

# mtc

Manufacturing  
Technology Centre

## Combining AM and Topology to Develop an Optimised Suspension Fork End

Andrew Triantaphyllou  
Senior Research Engineer

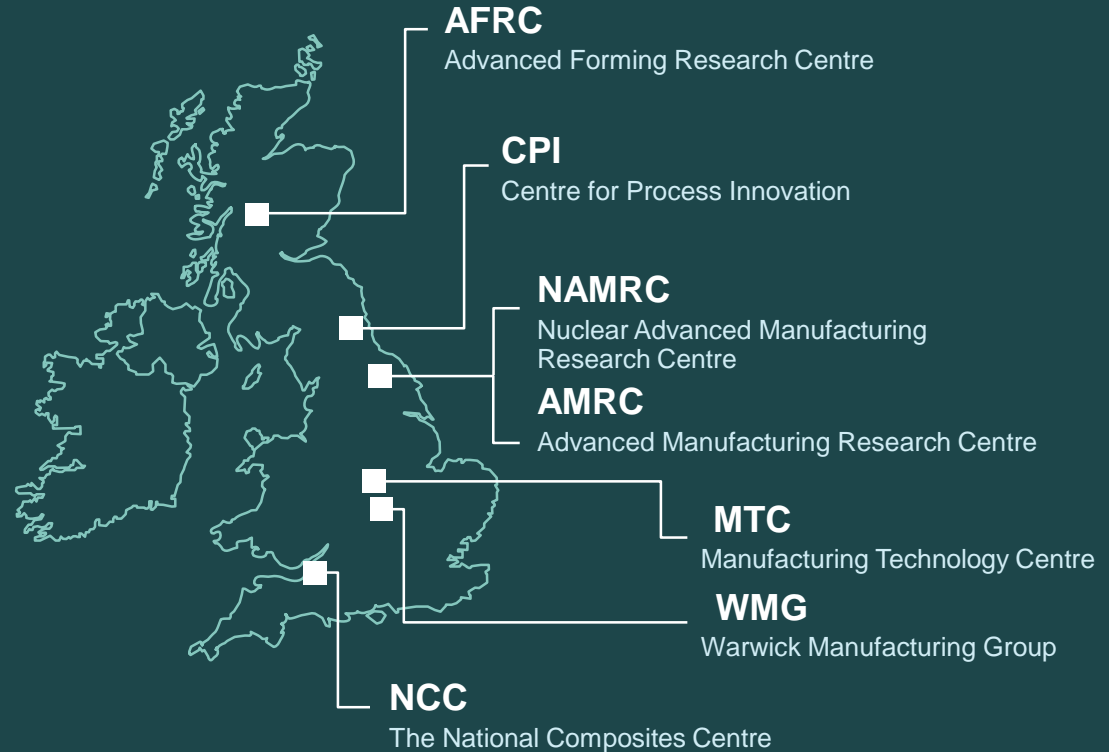
April 2016

mtc  
Manufacturing  
Technology Centre



# HVM CATAPULT CENTRES

MTC is the lead centre for  
**Net Shape & Additive  
Manufacturing**  
in the High Value  
Manufacturing Catapult



# BRIDGING THE VALLEY OF DEATH

Experimental research

Applied research

Technology implementation

UNIVERSITIES  
RESEARCH ORGANISATIONS  
RESEARCH COUNCILS

**MTC FOCUS**  
Innovate UK

“Valley Of Death”

INDUSTRY AND COMPANIES  
PRIVATE SECTOR FUNDS

# Project partners



- SME - Design and Manufacture motorcycle suspension units



- SME - Design Consultants
- Write optimisation tools

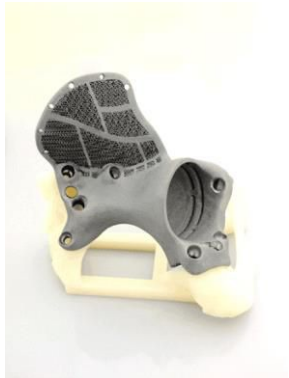


- Support for West Midland SMEs in modelling and simulation

# Overview

- ▶ Additive Manufacturing and the opportunity for Optimisation
- ▶ Project to optimise fork end
- ▶ Consideration of AM in design process
- ▶ How MTC can help you make use of AM

# What AM offers



<http://medicaldesign.com>



No tooling



[www.geaviation.com](http://www.geaviation.com)



