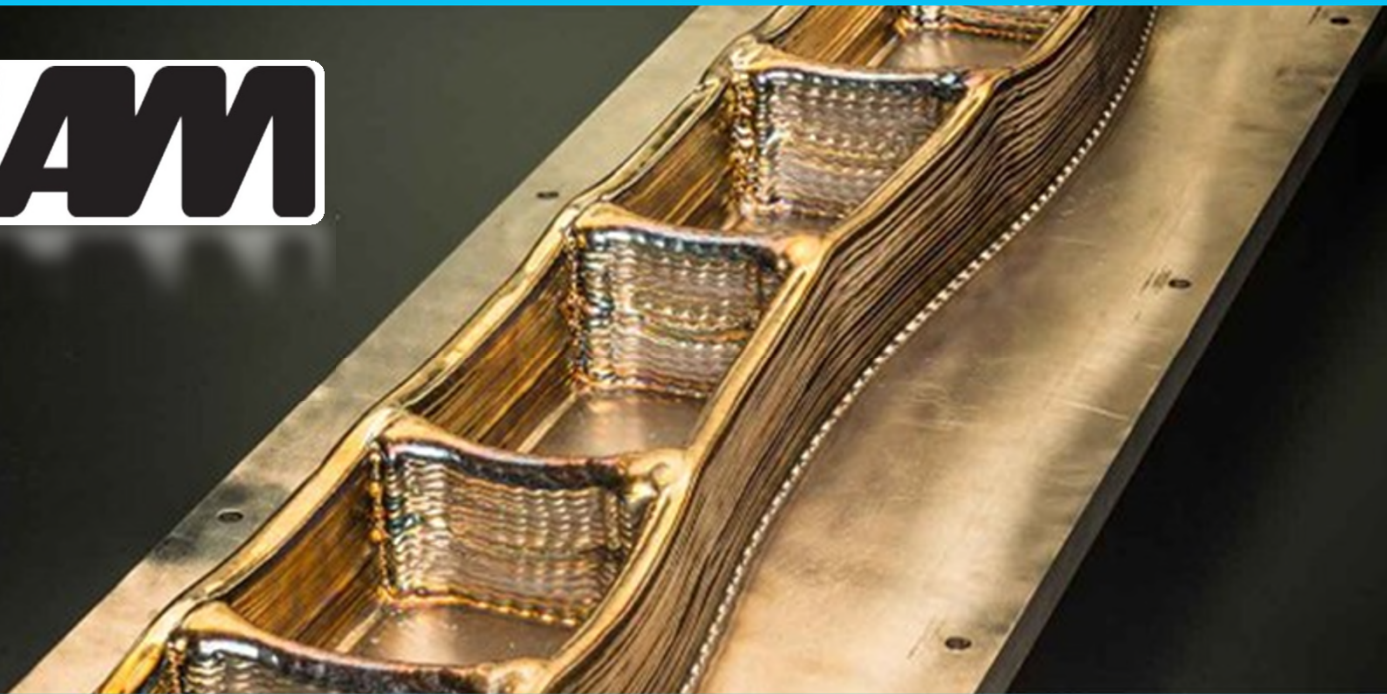


Large Scale Metal Wire + Arc Additive Manufacturing of Structural Engineering Parts

WAAM



Presented by Stewart Williams

Welding Engineering and Laser Processing Centre

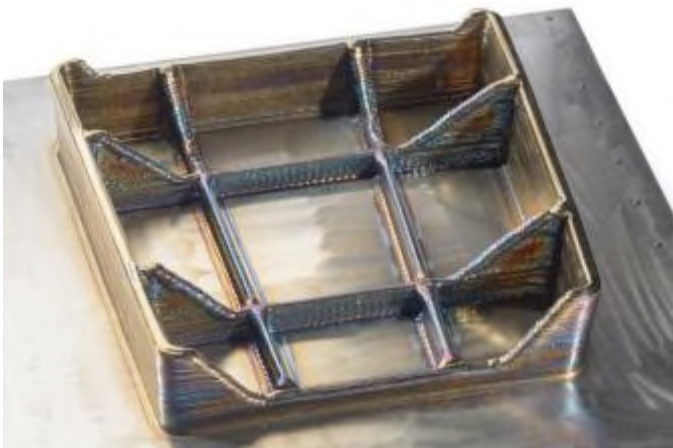
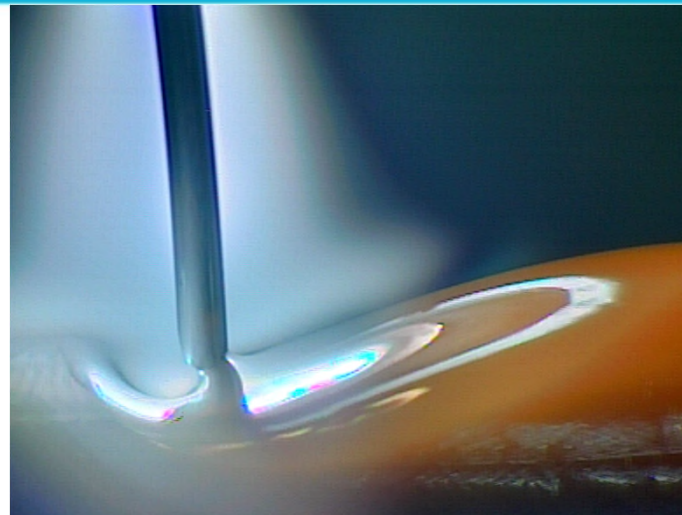
www.waamat.com

www.cranfield.ac.uk

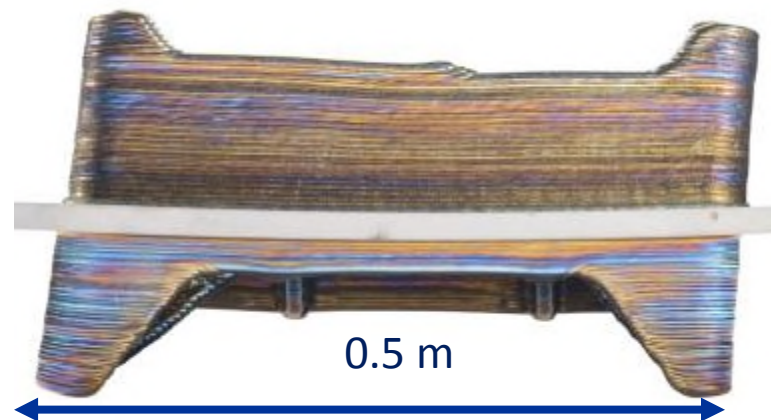
Topics

- Brief summary of Wire + Arc Additive Manufacture process in relation to other AM processes
- WAAM business drivers
- WAAM Systems
- Future plans

