

S2.03-9674 Additive Manufactured Very Light Weight Diamond Turned Aspheric Mirror

Contract No. NNX17CM27P (SBIR 2017-I) (MSFC)

Mirror Technology SBIR/STTR Workshop

November 14 – 16 , 2017

**Northrop-Grumman Aerospace Systems Presentation Center
Redondo Beach, California**

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

These SBIR data are furnished with SBIR rights under Contract No. NNX17CM27P. For a period of 4 years, unless extended in accordance with FAR 27.409(h), after acceptance of all items to be delivered under this contract, the Government will use these data for Government purposes only, and they shall not be disclosed outside the Government (including disclosure for procurement purposes) during such period without permission of the Contractor, except that, subject to the foregoing use and disclosure prohibitions, these data may be disclosed for use by support Contractors. After the protection period, the Government has a paid-up license to use, and to authorize others to use on its behalf, these data for Government purposes, but is relieved of all disclosure prohibitions and assumes no liability for unauthorized use of these data by third parties. This notice shall be affixed to any reproductions of these data, in whole or in part.

S2.03-9674 Additive Manufactured Very Light Weight Diamond Turned Aspheric Mirror

OUTLINE

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

Concept and Goals

- **Develop and demonstrate a process for producing a large very light weight, aluminum mirror substrate with additive manufacturing.**
- **Demonstration of joining hexagonal aluminum mirror segments with robotic welding of aluminum by laser and GTA welding processes.**
- **Diamond turning of spherical optical contours on welded additively manufactured mirror substrates.**
- **Optical and dimensional inspection and characterization of the finished mirror for overall optical figure accuracy and surface smoothness achieved by diamond turning.**

Development Process Sequence

DOS - CAD 3D Solid Model - Solid Works

DOS - Mirror design for additive manufacturing process.

Additive Manufacturing – DOS/Stratasys

Extensive development effort for additive process for successful build of complex structures.

DOS Metrology and machining to prepare AM mirror substrate for welding.

Development of welding processes.

DOS, ARC Specialties Inc., Laser Welding Solutions, Inc.

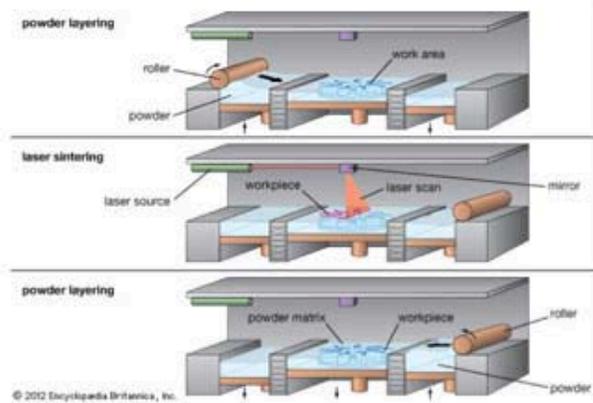
Metallurgy, material testing, welding experiments

Diamond Turning, Metrology, Optical Testing

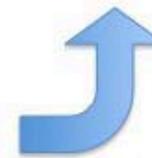
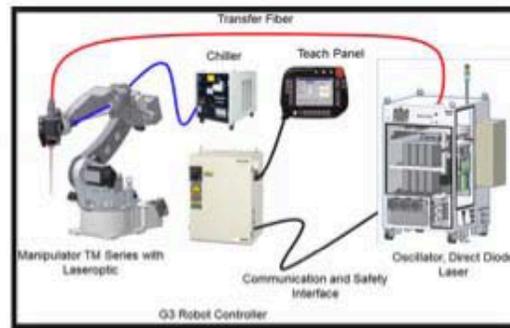
Large Optics Diamond Turning experience and tooling.

