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Invitation to an RAeS lecture in cooperation with the DGLR and VDI

Manufacturing the Future – The Case for Metals

Prof. Keith Ridgeway, Hon. FRAeS
Director, Advanced Manufacturing Centre (AMRC) with Boeing, University of Sheffield

Lecture followed by discussion

Entry free !
No registration required !

Date: **Thursday, 16th April 2015, 18:00**
Location: **HAW Hamburg**
Berliner Tor 5, (Neubau), Hörsaal 01.12

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences
Praxis Seminar Luftfahrt

There appears to be a relentless push to introduce more and more composite materials into aircraft manufacture. But what is happening in the metals industry? What new techniques are being developed and introduced and how can metals maintain competitiveness? And importantly how will these techniques come together in the component manufacturing facility of the future “Factory 2050”? The presentation will discuss “The case for metals”.

Keith Ridgway is the Director of the AMRC with Boeing at the University of Sheffield. He is a Fellow of the Royal Academy of Engineering, the Institution of Mechanical Engineers, the Royal Institute of Naval Architects and Honorary Fellow of the Royal Aeronautical Society. He was awarded the OBE in June 2005 and CBE in January 2012 for services to UK Manufacturing industry.

Download from:
http://hamburg.dglr.de
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The Case for Metals and the Factory of the Future

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Basic Premis

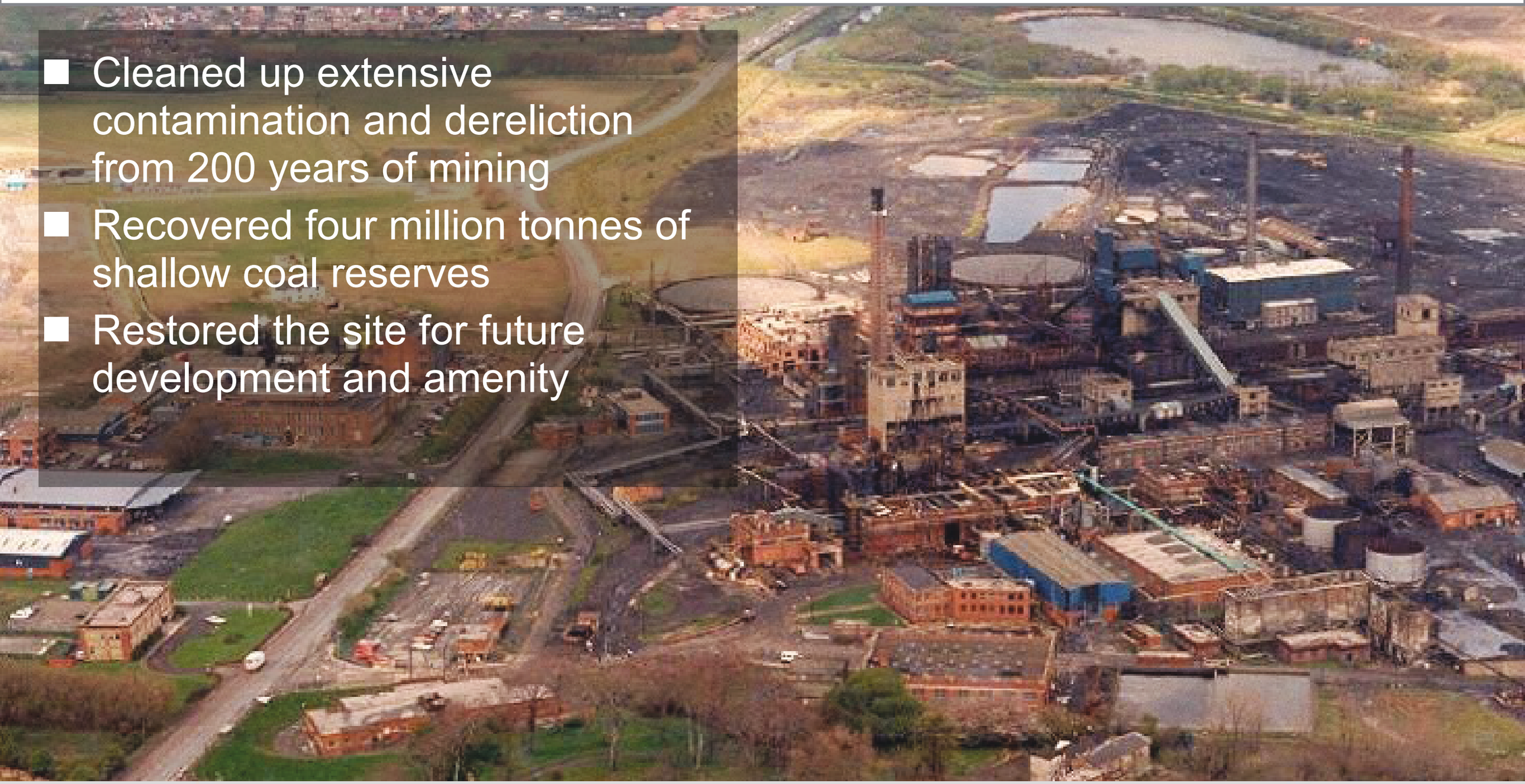
- Using technology we can make a paradigm shift in the cost of manufacturing with metals.
- These technologies can be integrated into the Factory 2050.

- What are the technologies and what will Factory 2050 look like.

The AMRC

A bit of social history

Orgreave Restoration Scheme - 1994



- Cleaned up extensive contamination and dereliction from 200 years of mining
- Recovered four million tonnes of shallow coal reserves
- Restored the site for future development and amenity

Development on the AMP

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The AMRC

- Rolls Royce Factory of the Future
- Composite Centre
- Assembly
- Test Centre
- Nuclear AMRC
- App Training Centre
- Renewables AMRC
- NAMTEC
- CTI
- Design Centre
- Factory 2050
- Medical AMRC

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VOLVO AERO
HOUGHTON
RENISHAW apply innovation™
real time location technologies
LPT
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Delcam
RTI International Metals, Inc.
NCMT
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WARDJet
HEXAGON METROLOGY
Vibrant NDT
KUKA
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Exova
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VIRTALIS
NATIONAL INSTRUMENTS
alicona
AMRC MANUFACTURING LIMITED
FOOTPRINT TOOLS
CGTECH VERICUT Software Solutions for Manufacturing
TYROLIT
ABB
TDM systems
VIRTEK A Gerber Technology Company
precision engineering Agemaspark
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TenCATE
GÜDEL
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Mastercam Robotmaster CAD/CAM for Robots
Eastman
API
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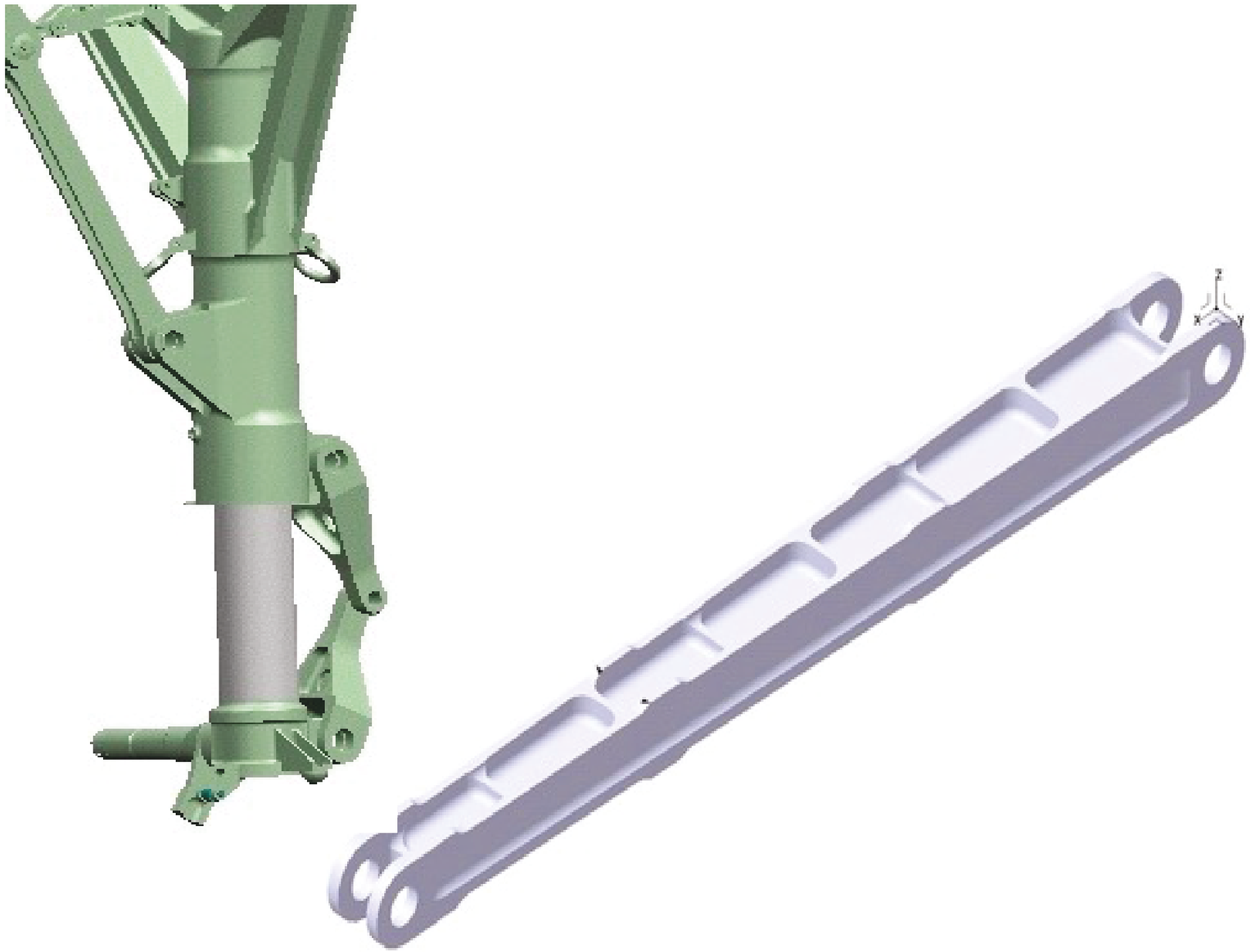
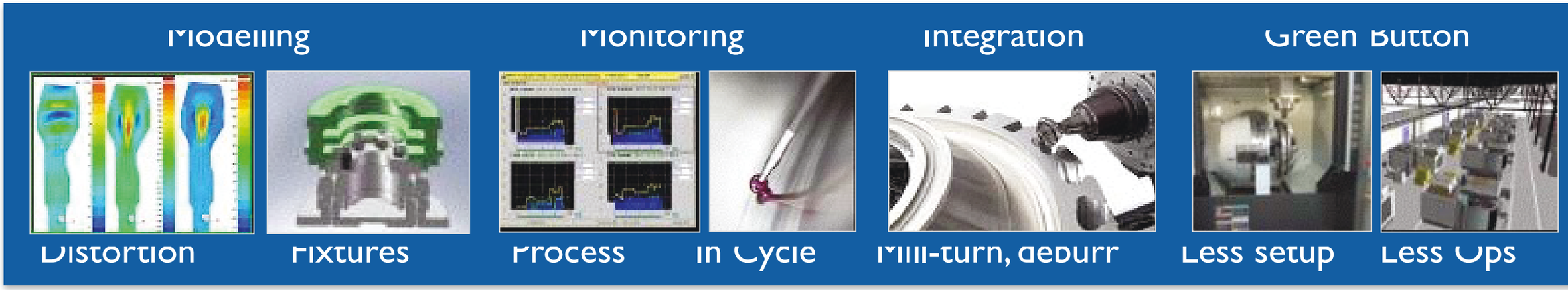
Case Study: Titanium Side Stay



Original time = 54 hrs
Target time = 27 hrs
Achieved time = 11 hrs

- Project as part of collaboration of between Messier-Dowty and AMRC
- Simple Prismatic part similar to Boeing Design
- New material: Ti-5553
- Study in specific machining time to extrapolate overall cost of Ti parts on 787 gear
- Representative design-for-manufacturing features

High Performance Disc Manufacture



- **Operations down 40%**
- **Hours down 50%**
- **Productivity up 100%**
- **Quality up 15% (RFT)**
- **Underpins new factory investment**

Fan Disc

HPDM will to halve the current value added time, double the productivity at zero consumable cost difference and achieve 6-sigma process capability

