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Additive Manufacturing & Solutions Centres

Clive Martell
Head of Global Additive Manufacturing
Renishaw plc

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Agenda

- **Additive manufacturing overview**
- Marketing Strategy
- Product roadmap
- Solutions Centre overview

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NB please note that some of the following slides vary slightly from those used at the Investor Day on the 12th May due to the reformatting of some of the animated slides.

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Technology definition – Laser powder bed fusion

- What is additive manufacturing (AM) and 3D printing?
  - 3D printing - generic term covering polymer and metal layer based manufacturing processes.
  - Industrial machines - referred to as additive manufacturing systems – or AM.
  - **Renishaw** AM systems produce functional metallic components from layers of atomised metallic powders – referred to as ‘Laser powder bed fusion’.

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The process – Laser powder bed fusion

- How does it work?
  - The process starts with digital data in the form of a Computer Aided Design (CAD) file.
  - QuantAM, Renishaw's file preparation software slices 3D CAD data into layers.
  - A machine readable file is created containing all the build data, such as the laser path etc
  - The data is used to guide the laser beam and control the intensity, applying energy only where needed to weld the metallic powder to form the finished object.
  - The process is repeated layer after layer until a completed 3D object is produced.
  - Unused raw material is then refined and re-used.

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Why AM for Renishaw?

Q. Why did Renishaw choose to get involved in the additive manufacturing industry?

A. It's an emerging manufacturing technology in sectors where Renishaw is already a leader.

Q. Why additive metal?

A. The scope for complex metal objects is vast – AM has the potential to unlock hidden performance benefits!

Q. Why now?

A. AM systems are in their infancy comparatively speaking and require a step change to be fully accepted in volume manufacturing.

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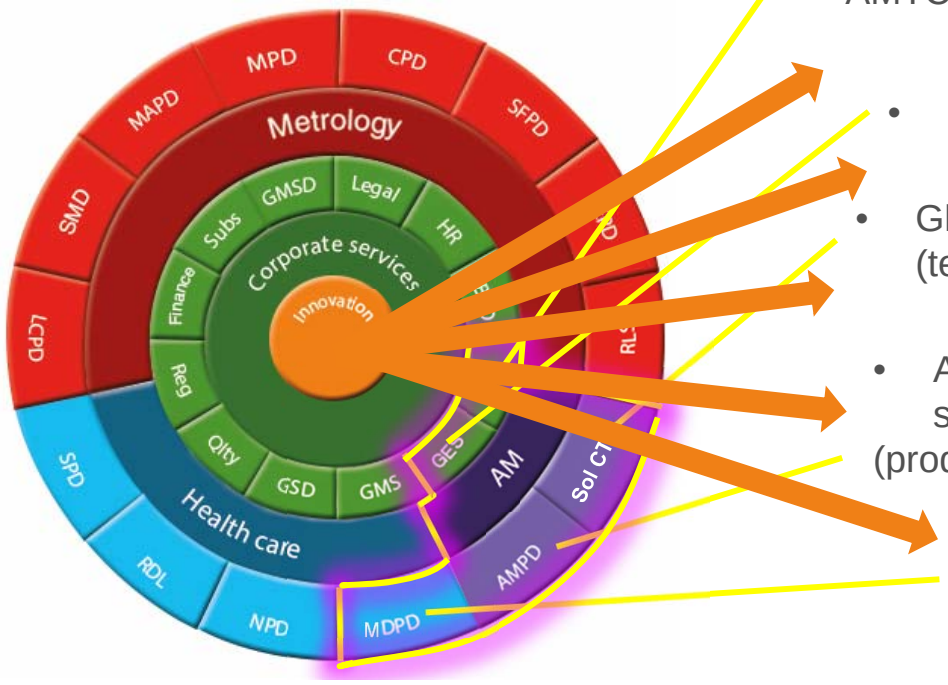
Corporate AM strategy – how we are organised

- Organisational structure



- AMTC, New Mills (technology development)
- Group Software Charfield, Pune, & Stone
- Global Solutions Centre Business unit (technology access)
- AMPD focused on integrating the complete solution - platform & process (product development & marketing)
- MDPD specialist focus on AM ‘healthcare’ applications

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Metal AM market – technology trends – near term/now

Technology demands	Why	Comment
In-process monitoring	Quality & stability	In progress
Multiple lasers	Productivity & efficiency	In progress
Automated powder recycling	Safety & reduced labour content	RenAM 500M
Higher laser power	Productivity & exotic materials	RenAM 500M
Larger & smaller build volumes	Prototyping & entry-level	Under review

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Metal AM market – Commercial & operational trends

Commercial/operational	Why	Comment
Distribution & subsidiary development	Local support	76 offices in 35 countries. 8 Solutions Centres
Recruitment of key engineering and commercial skills	Addressing an educated market - stringent demands	Renishaw, strong technical focus. Investment in global support teams
Skills & training gap. Competitors outsourcing. Renishaw network opportunity	Lowering barriers to entry into AM deployment	Solutions Centre approach. Accessible applications expertise. Select specialist partners (e.g. Hieta)
Software development – key enabler- QuantAM is vital and well received.	Tighter integration & better process optimisation	Vital building block for AM Strong education opportunity with QuantAM

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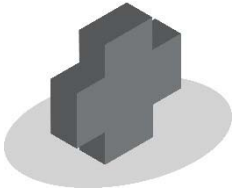
Raising our profile in key sectors

- Key strategic accounts – engagement & capture

– Who?	Key OEMs.
– Why?	Respected key accounts that offer credibility, influence supply chains and demand more industrialisation.
– How?	Seeding the market at selected partners. Clear terms of engagement. Solutions centre pathway, finance.
– Where?	Global support infrastructure already in place.