Fabricating diamond turned Al mirrors by welding hexagonal mirror segments

DMLS/SLM MFG. MIRROR



DIAMOND TURN ASPHERE



LASER WELDING MIRROR ASSEMBLY

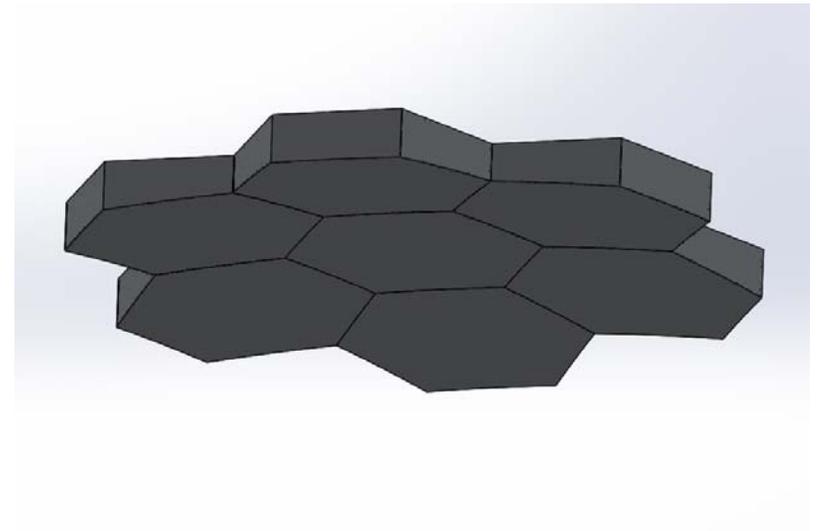
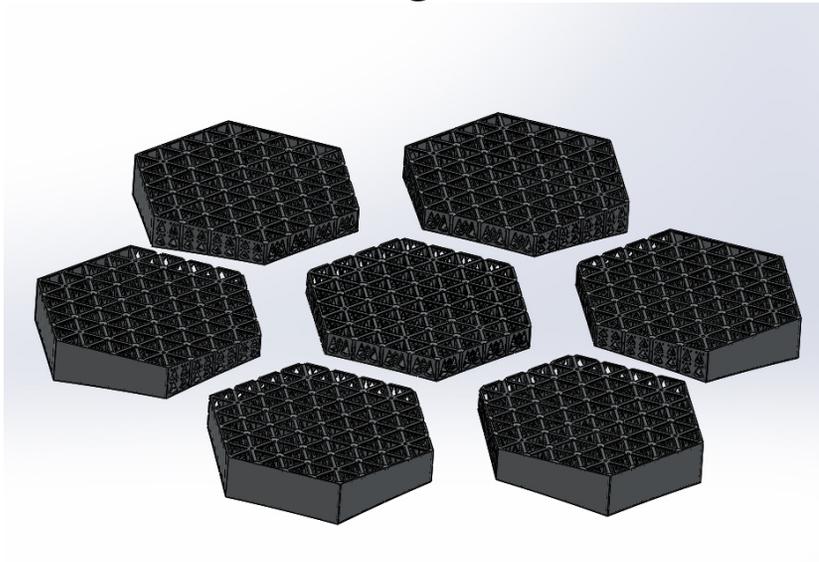
2.48 Meter Aluminum Mirror



