Cranfield
Manufacturing

Large-scale Cost-effective Metal Additive Manufacturing

10th September 2019

WAAM®

Dr Filomeno Martina + WAAMMat team

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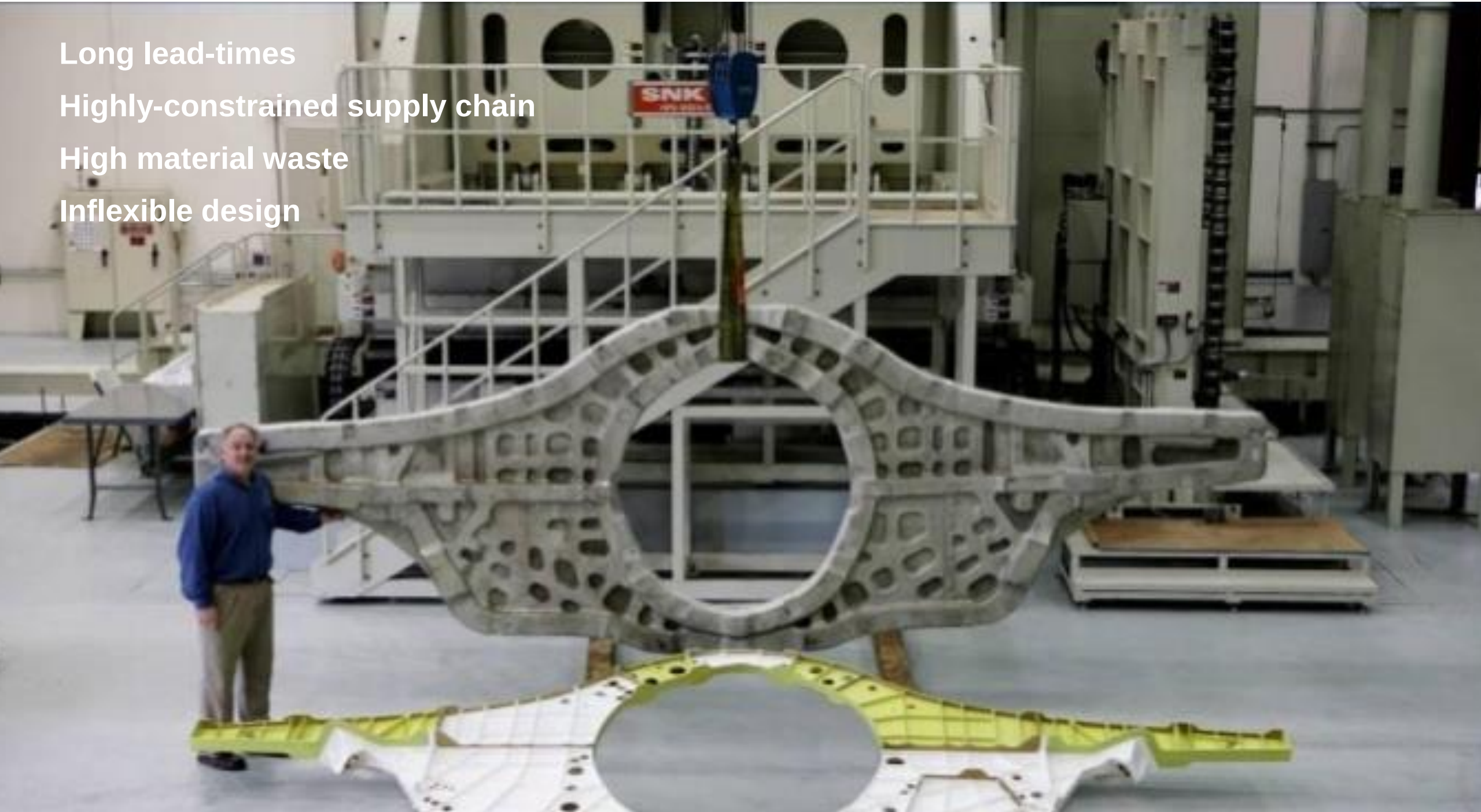
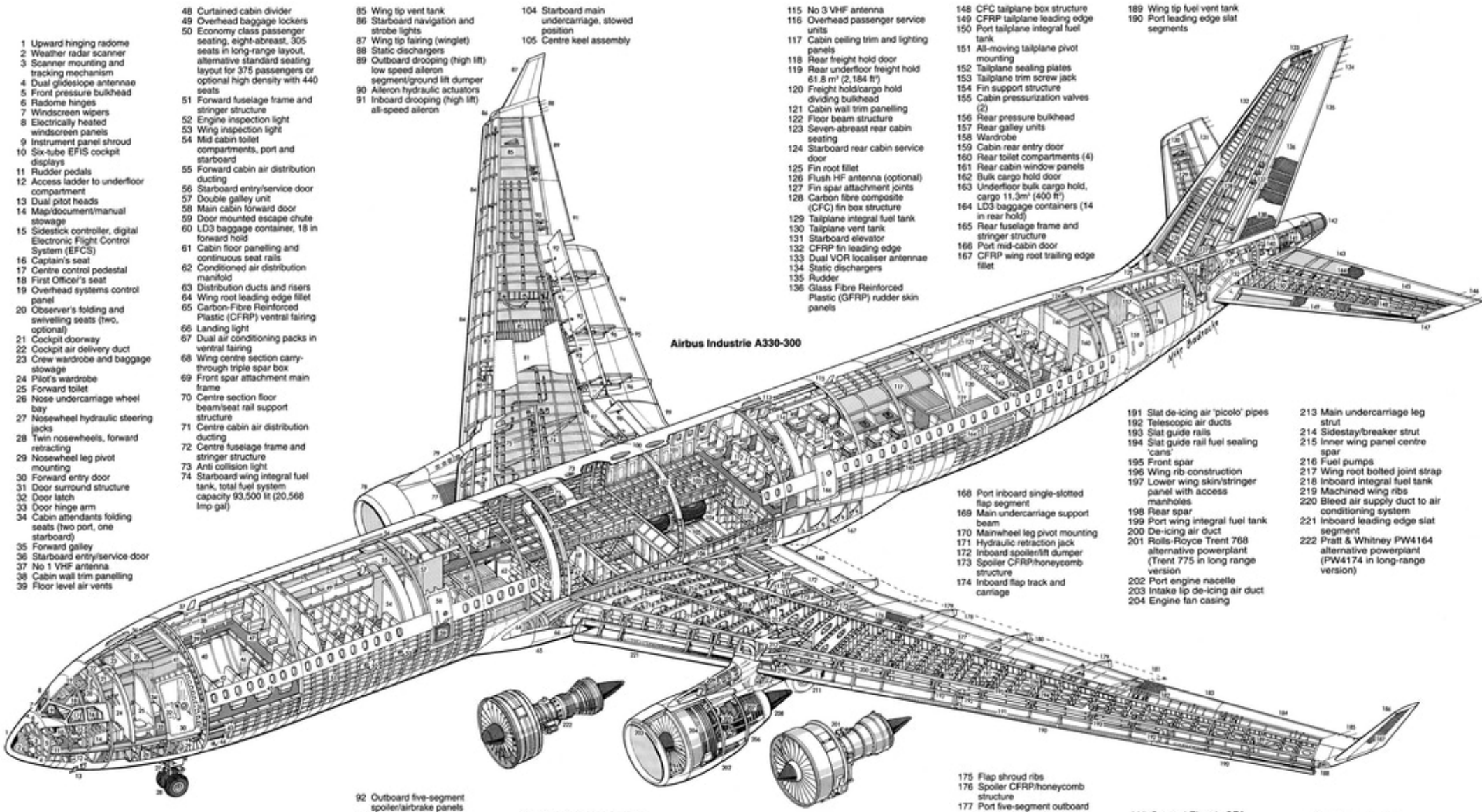