3TRPD

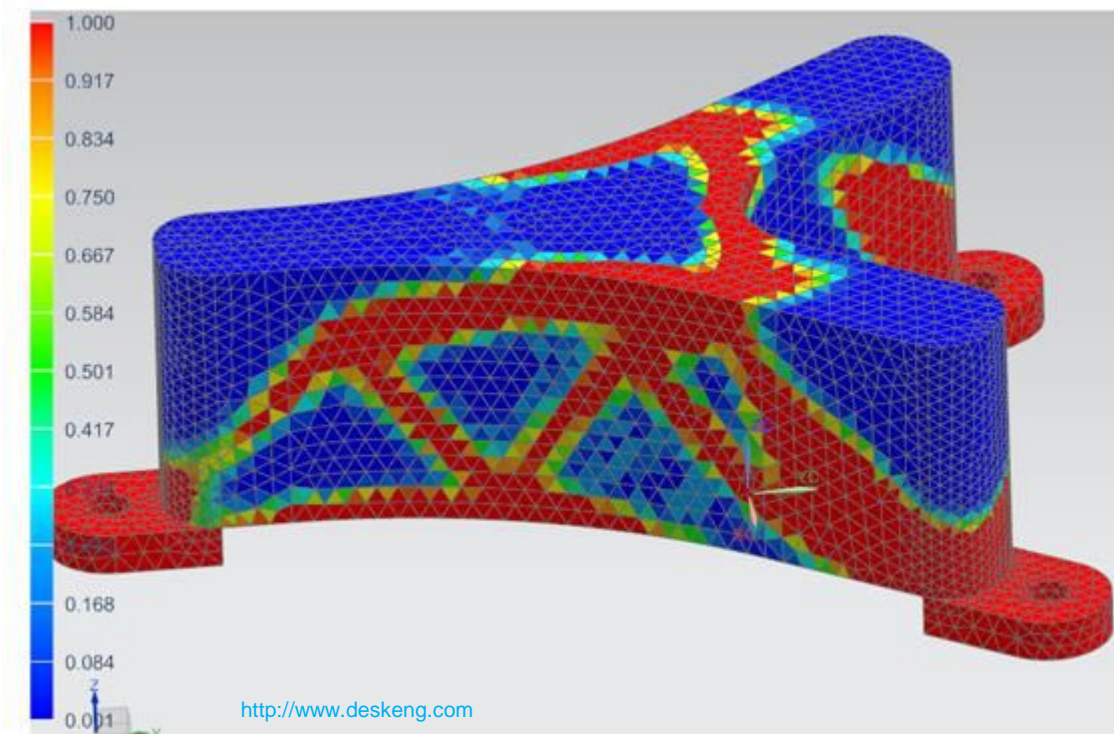


[metal-am.com](http://metal-am.com) / ARUP

# Electron Beam Melting



# Topology optimisation - simple illustration



# The Project

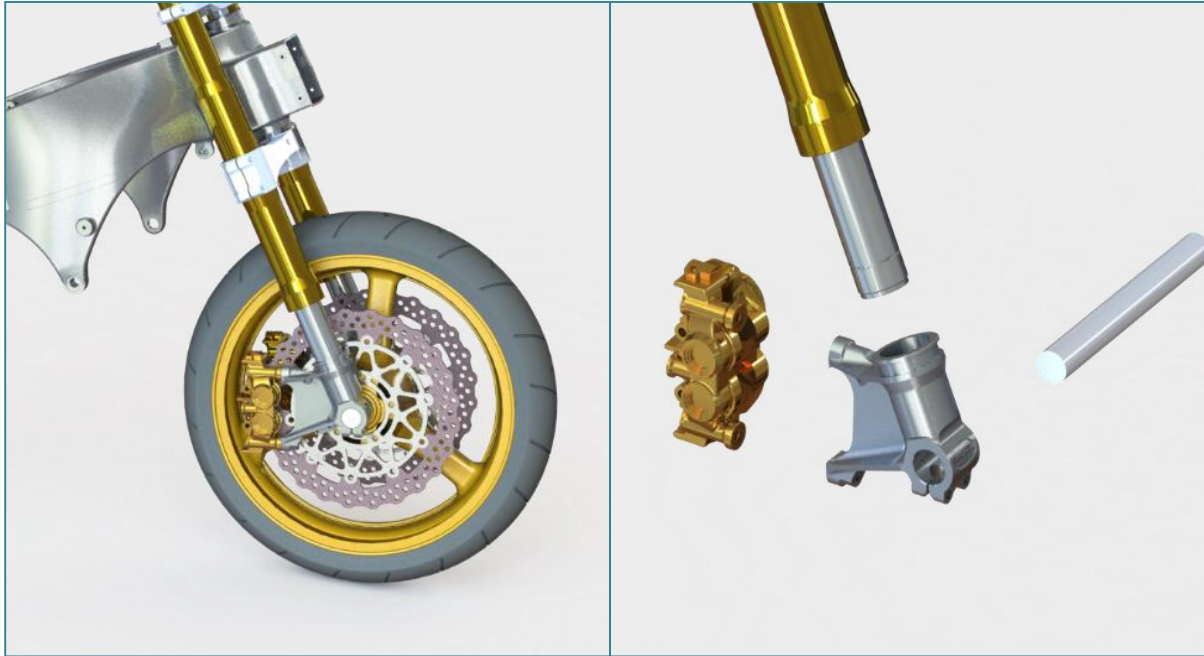
# GOAL: Understand rules for AM optimisation



