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University of Sheffield ADvanced Additive Manufacturing

James Hunt

Principal Engineer, Additive Manufacture

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Introduction to the University of Sheffield

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Equipment at Sheffield

Polymers:
(polyamides, elastomeric)

- Objet polymer jetting
- EOS Laser Sintering
- Custom made High Speed Sintering

Other Advanced Manufacturing Techniques:

- Metal Injection Moulding
- Spark Plasma Sintering
- Electron Beam Welding, with wirefeed capability

Metals:

Arcam Electron Beam Melting A2, S12
Renishaw AM250 + SLM 125,
Optomec Aerosol Jet
Huffman Contour Precision blown powder
ExOne binder jet printer

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Areas of research

- Minimum mass structures
- Lattice structures
- Alloy Development

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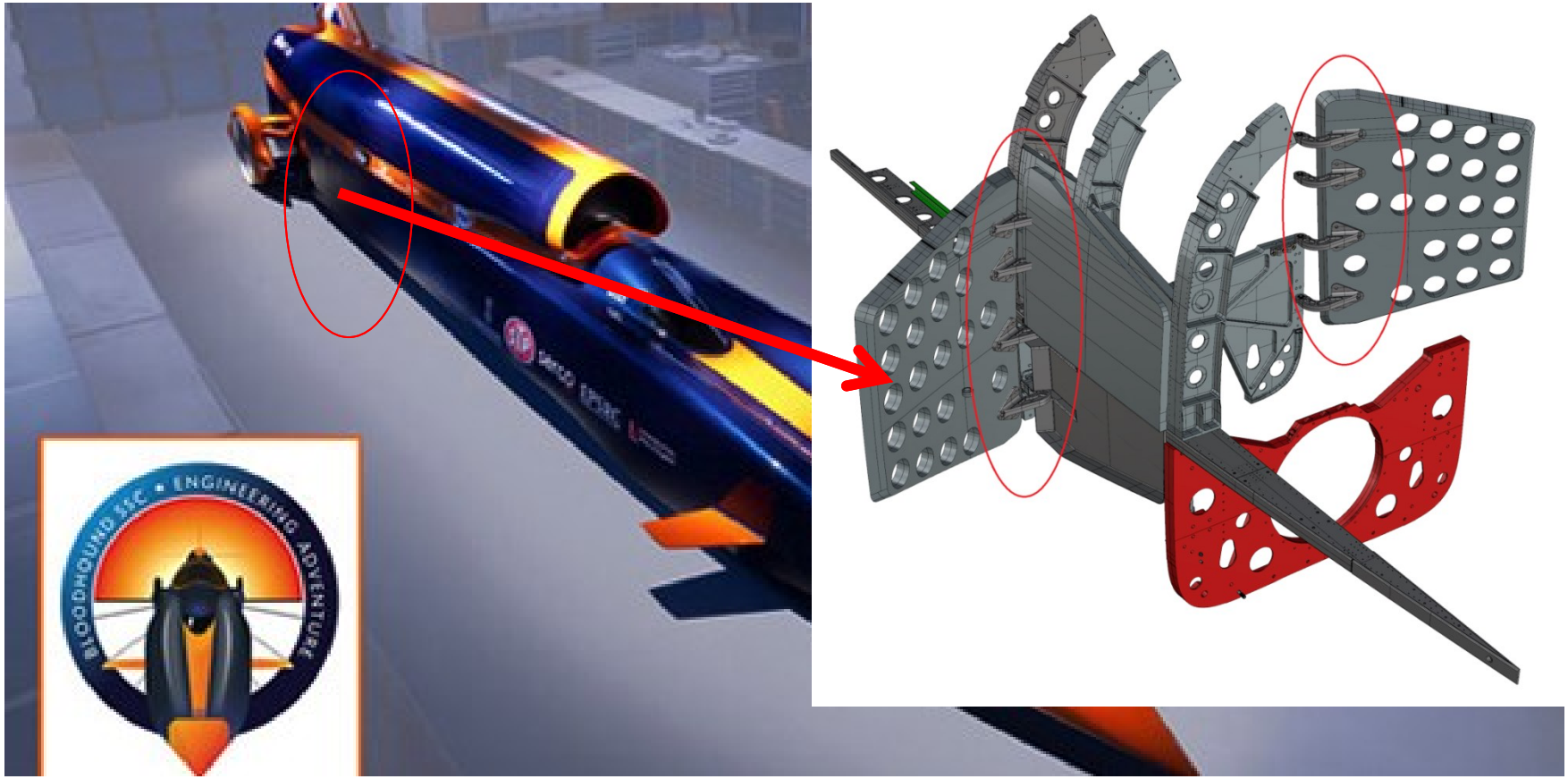
Bloodhound SSC



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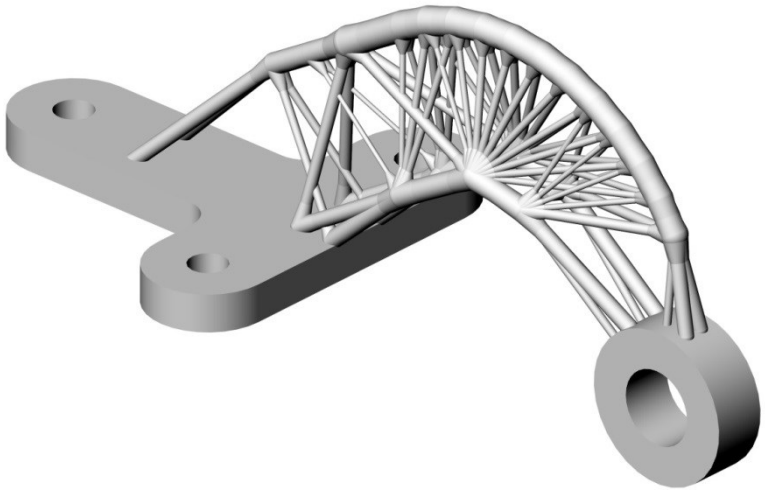
Minimal mass structures

