

Renishaw Investor Day 2018

The Renishaw Additive Manufacturing formula

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Renishaw and additive manufacturing

What is Renishaw additive manufacturing?

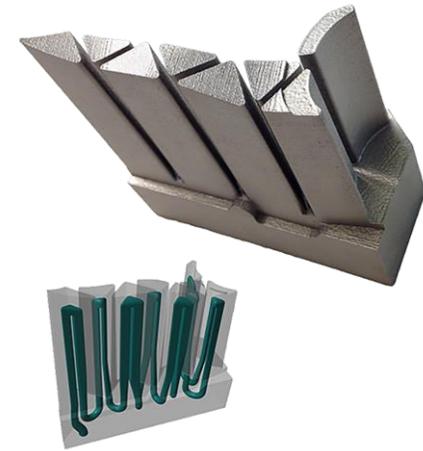
- Additive manufacturing (3D printing) is the process of creating a 3D object from a CAD model by building it up from thin layers, one by one
- Renishaw designs and manufactures metal additive manufacturing (AM) systems that use a process called **laser powder bed fusion (LPBF)**
- These systems use high powered lasers to fuse metallic powders to form functional solid objects.



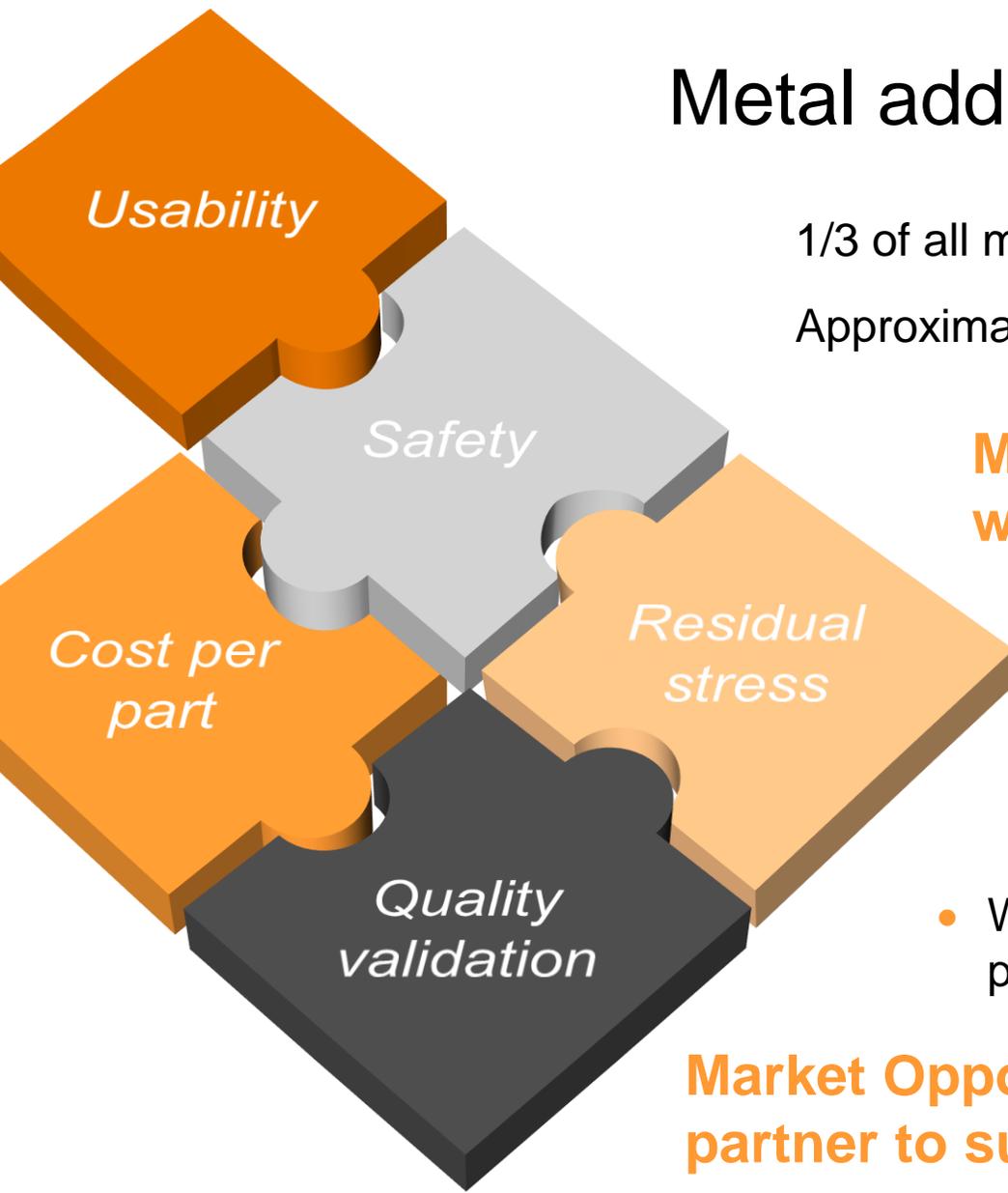
Why metal additive manufacturing?

Key benefits:

- AM is not constrained by the same rules associated with traditional manufacturing techniques
 - Produce complex geometries to improve part performance
 - Consolidate multiple parts to improve reliability and reduce inventory
 - Light weight – only build material where it is needed
 - Create fully customised components
 - Parts can be manufactured directly without tooling
 - Enables rapid design iterations



Metal additive manufacturing – Opportunity



1/3 of all metal AM systems were sold in the last 12 months

Approximately 80%» are mid-size 250 mm machines

Market Opportunity – target experienced AM users with higher performance AM technology

- Growing acceptance that AM is a viable manufacturing technology
- Many AM challenges have been overcome
- We are actively addressing the remaining requirements in our new products and innovations

Market Opportunity – many new users are looking for a trusted partner to support their AM adoption and implementation

