Laser Additive Manufacturing and Defence - 2040

Prof. M. Brandt
Director
Advanced Manufacturing Precinct and
Centre for Additive Manufacturing

- Why additive?
- Defence related AM research projects
- Challenges with AM technology and applications
- Summary

EDTAS

28-29 Nov, 2017, Melbourne

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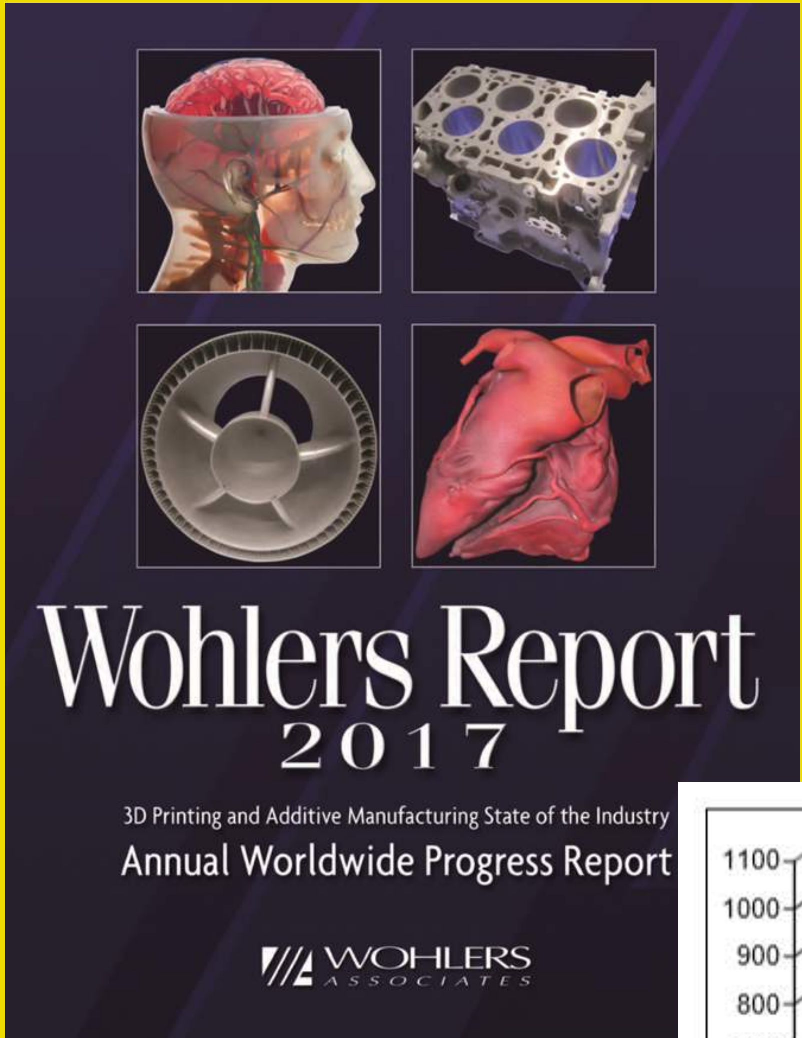
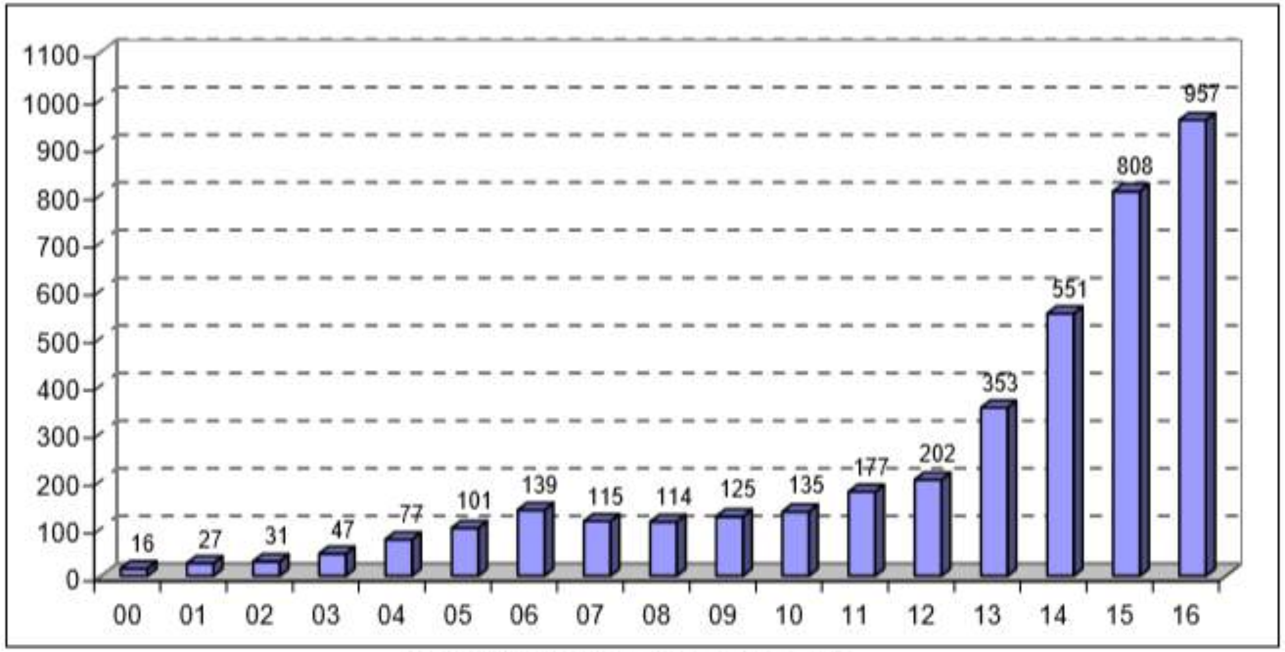


Additive manufacturing is a rapidly growing, fast changing global phenomena impacting all sectors of the economy – Will play a major role as a manufacturing technology in the future.

- The market size for AM systems and services estimated at US $6 billion in 2016.
- The CAGR over the past three years (2013–2016) was 25%.

957 metal systems sold in 2016 at US $1B



Source: Wohlers Associates, Inc.

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Benefits of AM

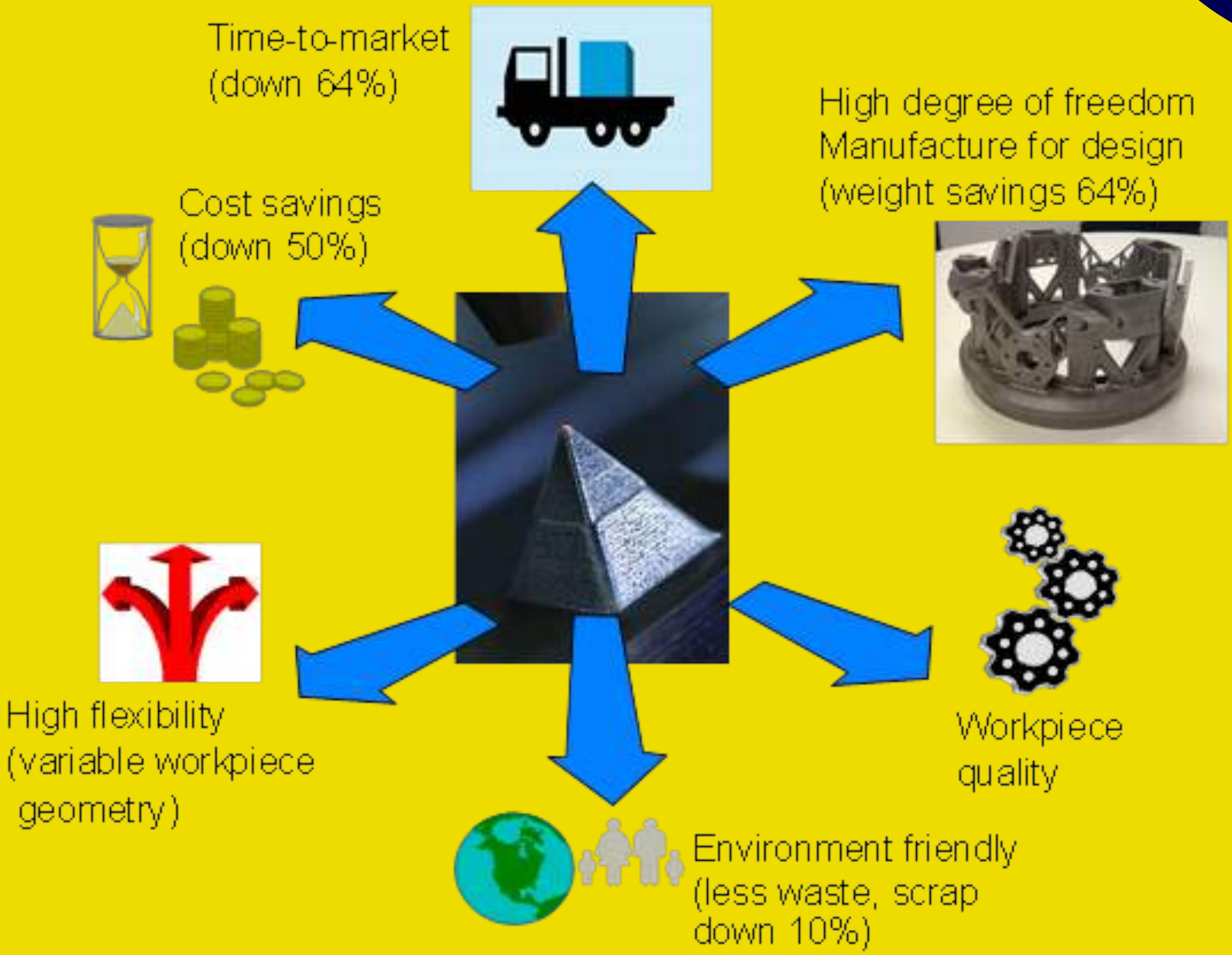

Figure in brackets refers to savings in aerospace and defence sectors.
Ref. J. Coykendall, M. Cotteleer, J. Holdowsky, M. Mahto, "3D opportunity in aerospace and defence". Deloltte University Press, 2013.