Designed using Structural Topology Optimisation

Original Design



Topology Optimised Design

69% weight saving achieved using through Structural Topology Optimisation

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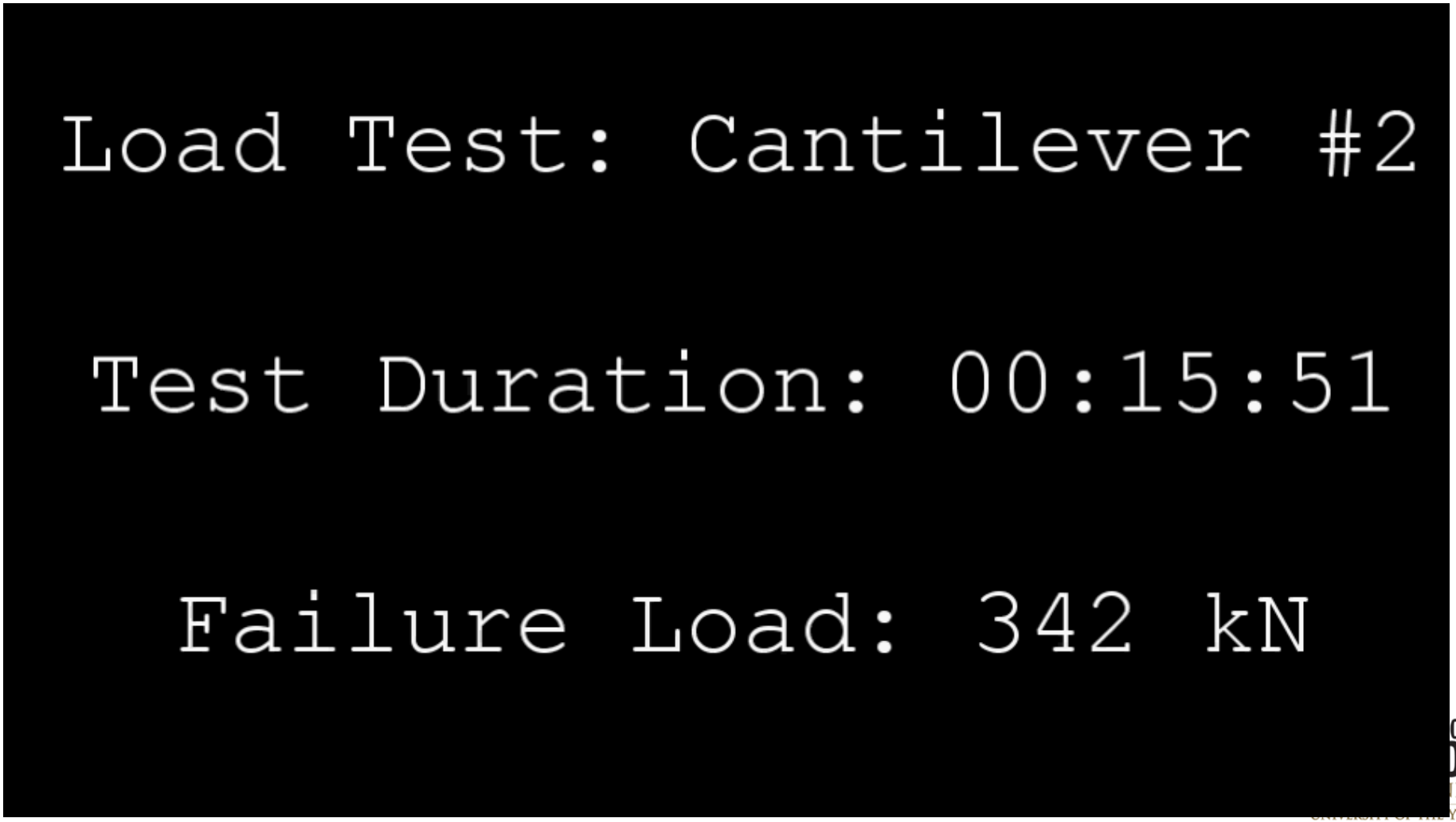
Minimal mass structures

Designed using Structural Topology Optimisation



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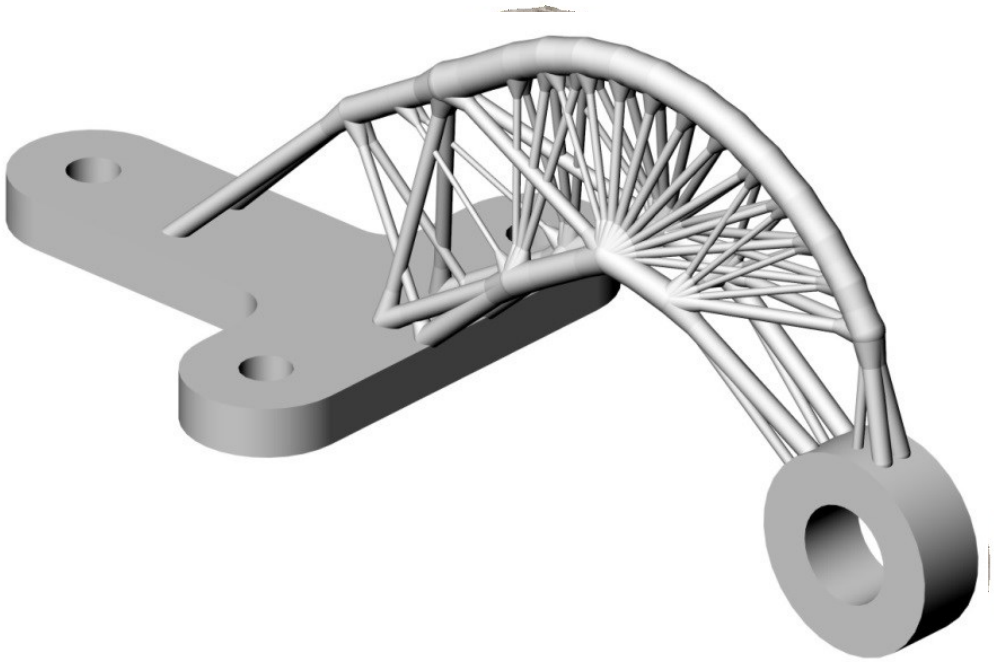
Minimal mass structures

