ATI Additive Manufacturing
Strategy & Roadmap

AEROSPACE TECHNOLOGY INSTITUTE

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01 Executive Summary

> **Additive Manufacturing** (AM) is set to play a pivotal role in enabling the UK's pursuit of Net Zero carbon emissions in commercial aircraft by 2050, while simultaneously bolstering the global competitiveness of the UK's Aerospace industry.

AM represents a significant step change in aerospace manufacturing and can result in products with improved fuel efficiency, enhanced thermal management capability, and reduced mass. AM can consolidate complex part assemblies into a single part, drastically lowering overall manufacturing costs, and assembly effort. Additionally, AM can accelerate the time to market of complex, high-value products by substantially reducing the time and cost of development cycles.

Internationally the rate of adoption of AM in the aerospace industry is growing rapidly.

General Electric GE Aerospace's GE9X engine incorporates over 304 metal AM parts in each future engine [1].Boeing alone has produced over 70,000 AM metal and polymer parts across both civil and defence aerospace applications [2]. General Atomics Aeronautical Systems Inc has qualified more than 350 flight-ready AM parts, accumulating over 300,000 hours of flight time on unmanned aircraft systems [3]. Airbus has produced over 9,400 locking shafts for their A350 aircraft at their Donauworth, Germany, facility since 2017 [4]. Avio Aero, a subsidiary of GE Aerospace based in Italy, has achieved production rates exceeding 60,000 low-pressure turbine blades per year [1].

The UK has established substantial AM technology capability in the aerospace sector, in industry as well as in research technology organisations (RTO) and academia. For example, Airbus has made significant progress in producing qualified metal AM parts for civil aviation at their Filton site [5]. Rolls-Royce has conducted substantial research & development (R&D) in AM, recently achieving a first flight of AM combustor tiles on the Pearl 10X engine [6]. In defence aerospace, BAE Systems [7] and Leonardo are successfully utilising AM across different aircraft platforms for end use applications [8]. Both are key members of the Global Combat Air Programme (GCAP), in which AM is set to play a role on the new demonstrator aircraft [9].

Progress in the UK has been supported by significant public and private investment. Since its inception in 2014, the ATI Programme has enabled over £113m worth of AM funding, supported by nearly £68m of grant funding. The programme has supported the development of AM research infrastructure including funding to establish the National Centre for Additive Manufacturing (NCAM) at the Manufacturing Technology Centre (MTC). NCAM has completed over 550 AM related projects with a wide variety of industrial partners, working to address key barriers to adoption. Since the publication of the ATI's INSIGHT paper on AM in 2018, the aerospace sector has undergone seismic changes, including the Covid-19 pandemic and an increased focus on sustainable aviation.

01 Executive Summary

These changes have resulted in a lack of clarity on timelines for introducing new civil aircraft, creating uncertainty on the potential uptake of AM. With AM adoption rates in UK aerospace lagging behind global leaders, and with the changing opportunities for AM in the aerospace sector, an update of the ATI's AM strategy was required.

This roadmap document has been created through working closely with OEMs and over 50 partners from across the aerospace supply chain to understand their journey with AM, the challenges they face, and the opportunities going forward. Our vision for 2030 is clear: An order of magnitude growth in the number of flying AM parts in civil aerospace, designed and delivered by a fully capable end to end UK supply chain. To realise this, it is crucial to synchronise technology development with the product decisions that key industry stakeholders are expected to take in the 2028 timeframe

The roadmap targets four key challenge areas: supply chain resilience, qualification, part cost, and increasing part opportunities. Overcoming these challenges will enhance confidence in AM, enabling decision-makers to confidently integrate this technology into future programmes. The UK possesses all the necessary ingredients to embrace full scale aerospace AM production including a comprehensive AM network boasting machine OEMs, rapidly growing supply chains, and unparalleled academic prowess. What is now required is a concerted effort - a collective leaning in - to change the focus from research & development towards the production of end use parts. Failure to act with urgency on these points risks not only stalling progress but jeopardising the substantial investments made thus far.

Image: Parker-Meggitt

02 Contributors

Ruaridh Mitchinson

Ruaridh is a technology manager for the AM team at the Manufacturing Technology Centre which is the National Centre of Additive Manufacturing.

His experiences in AM have included building up and running AM operations and research teams. Including setting up and running a pre-production AM facility for Rolls-Royce, building flight worthy propulsion components. Ruaridh is responsible for business development across the MTC's metal, polymer, and ceramic AM portfolio. In addition, Ruaridh is currently pursuing areas of research that include addressing qualification challenges, space applications in AM, and developing large applications for PBF-LB

Ruaridh is part of the AMUK Steering board, TCT AM Editorial Advisory Board, and ICAM Scientific Organisation Committee for Aviation.

Matthew Bailey

Matthew is a Lead Technologist in the ATI's Structures, Manufacturing & Materials team, joining the organisation in May 2021. Matthew is primarily responsible for metallic technologies at the ATI, which includes additive manufacturing. Matthew also co-ordinates the ATI's Advisory Network which spans six advisory groups covering the full ATI technology scope.

Before joining the ATI, Matthew worked for Airbus in several different roles. Having initially joined as a graduate in 2011, he subsequently spent nearly five years in research & technology, taking two composite technologies to technology readiness level (TRL) 6 as Lead Engineer. Most recently, he was part of the Cost Engineering team, leading manufacturing costing support to numerous projects up to entire wing level responsibility, as well as actively contributing to the digital transformation of the costing team.

Ross Trepleton

Dr Ross Trepleton is an Associate Director at the Manufacturing Technology Centre, part of the High Value Manufacturing Catapult. Ross leads the Component Manufacturing Technology group.

Ross has a key role within the National Centre for Additive Manufacturing, overseeing projects for aerospace, defence, power generation and space sectors. This has included the ATI funded collaborative project DRAMA which delivered national assets and capabilities to enable acceleration of metal bed additive manufacturing in the UK's aerospace supply chain. Ross is currently part of the Executive leadership team for the Defence Support Strategic Command led 'Additive Manufacturing as a Service Challenge' activity (project TAMPA). Ross is also chair of the ATIs Additive Manufacturing Community of Practice.

Alex Hickson

Alex is responsible for the ATI's work on aerostructures of the future. Alex joined the ATI in 2019, bringing experience from across various industries including aerospace, automotive, motorsport, wind energy and space. He has also worked across a breadth of companies, from start-ups and SMEs to blue chip companies including Lockheed Martin and GKN Aerospace.

In his previous role as Technology Manager at GKN Aerospace in Filton, he defined the technology requirements and strategy for the site, secured the funding, recruited the team and developed new technologies through to production. This was an exciting time in his career – being able to create new capabilities in the UK, build a team, and work with the High Value Manufacturing Catapults to mature and de-risk technology for the business.

03 Ensuring UK’s Place In The Market

Additive Manufacturing (AM) is recognised as one of the most promising Near Net Shape (NNS) technologies for the aerospace sector and a key enabler for unlocking future component design possibilities and bolstering supply chain resilience.

The decision to update the ATI's AM strategy and create a new roadmap came from a comparison of UK capability with those of other countries - and the finding that, despite significant efforts and investment to date, the UK is currently manufacturing fewer than 10 distinct metal AM civil aircraft part numbers that are in active use. As a result, the UK is lagging behind international competitors. Globally, governments and industrial organisations are increasingly recognising the importance of AM within their supply chains and moving quickly to secure future manufacturing capability. Examples include:

In the United States:

- GE Aerospace announced £128m of investment into additional AM equipment and supporting facilities [11]- in addition to spending over £1bn purchasing machine OEMs Arcam and Concept Laser, now branded, Colibrium Additive.
- OEM Divergent Technologies has received series D funding of £183m (led by Hexagon AB, Sweden) to continue development of a novel AM production system for automotive and aerospace applications [12].