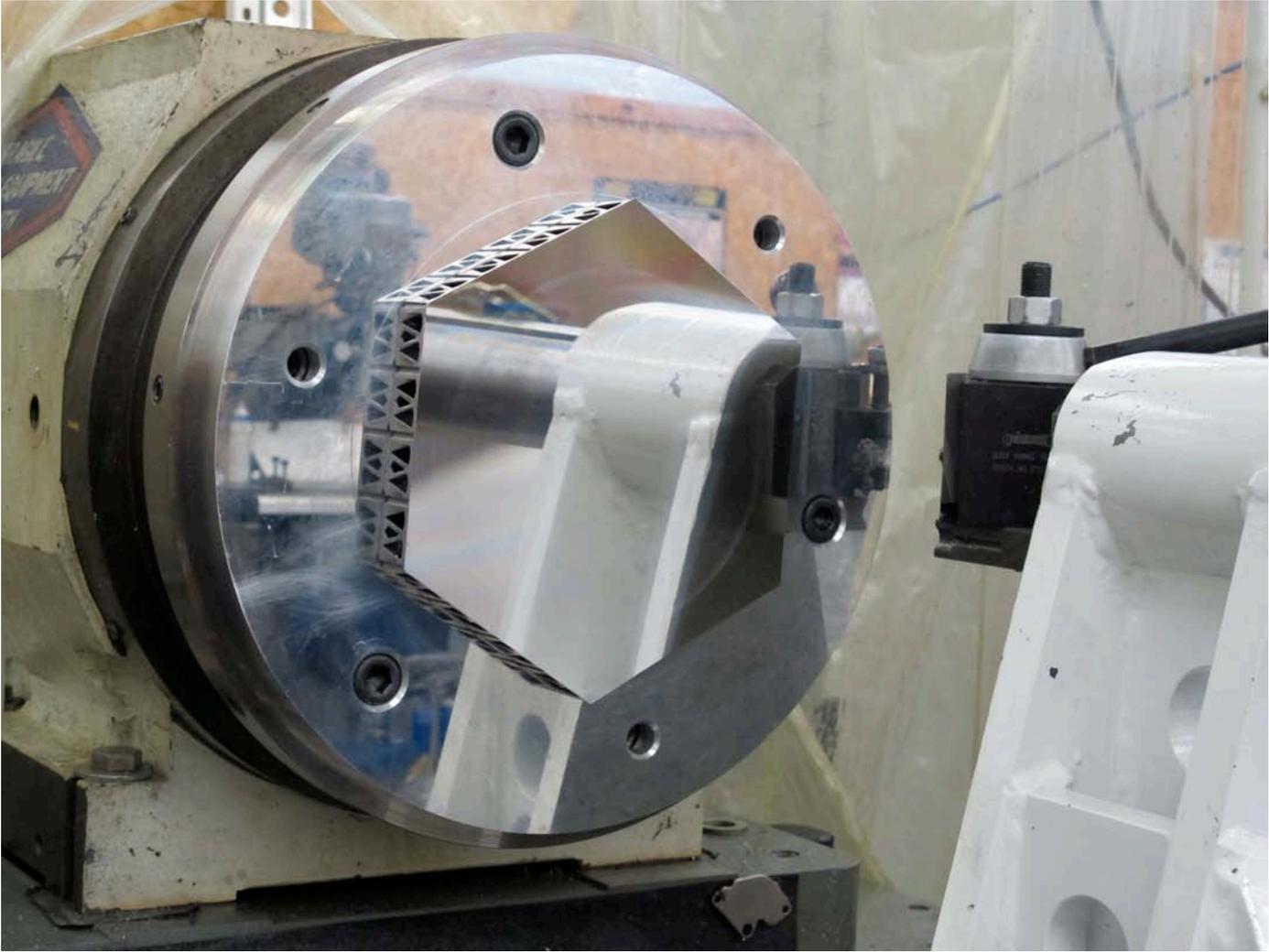


Additive Manufactured Off-Axis Contoured Mirrors Can Be Diamond Turned to Produce Segmented Mirrors of Large Size.

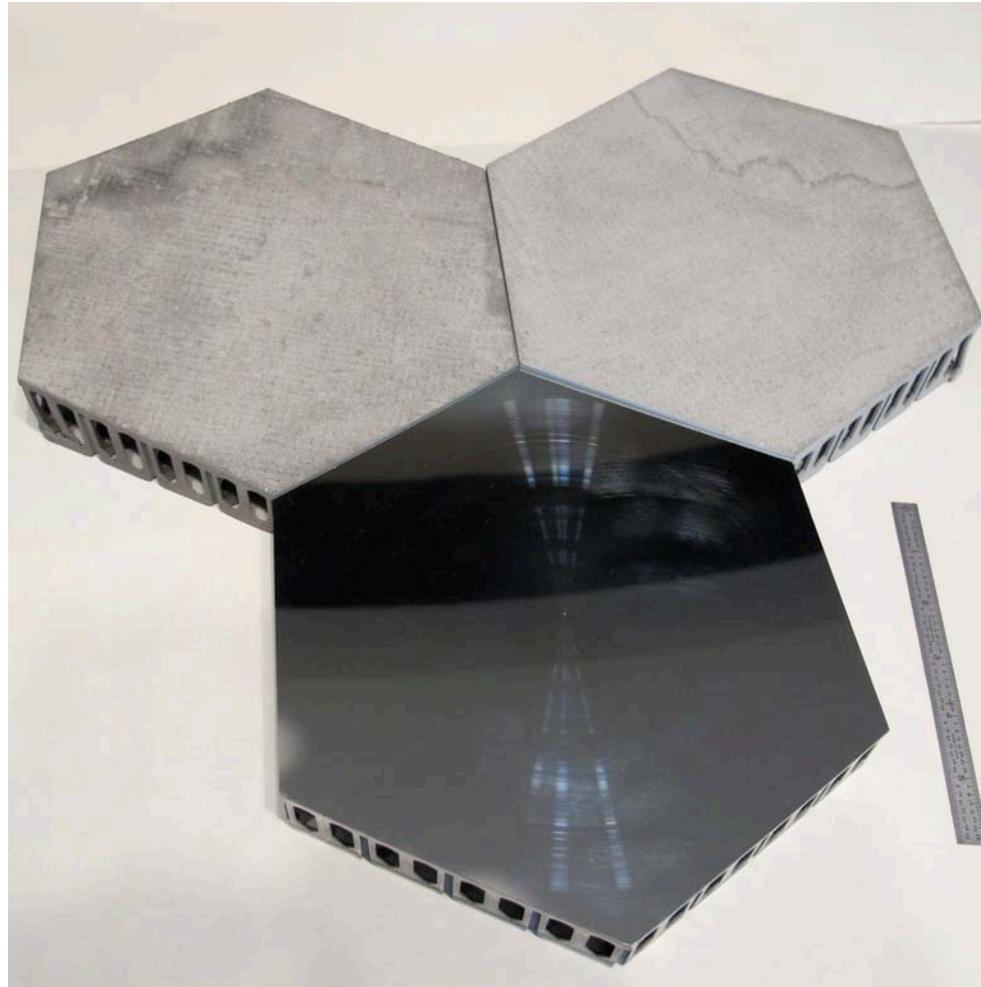
The largest currently available additive manufacturing machines are practically limited to about 0.4 meter diameter. Future machines are planned for up to 1 meter capacity. Deformable mirror segments are possible. Current work concerns design for fabrication and assembly of aluminum mirror segments.



