



Additive manufacturing of isogrid metal mirror

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Additive manufacturing

- Additive fabrication process of parts from 3D CAD model as oppose to subtractive manufacturing techniques.
- AKA direct manufacturing, rapid prototyping, 3D printing.
- Materials: polymers, metals, ceramics, metal-matrix composites, etc.
- Enables fabrication of **complex shapes** and **freeform design**.
- Ideally suitable for **small quantities**.
- Less material waste than subtractive manufacturing.
- Applications: human organs for transplant, aerospace components, lightweight mirrors.



Isogrid sugar candies





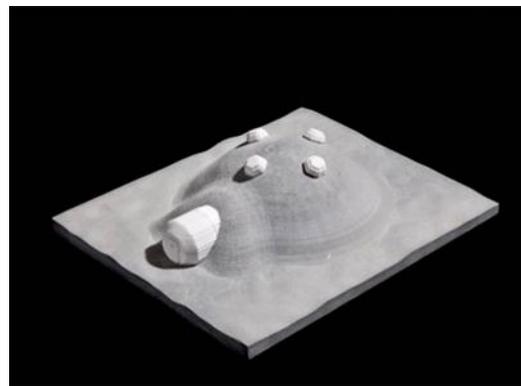
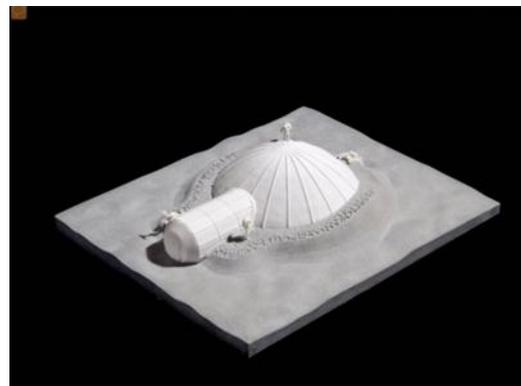
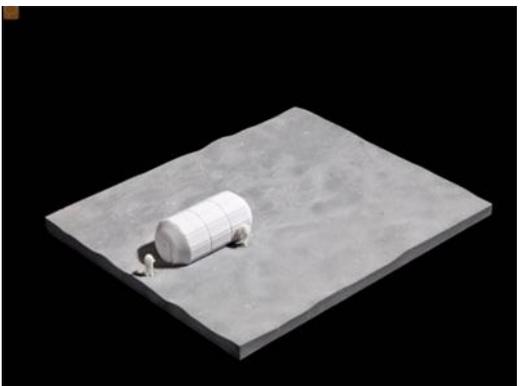
3D printer on International Space Station



- Developed by Made in Space, a Moffett Field, CA small business.
- 2010 NASA SBIR “3D Printing in Zero-G Experiment”.
- Launched on SpaceX Dragon cargo capsule, onboard ISS since Sept 2014.
- Maximum object size: 50 X 100 X 50 mm (x,y,z).
- Serves as test bed for 3D printed materials in space, and how it enables future space exploration.
- Next-gen 3D printer on ISS to enable plastic recycling, increase volume size, and additional materials.



Additive manufactured lunar base concept



Laurent Pambaguian, ESA



Metals additive manufacturing at MSFC

1. Selective laser sintering

- Concept Laser GmbH
- m1
- m2
- XLINE1000R
- Materials: Inconel 718, aluminum and titanium, cobalt-chromium alloy, SS, gold and silver alloys