Long lead-times
Highly-constrained supply chain
High material waste
Inflexible design

Civil:

Higher rates of production

Cheaper platforms

Less constrained supply chains



Military future platforms will require:

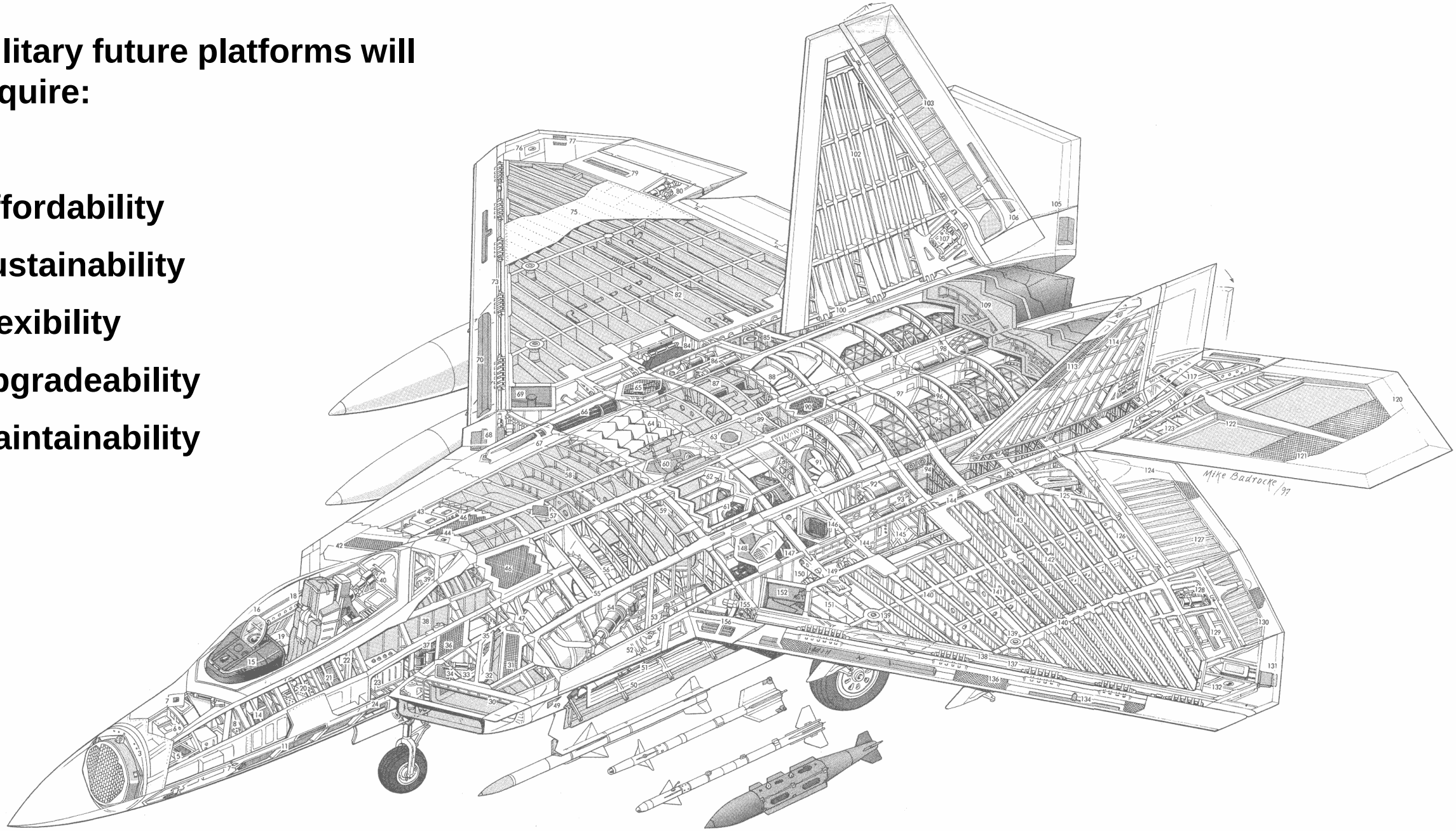