Hexagonal Aluminum Mirror on DOS diamond turning machine



**Two off-axis spherical hexagonal mirror substrates
with an on-axis spherical substrate that has been
diamond turned.**



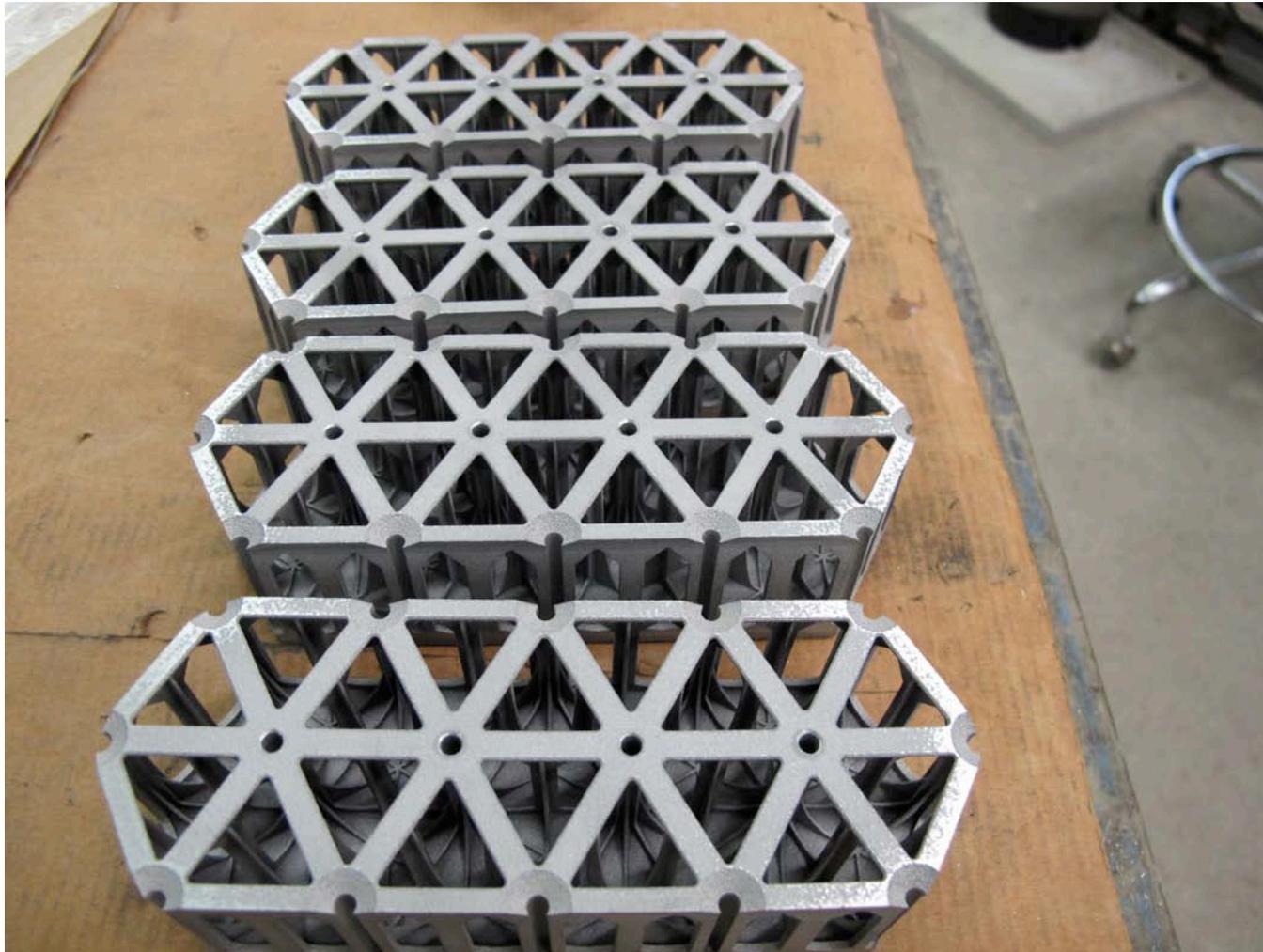
Properties of Al10SiMg Aluminum (10% Si) are similar to Alloy 6061-T651 with exception of higher Si