2. Electron beam melting

- Arcam AB
- Material: Ti6Al4

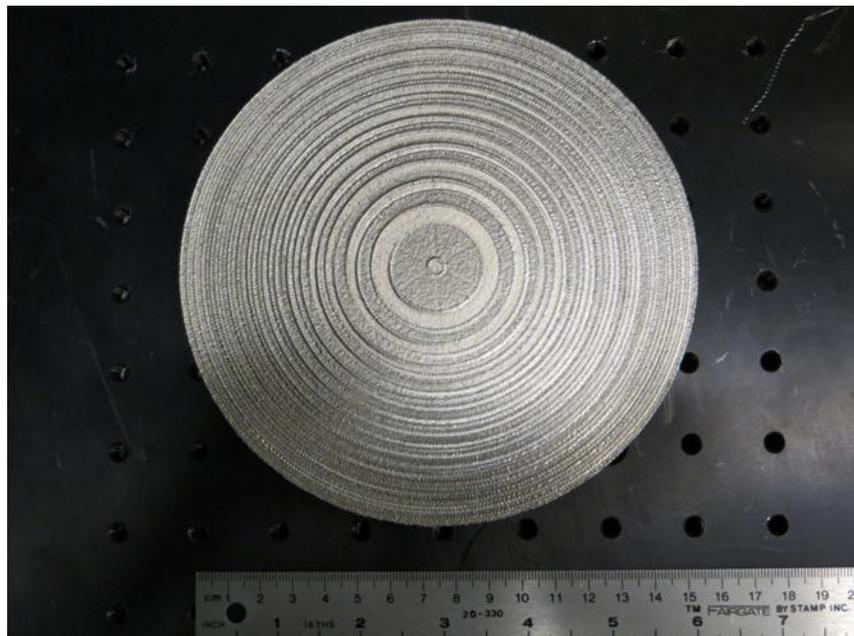
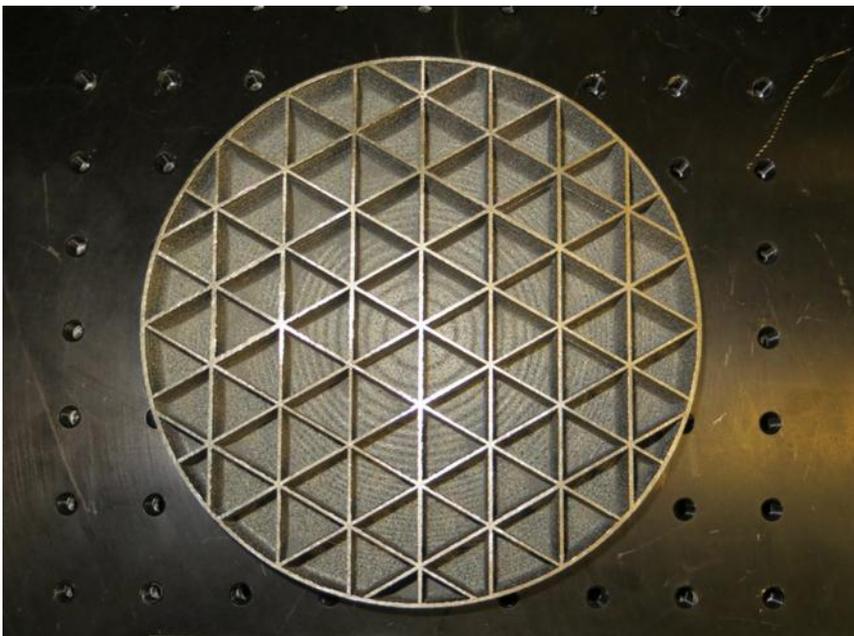


Metal 3D printing capabilities

Machine	Materials	Build volume (x,y,z)	Accuracy		
Concept Laser M1 Fiber laser 200 W (cw)	Inconel 718, Inconel 625	250x250x250 mm	±75 µm		
Concept Laser M2 Fiber laser 200 W (cw)	Titanium, Copper	250x250x280 mm	±75 µm		
Concept Laser X line 1000R Fiber laser 1kW (cw)	Inconel 718	630x400x500 mm	±125 µm		
ARCAM Q20 E-beam 3kW (max)	Ti-6Al-4V	200x200x200 mm	±180 µm		