Issues with dimensional accuracy



Truss members not aligned with the build direction are not fabricated accurately

**** They are always undersized ****

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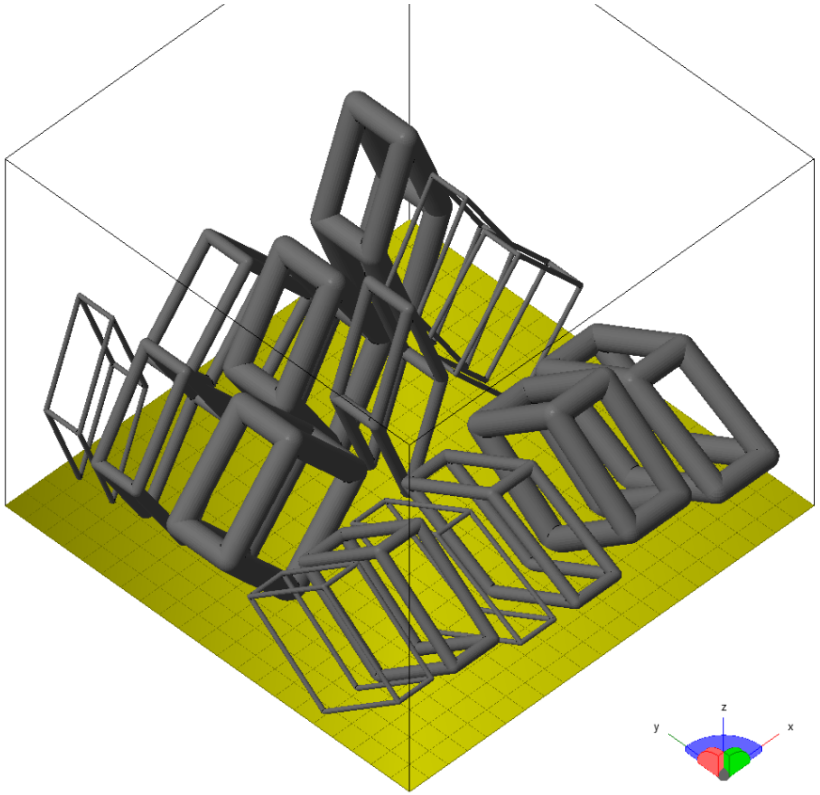
Characterizing the problem

Fabricating arbitrary truss specimens



Truss specimens with members at a range of angles to the build direction (20 - 60°)

Several member diameters explored (2, 5 and 10mm)

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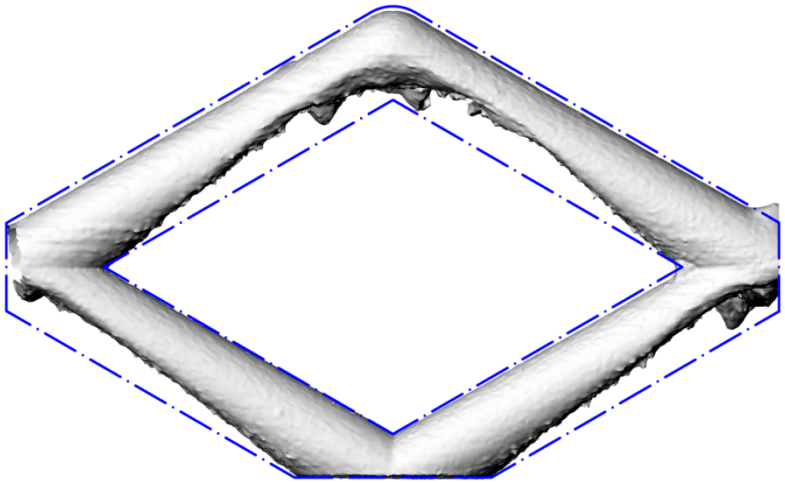
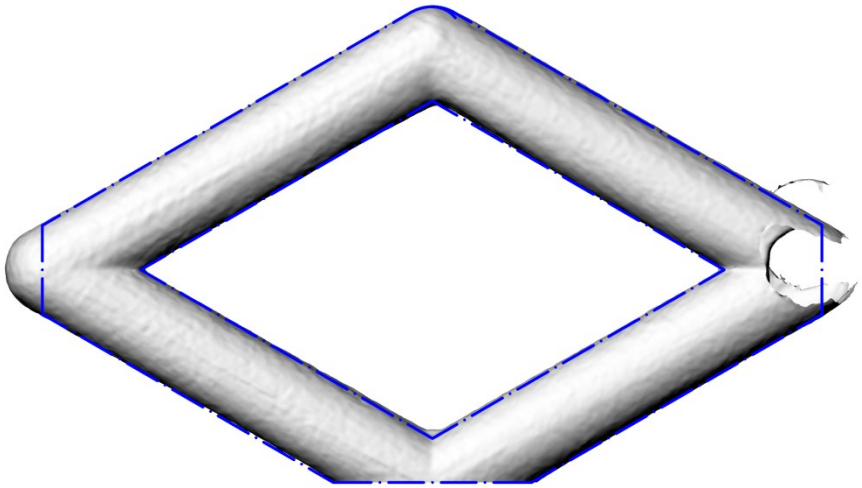
Comparison of scans



‘Default’



‘Modified 2’