In Scandinavia:

- GKN which has invested £50m to further develop AM capabilities at their Trollhättan facility, £12m of this was government funded [13]. In addition, regional funding supported GKN Trollhättan’s contribution to developing an Intermediate Compressor Case part for Rolls-Royce’s Ultrafan engine demonstrator [14].
- Norsk Titanium has had investment of £219m with an additional £99m from the New York State government to support a US facility, leading to serial production parts for both Boeing and Airbus aircraft. [15] [16]

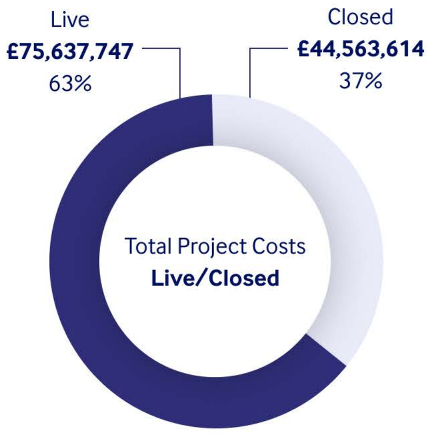
In Germany:

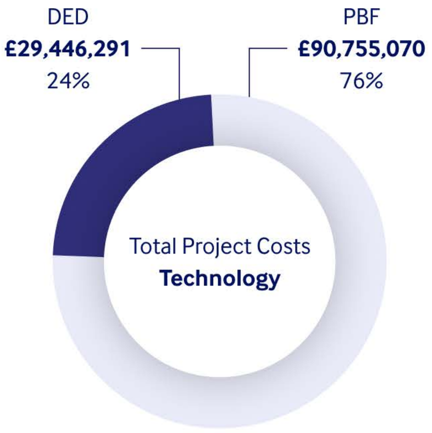
- Organisations such as Premium AEROTEC, MTU, and Airbus Helicopter (Donauworth, Germany) have now all achieved significant milestones in metal AM part production for civil aircraft. [17] [18] [4]
- Nikon acquired prominent OEM SLM Solutions for £533m [19].

To date the spent/committed funding for AM is in excess of:

Total Project Costs in excess of **£120m**

Grant Funding in excess of **£72m**





£10bn

Value of AM aerospace market by 2033[10]

£77bn

Value of total AM market by 2033[10]

03 Ensuring The UK's Place In The Market

The Aerospace Technology Institute is working to ensure that the UK secures its position in this market by understanding and supporting future requirements in both technology development and UK production capability for AM. The primary opportunity for wide-scale adoption of AM in aerospace lies with newly-designed aircraft (due to the high non-recurring costs associated with new manufacturing technology introduction). It is therefore critical that the UKs position is secured at pace as key decision gates for the integration of AM into next generation defence (~2026) and future civil aerospace programmes (~2028) are rapidly approaching. If these timeframes are missed there is a risk of long-term exclusion for a generation of aircraft.

> The UK has heavily invested in developing AM over the past decade, with UK Research and Innovation (UKRI) supporting 811 AM-related projects, with a **total value of over £552m** between 2013 and 2023 across a wide variety of sectors [20]. The ATI Programme has enabled over £120m worth of AM funding, supported by nearly £72m of grant funding for the aerospace sector.

Significant ATI Investments (capital) include:


Image: GKN Aerospace

£32m

GKN: Global Technology Centre (GTC)

Opened in 2020. The GTC accommodates GKN technical staff and facilitates collaborative research and development with universities, the UK's Catapult network, and GKN Aerospace's UK supply chain. The centre specialises in additive manufacturing, advanced composites, assembly, and Industry 4.0 processes, aiming to enable high-rate production of aircraft structures.


Image: MTC

£14.2m (2014 - present)

The MTC: National Centre for Additive Manufacturing (NCAM)

NCAM provides access to state-of-the-art facilities and expertise to support organisations de-risk their adoption of AM. Business and technology support packages developed through the ATI funded DRAMA project have been used by 70+ UK aerospace supply chain companies in their AM adoption journey.


Image: TWI

£6m (2018 – 2021)

TWI: Open Architecture AM (OAAM)

This TWI-led OAAM project demonstrated large metallic component manufacturing via Directed Energy Deposition (DED). Three DED platforms (laser, electron beam and wire arc) were commissioned at three separate facilities offering unique capabilities. These facilities have since provided routes for aerospace organisations to progress DED capabilities towards TRL 6.

04 Case Studies

Airbus - A320ceo Wingtip Fence part

Image: Airbus

The spares and repairs market, by its very nature, can be unpredictable. Additive Manufacturing has proved to be a key technology in supporting the aftersales market for "out of production" parts because of how quickly it can produce parts. Airbus has been able to pioneer Additive Manufacturing to supply parts, when existing traditional technologies were no longer possible.

The part in question is the A320 CEO Wingtip fence. The fully process-qualified facility at Airbus's Filton site successfully qualified and delivered more than 40 Titanium spares parts to the customer in 2020, realising a 45% reduction in setup costs and a direct delivery to the customer for lineside fitment.

Rolls-Royce Pearl 10X Combustor Tiles

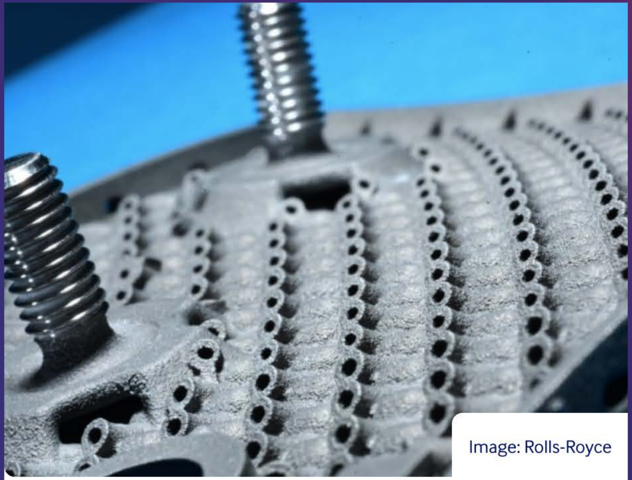


Image: Rolls-Royce

The concept for an additive manufactured combustion tile was initiated in 2015 within Rolls-Royce for the Pearl business aviation product designed in Rolls-Royce Germany. Through this project Rolls-Royce has developed a class-leading combustor that simultaneously enables both cost and functional optimisation, such as a 20% improvement in cooling efficiency that is not possible on tiles designed and manufactured via conventional manufacturing methods.

This project has led to the creation of a new additive facility sited in Rotherham, UK, to manufacture these combustor tiles with all associated benefits such industrialisation experience, manufacturing and materials science understanding that are now being used on further applications.

GKN – Additive Industrialisation for Future Technology (AIRLIFT)

Image: GKN Aerospace

Under the ATI-funded AIRLIFT programme, GKN Aerospace established Laser Metal Deposition by wire (LMDw, a DED technology) within the UK. This is the first installation of GKN Aerospace's in-house designed and built LMDw capability within the UK, targeting key opportunities in civil and defence aerostructures. The development carried out in the AIRLIFT project has directly led to engagements with three aerospace OEMs on opportunities for structural insertion of the technology.

04 Case Studies

Eaton – Additive manufacturing deployment strategy

Image: Eaton

In 2016, Eaton launched a strategic initiative to address the challenges limiting the adoption of metal additive manufacturing (AM) in the aerospace industry. This initiative was a huge success for Eaton and several customers. In total, the company received more than 26 commercial awards across military, civil and space applications. To achieve the commercial awards, Eaton had to overcome several challenges associated with adopting AM as a production method. These challenges included: no clear qualification path, no experience launching AM product and limited customer engagement.

Despite these challenges, Eaton achieved wins by addressing the lack of a clear qualification path, no prior experience in launching AM products, and limited customer engagement through identifying low-risk, low-volume programs. With the qualification framework in place, they built credibility and showcased how AM could facilitate superior solutions for next-generation aircraft.

One of the most impactful customer programs relates to the Airbus A330 fuel scavenge jet pump. Eaton's AM team delivered critical components that adhere to both EASA and FAA standards, including the consolidation of 11 parts into one, reduce weight by 30%, and decrease assembly time while enhancing product reliability and performance.

Eaton's global expertise has paved the way for AM collaborations in the UK and U.S. Additionally, the company's strong relationships with regulators and government officials has streamlined the qualification process, preventing redundant efforts.

In summary, Eaton's strategic approach has overcome barriers and positions AM as a game- changer in aerospace manufacturing.

Some notable successes Eaton achieved through AM include:

- Titanium manifold – 127 lbs of weight savings and 159 components and leak paths eliminated.
- Swivel joints – 25 lbs of machining waste avoided, and 96 components and leak paths eliminated.
- Jet pump – Bill of Materials (BOM) reduced from 54 to 25 parts which equates to eliminating 45,000 parts from the supply chain annually.