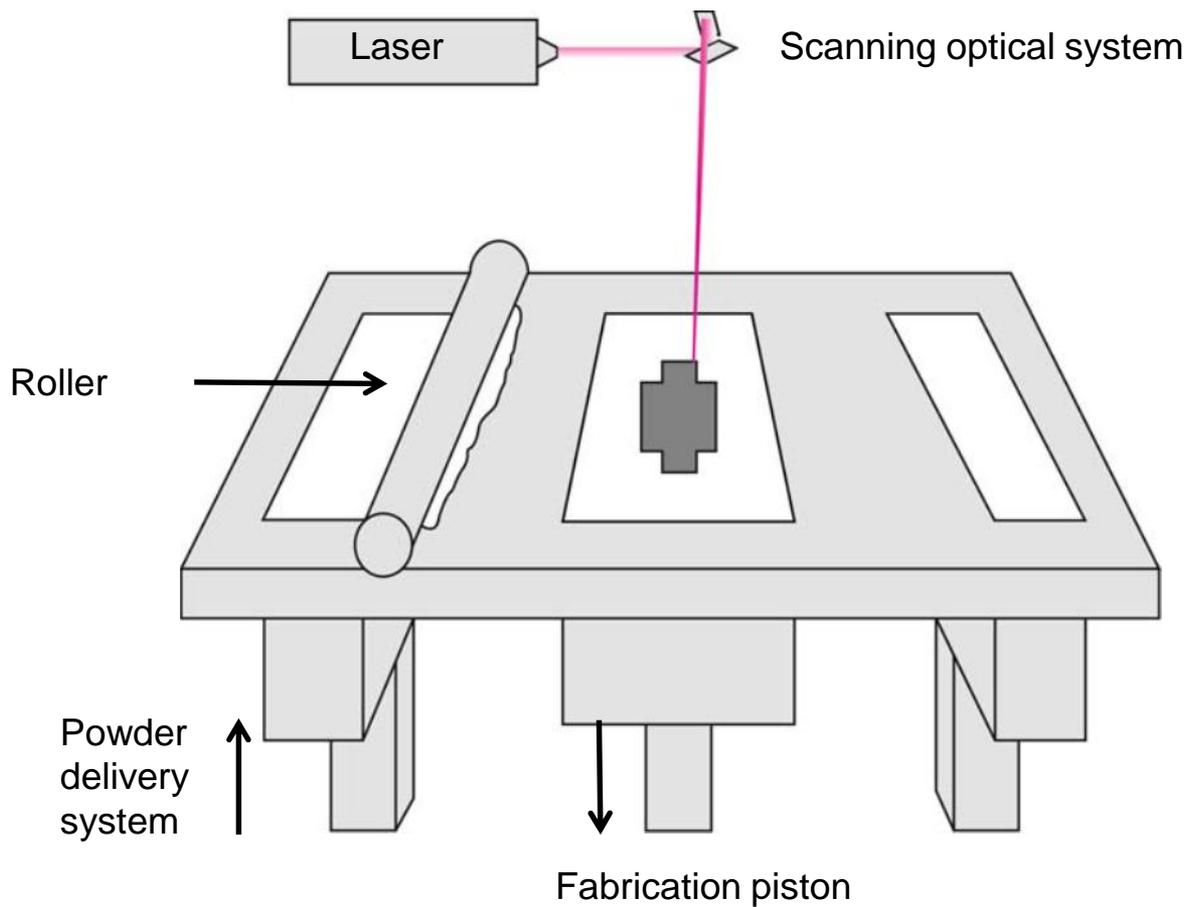
152mm f/8 Ti6Al4 mirror fabricated by e-beam



