S2.03-9125 Additive Manufactured Very Light Weight Diamond Turned Aspheric Mirror

Contract No. NNX15CM50P (SBIR 2008-I) (MSFC)

Mirror Technology SBIR/STTR Workshop

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John M. Casstevens
Dallas Optical Systems, Inc.
972-564-1156

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OUTLINE

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

Concept and Goals

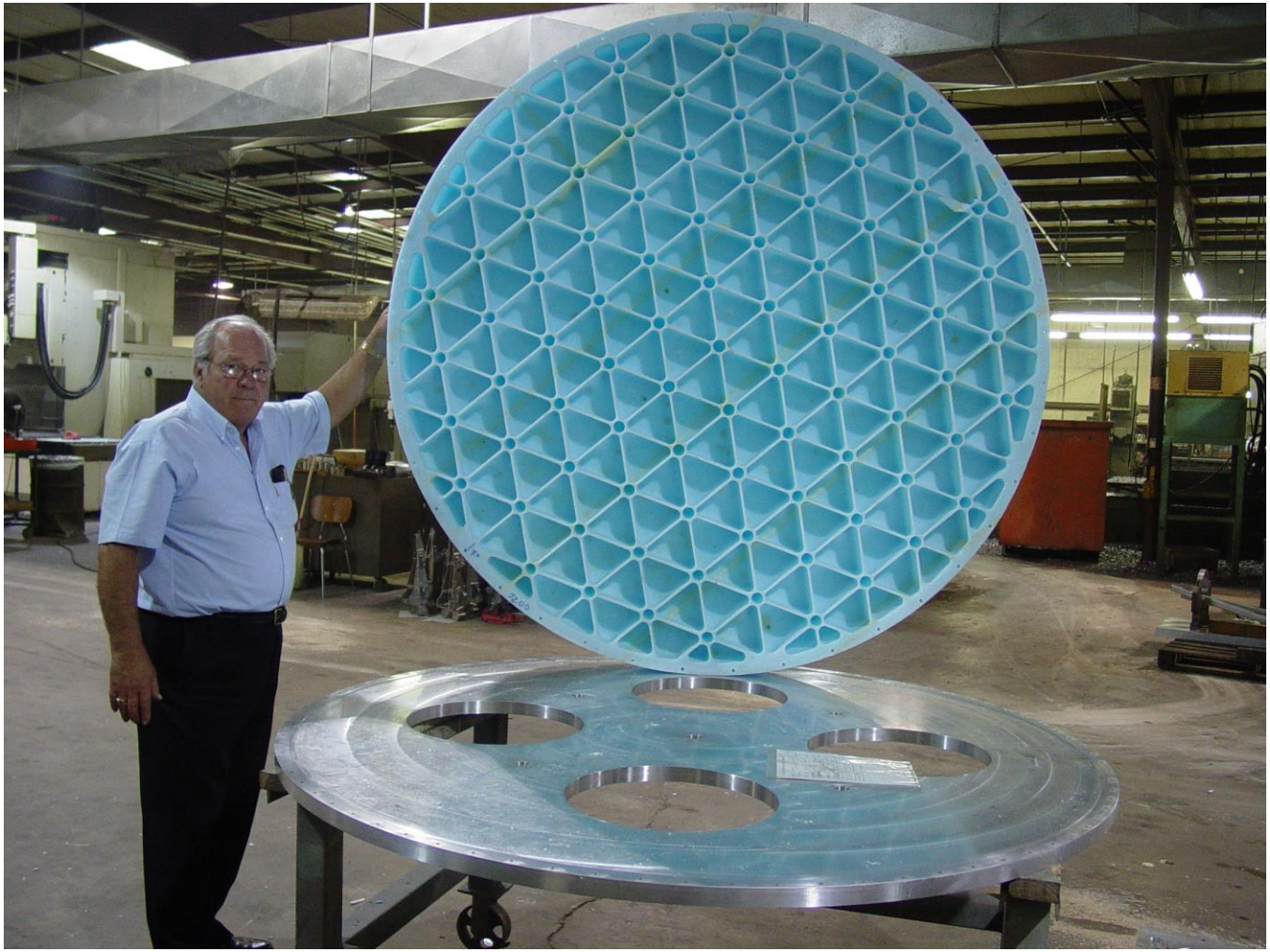
--- Develop and demonstrate a process for producing a very light weight, stiff mirror substrate with Direct Metal Laser Sintering DMLS of Inconel superalloy and other steel powders and also aluminum powders.