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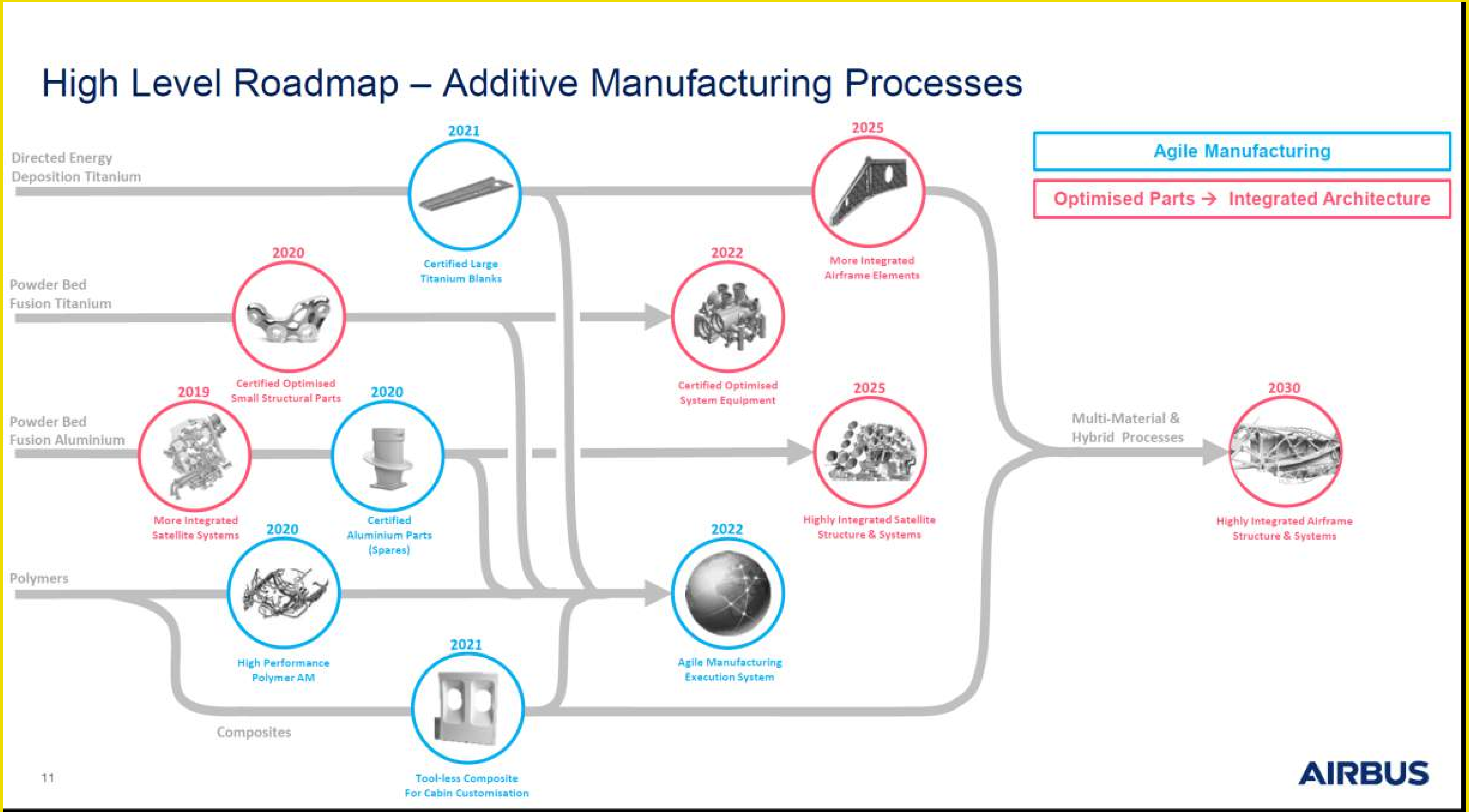
Additive Manufacturing technology roadmap

John Meyer, Airbus – 1st AM Technology Conference
8-9/10/17, Munich, Germany



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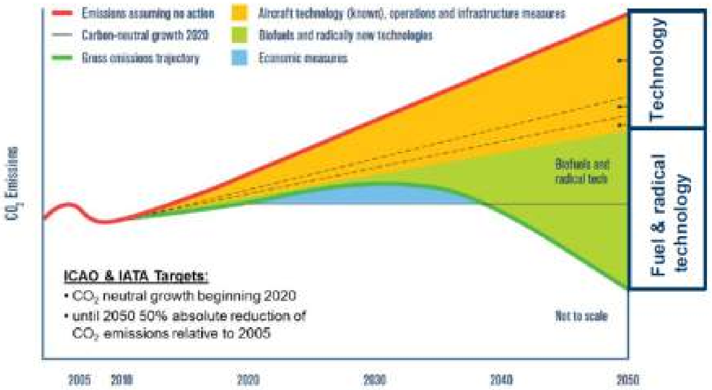
Additive Manufacturing at MTU

10/11/2017 – M. Schreyögg – Vorstand Programme MTU Aero Engines AG

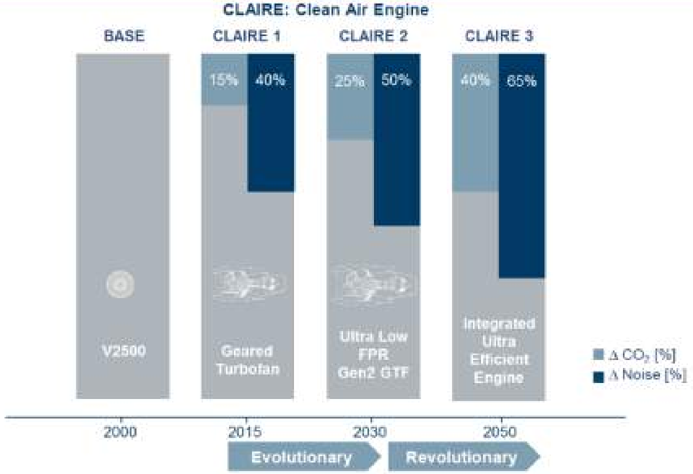
1st Munich Technology Conference on Additive Manufacturing

Demanding targets for civil aviation require a strong contribution on the engine side

Flightpath 2050: carbon emission targets



MTU-Roadmap supporting 2050 targets



- ➢ Long-term growth in aviation calls for efficiency, environment protection and noise reduction
- ➢ Evolutionary designs in support of 2030 targets: conventional engines with increased AM part share

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AM parts contribute to reduce fuel burn through bionic designs and functional improvements

$$\text{Fuel Burn} \sim \text{Weight} \times \frac{\text{sfc}}{\text{L/D}} \times \text{Time}$$

$$\sim \frac{1}{\eta_{th}, \eta_{prop}} \Rightarrow$$

Thermal efficiency:

- Increased overall efficiency
- Lower demand for cooling air
- Increased overall pressure ratio

Propulsive efficiency:

- Reduced Fan Pressure Ratio
- Increased Bypass Ration

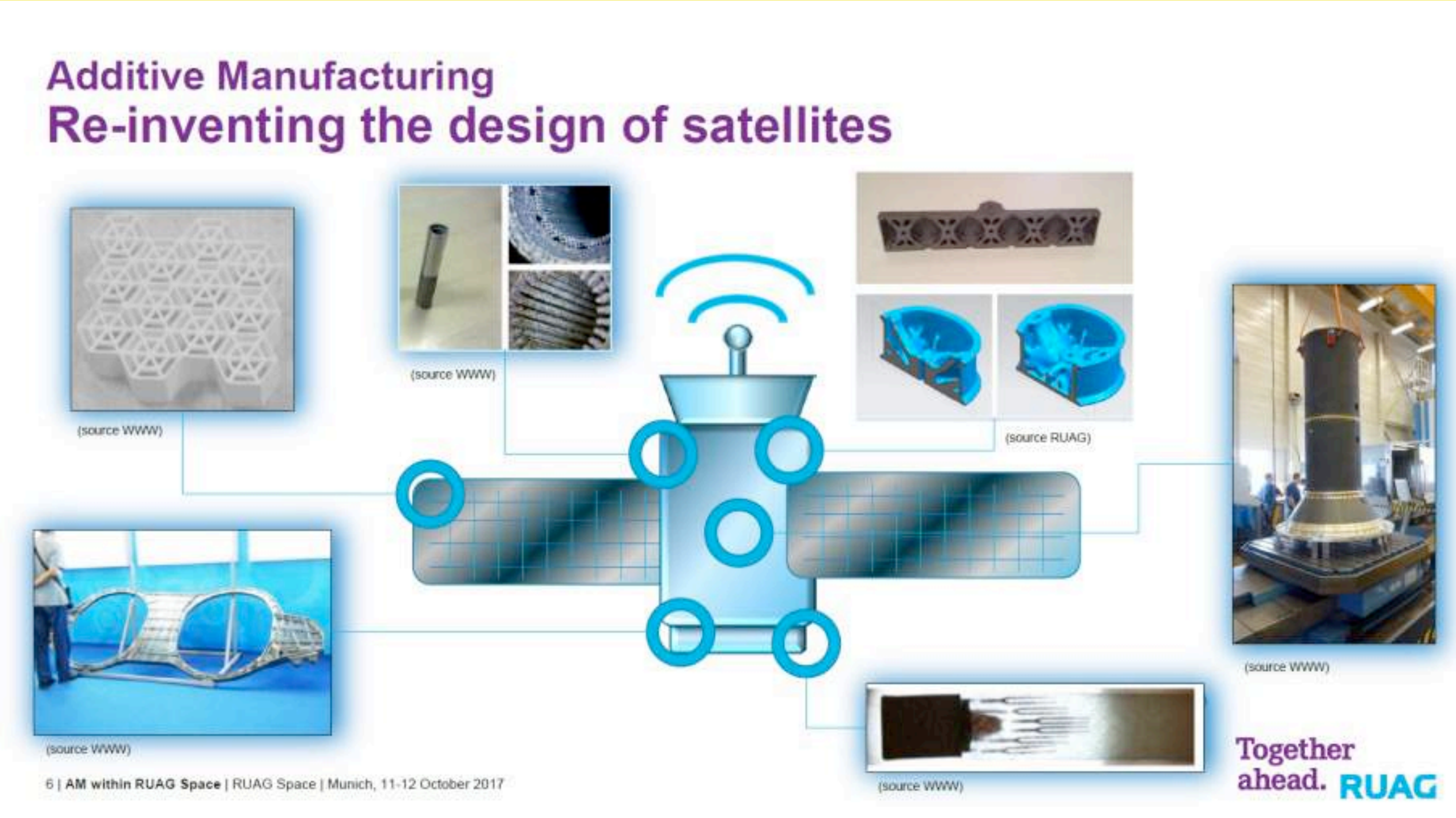
High Lift/Drag

Low weight structures

- Bionic designs
- Lightweight structure and materials

➢ **Higher design complexity and more sophisticated manufacturing capabilities**

Franck Mouriaux, General Manager Structures
RUAG Space
Munich, 11-12 October 2017



Franck Mouriaux, General Manager Structures
RUAG Space
Munich, 11-12 October 2017

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RMIT AMP Additive manufacturing capability 2018

Polymer

FDM – Fortus 900mc, Uprint, 10 Makerbot, 10 Zortrax, Markforge

SLA – 3D Systems Projet 7000, DLP systems

MJ – Polyjet J750, Connex 350

Metal

SLM – SLM Solutions 500HL,

2x250HL, 125 HL, TRUMPF 1000

LMD – TRUMPF TruLaser 7020

Supporting

CNC – 3 & 5 Axis machining centres

Metrology – 3D scanning, CMM, CT

Simulation – Virtual design, Optimisation

Mechanical Testing – Extensive capabilities

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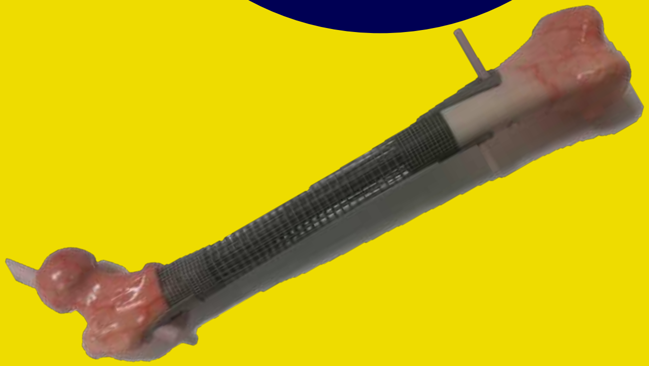
Centre for Additive Manufacturing formed 2014:
14 Academics and 25 HDR students, research focus

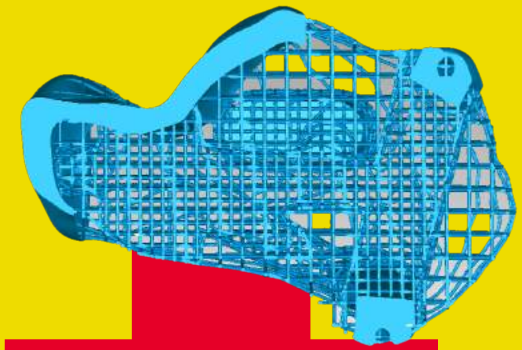
Design

- *Topology optimisation algorithms*
- *Self supporting structures algorithms*
- *Design for additive*

Materials and manufacture

- *Process optimisation*
- *Structure optimisation*
- *Process control*
- *Alloy development*
- *Modelling*





Targeting opportunities in high customisation and complexity in Aerospace, Biomedical, and Defence industries

Focus on generating new IP

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Additive manufacturing technologies

- Polymer
- Metal

- **Liquids**
  - Photo Curable
    - Direct focus beam methods
      - **Stereolithography (SL)**
      - **Digital Light Processing (DLP)**
      - **Direct photo shaping (DPS)**
    - Masking methods
      - Solid Ground Curing (SGC)
    - Jetting head type
      - **PolyJet**
  - Electrically conductive
    - Electrochemical Fabrication (EFAB)
- **Sheet**
  - Lamination
    - Bonding of sheets
      - Laminated Object Manufacturing (LOM)
- **Powder**
  - Melting
    - **Selective Laser Melting (SLM)**
    - **Laser Metal Deposition (LMD)**
    - **Electron Beam Melting (EBM)**
  - Sintering
    - Selective Laser Sintering (SLS)
  - Binding
    - 3D Printing (3DP)
- **Solids**
  - Extrusion
    - **Fused Deposition Modelling (FDM)**

Laser Additive Manufacturing

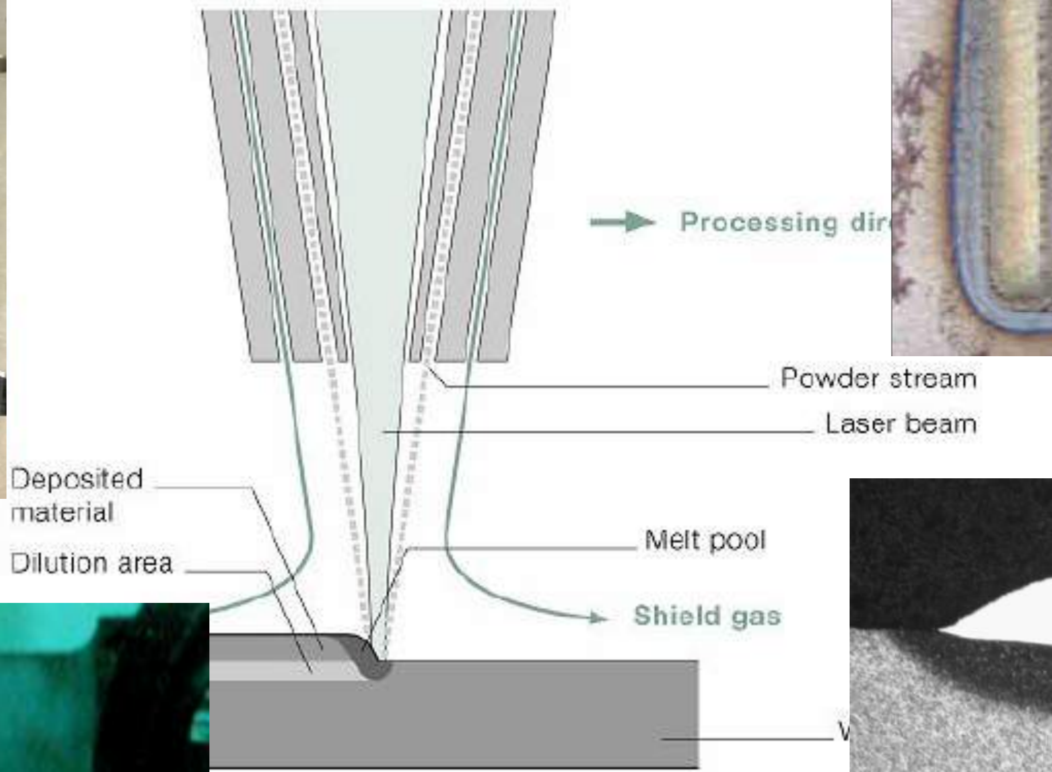
Two directions:

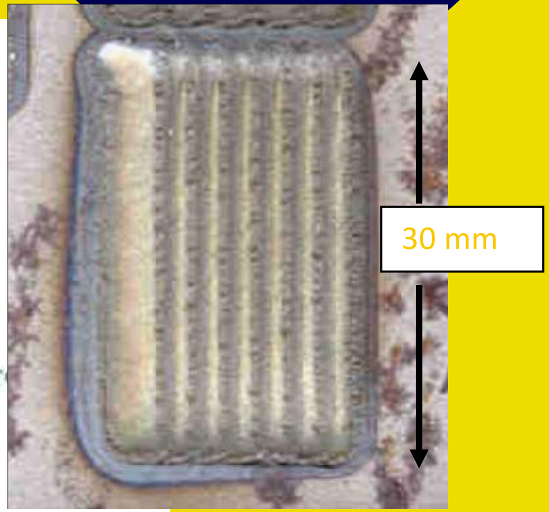
Repair and manufacture – laser cladding + 3D (powder fed)

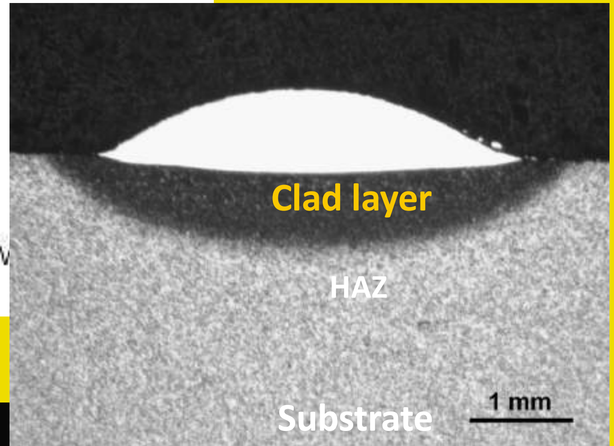
Additive Manufacture – Selective Laser Melting (powder bed)

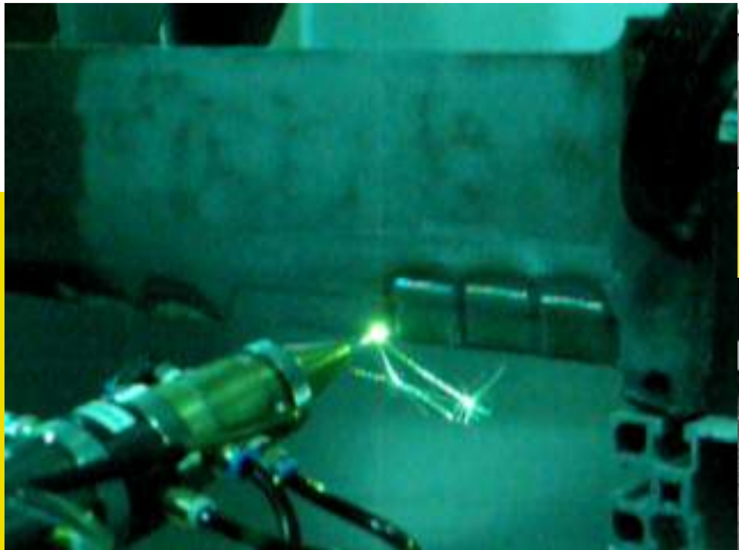
- Both processes use a laser beam and powder stock which is melted and fused to the substrate or the layer below

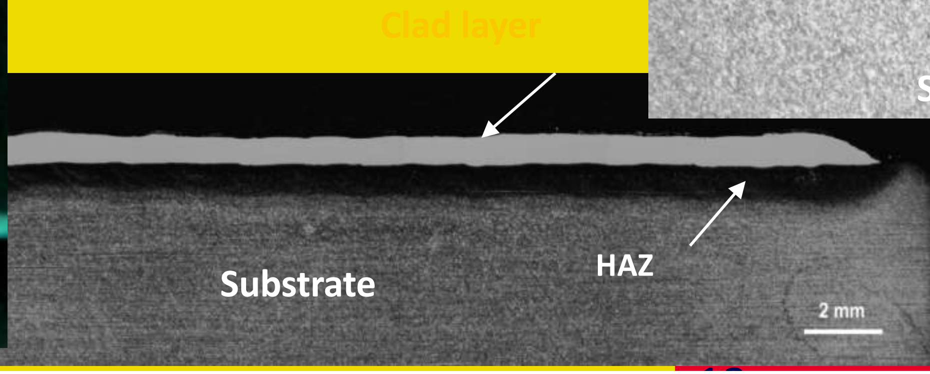
Laser Metal Deposition – Invented in UK in late 1970s









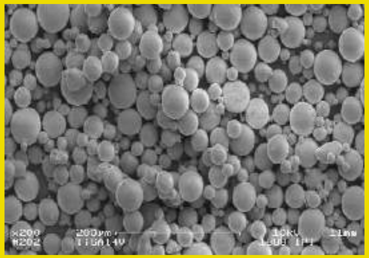


Selective Laser Melting Process
Invented at ILT ~ 1995
How it works

Ar processing chamber

3D-CAD model
subdivided into layers

+



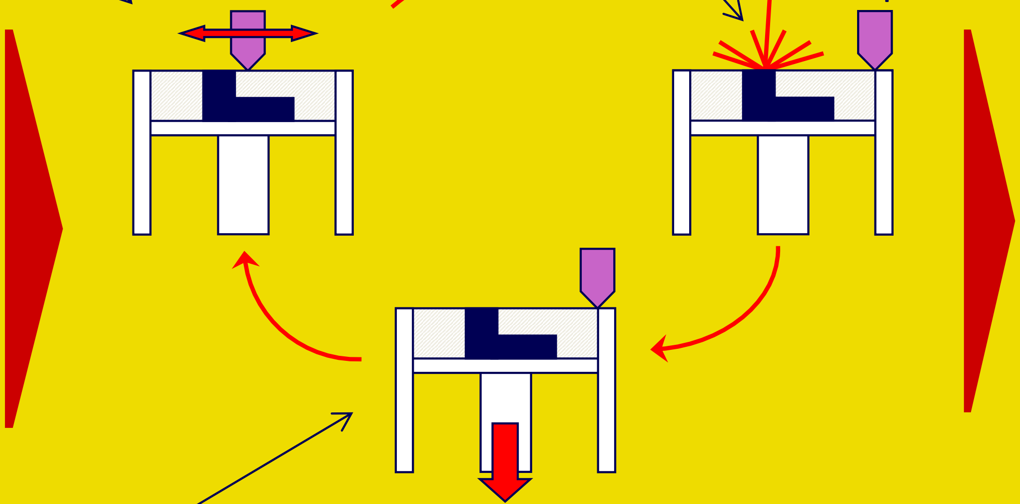
metal powder

STEP 1

application of
powder layer

STEP 2

melting of
the powder



lowering the platform

STEP 3

metal part made
of serial material

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Fraunhofer ILT

Some research examples

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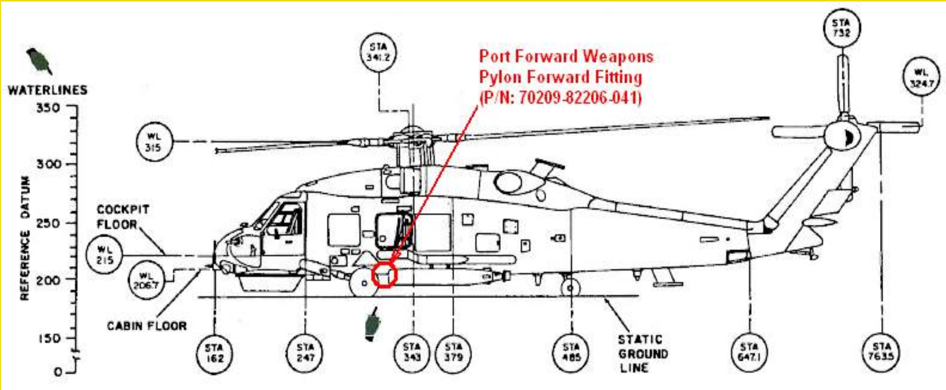
Motivation: repair and restore legacy and new components and develop lighter structures



New Systems

Issues:

- Wear
- Corrosion
- Fretting
- Impact
- Fatigue

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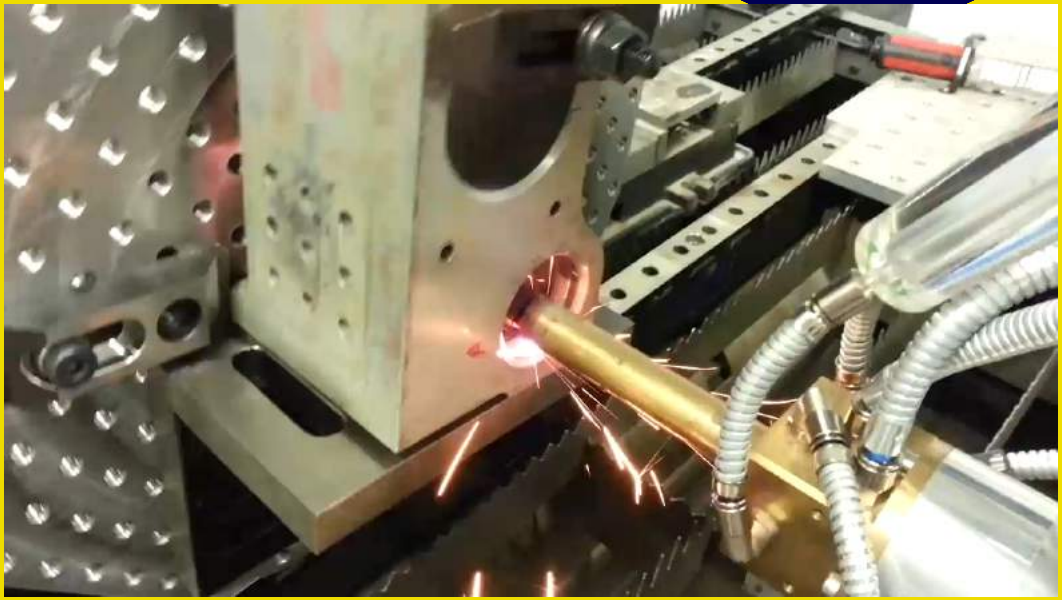
DMTC