Wire + Arc Additive Manufacture (WAAM) Process

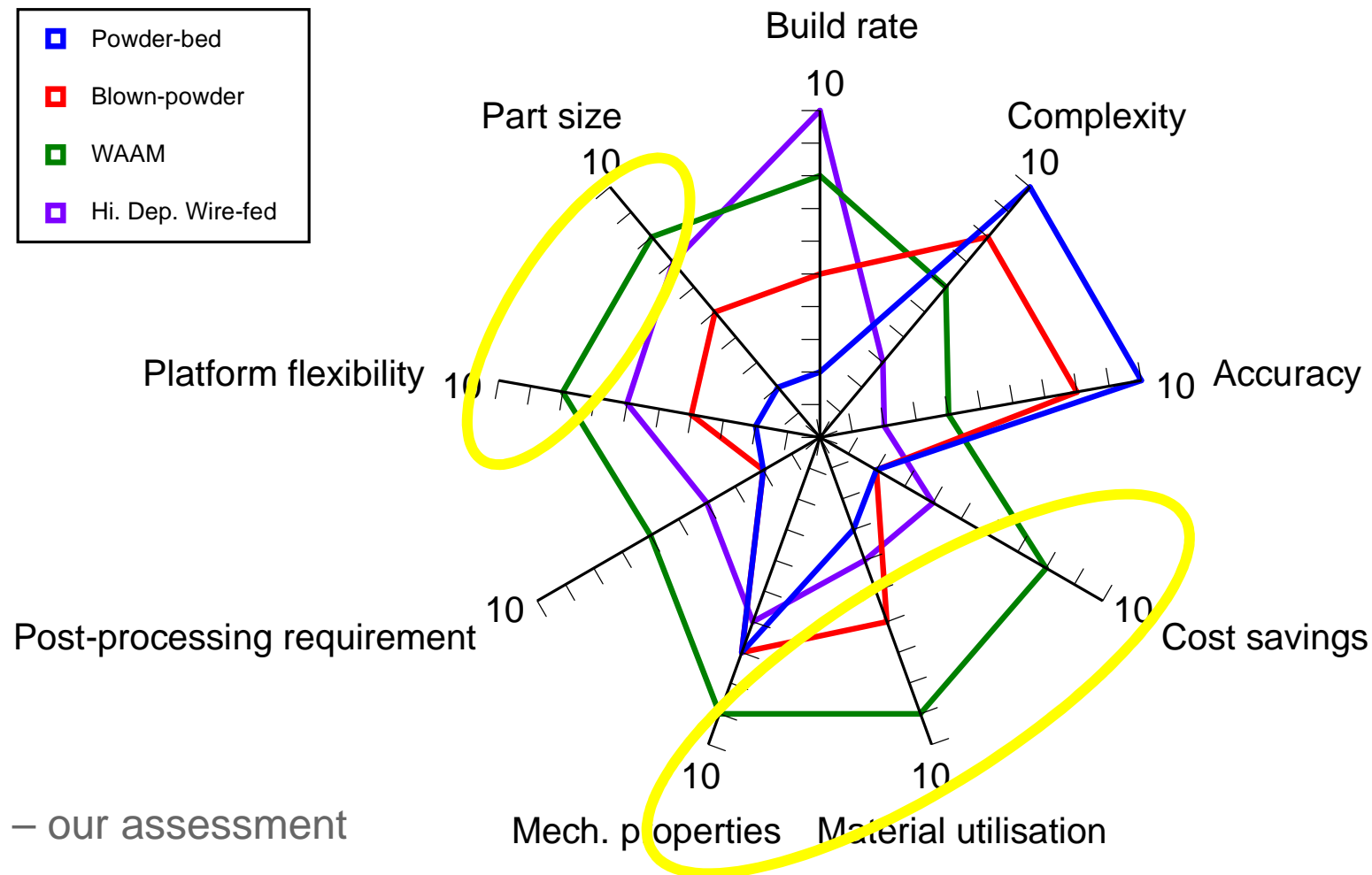
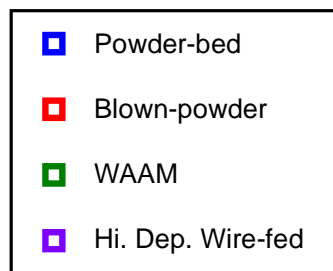


Deposition time 24 hours



0.5 m

Benefits and limitations



Note – our assessment

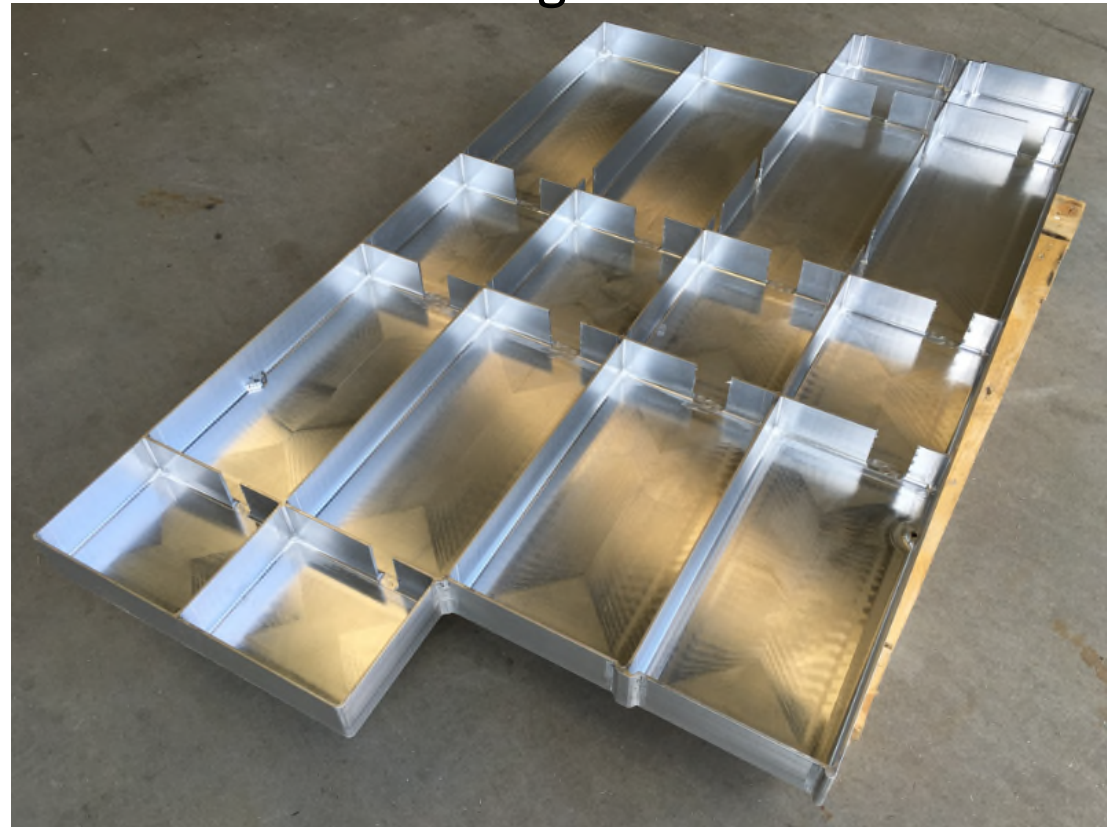
Key WAAM process features

- Build rates 0.5 - 4 kg/hour – typical 1kg/hr titanium
- Unlimited build volume
- Buy to fly ratio – typical 1.5 but always <2
- Fully dense materials with excellent mechanical properties
- Minimum feature size 2 mm
- No commercial systems available – yet