70 microns Arcam Ti powder



Laser sintering





Concept Laser GmbH m1



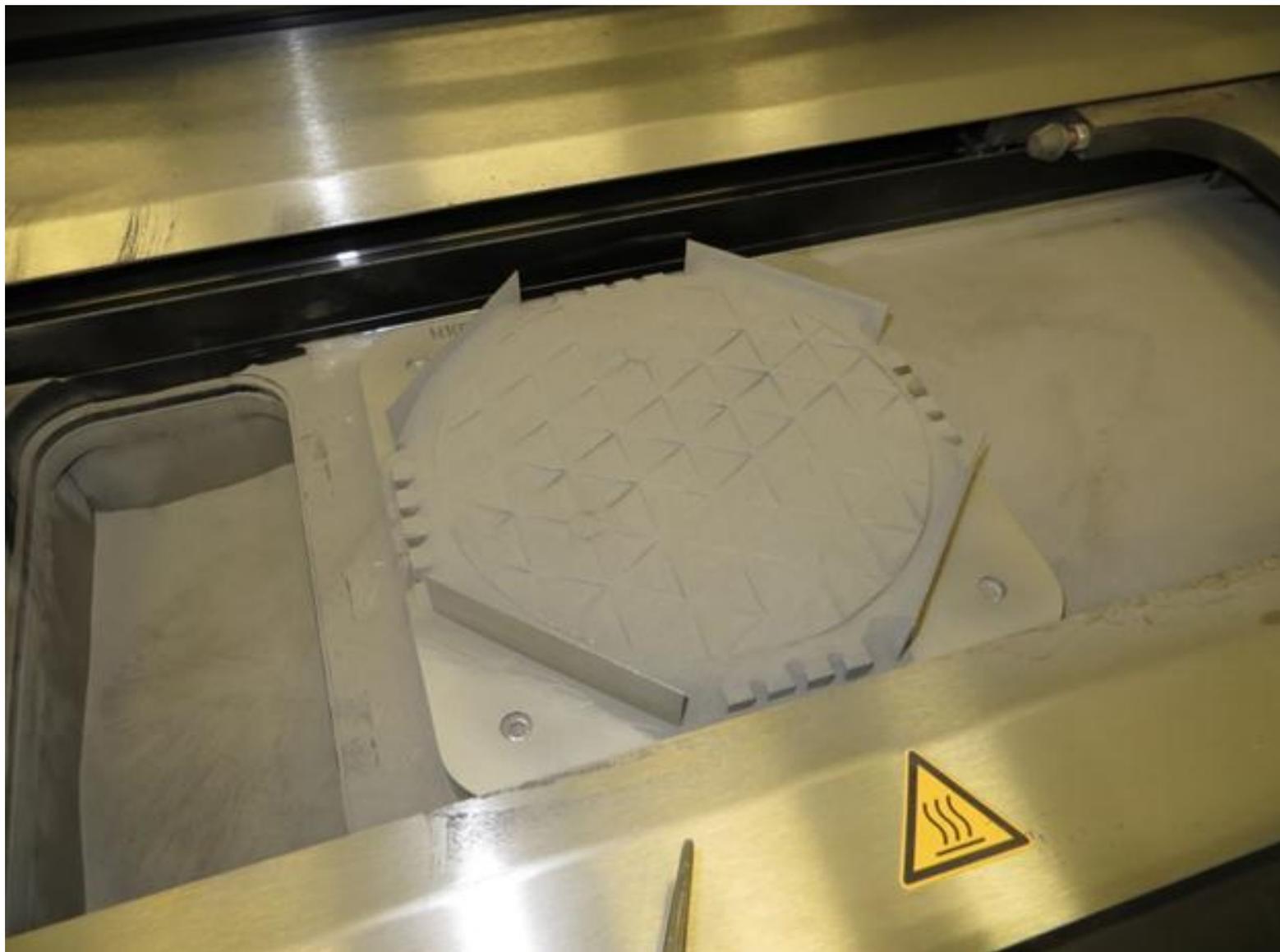


Inconel plano mirror by laser sintering

- Mirror diameter: 203.2mm
- Mirror thickness: 12.5mm
- Face sheet thickness: 2mm
- Edge thickness: 1mm
- Inner rib thickness: 0.8mm
- 3 #8-32 inserts for SPDT and plating
- Mass: 780.3 gm (76.5% lightweighting)
- 30 microns Inconel powder vs 70 microns Ti powder produces better surface finish.