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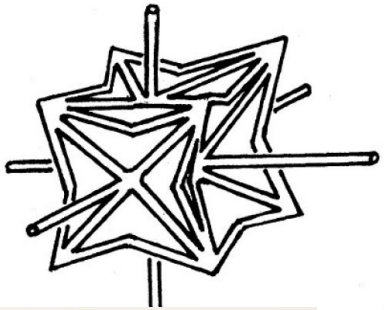
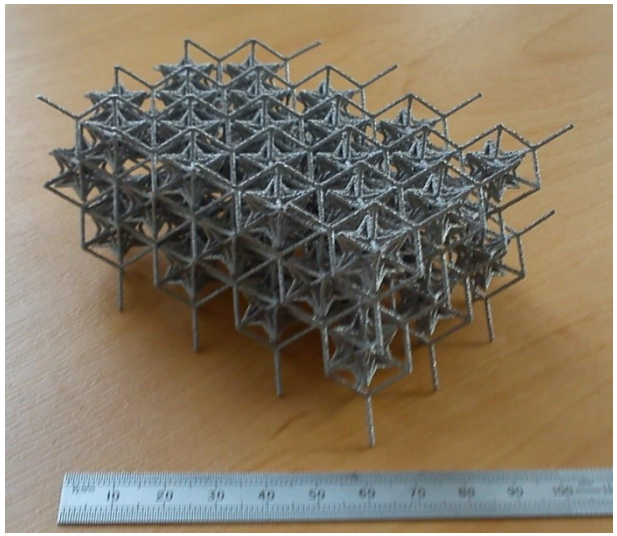
Lattice Structures:

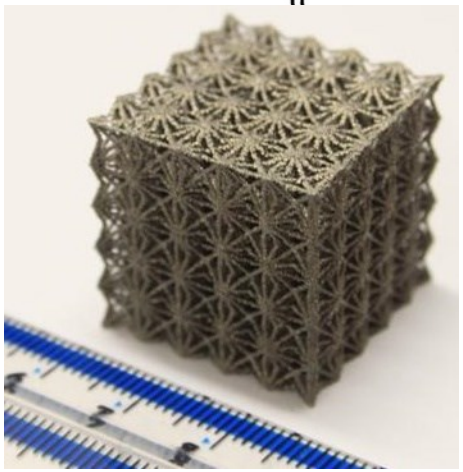
Different Lattices

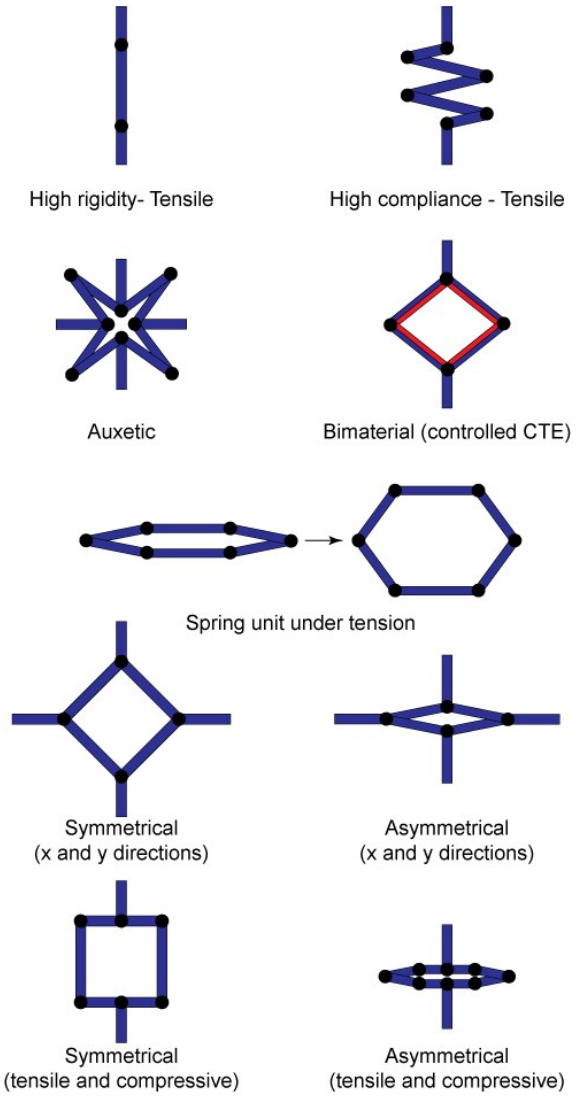
- Aim to understand simple elements of repeated lattices
- Potential to design in *"metamaterial"* behaviours