05 Consultation Process

To refresh the ATI's AM strategy and create this roadmap, a comprehensive consultation of the industry was undertaken. Three methods of engagement were used to gather expert insights:

- **Community of Practice**: The AM community of practice (CoP) leadership group was formed in June 2023 and is comprised of key industrial stakeholders that represent the primary route for exploitation of the technology. This leadership group is jointly led by ATI and NCAM. In addition, 4 sub-working groups were established comprising of subject matter experts covering the following areas: DED, Metal Powder Bed Fusion (MPBF), Digital Thread, and Supply Chain.
- **Key Stakeholder Interviews**: 17 in-depth interviews were conducted with industry stakeholders, including aerospace end users, AM machine OEMs, SMEs, and academia to gain specific detail regarding blockers to adoption.
- **Open Access Workshops:** An open call was issued for wider supply chain participants to provide feedback through a workshop that was held at The MTC in November 2023.

Information from each of these strands was anonymised, collated, and prioritised with multiple feedback iterations through CoP leadership group and sub-working groups, culminating in the finalised strategy and roadmap document.

AM CoP Leadership Group

Aerospace Technology Institute
AIRBUS
ASTM International
BAE SYSTEMS
BOEING
CATAPULT High Value Manufacturing
Department for Business & Trade
EATON
GKN AEROSPACE
Honeywell
ITP Aero
LEONARDO
mtc where progress happens
Ministry of Defence
Parker
Rolls-Royce
TWI

Wider participants involved in strategy refresh

Ai BUILD
Additive Manufacturing UK
additiveflow
Alloyed
Additure
AMFG Autonomous Manufacturing
AMRC Advanced Manufacturing Research Centre
AMS Additive Manufacturing Solutions Ltd.
Ansys
APEX Additive Technologies
AUTHENTISE
BEAMIT
CARPENTER ADDITIVE
DMC Digital Manufacturing Centre
DNA.am
DOMIN
ENABLE print. cast. deliver.
eos
FDM Digital Solutions
FORG3D
Lloyd's Register
MAPP
MELTIO
midlands aerospace alliance
North West Aerospace Alliance
PRI Performance Review Institute
PROTOTAL
RENISHAW apply innovation
SIEMENS energy
TESTIA an Airbus company
wallwork
ToffeeX
WAYLAND ADDITIVE
WAAM Wire Arc Additive Manufacturing
WMT&R Ltd Westmoreland Mechanical Testing & Research
3T additive manufacturing

06 Consultation Output: Key Themes

Through the consultation process common topics emerged regarding the challenges currently hindering adoption of metal AM by members of the aerospace supply chain. These common topics have been distilled into eight interconnected themes:

- **Clarity on future product timelines**
- **Qualification and certification experience**
- **Costs**
- **Perceived Stagnation**
- **Myriad of AM technology solutions across the process chain**
- **Senior Stakeholders 'Buy In'**
- **Supply Chain Configuration**
- **Duplication of Effort**

Clarity on future product timelines

The timescales for the introduction of the next generation of civil aerospace programmes, including their engines, are not clear. This uncertainty sets off a cascading effect for the whole AM supply chain resulting in a lack of clarity of where, when, and how AM will be used in future aircraft.

As a consequence of this lack of clarity, supply chain organisations are uncertain of future aerospace requirements. This in turn hinders their investment in skills, capital equipment, and facilities. Those that do invest must look at cross-sector opportunities to reduce risks and maximise returns. For example, in adjacent sectors such as the highly regulated markets of defence aerospace and space, AM is being used for highly-demanding applications including unmanned air systems (UAS), rocket launch vehicles (Space), and satellites. Incorporating AM into these application areas has enabled critical manufacturing and flight data to be gathered - a key element in building confidence in the technology.

As the majority of OEMs and Tier 1 aerospace organisations within the UK serve both defence and civil aerospace it is suggested that short-medium term demands of industries such as defence aerospace could be used as a strategic link to build supply chain capability and capacity which in the medium-long term can supply into civil aerospace programs.

Image: Airbus

06 Consultation Output: Key Themes

Qualification and certification experience

From data shared during the course of this consultation it is estimated that there are fewer than 10 certified civil aerospace metal AM part numbers that are manufactured in the UK. This highlights there is limited (albeit growing) competence, capability and heritage in qualifying and certifying AM components for civil aerospace in the UK supply chain. Although there are high technical and commercial barriers to achieving a certified AM part, the value and competitive advantage associated with organisations that do overcome these barriers is high, increasing the likelihood of securing future opportunities.

There is a strong desire from the supply chain to develop the skills and capability required to design and manufacture AM parts for civil aerospace, with many organisations currently working diligently to realise this ambition. Progress is hindered by a lack of common consensus on which standards should be used to qualify end use civil aerospace parts. Standards organisations are vying to secure their future position in this manufacturing landscape with an increasing number of standards comprehensively covering key AM technologies. This competition, combined with differences in machine specifications between leading OEMs, creates confusion within the market as to the steps required to get parts into end use.

Costs

Opportunities to use AM as a substitute for existing parts on commercial aircraft are limited; as a new technology, the cost of the development and qualification of the AM part has to be amortised on top of the manufacturing cost. This typically makes an AM part more expensive than conventionally manufactured alternatives so opportunities are limited to those where traditionally manufactured components cannot be sourced efficiently. In addition to limited cost saving opportunities, other potential benefits of using AM technology (such as lightweighting) are minimal due to restrictions on part redesign. Counter arguments for using AM, in terms of longer-term strategic views of developing future technology, and improvements in through life costs due to adopting AM, currently play a secondary role compared to part cost during procurement.

Image: Renishaw

06 Consultation Output: Key Themes

Perceived Stagnation

Significant R&D activity has been directed towards process and application development to showcase the potential of AM within civil aerospace, with applications showing clear promise advancing to the more expensive pre-production and qualification phases. Publicly available information regarding progress of these activities is often limited, which has created the perception that the adoption of AM is stagnating. Nevertheless, these ongoing research and development activities steadily accumulate knowledge and essential experience in AM. This sustained endeavor is crucial for cultivating a pool of skilled personnel and AM capability, that are ready to take advantages of opportunities such as new product launches as they arise.

There is currently limited government funding available to progress AM technology beyond TRL 6 in aerospace. This presents a significant hurdle to organisations that wish to gain vital experience in qualifying and certifying AM parts, as although relatively mature by TRL 6 there is still a significant level of risk, potentially beyond the appetite of private investors, to industrialise the technology. By not reaching higher manufacturing readiness levels (such as 8 or 9) organisations do not get the required skillsets and experience in qualification & certification of AM parts. It is also observed that the cost of qualifying and certifying parts decreases over time for an organisation as they become increasingly competent in the activity.

It is in the interest of all within the community that the number of AM parts that are certified for aerospace grows, breaking the perception of a continuous cycle of AM R&D projects. As this will likely increase confidence of industry decision makers that AM is a mature and viable manufacturing technology for end use parts.