Affordability

Sustainability

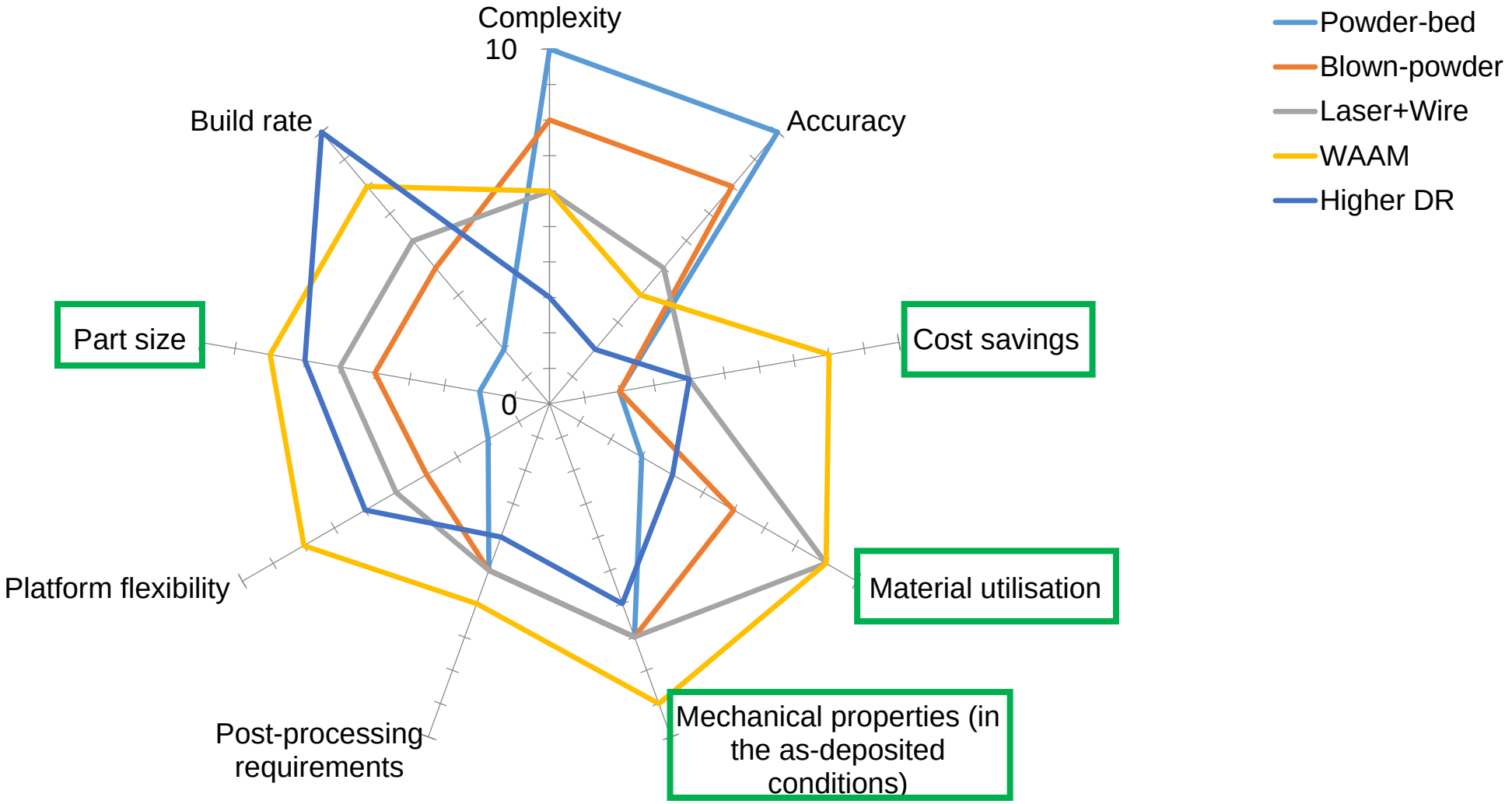
Flexibility

Upgradeability

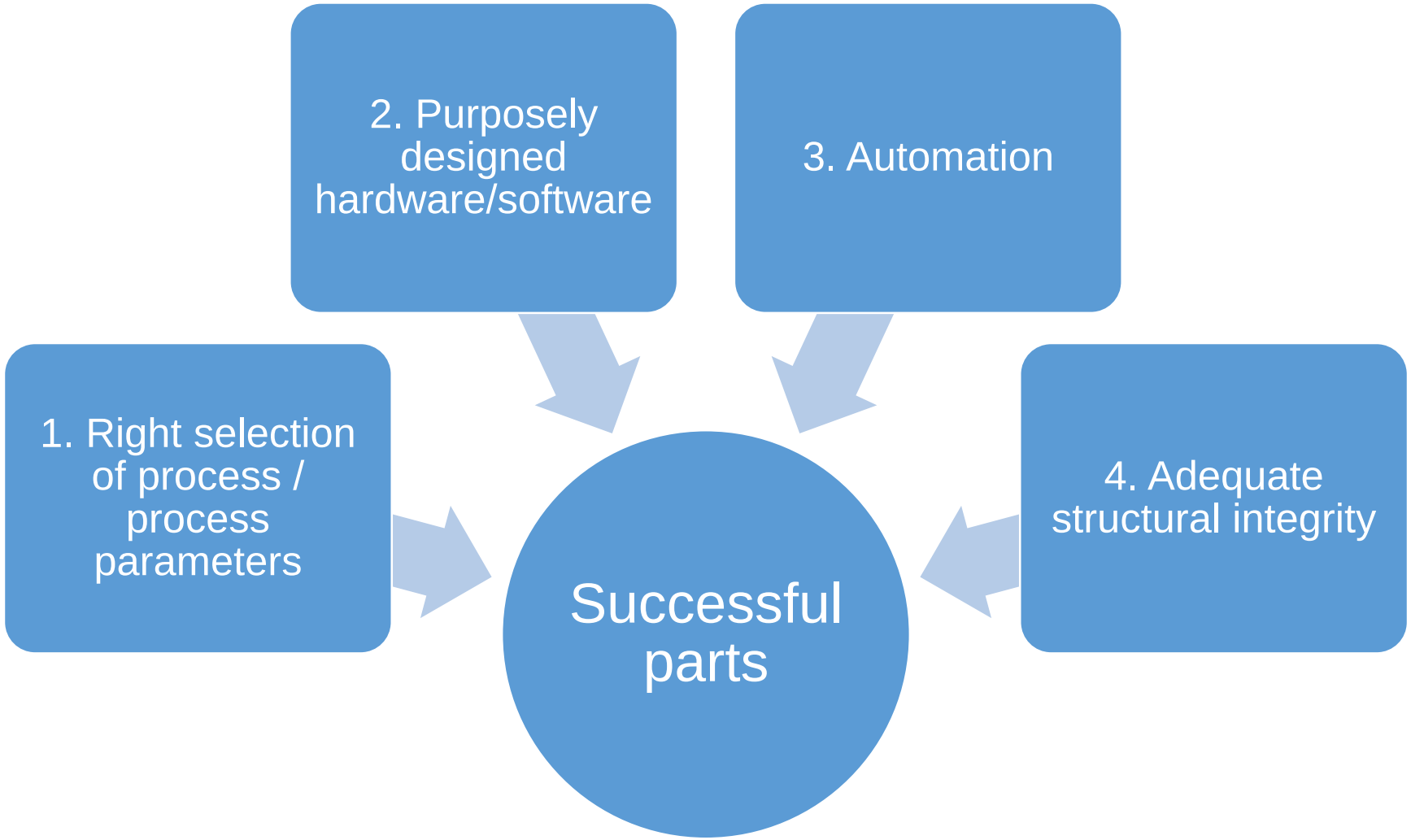
Maintainability



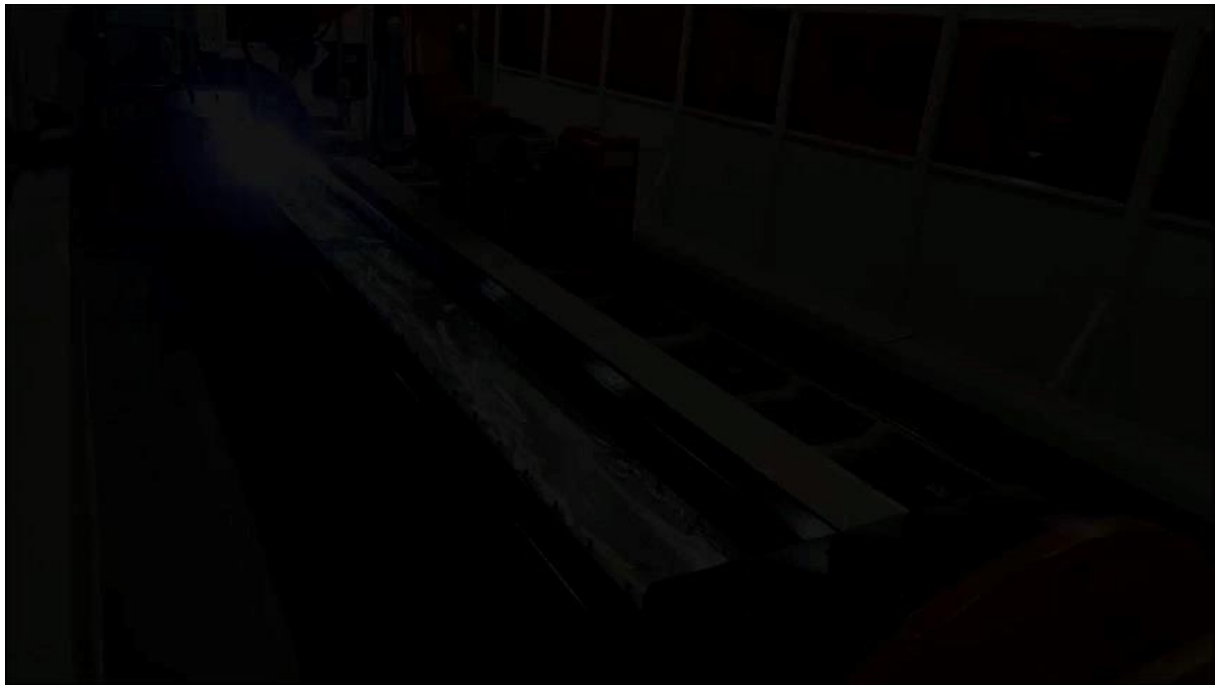
Capabilities of processes



What is needed to make these parts?