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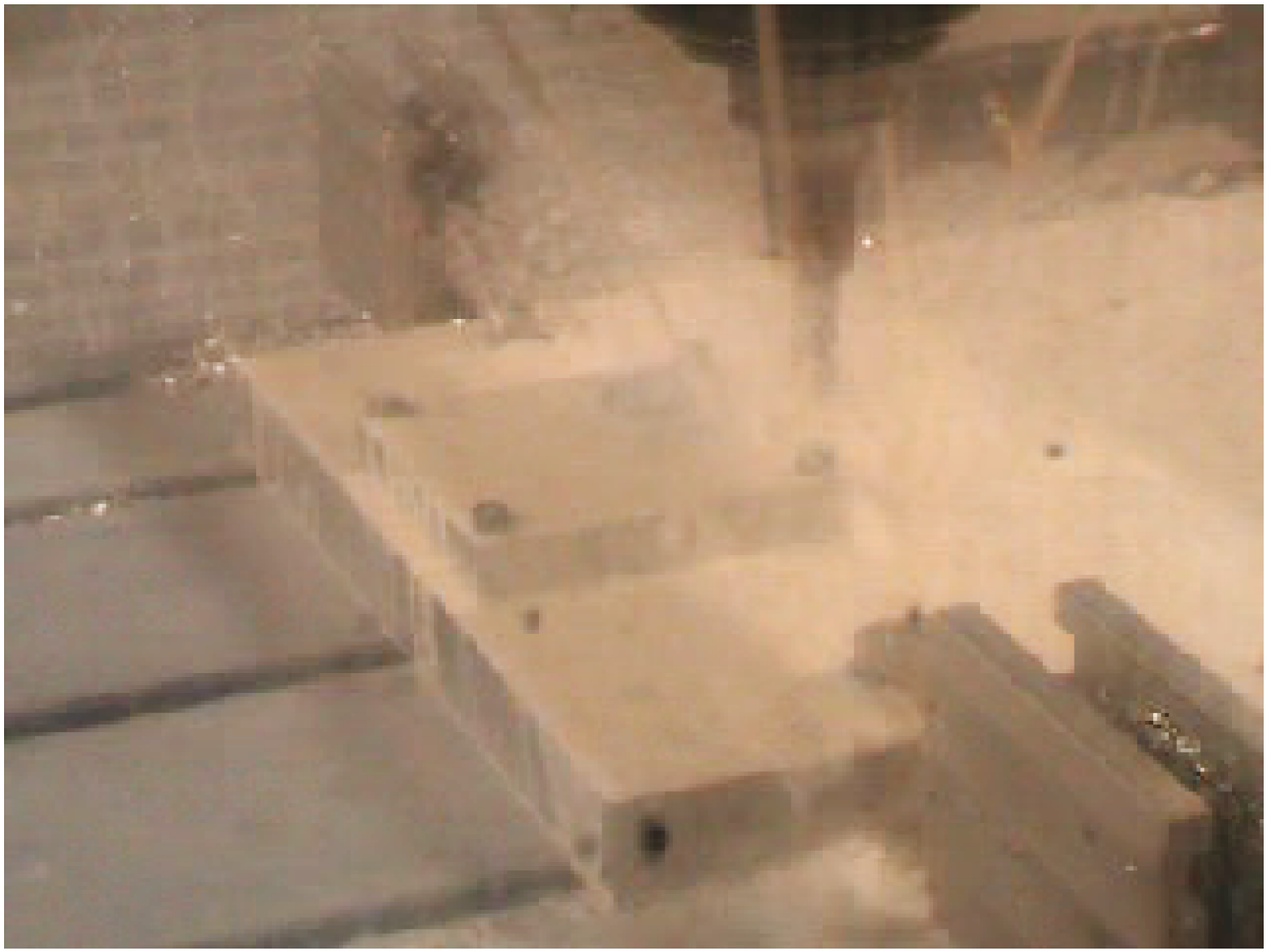
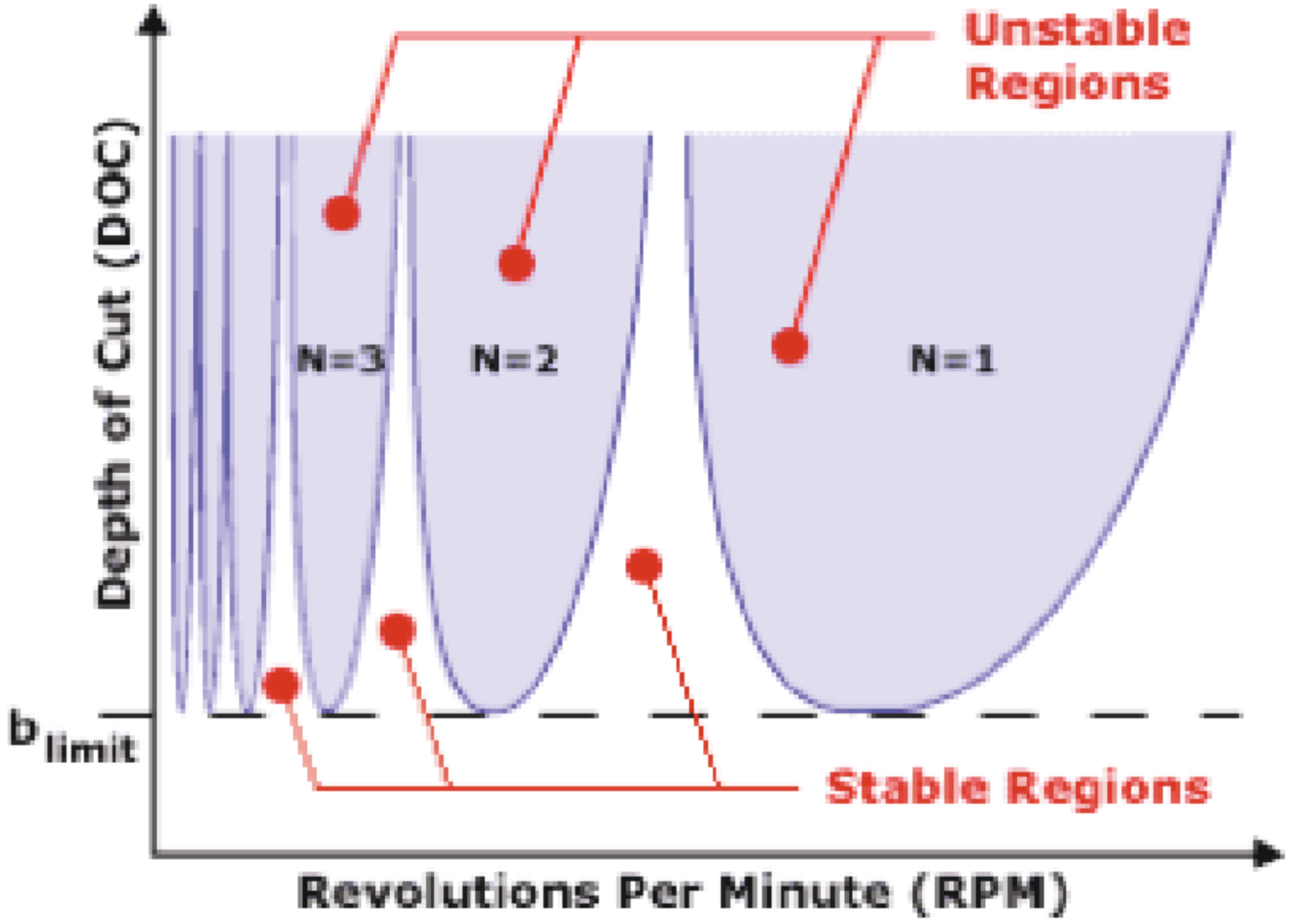
The Technologies