*Image: Copyright Scott Jones, via K-Tech*



# Component: Fork end



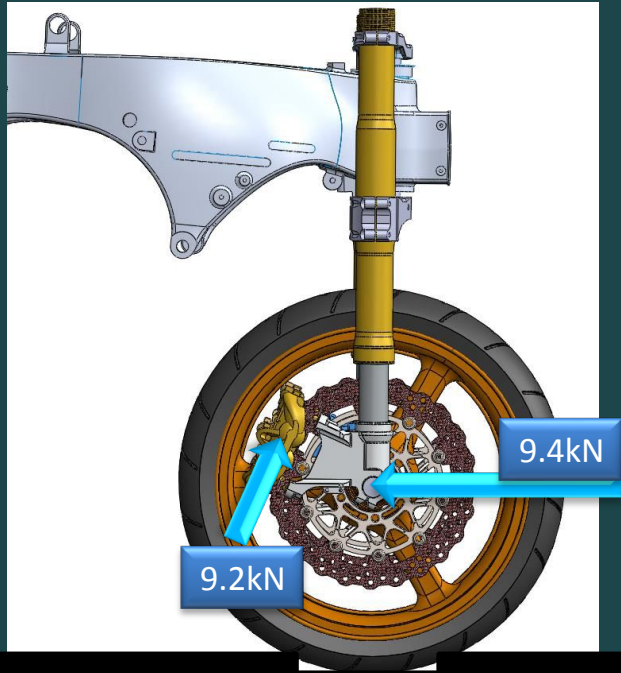
*Modelled by K-Tech*

Current design

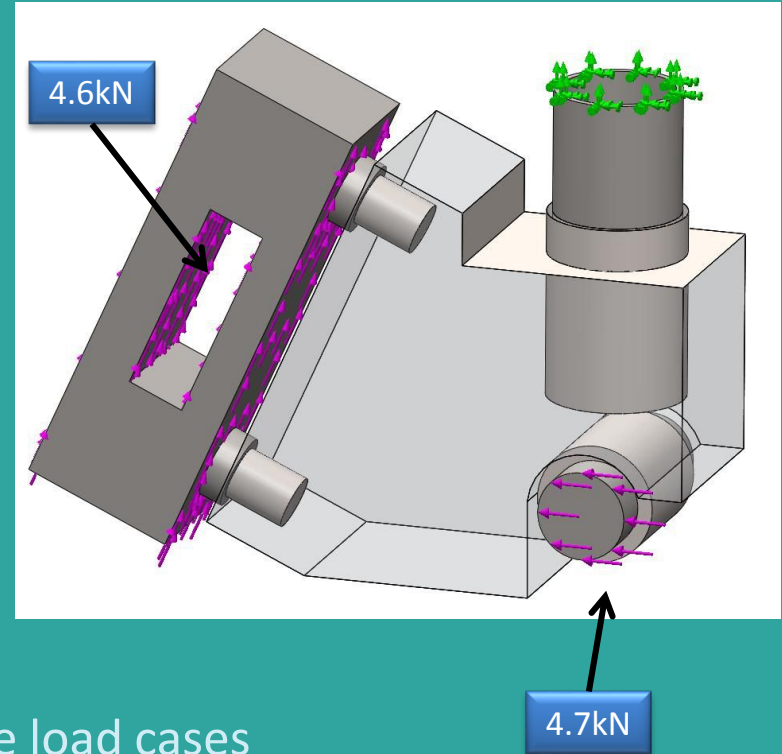


Road bike  
construction:  
Machined 6082-T6

# 3g braking into a pothole



# Design volume

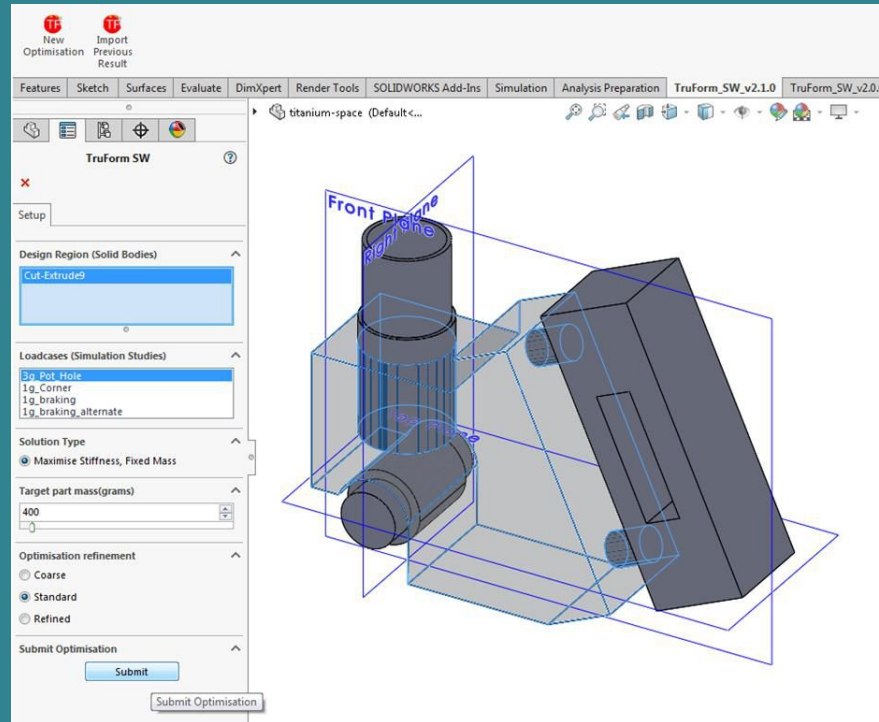


Repeated for alternative load cases

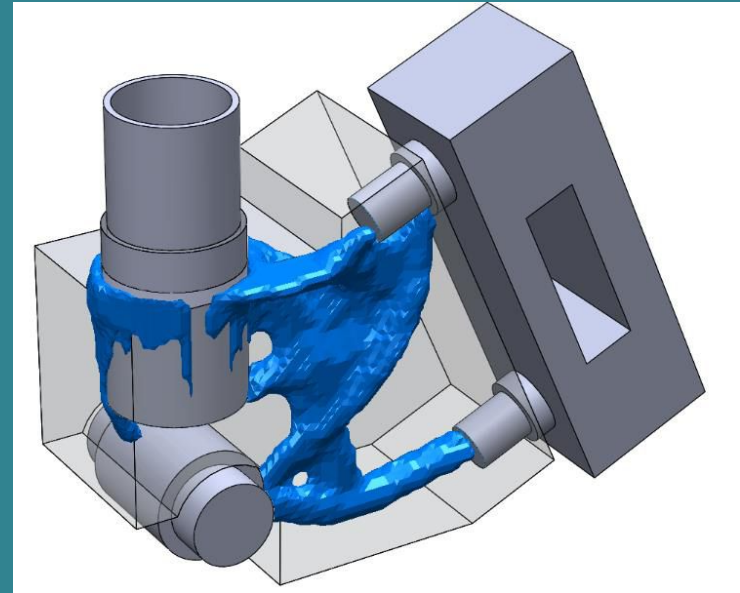
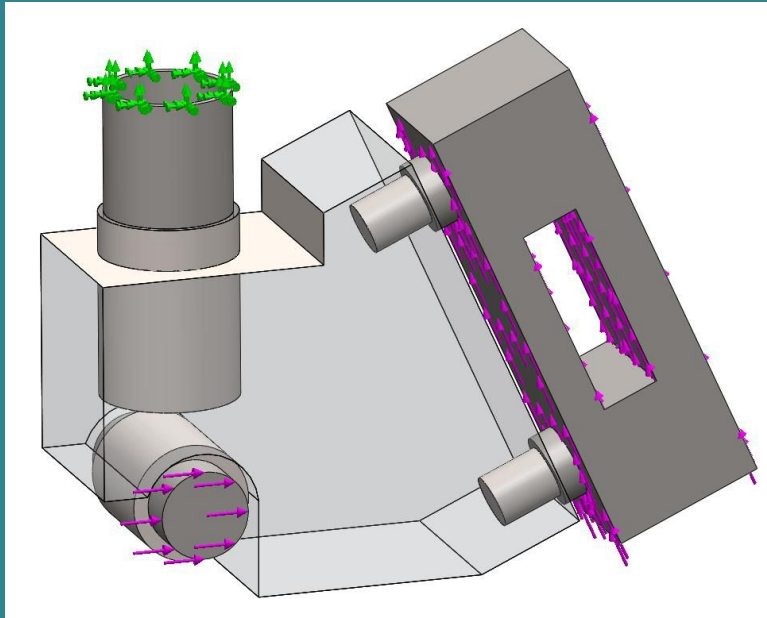
# Selective Laser Melting material choices



# Designed Using Truform in SW environment



# Topology Optimisation: The algorithm suggests a solution

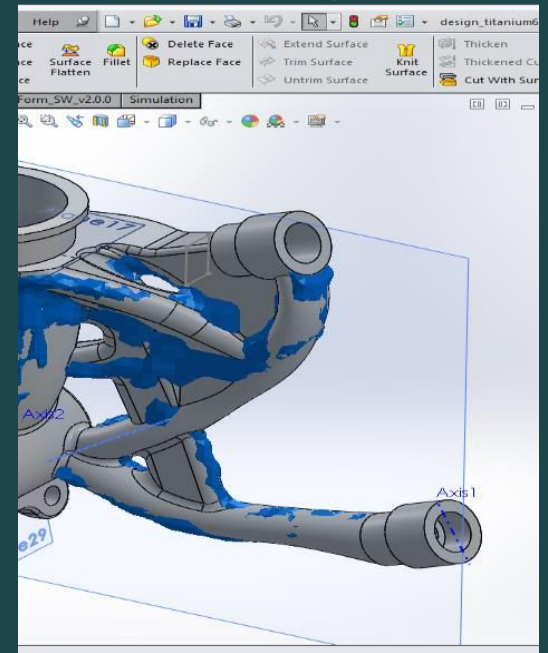
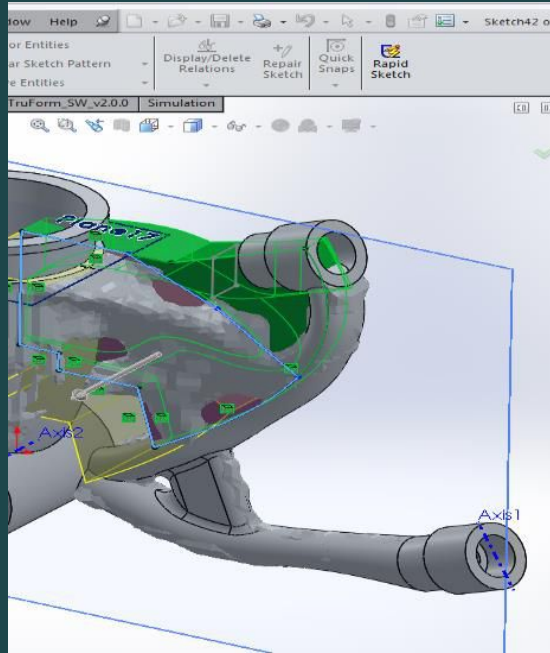
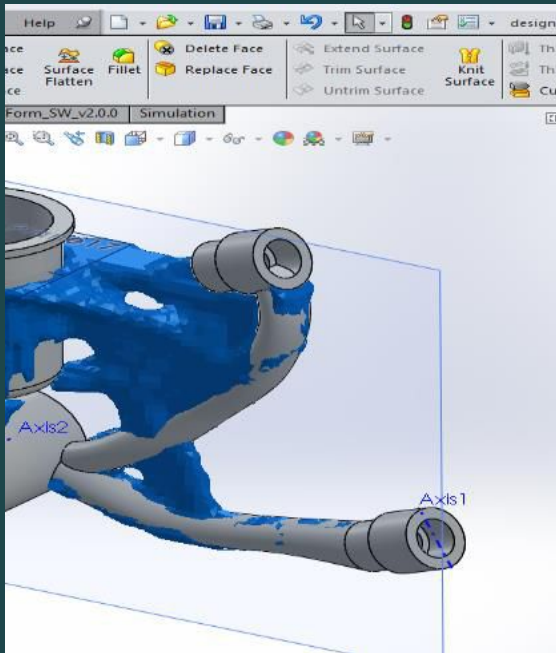