* Based on Wohlers 2018 and Renishaw market intelligence

» Based on Renishaw market intelligence

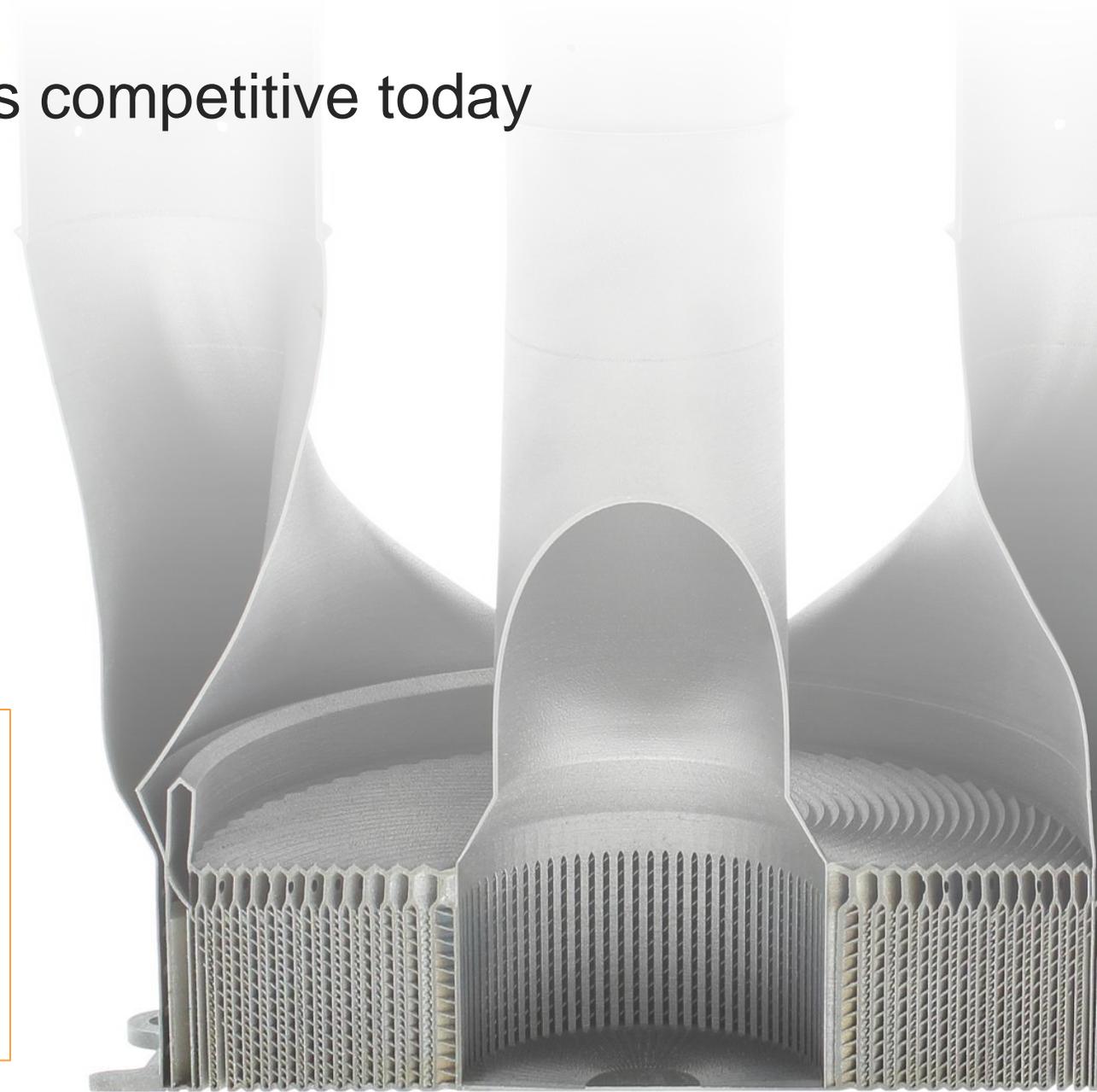
Where metal AM is competitive today

High-value manufacturing

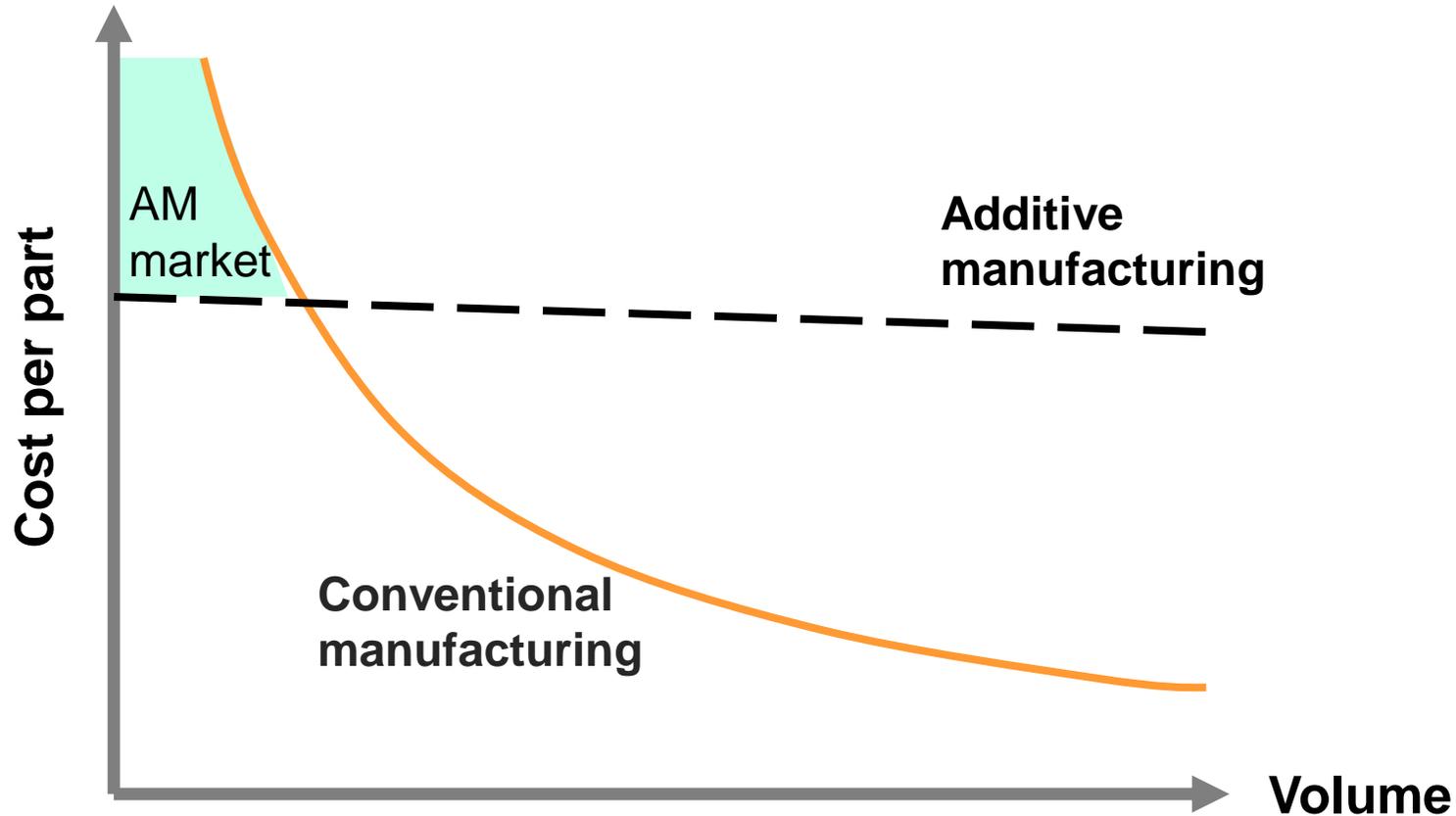
- Complex, high-performance products
- Difficult-to-process, expensive materials
- Where weight is critical
- Extensive quality assurance is acceptable
- Customised or low / medium volumes