Medical

Aerospace

Automotive

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Strategy – Customers #1

- Major manufacturing OEMs.
  - Multiple machine sales opportunities – reduced cost of sale overall
  - Key driving force in supply chain – influence system choice with T1 & T2 suppliers
  - High professional standards – structured & planned approach
  - Have a long term vision for AM integration – Board level AM strategies
  - Have design or specification rights on their products – key for enhanced value prop.
  - Expect to ‘engineer in’ the benefits of AM into the part – long term vision
  - Already Renishaw customers for Metrology products - access

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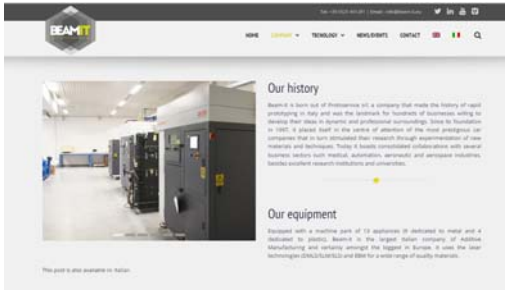
Strategy – Customers #2

- Research institutes and educators
  - Access to next generation of engineers – skills gap
  - Places us in partnerships supporting OEMs – funded projects
  - Seed bed for future sales into OEMs – many gain 1st sight of our products
  - Potential for new materials/innovations/etc
  - Yields scientific data about our tech. – independent respected view

- Bureau (sub contract manufacturers) two types…
  - 1. ex Rapid Prototyping bureaus
  - 2. New entrants from ‘traditional’ manufacturing



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Hardware & software product portfolio

AM Product portfolio

AM400
400W/70um
Release Q2 2016 (CY)

QuantAM 2016
File preparation software
Released January 2016

RenAM 500M
Production machine
Ship H2 2016 (CY)

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AM400 platform at a glance

- Aimed at users who require flexibility of materials
- Increased laser power (compared to AM250)
- Class leading low cost of ownership
- Low gas consumption & rapid chamber preparation using vacuum
- Class leading build atmosphere (Ti runs at <10ppm O_2)
- Smallest factory footprint
- Key safety features including glove box

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RenAM 500M at a glance

- Aimed at industrial users who require a robust productive manufacturing system
- Increased laser power (compared to AM400)
- Sealed powder handing with on board sieving
- Class leading AM400 features maintained
- Based on Renishaw engineered and manufactured sub-systems
- Quality monitoring capabilities

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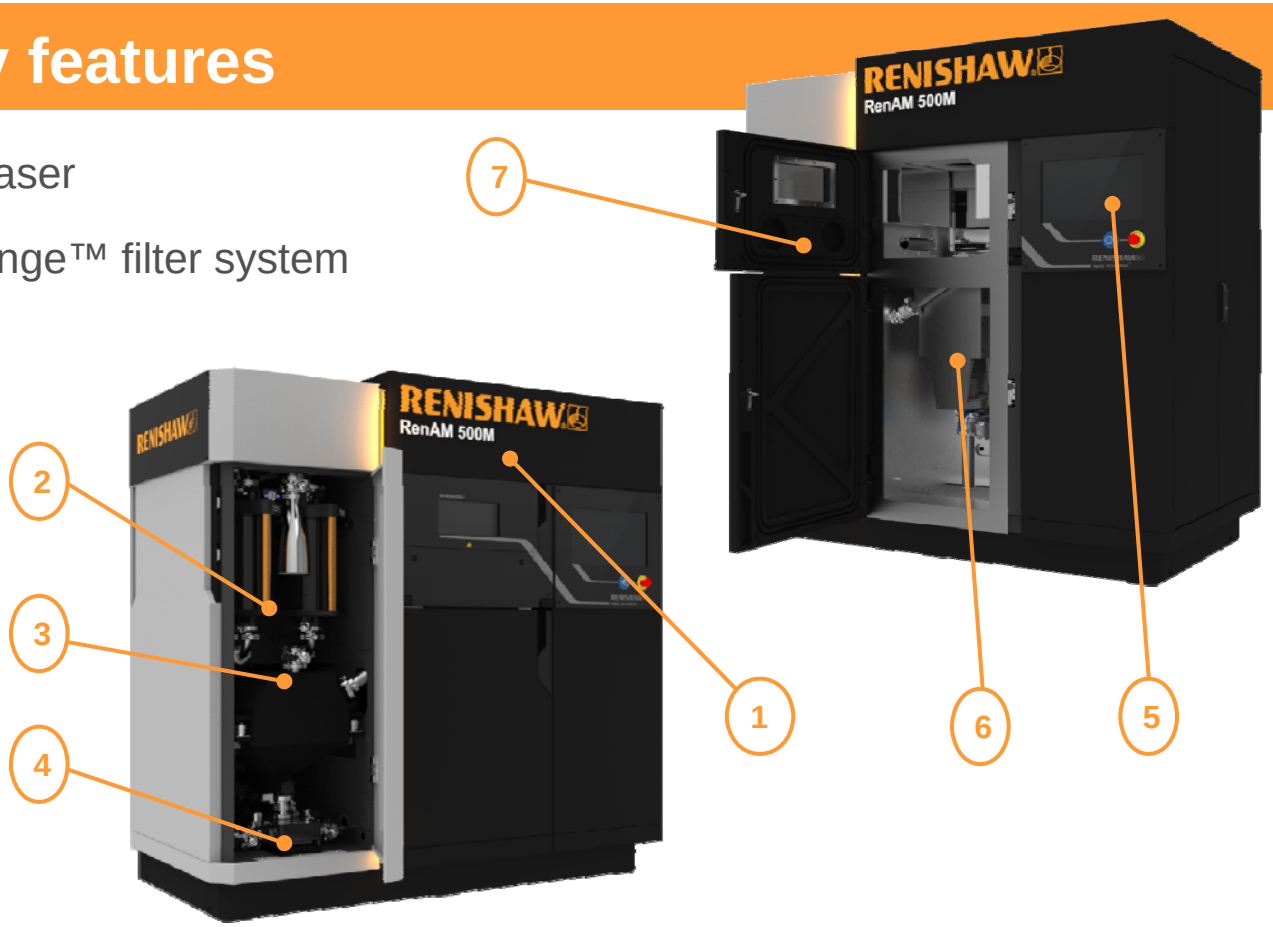
RenAM 500M Key features

1. Optical system with 500 W laser
2. Dual high capacity SafeChange™ filter system
3. Ergonomic load hopper
4. Ultrasonic sieve
5. 19 inch user interface
6. Z-axis with RESOLUTE™ encoder
7. Argon safety glove box