# Remodelling

1

2

3

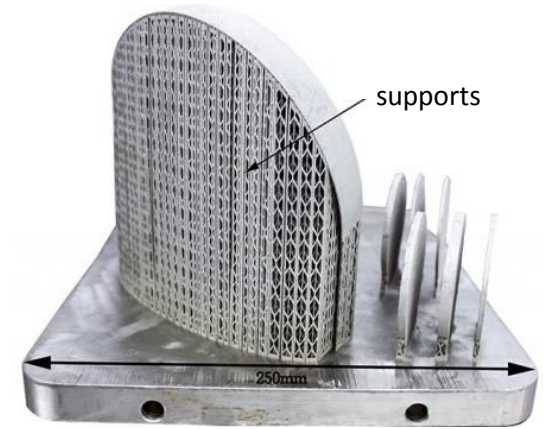


# Workshop: Important DfM considerations for metal powder bed AM design

- ▶ “Supports” (actually anchors).
- ▶ Feature sizes, holes, orientation.
- ▶ Surface texture – will need post processing.
- ▶ Material.

# Support Structures in SLM

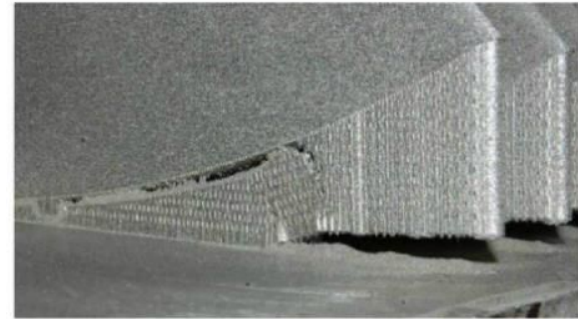
- Added during build preparation
- Fix the part to the platform
- Prevent distortion and delamination
- Manage large thermal gradients



Courtesy of [www.croftam.co.uk](http://www.croftam.co.uk)