Repair on actual component
(C-130 landing gear shelf bracket)



Powder material: 420 SS
Substrate material: AISI 4140 steel

As-clad

Post-clad machining

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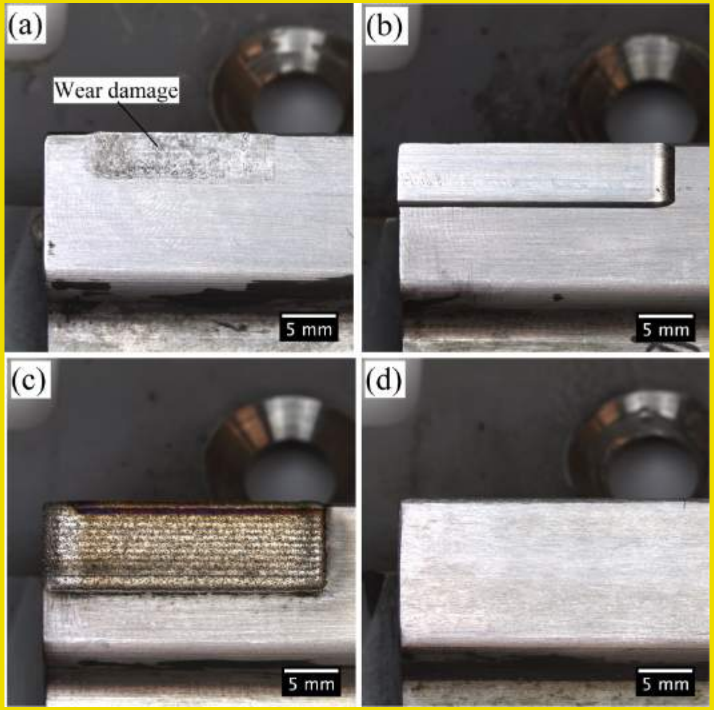
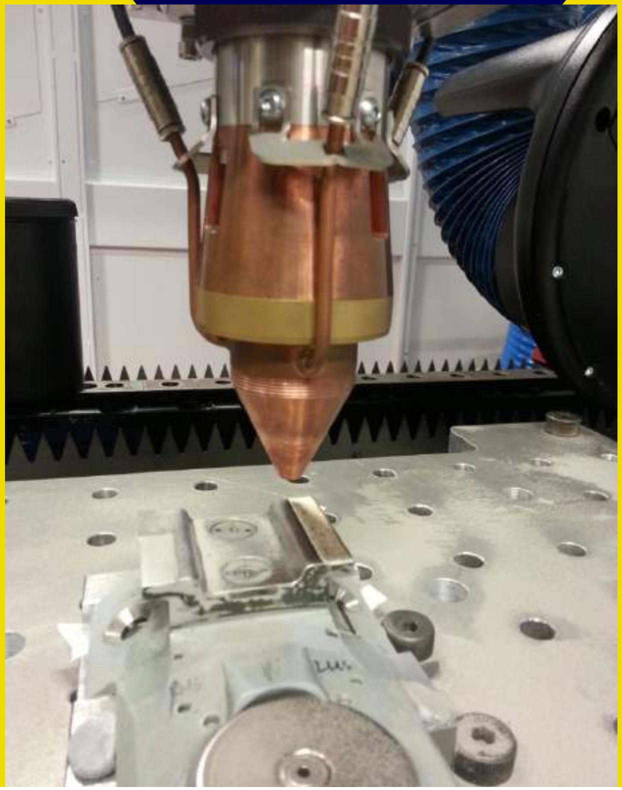
Laser repair of forward hanger assembly (F/A-18)





Substrate material: 13-8 PH SS
Objective: Match hardness of the substrate
Approach : Mixing powder alloys to tailor hardness
Solution: Powder material: 420 SS + 17-4PH

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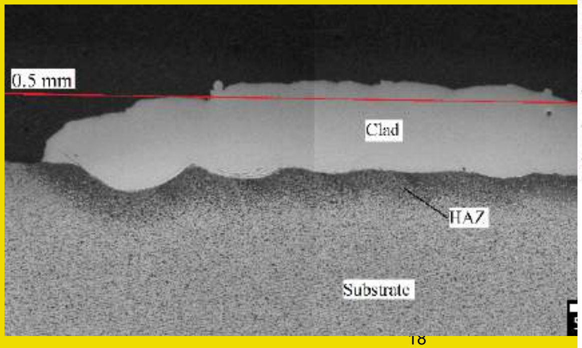
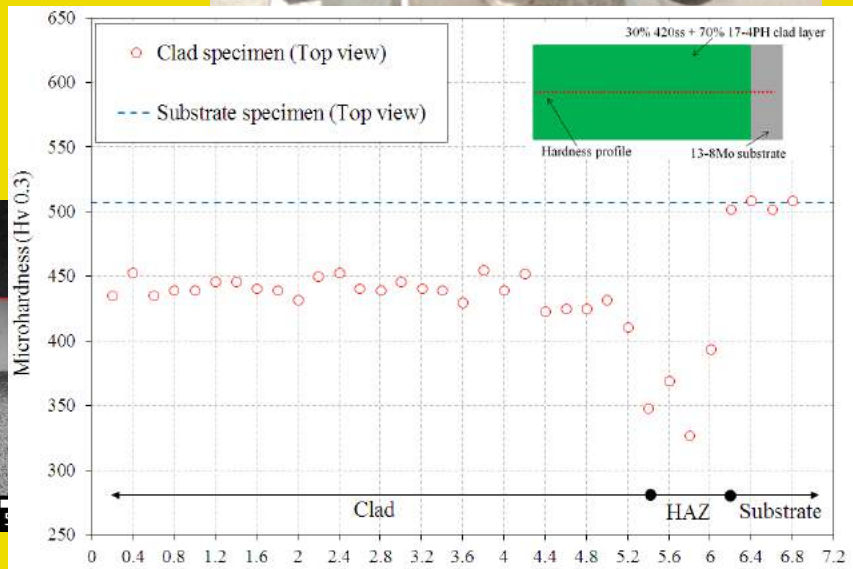




CERA Project (RMIT/DST):
Additively Manufactured Lightweight Hybrid Ballistic Protection

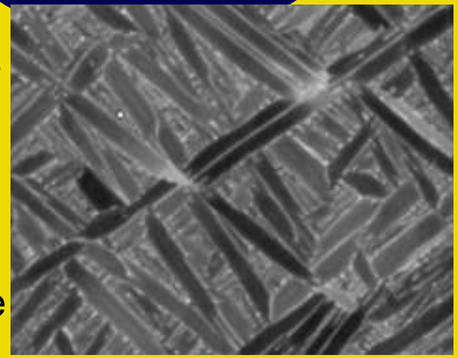
Why AM

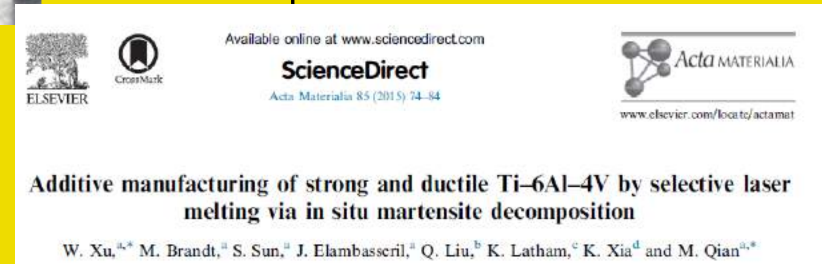
- ❖ **New design philosophy**
- ❖ **Hybrid materials**
- ❖ **Rapid prototyping = Rapid T&E**
- ❖ **In-country armour supply**
- ❖ **Rapid support to Operations**
- ❖ **Cost??**

Laser Metal Deposition
Selective Laser Melting
+
+
+

In-situ modified microstructure

- ➢ Microstructure
- ➢ Mech Prop.