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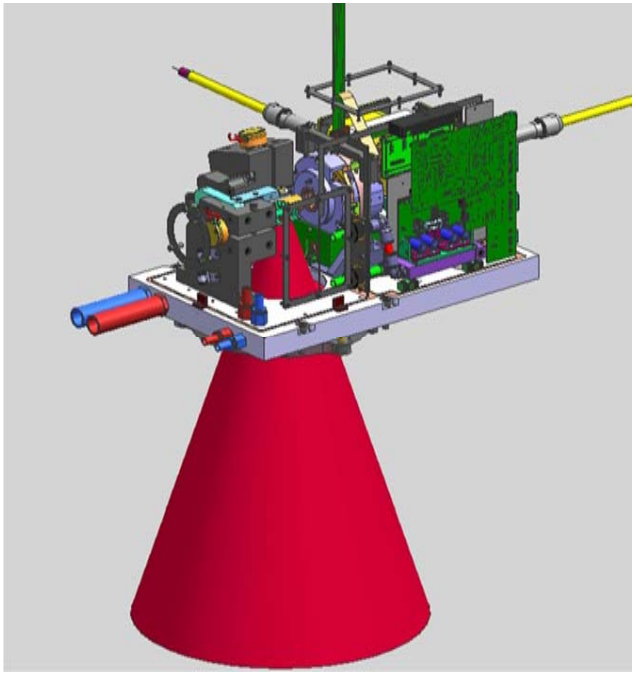
RenAM 500 platform at a glance

Renishaw designed & built optical system



Why it is important

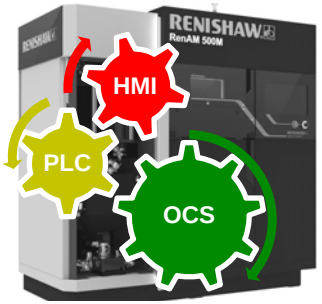
- Allows Renishaw to implement new innovations independently
- Enables close control integration with Software
- Componentry is the fundamental building block for all foreseeable future products
- Acts as a platform technology for multiple laser systems
- Helps us maintain competitiveness through quality and cost control
- Removes dependency on 3rd party suppliers, some of whom are competitors.

RenAM 500M at a glance

Renishaw Control system & software

Why it is important

- Removes reliance on 3rd parties for system control
- Is essential for process control
- Platform for closer integration with file preparation & other software tools
- Essential for future multiple laser systems
- Minimises training burden through ergonomic work flow
- Provides access to build reports and system data for both onboard viewing and data export



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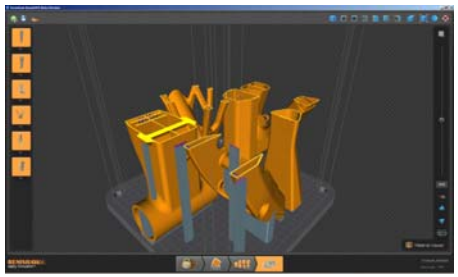
QuantAM software at a glance

QuantAM



Why it is important

- Forms a key part of the integrated process strategy
- Simple to learn and use
- Subscription based licensing
- Essential to allow maximum performance and utility from multiple lasers
- Provides a powerful and responsive tool for process development and optimisation

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Additive Manufacturing Solutions Centres

Marc Saunders
Director – Global Solutions Centres
Renishaw plc

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Levels of Additive Manufacturing deployment

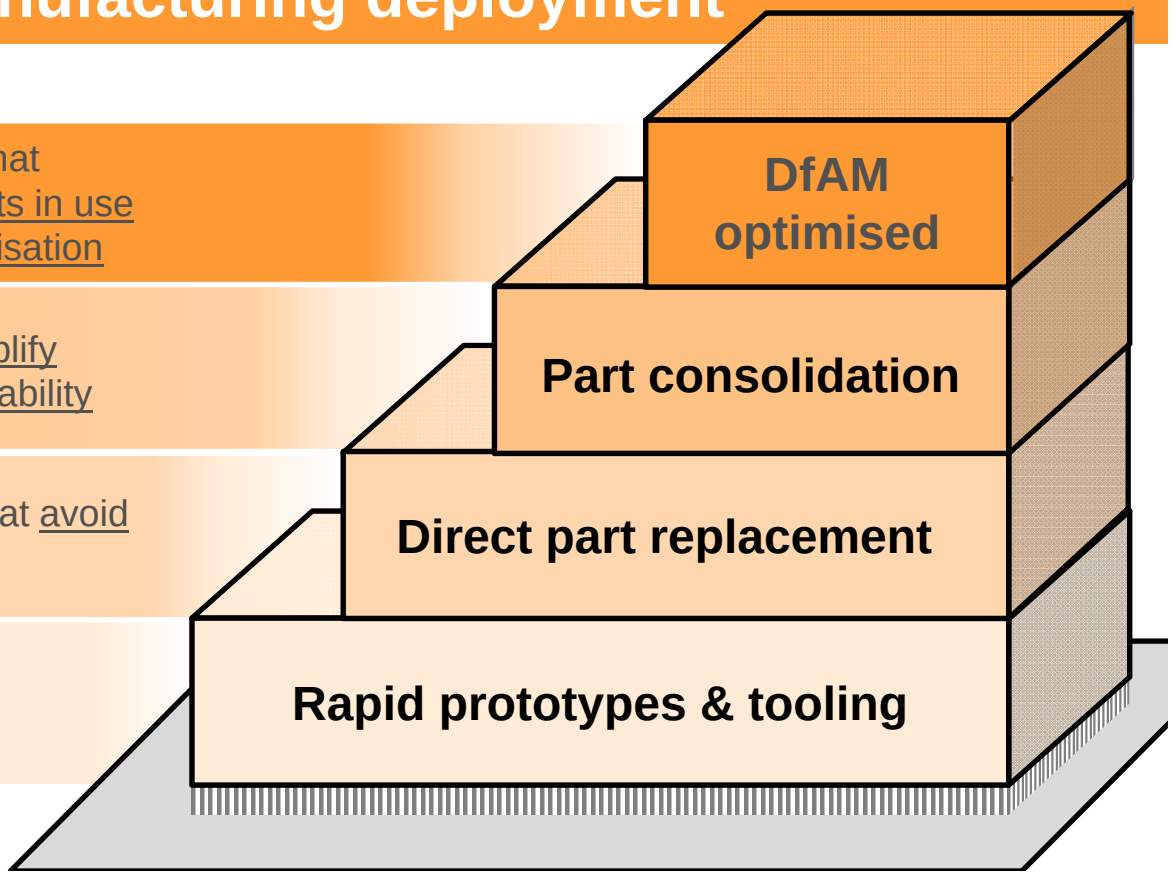
Value creation
Commitment
knowledge

New product designs that
1. Deliver lifetime benefits in use
2. Provide mass customisation