Material data sheet

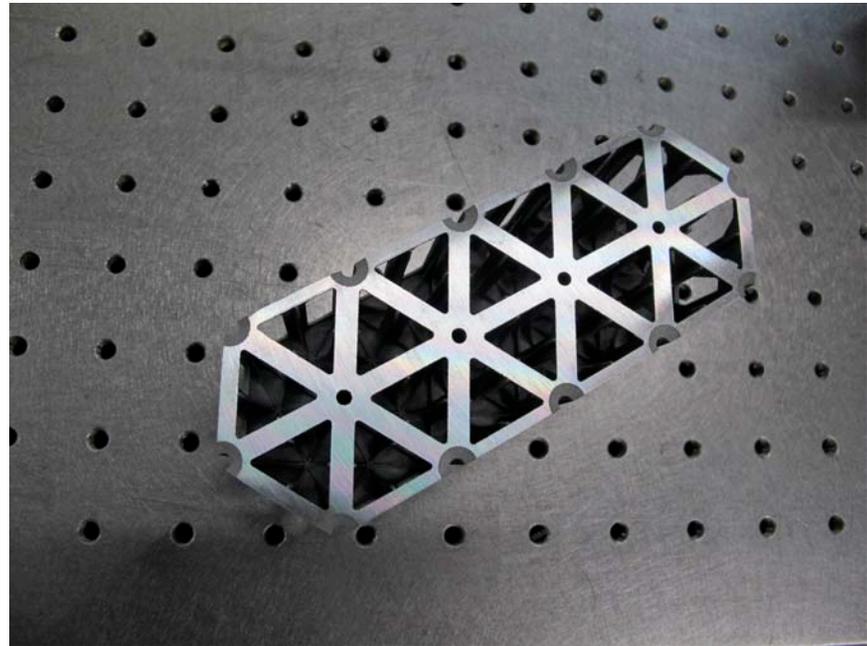
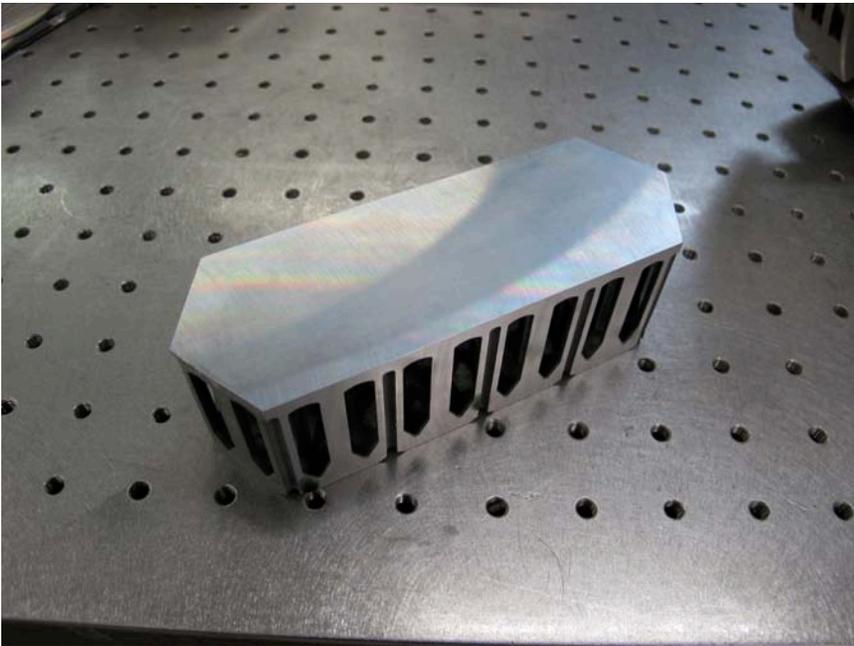
Physical and chemical properties of the parts