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Acta Materialia 85 (2015) 74–84
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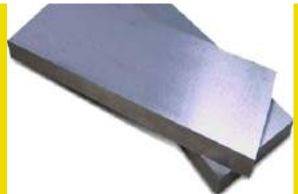
Additive manufacturing of strong and ductile Ti–6Al–4V by selective laser melting via in situ martensite decomposition

W. Xu,[a,*] M. Brandt,[a] S. Sun,[a] J. Elambasseril,[a] Q. Liu,[b] K. Latham,[c] K. Xia[d] and M. Qian[a,*]



Threats

KE
+
Frag.
+

MIL-DTL- AM???
+
+

- ❖ **Vehicle Applique**
- ❖ **Body Armour**
- ❖ **Structural armour**

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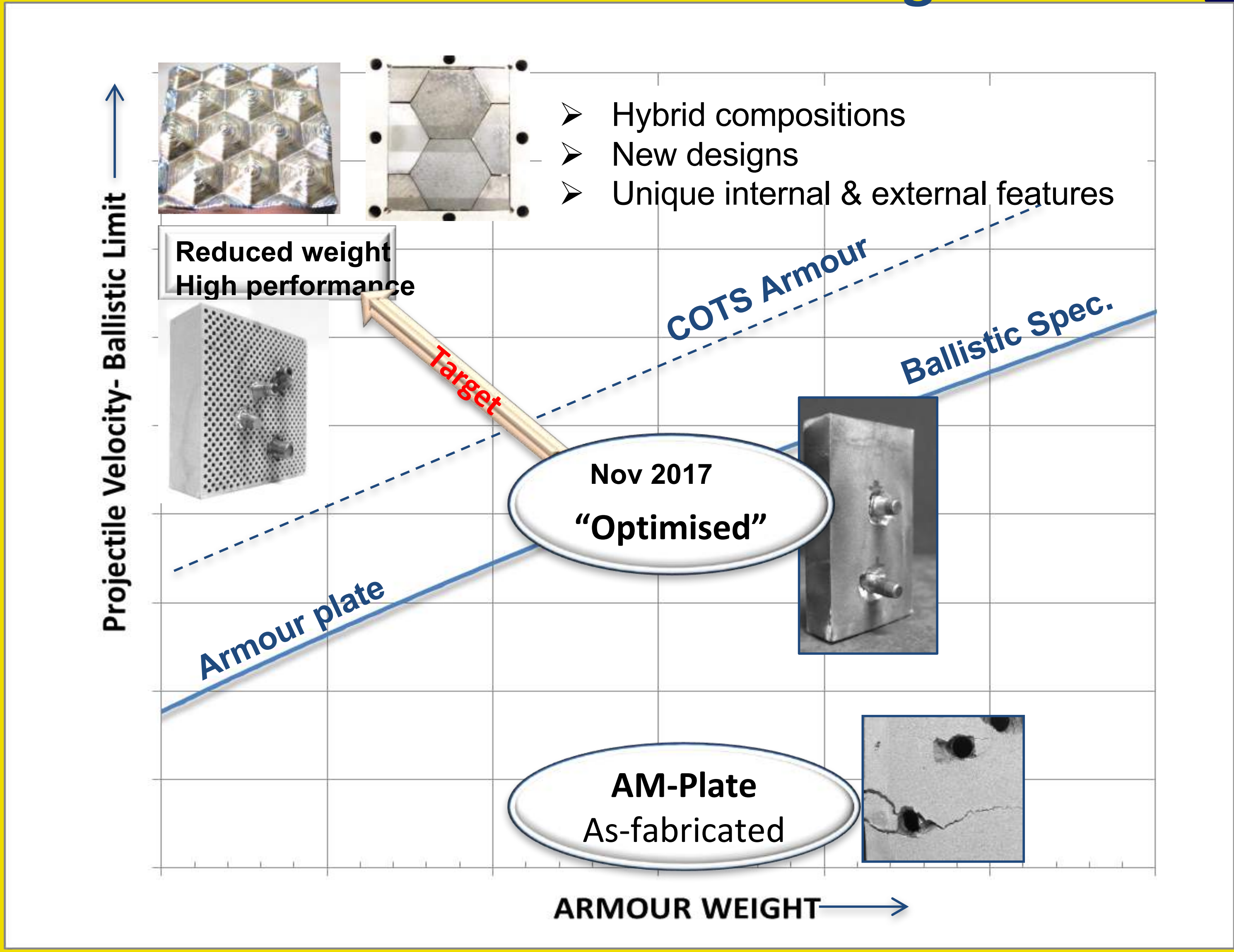
Phase 1: Progress



Combining materials and design able to meet armour plate ballistic specification

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Challenges with Laser Additive technology

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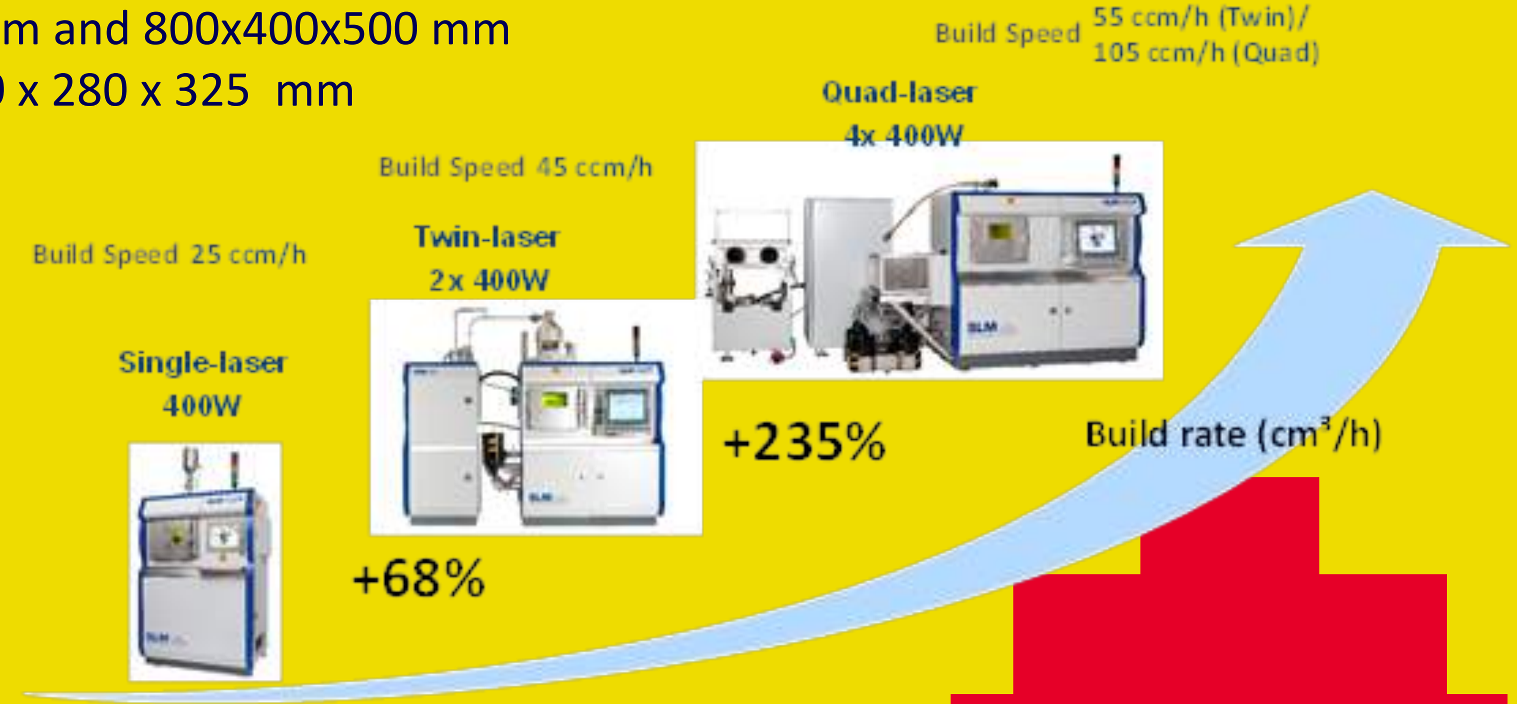
SLM Technology – Build rate approach limited and single material : Need new concept?

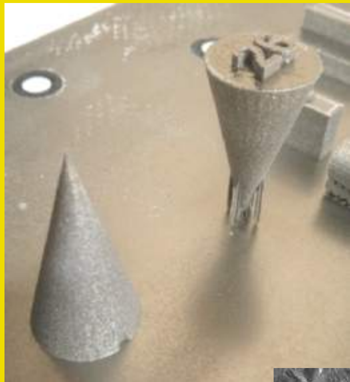
Global players: EOS, GE (Concept Laser), SLM Solutions, Realizer, Phoenix (3D Systems), Renishaw, TRUMPF

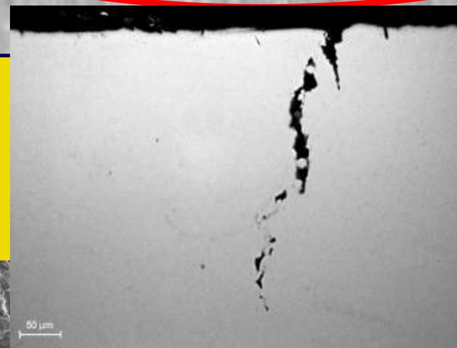
1. Laser source – Increasing power up to 1000W
2. Beam delivery – multiple sources
3. Powder delivery and platform size: typical 250 x 250 x 300 mm.
   New systems: Concept laser,
   640 x 400 x 500 mm and 800x400x500 mm
   SLM Solutions 500 x 280 x 325 mm