Complex parts that simplify assembly & enhance reliability

Re-production parts, that avoid complex manufacturing

Low volume parts
made direct from CAD



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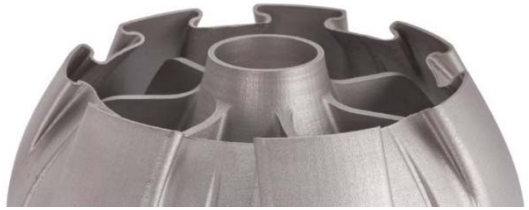
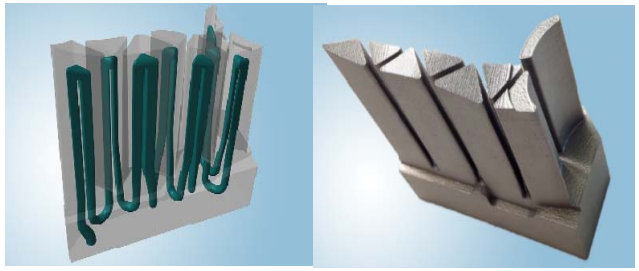
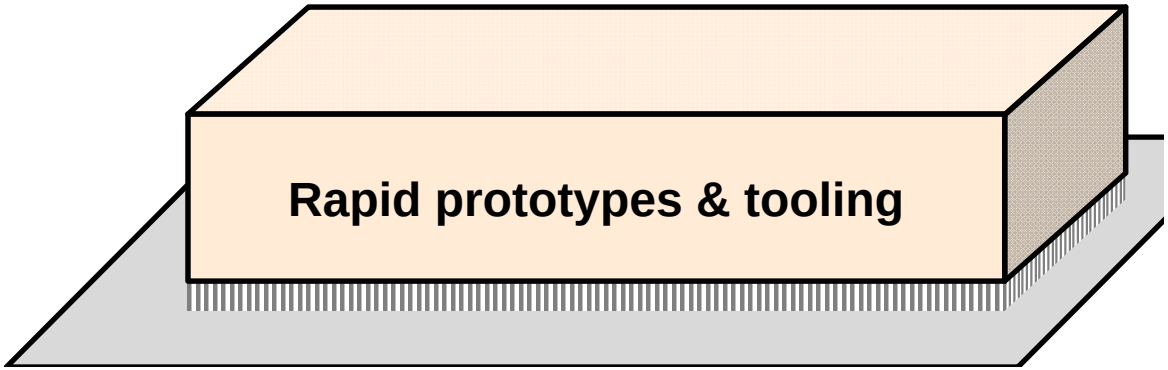
Unique AM capabilities

Repeatable ‘CNC’ process



Conformal cooling





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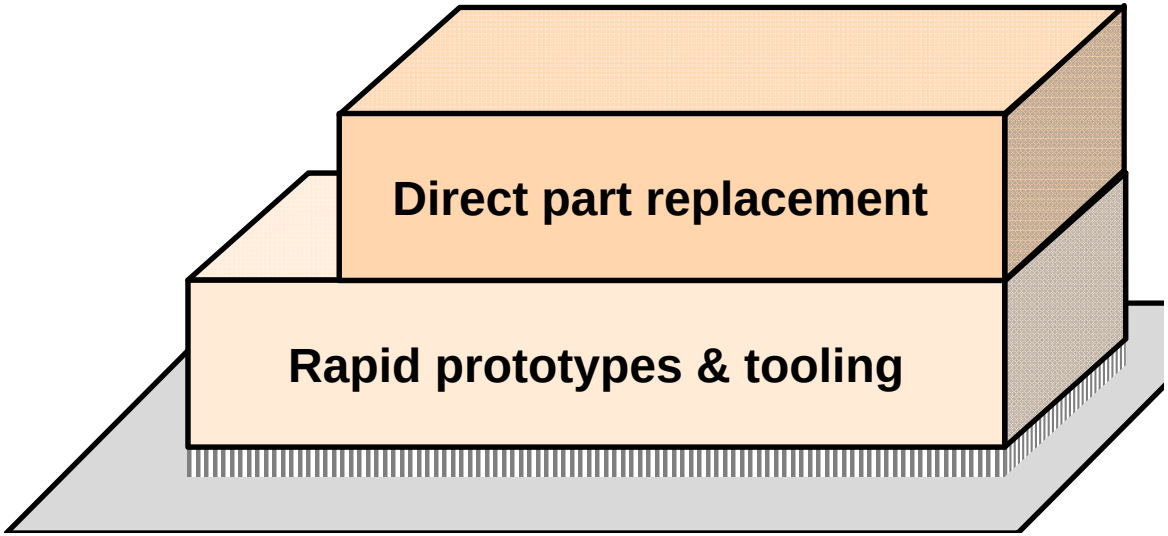
Unique AM capabilities

Near-net-shape manufacture

Localised manufacturing



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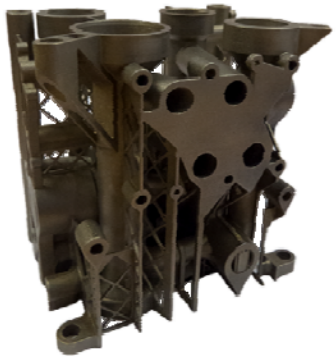
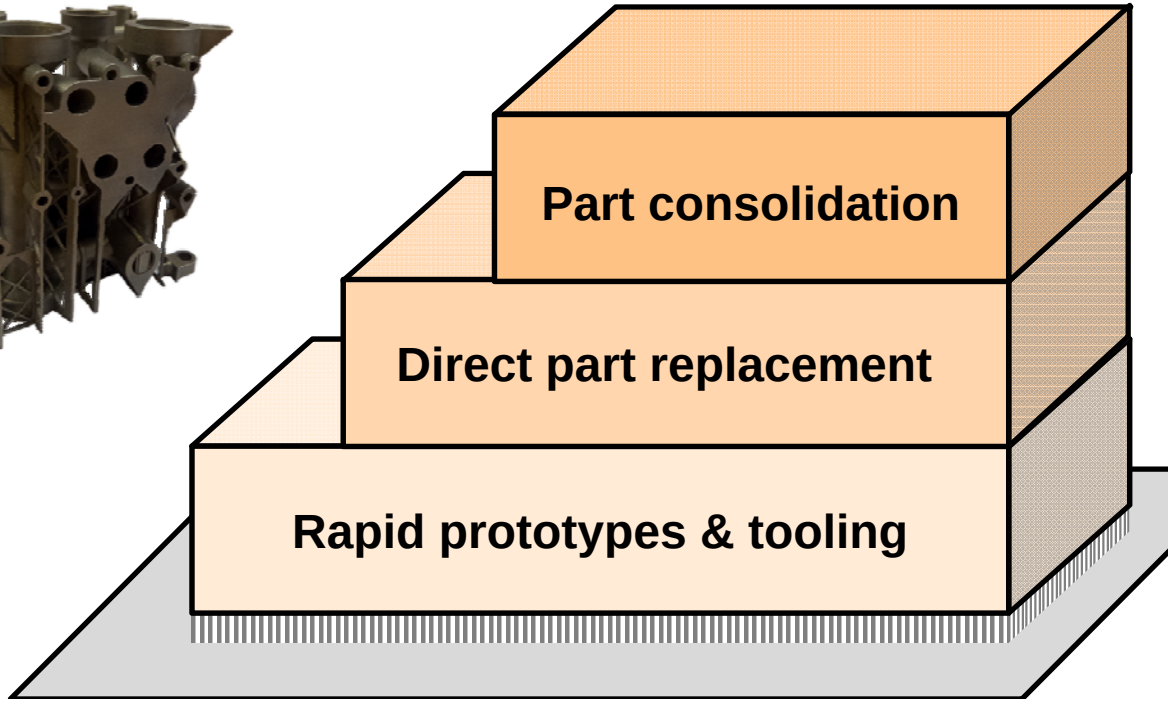
Unique AM capabilities

