

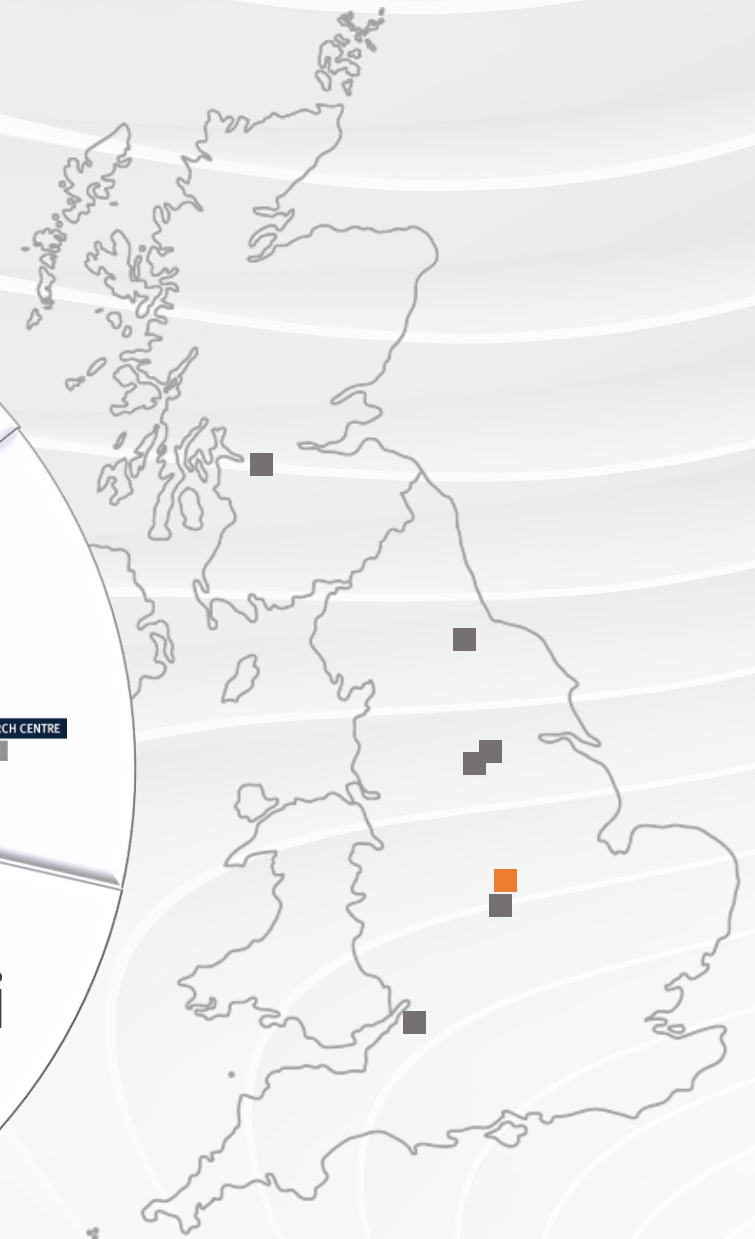
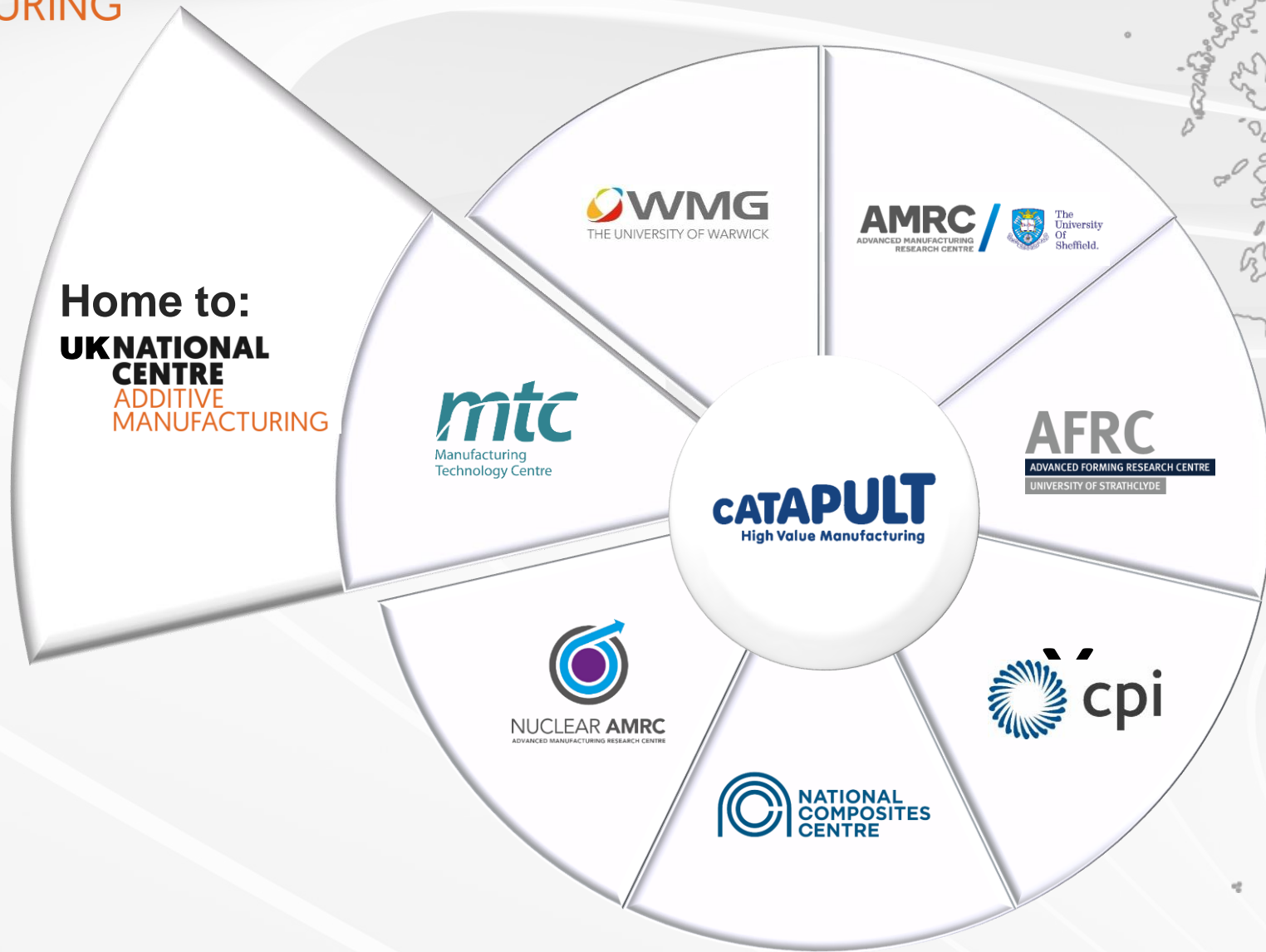
Accelerating Uptake of Additive Manufacturing by Aerospace

Dr Katy Milne

7th Nov 2019



NATIONAL CENTRE ADDITIVE MANUFACTURING



The UK's National Centre for Additive Manufacturing (NCAM)
is the UK's independent AM body supporting supply chain companies
adopt and mature additive manufacturing...

Shaping your AM strategy

Maturing your AM process

Improving your workforce
competency

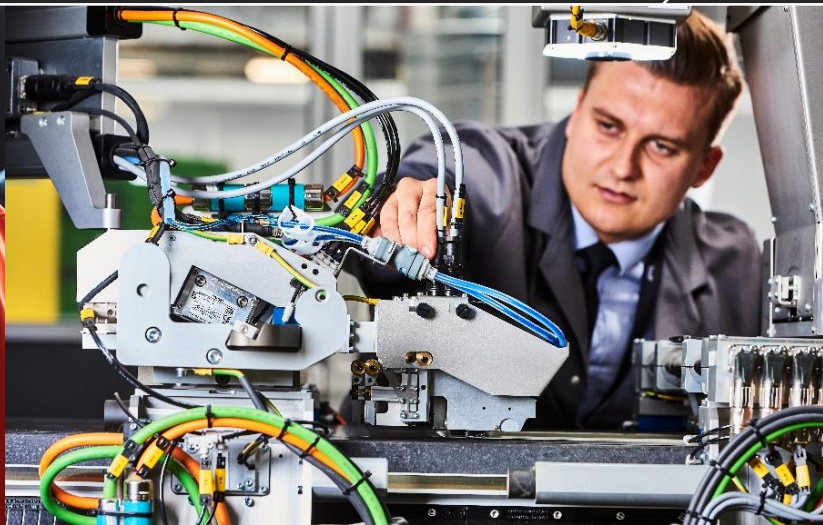


...and develop and demonstrate their technology solutions.