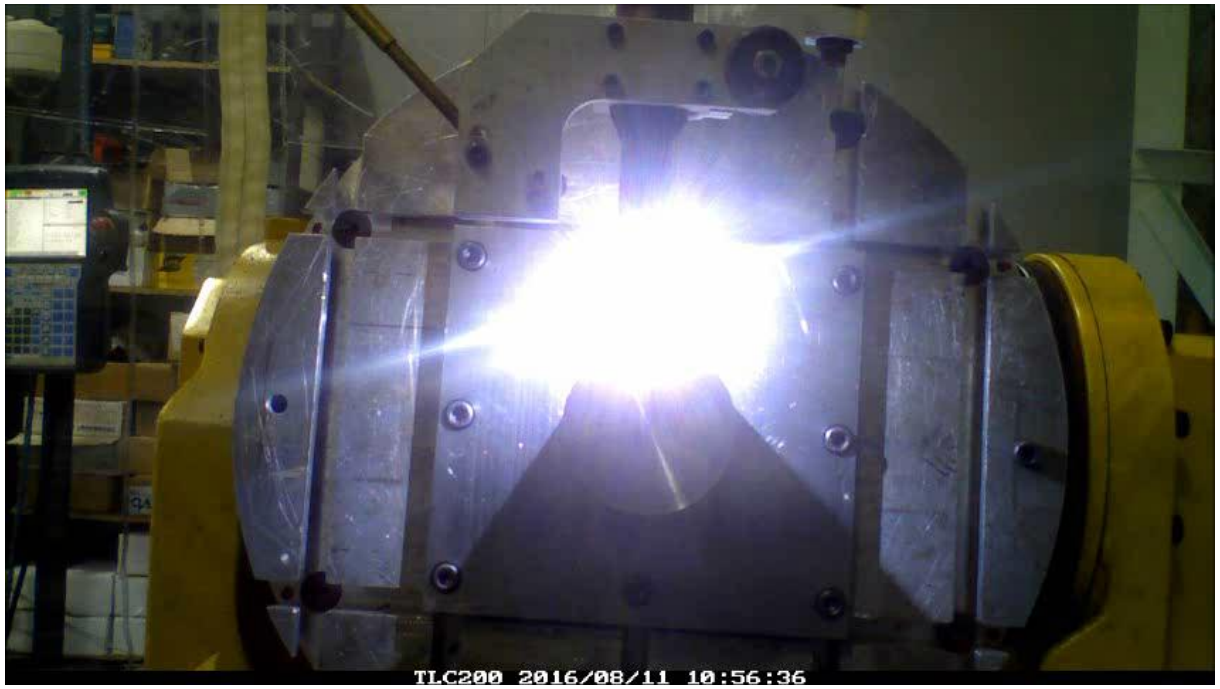


1. Which process?



MIG or CMT

High-build rate, fewer parameters, coaxiality
No independent control of Heat input and WFS

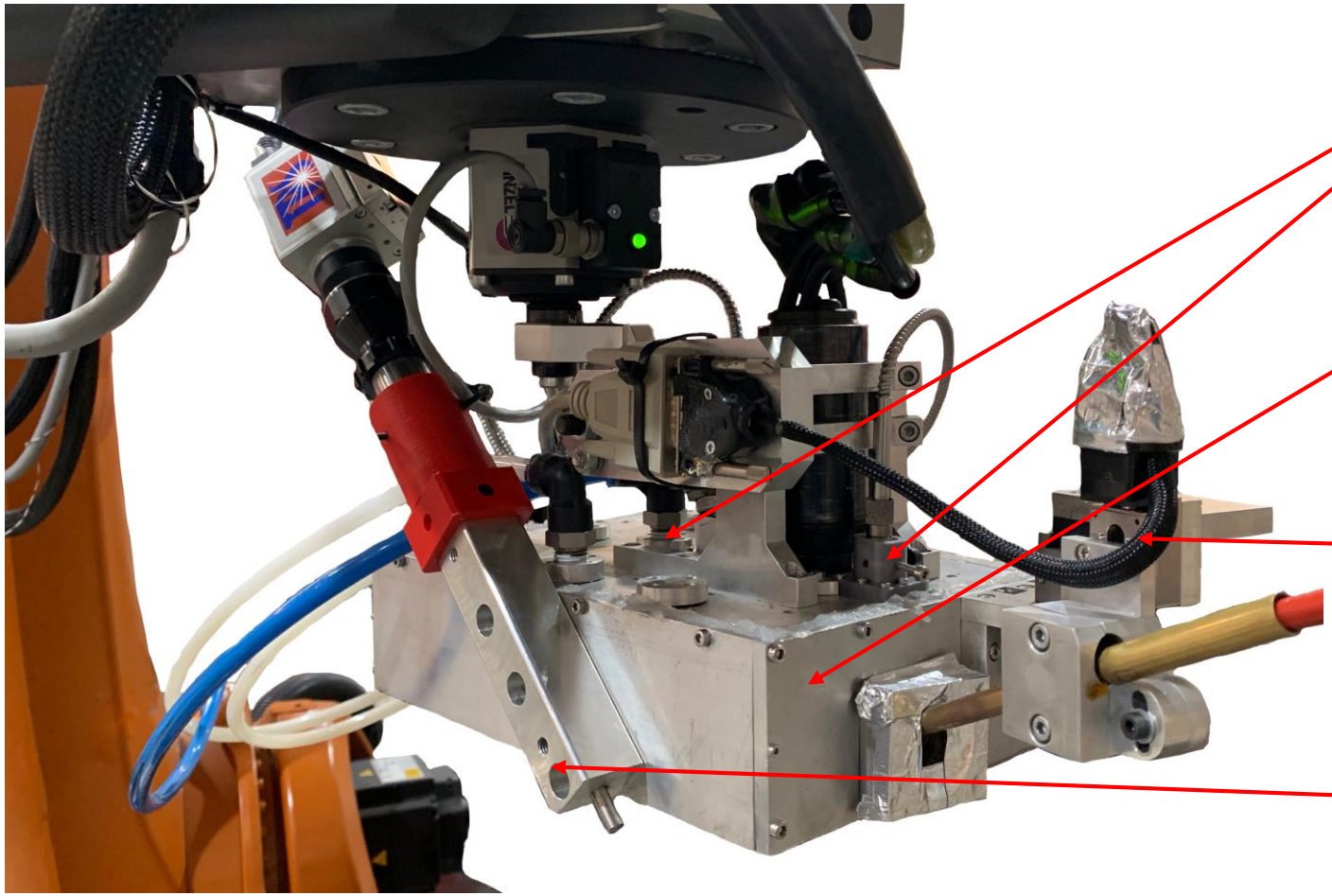


Plasma

Independent control of Heat Input and Wire Feed Speed
(+ other variables)
Lower build rate