Removal of joints

Mechanisms

Feature-rich parts





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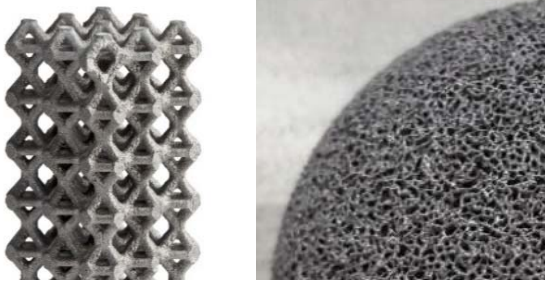
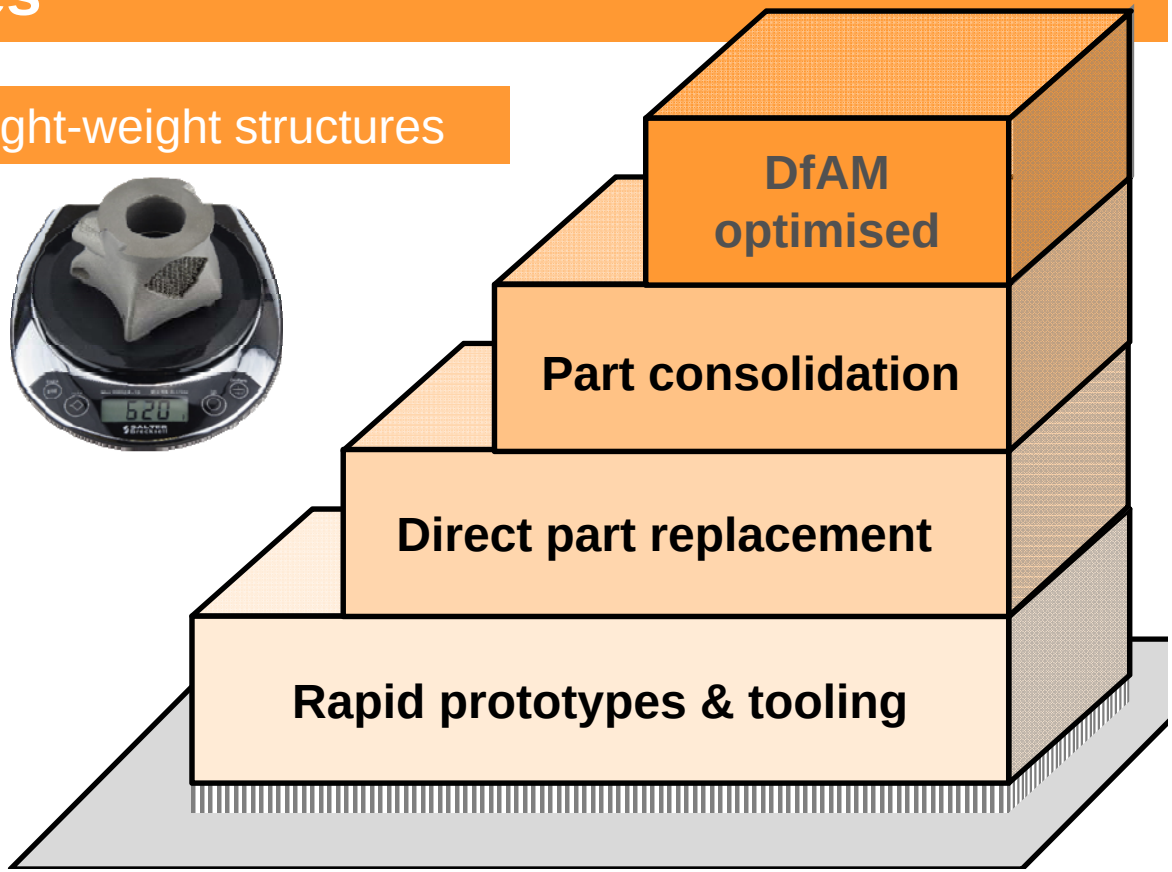
Unique AM capabilities