Mature applications

- Aerospace
- Healthcare
- Tooling

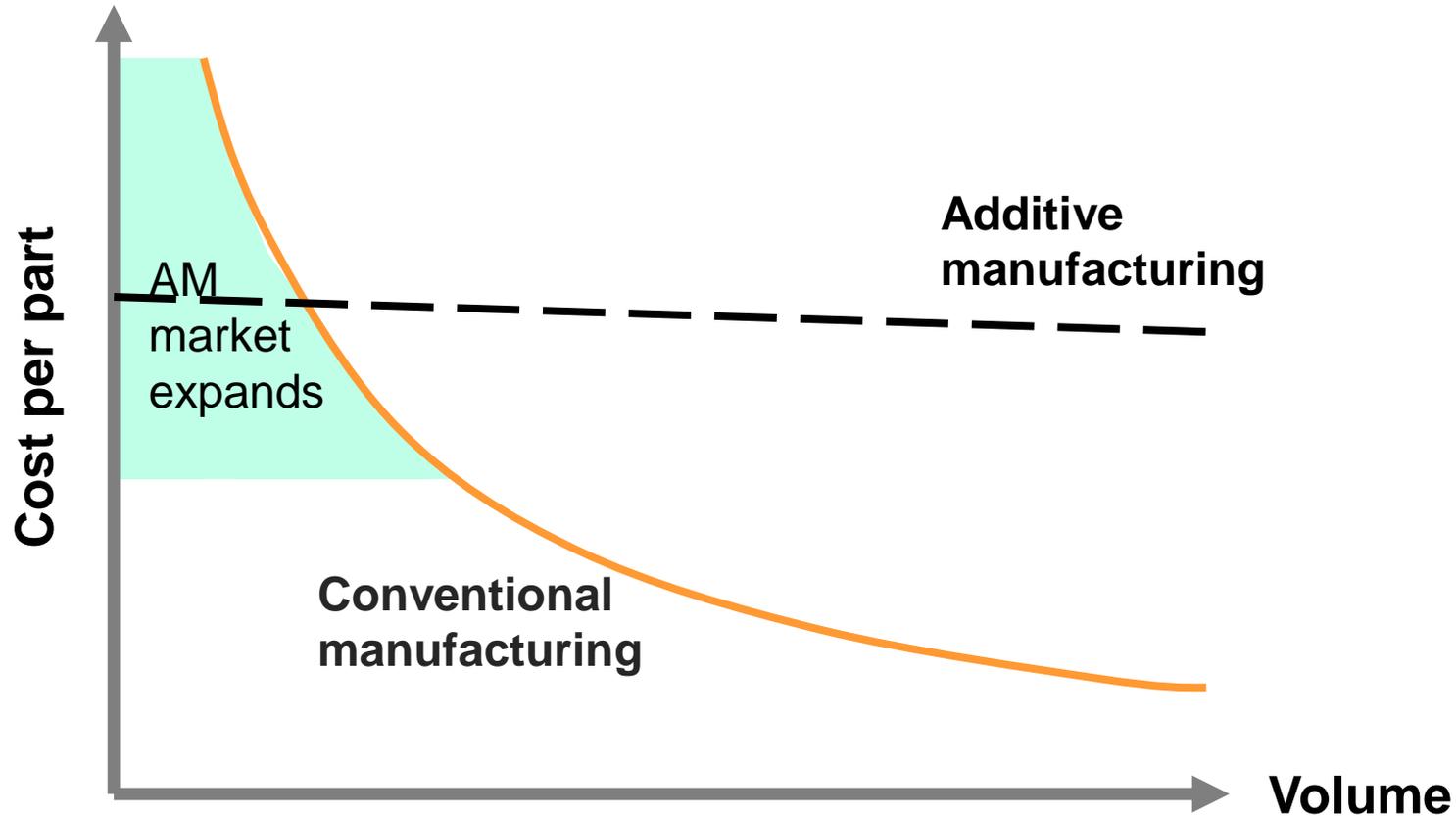


Current market position for AM applications



High unit costs have confined AM to low volume, specialist applications

Future market position for AM applications

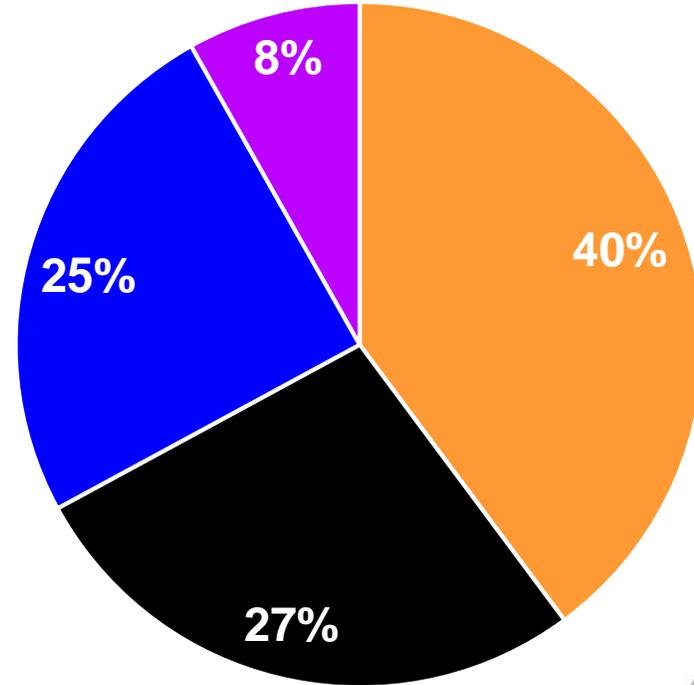


Reducing AM part costs will open up new market opportunities

What drives costs for AM parts?