2. Purposely designed hardware/software

Example: the end effector



CORRI and pyrometers sensor location

Shielding device

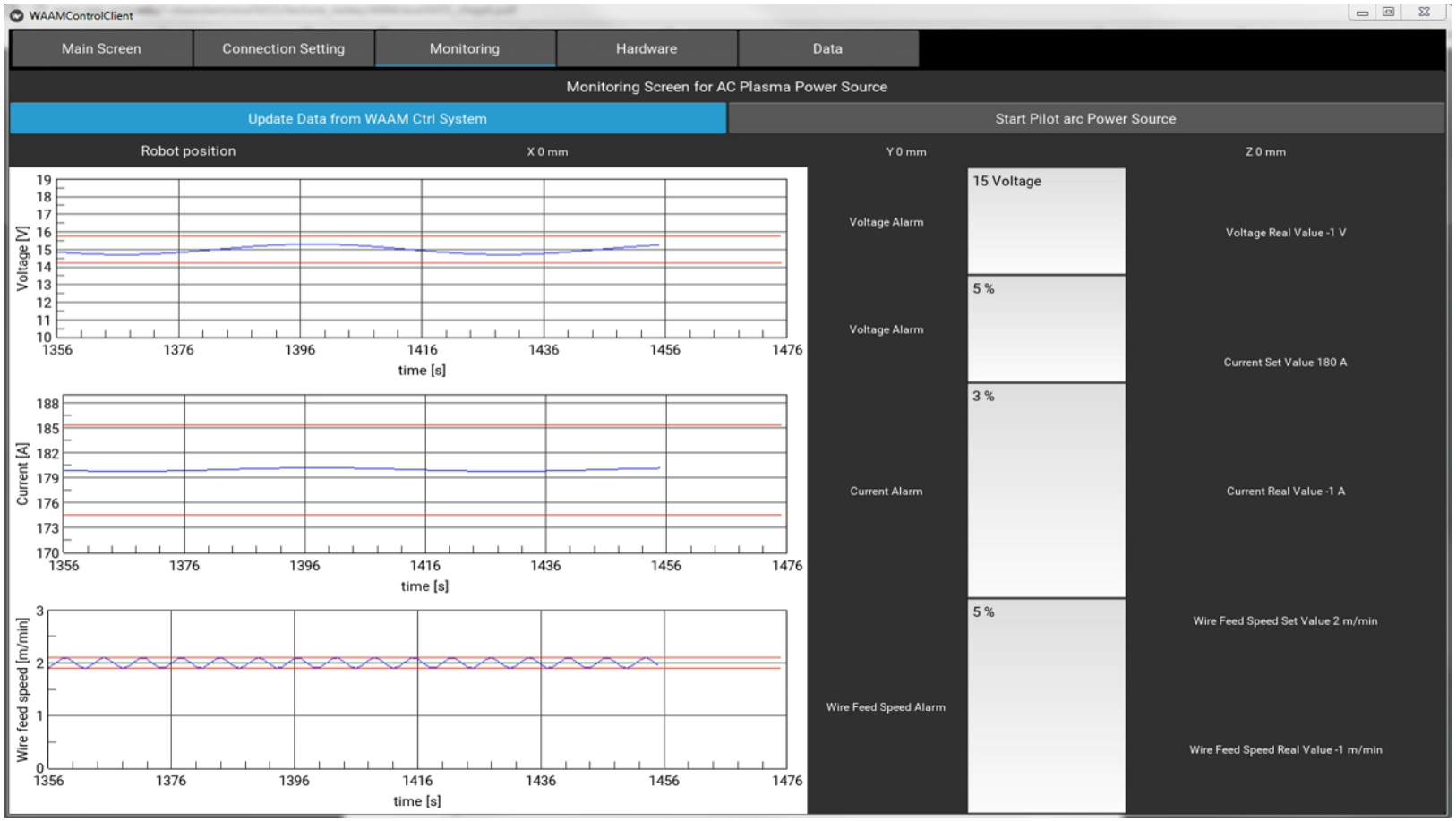
Electronic adjustment of wire position

Borescope for welding monitoring

2. Purposely designed hardware/software

Example: WAAMCtrl®

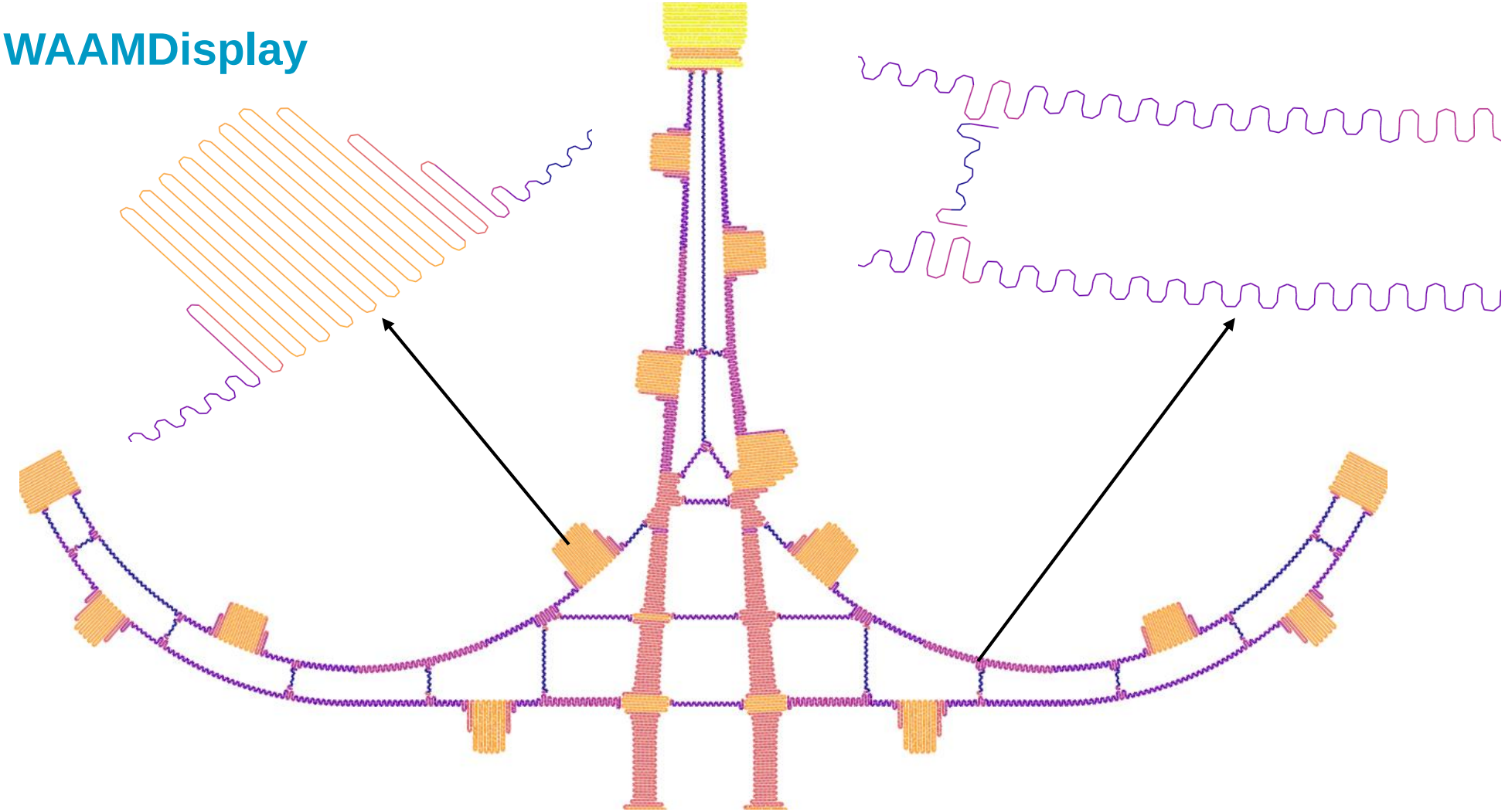
Challenge: properties and geometry are created at the same time



- **Data**:
  - Melt-pool imaging
  - Time
  - Robot position
  - Current
  - Voltage
  - Wire feed speed
  - Layer height
  - Temperature
  - Gas flow in local shield
  - Oxygen
- To file and/or database
- Desired frequency of a data acquisition