Topological optimisation

Light-weight structures

Increased surface area





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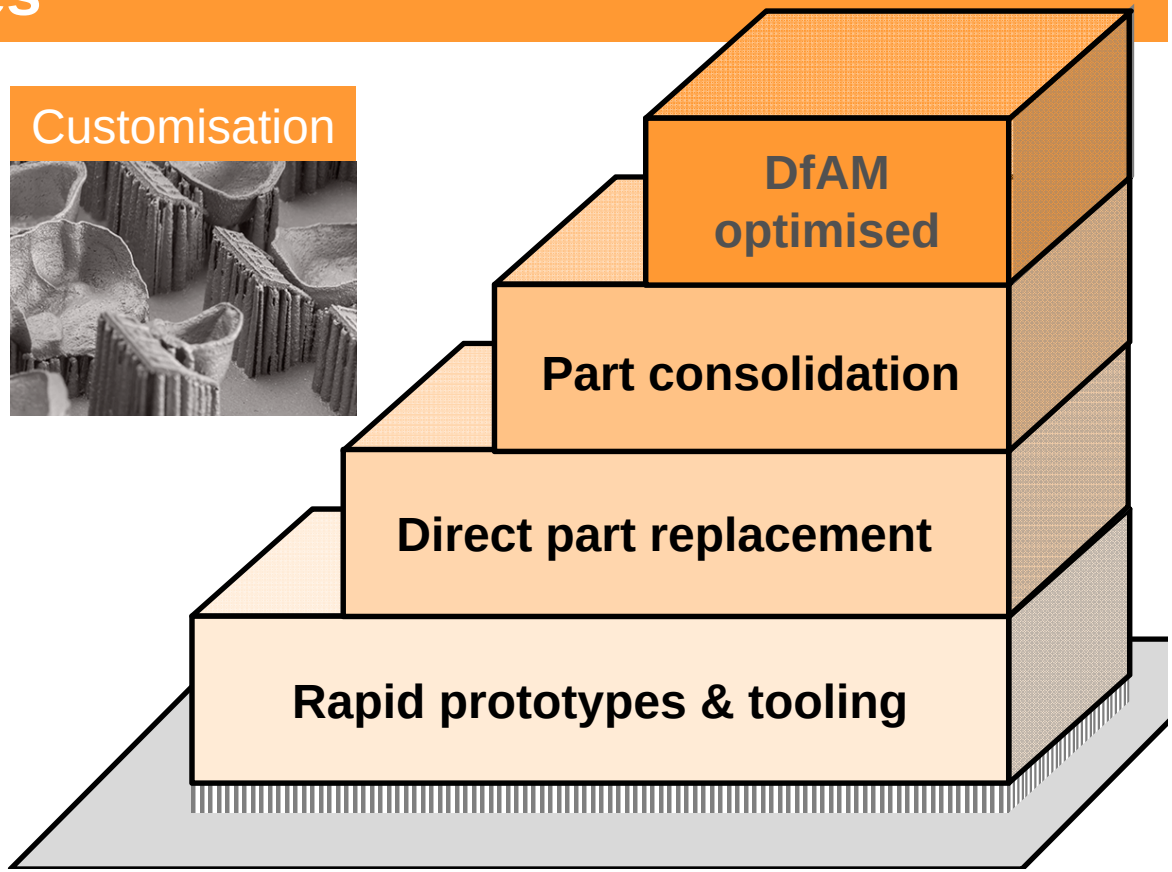
Unique AM capabilities

Heat transfer

Metal foams

Customisation

Build the B.O.M.



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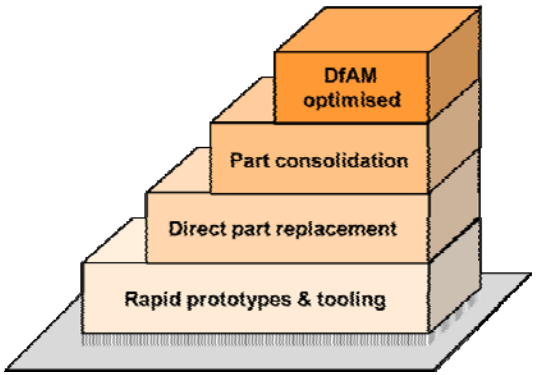
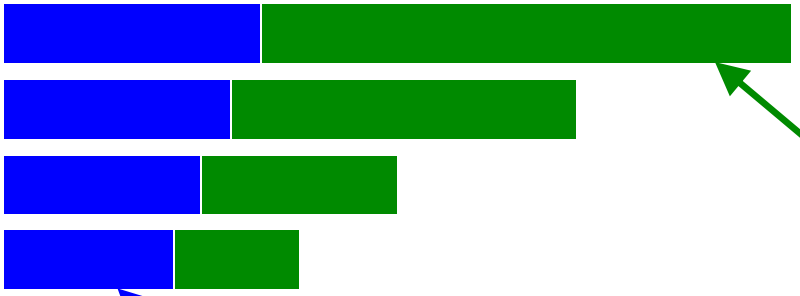
Industrial applications driven by lifetime value creation



Financial benefit →



Production benefits

- £ Less materials
- £ Lower tooling costs
- £ Shorter process time
- £ Shorter lead time
- £ Simpler assembly
- £ Automation

Lifetime benefits

- £ Less weight
- £ Faster product launch
- £ Product reliability
- £ Higher performance
- £ Better adaptation
- £ Product attraction
- £ Reduced stocking
- £ Higher responsiveness

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Few companies are using AM in volume production –

Barriers to AM process adoption

- **What is possible?**
  - Design for Additive Manufacturing (DfAM) knowledge
  - Rapid manufacturing technology change
- **Does it really work?**
  - Time & effort to optimise and validate new designs
  - Qualify and control new processes
- **What else do I need to know?**
  - Finishing operations to complete part production
  - Safe powder handling facilities and practices
- **What is the business case?**
  - Significant costs for initial machine, facility and staffing
  - Quantify performance and cost benefits

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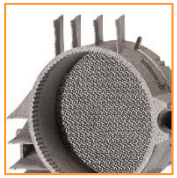
Lowering the entry barrier for AM

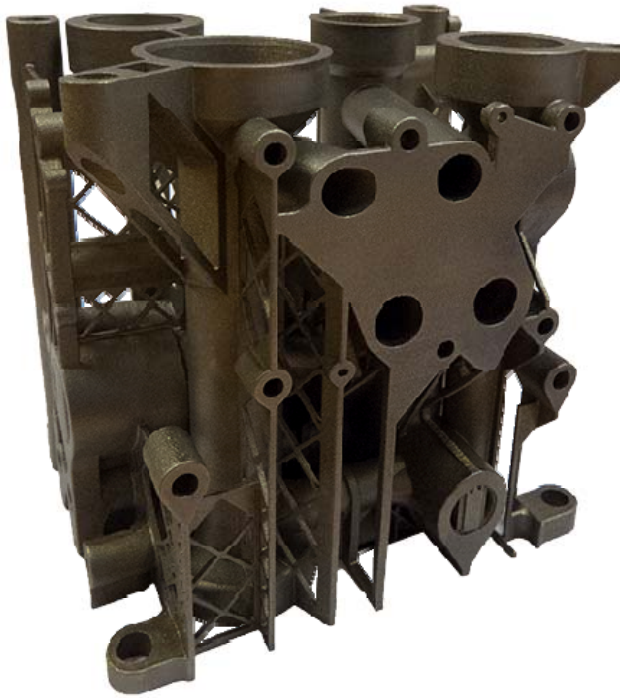
Metal additive manufacturing technology for industrial applications