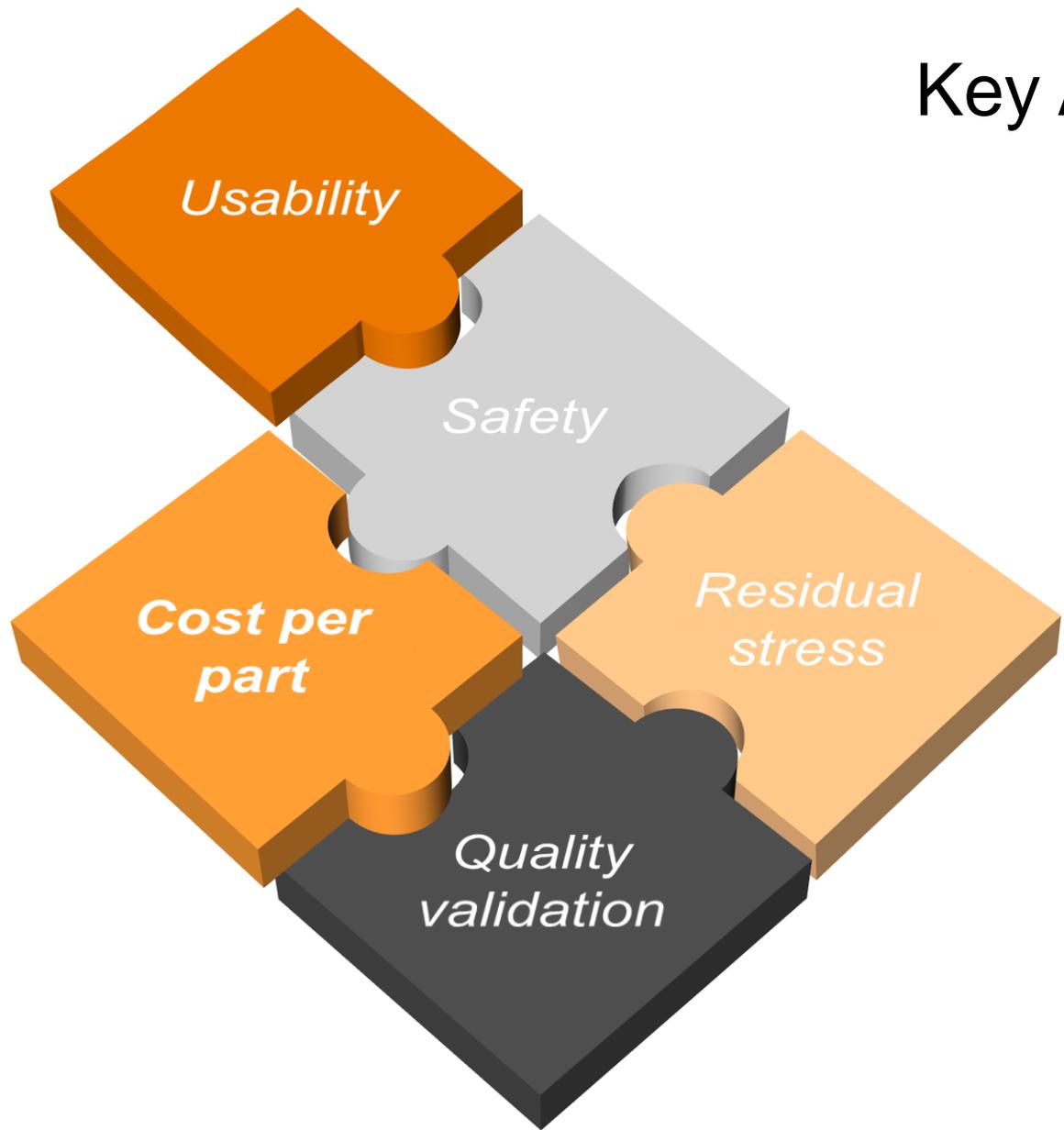
AM component typical cost drivers *

- **Build time** (machine depreciation & running costs)
- **Powder** (cost per kg)
- **Post-processing** (heat treatment, machining, inspection etc)
- **Labour** (part & powder handling)



* Based on standard Renishaw market rate cost model, example shown for Robot Bike Co..

Key AM challenges



RenAM 500Q family



RenAM 500Q - multi laser AM system

- Target market - experienced users manufacturing series parts
- High performance replacement for competitor mid-size machines
- Superior gas flow performance to preserve processing conditions using up to 4 lasers
- Accelerating production ramp-up
- Priority access via the Solutions Centre

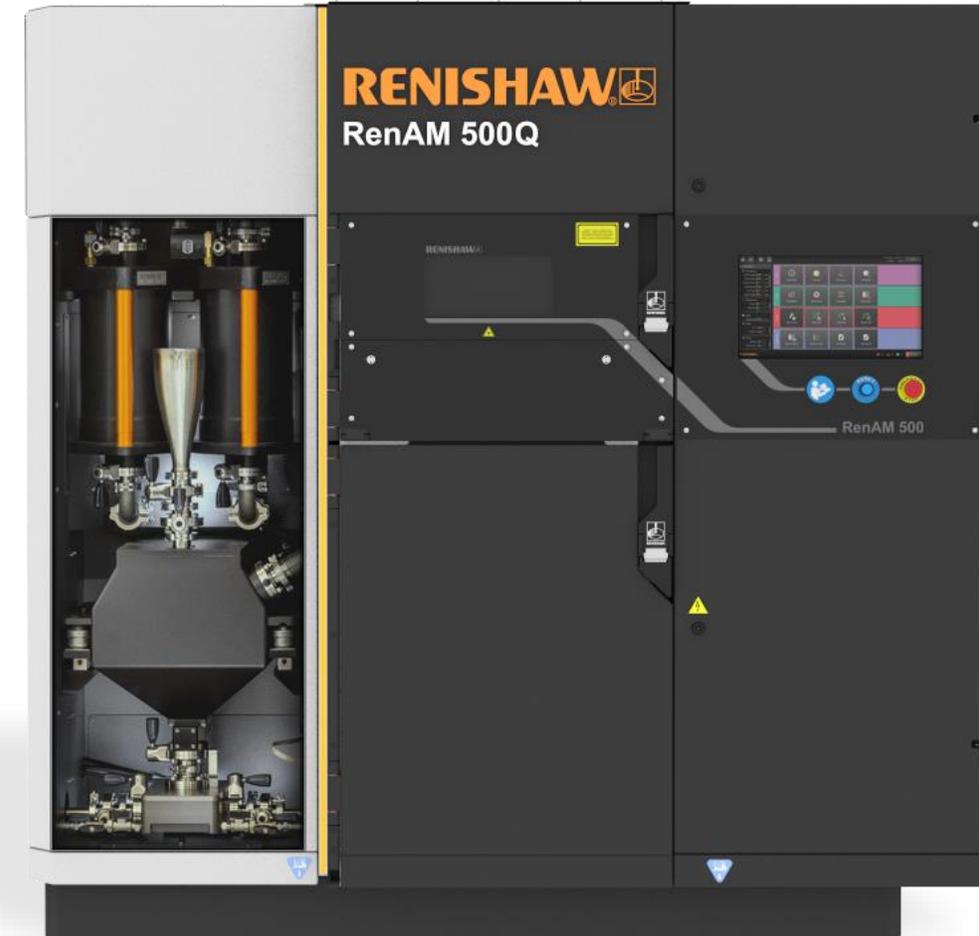
Key design changes that impact on performance

