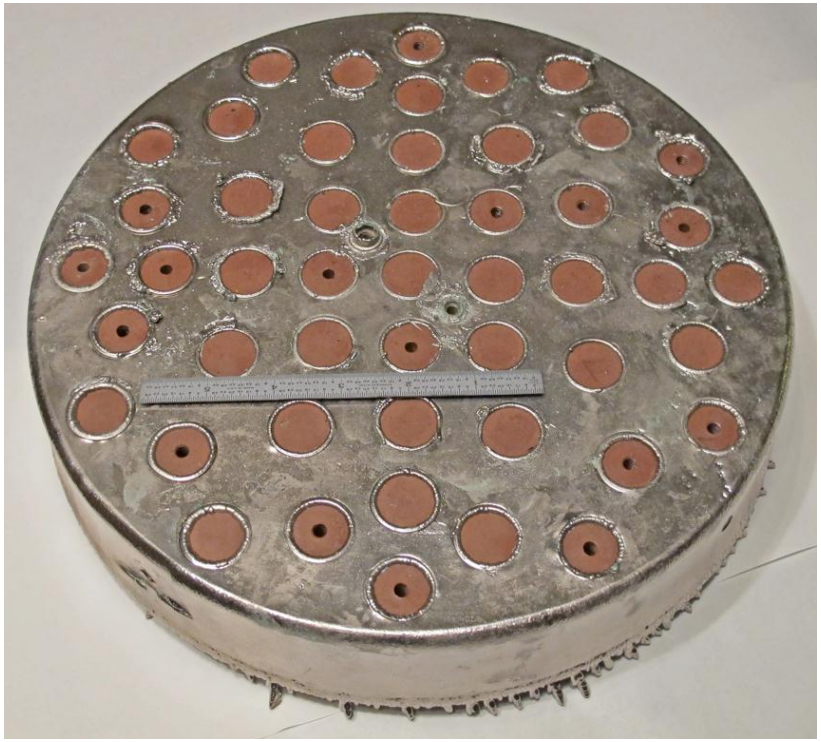
302mm dia. x 50mm SNi pre-plated foam mandrels (49 holes)



302mm mirror ready for NiP plating

First 300mm development test mirror after encapsulation with NiP plating

Front of Mirror Substrate



Back of Mirror Substrate

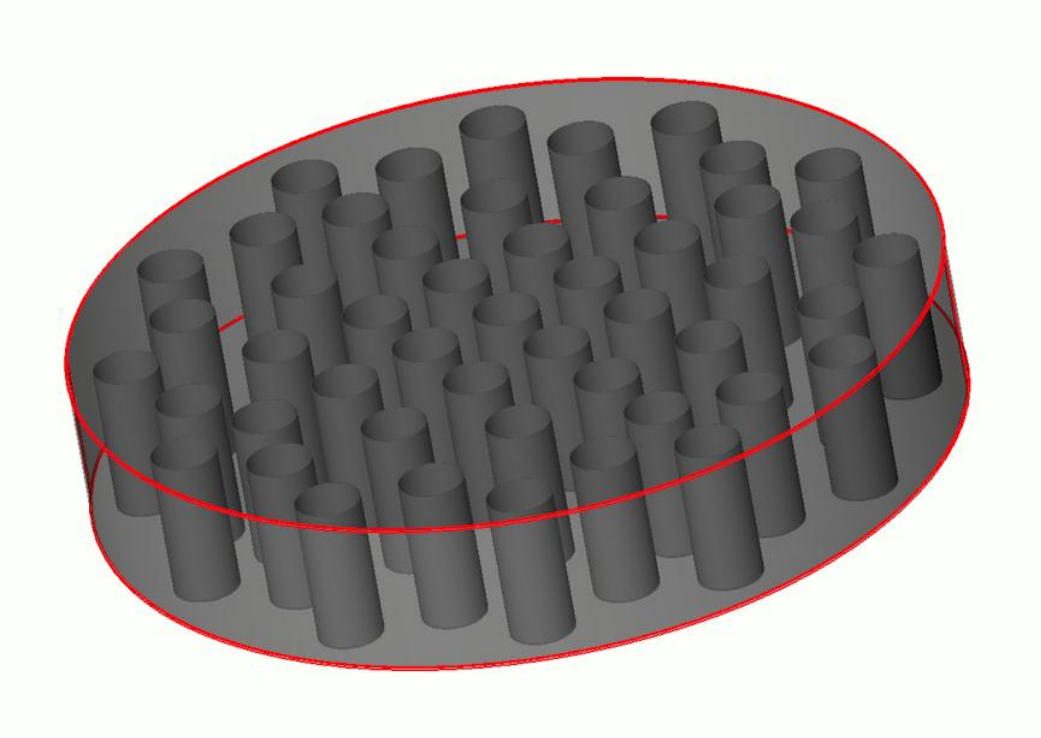
Surface preparation of mandrel assembly to smooth surface and remove small imperfections is very important to prevent uncontrolled electroplated deposits.

Back views of the first 300mm (12”) dia. x 50mm (2”) NiP mirror

Front views of the first 300mm (12”) dia. x 50mm(2”) NiP mirror

Weight of mirror substrate is 8.5 lb. Mirror dia. 310mm. Areal density 51.6 kg/sq. meter. 88 percent lightweighted.

CAD Model of 310mm Electroformed NiP Mirror Substrate



- **Excess electroplated NiP material increases measured areal density over expected 27.7 Kg/Sq. Meter and 94 % lightweighting.**

SUMMARY

- **Low cost mirror *SUBSTRATE* by electroplating of NiP.**
- **Diamond turning of NiP electroformed substrate is a very low cost, very fast and very flexible manufacturing process for large mirrors.**
- **Low (10-30 kg/sq. meter) areal density, very stiff metal mirror.**
- **Only one material means low thermal distortion.**
- **The developed manufacturing process for electroformed mirror substrates is scalable to 3 meters and larger.**
- **Electroplating of NiP to produce a hard, low stress, corrosion resistant deposit to any desired thickness is well developed.**
- **More development needed on electroplating process to remove surface imperfections.**