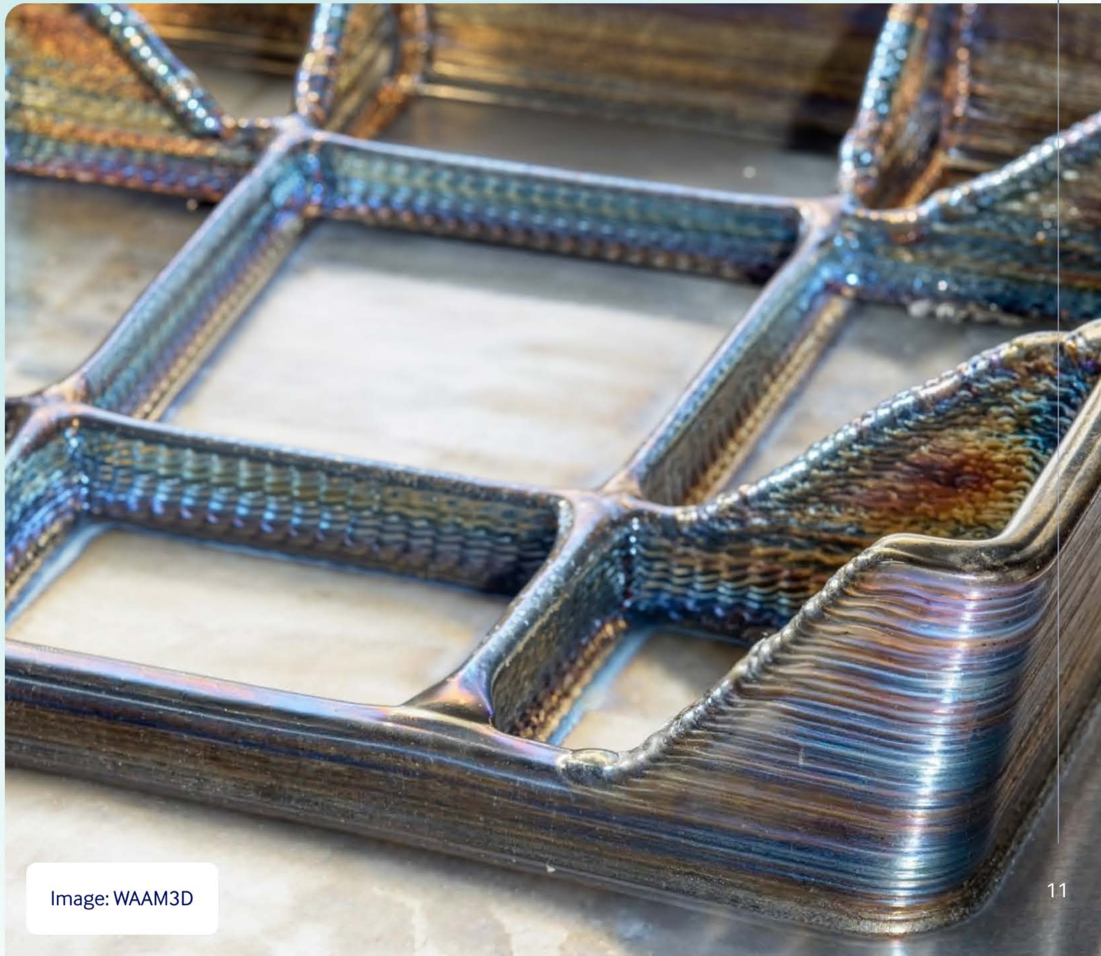


Image: WAAM3D

06 Consultation Output: Key Themes

Myriad of AM technology solutions across the process chain
Over the past decade there has been a proliferation of AM equipment suppliers (for solutions across the AM process chain) as companies look to secure a proportion of this lucrative market opportunity. Typically, aerospace organisations have selected specific AM machine vendors and collaboratively developed the AM process. With such a vast array of pre- and post-processing equipment also available, many aerospace primes are assessing different options across the process chain as they strive towards optimised methods of manufacture for their components.

With aerospace primes taking different approaches, there is no common consensus within the industry of what technology should be used across the AM process chain. From a supply chain perspective this creates hesitation regarding future investment decisions due to risk of obsolescence. In the short term, OEMs and Tier 1s could provide capability and capacity forecasts to minimise the risk of these investment decisions, and foster supply chain growth.

Longer term, R&D efforts are underway to decouple the relationship between part properties (material and mechanical) and the specific AM machine that the part is produced on. Resolving this challenge is a key component to improving supply chain confidence and increasing agility.

Image: MTC

06 Consultation Output: Key Themes

Senior Stakeholders 'Buy In'
Senior stakeholder "buy in" for using AM is a key component for the successful implementation of AM parts into production. Decisions regarding whether to adopt AM within an aircraft or engine are taken by senior programme owners and executives, and not by personnel within AM R&D departments. 'Buy in' ensures that long-term AM technology projects that may have a longer return on investment are seen through to implementation, rather than pushed out for shorter term goals. Furthermore, senior stakeholder commitment can also help overcome challenges in placing AM in existing platforms (where it may not be currently cost effective). Senior leaders can promote a more strategic, long-term approach where the value of the learning and data gained from using AM for direct part substitution, offsets potential cost increases. This longer term view builds confidence and lowers the risk for the introduction of AM components in the next generation of aircraft.

To gain and maintain 'buy in' it is vitally important for AM personnel to regularly update senior stakeholders on the latest developments in the AM market. This ensures that any potential perceptions of stagnation or past experiences with the technology align with current progress, and new opportunities are identified quickly. Developing mechanisms to improve communication with key stakeholders will be a key focus area for future ATI AM CoP activities and other relevant industry forums such as AM-UK.

Image: ATI

06 Consultation Output: Key Themes

Supply Chain Configuration
Aerospace primes are expecting to use the supply chain to produce a significant proportion of their AM portfolio. Tier 1 suppliers that hold design authority and/or ones that have existing relationships with primes and components catalogues are leading candidates for the production of AM parts. An emerging trend from the interview process, in part driven by global instabilities, is the opportunity to use AM as a replacement for forging and castings parts that can no longer be sourced within the required timescales.

Beyond AM part manufacturing, there are additional opportunities for provision of equipment and services across the process chain (such as heat treatment, material testing, machining etc...). Through the consultation interviews several aerospace primes described sending AM parts/ test coupons overseas for processing as there is no UK alternative supplier - This represents a key long-term opportunity that many UK supply chain organisations are working towards.

Emphasis should be placed on ensuring that the supply chain understands which opportunities are most appropriate for them, whilst also highlighting potential barriers to entry with suggested mitigations. New AM markets entrants aiming to supply the aerospace supply chain will require support understanding the requirements both technically and commercially to civil aviation programmes. Existing aerospace suppliers will have greater understanding of quality, control, and commercial requirements, thus will likely find reduced barriers to entry.