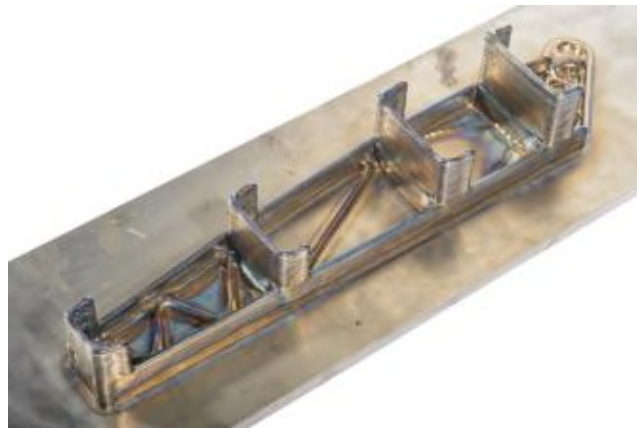
Aluminium stiffened frame

After machining



WAAM - Business Drivers

- WAAM business drivers are
 - ✓ Cost and material saving compared to current manufacturing methods
 - ✓ Greatly reduced lead times
 - ✓ Application to large engineering structures



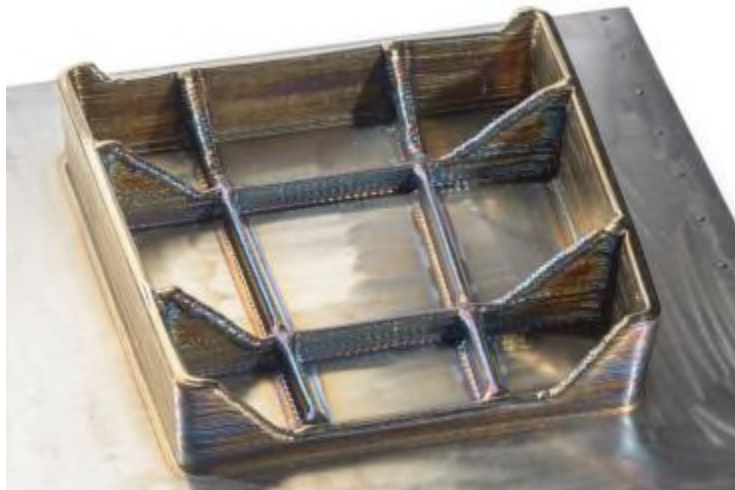
Titanium wing frame



Design option (MRR = 65 kg/h)	BTF	Cost (£k)	Cost red.
Machined from solid	69	4.9	-
WAAM + machining	8	2.4	>50%

WAAM business driver – cost saving case studies - Bombardier rib

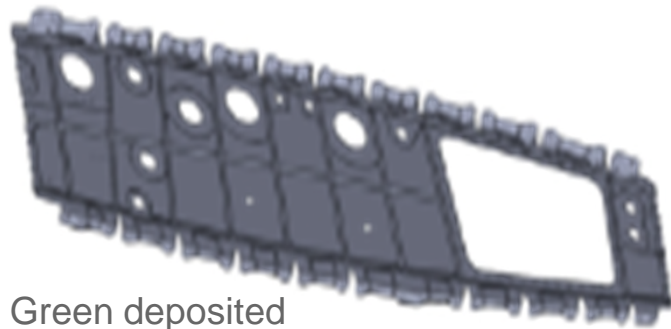
Design option	Mass (kg)	BTF	Cost (£k)	Cost red.
Original machined	20	12	16.2	-
WAAM + machining	20	2.3	5	69%



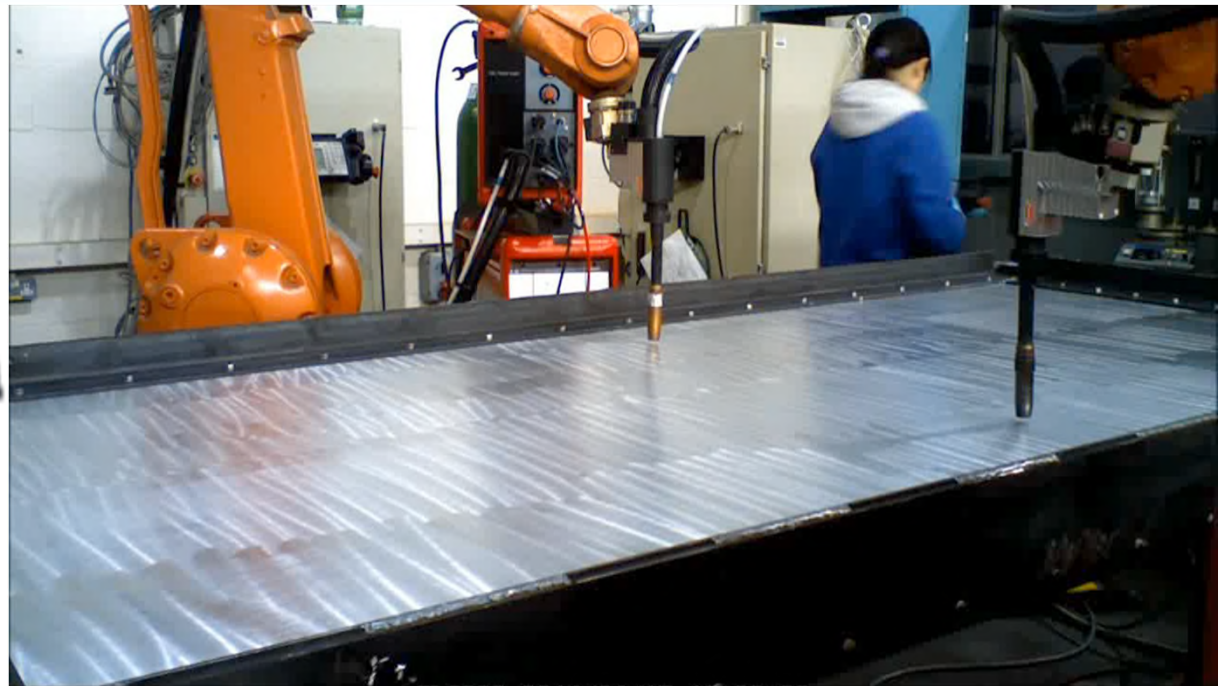
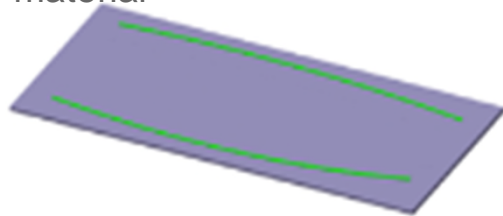
Design option	Mass (kg)	BTF	Cost (£k)	Cost red.
Original, machined	36	12	1.6	-
WAAM + machining	36	2.3	0.7	55%

WAAM business driver – cost saving case studies

CAD:



Green deposited material



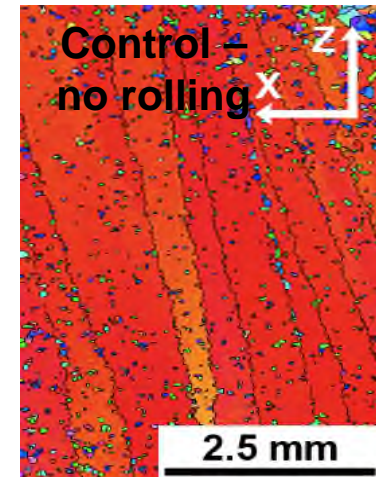
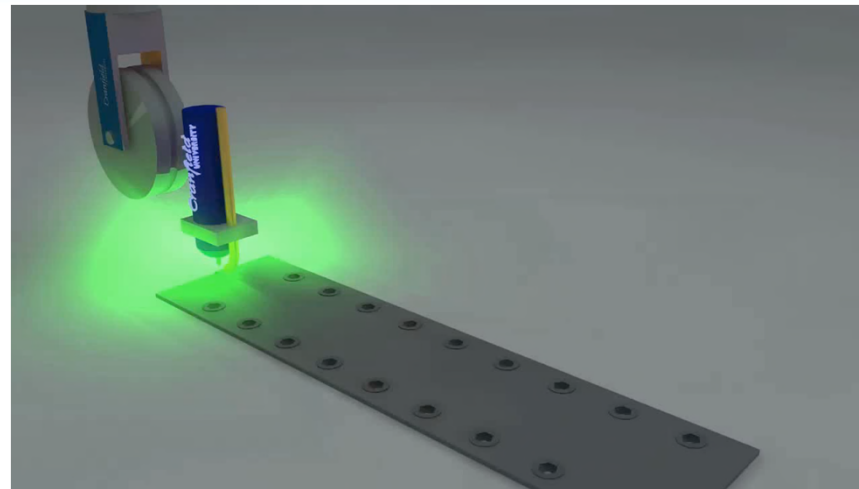
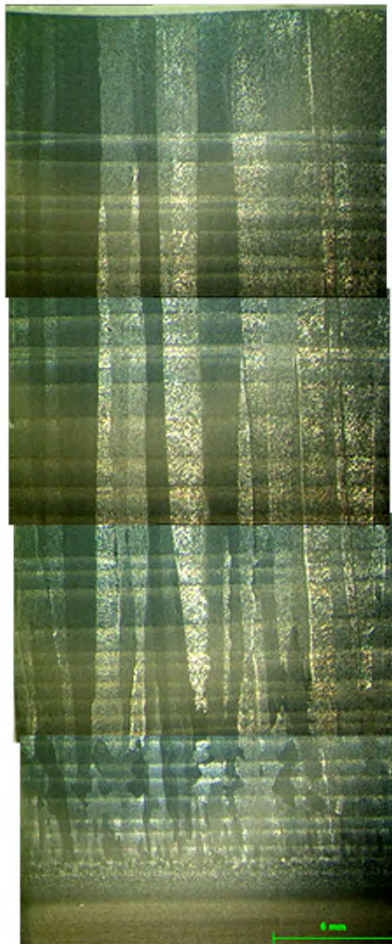
Design option	BTF	Cost (£k)	Cost red.
Machined from solid (MRR = 332 kg/h)	45	4.4	-
WAAM + machining	12.3	1.9	56%

15 kg aluminium wing rib (DR = 1kg/h)

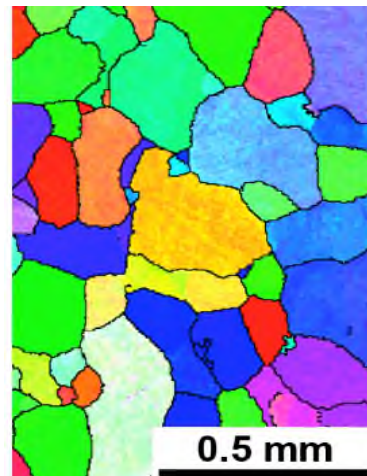
What we've deposited so far

- **Ti-6Al-4V**
 - Grade 5
 - Grade 23
- **Aluminium**
 - 2024
 - 2319
 - 4043
 - 5087
- **Refractories**
 - Tungsten
 - Molybdenum
 - Tantalum
- **Steels**
 - ER60
 - ER80
 - ER90
 - ER120
 - Maraging grade 250
 - Maraging grade 350
 - Stainless (17-4 PH, 316L)
- **Inconel**
 - 625
 - 718
- **Bronze**
- **Copper**

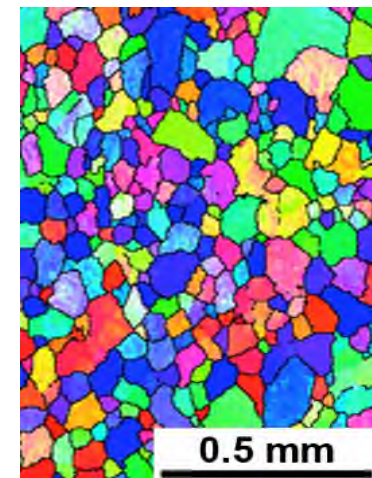
Unique features - cold work



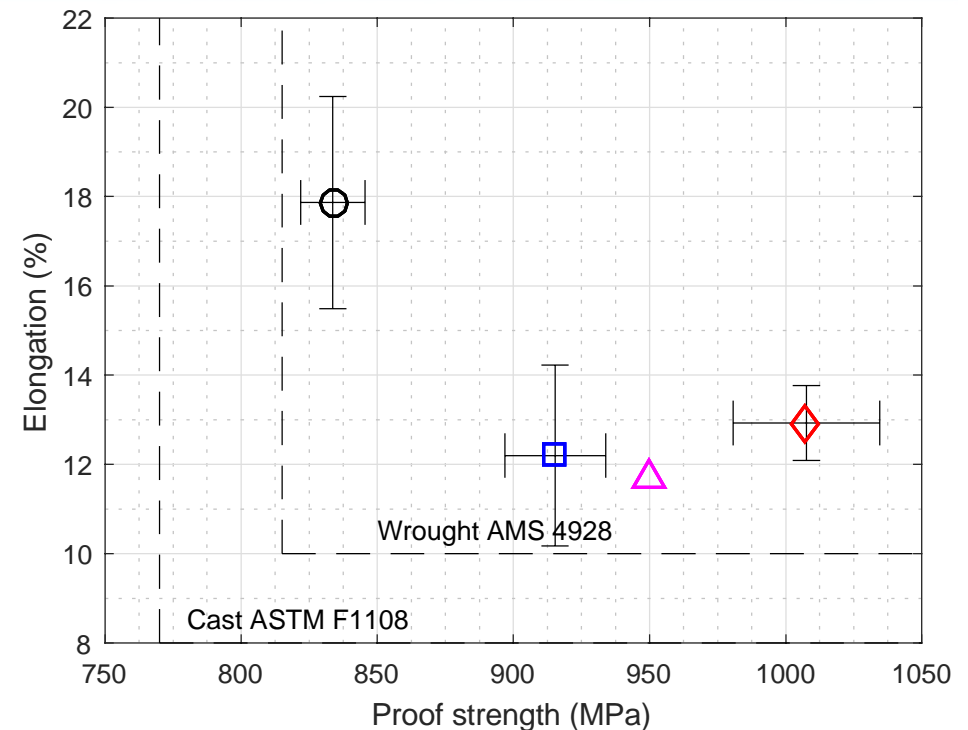
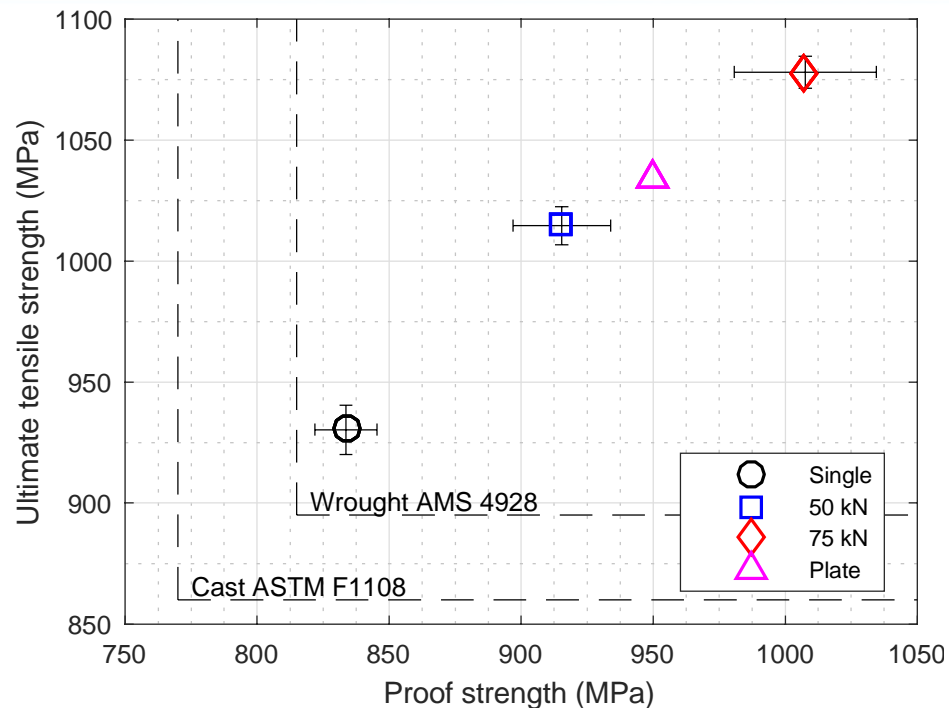
Rolled @ 50 kN
139 μm