Material composition	Al (balance) Si (9.0 – 11.0 wt-%) Fe (\leq 0.55 wt-%) Cu (\leq 0.05 wt-%) Mn (\leq 0.45 wt-%) Mg (0.2 – 0.45 wt-%) Ni (\leq 0.05 wt-%) Zn (\leq 0.10 wt-%) Pb (\leq 0.05 wt-%) Sn (\leq 0.05 wt-%) Ti (\leq 0.15 wt-%)
Relative density	approx. 99.7 %
Density	2.67 g/cm ³ 0.096 lb/in ³

Additively Manufactured Weld Test Pieces.



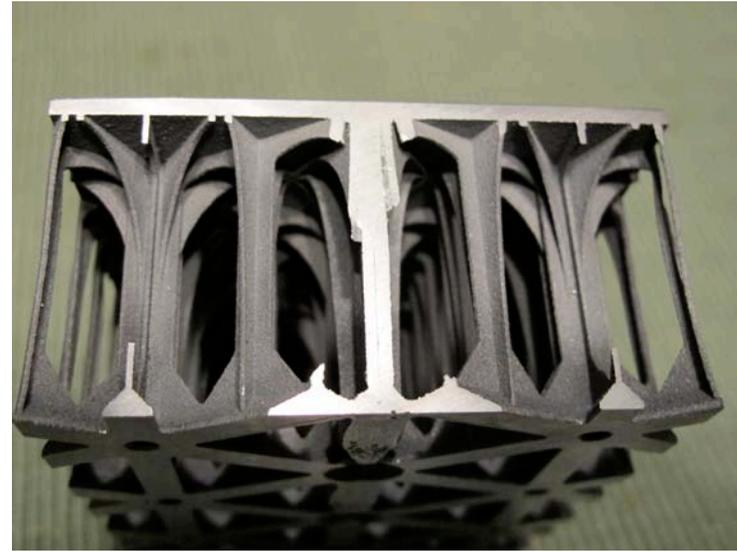
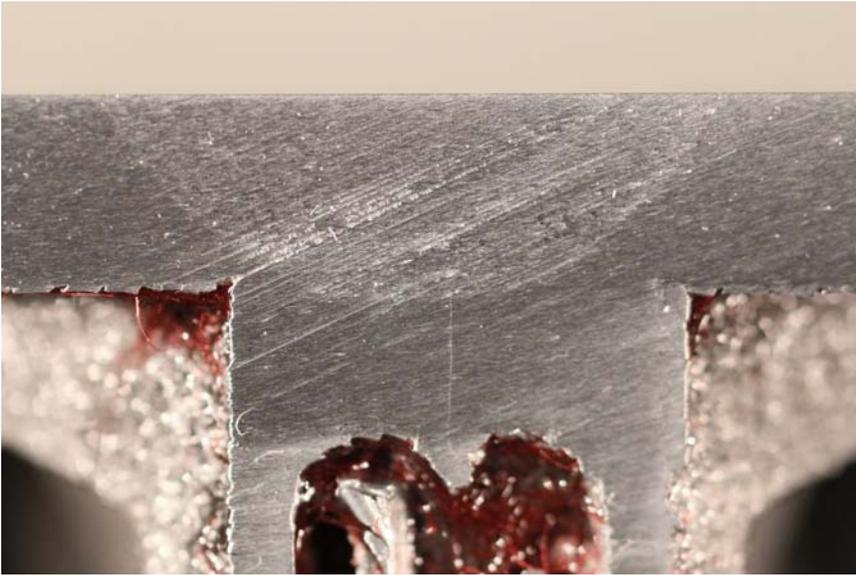
Machined Additively Manufactured Weld Test Piece To Remove Surface Oxide For Welding