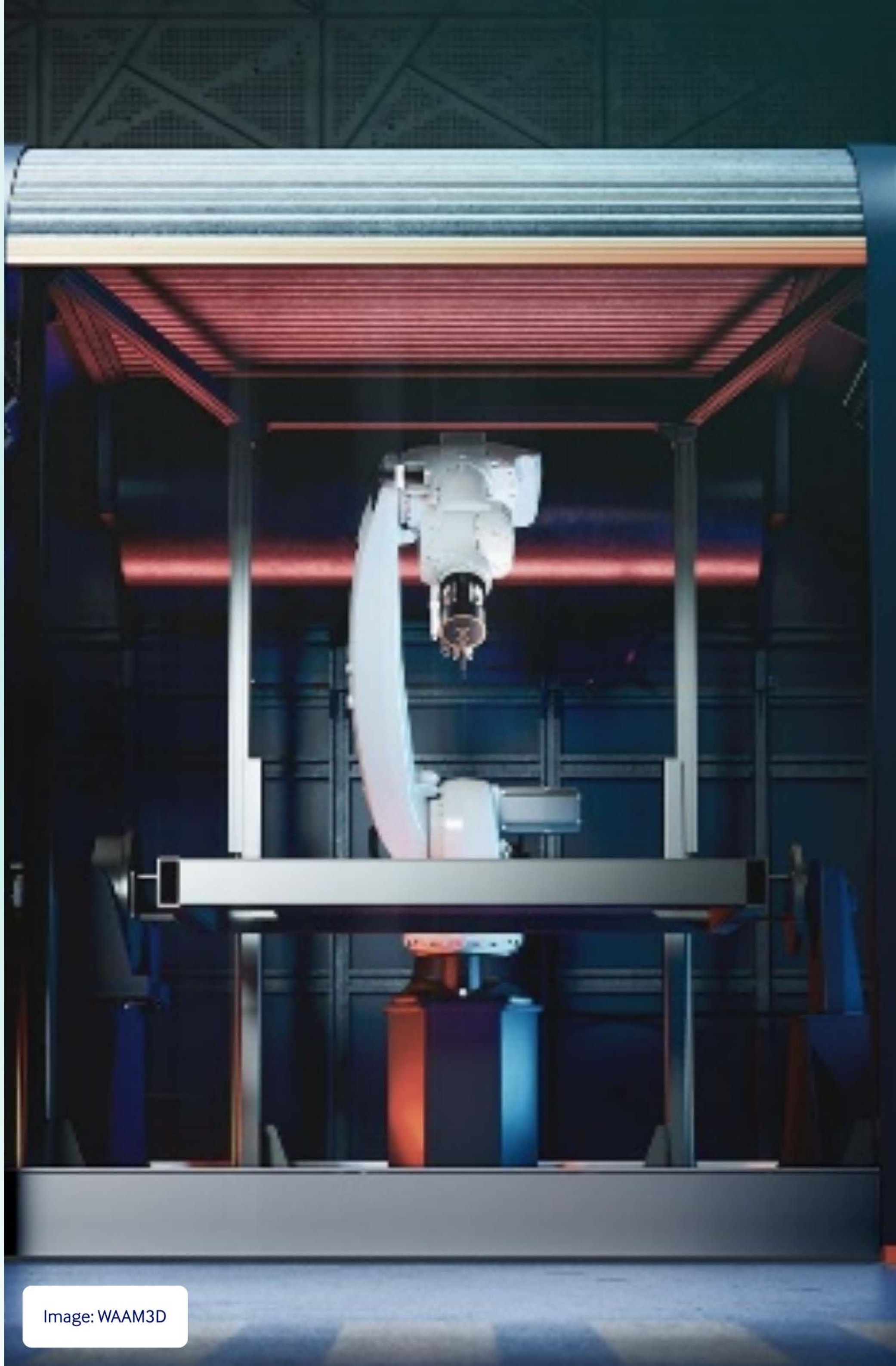


Image: WAAM3D

06 Consultation Output: Key Themes

Duplication of Effort

To date, information sharing among aerospace organisations and from completed publicly funded projects has been limited. There's a growing consensus that organisations should reassess what constitutes sensitive company intellectual property (IP) and consider sharing non-sensitive IP within the community to reduce duplication of effort and accelerate collective progress. For instance, if a company gains insights from a funded project on utilising a multi-laser powder bed fusion (PBF) system, it's unclear how others would access that knowledge without applying for similar funding.

This siloing of information has led to completed project findings being underutilised through limited dissemination resulting in duplicated efforts and inefficient development on industry-wide challenges. To address these issues the sector should look to share information on the key direction of research, exchanging findings and best practice (respecting confidentiality where necessary). Moreover, there's an urgent need for cooperation across civil and defence aerospace sectors to unlock funding, pool resources, and facilitate shared learning to tackle common challenges effectively.

To ensure successful adoption of metal AM in the UK aerospace supply chain, activities to address the eight themes described above must be considered alongside AM technology advancements. For this reason, the roadmap (section 10) has been structured to address these key underpinning current themes, while also ensuring activities developed by each CoP sub work group are progressed to mature future technologies and enable long term global competitiveness. The targeted activities have been collated into four key challenge areas:

- **Developing a resilient and cohesive supply chain**
- **Improving efficiency of qualification and certification of AM parts for aerospace**
- **Drastically reducing cost of AM parts**
- **Expand the possible application areas for utilising AM**

Image: Domin

07 Vision for 2030

The ATI maintains a firm belief that with steadfast commitment and collaborative efforts, the UK aerospace sector has the capability and desire to overcome these challenges. We are optimistic about paving the way for a transformative era in aerospace manufacturing, delivering our **Vision for 2030:**

> **"An order of magnitude growth in the number of flying AM parts in civil aerospace, designed and delivered by a fully capable end-to-end UK supply chain"**

Realising this vision will demand substantial effort, the challenging of prevailing perceptions and robust national & international collaboration. Through unwavering commitment and collective action, we are confident we can overcome these obstacles and usher in a transformative era for aerospace manufacturing, one marked by innovation, sustainability, and global leadership.

These efforts will not be conducted in isolation and are closely aligned with the strategic directions of the Aerospace Technology Institute (ATI); the Manufacturing Technology Centre, as the National Centre for Additive Manufacturing (NCAM) and representative of HVMC; and the Ministry of Defence, reflecting our combined dedication to a unified, sector-wide effort going forward.

08 AM CoP Leadership Mission

The ATI AM Community of Practice aims to convene specialist expertise from aerospace organisations to address challenges hindering wider adoption of AM within Civil Aerospace. Coordinated by ATI and NCAM, it aims to identify key adoption challenges, propose tangible activities, advise on priorities, share best practices, involve expertise from other regulated industries, and disseminate outputs to the wider UK AM and aerospace communities.

> Moreover, the CoP will **actively drive forward AM implementation** to ensure progress and tangible results.

AEROSPACE TECHNOLOGY INSTITUTE
AIRBUS
ASTM INTERNATIONAL
BAE SYSTEMS
BOEING
CATAPULT High Value Manufacturing
Department for Business & Trade
EATON
GKN AEROSPACE
Honeywell
ITP Aero
LEONARDO
mtc where progress happens
Ministry of Defence
Parker
Rolls-Royce
TWI

09 Roadmap Explainer

The ATI's aerospace AM roadmap, on the following pages, outlines the key activities to achieve the vision for 2030. To support this, some key context is provided below:

- This roadmap centres around the idea that the ATI/HVMC CoP activities continue as a means of driving progress and ensuring alignment and knowledge transfer within the community (including with regulatory organisations)
- While not all activities on the roadmap are within the scope of ATI funding, it is anticipated that involved organisations will be capable of sign posting to suitable alternative funding sources and/or pooling resources to address these activities.
- The roadmap primarily focuses on Metal PBF and DED due to the higher value parts that are associated with these technologies, however it is recognised that there are strong opportunities for polymer AM and alternative processes.
- It is assumed that key technology bricks must be at TRL 6 maturity or higher by 2028 to enable their consideration for the next generation of products.
- It is anticipated that defence aerospace organisations can use this roadmap as a means of unlocking technology development funding, through enabling clearer descriptions of how certain areas of development benefit both civil and defence aerospace.
- The ATI's primary focus is on progressing technology for large civil aircraft. Where other platforms and opportunities, such as business jets or defence aerospace, could act as a stepping stone, these are considered to be in scope.
- The roadmap and strategy should prioritise the use of existing technology for end-use parts, while also creating a route for future (lower TRL) technology developments as a secondary priority. Collaboration efforts are encouraged to maximise efficient use of resources.