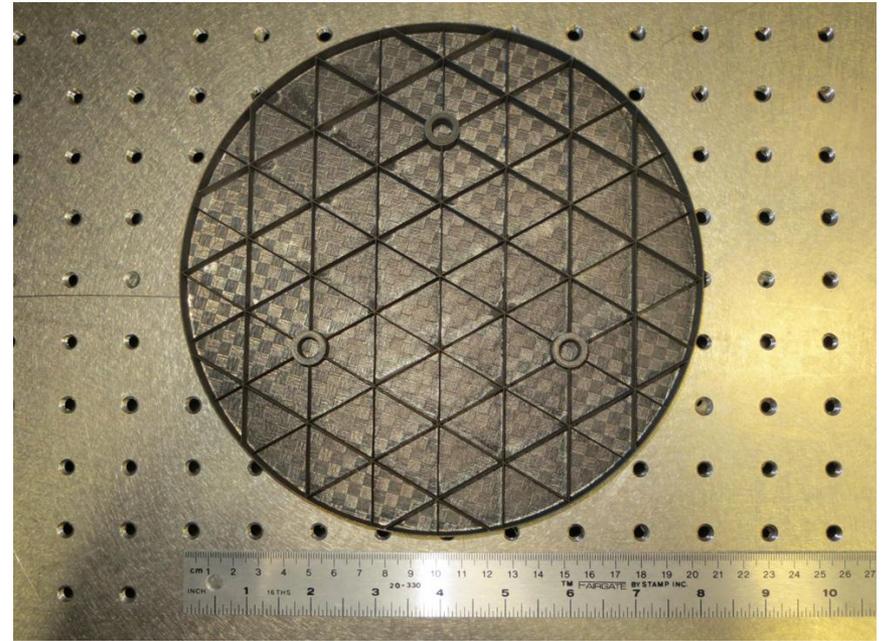
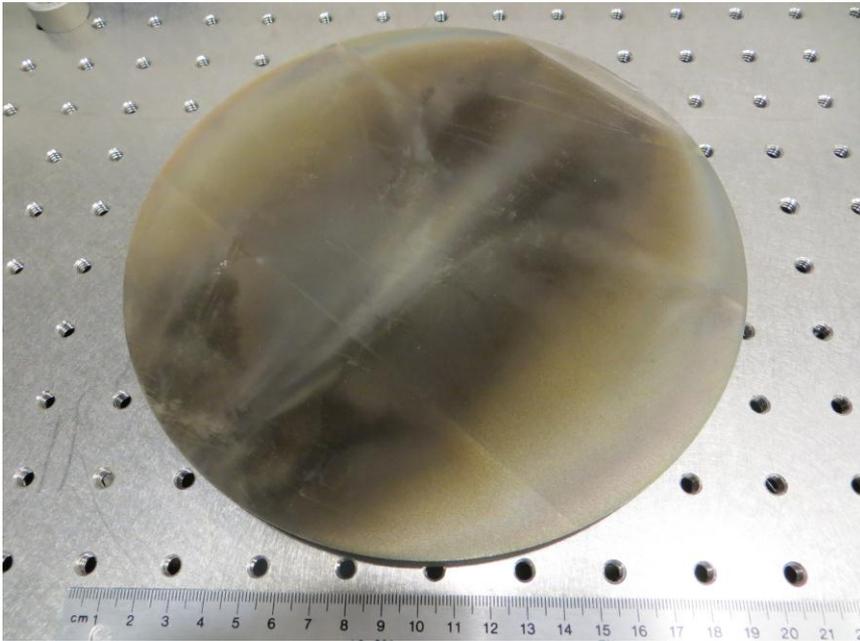