R Lakes, Science ***235*** *(1987) 1038*



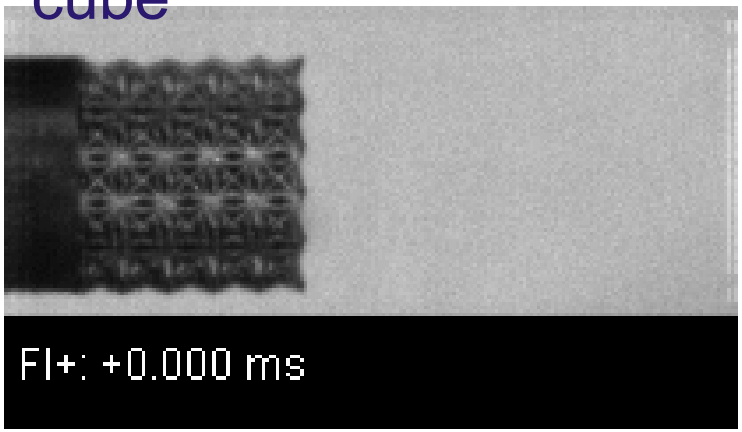


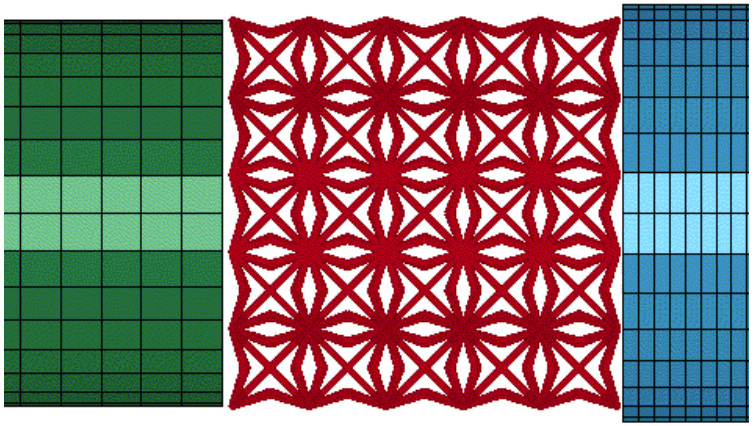




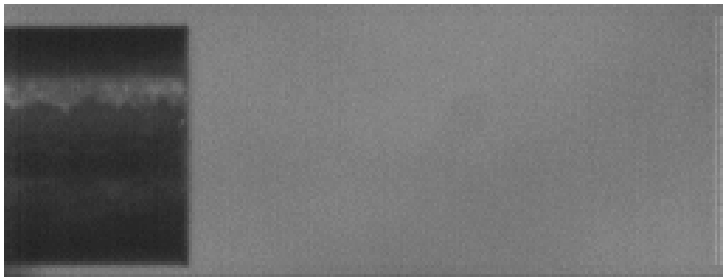
Dynamic tests

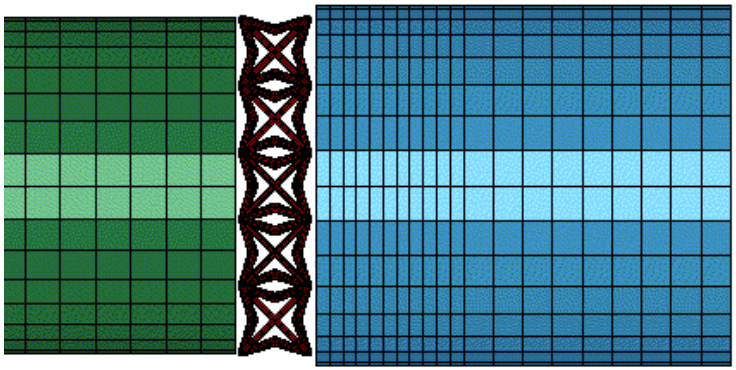
"Distal-face" tests. HDPE striker ≈200m/s, re-entrant cube





"Impact-face" tests. HDPE striker ≈136m/s, re-entrant cube



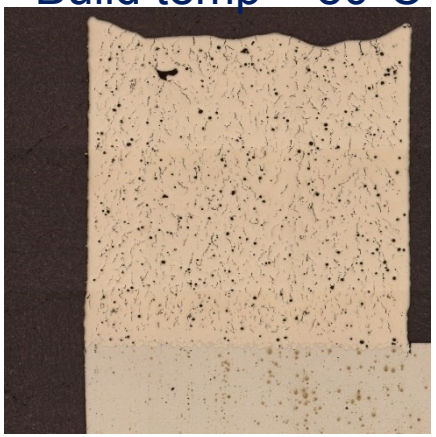


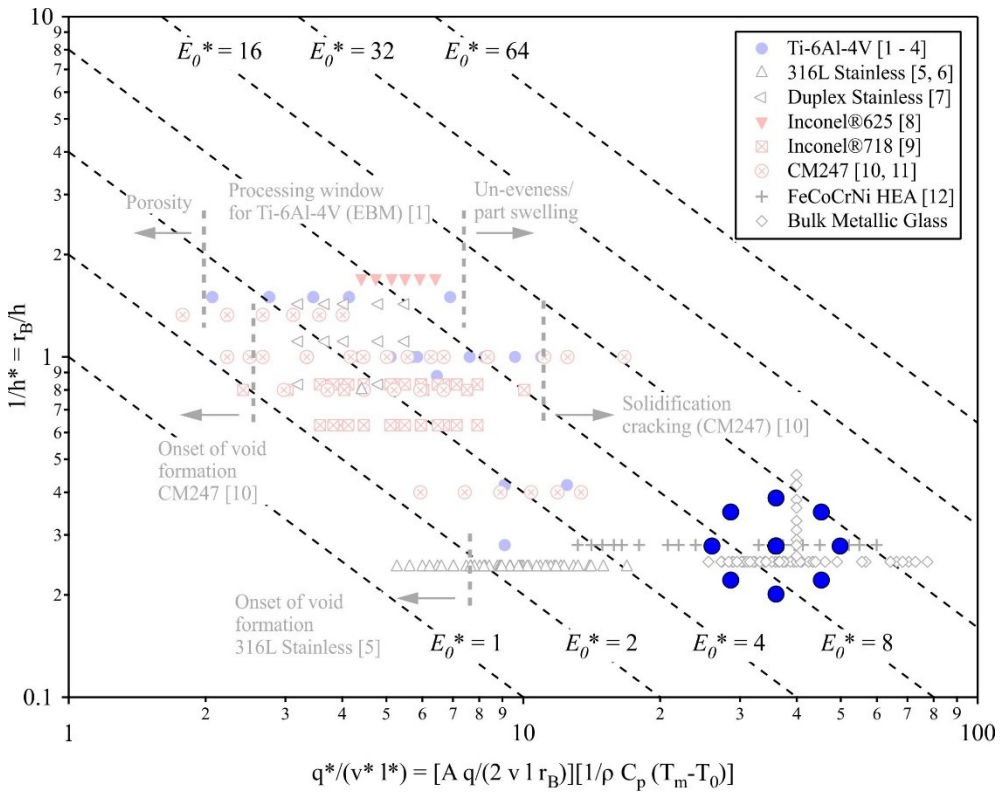
Material development

Material development approach

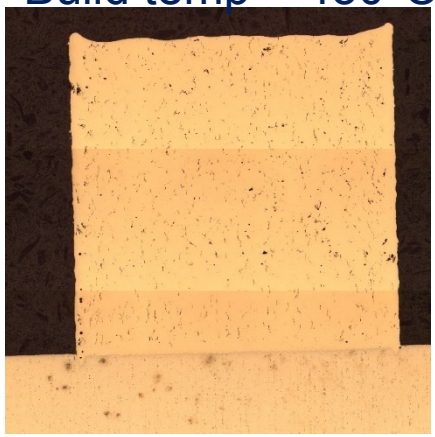
- Process maps based on heat input and material physical properties