**Building partnerships for
innovation**

**Proving out your
technology**

**Demonstrating your
technology**



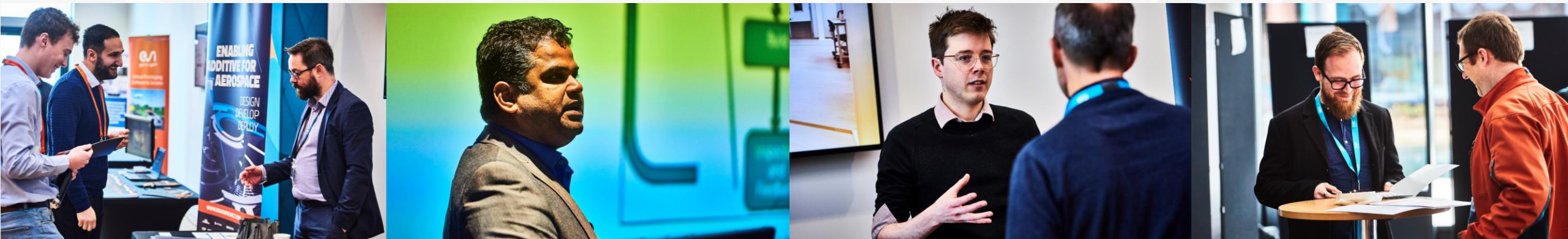
Working with the National Centre:

- World-class facilities and expertise covering the whole process chain – from design through to inspection.
- Substantial activity in metal, polymer and ceramics.
- Process and vendor agnostic.



Working with the National Centre:

- We are the UK's focal point for AM innovation and exploitation, signposting to potential partners.
- We can help you access government support.



UPCOMING EVENTS



<https://www.eventbrite.co.uk/e/mastering-am-2020-save-the-date-tickets-74816675691>



<https://www.eventbrite.co.uk/e/made-for-space-save-the-date-tickets-65402670147>

MEMBERS' RESEARCH PROGRAMME

Updated May 2019

2019

29. Robust Quality Approach for AM via in-process and NDT (RAMPID)
£265k (33778-04)

30. Internal Finishing for AM
£141k (33778-06)

31. Machine Finishing of AM and Net Shape Components
£90k (33778-01)

32. Hybrid Polymer AM for Large Scale Applications
£110k (33778-09)

2018

28. AM HIP and Heat Treatment Handbook – Volume 2
£168k (32805)

27. Powder sensitivity of AM - Phase 2
£XXXk (32801)

2017

26. NDT Standards for AM – Phase 2
£XXXk (32300)

25. Residual Stress Evaluation of Metal AM Components
£115k (32299)

24. Novel Emerging AM Equipment Technology Evaluation
£140k (31902)

23. AM HIP and Heat Treatment Handbook
£107k (31909)

2016

22. Matsuura Hybrid Additive System Assessment
£100k (31514)

21. Design Process Control for Improved Surface Finish of Complex Parts
£XXXk (31494)

20. Simulation-Enhanced Inspection Phase 2
£62k (31489)

19. H-S Metal Powder AM Extension
£105k (31159)

18. Rate-Scalable XCT Inspection
£90k (31157)

17. Powder Sensitivity of AM
£200k (31151)

2012

2. High Productivity Laser Cladding
£63k (21711)

1. High Performance SLM
£100k (21718)

2013

5. Technology Mapping In-situ Inspection for AM
£60k (30234)

4. Powder Degradation in AM
£45k (30233)

3. Surface Texture Measurement for AM
£80k (22006)

2014

11. Health and Safety – Metal Powder AM
£117k (30523)

10. Post-Processing of AM & Non-Conventionally Machined Components
£83k (30522)

9. Technology Review of X-Ray CT
£XXX (30520)

8. Design for AM
£42k (30516)

7. Technology Road Map For Metals AM
£68k (30418)

6. Finite Element Modelling Of AM

2015

16. Quality Data Framework for AM
£200k (30871)

15. Modelling and Validation of Lattices
£XXX (30646)

14. Fine Detail EBM
£106k (30642)

13. Simulation Enhanced Inspection
£95k (30640)

12. NDT Standard for AM
£49k (30635)

MEMBERS

Some of our members...

Design



Materials



AM Process



Post-Processing



Inspection



- Portfolio of EU and UK funded projects:

AddMan
Admire
Amable
AMAZE
ANVIL
CONFIGURE
DRAMA
ENCOMPASS

EWIRA
Flexifinish
IMPULSE
PowderCleanse
OPENHYBRID
RAMP
SEAMLESS

Electron beam additive manufacturing of front bearing housing aerofoils for ground and flying tests bed engines

The MTC worked with Rolls-Royce on the additive manufacture of a flight test front bearing housing – the largest aero engine structure to fly, incorporating ALM components, in the world to-date.

MTC's Solution:

- Working the Rolls-Royce and Arcam, the MTC developed processes from powder inspection through component manufacture to post process non-destructive testing of the ALM components

Outcomes & Benefits:

- 30% improvement in lead time for first development parts to stores
- Fast iteration and design change implementation throughout project
- Transferable capability and knowledge obtained as a result



This project has provided a key step in developing the industrial viability of ALM processes and has established a vital body of knowledge to inform and shape the next steps of this journey

*Neil Mantle, Head of Additive Layer Manufacturing
Centre of Competence, Rolls-Royce*



GLOBAL COLLABORATION ON STANDARDS



Part of the ASTM Centre of Excellence for AM since April 2018. Working to:

- Accelerate standardisation and close standards gaps in AM
- Create strong global partnerships among AM developers, users and stakeholders
- Support education, training, proficiency testing, and certification programs

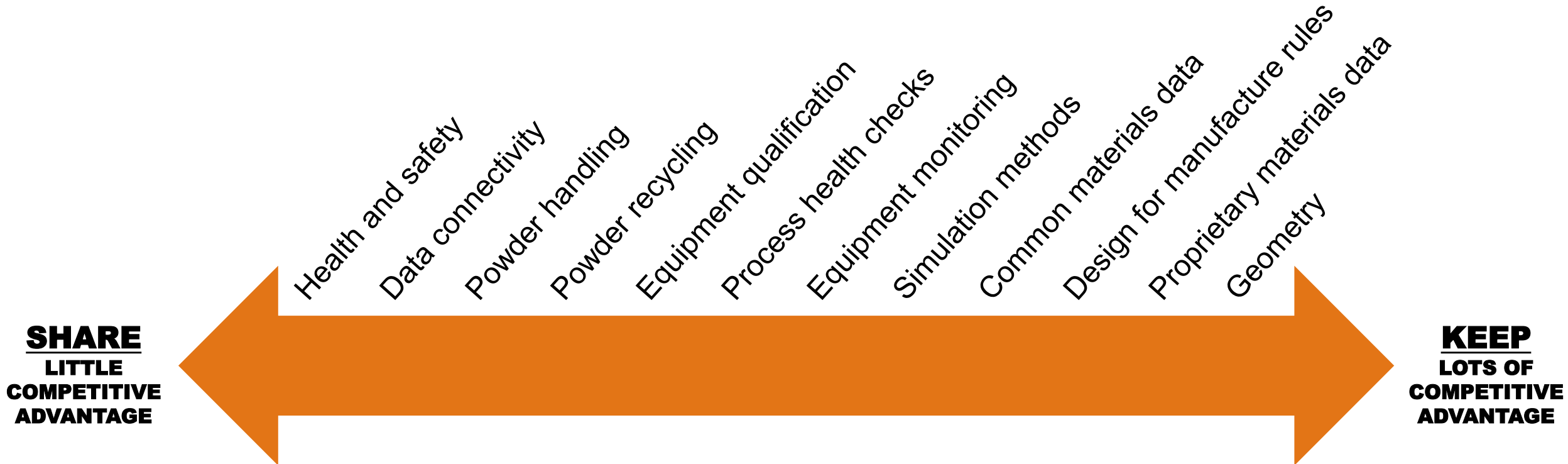
Founding partners



Strategic partners



KNOWLEDGE - SHARE OR KEEP?