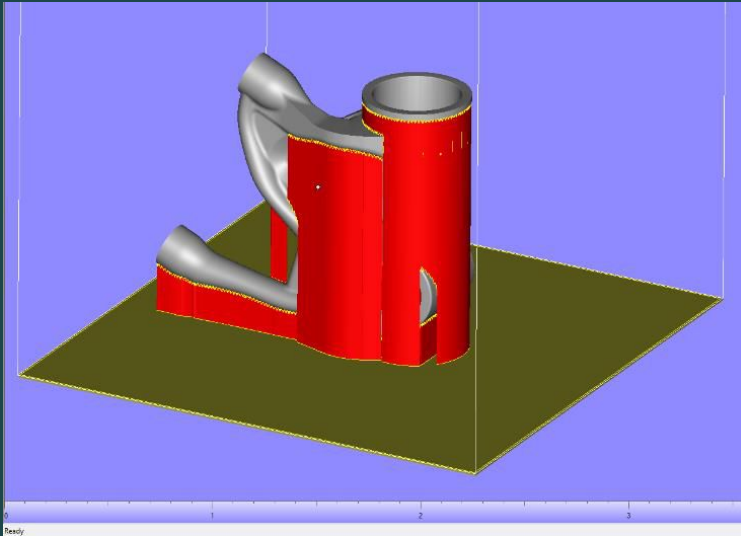


<http://www.digital-engineering-magazin.de>

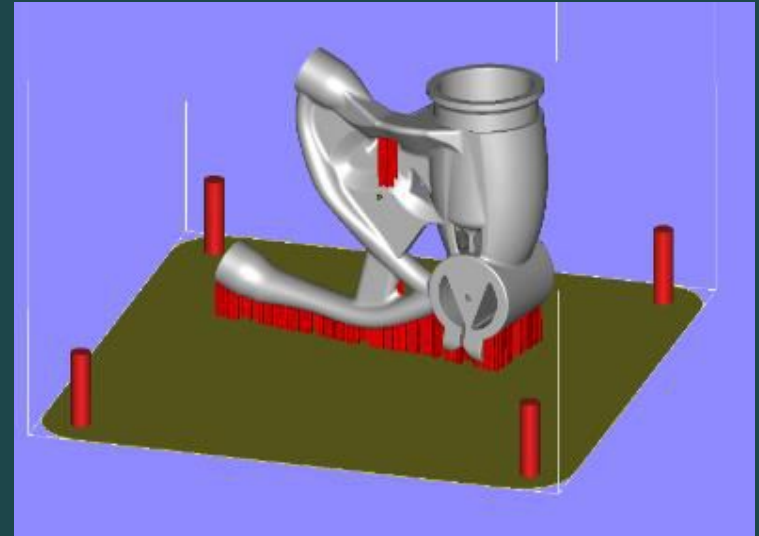


<http://www.crucible-design.co.uk/>

# Remodelling for supports



▶ Modelled for function



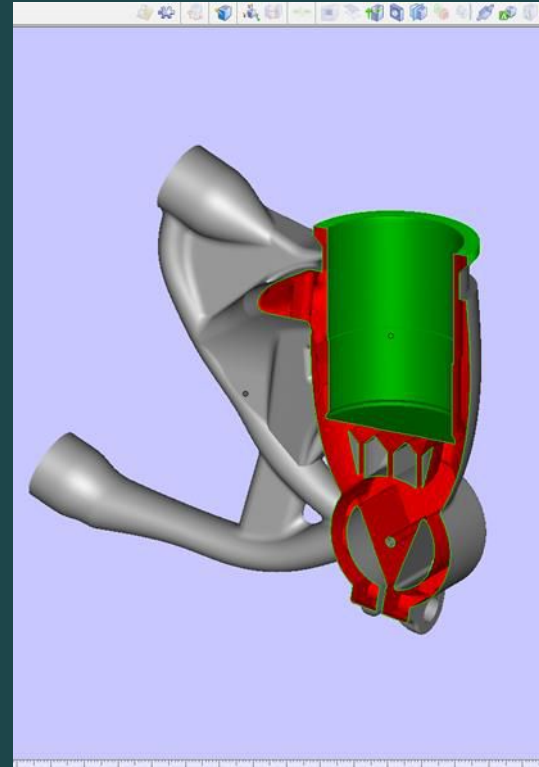
▶ Optimised for supports

*Supports added using Magics*

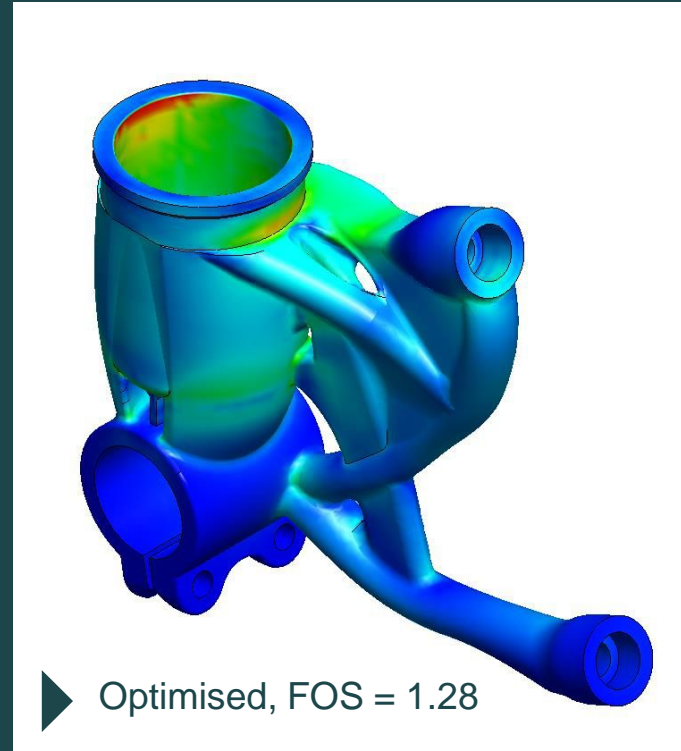
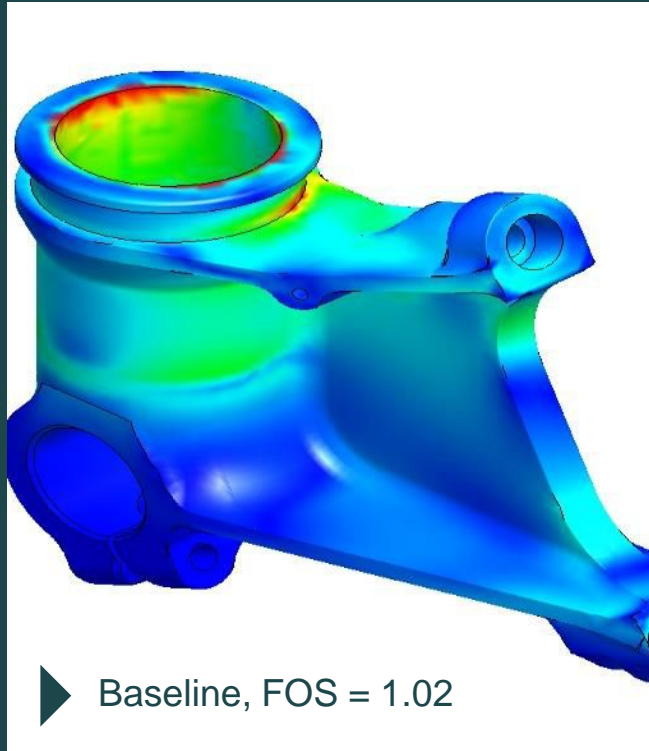
# Combat fatigue

Allow for improving surface texture by:

- ▶ Machining interior (green area)
- ▶ Grit blasting exterior (grey area)

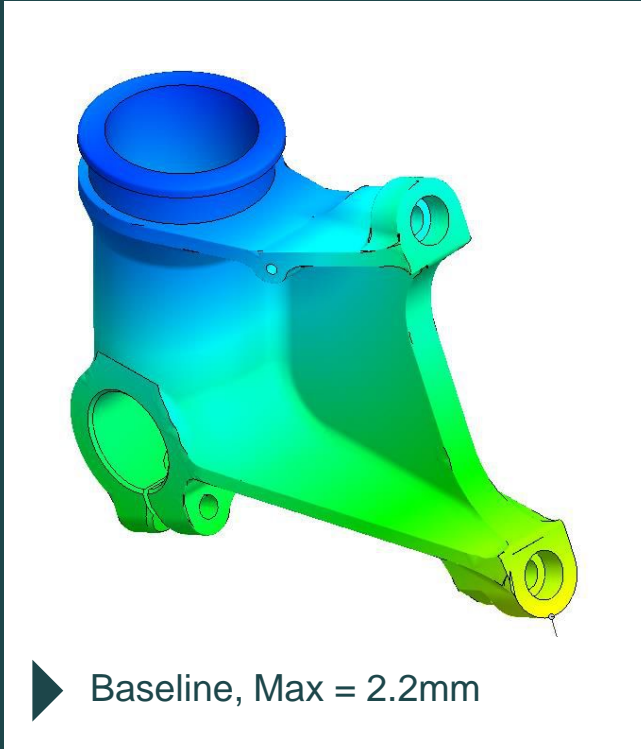


# Validation and comparison - Stress



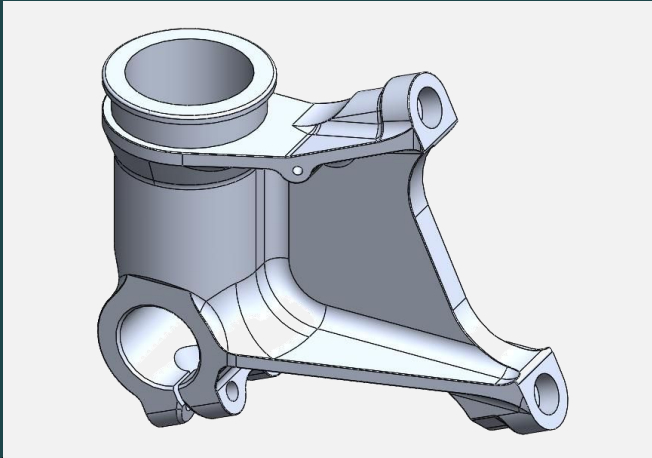
*Simulation by GRM using SolidWorks Premium*

# Validation and comparison – Displacement



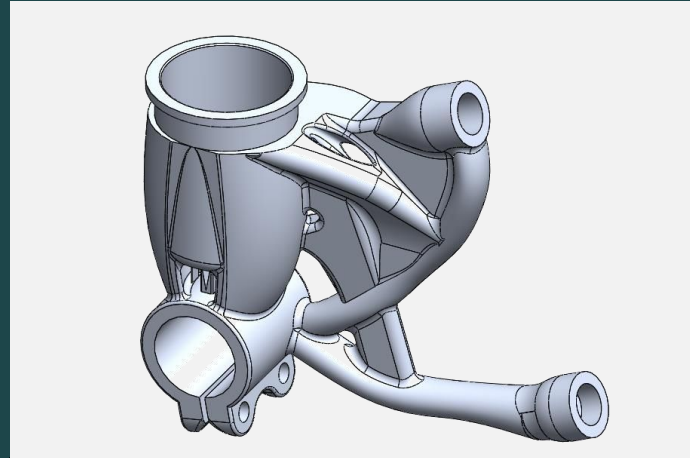
*Simulation by GRM using SolidWorks Premium*