Multiple lasers that each address the whole bed

- Flexible laser assignment
- Reduced layer time
- Manageable laser interaction effects

Improved gas flow

- Maintains laser transmission efficiency
- Reduced variation in performance across the build plate
- Reduction in spatter incorporation in the part



Productivity improvements

- Significantly reduced machine cleaning
- Reduced in-chamber condensate
- Faster turn-around between builds
- Extended filter life using pre-filter cyclone
- Reduced maintenance frequency

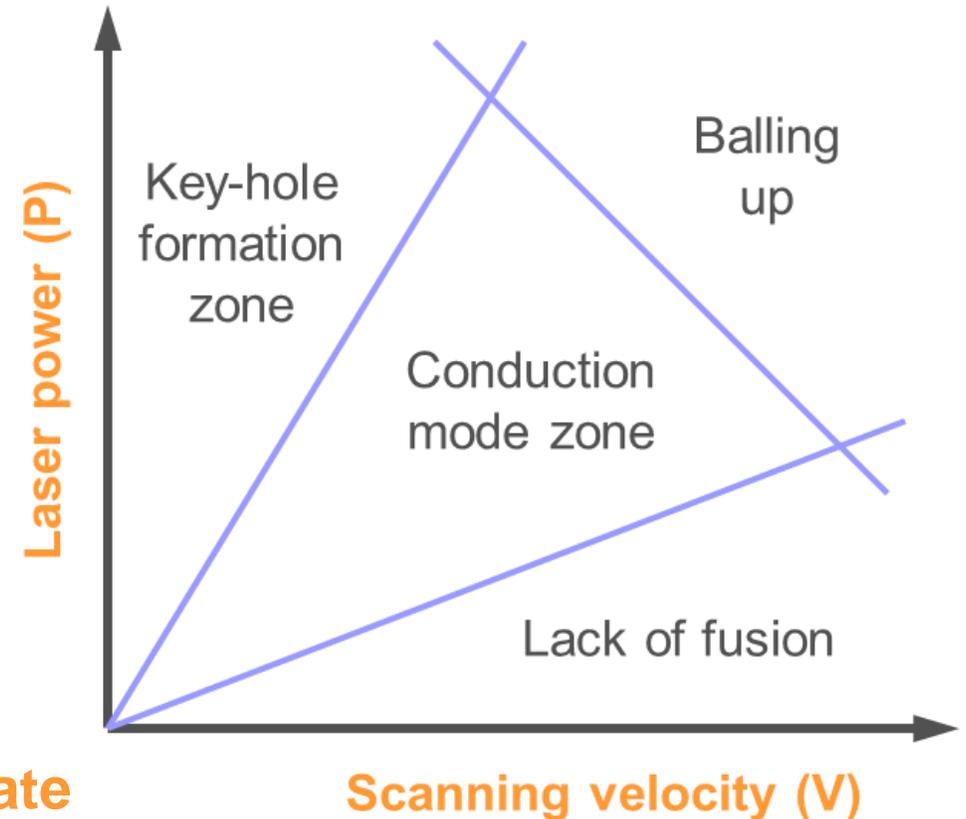
Improving process quality and driving down cost per part to broaden the available market

Performance summary

We are now achieving high quality processing over a wider bandwidth

- High consistency throughout the build volume
- Ductility improvements in all tested materials
- Low oxidation for consistent mechanical properties
- Very good surface finish
- Very high and consistent material density
- Achieving a wide operating window to allow for a range of part geometries – e.g. changes in section, thin walls

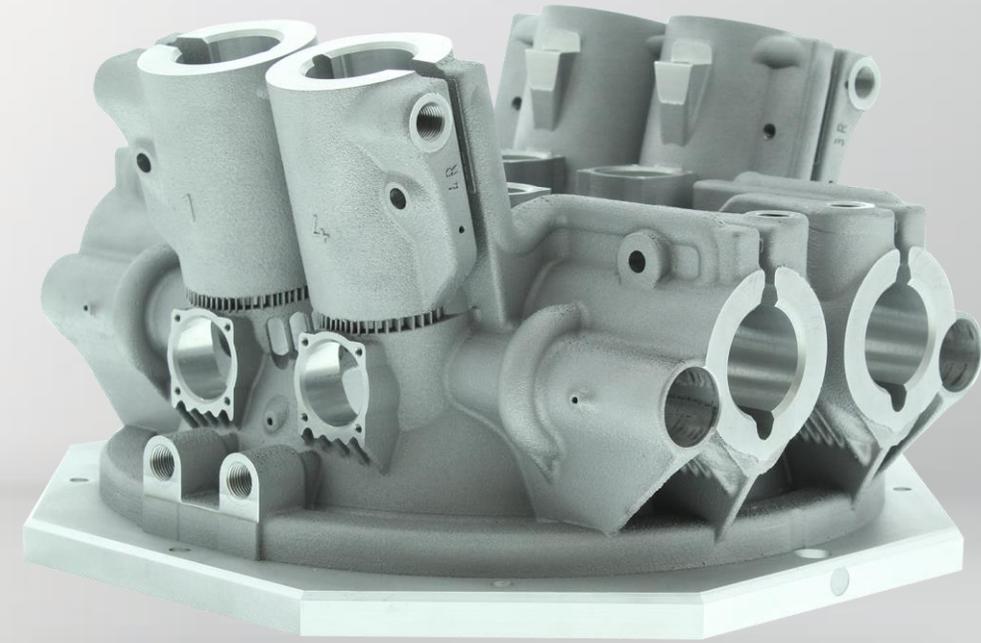
Wider processing capabilities help users integrate AM into their factories more easily



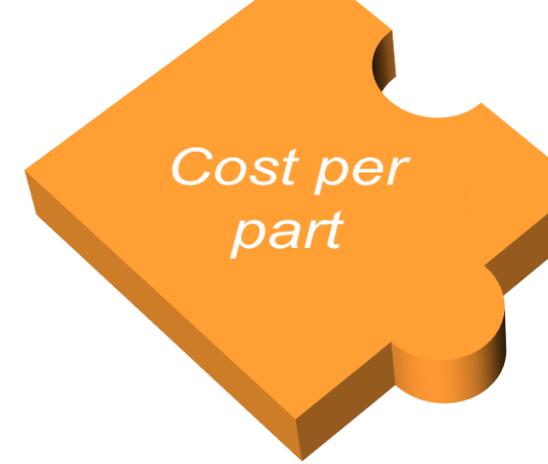
Applying Renishaw innovation using AM

AM is an enabling technology for the RenAM 500Q

- We use AM very effectively in the manufacture of the optical system for our range of multi-laser AM products
- This is the basis for our future product developments and is a demonstration of our vertically integrated engineering strategy
- It allows us to engineer a thermally stable, compact system system
- It builds on years of optical experience to overcome the challenge of precise multi-beam processing
- Results show us that we can achieve high levels of metallurgical performance when processing with multiple lasers on a single part