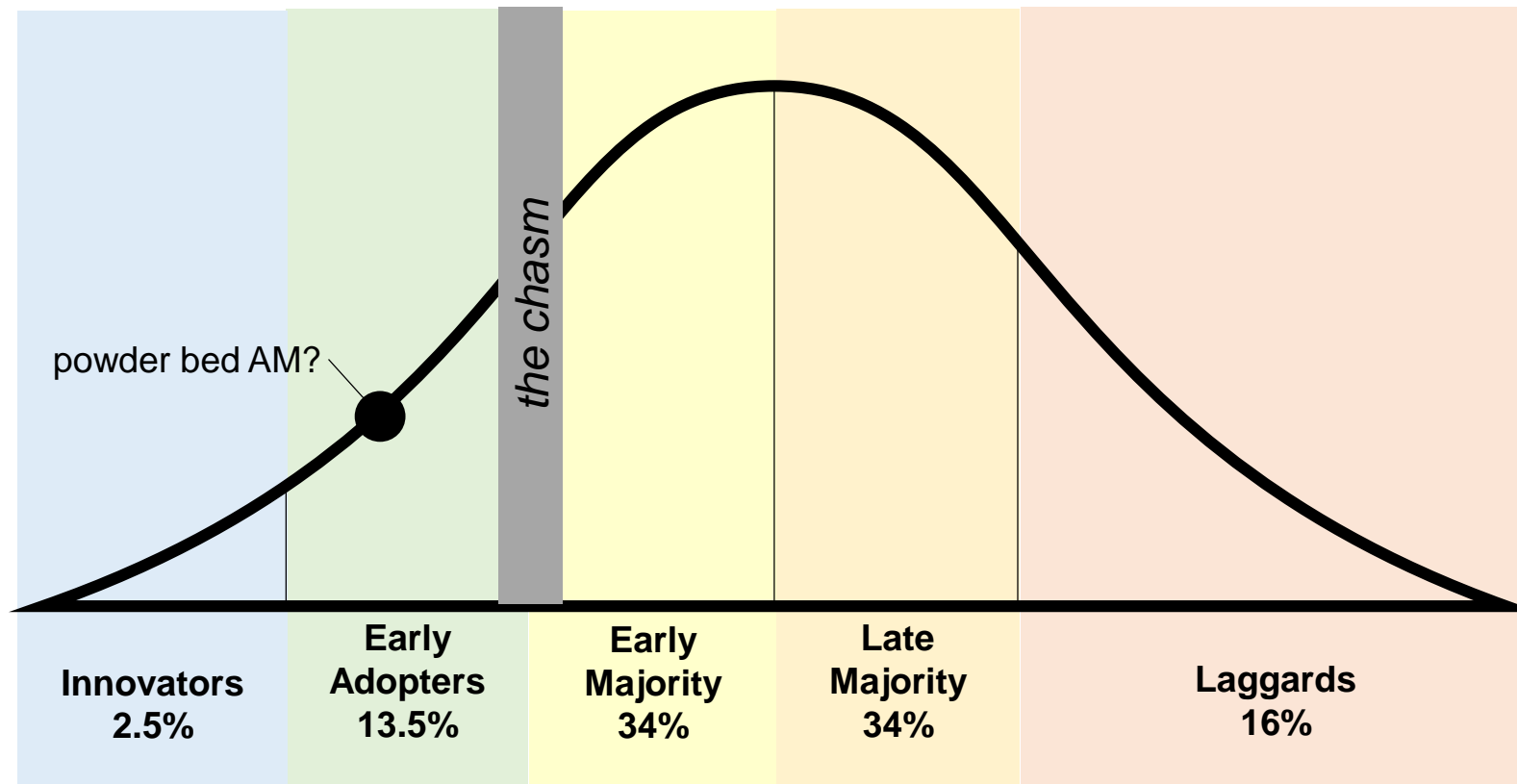
PRIORITIES FOR AEROSPACE

IN 2015...

- Primes rapidly building AM capability within their businesses.
- Some Tier Ones rapidly developing AM capability. Other Tier Ones trying to decide whether to 'dive in'.
- Long tail of the supply chain has varying levels of awareness AM. Unsure how it will affect them – is it an opportunity or a threat?

THE NEED FOR KNOWLEDGE TRANSFER THROUGH THE SUPPLY CHAIN

If the early majority have to undertake the same risk as the innovators and early adopters, the technology will not be adopted throughout the supply chain.

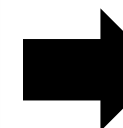
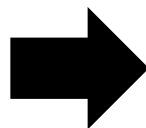


Roger's bell curve from *Diffusion of Innovation*

UK AEROSPACE TECHNOLOGY INSTITUTE

**NATIONAL
CENTRE**
ADDITIVE
MANUFACTURING

2018 sector consultation



Key findings

Materials

Process

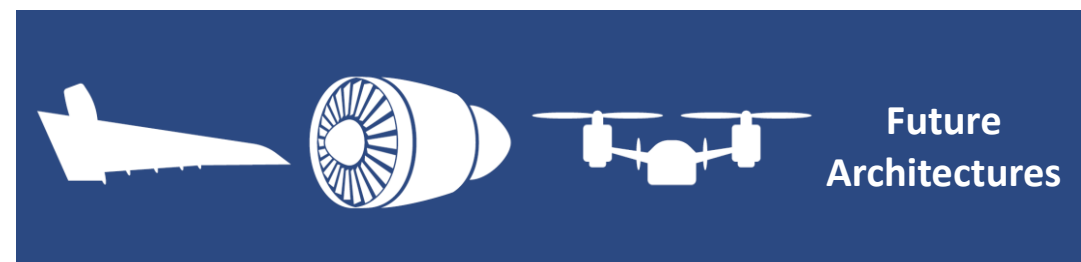
£70_M

Total in Additive
Manufacturing
Projects



UK AEROSPACE TECHNOLOGY INSTITUTE

ATI identified these opportunities for additive in aerospace





ENABLING ADDITIVE FOR AEROSPACE

Building stronger supply chains

Consortium



Supported by



Funded by



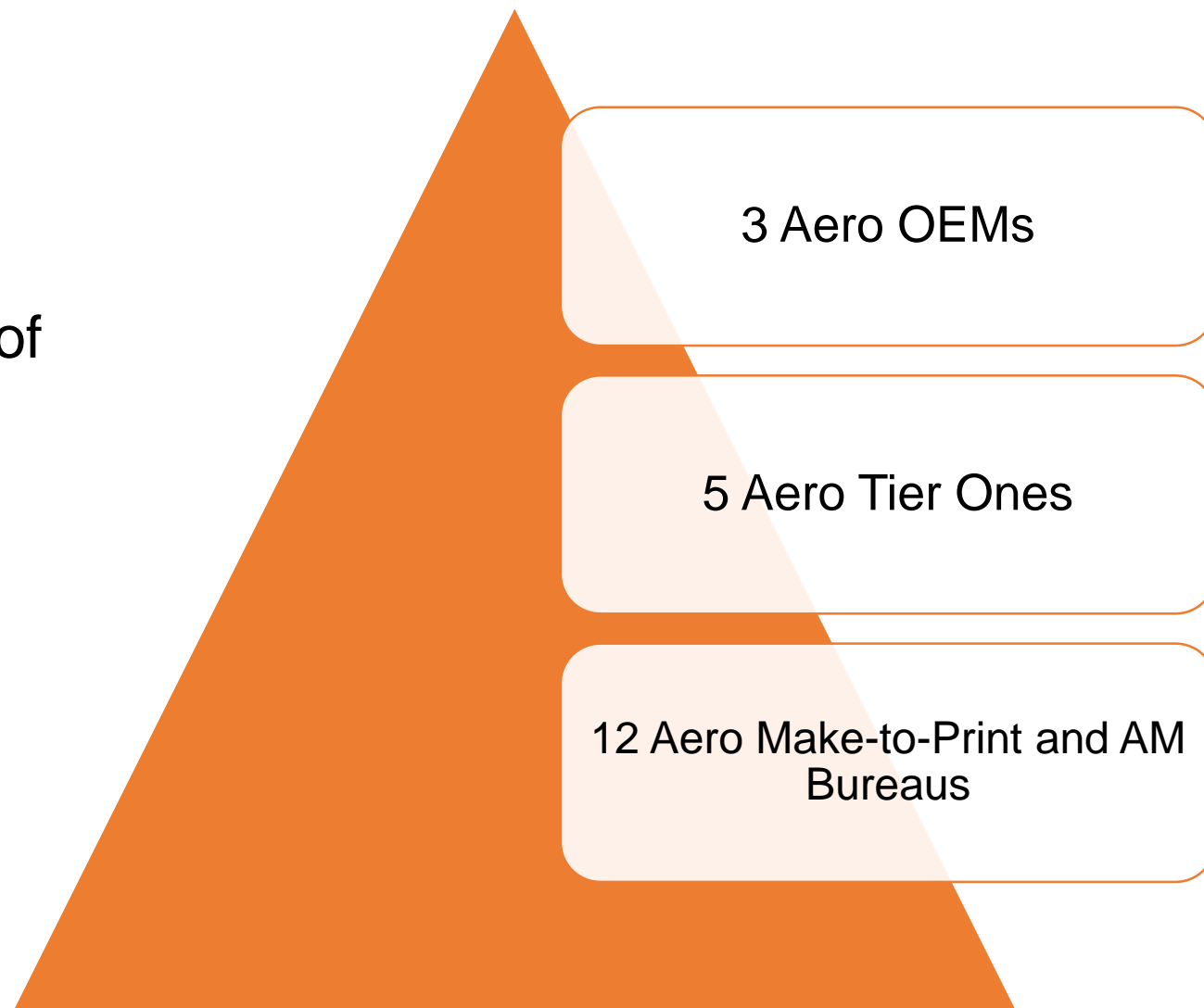
The DRAMA project is funded by UK Research and Innovation through the Industrial Strategy Challenge Fund.

From November 2017, the Industrial Steering Group for the DRAMA project have been providing advice and challenge to the National Centre as to how best we can support the UK aerospace additive supply chain.