--- Demonstration of plating NiP alloy on a DMLS additively manufactured mirror substrate to provide a thermal expansion matched coating suitable for diamond turning as a method of producing a high quality optical surface.

--- 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.

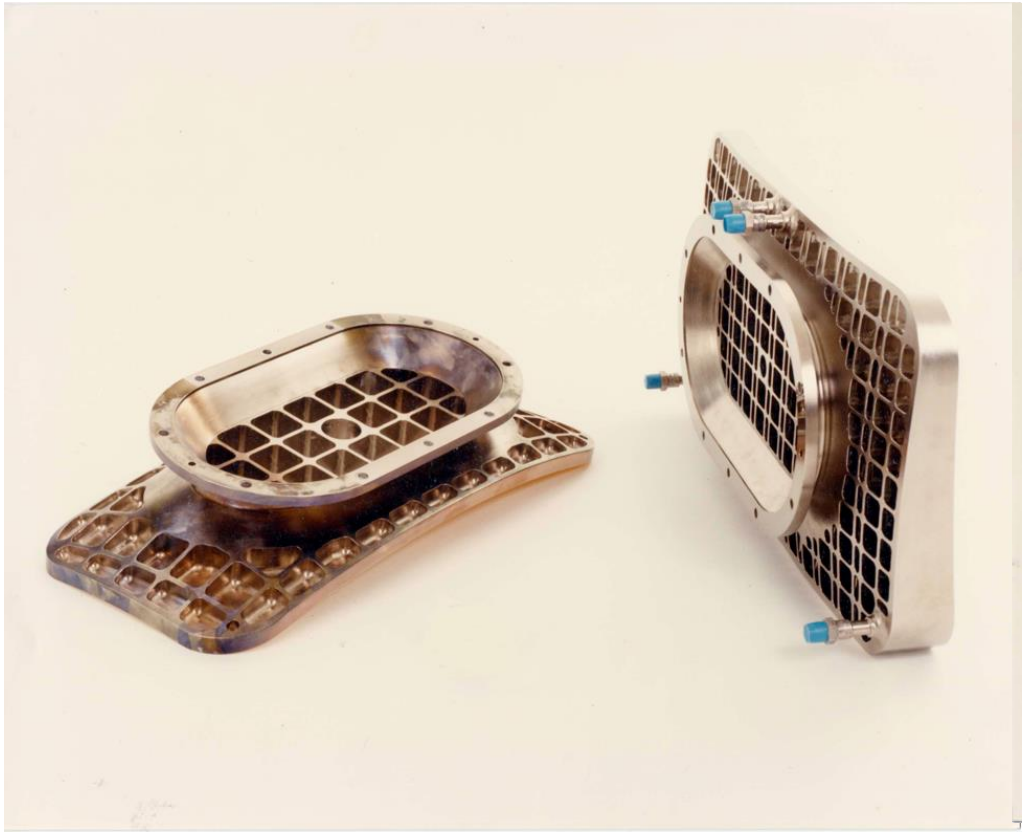
--- Optical and dimensional inspection and characterization of the finished mirror for overall optical figure accuracy and surface smoothness achieved by diamond turning.

1.8 Meter Diameter Foam Plastic Mirror Substrate



2.48 Meter Aluminum Mirror

Diamond Turned Off-Axis Light Weighted Electroless Nickel Plated Aluminum Mirrors