Inconel mirror after laser sintering



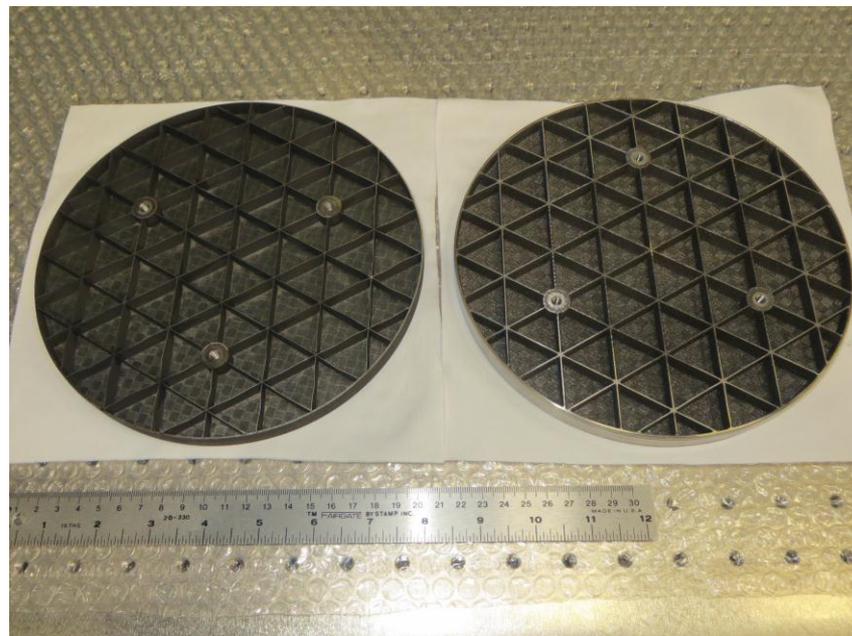
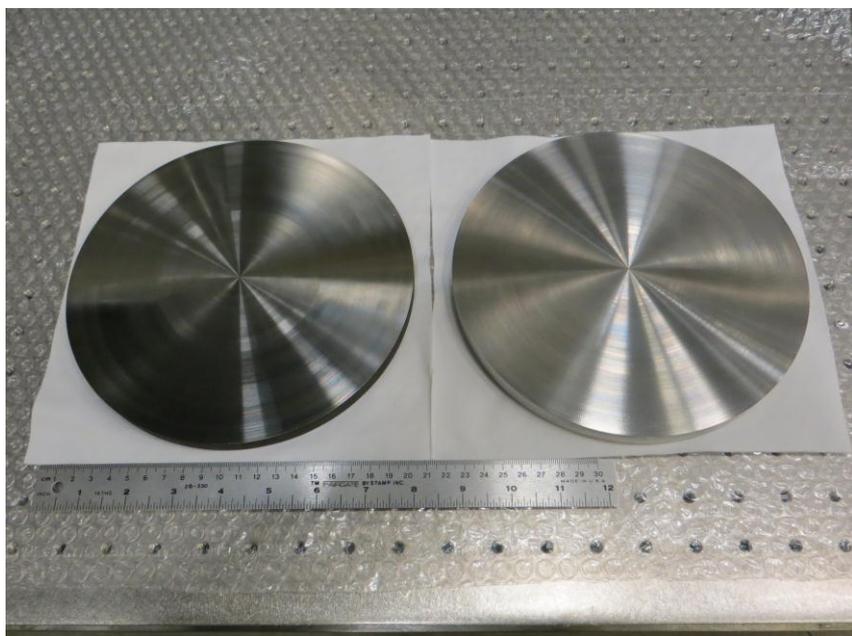


Inconel mirror after wire EDM





Inconel mirrors after machining with carbide tool





Future collaborative efforts

1. Additive manufacturing is added to S2.03 - Technologies for normal incidence mirror systems.
2. MSFC can provide additive manufacturing and testing resources.



Thank you



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