Machining at 9670 rpm 5mm DOC

Machining at 10932 rpm 5mm DOC

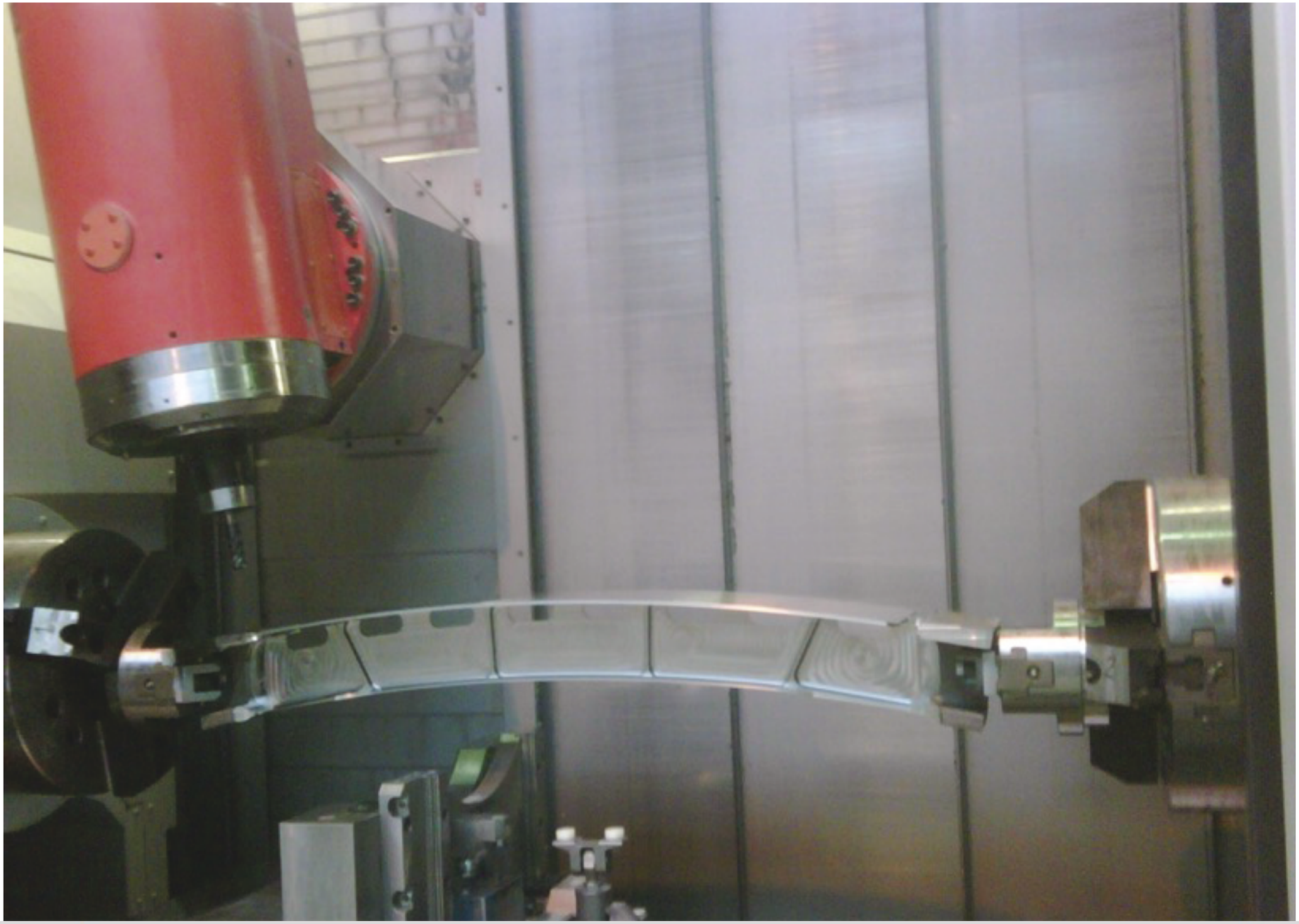


Machine dynamics

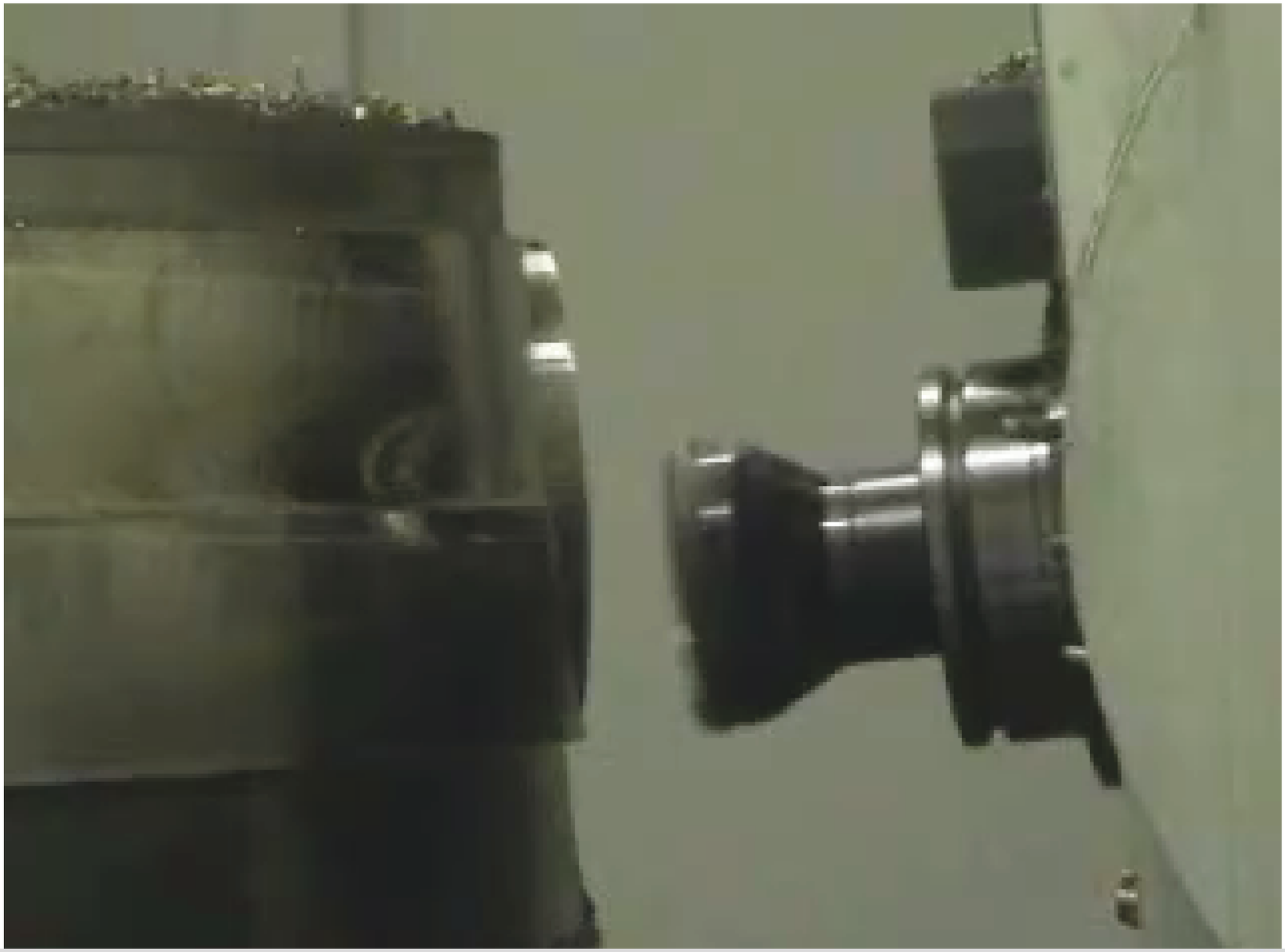


Patented casing fixture

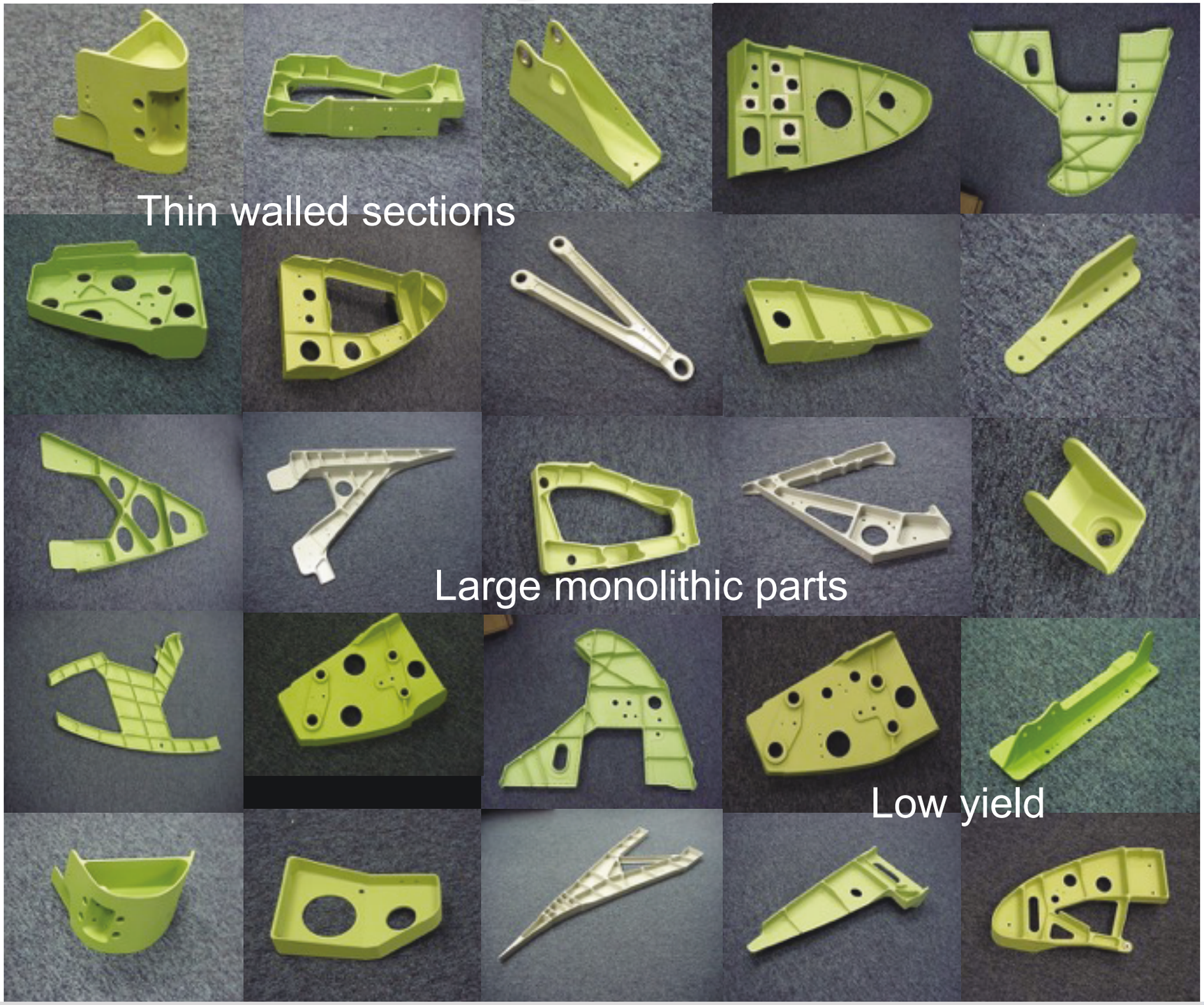
Crown frame machining



Making it affordable



The good old days…



The good old days…Why?

- Hundreds of parts per aircraft.
- 4:1 Fly to Buy ratios.
- $millions of wasted time, material, cost per aircraft.
- Doesn't stack up economically or environmentally.
- Oligopoly laughing.

There must be a better way!

Additive Layer

Polymers:
(polyamides, elastomeric)

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

Metals:
(titanium, steel, nickel alloys)

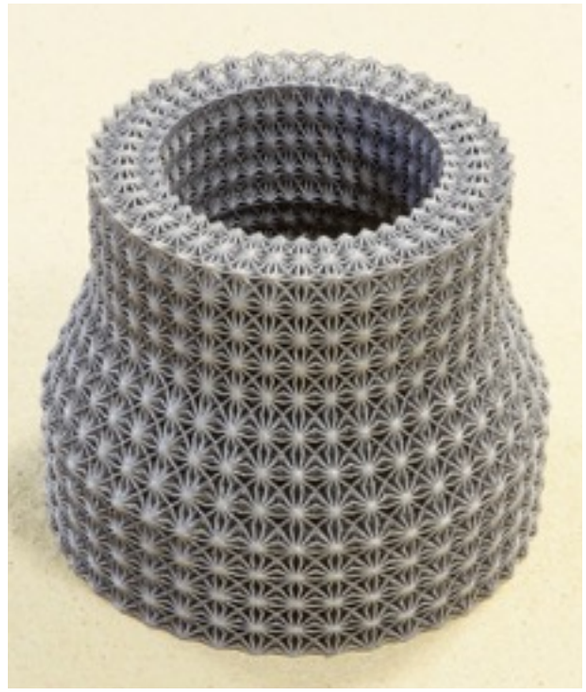
- Arcam Electron Beam Melting
- Renishaw laser melting
- Exone binder jet
- Optomec Aerosol Jet

Other Advanced Manufacturing Techniques:

- Metal Injection Moulding
- Spark Plasma Sintering
- Electron Beam Welding

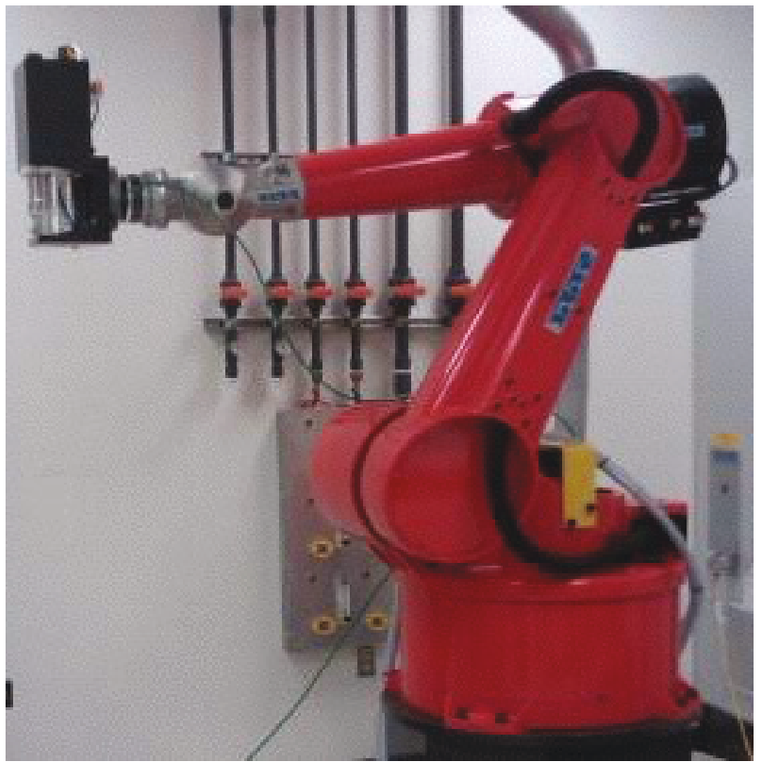
Current Research Activities

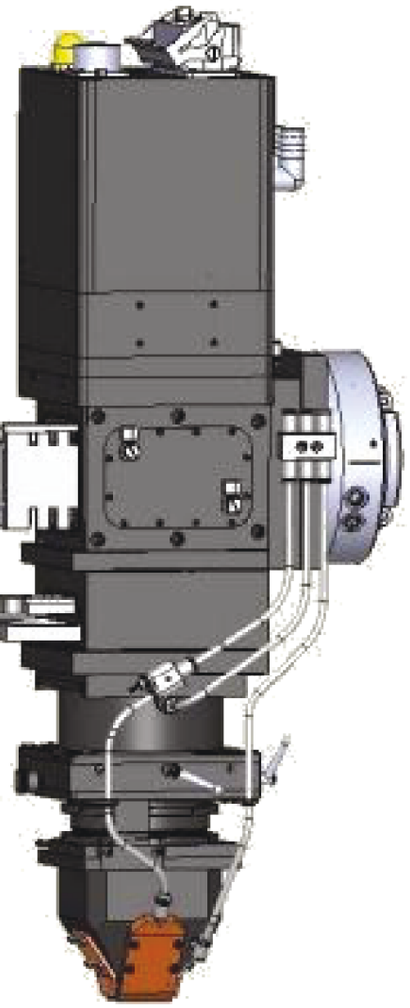
- Process – property relationships
  - microstructure
  - defects
  - surface finish
  - mechanical properties
- Process optimisation
  - increase build speed
  - Improve consistency and repeatability
- Geometries
  - Thin wall sections
  - Lattice structures

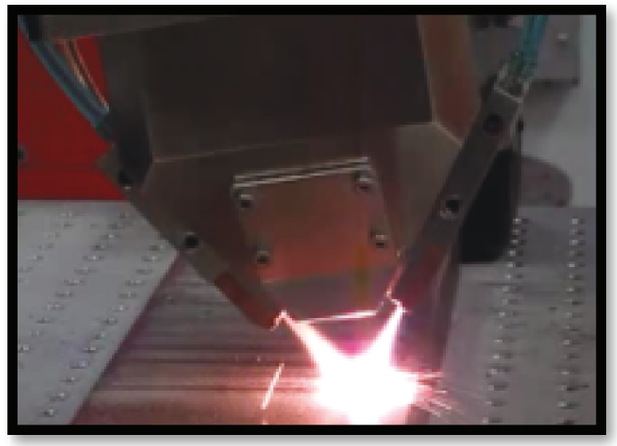


High Power Direct Diode Laser (HPDDL)

- 8-15kW Diode Laser with beam spreading for the cladding of vessels, heat exchangers and potentially building parts
  - High powder metal deposition rate (up to 20kg/hr), using beam spreading (up to 30mm wide and up to 30mm x 12mm beam shape)
  - Low dilution and very high integrity clad layers