Large Part Diamond Turning Experience

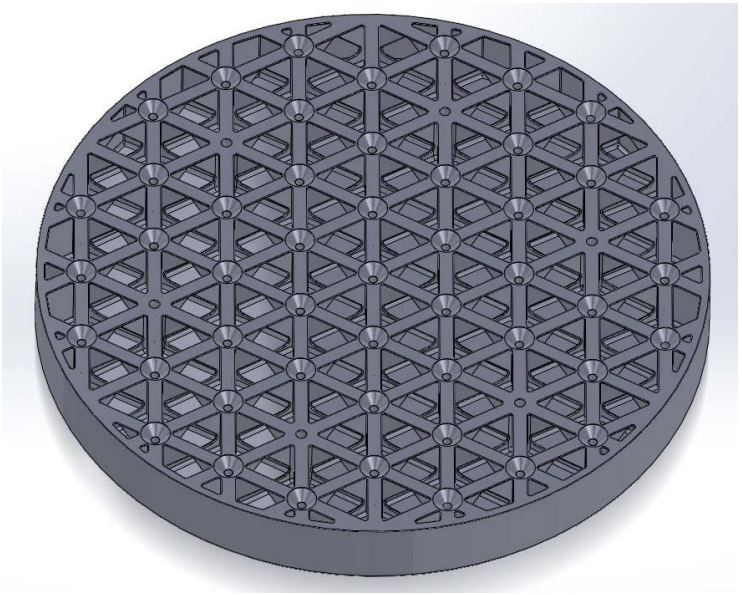
Thermal Expansion of NiP Plating and Steels

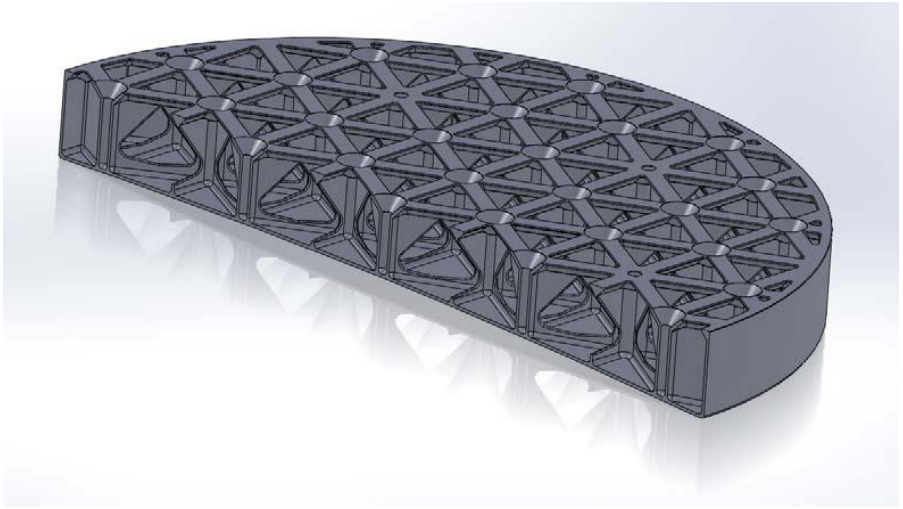
Comparison of Nickel Phosphorus Deposition to Other Processes

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

Material	Thermal Expansion – ppm / C
Inconel 718	12.2
Stainless steel alloy 17-4PH	10.4
Mild Steel AISI 1010	12.2
Ni 11-13 % P	12.5
Stainless steel 304	14.7

Light weight NiP Plated Additive Manufactured 718 Inconel Mirror Design Pat. Pending