**AIRBUS****BAE SYSTEMS****MEGGITT****BOMBARDIER****Collins Aerospace**

INDUSTRIAL CONSULTATION

In early 2018, as part of the DRAMA project, the UK's National Centre interviewed UK supply chain companies to ask what their challenges are around the adoption of additive manufacturing and how we could help them.



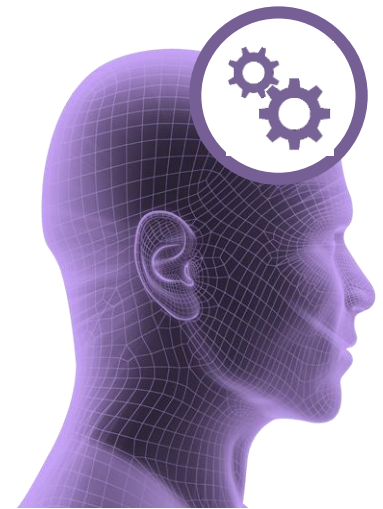
AERO ADDITIVE USERS



**Potential User
(No Capability)**

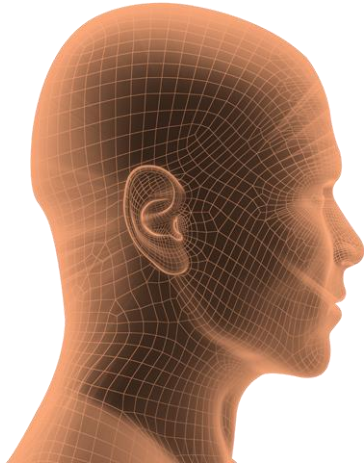


**New User
(Limited Capability)**

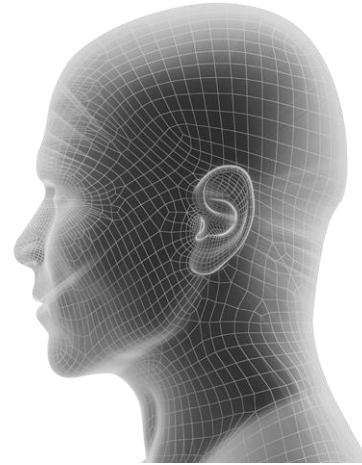


**Experienced User
(Advanced Capability)**

AERO ADDITIVE USERS

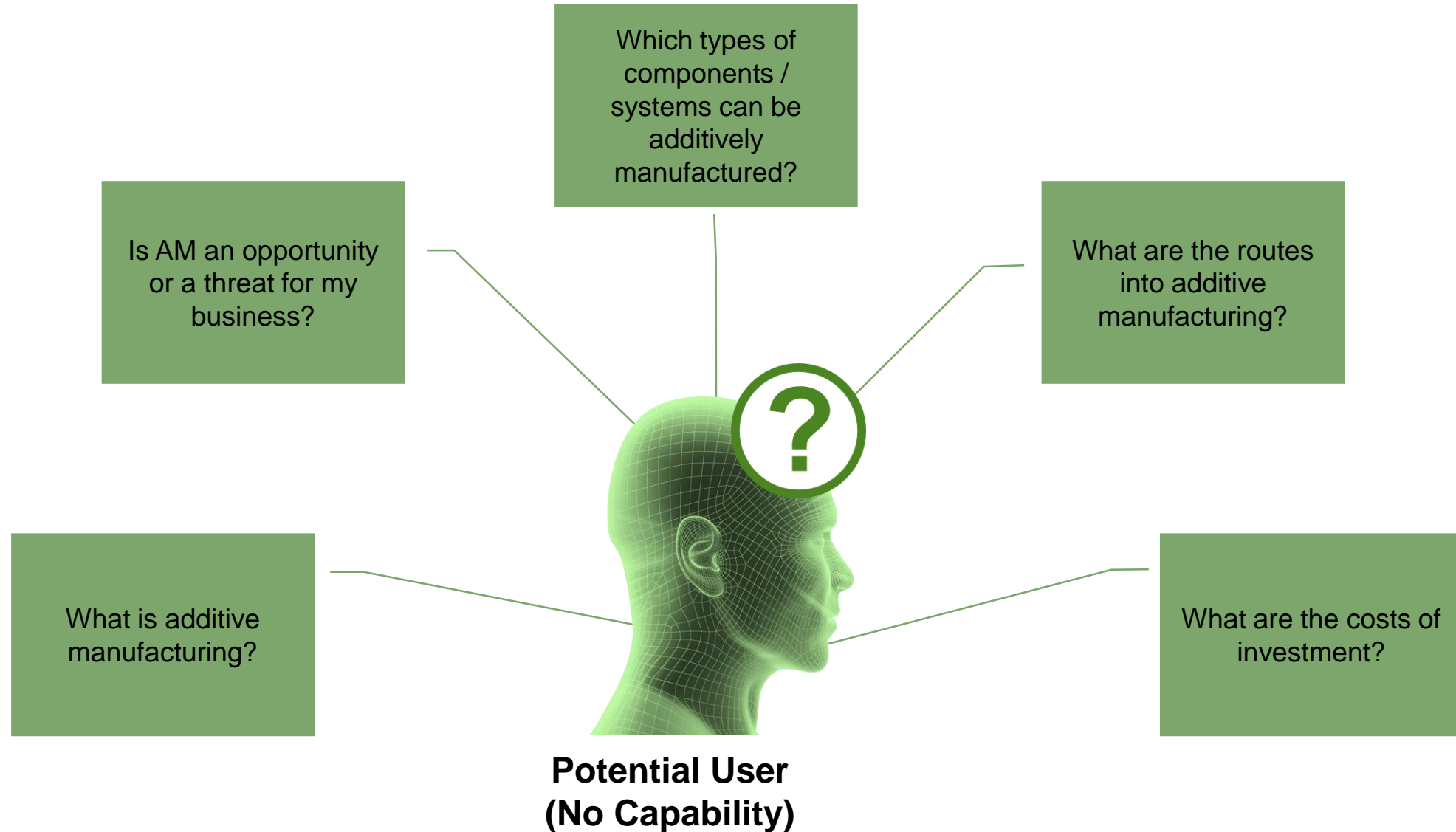


AM Entering Aero

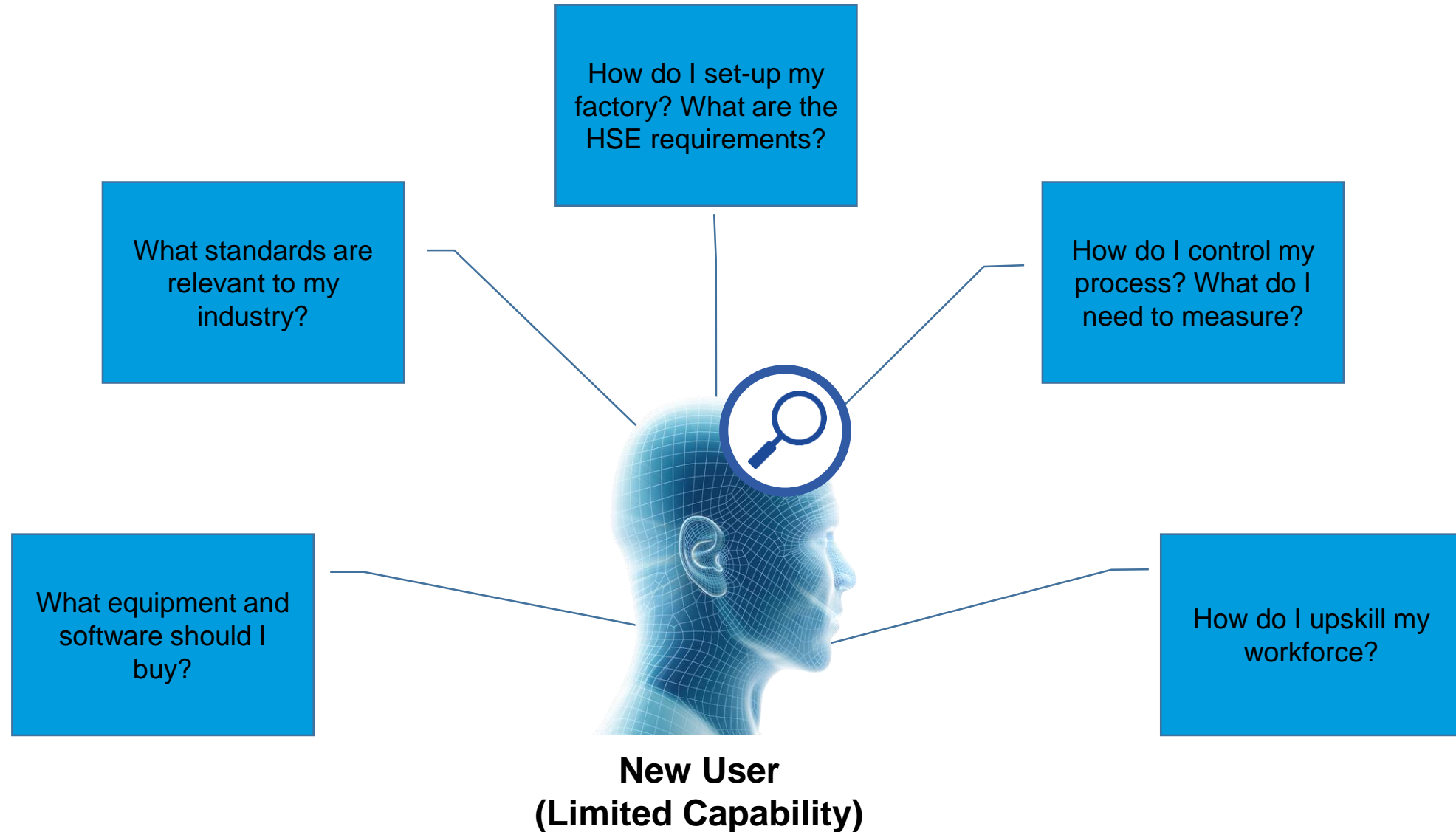


Aero Entering AM

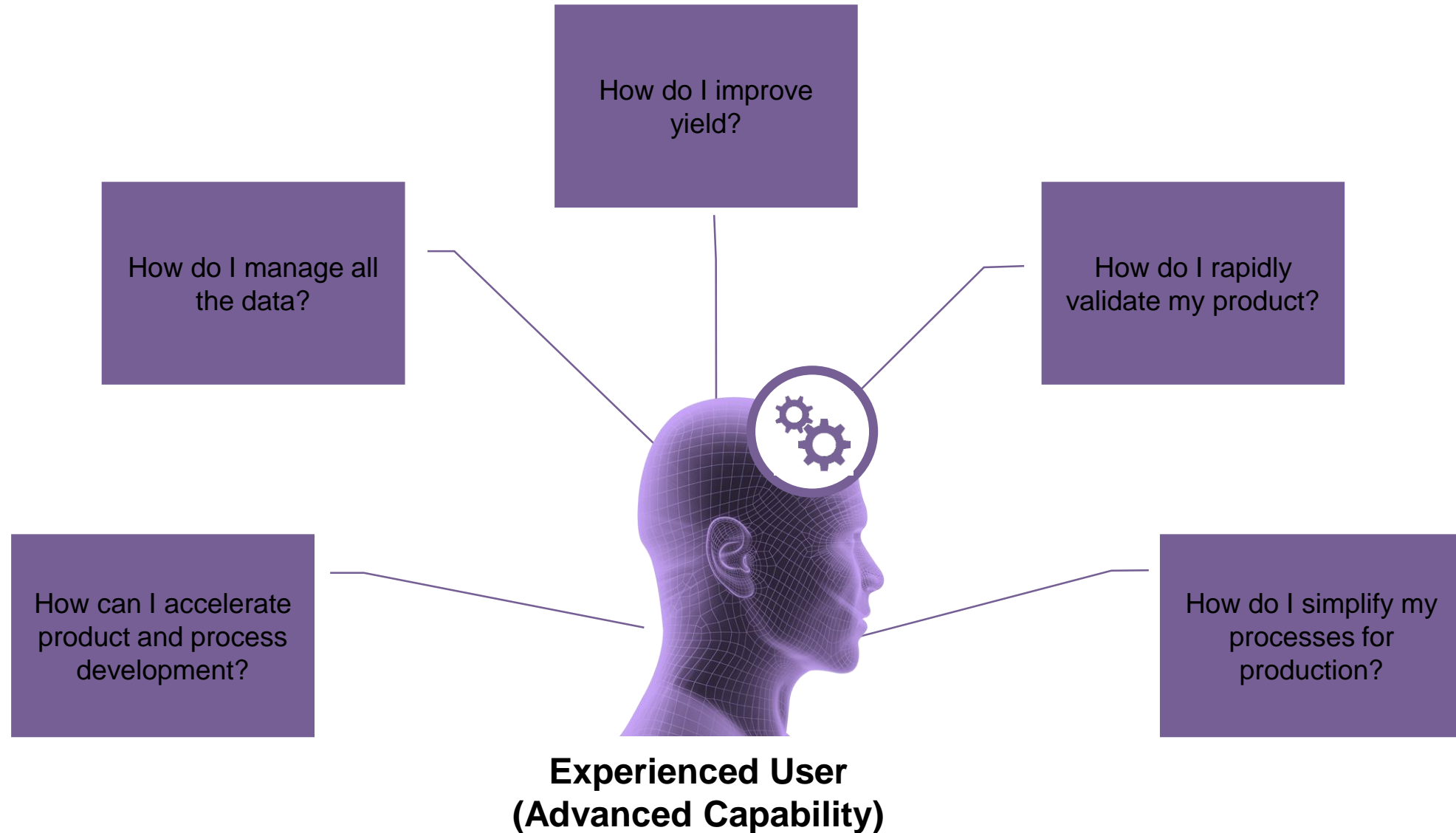
POTENTIAL USER



NEW USER



EXPERIENCED USER



Our mechanisms for knowledge transfer...

- The Knowledge Hub is our online reference library.



KNOWLEDGEHUB

knowledgehub.the-mtc.org/knowledge-hub

KNOWLEDGEHUB WILL HELP YOU GET UP TO SPEED. IT WILL SIGNPOST YOU TO RESOURCES AND TO PEOPLE WHO CAN HELP FURTHER. IT WILL LET YOU TRACK YOUR PROGRESS THROUGH ADOPTION AND IMPLEMENTATION.

To start, we have populated the Knowledge Hub with content from the National Centre Additive Manufacturing, particularly focussing on metal additive manufacturing - but more content will be coming soon covering a range of manufacturing technologies.






Keywords ...

Tags ...

▼ 🔍 ... ?


☰ ☷



Polymers for Additive Manufacturing