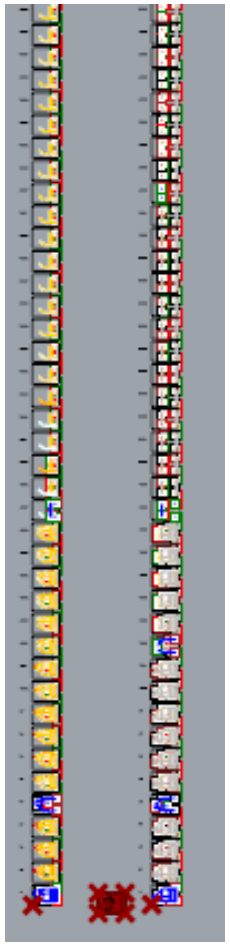
2. Purposely designed hardware/software

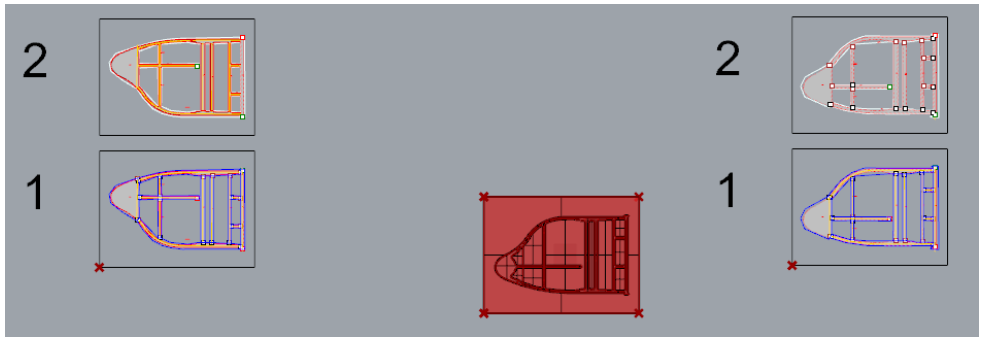
Example: WAAMDisplay

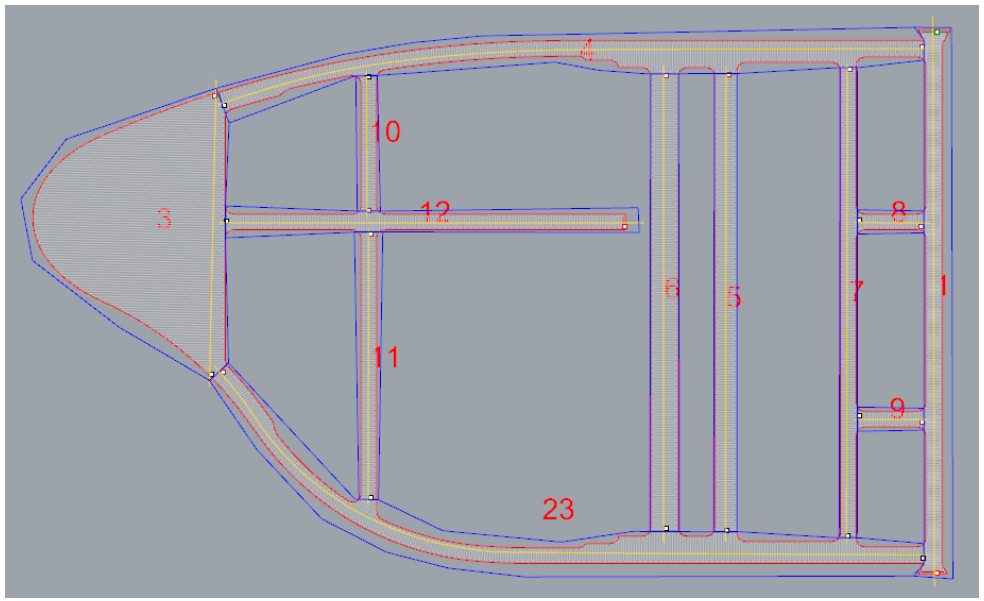


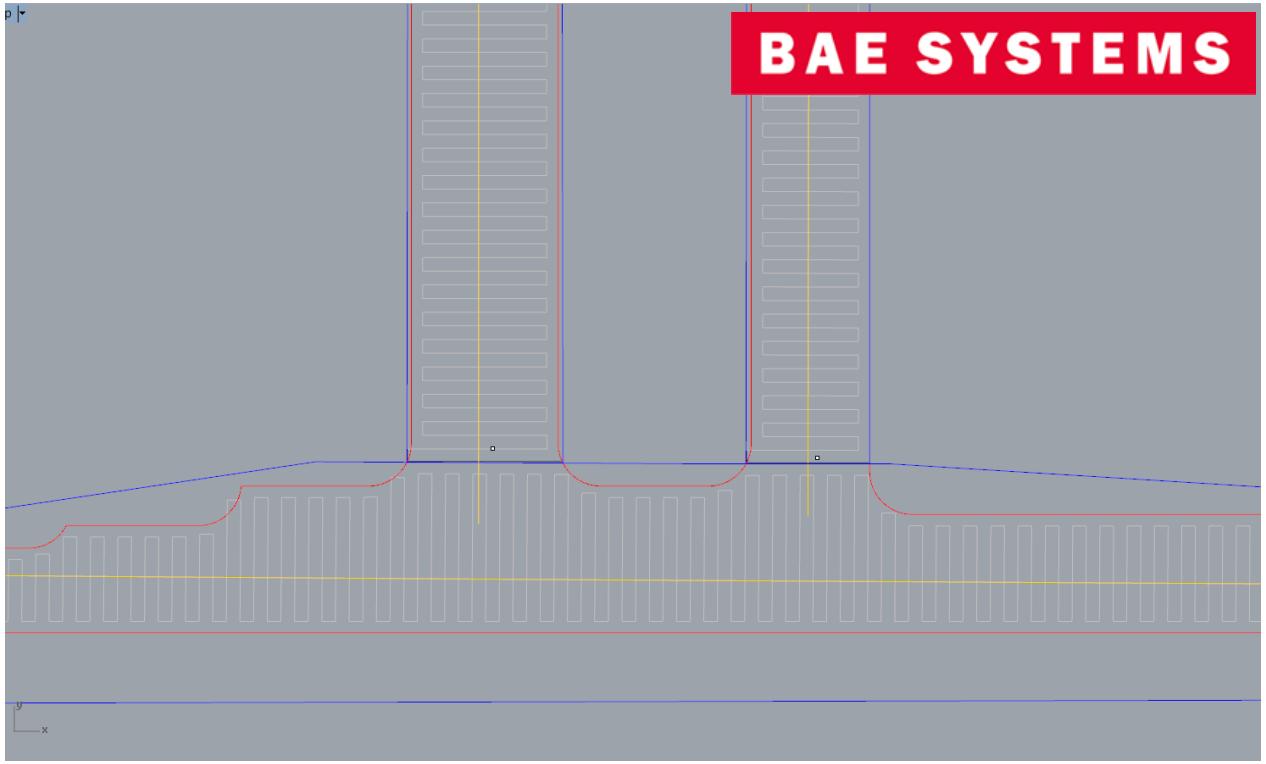
2. Purposely designed hardware/software

Example: WAAMPlanner





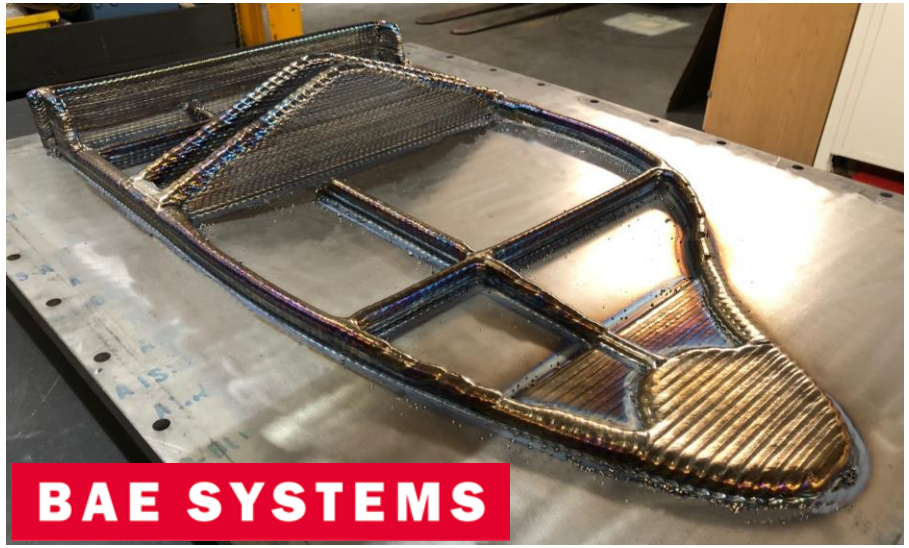




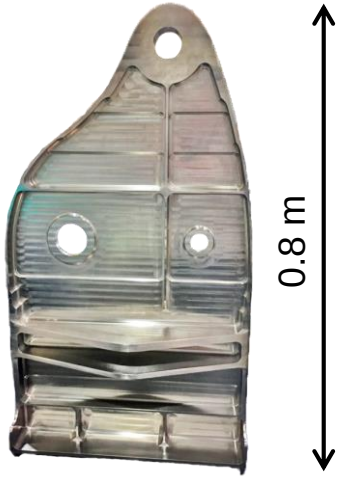
- Commercial version available now – Ti64, Alu, steel, Inconel®
- **Backbone suitable for all DED processes:**
  - WAAM
  - Wire + laser
  - CLAD®
  - E-beam + wire
- Kuka, ABB, Fanuc, Fanuc CNC, etc