Rolled @ 75 kN
66 μm

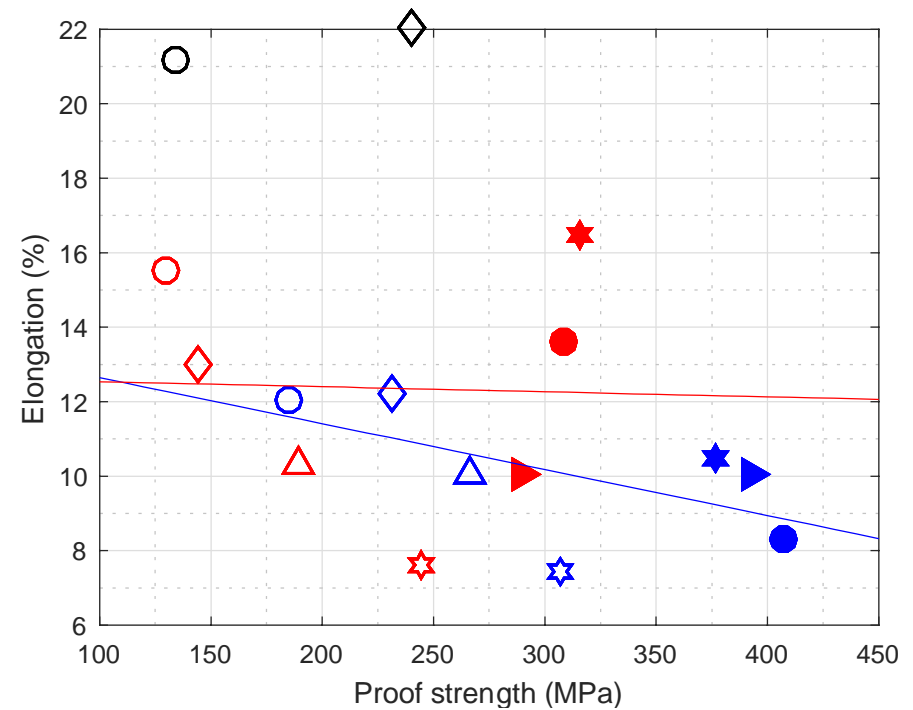
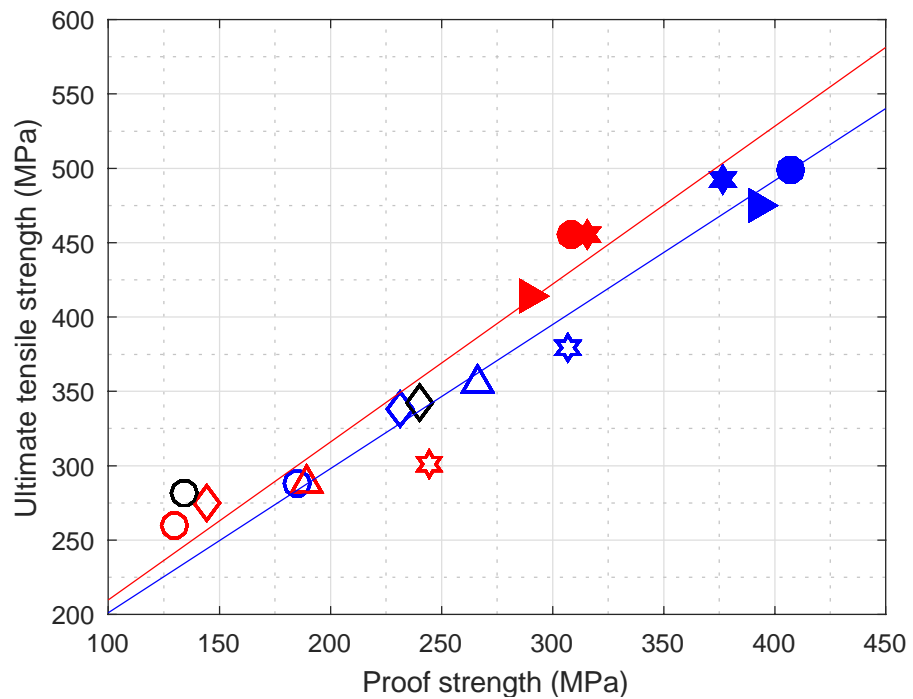


Ti64 // Static properties (average)



- Reduction in prior β grain size
- Reduction in α lamellae thickness
- Possibly some work-hardening effects still left in the structure

Aluminium properties (2024 – 2319 – 5087 (average))



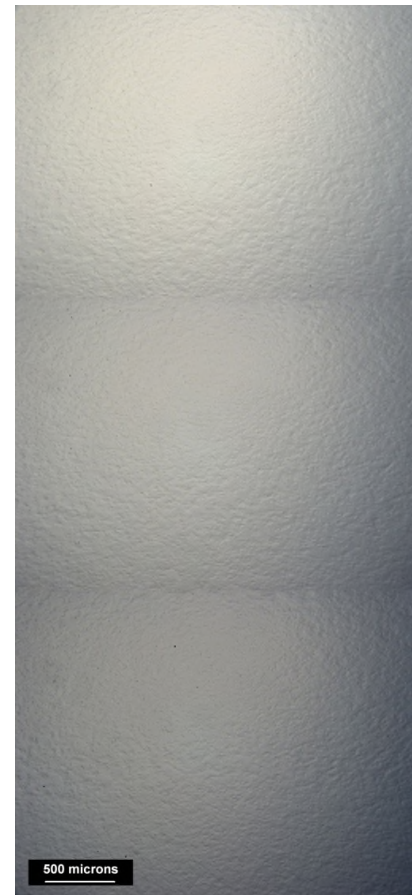
2319 // Effect of rolling + HT on porosity



As deposited



ST+AA



Rolled +
ST + AA

There is no porosity in the rolled + heat treated sample.