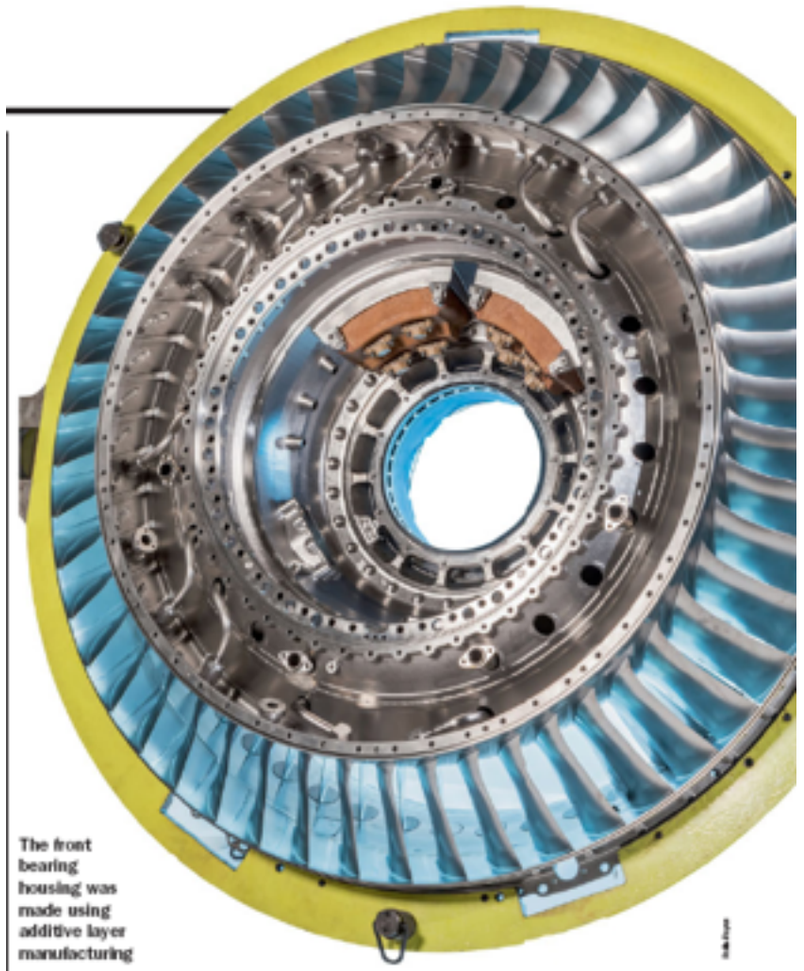




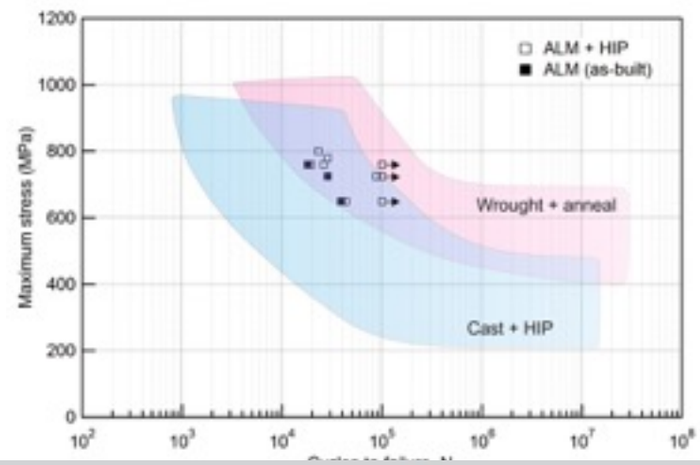
Aerospace case study

Rolls Royce Engine Stator Vanes for Ring of Vanes

- Build orientation and support structures
- Process optimisation- build quicker, eliminate defects
- Support to down stream processes e.g. machining, finishing & welding
- Pre-production repeatability
- Key process variables identified and controlled
- Supporting pack of materials testing

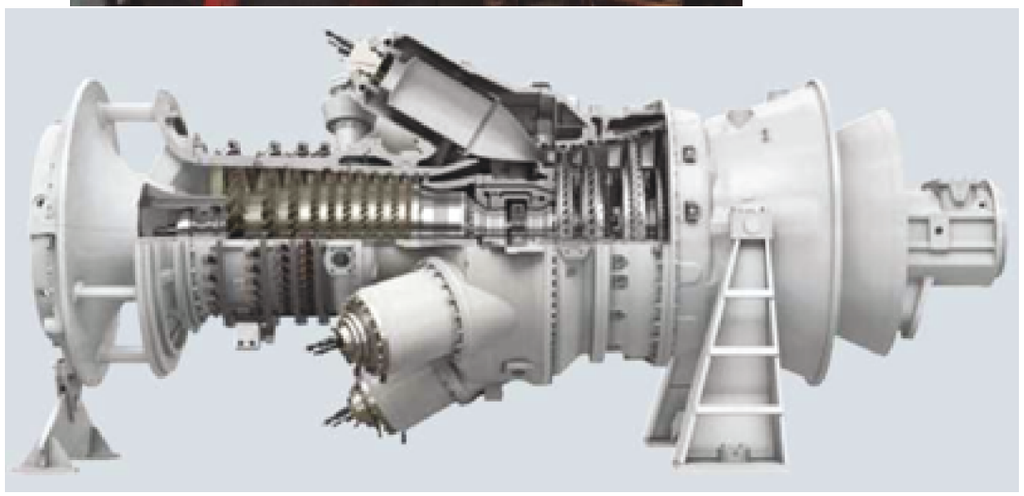


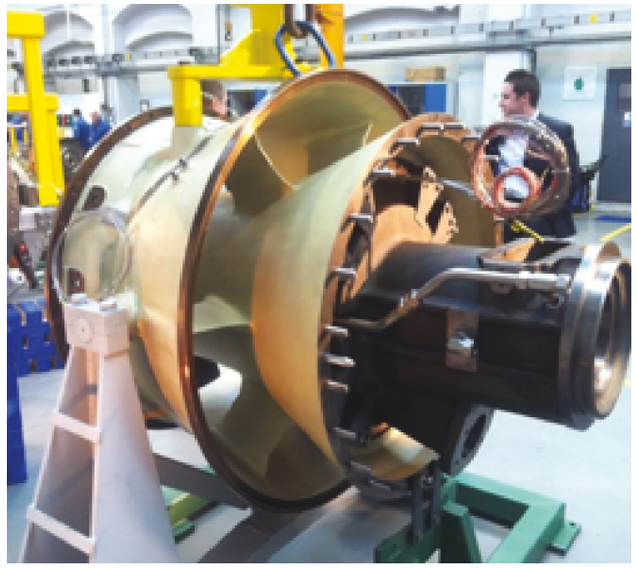
The front bearing housing was made using additive layer manufacturing

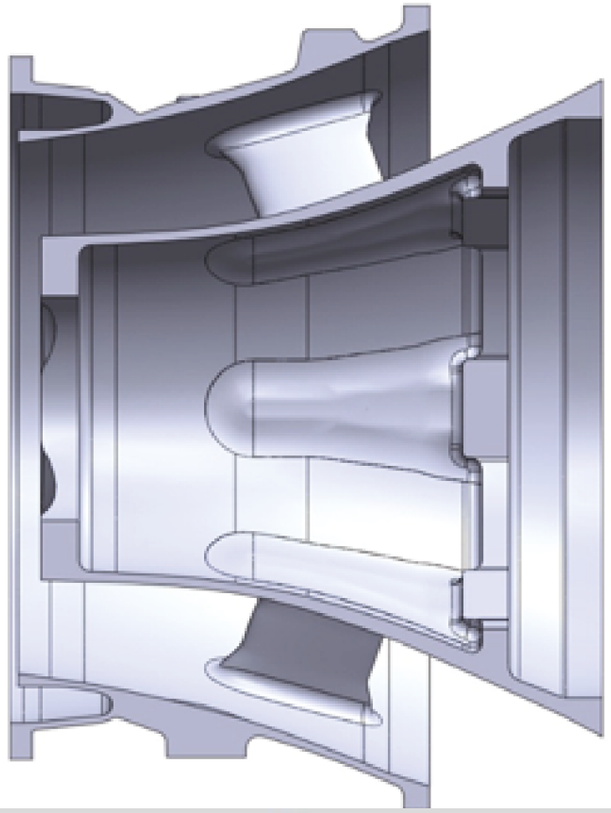


MEGAshell®

Precision ceramic mould making facility producing the largest moulds in Europe







High efficiency gas passage

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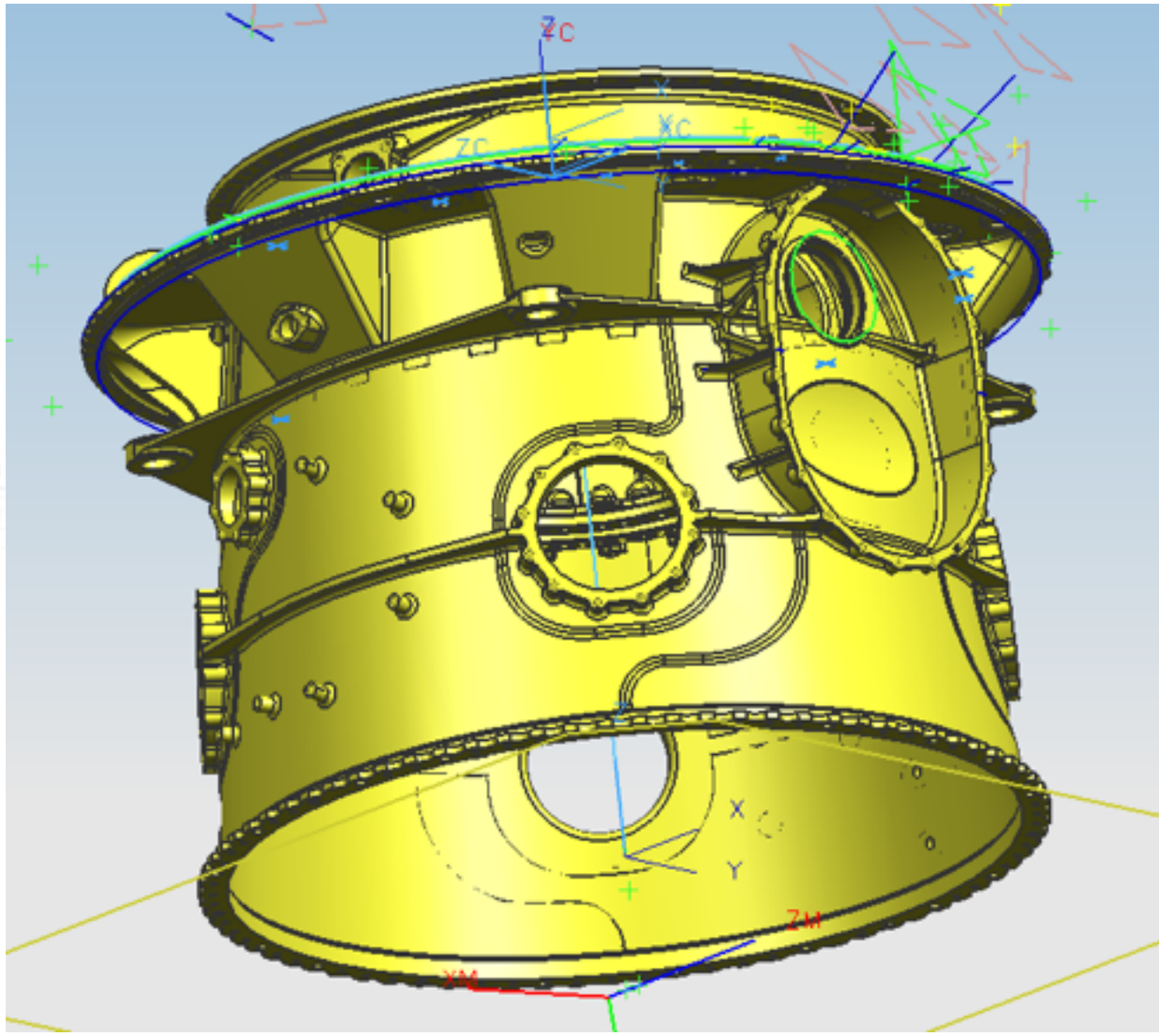
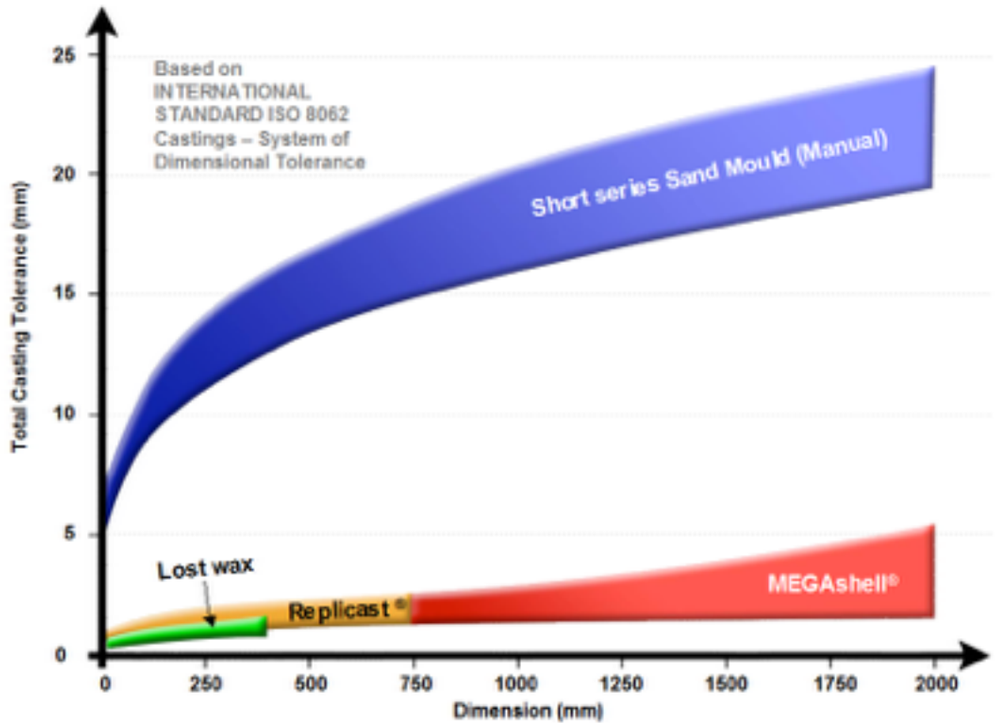
Large-scale, precision titanium casting