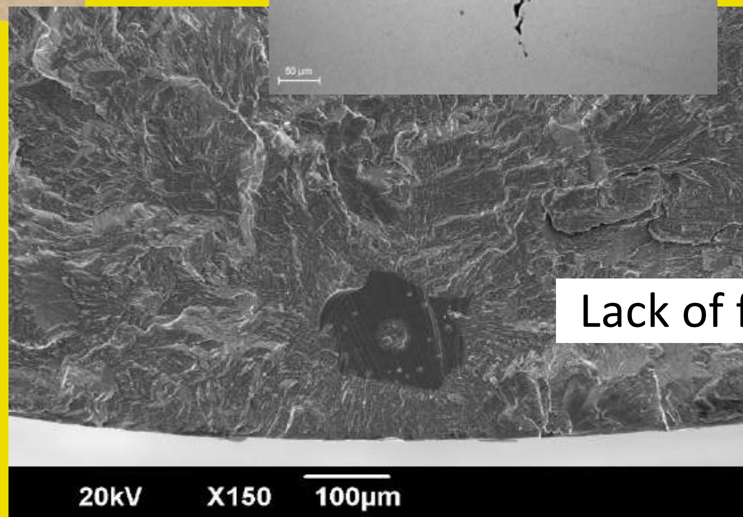


Major scientific challenges with metal AM technology – materials and manufacturing optimisation

- Lack of fusion at interface – LMD
- Lack of fusion in SLM parts
- Porosity in SLM parts
- Cracks

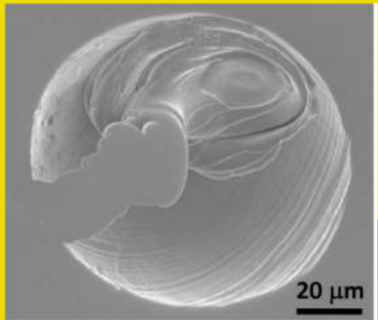


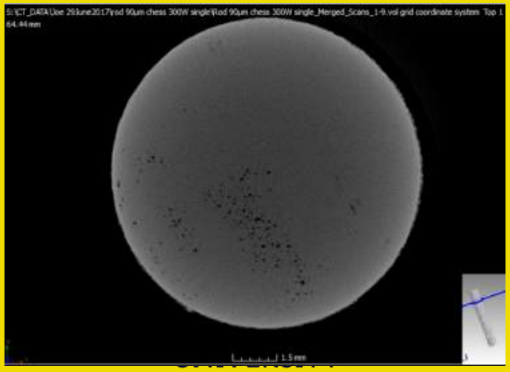


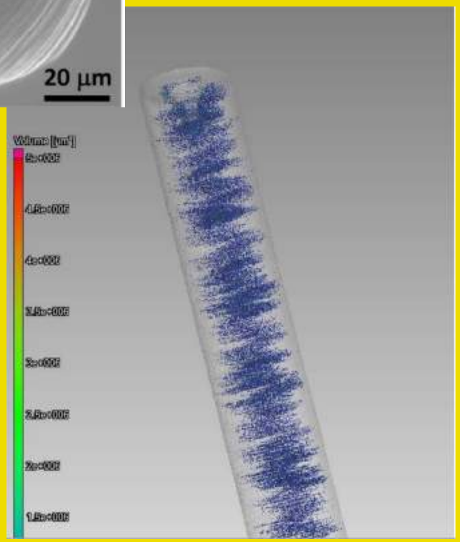


Lack of fusion

Gas pore





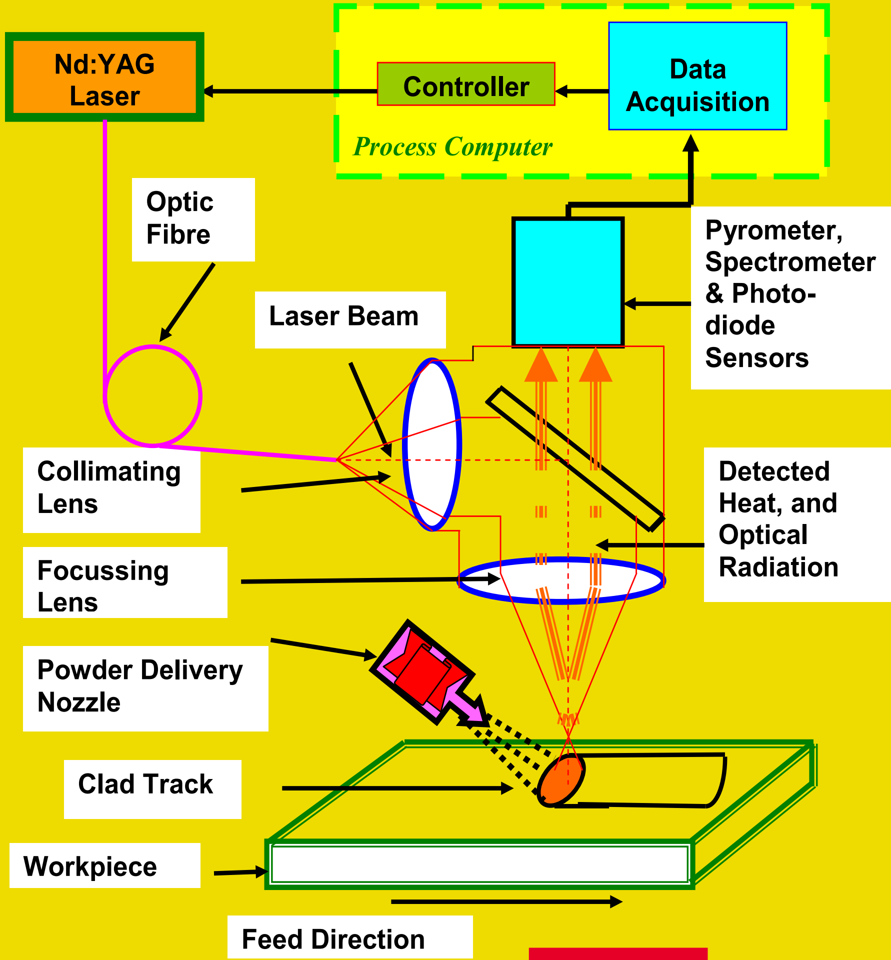


Major challenges with metal laser AM technology – sensing and control

Lot of research has been done and is ongoing in particular with SLM technology but no real commercial devices – *critical for QC and certification*

SLM+LMD

- Layer thickness
- Porosity
- Lack of fusion
- Interface defects
- Heat build up
- Phase ? Dilution?



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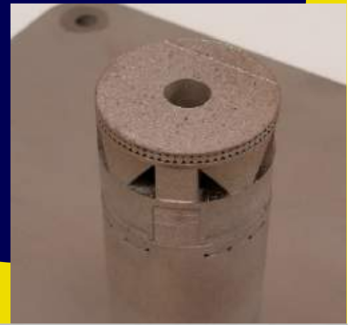
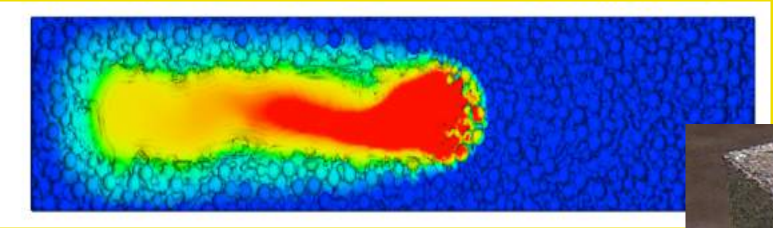
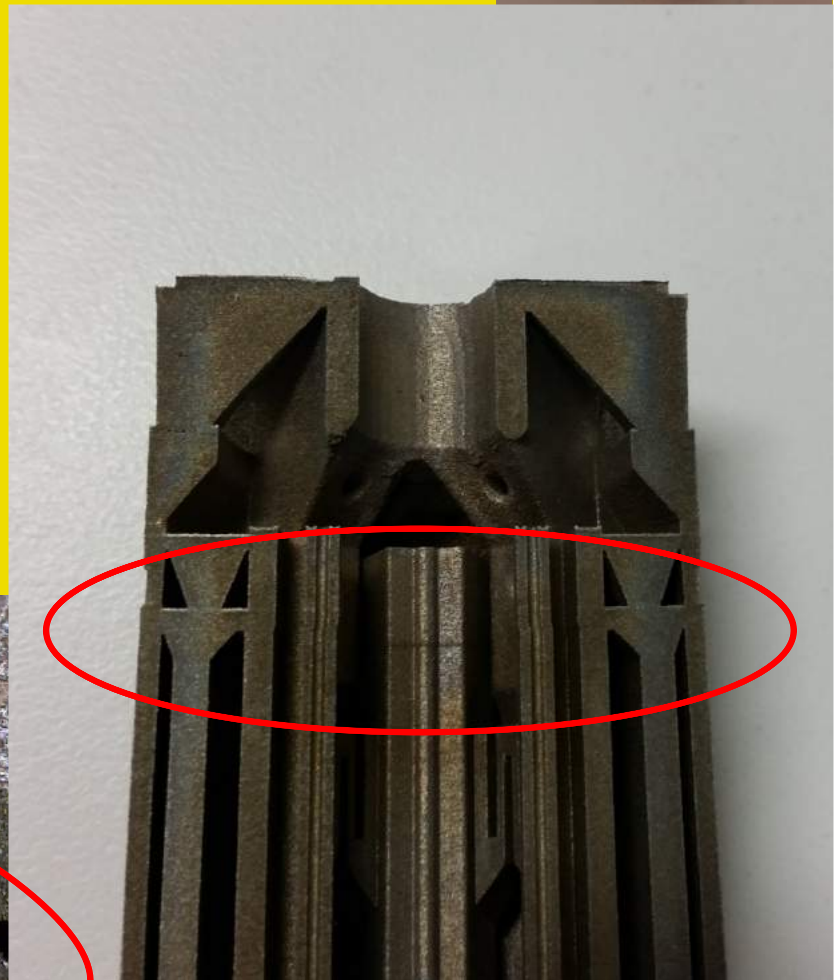
Major challenges with metal AM technology – modelling and manufacturing