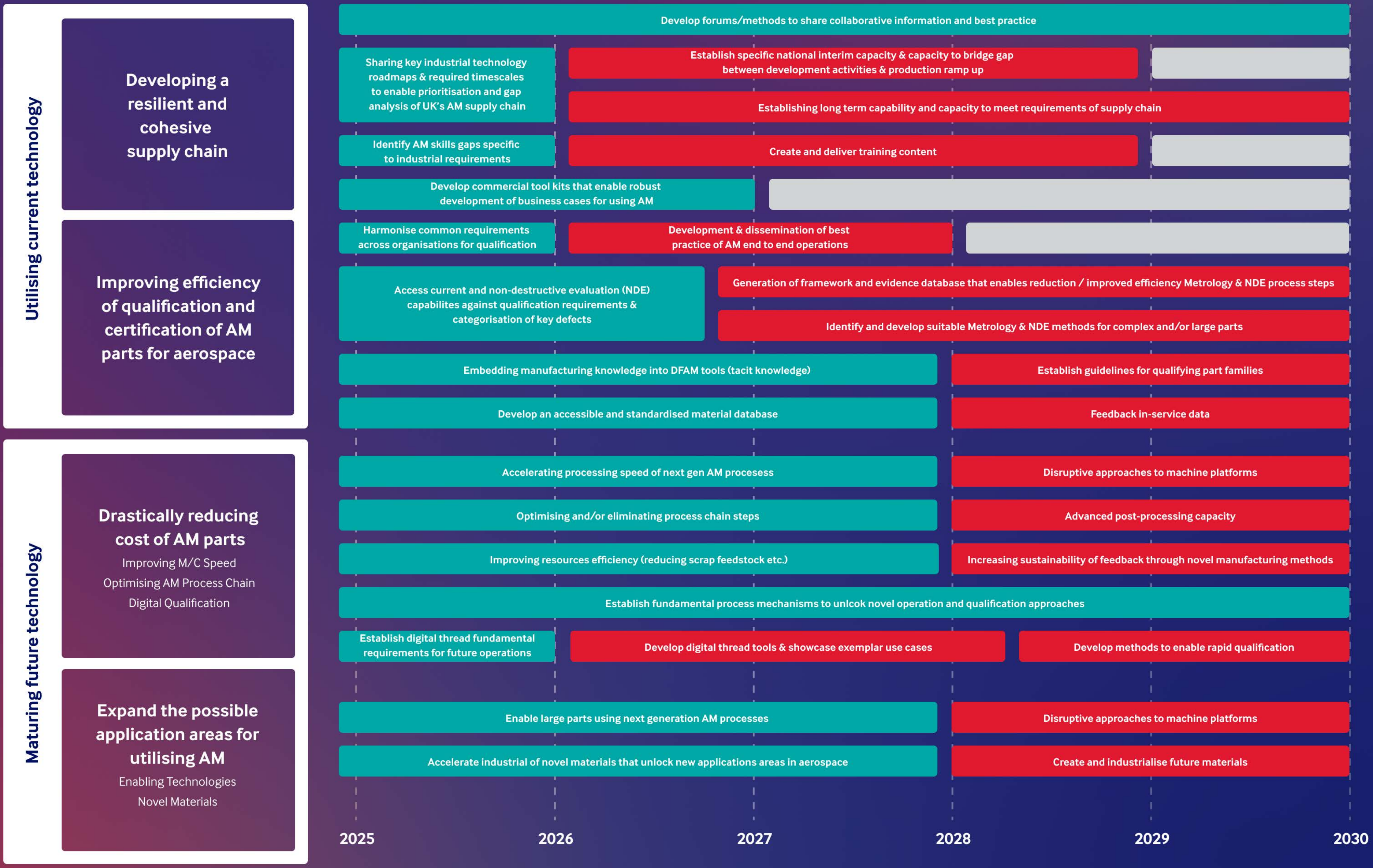
Image: Rolls-Royce

10 ATI Aerospace AM Roadmap

🟩 Main R&D activity, significant and targeted R&D in this timeframe is expected

🟥 Transition does not mean a phase out of R&D, however a change of R&D empasis

⬜ R&D significantly matured, expect industry lead approach until superseded



Utilising current technology

Developing a resilient and cohesive supply chain

Develop forums/methods to share collaborative information and best practice

Sharing key industrial technology roadmaps & required timescales to enable prioritisation and gap analysis of UK's AM supply chain

Establish specific national interim capacity & capacity to bridge gap between development activities & production ramp up

Establishing long term capability and capacity to meet requirements of supply chain

Identify AM skills gaps specific to industrial requirements

Create and deliver training content

Develop commercial tool kits that enable robust development of business cases for using AM

Improving efficiency of qualification and certification of AM parts for aerospace

Harmonise common requirements across organisations for qualification

Development & dissemination of best practice of AM end to end operations

Access current and non-destructive evaluation (NDE) capabilites against qualification requirements & categorisation of key defects

Generation of framework and evidence database that enables reduction / improved efficiency Metrology & NDE process steps

Identify and develop suitable Metrology & NDE methods for complex and/or large parts

Embedding manufacturing knowledge into DFAM tools (tacit knowledge)

Establish guidelines for qualifying part families

Develop an accessible and standardised material database

Feedback in-service data

Maturing future technology

Drastically reducing cost of AM parts

Improving M/C Speed

Optimising AM Process Chain

Digital Qualification

Accelerating processing speed of next gen AM processes

Disruptive approaches to machine platforms

Optimising and/or eliminating process chain steps

Advanced post-processing capacity

Improving resources efficiency (reducing scrap feedstock etc.)

Increasing sustainability of feedback through novel manufacturing methods

Establish fundamental process mechanisms to unlcok novel operation and qualification approaches

Establish digital thread fundamental requirements for future operations

Develop digital thread tools & showcase exemplar use cases

Develop methods to enable rapid qualification

Expand the possible application areas for utilising AM

Enabling Technologies

Novel Materials

Enable large parts using next generation AM processes

Disruptive approaches to machine platforms

Accelerate industrial of novel materials that unlock new applications areas in aerospace

Create and industrialise future materials

10 ATI Aerospace AM Roadmap

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Utilising current technology

Developing a resilient and cohesive supply chain

Development of a resilient and cohesive additive manufacturing supply chain is an essential linchpin to ensuring that future building blocks of this strategy can be realised. An informed and strategically aligned supply chain, including regulators, will need to be formed at pace to ensure that the UK positions itself to meet short-medium term demands of industries, such as defence aerospace, whilst strategically building towards a medium-long term aim to supply into civil aerospace programs. Failure to do so will result in disparate efforts, leading to reduction in global competitiveness in AM in key UK markets. This roadmap aims to ensure that key UK organisations have reached TRL 6 across relevant AM technologies and accompanying end to end process chains in preparation for future civil aviation product decisions, which are expected to be decided circa 2028.

Improving efficiency of qualification and certification of AM parts for aerospace

Improving the efficiency of the qualification and certification process for AM parts is crucial to ensure that the promise of AM is realised for aerospace. Building on extensive national and international efforts, this section will work to create clear understanding of the actions that are required to qualify and certify a part. It will look to develop common consensus on requirements whilst developing and disseminating best practice across the AM supply chain in delivering end use parts.

Effort will be placed in ensuring there is clear guidance regarding measuring and inspecting AM parts, ensuring to pull through existing information on this subject. Emphasis will be placed on contextualising data gained throughout AM processes with respect to the affect on final part performance. This work will aim to improve confidence in AM parts, whilst looking for suitable opportunities to reduce metrology and NDE requirements to improve part cost. Further efforts to improve efficiency and confidence will be tackled through investigating novel methods to qualify part families and developing accessible material databases that have standardised data formats that can empower designers, materials scientists, and decisions makers to accelerate their use of AM with confidence.

Maturing future technology

Drastically reducing cost of AM parts

Improving M/C Speed

Optimising AM Process Chain

Digital Qualification

Drastically reducing the cost of AM parts is vital to securing the place of AM in future civil aerospace programmes.

Improving AM processing speed will support the development of methods within the AM build process to address one of the key contributors to part manufacturing costs. Investigating routes such as increasing deposition speed and future approaches to build processes.

Optimising AM Process Chain will investigate methods of optimising or eliminating steps in the end to end AM process chain with the aim of reducing recurring costs to AM parts

Digital Qualification will explore novel approaches to increasing the efficiency of qualification & certification methods through developing fundamental physics based understanding of processes and extensive data capture & analysis combined in a digital thread.

Expand the possible application areas for utilising AM

Enabling Technologies

Novel Materials

Increase number of opportunities for AM to be used by supporting the use of promising technologies and materials which will increase the number of aerospace applications that AM can be applied to. Supporting technology that allows larger parts to be manufactured with confidence, increasing the envelope of potential parts which can be considered for AM. Adoption of existing novel materials will be encouraged to unlock new applications in aerospace, including polymer and ceramic materials, that feed into future strategic directions for civil aerospace such as Net Zero

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Utilising current technology

Developing a resilient and cohesive supply chain

Improving efficiency of qualification and certification of AM parts for aerospace

Maturing future technology

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Improving M/C Speed

Optimising AM Process Chain

Digital Qualification

Expand the possible application areas for utilising AM

Enabling Technologies

Novel Materials

1.1 Develop forums/methods to share collaborative information and best practice

1.2 Sharing key industrial technology roadmaps & required timescales to enable prioritisation and gap analysis of UK's AM supply chain

Establish specific national interim capacity & capacity to bridge gap between development activities & production ramp up

Establishing long term capability and capacity to meet requirements of supply chain

1.3 Identify AM skills gaps specific to industrial requirements

Create and deliver training content

1.4 Develop commercial tool kits that enable robust development of business cases for using AM

1.1

Develop forums/methods to share collaborative information and best practice

- Regular AM Community of Practice meetings must be maintained to ensure momentum and focus on delivering this strategy. These should include representation from regulators .
- Mechanisms for transferring generic non-part sensitive information gained from government funding between organisations should be developed, such as AM knowledge hubs and/or databases. Reducing possibility of duplication in research applications and previously funded work.
- Develop mechanisms and incentives to share findings that address roadmap topics from previously funded work.
- Representatives from relevant key working groups (EASA/FAA AM Working Groups, EAAMIRG, ASTM, SAE G-37) should be in included / or at a minimum regularly consulted to reduce duplication of efforts and maximise collaborative efforts.