The systems



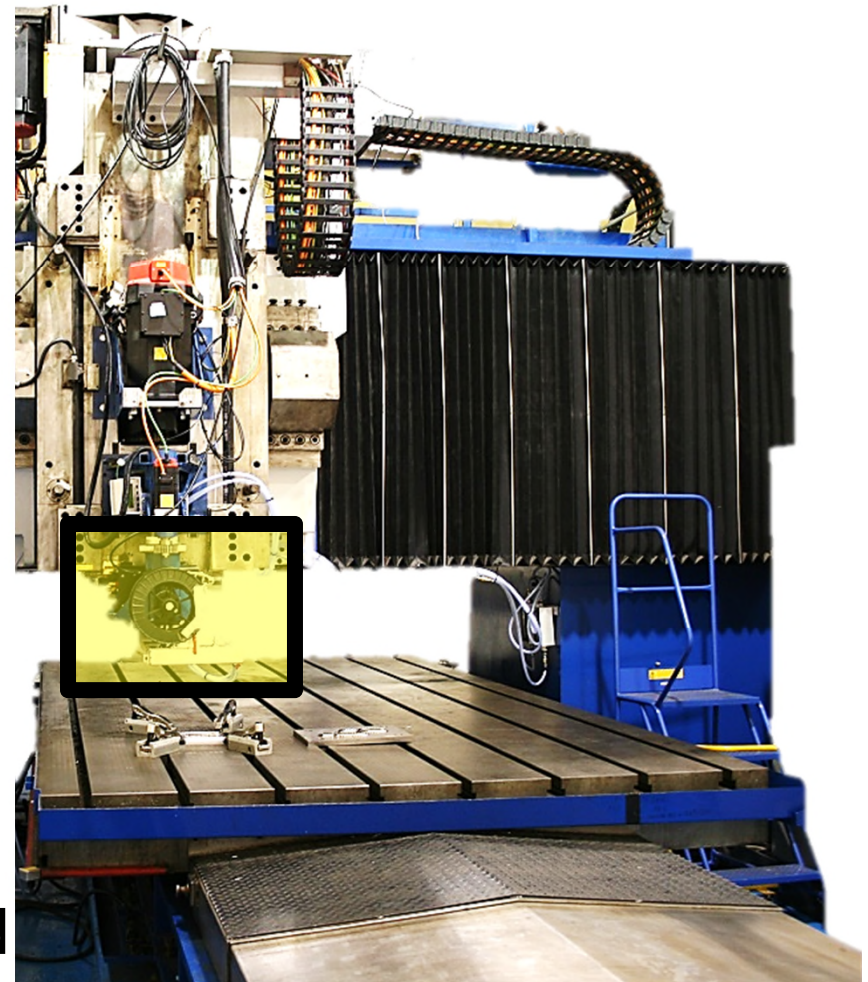
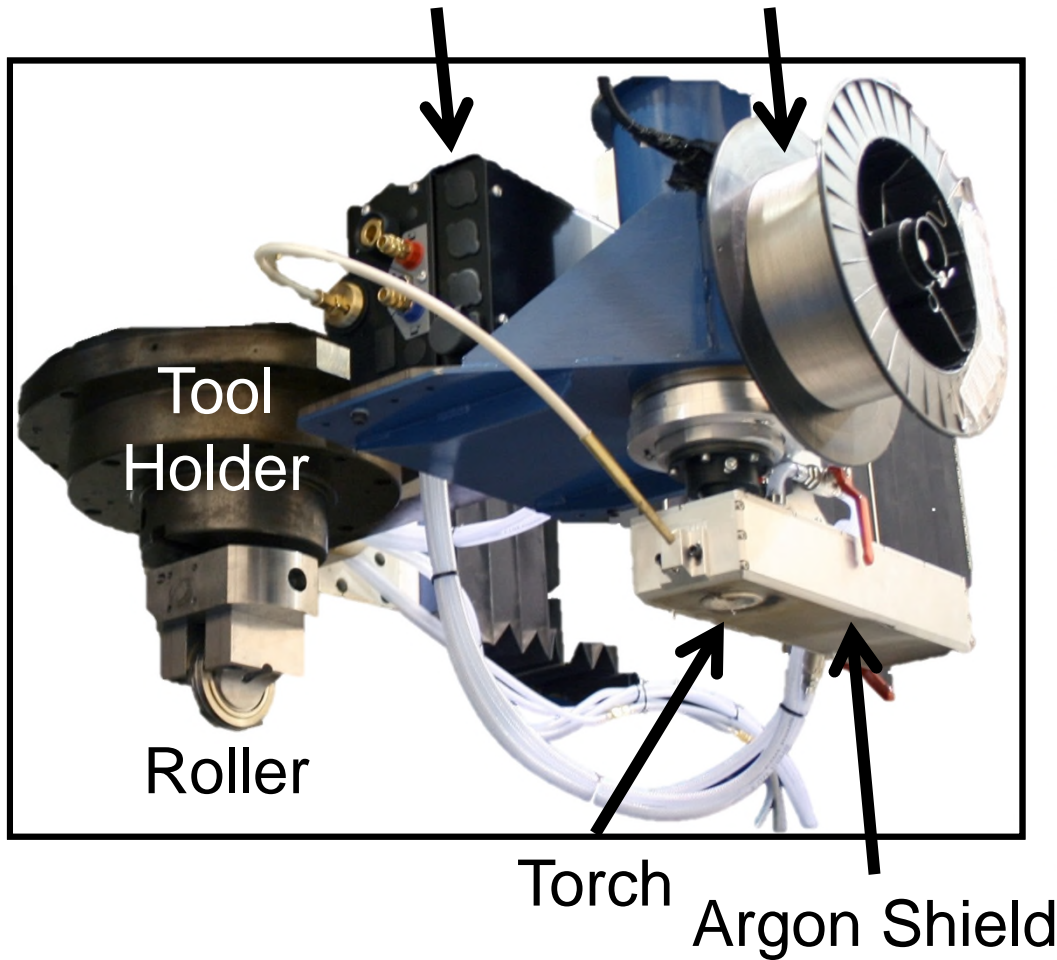
Tent + part rotator option