- 1000kg poured weight
- Working envelope Ø 2.5m x 2.5m x 2.5m
- Centrifugal table Ø 2.5m

Future – Products



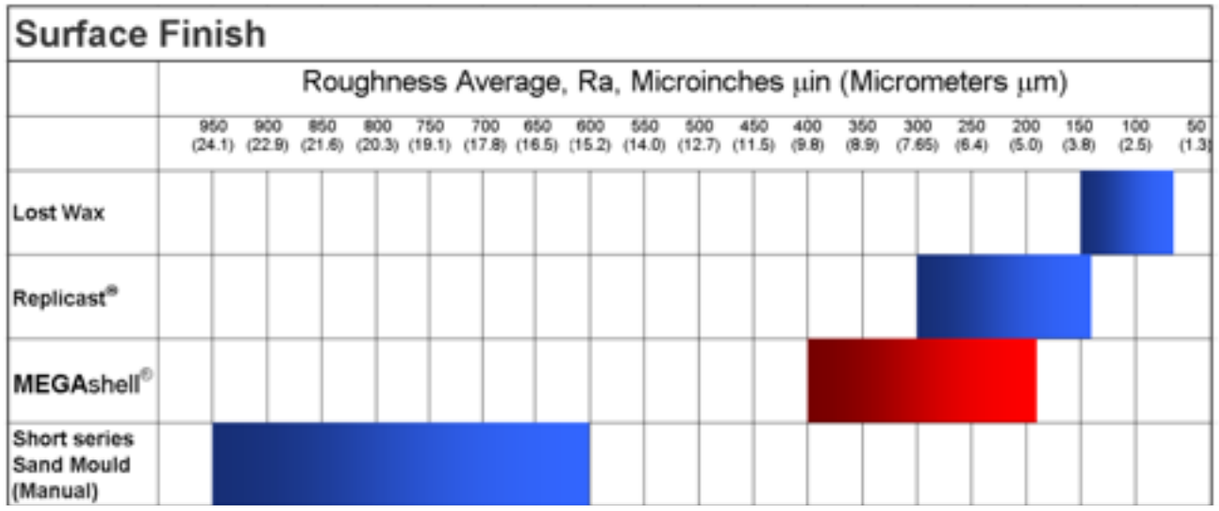
Dimensional Tolerance



MEGAshell®

Dimensional tolerances and surface finishes potentially achievable with MEGAshell® (based on proof of concept activities) compared with the standards for Lost Wax and sand moulding.

Surface Roughness



Tailored blanks

- Machined Part Weight: 51.15 lbs.
- Product Form Weights:
  - Die Forging – 412 lbs
  - LAM – 164 lbs
  - LFW – 190 lbs
- Product Form Costs:
  - Die Forging - $10,300
  - LAM - $10,750
  - LFW - $4,862
- Machining Costs:
  - Die Forging – $7,209
  - LAM – $4,150
  - LFW - $4,150
- Total Costs
  - Forging – $17,509
  - LAM – $14,900
  - LFW – $ 9,012

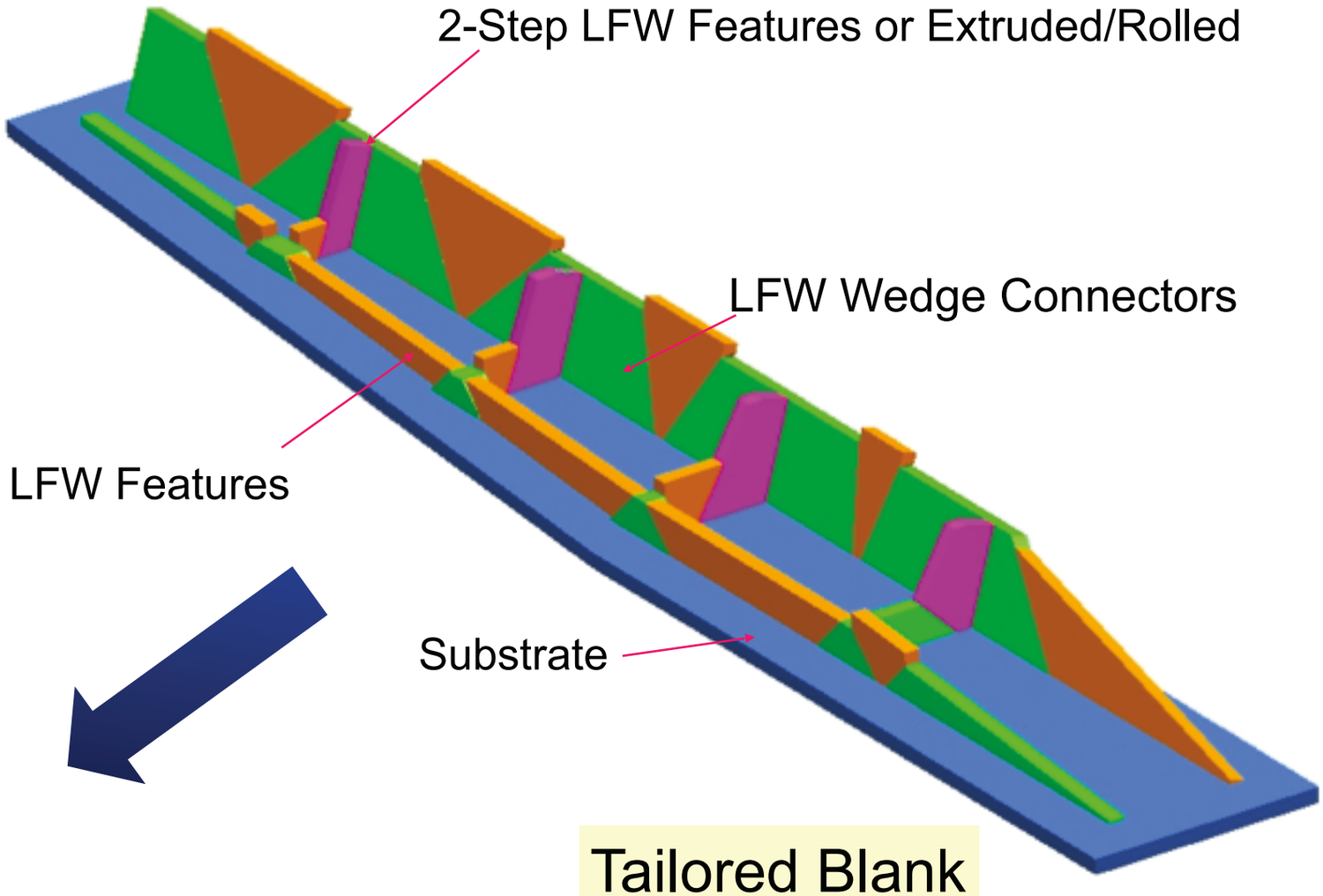
Linear Friction Welding

- Linear Friction Welding currently used by engine companies to make integrally bladed rotors (BLISKS).
- Involves rubbing two pieces against each other to generate heat and forcing together to weld to base metal properties.
- Tailored blank concept uses smaller pieces that are also joined together to make large features.

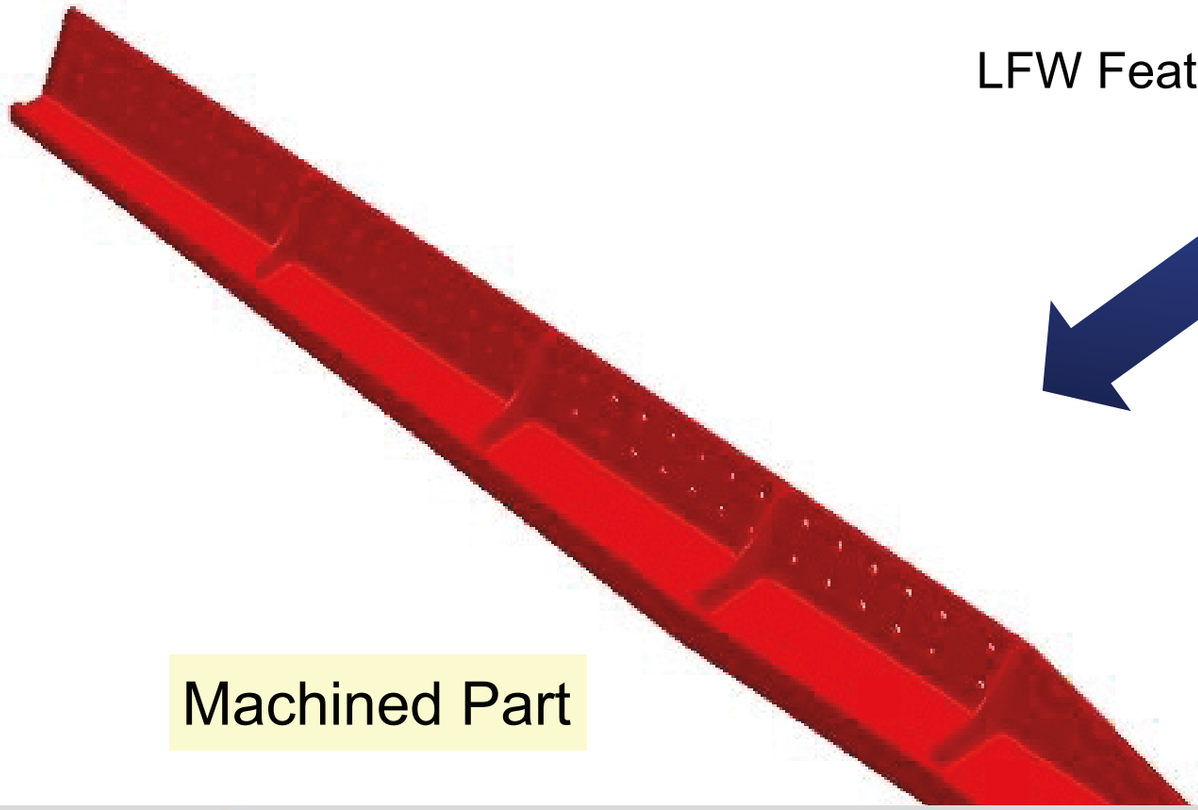
- Primary alloy of interest is Ti-6Al-4V although other alloys (Ti, Fe, Ni, Al) can also be joined.
- Will require unique build machines for full exploitation.
  - High build rate (~4 parts/hr)

Linear Friction Welding

- Cut material with index features
- Fixture & weld side 1
- Fixture & weld side 2
- Ultrasonic Inspect (Before IPQA)
- Heat Treat
- Machine using index features
- Penetrant Inspect Machined Part