This document shows the availability of polymer materials by additive manufacturing processes and by the application.


+



Metal Powder Bed Processes

This guide has been written to help a user determine the capability and limitations of equipment for metal powder bed additive manufacturing. It starts with an overview of the fusion technologies.

+



Finishing for Metal Additive Manufacturing

This document gives an overview of the challenges of finishing metal components manufactured additively and of some of the finishing solutions available. The purpose of the document is to provide guidance to help designers and manufacturing engineers.

Finishing is just one part of the post-build processing chain, which may also typically include removal of the component from a base plate, removal of supports, heat treatment, consolidation (such as hot isostatic pressing), machining and surface treatments.

Download

Designer

Process engineer

Applications engineer

Developing capability in additive

In serial production

Metal

Powder bed fusion

New to additive

Looking for cutting edge tech

Post-build process chain

Binder jetting


Direct energy deposition

Sheet lamination

Material extrusion

-


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Links to Additive Manufacturing Design Guides

This document contains a number of free guides that might assist your design decisions for additive manufacturing.

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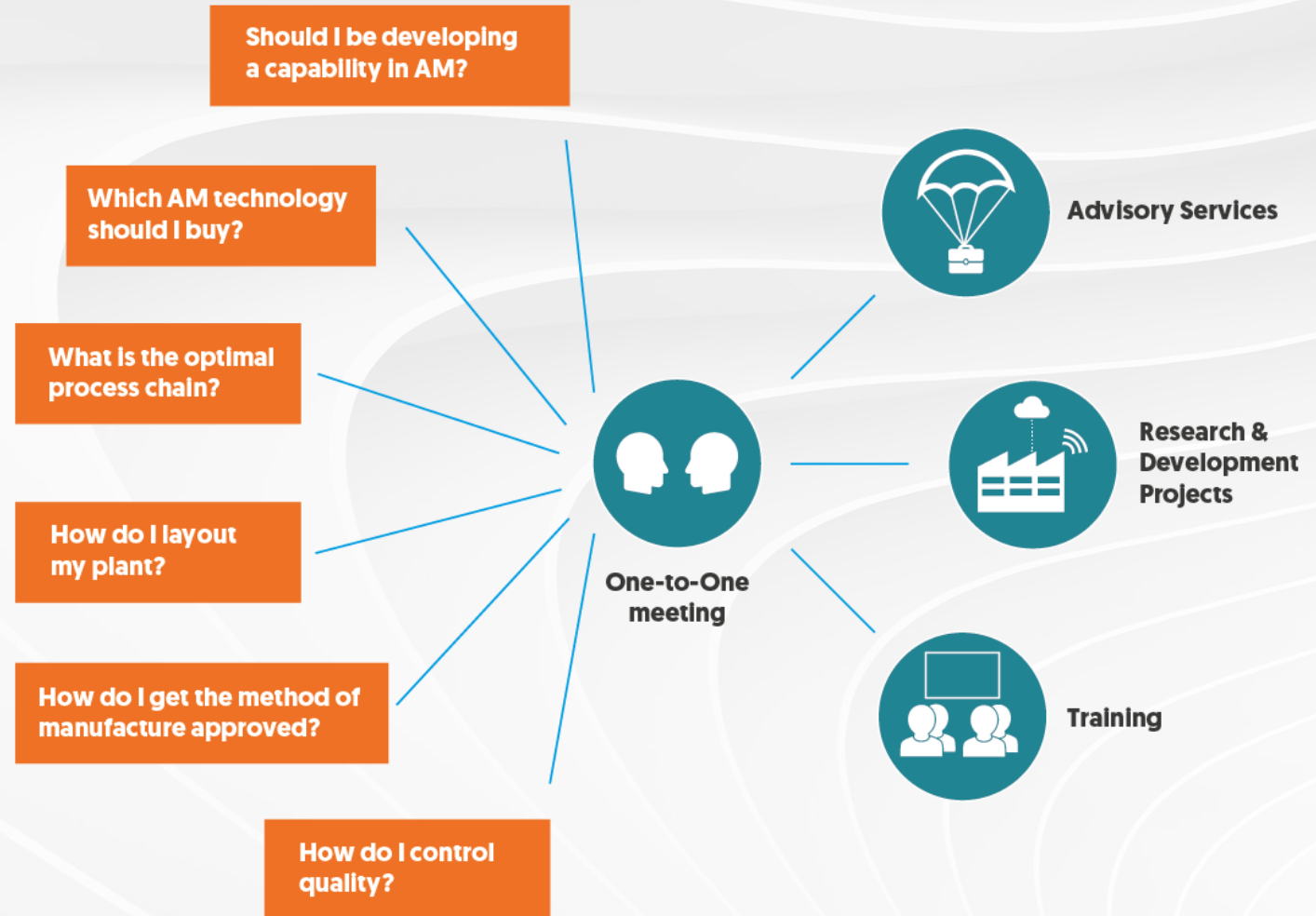
Useful Additive Manufacturing Websites