# Before



Material	6082-T6
Mass	570g

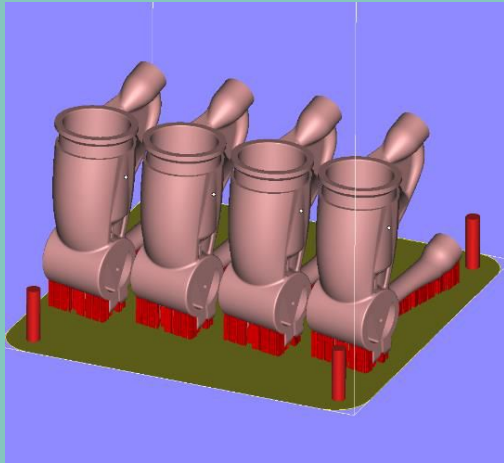
# After



Material	AlSi10Mg
Mass	419g
<b>Saving (both forks)</b>	<b>-302g</b>

# What will it cost for AM build?

Batch of 4



Cost for build

Pre-process files 5 hrs

---

Operator for build 5 hrs

---

Build (depreciation) 65 hrs

---

Powder @£80/kg

---

Post-process £ 230

---

*Per component ~£1,200*

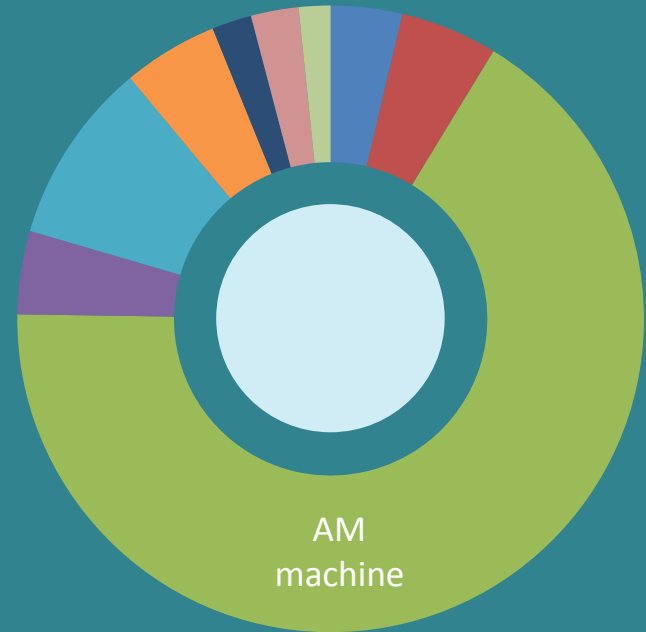
---

*~£2.5K /Kg*

# Cost Factors

Machine utilisation is the main factor

- ▶ Model prep
- ▶ Operator
- ▶ Machine
- ▶ Powder
- ▶ Residual stress HT
- ▶ EDM (removal)
- ▶ Fettle
- ▶ Blast



# Result

- ▶ Too expensive for mass production.
- ▶ How about for race use?
- ▶ Race spec alloy is 7075-T6.
- ▶ AlSi10Mg can't match those properties.

# Next question

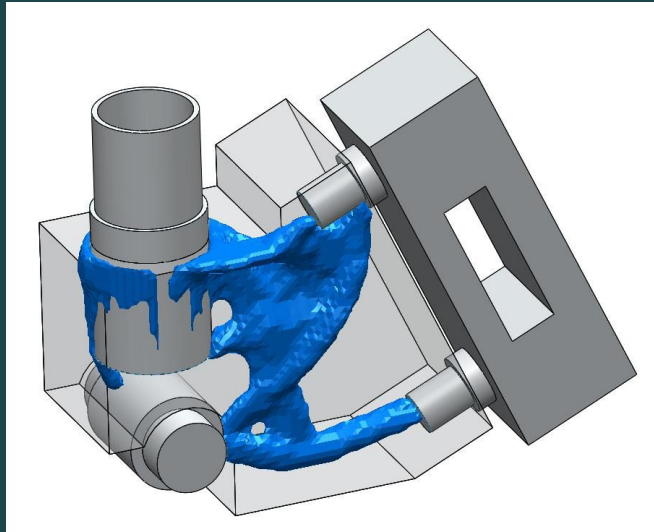
- ▶ Can Ti can provide a race solution?
- ▶ Ti build cost similar or less than Al.
- ▶ Are a few tenths worth £2,400?