Multi-laser productivity impact

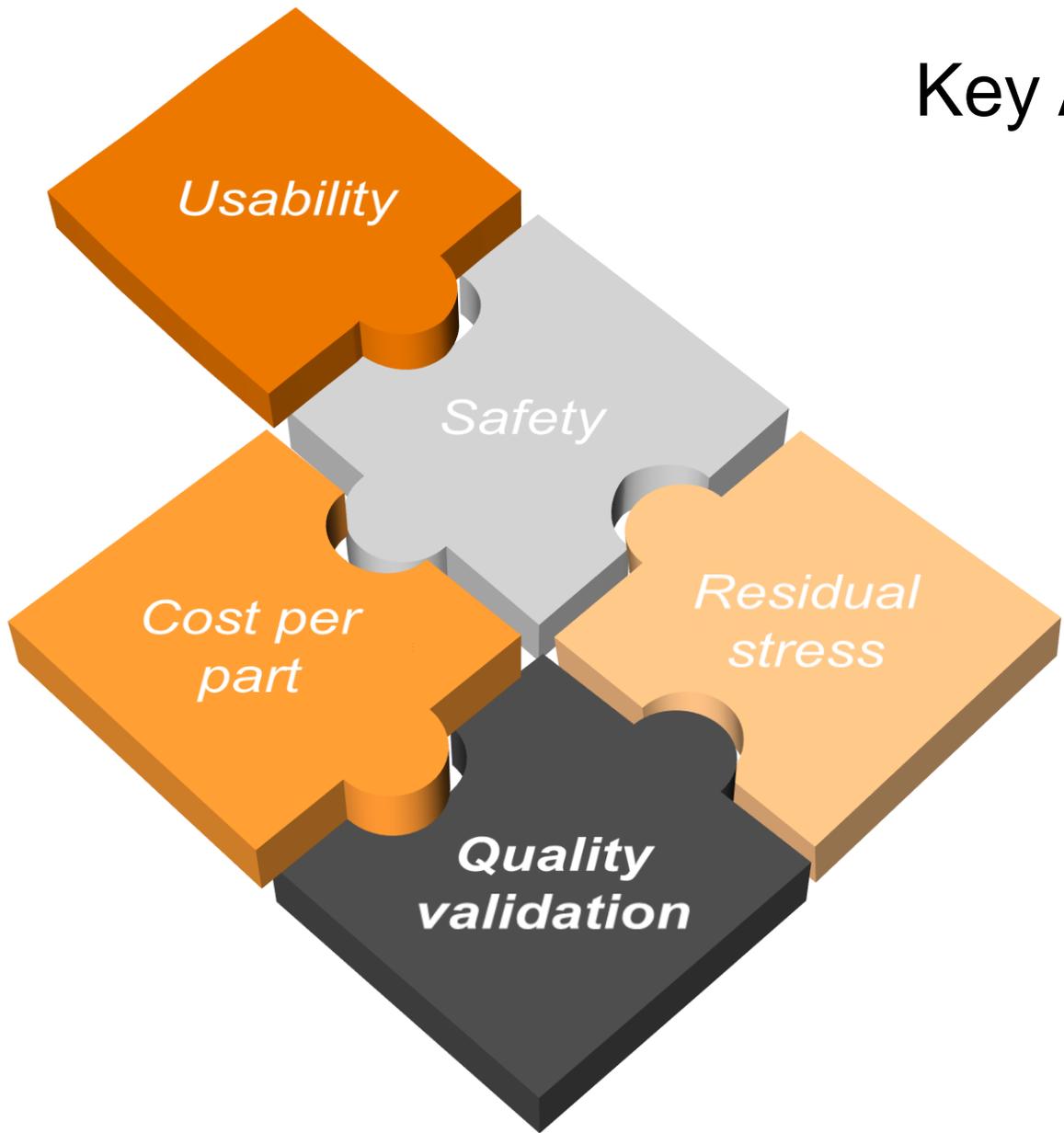


Quad laser galvo mounting block

- AISi10Mg
- 60 μm layers
- 1,454 cm^3 / 3.9 kg (including supports)
- Build time = 19 hours
- Build rate = 77 cm^3/hr
0.21 kg/hr



Key AM challenges



AM process development & control challenges

- Metal AM gives us great design freedom
- BUT process development and qualification can be challenging in demanding applications
- Process anomalies can produce defects that affect fatigue life
- Heavy reliance on post-build testing and costly production process control
- New technologies give the opportunity to detect and identify defects through process design, and possibly to repair defects during the build



InfiniAM Spectral

Multi-sensor data visualisation

High-frequency data across a range of wavelengths

- Infrared thermal sensor
- Near-IR plasma sensor
- Laser input energy

Synchronised with actual galvo mirror positions to enable 3D modelling and visualisation