Global network of Renishaw Solutions Centres



Applications expertise in a wide range of industries

Integrated manufacturing solutions



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Global network of Solutions Centres

A mutually supporting network of centres, each with applications specialisms to suit local industrial demand

Additional locations to be announced

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Solutions Centre services

1 Design for AM concept

Concept embodies AM benefits

2 Proof of concept

Benchmark part: benefits tangible

3 Process validation

Optimise process & verify part

4 Process capability

Demonstrate process stability

5 Production deployment

AM & finishing processes to make saleable product

Application engineering support | Dedicated incubator cell | Pre-production facility | Your supply chain

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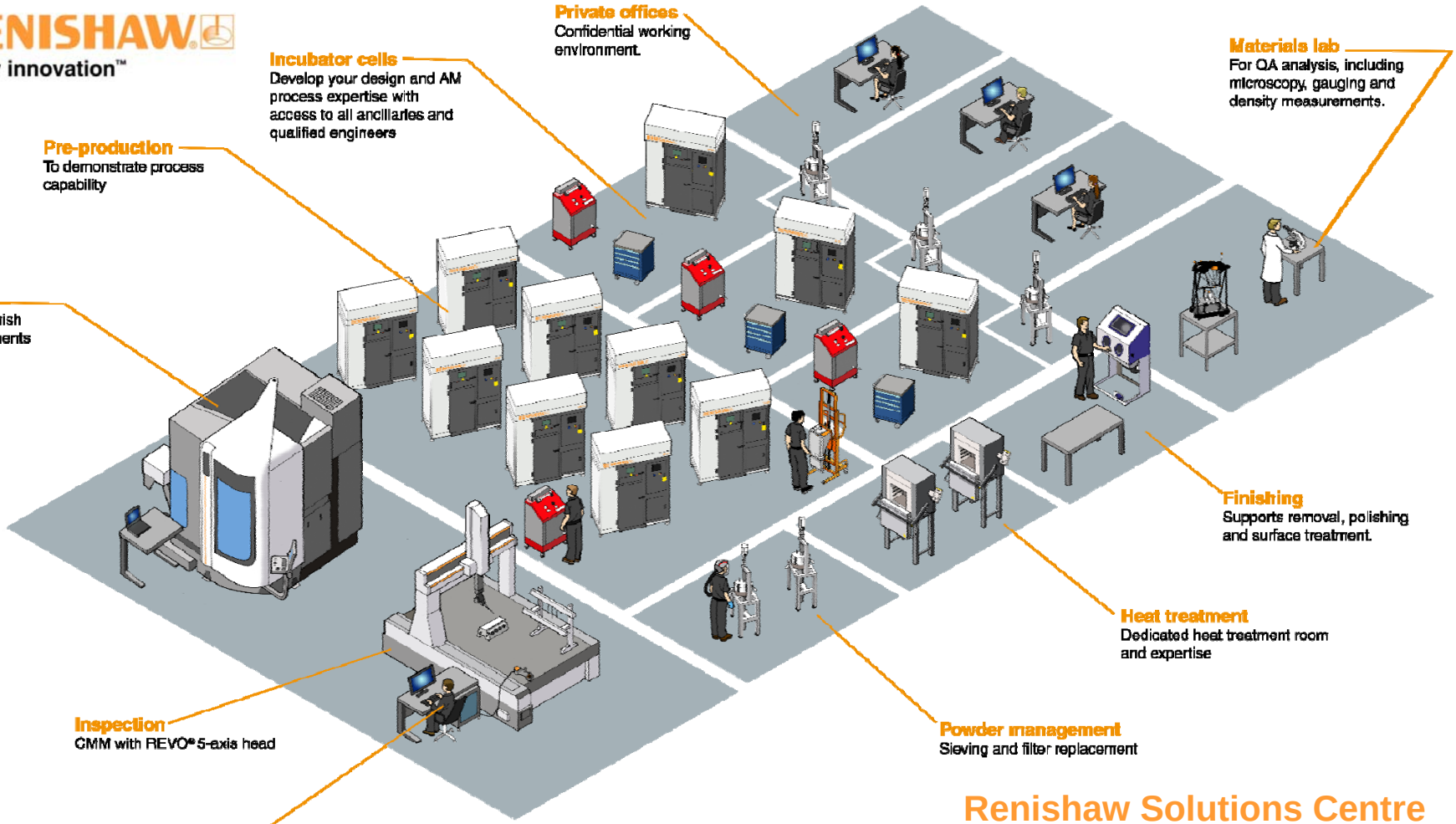

Renishaw Solutions Centre
for Additive Manufacturing

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Why we need process chains for additive manufacturing

The advertising promise

The reality

Additive manufacturing is not an island!