1.2

Providing clarity on future industrial requirements

- Key industry stakeholders to share future visibility of their product plans, technology roadmaps (Including timelines), process, and material preferences to enable determination of national requirements for whole AM supply chain.
- Map UK's AM supply chain to identify gaps, bottlenecks, threats, and opportunities against national stakeholder requirements. Track updates to supply chain to measure progress (such as suppliers with AS9100).
- If required establish national interim capability to bridge gap between development activities & production ramp up. Example activities could include AM build capability, heat treatment, material specimen testing, or non-destructive evaluation for example.
- Establish long term capability to meet requirements of supply chain.

1.3

Identify AM skills gaps specific to industrial requirements

- Building on previous AM skills development activities. Community to understand what are the future aerospace AM skills requirements and identify key gaps in workforce, across whole process chain, to create competency framework. Additionally align activities with organisations such as the Aerospace Growth Partnership.
- Create and deliver standardised training content at scale for wide range of roles found within the AM process chain including: Technicians, Engineers, Designers, Procurement, and Executives
- Novel methods of training and ensuring skills are maintained to be considered such as using VR/AR/MR
- Accelerate awareness of AM through supporting the utilising of AM for indirect parts such as jigs, tools, and fixtures. Enabling companies to build confidence and awareness of AM.

1.4

Developing commercial tool kits

- Develop commercial tool kits that can assist professionals develop robust business cases for using AM including topics such as: Through life cost models, frequently asked questions, mythbusting pointers, specific AM LCA tools, forecast generators, and standardised cost models.
- Provide commercial centralised data sharing for forecast generators, including up to date capability of UK supply chain.
- Showcase best in class examples of latest R&D in AM technology, supply chain opportunities, and highlight success stories of AM technology being used in end use applications to senior stakeholders within Aerospace industry.

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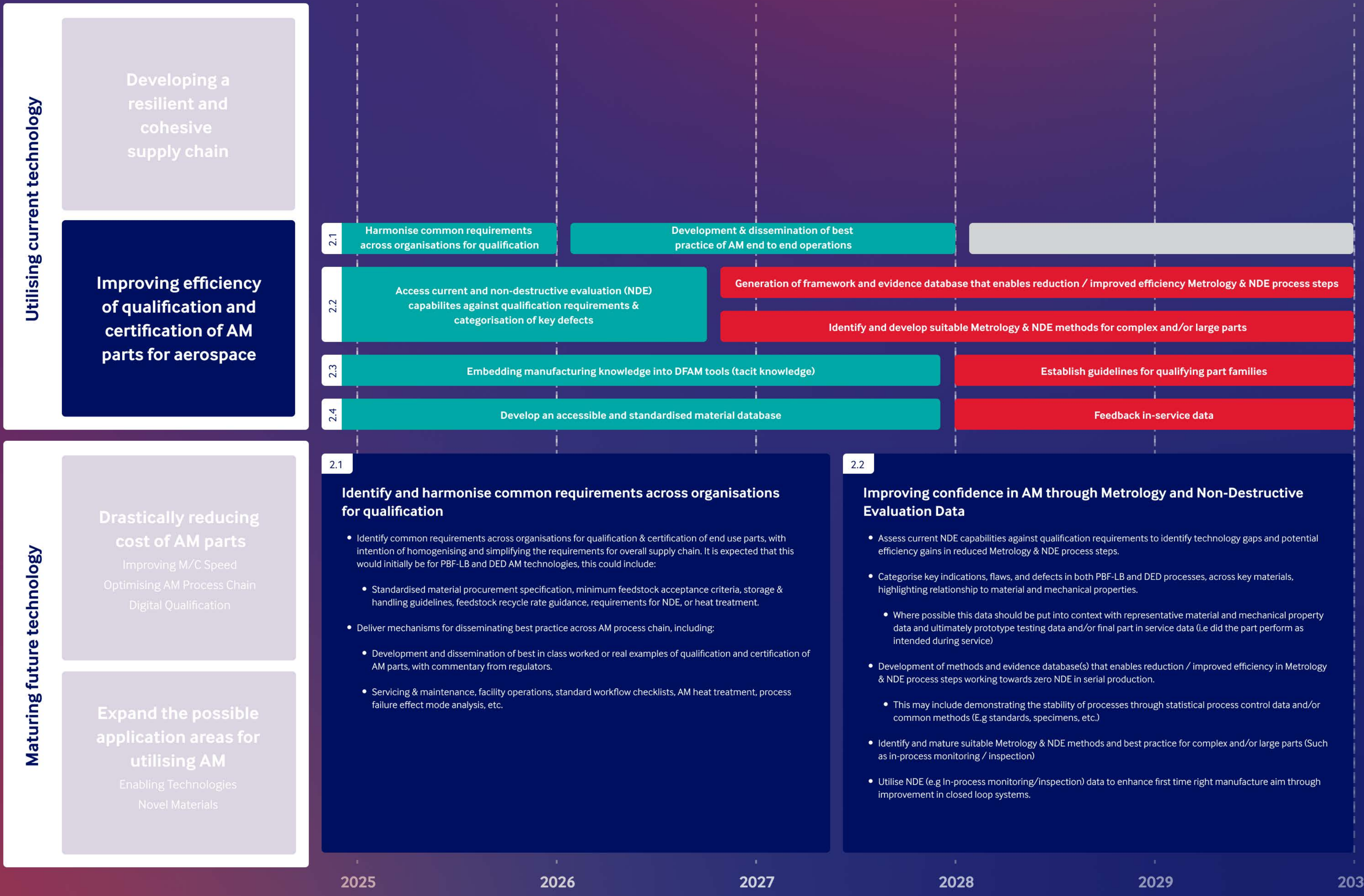

Utilising current technology

Developing a resilient and cohesive supply chain

Improving efficiency of qualification and certification of AM parts for aerospace

2.1 Harmonise common requirements across organisations for qualification | Development & dissemination of best practice of AM end to end operations

2.2 Access current and non-destructive evaluation (NDE) capabilites against qualification requirements & categorisation of key defects | Generation of framework and evidence database that enables reduction / improved efficiency Metrology & NDE process steps | Identify and develop suitable Metrology & NDE methods for complex and/or large parts

2.3 Embedding manufacturing knowledge into DFAM tools (tacit knowledge) | Establish guidelines for qualifying part families

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Maturing future technology

Drastically reducing cost of AM parts

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Expand the possible application areas for utilising AM

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Novel Materials

2025 2026 2027 2028 2029 2030

2.1

Identify and harmonise common requirements across organisations for qualification

- Identify common requirements across organisations for qualification & certification of end use parts, with intention of homogenising and simplifying the requirements for overall supply chain. It is expected that this would initially be for PBF-LB and DED AM technologies, this could include:
  - Standardised material procurement specification, minimum feedstock acceptance criteria, storage & handling guidelines, feedstock recycle rate guidance, requirements for NDE, or heat treatment.
- Deliver mechanisms for disseminating best practice across AM process chain, including:
  - Development and dissemination of best in class worked or real examples of qualification and certification of AM parts, with commentary from regulators.
  - Servicing & maintenance, facility operations, standard workflow checklists, AM heat treatment, process failure effect mode analysis, etc.

2.2

Improving confidence in AM through Metrology and Non-Destructive Evaluation Data

- Assess current NDE capabilities against qualification requirements to identify technology gaps and potential efficiency gains in reduced Metrology & NDE process steps.
- Categorise key indications, flaws, and defects in both PBF-LB and DED processes, across key materials, highlighting relationship to material and mechanical properties.
  - Where possible this data should be put into context with representative material and mechanical property data and ultimately prototype testing data and/or final part in service data (i.e did the part perform as intended during service)
- Development of methods and evidence database(s) that enables reduction / improved efficiency in Metrology & NDE process steps working towards zero NDE in serial production.
  - This may include demonstrating the stability of processes through statistical process control data and/or common methods (E.g standards, specimens, etc.)
- Identify and mature suitable Metrology & NDE methods and best practice for complex and/or large parts (Such as in-process monitoring / inspection)
- Utilise NDE (e.g In-process monitoring/inspection) data to enhance first time right manufacture aim through improvement in closed loop systems.