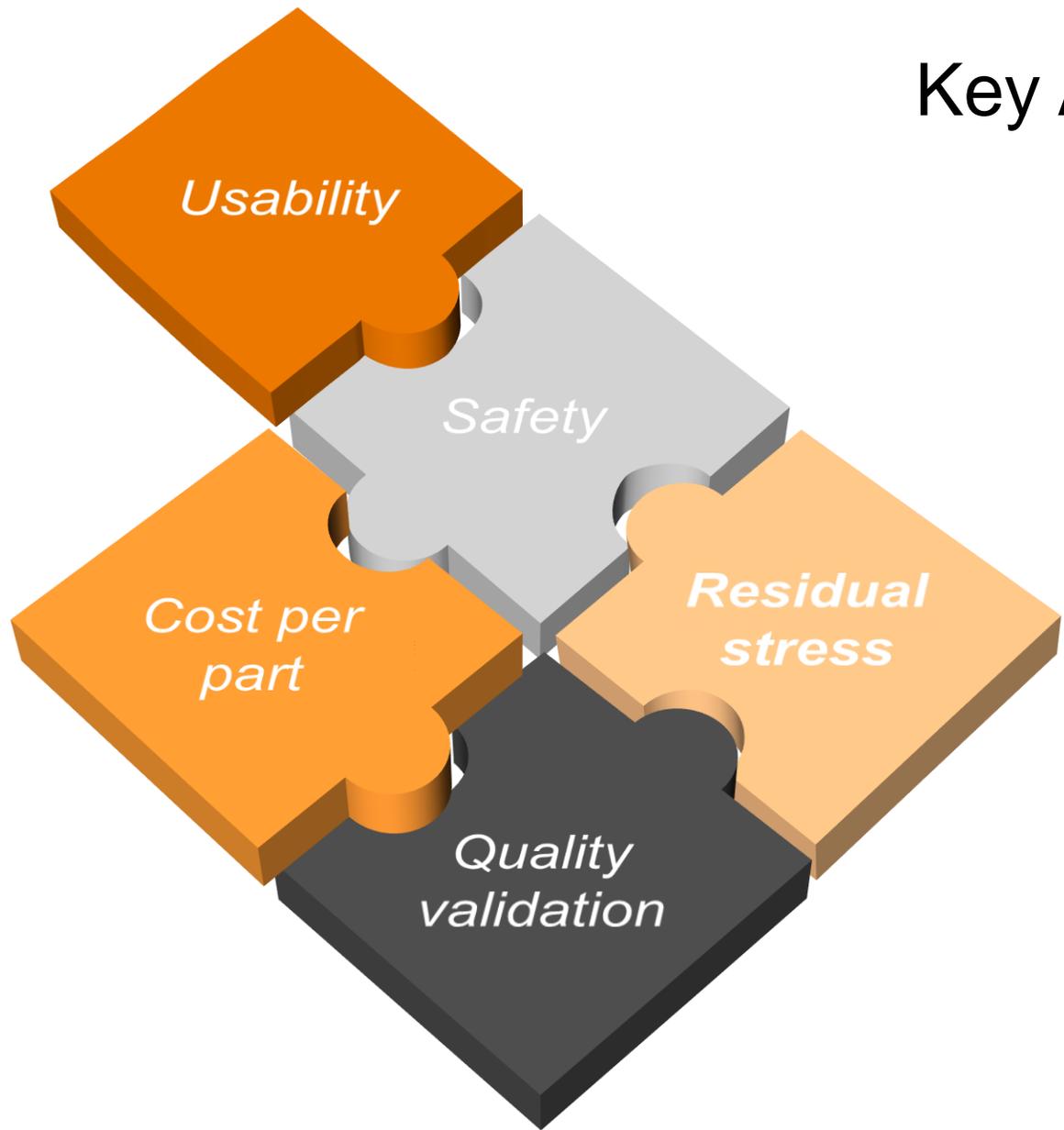
InfiniAM Central

AM factory planning and monitoring software

- Real time insight into live AM processes
- System sensor data and build information graphically displayed
- Available as a smartphone app
- External integration with proprietary MRP systems via Renishaw APIs



Key AM challenges



High temperature processing



Proving project on AM 400HT

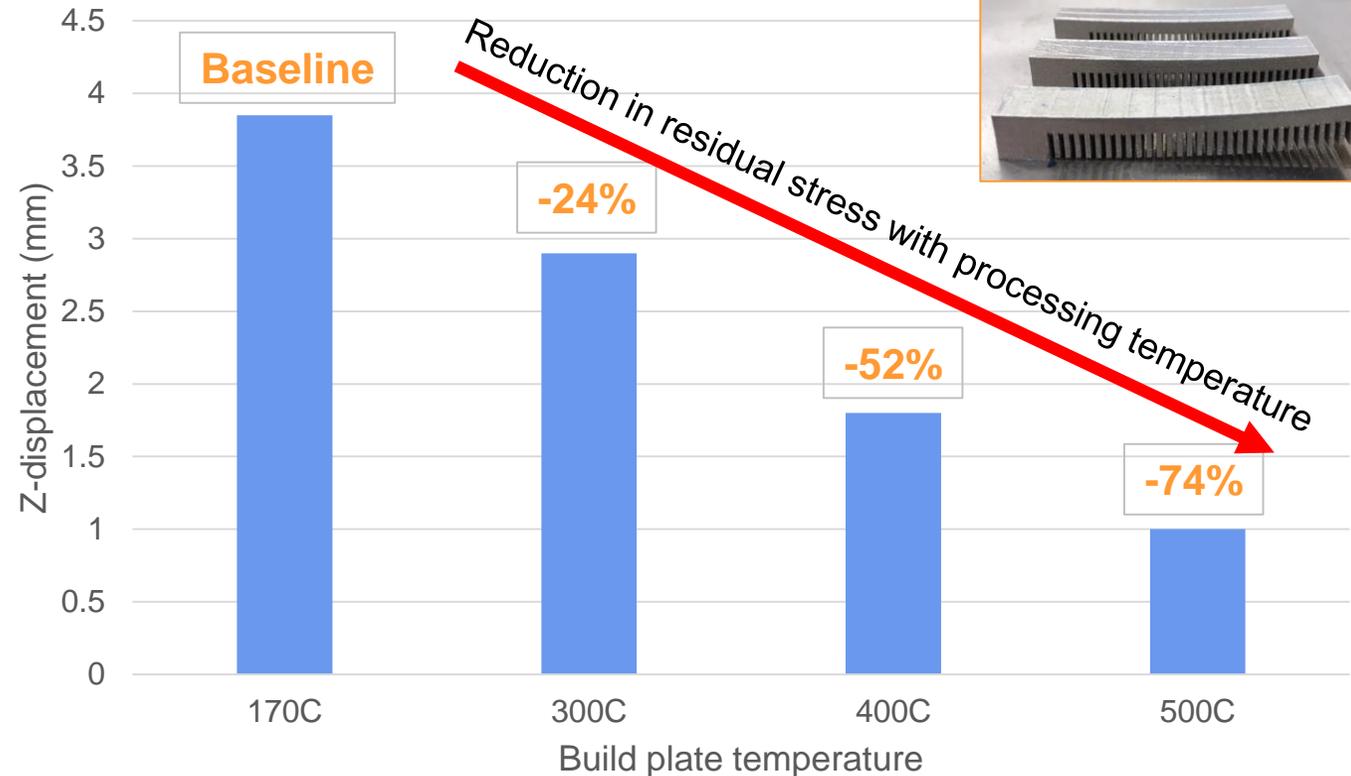
Establishing the benefits of pre-heating substrate to reduce residual stress build-up

- Residual stress reduces with higher pre-heating
- 74% reduction in displacement at 500 °C

Processing at higher temperatures broadens the market by:

- Allowing the processing of more challenging geometries
- Broadening the range of materials

Cantilever displacement as an indicator of residual stress



Solutions Centres

Lowering the entry barrier to industrial AM

- Customers can develop their products and processes, acquire knowledge, build their business case
- Global network of centres providing facilities, machines, post-processing and engineering support
- Risk-managed 'stage-gate' process
- Design for AM training
- Open platform – transparent parameters
- Develop parameters for new alloys
- Options for supply chain development