Build temp = 80°C





Build temp = 450°C



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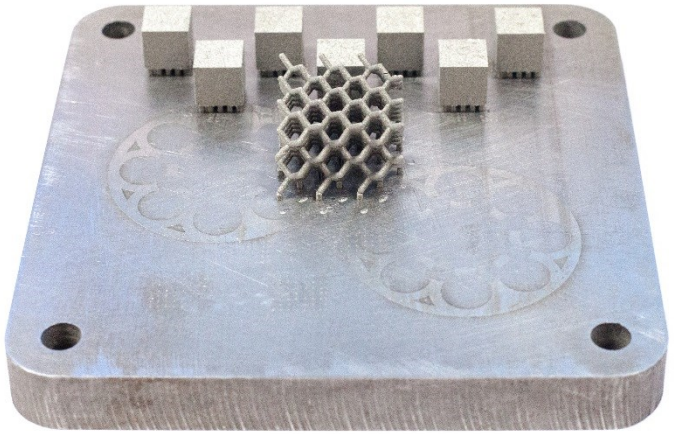
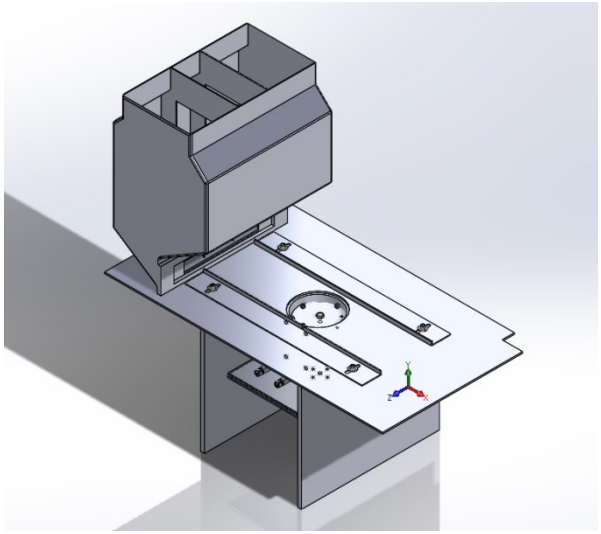
AM Tungsten

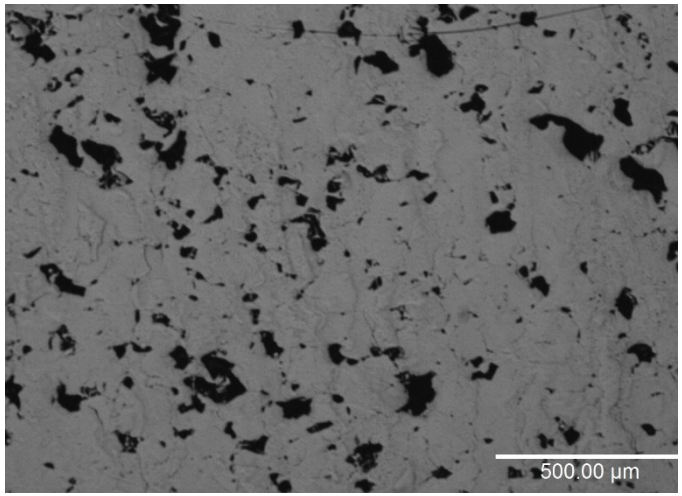
Tungsten used in first wall due to :

- Low activation under neutron irradiation
- High melting point
- Good thermal conductivity

- SLM Tungsten Density 94%
- Future work – EBM Tungsten via small build tank







SLM Tungsten Porosity

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Overview of AM Technologies

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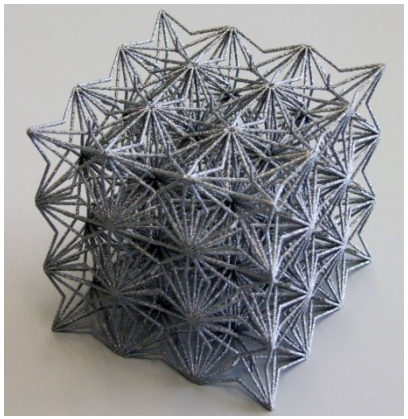
Additive Manufacture

Laser sintering

Micro-scale 3D printing

Metals
Polymers
Hybrid structures



Complex shapes

Less waste

Fewer processing steps

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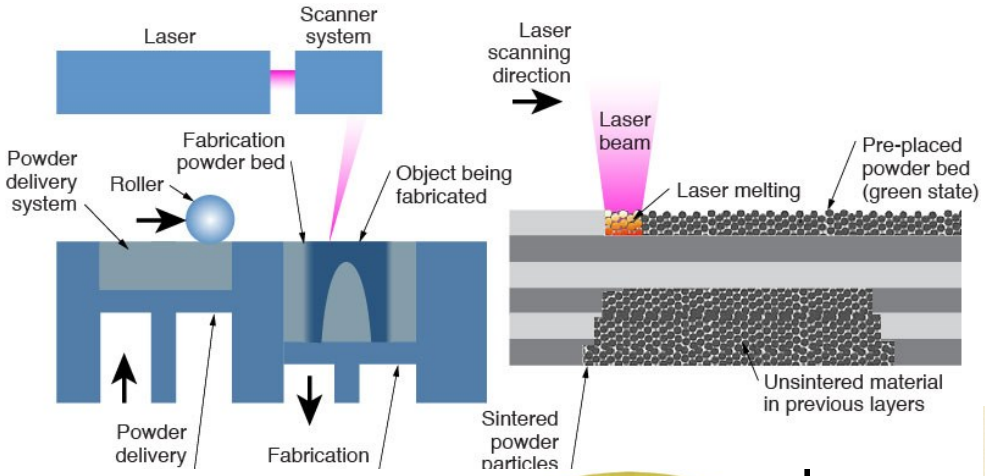
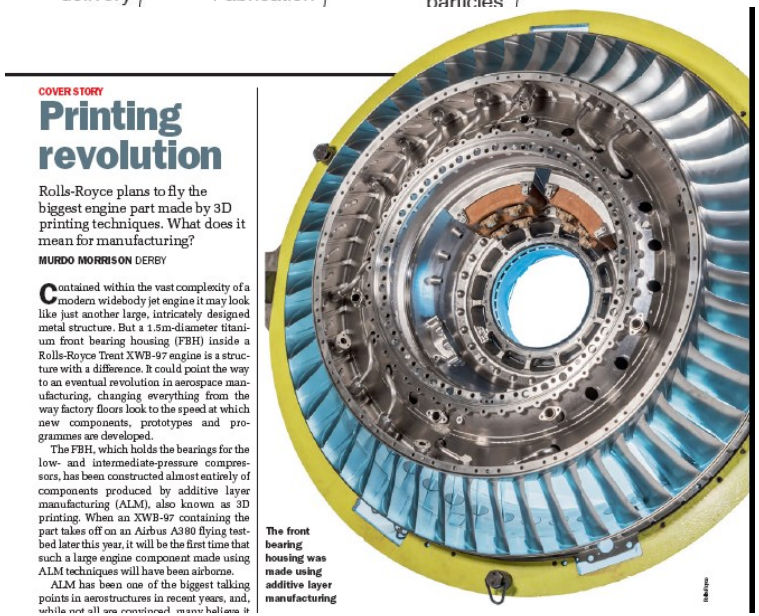
Powder bed systems