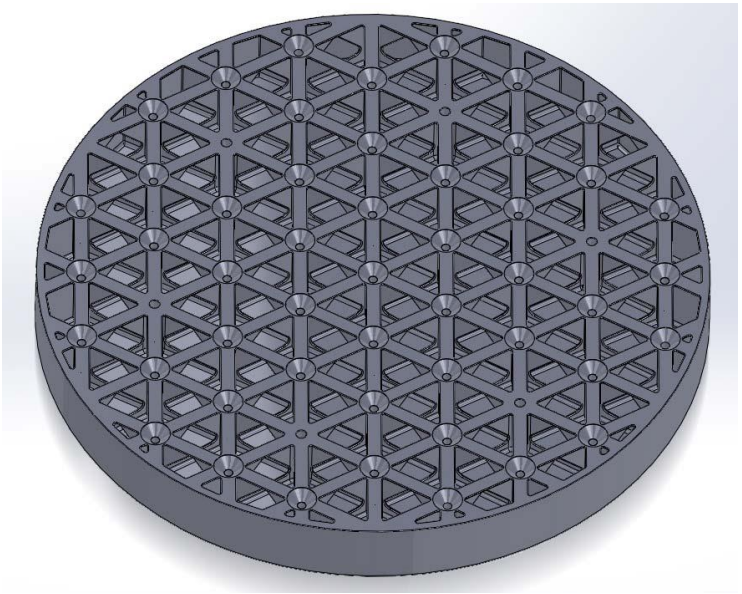


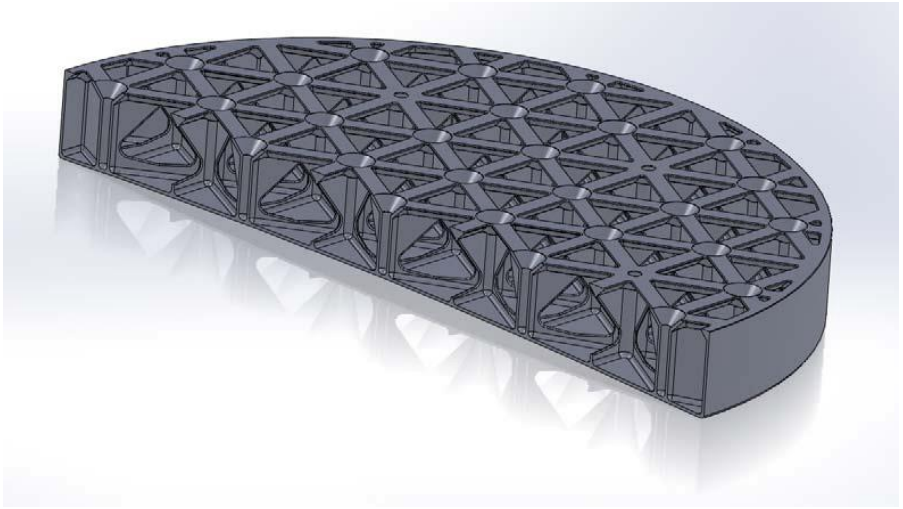


Wall thickness: 0.89mm
Diameter 0.24 meter
Thickness: 25.4 mm
Spherical Mirror - 2.3 meter radius
Weight: 1.4 kg
Areal density: 31 kg/sq meter

Wall thickness: 0.51mm
Diameter 0.24 meter
Thickness: 25.4 mm
Spherical Mirror - 2.3 meter radius
Weight: 0.8 kg
Areal density: 17.6 kg/sq meter

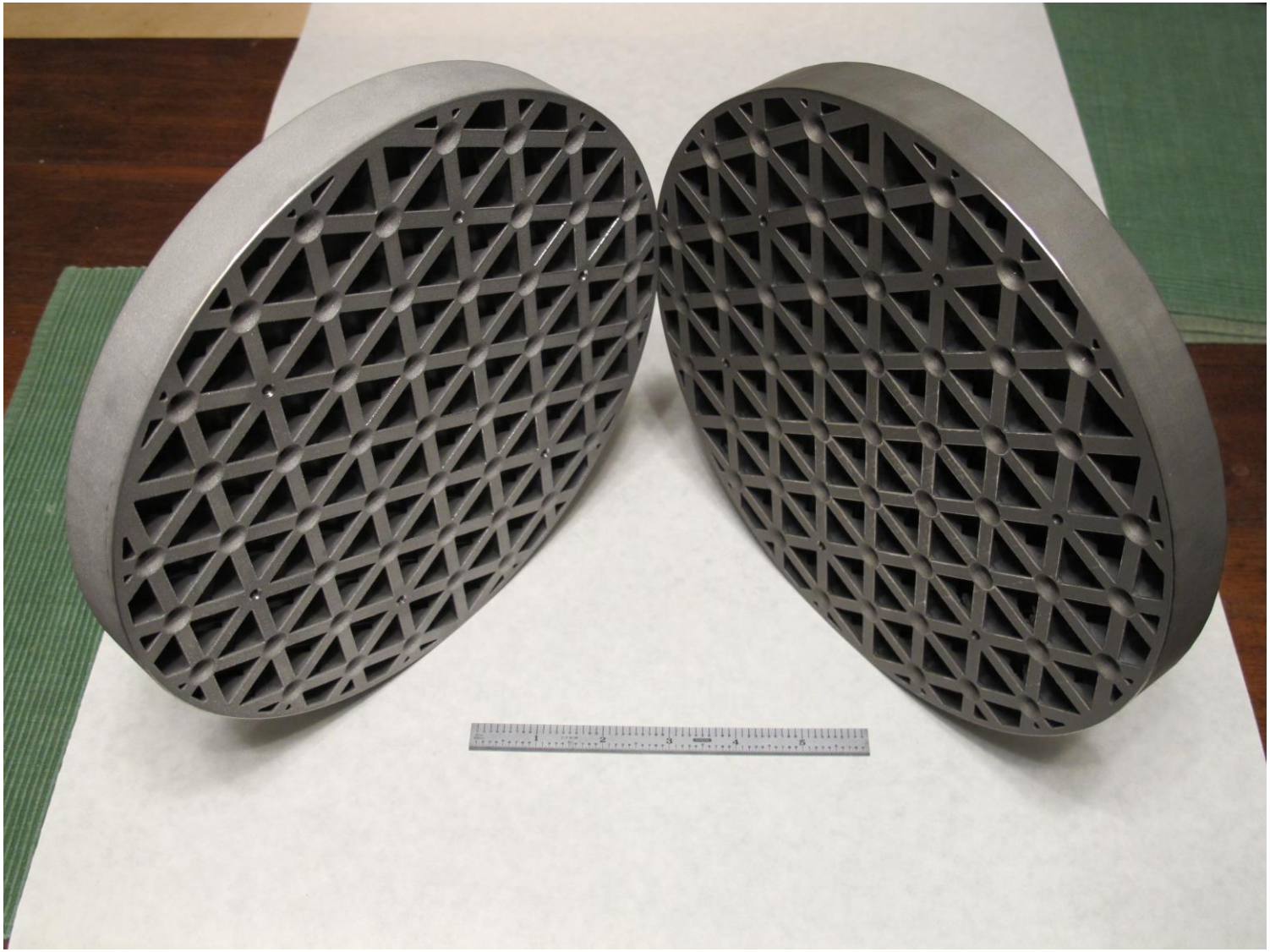
Light weight Additive Manufactured Aluminum Mirror Design Pat. Pending