Solutions Centre – project progression

1 Design for AM concept

Concept embodies AM benefits



Application engineering support

2 Proof of concept

Benchmark part: benefits tangible



Dedicated incubator cell

3 Process validation

Optimise process & verify part



Pre-production facility

4 Process capability

Demonstrate process stability



Your supply chain

5 Production deployment

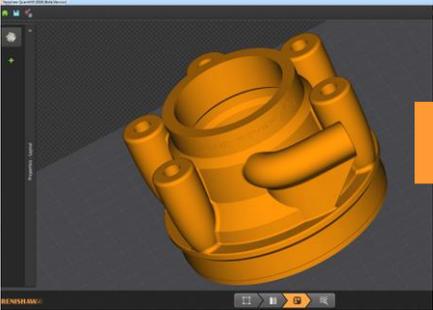
AM and finishing processes to make saleable product



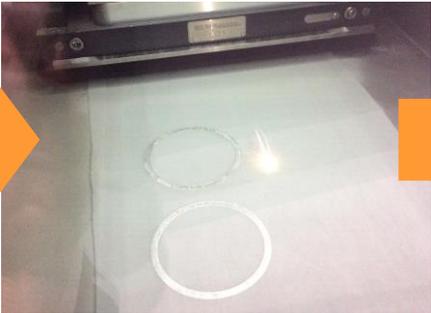
Renishaw solutions across the whole process chain

Processes

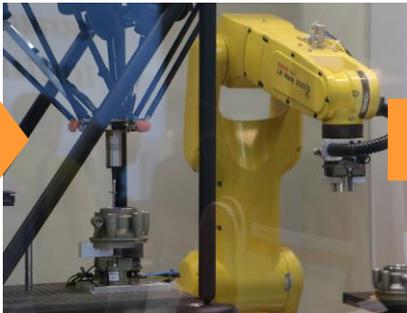
Design for AM



AM build



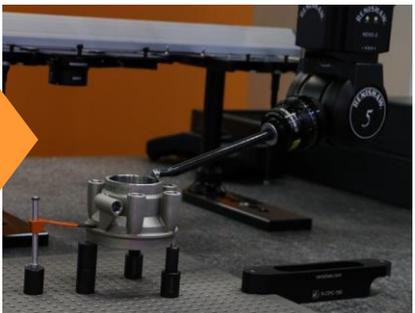
Gauging



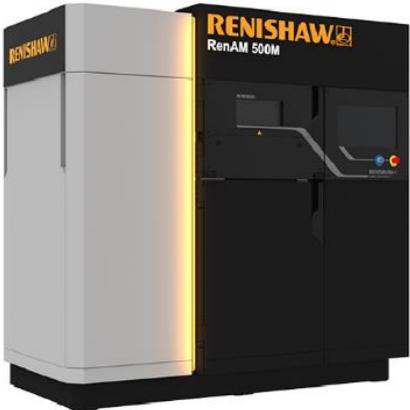
Machining



Inspection



Tools

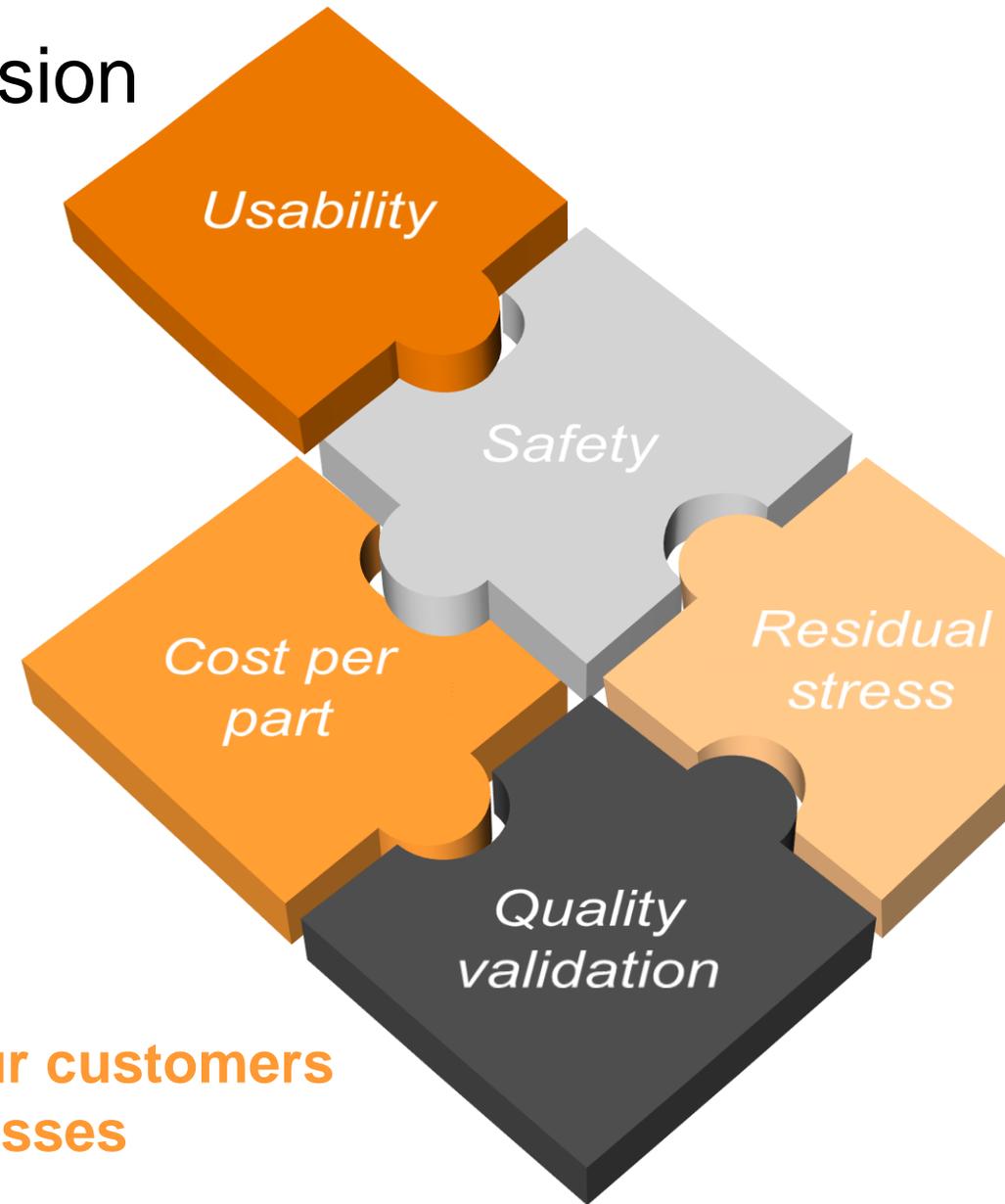


Renishaw AM mission

Growing our market by...

- Focussing on core technology
- Creating high performance products
- Developing our people and support network
- Investing in high quality manufacturing
- Developing enhanced quality monitoring
- Class leading safety systems

Bringing the puzzle pieces together to support our customers as they embed AM into their manufacturing processes





Thank you

Clive Martell

Head of Global Additive Manufacturing