Links to useful additive manufacturing websites.

+

Our mechanisms for knowledge transfer...

- Advisory Services
- R&D projects
- Training

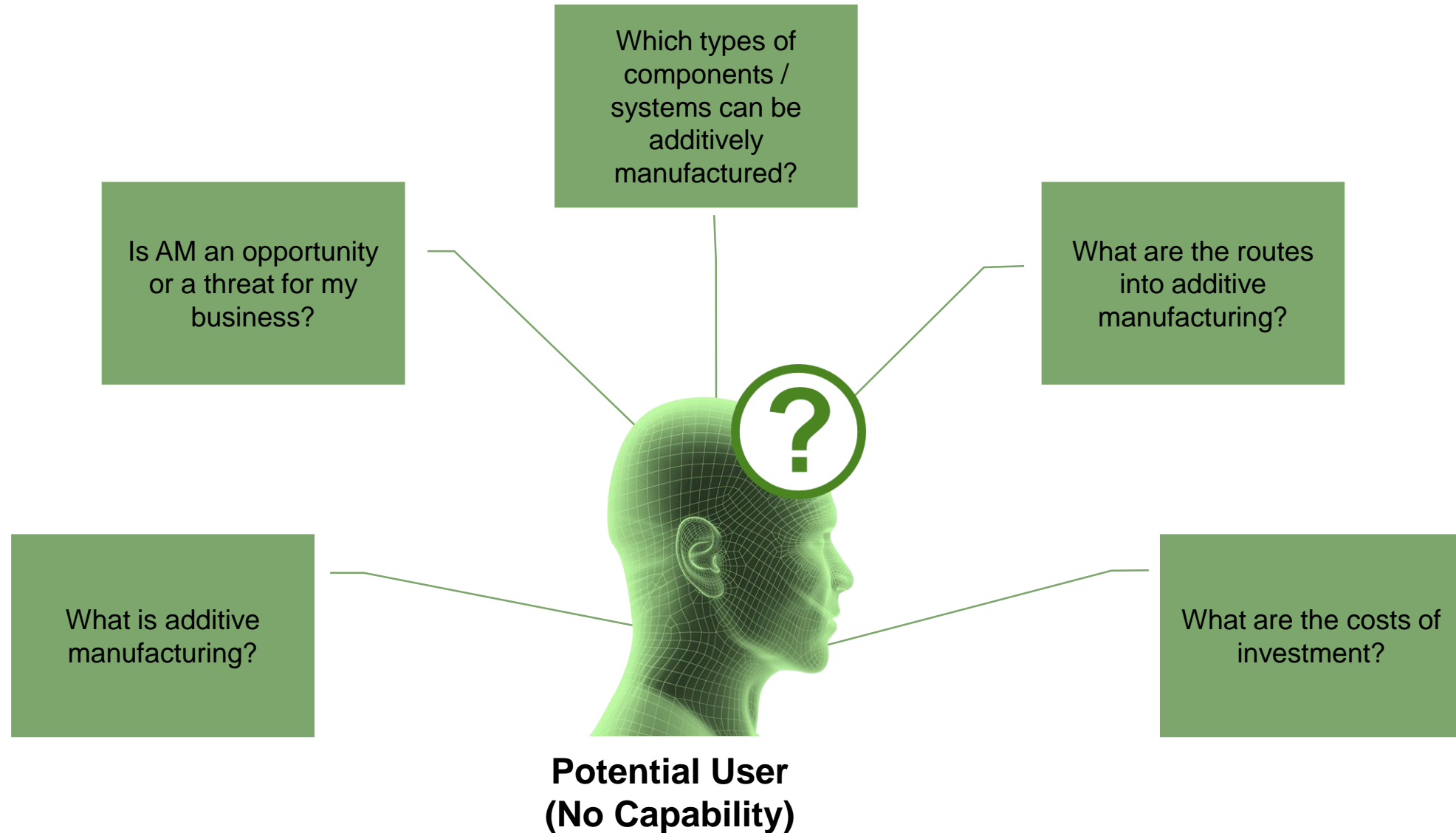


Training

The National Centre Additive Manufacturing with our sister training centre has generated:

- A Competency Framework for Additive Manufacturing
- An Online Training Needs Analysis Tool
 - <https://the-amtc.co.uk/training/training-needs-analysis-system/>
- An AM apprenticeship
- A series of short course for engineers and business leaders
 - <https://the-amtc.co.uk/training/engineer-training/additive-manufacturing/>

POTENTIAL USER



WHICH COMPONENTS OR SYSTEMS?



Support package

Company: Harlow Engineering Ltd

Synopsis:

Harlow Engineering manufactures a very wide range of bus bars in aluminium and copper, many of which are destined for high integrity applications including aerospace.

The low production volumes and complex geometry make these parts expensive to manufacture with a high labour content. Harlow want to understand whether a metal AM powder bed process might be a viable alternative.

AM Background:

- ☐ Wire arc deposition AM for production parts



WHAT ARE THE COSTS OF INVESTMENT?



Support package

Company: Hyde Aero Products Ltd

Synopsis:

Hyde Aero Products has registered a new subsidiary company which will provide AM parts for aerospace and needs assistance in working through the business case.

To help inform the business case, some sample complex Class III helicopter parts will be built by metal AM.

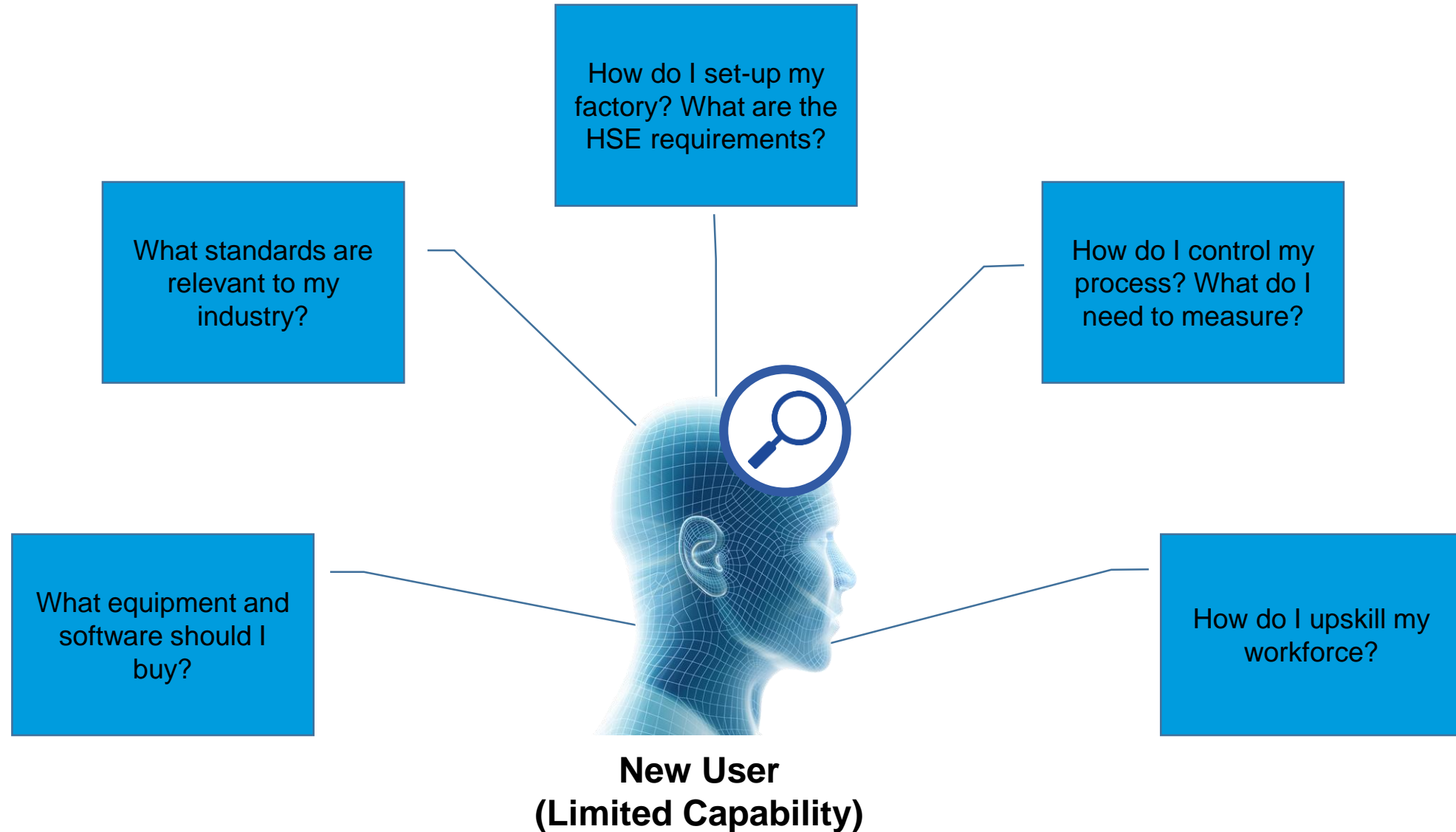
AM Background:

- ☐ Polymer AM for tooling
- ☐ Experience of design for additive, including optimisation

 Hyde Aero Products



NEW USER



WHAT EQUIPMENT SHOULD I BUY?



Support package

Company: Glenair UK Ltd

Synopsis:

For high integrity connector manufacturer, Glenair, polymer 3D printing has been firmly embedded into the business for a number of years, both for specialist tooling and for proof-of-concept prototypes.

Glenair is now investigating metal AM in order to make fully functional prototypes and potentially complete small production runs of complex parts. They want to understand what metal AM equipment to buy.

AM Background:

- ☐ Polymer AM for tooling and prototypes



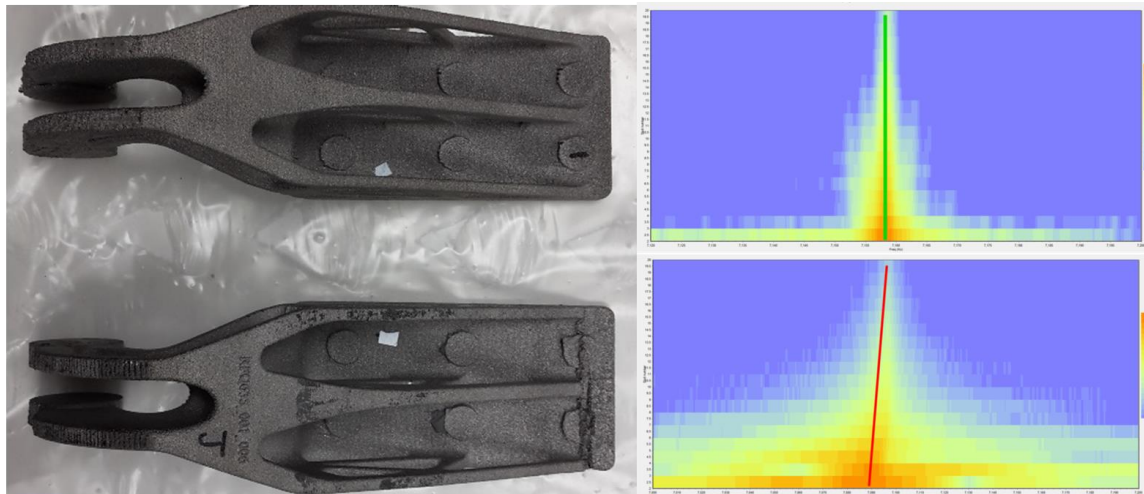
WHAT EQUIPMENT SHOULD I BUY?



Rate capable product verification:

- 3-in-1 X-ray CT
 - XCT for dimensional, defects and surface roughness
- Conventional X-ray instead of XCT
 - Using simulation for planning
 - Using automatic defect recognition
- Resonance and nonlinear testing
- In-process monitoring

Nonlinear acoustic testing of AM bracket by Theta Tech Ltd



aPod 2 'good' (top) and 'bad' (bottom) builds

Corresponding non-linear responses

WHAT STANDARDS ARE RELEVANT TO AEROSPACE?



Support package

Company: Metron Advanced Equipment Ltd

Synopsis:

Metron has built a reputation for the design and manufacture of high performance metallic components for industries including motorsport, marine, space and medical, using an EBM machine. The company now wishes to extend its portfolio to include aerospace.

Metron want to gain a better appreciation of the additional quality requirements which aerospace customers are likely to mandate for AM parts.

AM Background:

- ❑ Design and manufacture of prototype and production parts using EBM

METRON
Additive Engineering



WHAT STANDARDS ARE RELEVANT TO AEROSPACE?



- Addressing gaps identified by ANSI www.ansi.org/amsc : Gap PM1 Flowability and Gap PM2 Spreadability.
- Round robin on powder flow test methods.

Group	Standard / Test method	Cost	Data complexity & time	Test data variability	Relevance to PBF
Funnel flow	B213-17 - Hall flow rate	***	***	*	*
Density methods (Carr/Hausner ratio indices)	B527-15 - Tap density	***	**	***	*
Shear cell	D7891-15 - Shear cell: FT4 Powder Rheometer	*	*	*	**

WHAT STANDARDS ARE RELEVANT TO AEROSPACE?



- **ISO/TC261/JG59** is a Joint Group for Non-destructive Testing of Additive Manufactured Parts, developing a guide that will include post-process NDT of Additive Manufacturing (AM) for metallic parts.
- **ISO/TC261/JG60** is a Joint Group for “seeding” of nondestructively detectable flaw replicas of metal alloy PBF and DED structures.

HOW DO I SET-UP MY FACTORY?



Support package

Company: KW Special Projects Ltd

Synopsis:

Having established a strong background in motorsport, KW Special Projects is currently building a new 1660 m² digital manufacturing facility, which will extend its existing polymer AM capabilities to include metals.

KW Specialist are getting help on factory set-up to ensure that the new production facilities are efficiently arranged, take into account aerospace quality requirements, and cater for the added complexity of working with metal powders.

AM Background:

- ☐ Design of 3D printed parts
- ☐ Manufacturing of polymer parts
- ☐ Supply of metal AM parts using external partners



WHAT ARE THE HSE REQUIREMENTS?

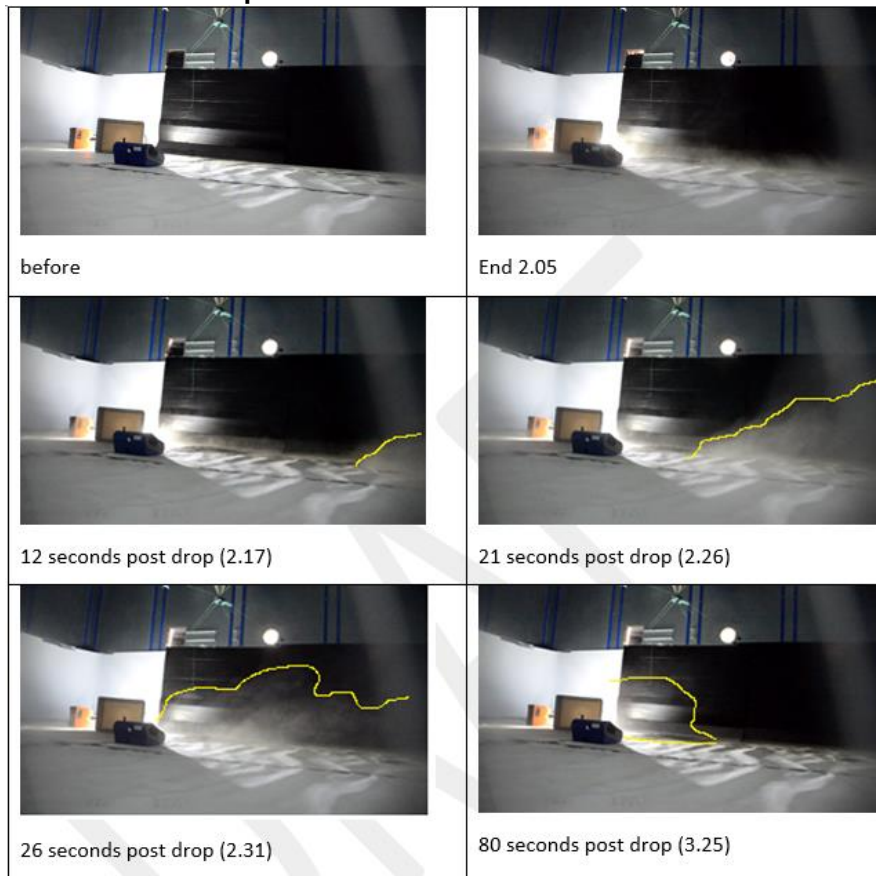


Powder Handling

Understanding the migration of powder – and so the control measures required to avoid hazard to health and safety. Also has implications for contamination.