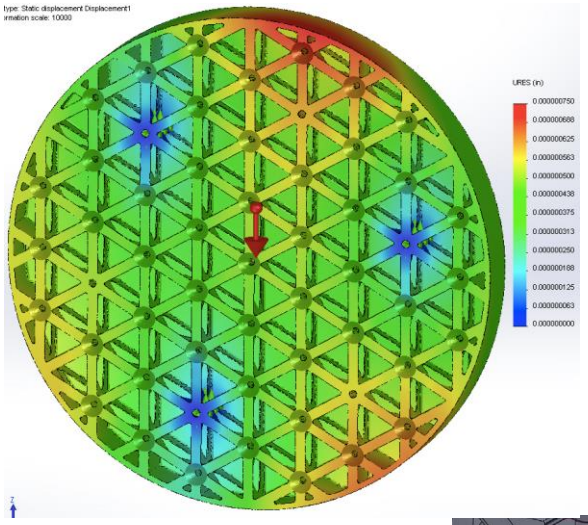


Wall thickness: 0.89mm
Diameter 0.24 meter
Thickness: 25.4 mm
Spherical Mirror - 2.3 meter radius
Weight: 0.483 kg
Areal density: 10.6 kg/sq meter

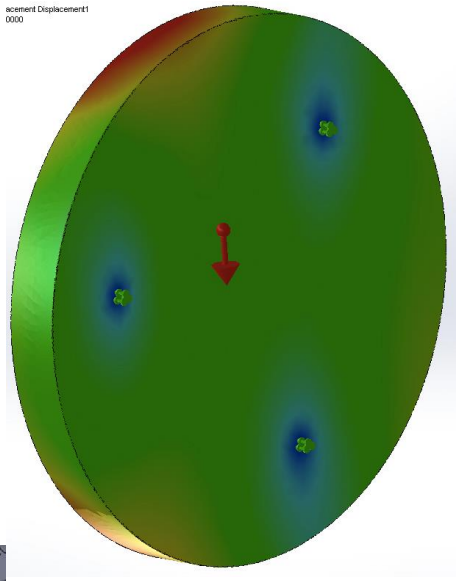
Wall thickness: 0.51mm
Diameter 0.24 meter
Thickness: 25.4 mm
Spherical Mirror - 2.3 meter radius
Weight: 0.28 kg
Areal density: 6 kg/sq meter