Results: aerospace primary parts

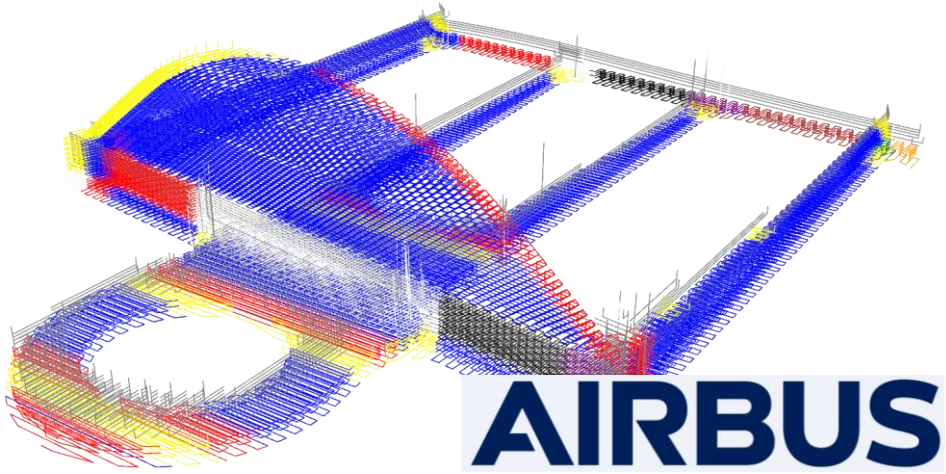
Fast jet titanium frame

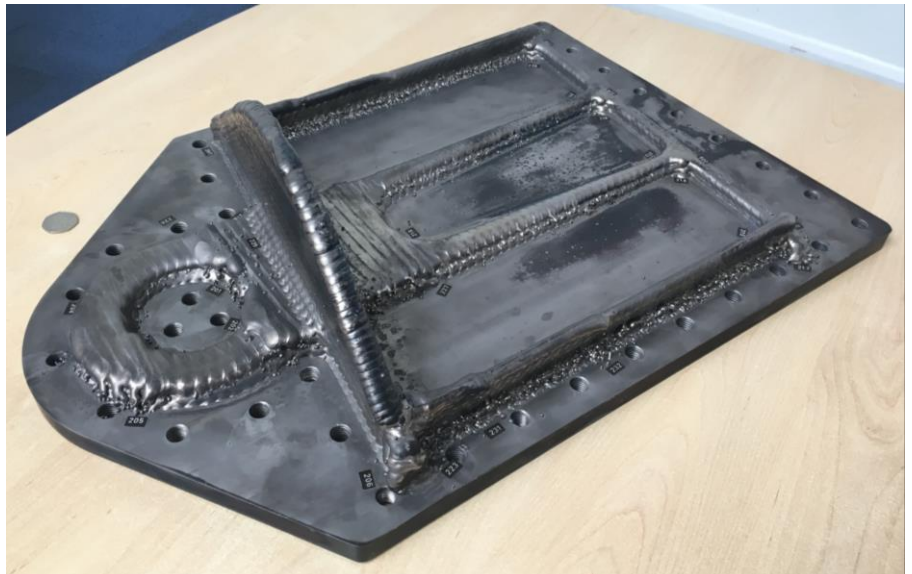


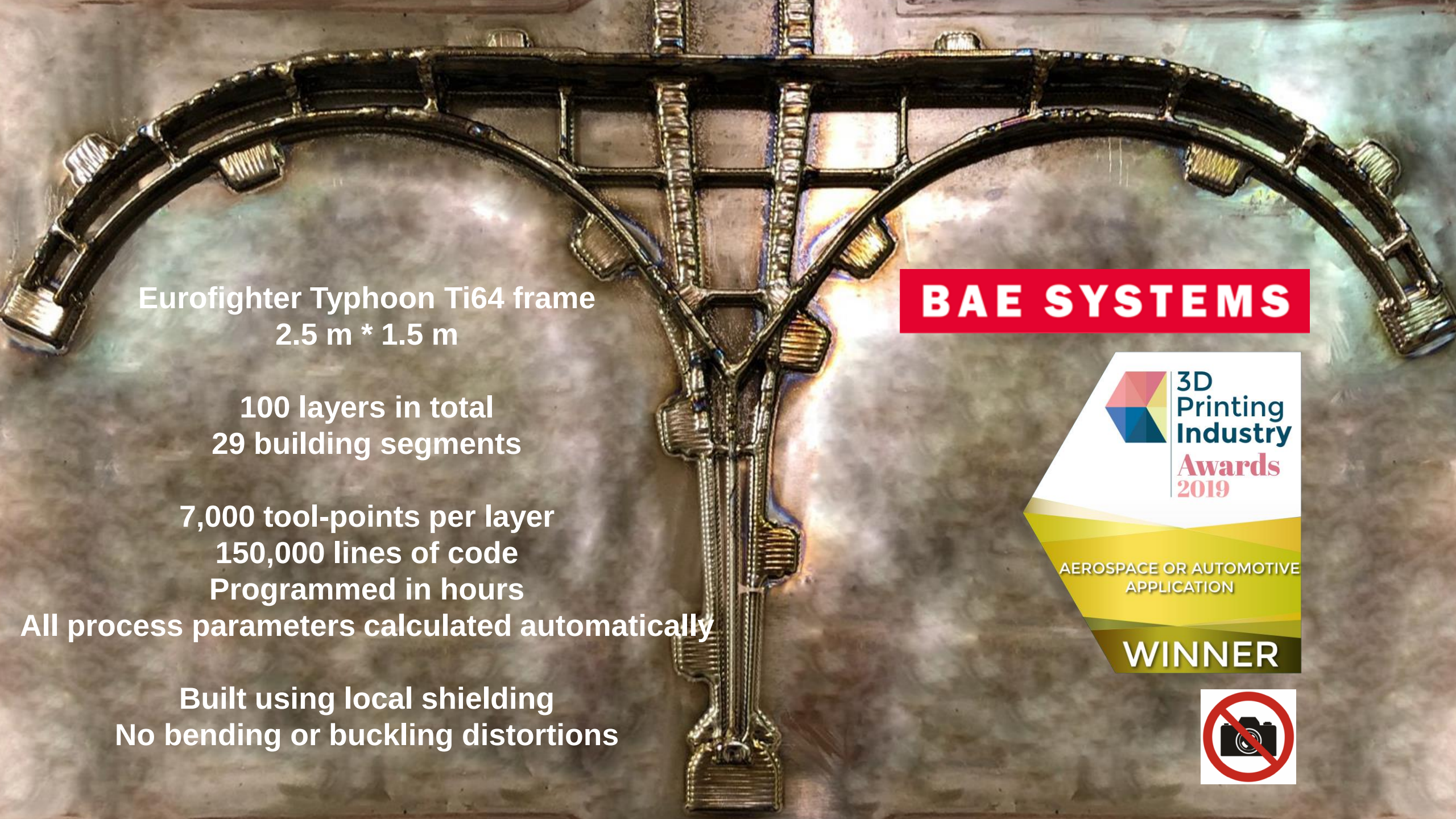
- Tool-path-plan performed using our own **WAAMSoft**
  - ~hours from CAD to tool-path
  - Current, travel speed, wire feed speed **automatically calculated** including zoning and compensation strategies
- 75 um distortion after HT