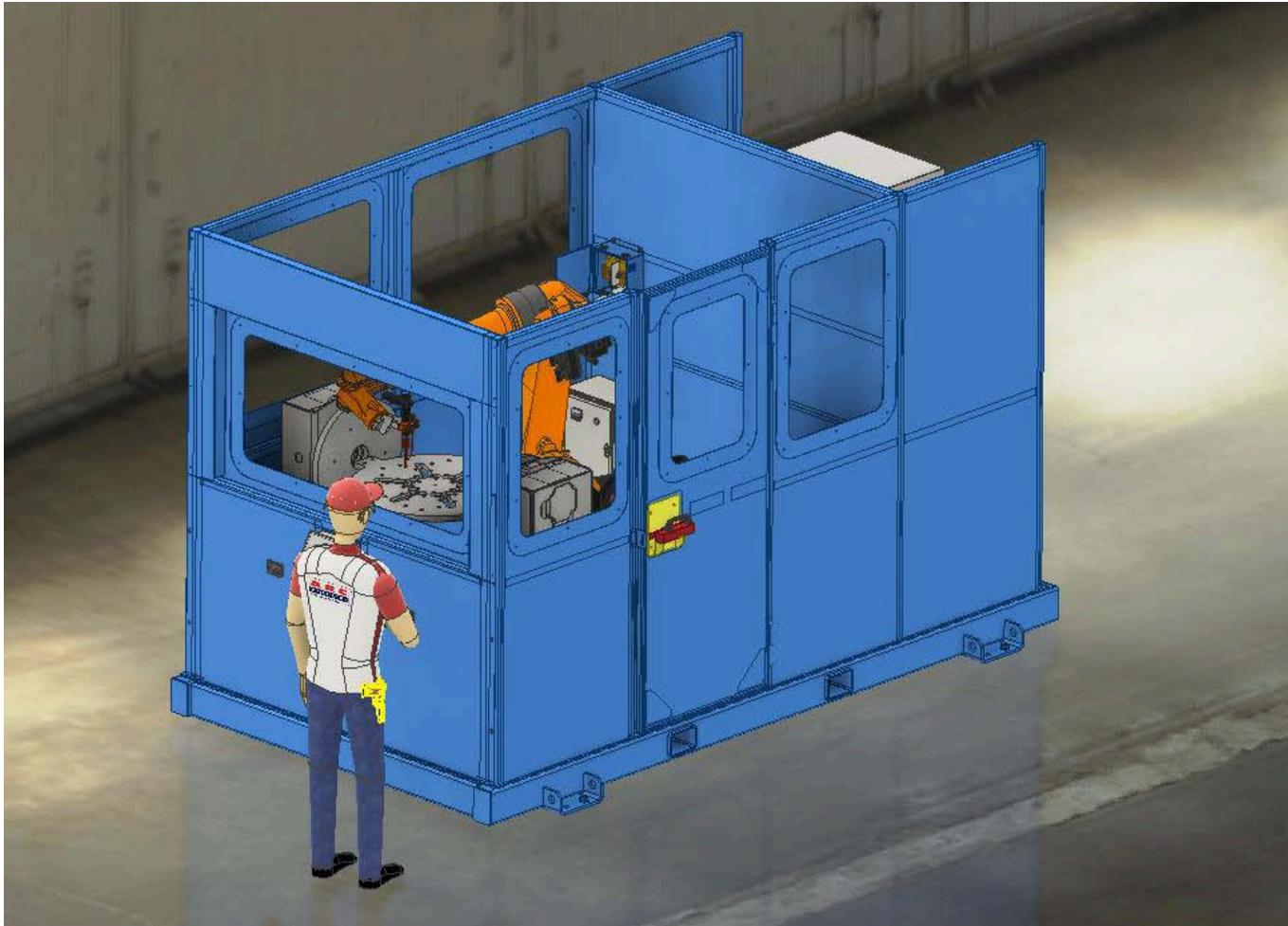
Welding Test Fixtures



Welding Testing with GTA of Al10SiMg



ARC Specialties Robotic Welder Concept



SUMMARY

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

Diamond turning of aluminum substrates is a very low cost, very flexible manufacturing process for mirrors and mirror system metering structures.

Low (6-20 kg/sq. meter) areal density, very stiff metal mirror.

Joining additively manufactured aluminum segments offers the potential of making very large mirrors.