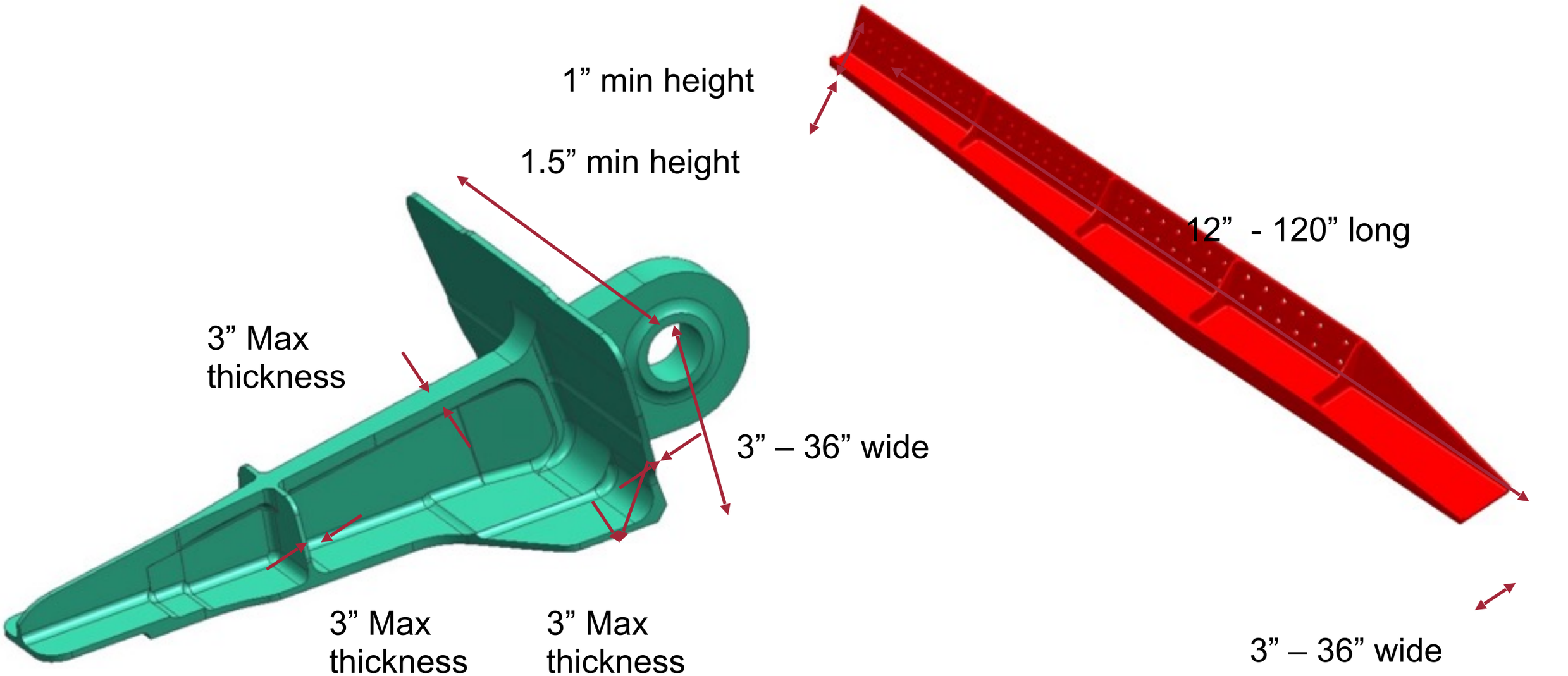


Tailored Blank



Machined Part

LFW typical parts

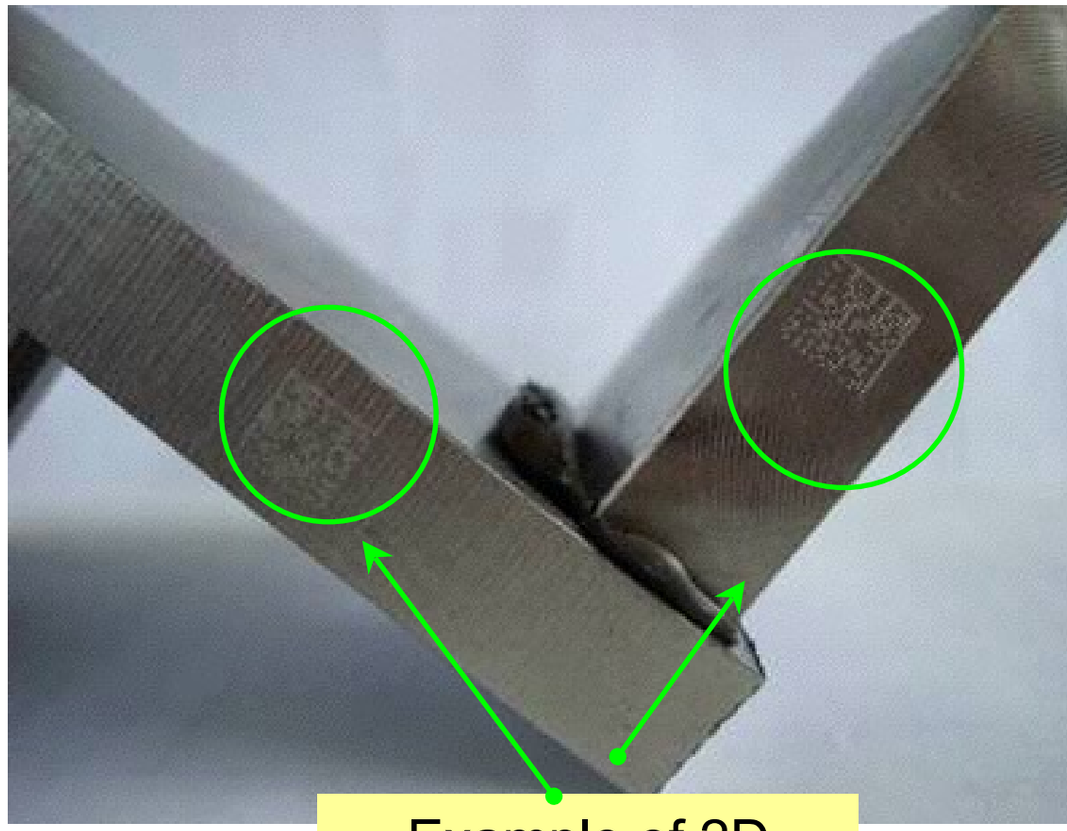


Process Development and Definition

- Design of Experiments - Complete
- Intersection feasibility - Complete
- Part demonstration - Complete
- Stand-alone & Flange before keystone welds - Complete
- Keystone welds
  - Feasibility - Complete
  - Definition - In-Work
  - Off-normal - In-Work
- Define basic heat treatment - Complete
- Demonstration of equivalency between large (8in^2) and small machines (2in^2) - Complete
- Long-T welds – Complete
- Prototype Floor Beam End Fitting – Complete

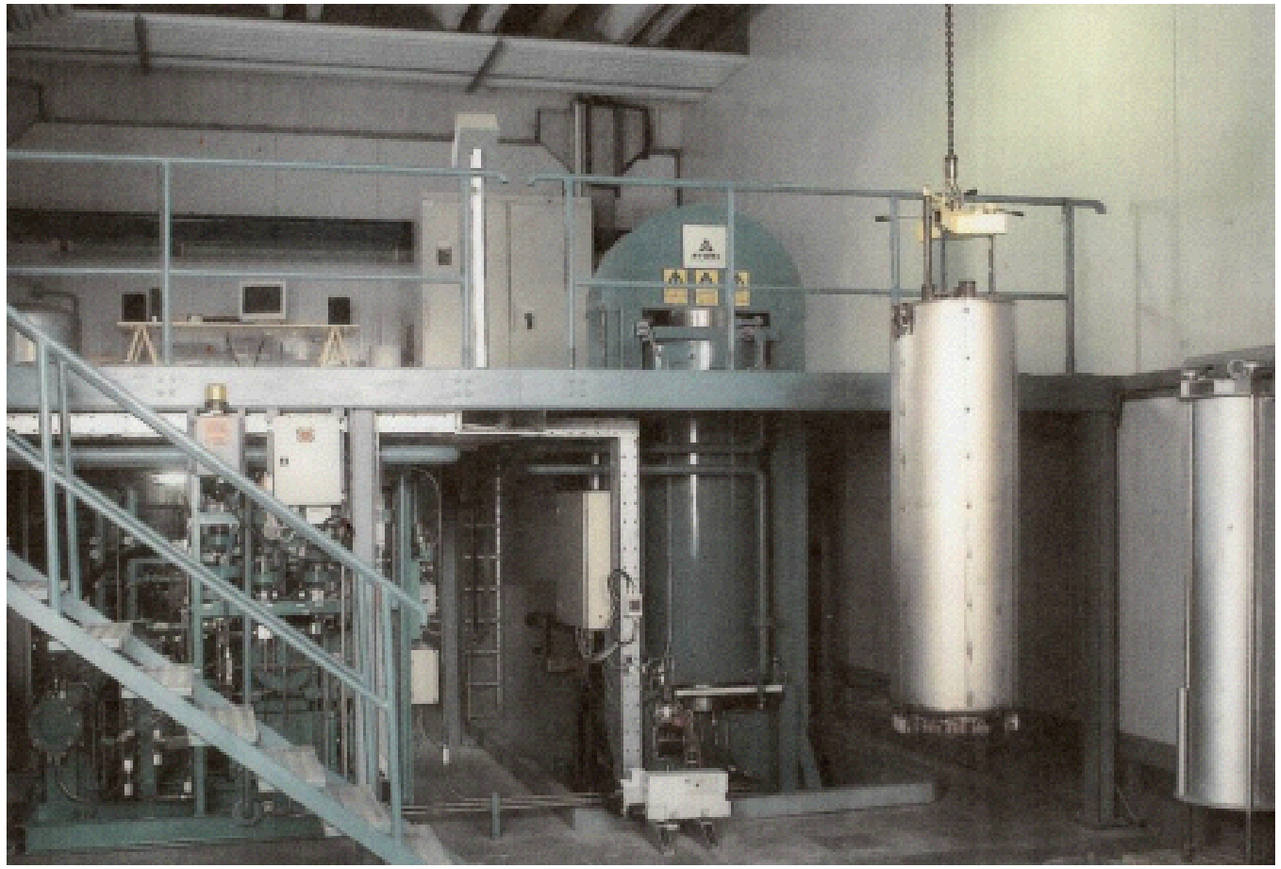
Thompson E-100 1-Axis LFW Machine

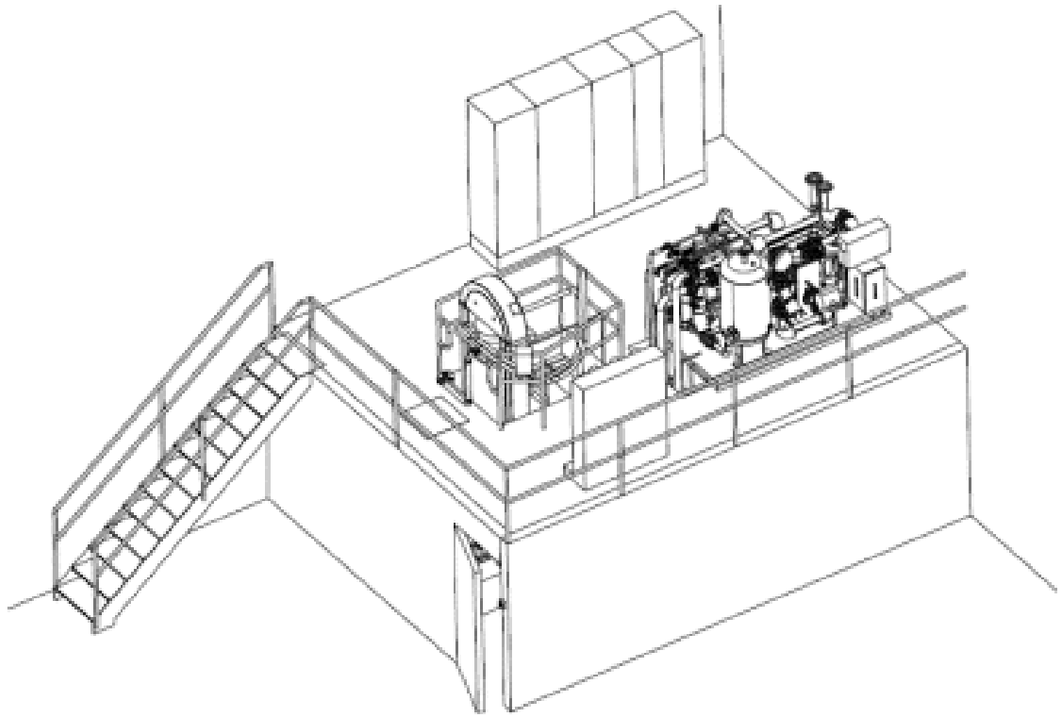
- 100 ton machine installed in UK.
- In-Process QA is installed on machine.
- Qualification Welds in Work



Example of 2D matrix weld data storage & mat'l cert traceability

Powder Metallurgy - Hot Isostatic Pressing





- HIP vessel working volume of approx. 500mm x 1400mm
- Accelerated / controlled cooling capability

The Factory of the Future
“Factory 2050”

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Context

- Focus on sectors most important to future UK manufacturing and in particular UK exports.
  - Initially aerospace, automotive, fabricated products, equipment, chemicals, pharmaceuticals and bio/life sciences.
- Automation is a given (but need organisation and people to get the best out of it)
- Few look outside their own businesses and sectors
- Urbanisation and servitisation not well understood
- Demand is better, cheaper, greener, faster

UK topics reflect international perspectives

- Sustainable manufacturing and green manufacturing.
- Improved and simplified ICT
- Advanced robotics and intelligent manufacturing systems.
- Next generation materials with novel functionalities
- Reconfigurable facilities and fast ramp up as demand grows
- New business models and urbanisation
- The importance of talented, well educated and creative people.

People issues

- Talent
  - "Nothing will matter more than talent" (World Economic Forum, 2012)
  - Creativity & innovation
- Flexibility
  - Multi-disciplinary teams, empowered, agile
  - Knowledge workers who can Integrate
- Attractiveness of manufacturing
- Demographic changes
- Education & training
- Systems view (total factor performance, McKinsey, 2012)

Aerospace

- Long Product Life Cycle: Next aircraft are known
- Material of major structures will be a major factor
- Supply chain will need to consider global market and “Risk and Reward” in financing development
- Assembly using few tools and modern GPS enabled environments etc
- Potential for supply parks sharing resource
- “Reconfiguration Wand”