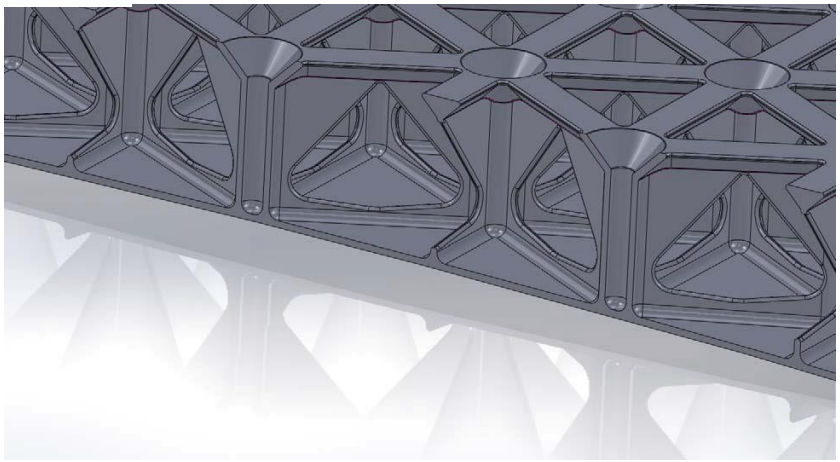


Light weight Additive Manufactured Tailored Stiffness Mirror Design Pat. Pending



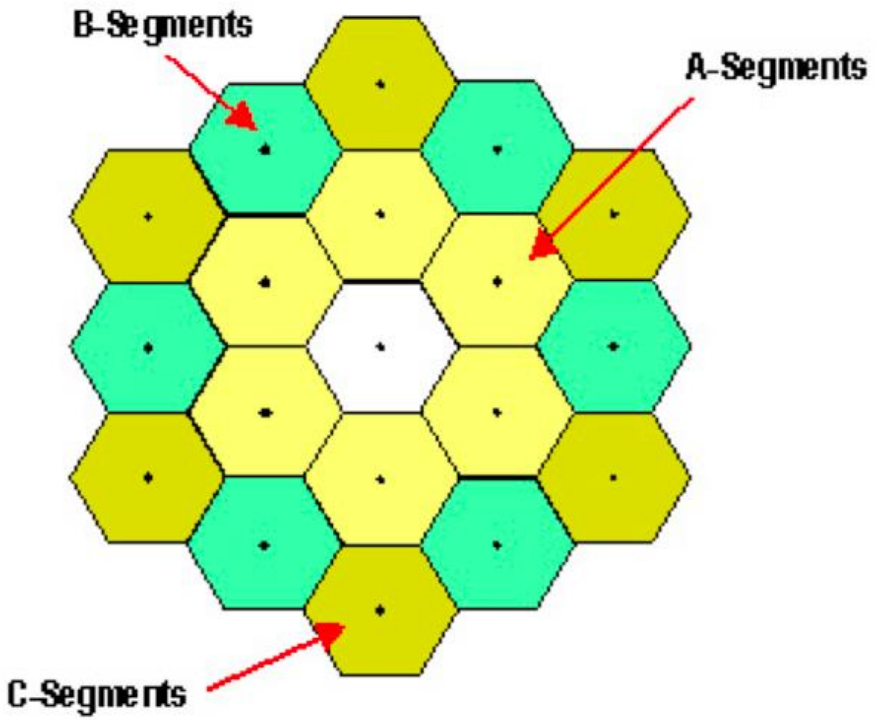
Internal bracing allows tailored stiffness to make the rear Mounting surface of the mirror Substrate stiffer than the front optical contoured surface.





Additive Manufactured Off-Axis Contoured Mirrors Can Be Diamond Turned to Produce Segmented Mirrors of Large Size.

The largest currently available DMLS additive manufacturing machines are practically limited to about 0.4 meter diameter. Future machines are planned for up to 1 meter capacity. Deformable mirror segments are possible.



SUMMARY

Additive manufacturing can quickly produce mirrors of arbitrary periphery and aspheric contour.

Diamond turning of NiP plated mirror substrates with matched thermal expansion is a very low cost, very flexible manufacturing process for mirrors and mirror system metering structures.

Low (10-30 kg/sq. meter) areal density, very stiff metal mirror.

Matching mirror thermal expansion to NiP means low thermal distortion.

Electroplating of NiP to produce a hard, low stress, corrosion resistant deposit to any desired thickness is well developed.