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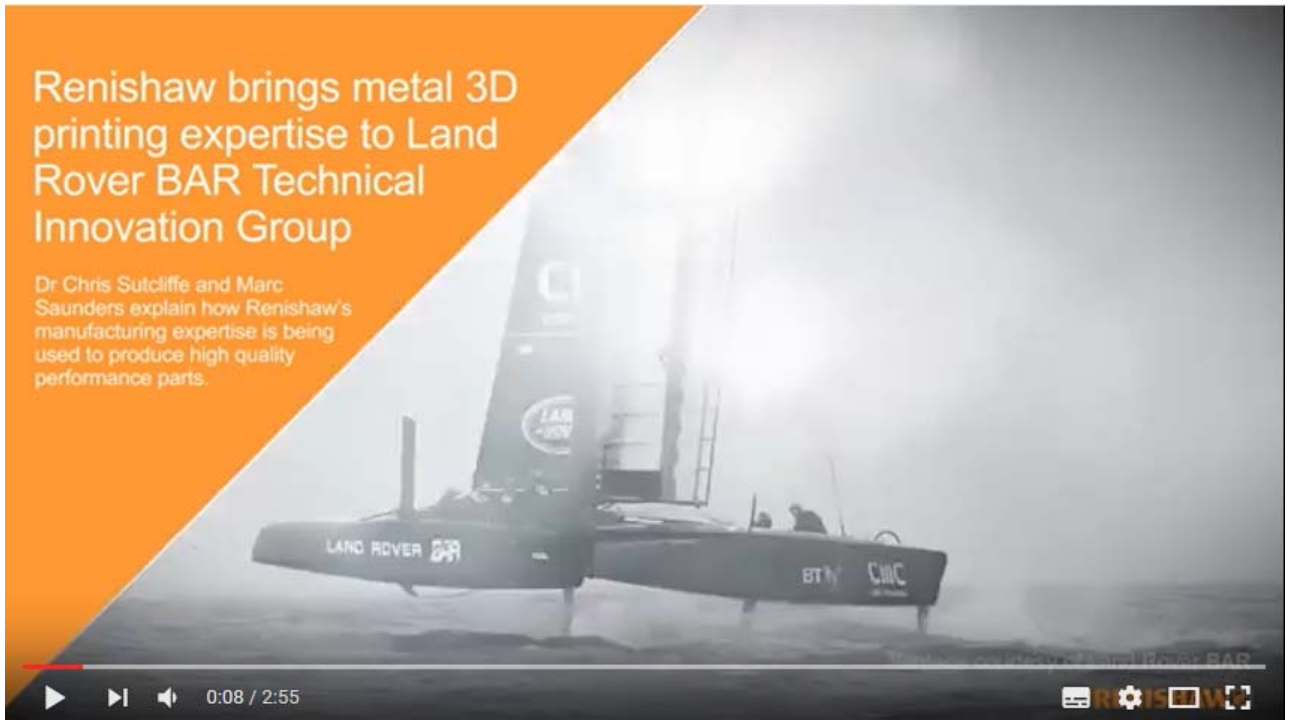

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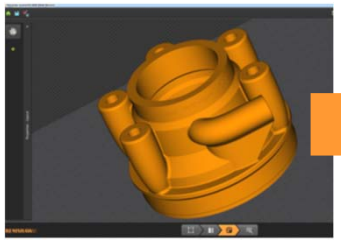
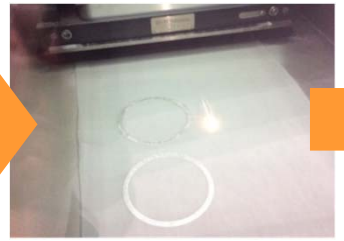
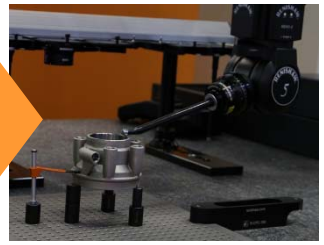
Sailboat manifold – process chain

	Design for AM	AM build	Gauging	Machining	Inspection
Processes					
Tools					

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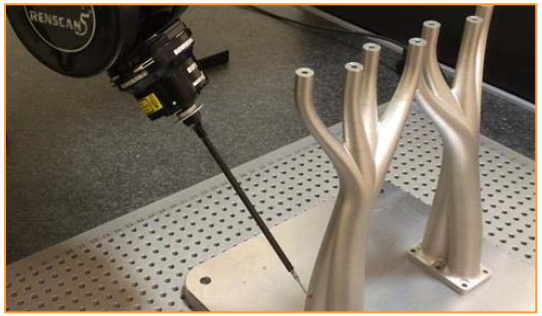
Industrial applications expertise

Healthcare



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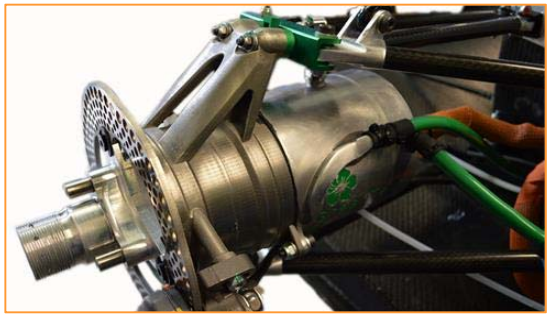
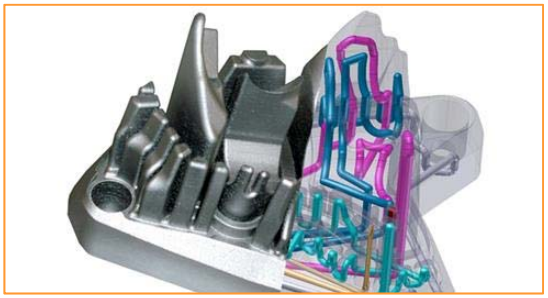
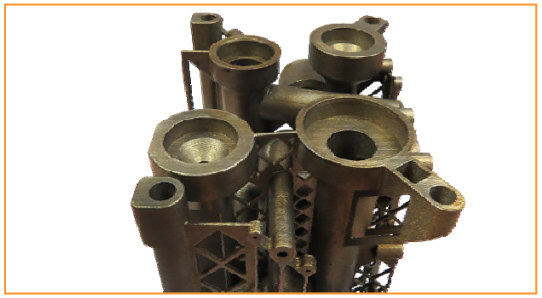


Automotive



Mould & die



Oil & gas

Consumer

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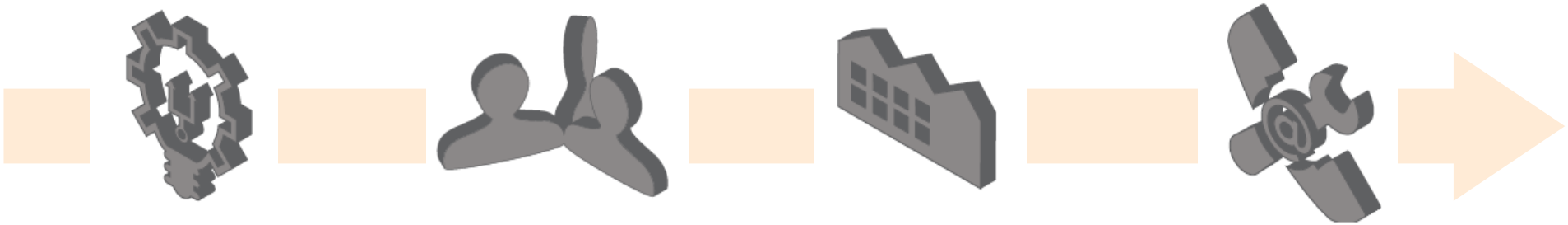
Thank you



Your product design

Renishaw expertise

Your AM process

Global support

your product
our expertise