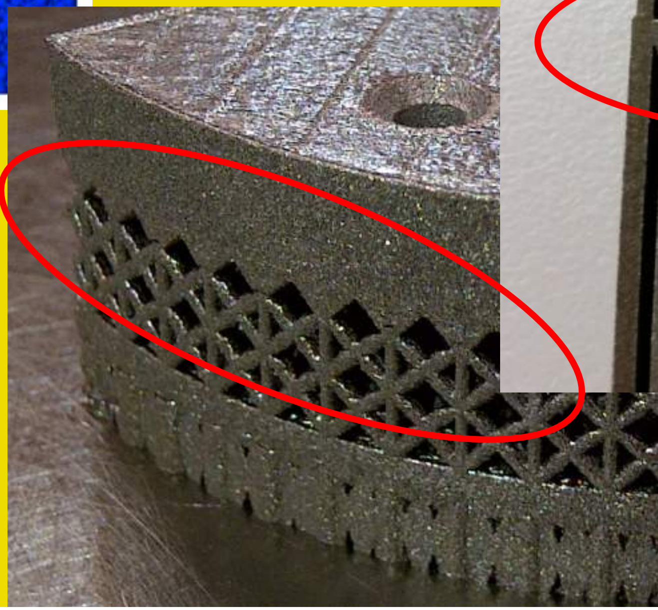


- Distortion is an issue with additively manufactured parts and strategies need to be developed to minimize it
- Process and microstructure modelling



Powder bed fusion





FLOW-3D®

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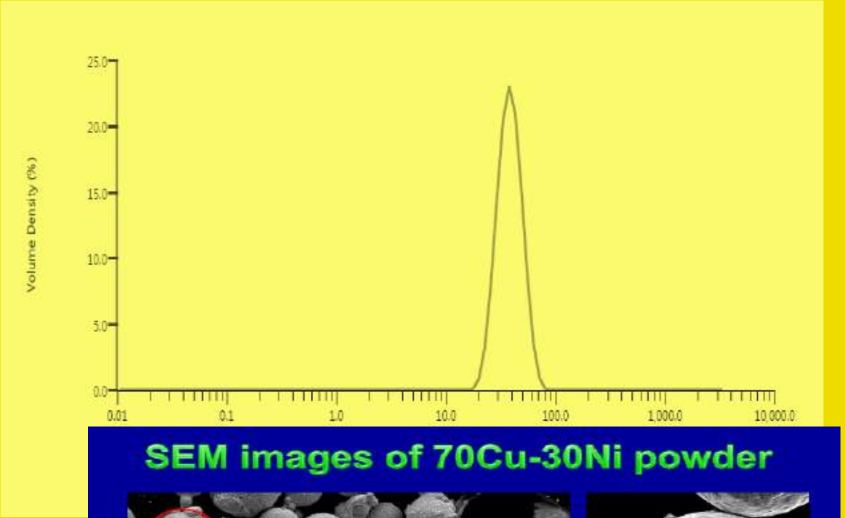
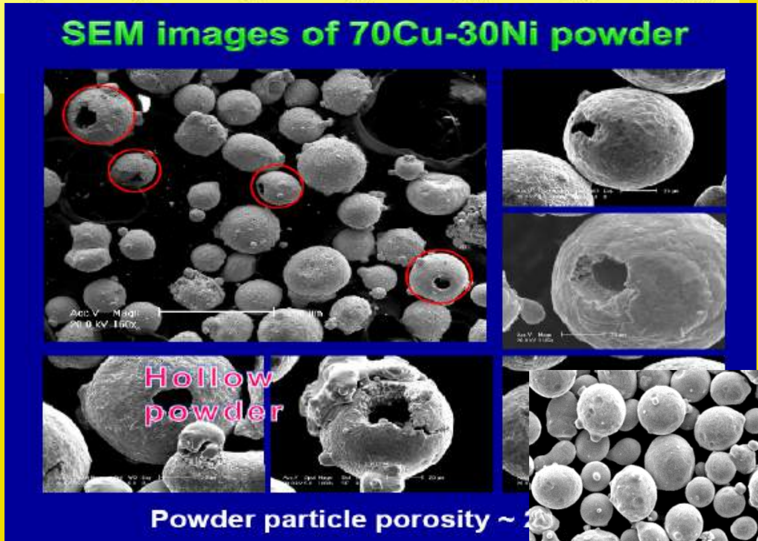
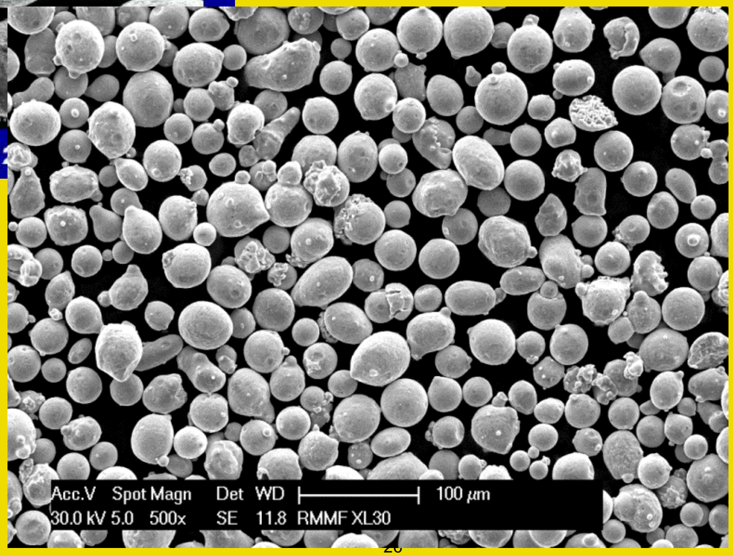
Powder stock LMD and SLM: critical to successful outcome





- Powder manufacturability influences the quality, microstructure and layer properties
- Powder bed: 20-60 microns
- Powder fed: 45–90 microns
- New powder alloys

H13



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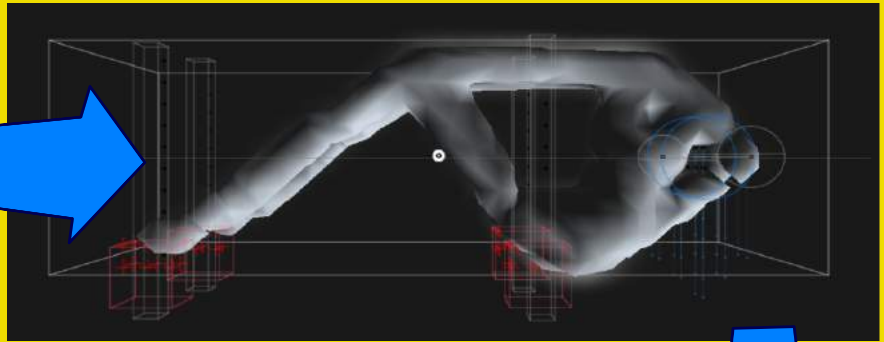
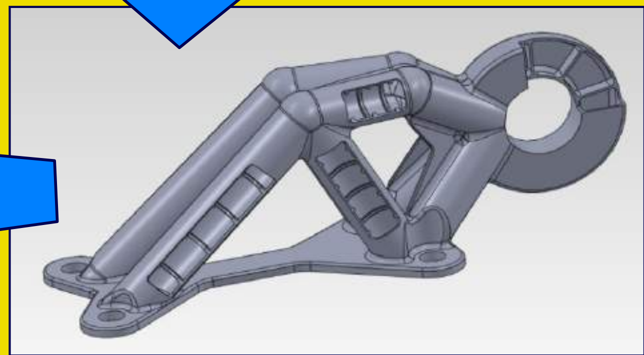
Major challenges with metal AM technology – design optimisation tools

Part design

Process steps complex requiring several software packages



Topographically optimal



CAD Equivalent

Manufactured

40-60% Mass reduction (depending on loading)

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Additive Manufacturing Opportunities – up to 2040

Message

- AM technology growing and will play an increasing role in manufacturing in the future because of the many benefits it offers compared to traditional technologies

- Research in AM technology will deliver new more efficient, cheaper and fully instrumented devices

- New materials and software design and process modelling tools for AM need to be developed

- The applications of the future are yet to be discovered and developed

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Conferences

Prof. Ma Qian, RMIT, Co-chair

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Thank you.
Questions?

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