Boeing 767 Assembly Line

Boeing 787 Assembly Line

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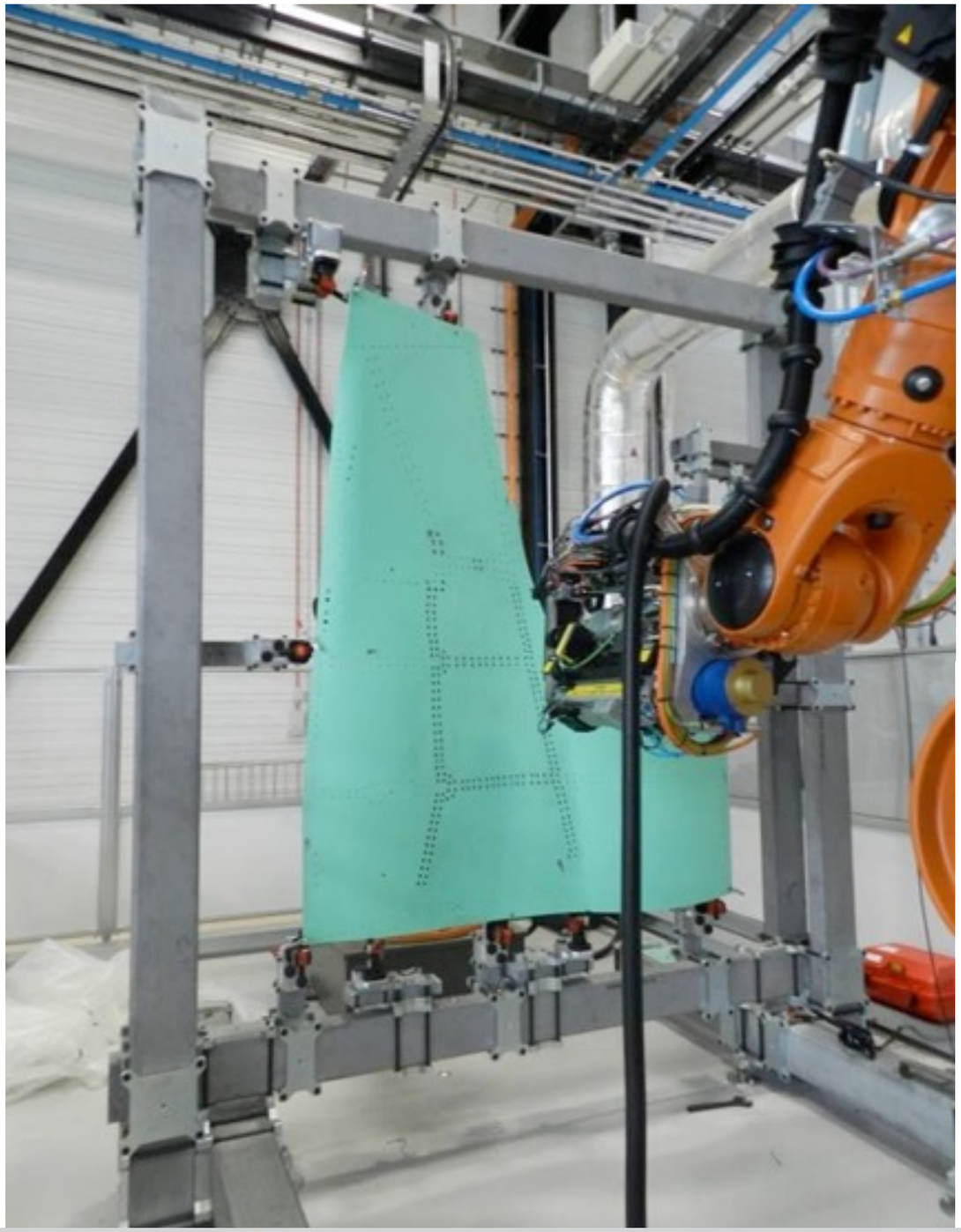
Aerospace: Flexible Automation



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Highly Flexible Machining

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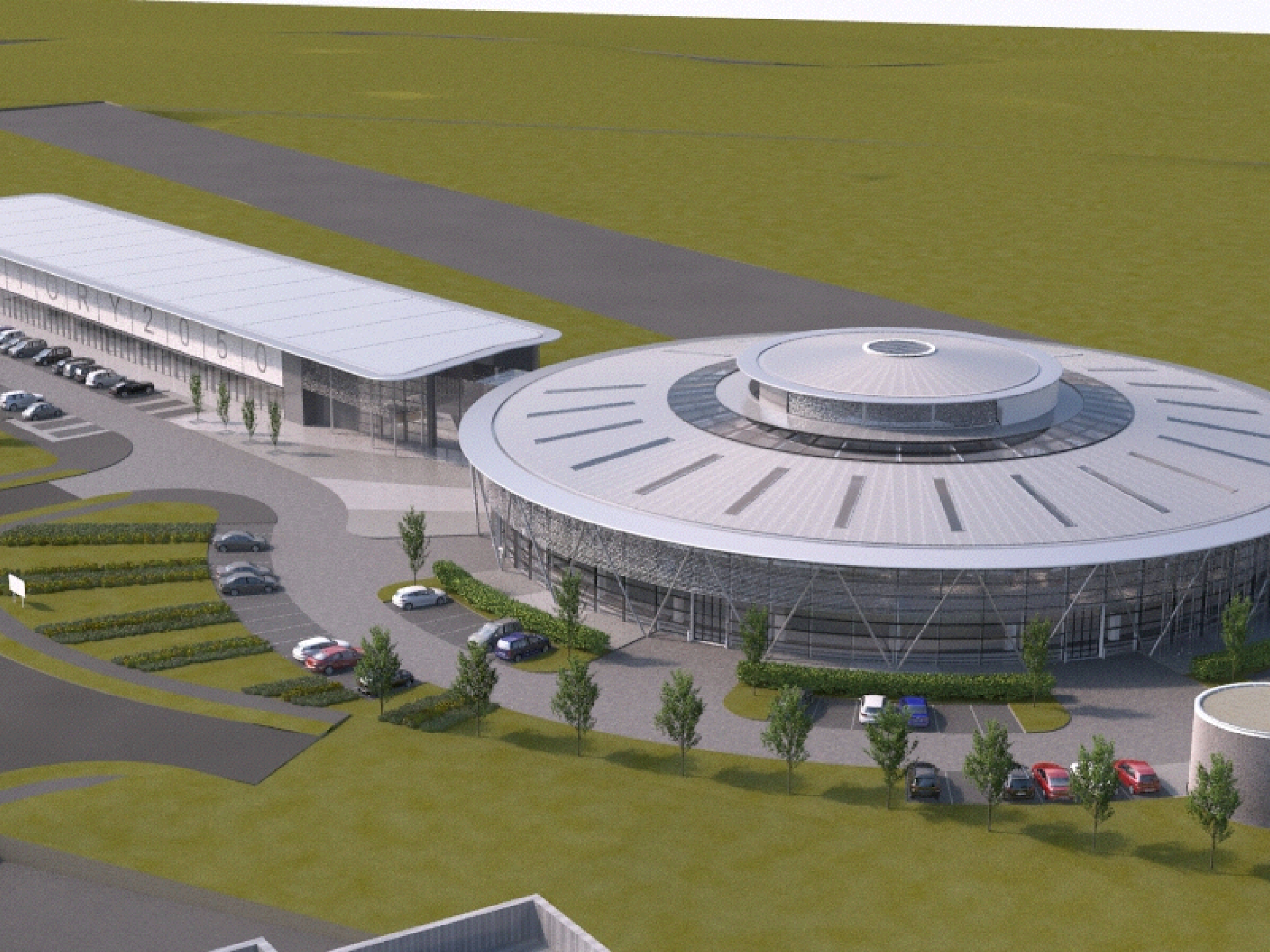
Recommendations

Opportunities in 6 inter-related areas:

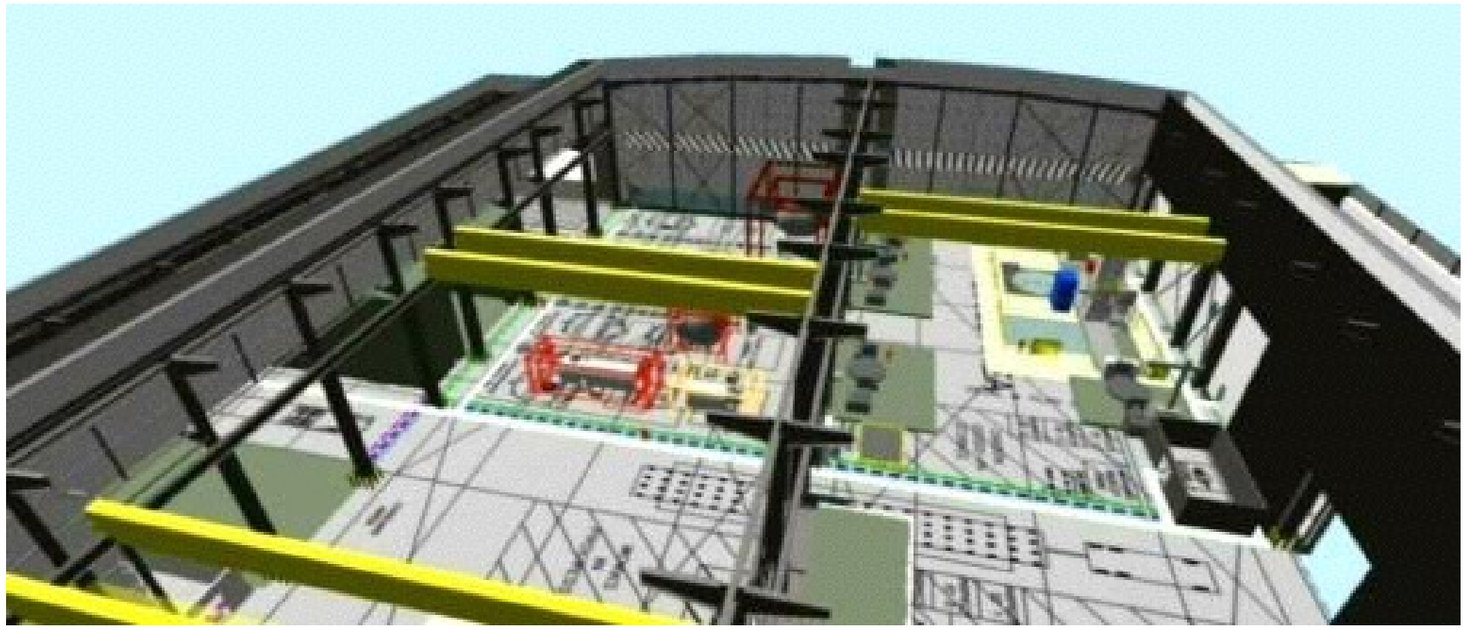
- **More integrated and optimised supply/ value chains (incl. supply parks)**
- Stronger long term collaborations between manufacturing companies and UK Universities to improve the rate and uptake of R&D
- Increased benchmarking & cross-sector learning
- Systems view of the FoF, integrating people, organisation and technology – characterised by
  - Flatter, skilled, leaner, integrated, small, clean, flexible, open, buzz
- **Reconfigurable factories**
- **Attracting talent into manufacturing**


FACTORY 2050

Bringing it all together

Virtual and Augmented Reality (VR/AR)

- Full immersion, interactive “cave”
- Interactive “power wall”
- Capability:
  - Virtual Product visualisation
  - Assembly and Maintenance simulation
  - Factory layout optimisation linked to Discrete Event Simulation



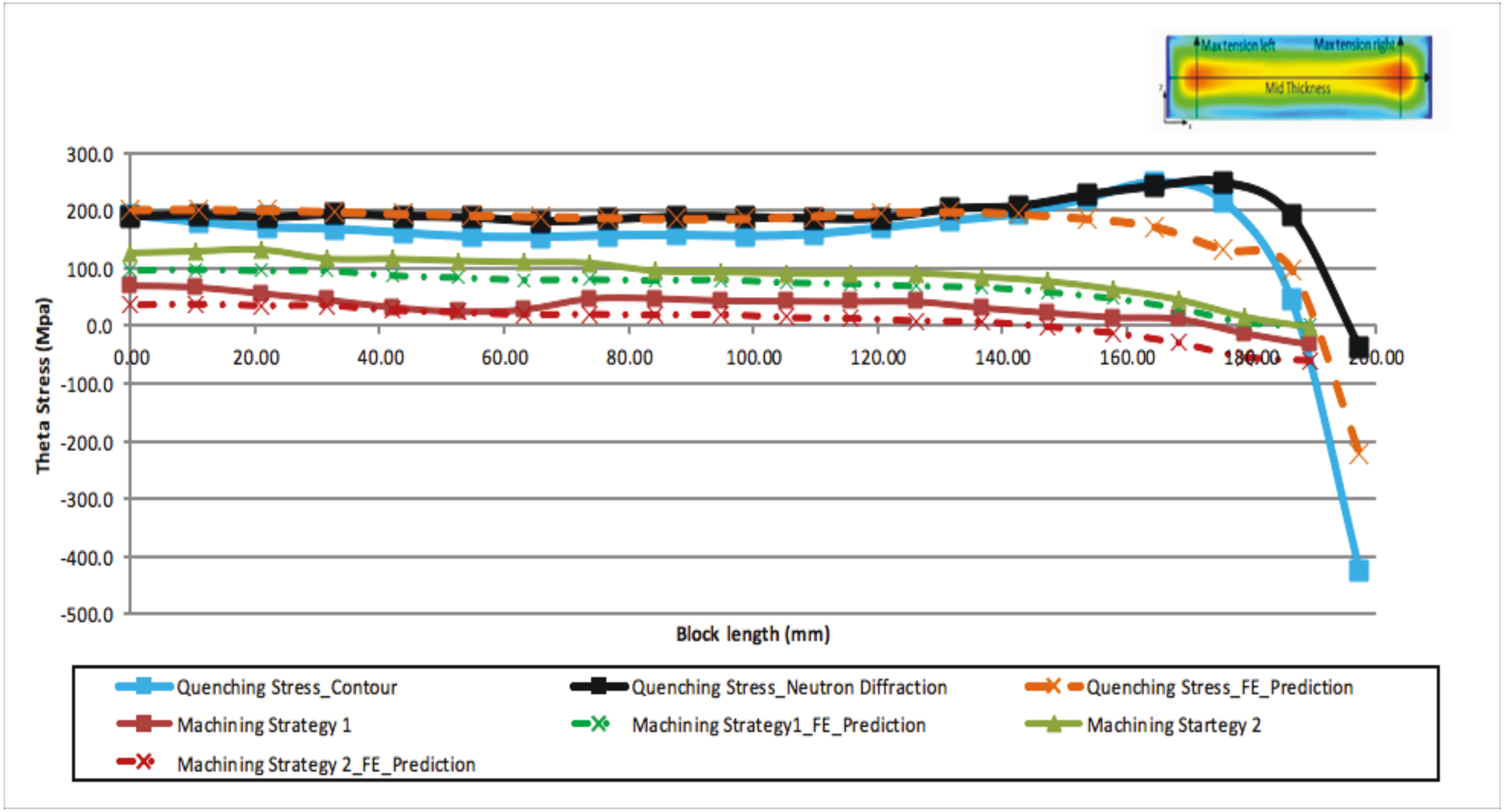
Residual stress management

- **Residual stresses (RS) are stresses that exist in a material without any influence of an external load.**

- **These stresses are found following majority of the manufacturing operations and play a major impact on the material performance during its manufacturing or in-service cycle.**

- **Distortions are one of the by-products during the redistribution of these residual stresses and increase:**
  - **Costs (re-machining)**
  - **Scrap rates**
  - **Production / lead time.**

Results



Residual stress measurement and FE prediction after quenching and machining

Assuring Part Conformance Today

Process Specification
...
...
...