*Image: Courtesy of Jon Jessop photography, via K-Tech*

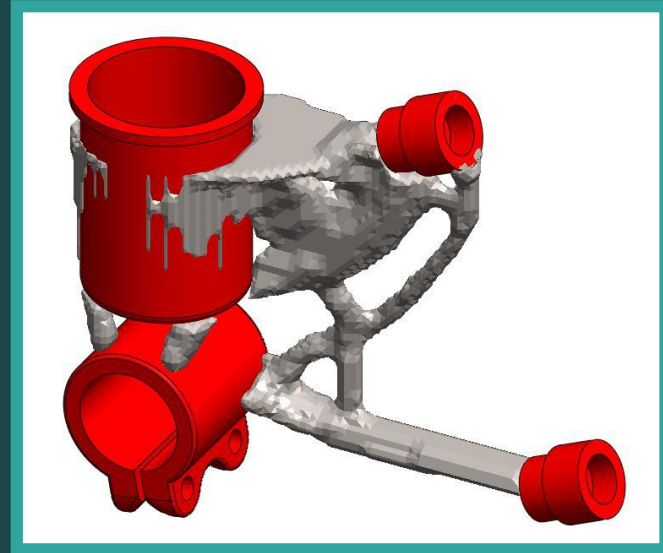
AlSi10Mg

E-Modulus 65 GPa  
UTS 325 MPa  
Yield Strength 220 MPa  
Ductility ~ 9%



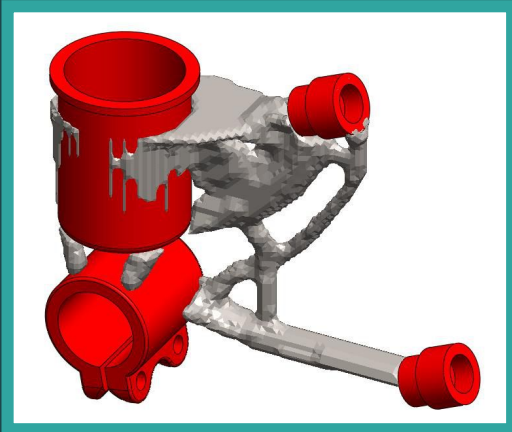
Ti6Al4V

112 Gpa  
1050 MPa  
930 MPa  
~ 9%

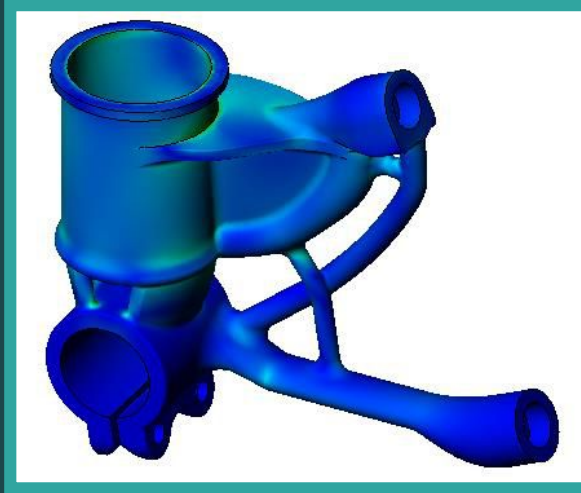


# TopOp Iterations for Ti64 model

- ▶ Optimal
  - ▶ Too spindly

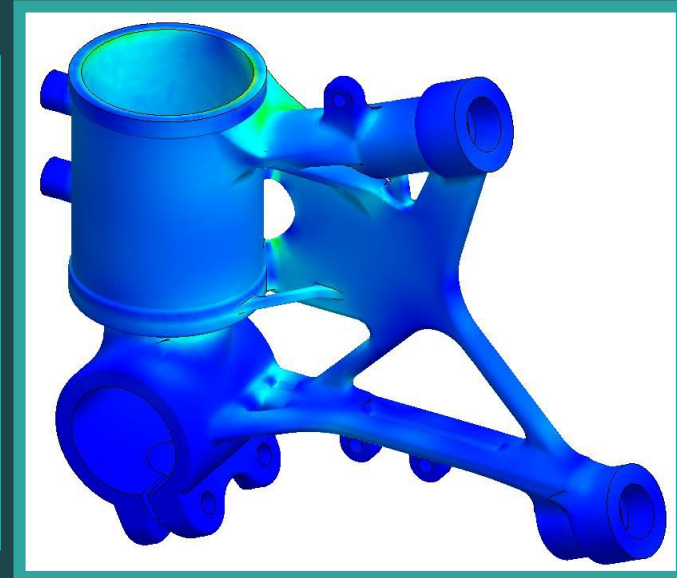


- ▶ Hollow struts
  - ▶ Disconcerting



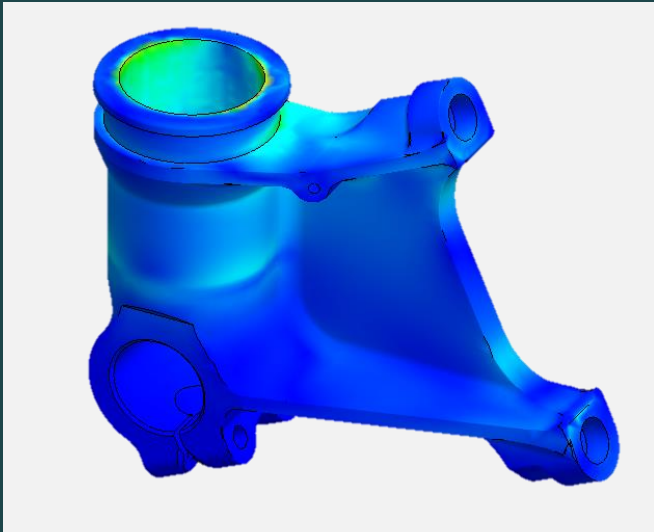
495g

- ▶ Restricted Design Space
  - ▶ Just right



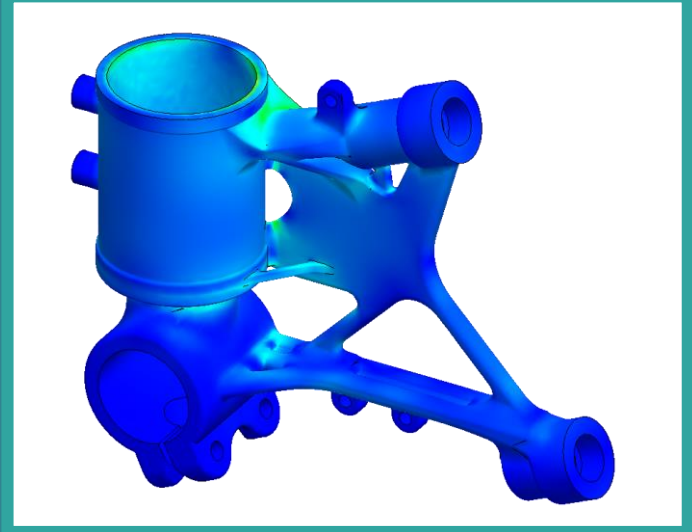
520g

# Before – Machined Al



Material	7075-T6
Mass	570g
FOS	2.1

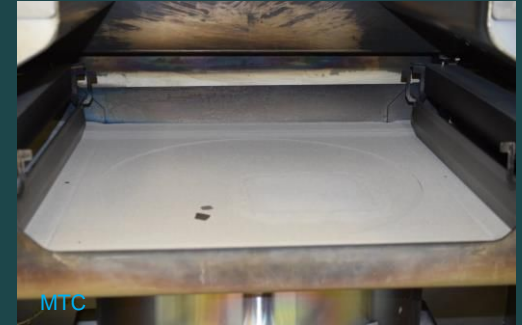
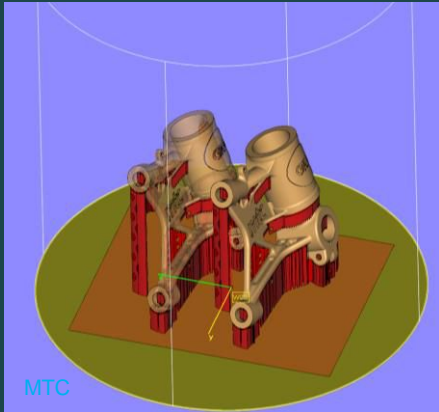
# After – AM Ti64



Material	Ti6Al4V
Mass	520g
FOS	3.1
Fracture toughness	~ x3
Saving (both forks)	-100g

# The build, and post-processing

# EBM Build Set & Powder Recovery Process Flow



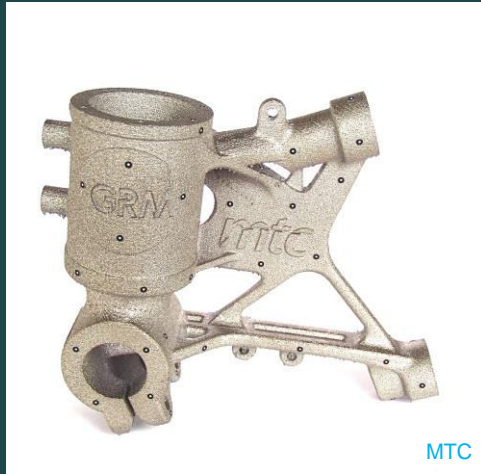
# It's not just the build: next steps

- Support removal
- Blast surface
- 3D scan dimensional check
- CT Scan or other NDE
- Surface finishing