- Accurate beam positioning allows fine details
- Surrounding powder supports complex structure
- Restricted by bed size



COVER STORY

Printing revolution

Rolls-Royce plans to fly the biggest engine part made by 3D printing techniques. What does it mean for manufacturing?

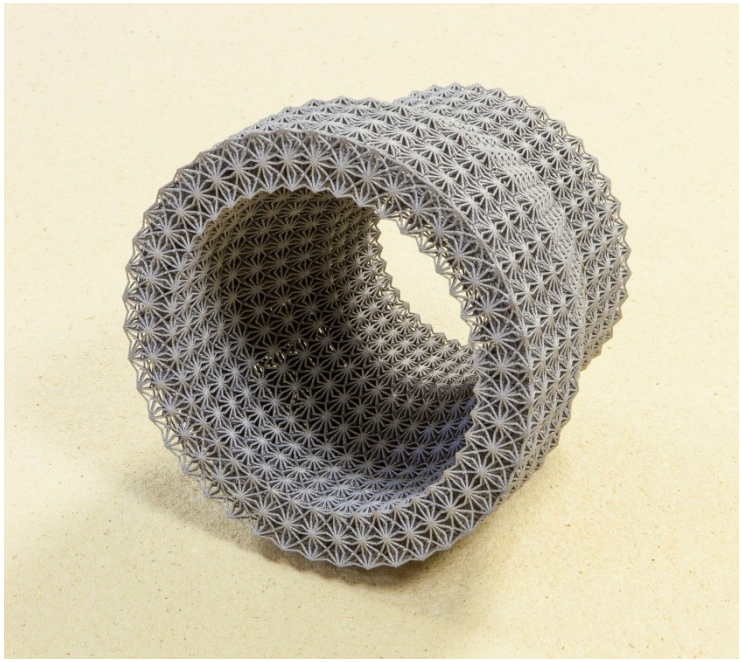
MURDO MORRISON DERBY

Contained within the vast complexity of a modern widebody jet engine it may look like just another large, intricately designed metal structure. But a 1.5m-diameter titanium front bearing housing (FBH) inside a Rolls-Royce Trent XWB-97 engine is a structure with a difference. It could point the way to an eventual revolution in aerospace manufacturing, changing everything from the way factory floors look to the speed at which new components, prototypes and programmes are developed.

The FBH, which holds the bearings for the low- and intermediate-pressure compressors, has been constructed almost entirely of components produced by additive layer manufacturing (ALM), also known as 3D printing. When an XWB-97 containing the part takes off on an Airbus A380 flying testbed later this year, it will be the first time that such a large engine component made using ALM techniques will have been airborne.

ALM has been one of the biggest talking points in aerostructures in recent years, and, while not all are convinced, many believe it

The front bearing housing was made using additive layer manufacturing



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Powder bed systems

Build envelope

- Max laser system 800mm x 400mm x500mm
- Max EB system dia. 350mm x 380mm

Deposition rates

- 20 to 80cm^3/hr

Min feature size

- 100 to 400µm

Materials readily processed

- Titanium alloys
- Nickel based alloys
- Steels/stainless steels
- INVAR
- Precious metals

Materials possible

- Aluminium alloys
- Copper alloys
- Tungsten
- Bulk metallic glasses
- High entropy alloys
- Ceramics

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Blown powder systems

- High deposition rates
- Cladding and repair capability
- Multi materials possible
- Adding features to existing parts