Processes

Inspection

Product

Inspection & Report
...
...
...

Assuring Part Conformance in 2050

Process Specification
...
...
...

Processes

Product

&

Process Report

-Part
-Machines
-Tooling
...

Process Control

Decision Support

AMRC centres:

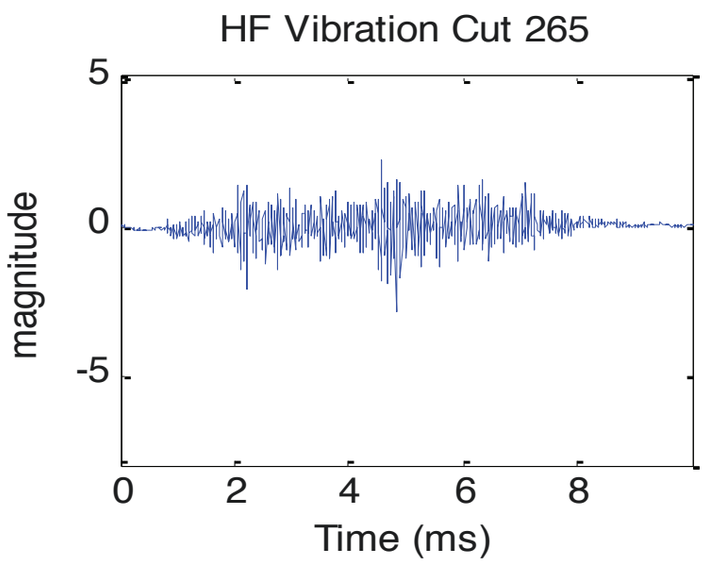
In-Process Data

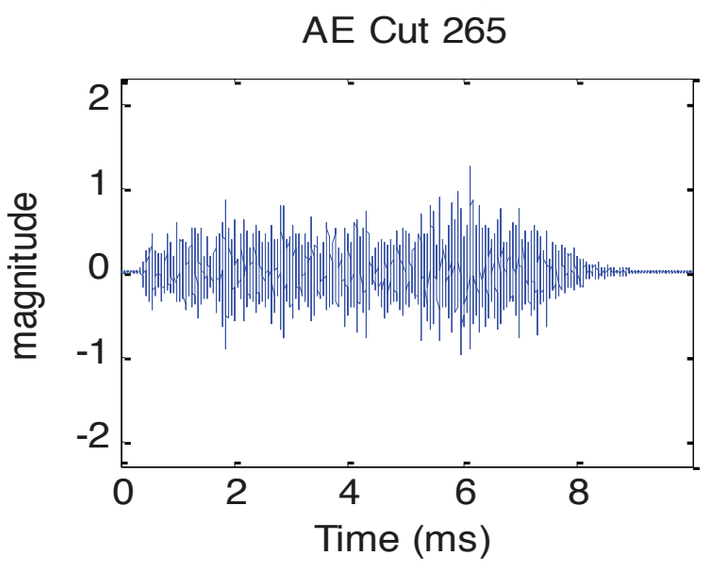
- A measurement that can be taken **during** processing steps e.g.
  - Vibration
  - Temperature
  - Force
  - Flow Rate
- A measurement that can be taken **between** processing steps e.g.
  - Tool Measurement
  - Tool Wear
  - Machine Kinematics
  - Part Inspection

…with minimal cost or quality implication on the process

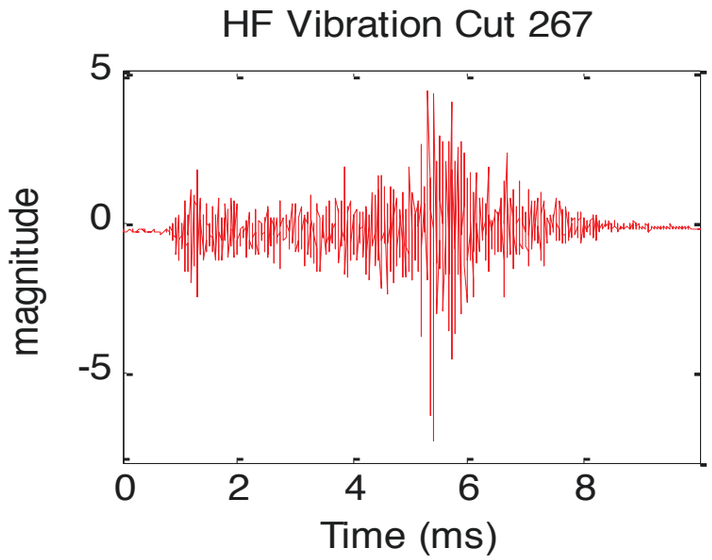
Example – Vibration in Milling

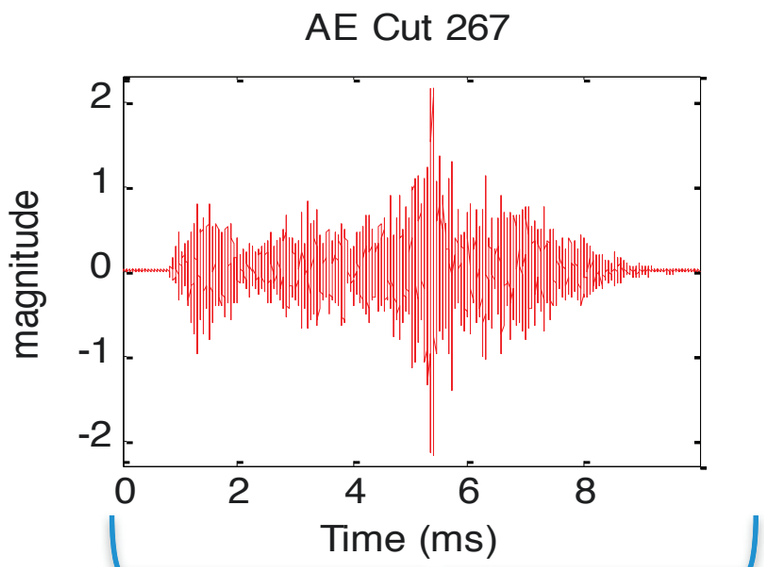
Normal Operation





Chipping





One Flute Pass

Z axis Vibration Sensor

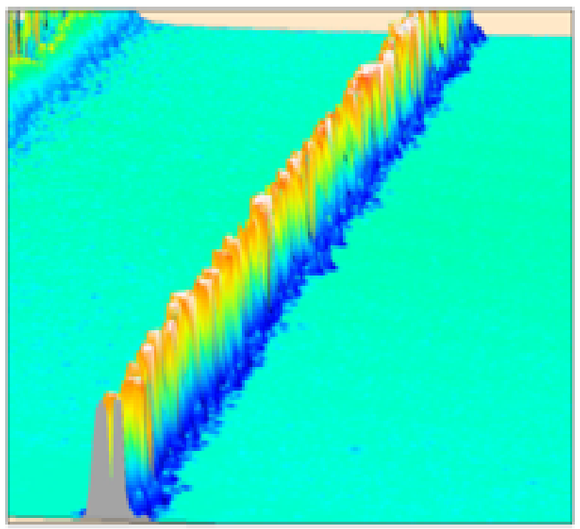
100mV/g
+/-50g
0.5-5000Hz range +/-3dB

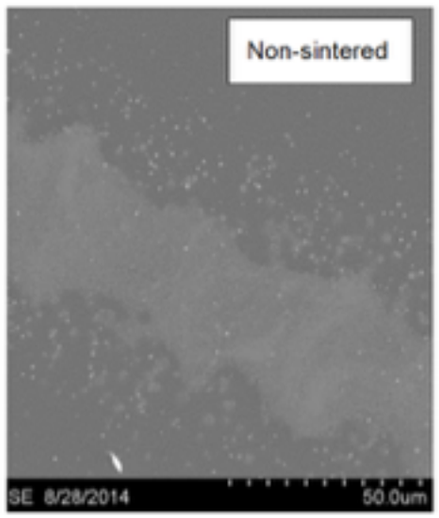
Automating the process

Sensor development

Printed Thermocouples - Enabling low cost, disposable temperature measurement closer to the cutting-workpiece interface

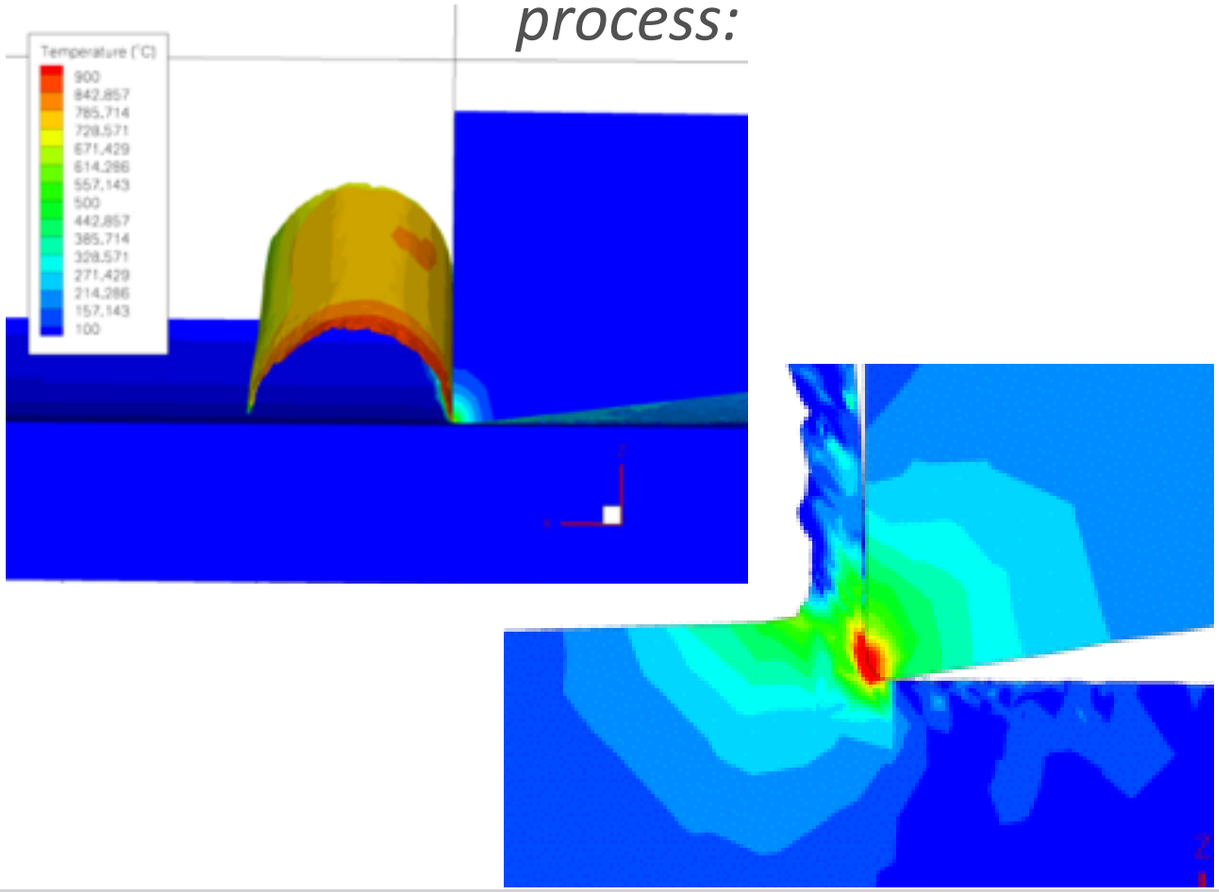
1. Circuit Design
2. Surface Planarisation
3. Ink Development and Printing
4. Sintering
5. Testing





SEM measurement of printed tracks

Thirdwave Simulation of a finish turning process:



The Enabler: Big data and informatics

Machine Tool Monitoring

In-Process Measurement & Machine Tool Metrology

Machine Utilisation & Condition Monitoring

Manufacturing Informatics

Embedded Sensing and Signal Processing

Intelligent Systems and Information Capture

Process Control

Discrete Event Simulation and Process Mapping

Thank-You