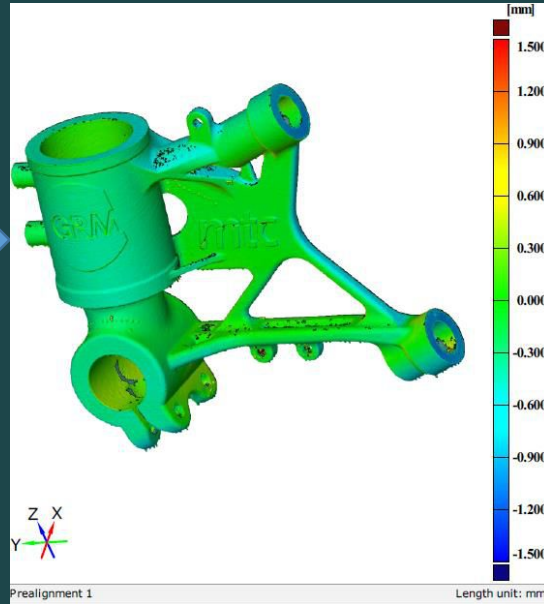


- Toolpath setup
- Jig preparation
- Machining
- Final inspection

# EBM Support removal, NDE and final blasting



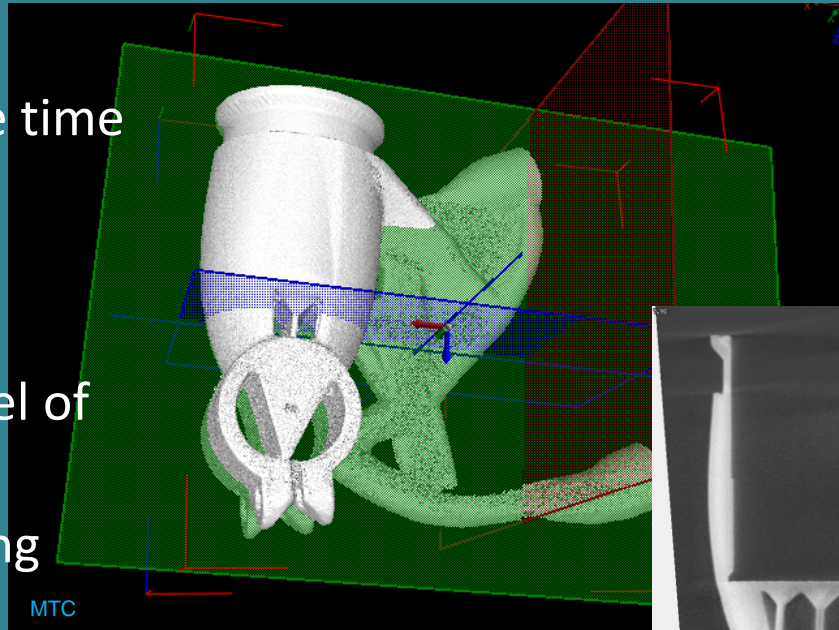
MTC



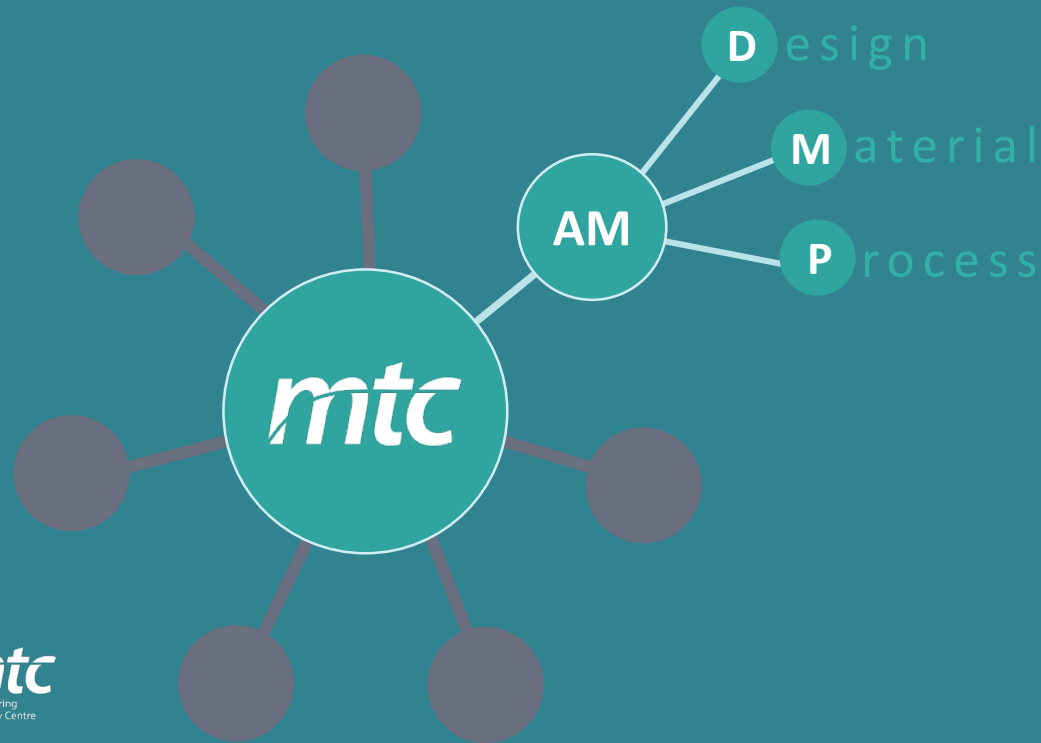
MTC

# Post-build inspection is key

- ▶ Material is created at same time as geometry
- ▶ Possibility of non-perfect material creation
- ▶ Design for an expected level of material porosity
- ▶ Several methods of checking material
- ▶ Xray CT scan is most convenient



# MTC is working to industrialise AM



- Standards
- Quality control
- Process insertion
- H & S
- Powder characterisation
- Workshops
- Case studies

# Who is the MTC Reach program for?

Any business in one or more of these scenarios



12. We need to change our manufacturing process - but don't know where to start!

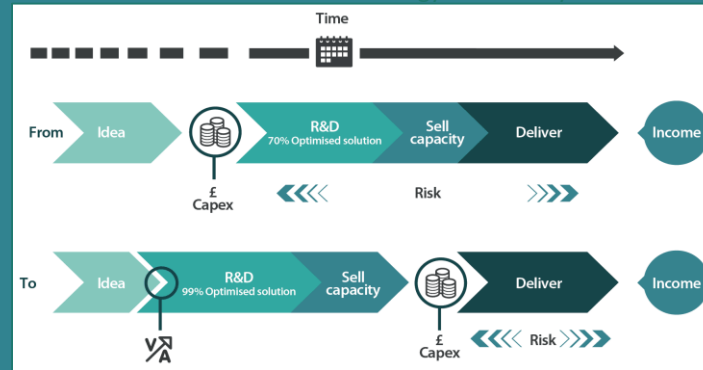
Fig 1.1: Scenarios typically faced by a small or medium business

## The MTC Reach goal;

*'Help SMEs across UK supply chains use manufacturing technology to raise productivity'*

The MTC has developed over 100 *value accelerators*. A value accelerator is any toolkit, methodology, or transferable best practice that;

- improves productivity
- reduces cost
- embeds innovation
- de-risks the use of new technology in a factory



The value accelerators will be of interest to any business wishing to engage with new – or new to them – manufacturing technologies

The MTC offers a *complimentary* review of your operations. This can discover opportunities for cost saving, de-risking and accelerating the introduction of technology and improved processes into your business.

If an SME invests in 5 days of support from the MTC, up to a further 5 days of funded support may be available. If an SME invests in additional support, again matching days may be funded.

To find out more contact: [handbook@the-mtc.org](mailto:handbook@the-mtc.org)

+44 (0) 2476 701 667

# Thank-you

We would like to thank CASIM and the Catapult 3DP Forum for part-funding this project.



## DISCLAIMER:

The data contained in this document contains proprietary information and it may not be copied or communicated to a third party or used for any other purpose than that which it was supplied without the MTC's prior written consent. © MTC

For more information please contact:

[Andrew.Triantaphyllou@the-mtc.org](mailto:Andrew.Triantaphyllou@the-mtc.org)

**Manufacturing Technology Centre**

Pilot Way

Ansty Business Park

Coventry

CV7 9JU

[www.the-mtc.org](http://www.the-mtc.org)