A320 aft pylon bracket mount






Eurofighter Typhoon Ti64 frame
2.5 m * 1.5 m
100 layers in total
29 building segments
7,000 tool-points per layer
150,000 lines of code
Programmed in hours
All process parameters calculated automatically
Built using local shielding
No bending or buckling distortions
BAE SYSTEMS
3D Printing Industry Awards 2019
AEROSPACE OR AUTOMOTIVE APPLICATION
WINNER

Propellant tanks

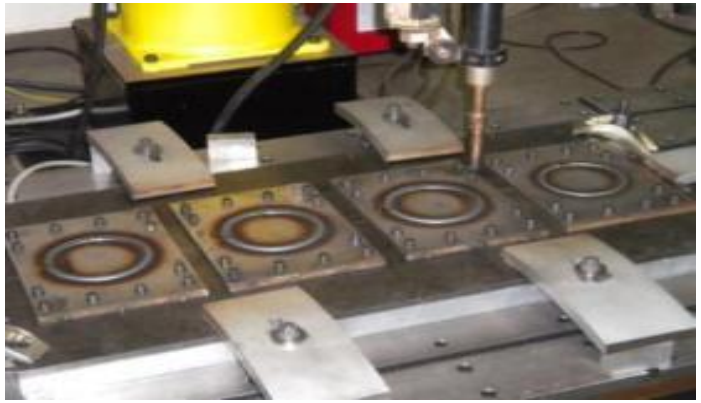
- 75 cycles at 20 bar
- 4 cycles at 83 bar
- failure at 103 bar
- failure mode as per legacy

- 50% cost savings
- Lead time reduced to weeks
- Bespoke geometry for missions

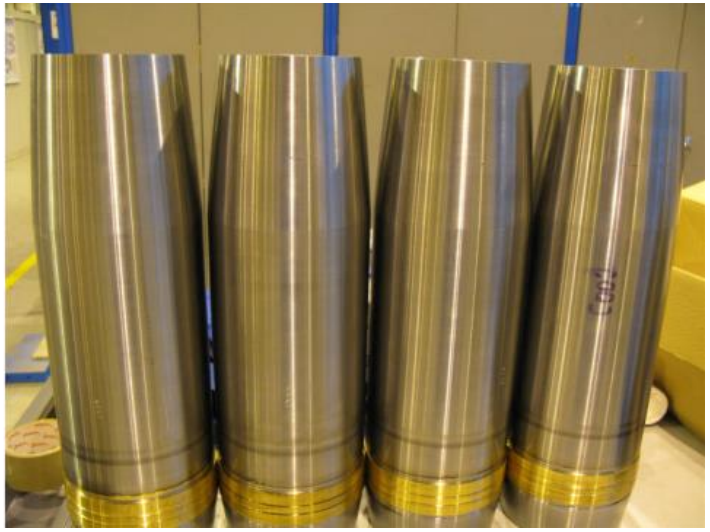
Pressure tank for space missions

- Small batch
- Reduction in non-recurring costs (tooling and tooling iterations)
- Part consolidation
- Reduction in recurring costs
  - Machining
- 65% reduction in lead time
- 200 kg Ti64 saved – 40% cheaper

Projectiles



Mass 32 kg each // Deposition rate 4 kg/hr



After machining

After assembly and just before firing

Other recent parts

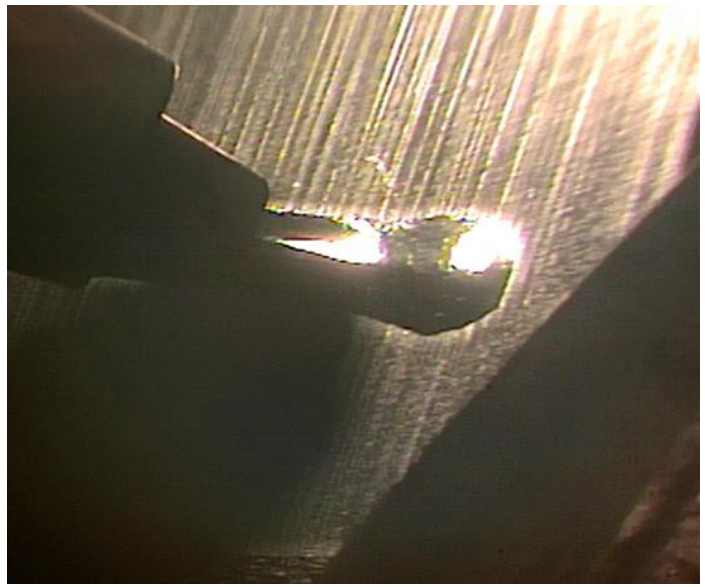
Suspension boogie pad

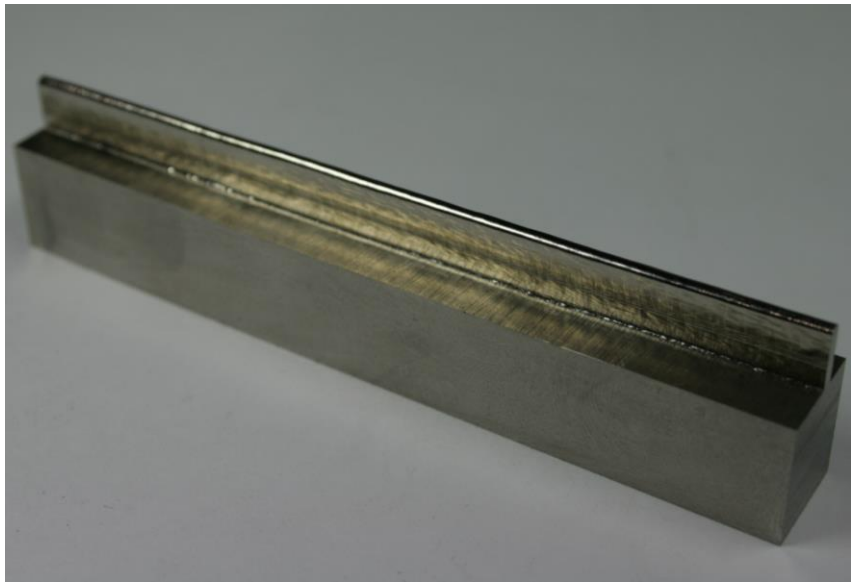
1.2m Satellite bread board

Wheel cover

Rocket/missile components

Increasing process capabilities





As-built

Cold-worked

- **Wire + laser**
- **Multi-energy heat source** → next generation of DED processes. Patent filed. Targets:
  - 8 kg/h
  - Net-shape deposition

Materials portfolio

- **Titanium**
  - Grade 2
  - Grade 5
  - Grade 5 + O_2 doping
  - Grade 23
  - 5553
  - Timetal 407
- **Aluminium**
  - 2024
  - 2319
  - 4043
  - 5087
  - Safra 66
  - ZL205A
  - Aluminium Nickel Bronze
  - AlMgSc
- **Refractory metals**
  - Tungsten
  - Molybdenum
  - Tantalum
- **Invar®**
- **Steels**
  - ER60
  - ER80
  - ER90
  - ER120
  - Maraging grade 250
  - Maraging grade 350
  - Stainless (17-4 PH, 316L, 420, + others)
- **Inconel®**
  - 625
  - 718
- **Bronze**
- **Copper**
- **Magnesium**

waammat.com/mechprop

Conclusions

- **Wire + Arc Additive Manufacturing** is delivering on the promise of:
  - **Reduction in lead times** from years to weeks/months
  - **Reduction in manufacturing costs**, as much as 60%
  - **Quasi-tool-less production** and quicker prototyping

- Cranfield University is supporting major OEMs along the **qualification** journey
- Cranfield University is working on **higher build-rate processes**:
  - Stronger business case with lower £/kg of deposited material
  - Net-shape capability
  - Even quicker turnaround
- **WAAM3D Limited** is now exploiting these research achievements, commercially

WAAM3D Limited

Our product portfolio

Suite of products based on a core competencies designed to give customers total technology solutions

Thank you for your attention

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