Approach and analysis reviewed by UK Health and Safety Executive.

Powder drop tests



HOW DO I UPSKILL MY WORKFORCE?



26 UK supply chain companies supported April-October 2018 with funded places on pilot training courses through DRAMA project on: Intro to AM, Design for AM, Practical Insight into AM.



HOW DO I UPSKILL MY WORKFORCE?

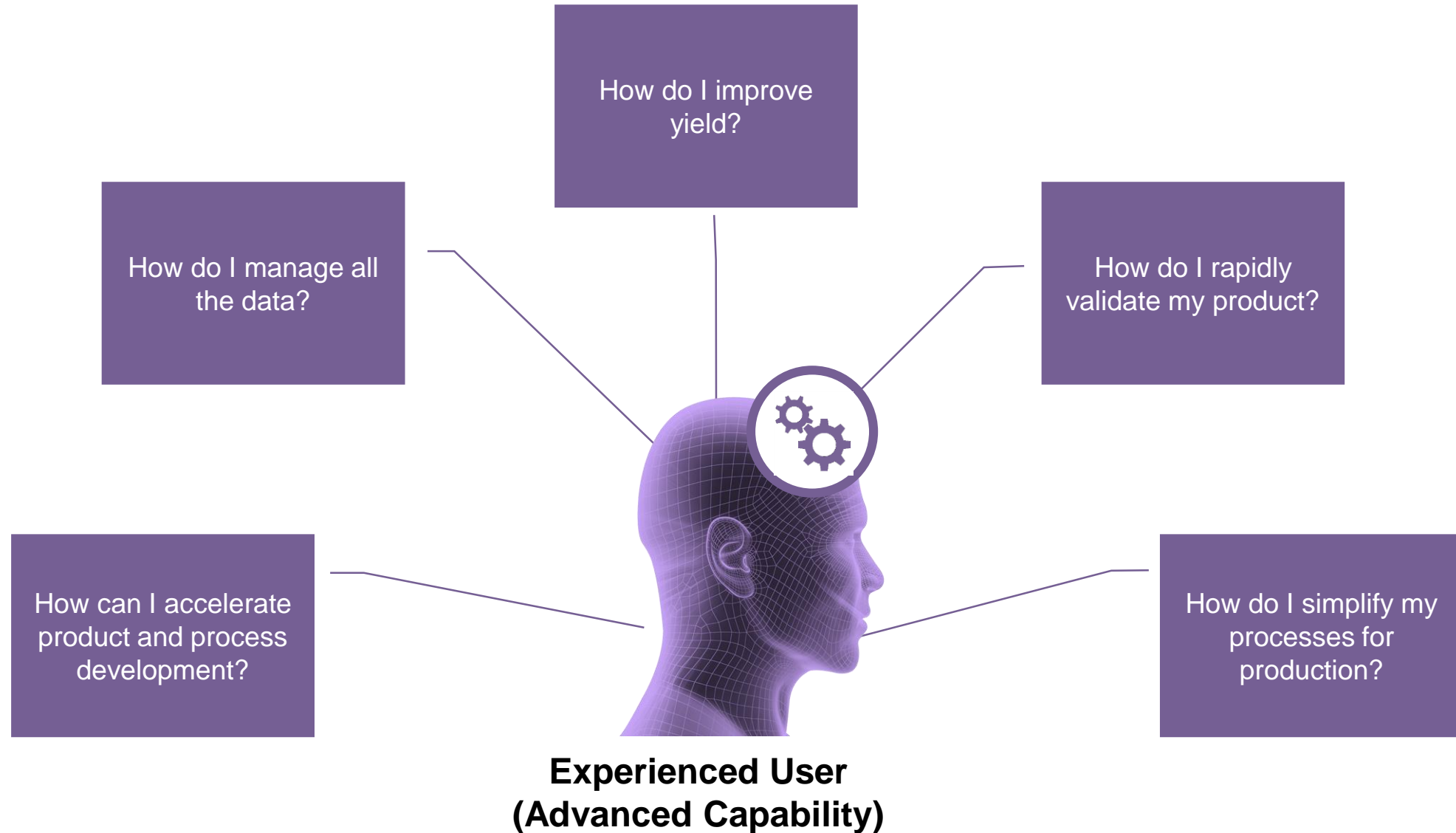


Training

Funded places on pilot of courses for UK companies through DRAMA project

Best practice in process selection	Face-to-Face	1 day	This course will be delivered on the 26th November 2019
Developing the Business Case for AM Adoption	Scheduled - Online Learning	6 hours	This online learning course runs from the 4th November 2019 for 3 weeks
AM Health, Safety, Risk and Mitigation	Anytime - Online Learning	1.5 hours	This online learning course is available from the 7th October 2019
Design rules for Laser Powder Bed Fusion	Anytime - Online Learning	1 hour	This course is available anytime online
Design rules for Electron Beam Powder Bed Fusion	Anytime - Online Learning	1 hour	This course is available anytime online
Design for Metal Powder Bed Fusion	Scheduled - Online Learning	8 hour	This online learning course runs from the 3rd February 2020 for 4 weeks
Best Practice in Powder Management	Face-to-Face	1 day	This course will be delivered on the 27th January 2020
Powder Handling	Face-to-Face	2 days	This course will be delivered on the 18th and 19th February 2020

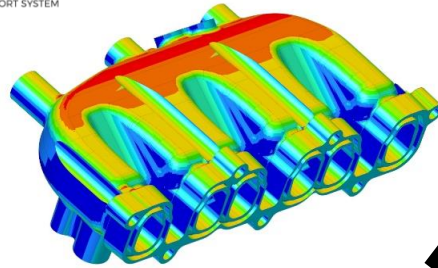
EXPERIENCED USER



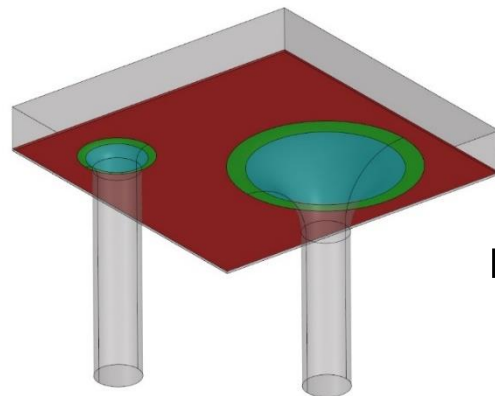
HOW CAN I ACCELERATE DEVELOPMENT?



R&D project



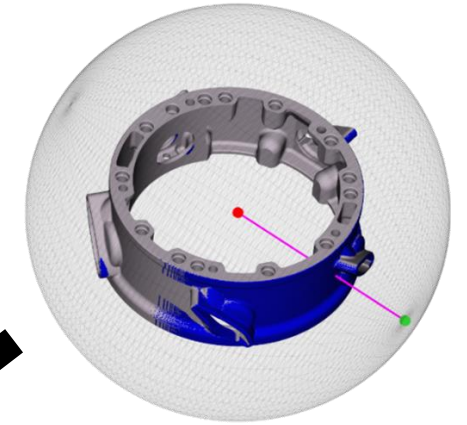
Design for build – surface roughness (Altair)



Design for build – transitions (Altair)



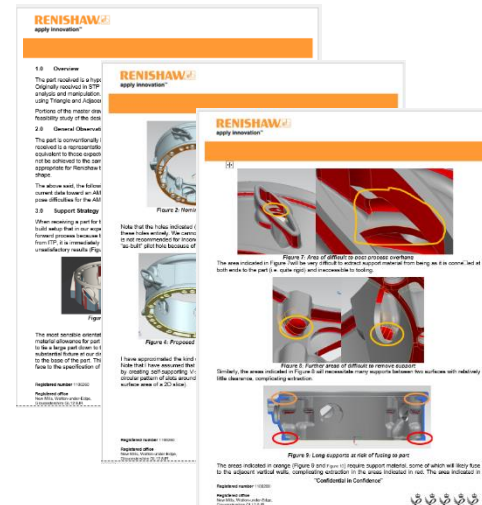
Design for powder removal (MTC)



Design for optical inspection (MTC)



Design for X-ray Inspection (MTC)



Extracts from ITP manufacturability assessment (Renishaw)

HOW DO I MANAGE MY DATA?



R&D project



NEXT STEPS

- **Through the DRAMA project (focussed on UK aerospace supply chain) we will:**
 - Provide 20 companies with advice to support their adoption of additive
 - Run 10 development projects across Renishaw and National Centre Additive Manufacturing
 - Upskill around 40 people from 30 companies

- **Beyond DRAMA we are working on:**
 - Other materials and AM processes
 - Other sectors
 - Funding mechanisms for ongoing support for UK supply chain companies.