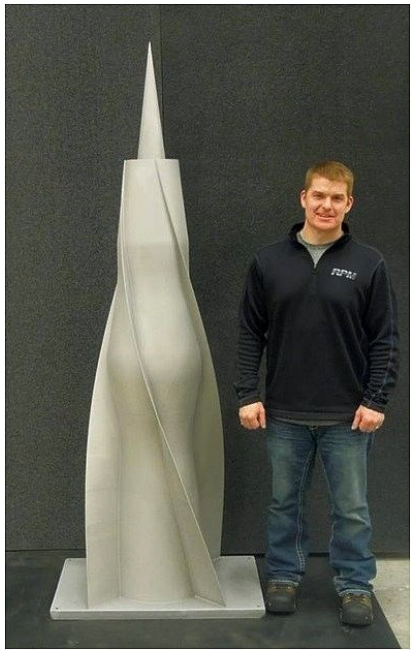


Image courtesy of RPM Innovations

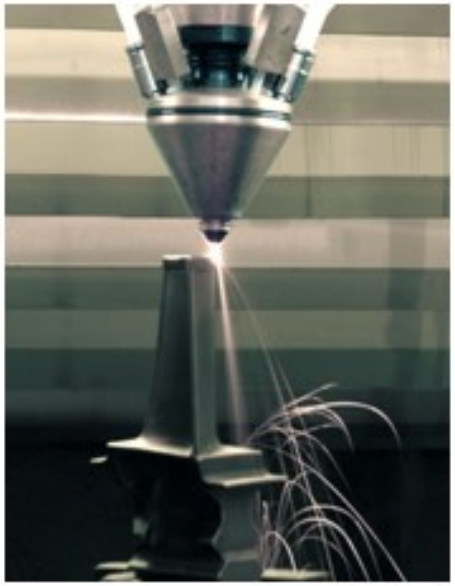
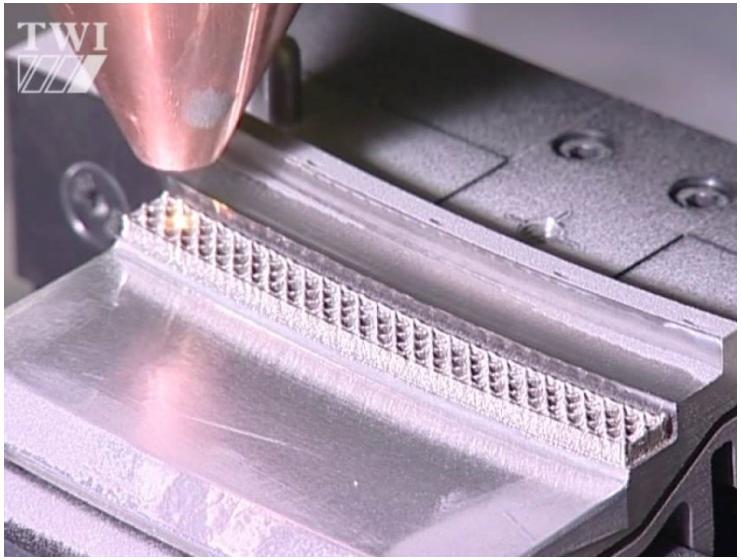


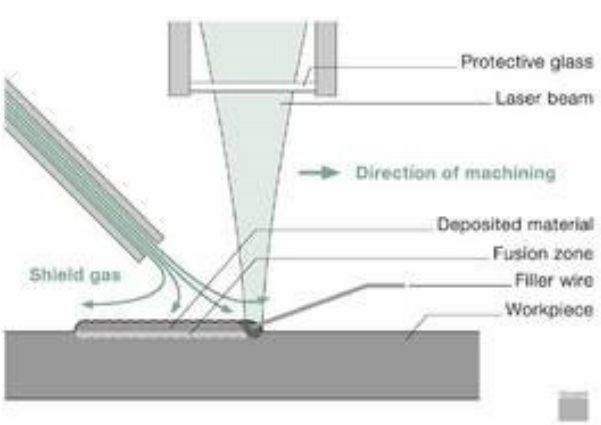
Image courtesy of Contour Precision

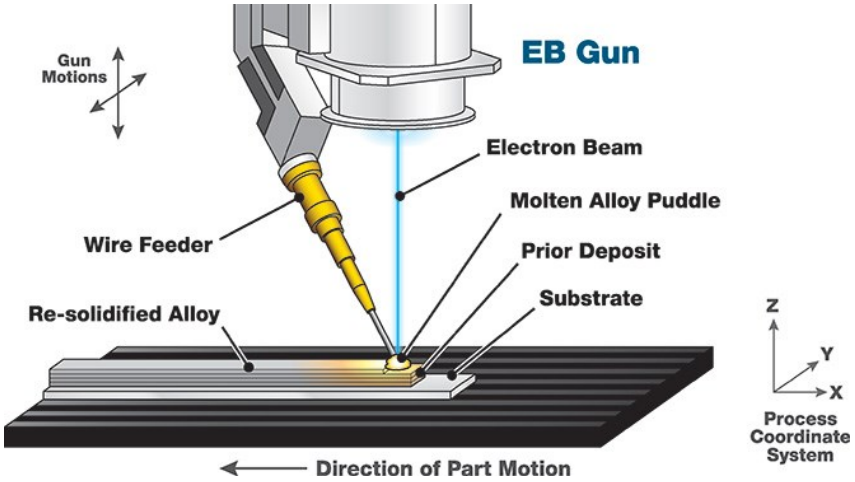


Blown powder systems

High Deposition rates 25cm^3/hr to 160cm^3/hr
Layer thickness 0.1 to 1.5mm
Positional accuracy +/- 0.25mm
Minimum feature size 0.5 to 1mm

Wire deposition





Very high Deposition rates

- 100cm^3/hr to 320cm^3/hr

Build envelope

- Chamber systems up to 1.5m x 1.5m

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Wire deposition

- Large component manufacture
- Requires machining to net shape
- Add features to simple shapes

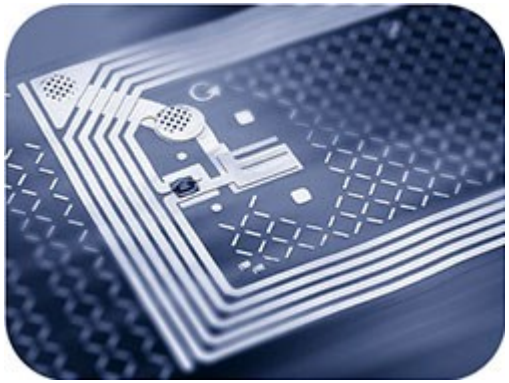
Materials
- Aluminium
- Stainless steel
- Titanium
- Nickel alloys

Image courtesy of NASA.

Hybrid systems

Combines blown powder with CNC machining

Functional printing



Inkjet or Aerosol Jet printing allows direct write of electronic circuits

Integration of:
Printed structures
Channels for wiring
Printed electronics

Printoptical

3D printing of optical lenses

- Full transparent
- Perfectly smooth
- Optically functional

LUXEXCEL