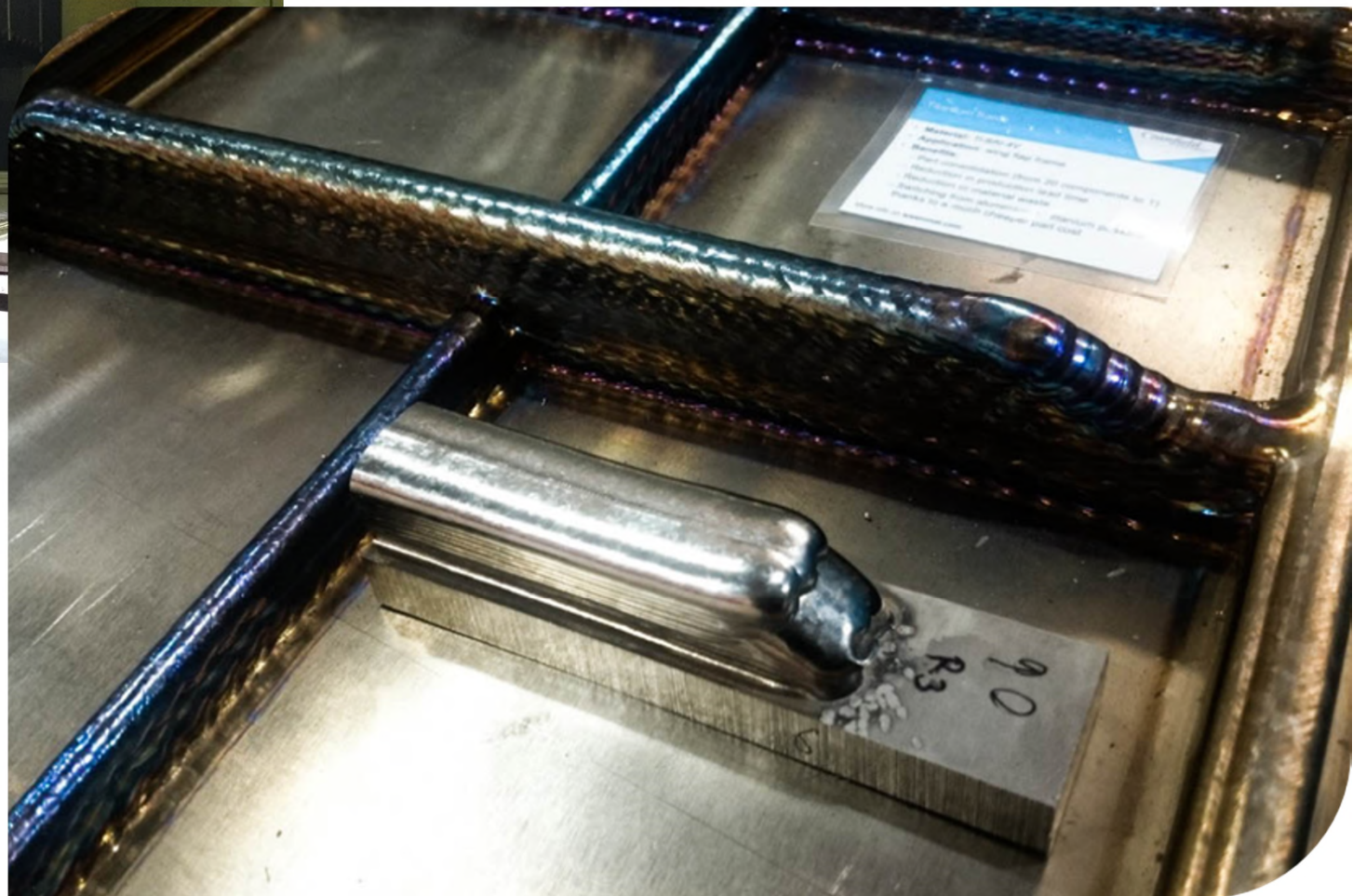
Open architecture systems

Rolling Assisted WAAM

Wire Feeder and Spool



Local shielding and 2 D rolling



WAAM system developments – multi robot systems for parallel processing



Parallel processing

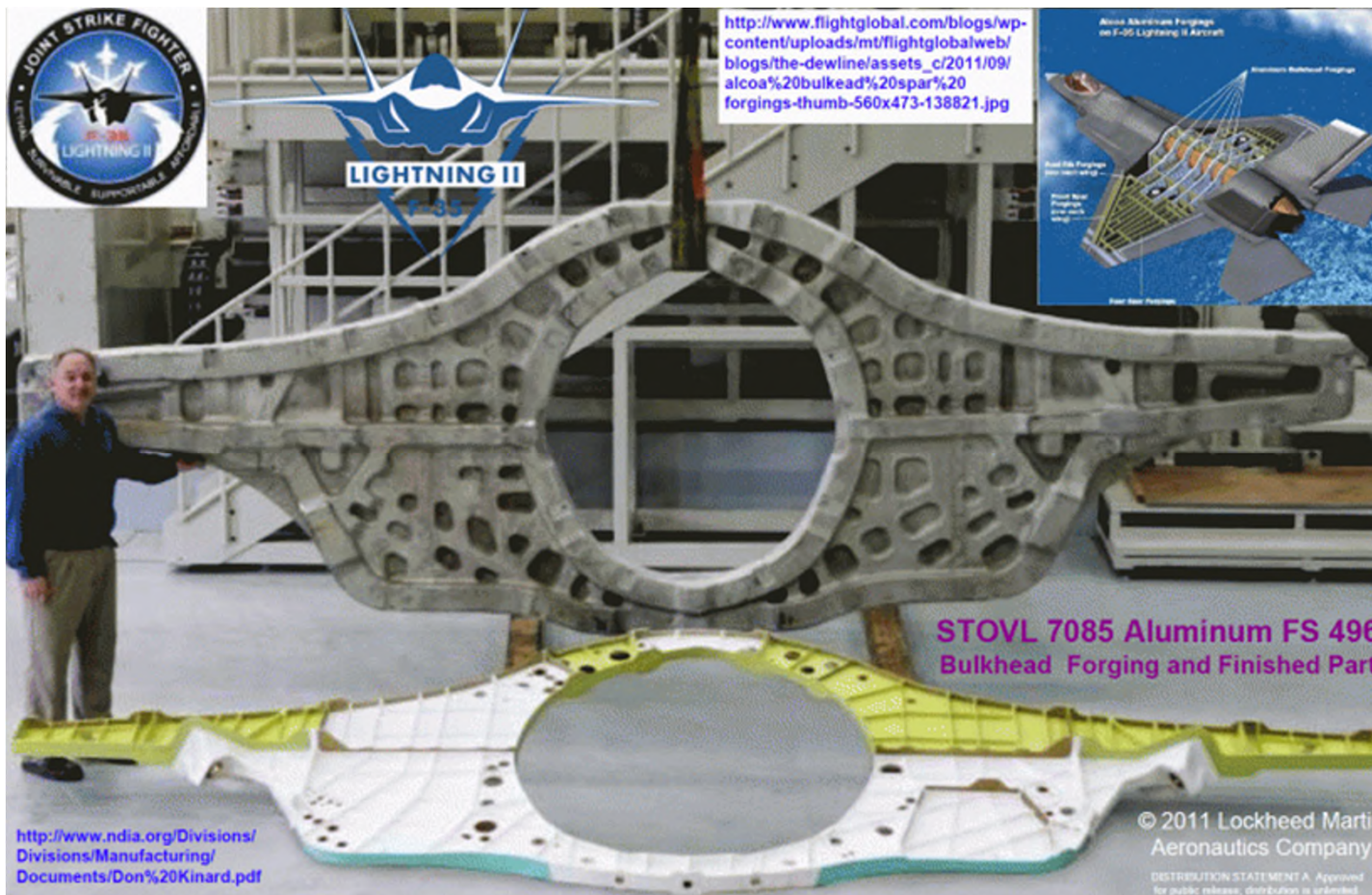
- 2 x deposition
- Deposition + NDT + layer removal (machining)
- Deposition + metrology
- Deposition + cold work
- Combinations of the above

10 m maximum part size and/or multiple parts

WAAM system developments first long linear part



Where we are aiming - HELP!



Aluminium:

- 14 months for forging
- 4 months for machining
- 90% waste

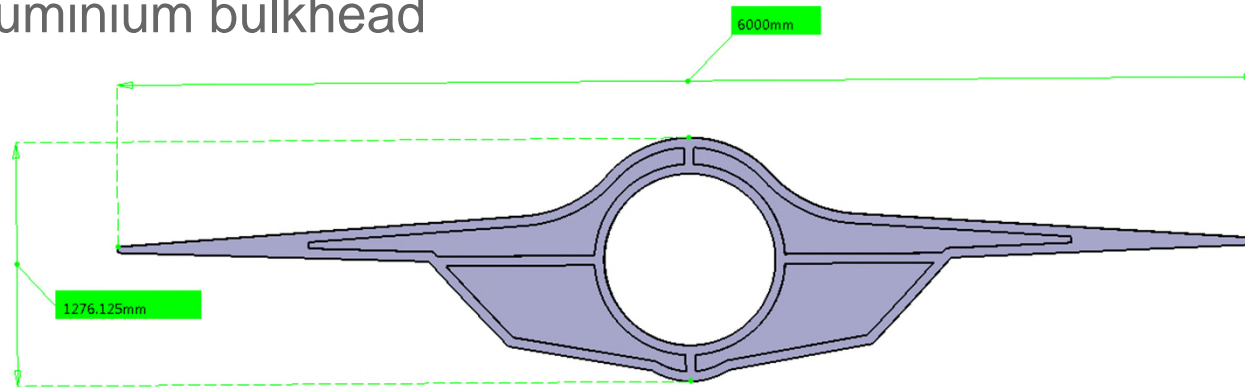
Titanium:

- 10 times worse problems

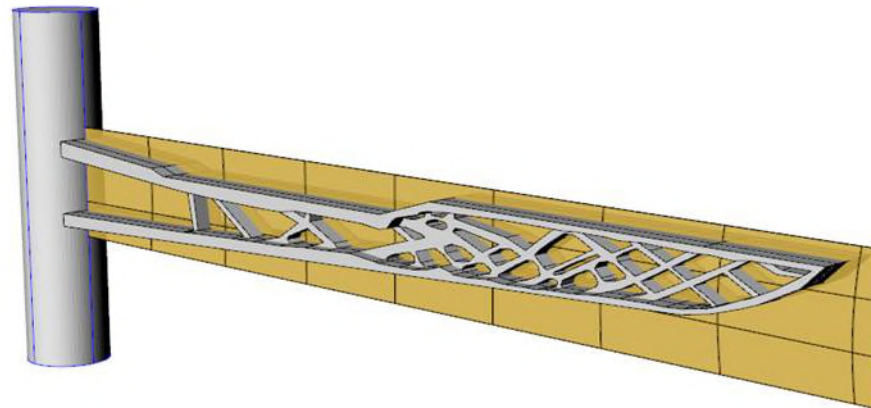
This summer/autumn

World's largest metal AM parts:

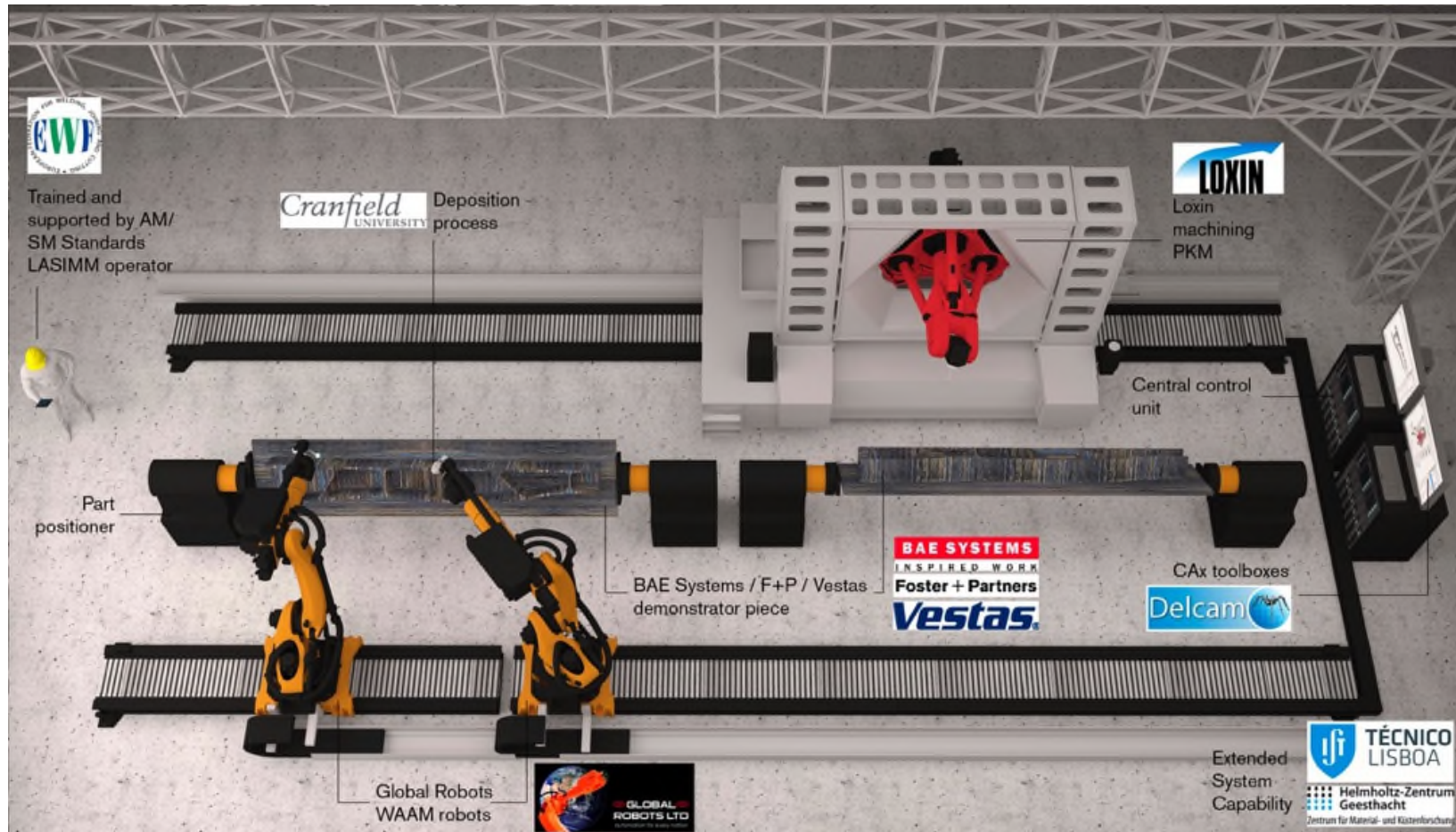
- 6 m aluminium bulkhead



- 7 m steel cantilever beam (1500 kg)



WAAM system developments – multi robot systems for parallel processing



Future Developments

- Completion of software development - including parallel processing
- Process control systems
- On-line NDT
- Development of multi – robot and process systems
- Materials development
 - Higher strength aluminium > 500 MPa UTS
 - Refractory metal parts
 - Graded and mixed materials
 - MMCs
- Qualification for aerospace and oil & gas
- Commercial system development

Delivery - WAAMMat Programme

- WAAMMat programme aim is to reach TRL6 by 2019
- It is a rolling technology programme incorporating over 65 projects – total value approximately £3M (Industry, collaborative, PhDs/Masters, internal projects)
- Team of 26 at Cranfield to deliver the technology (academics, researchers, technicians and students)
- 14 academic partner institutions
- 19 industrial programme members (both end users + exploitation partners)

Much more information on our website

waammat.com



THANK YOU FOR YOUR
ATTENTION 😊



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