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2.3

Embedding manufacturing knowledge into DFAM tools (tacit knowledge)

- Establish design for AM guidelines per process & materials, including suitable considerations for qualification and end to end process steps such as depowdering, heat treatment, surface finishing, machining, metrology, and NDE.
- Developing methods to accelerate the transfer of tacit design and manufacturing knowledge into design tools to inform design decisions considering the whole end to end AM process chain.
  - Activity areas might include design considerations for optimising depowdering of parts, minimising supports, minimising distortion, mitigating gas flow or recoater issues, machining considerations, anchor points, machine limitations, improving communication between design, stress and manufacturing engineers, etc.
- Develop tools that can make accessing key materials data, design allowables, process, simulation information more accessible. Such as using large language models to provide answers to engineering queries.
- Establish guidance (Including design best practice) for qualifying part families. With aim of reducing effort to qualify parts that share suitably similar characteristics through demonstrating a suitable level of equivalent from prior information.

2.4

Develop accessible standardised material database

- Capture lesson learned from existing materials data sharing activities to minimise duplication of efforts.
- Develop accessible standardised material database. Share raw data from materials and mechanical data across industry relevant processes, materials, applications. Working towards building a mature database that can be utilised to accelerate part development, whilst reducing upfront non-recurring expenditure.
  - Develop standardised, or align to existing, template for data input into database.
  - Develop standardised logic on what test coupons to use, suitable locations to place specimens, and when to use them.
  - Create generic design allowables that are prioritised against industry requirements in an accessible format, link to future design tools.
  - Database should be open access to UK organisations with ability for developers to build tools via APIs, etc.
  - Develop equivalence methods to provide supply chain agility and reduce costs.
- Provide mechanism and incentivise feedback of in-service data to validate material and mechanical data, estimations, or digital tools.
  - Likely this will not initially be from Civil Aerospace. However, if there are opportunities to utilise data from other applications areas such as defence, power, energy, or motorsport industries to hone data, estimations, or digital tools, with the aim of building confidence in their validity for long term use in civil aerospace.

2025 2026 2027 2028 2029 2030

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3.1

Accelerating processing speed of existing additive processes

- Accelerate processing speed of current AM processes and platforms by implementing innovative methodologies to decrease build times, thereby facilitating improved viability of part business cases.
  - Examples of methods to consider include multiple energy sources on single parts, beam shaping, high powered energy sources, optimised process parameters, or improved software.
  - Strategic link to increasing part size, where it is vital that processing speed increased for thermal management and economic reasons.
- New approaches to machine platforms should be considered as and when required. Preference should be placed on existing platforms initially before moving to lower TRL alternatives if existing platforms do not meet collective market demands.
  - Topics to consider include exploring ways to lower upfront capital expenditure of equipment.

3.2

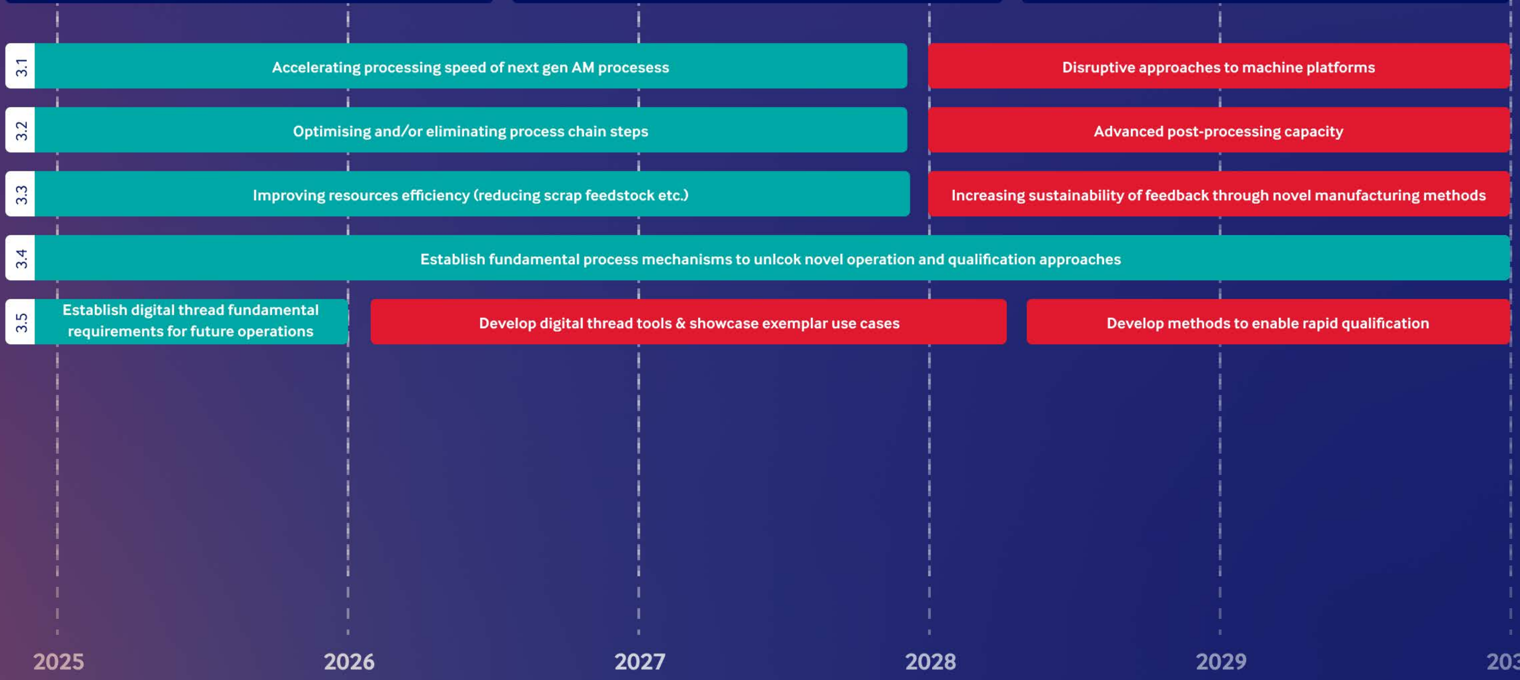
Optimising End to End AM Process Chain

- Develop methods to optimise and/or eliminating AM process chain steps to drive cost and time reductions to ultimately improve viability of part business cases.
  - Example methods may include: Improved DfAM tools (Including simulation & modelling), optimisation or removal of heat treatment steps, improving surface finish processes, automated post processing solutions, and optimisation of metrology steps.
  - Emphasis should be placed on developing methods and evidence that enables reduction and/or improved efficiency in NDE process steps working towards zero NDE in serial production.
- Develop methods to reduce costs of material feedstock that is suitable for civil aerospace.

3.3

Improving resource efficiency and environmental credentials of feedstock

- Improving resource efficiency (Reducing scrap feedstock etc.)
  - Developing best practice in feedstock management. Topics might include: Batch and powder lot control logic, minimising sieving losses, feedstock shelf lifespan, etc.
  - Efforts to reduce material feedstock costs: Supporting substitution of existing alloys for novel alternatives (Deploying value engineering e.g is there a lower cost material that can meet 95% of the requirements etc.) or utilising collective purchasing power.
- Increasing sustainability of feedstock through novel feedstock production methods.
  - Include methods to reuse feedstock, understanding that reused feedstock may not be acceptable to aerospace requirements however "waste feedstock streams" could be transferred to other industries where it still is within spec to improve business cases and reduce overall process waste.



3.1 🟩 Accelerating processing speed of next gen AM processes (2025–2028)
🟥 Disruptive approaches to machine platforms (2028–2030)

3.2 🟩 Optimising and/or eliminating process chain steps (2025–2028)
🟥 Advanced post-processing capacity (2028–2030)

3.3 🟩 Improving resources efficiency (reducing scrap feedstock etc.) (2025–2028)
🟥 Increasing sustainability of feedback through novel manufacturing methods (2028–2030)

3.4 🟩 Establish fundamental process mechanisms to unlcok novel operation and qualification approaches (2025–2030)

3.5 🟩 Establish digital thread fundamental requirements for future operations (2025–2026)
🟥 Develop digital thread tools & showcase exemplar use cases (2026–2028)
🟥 Develop methods to enable rapid qualification (2028–2030)

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Optimising AM Process Chain

Digital Qualification

Expand the possible application areas for utilising AM

Enabling Technologies

Novel Materials

3.4

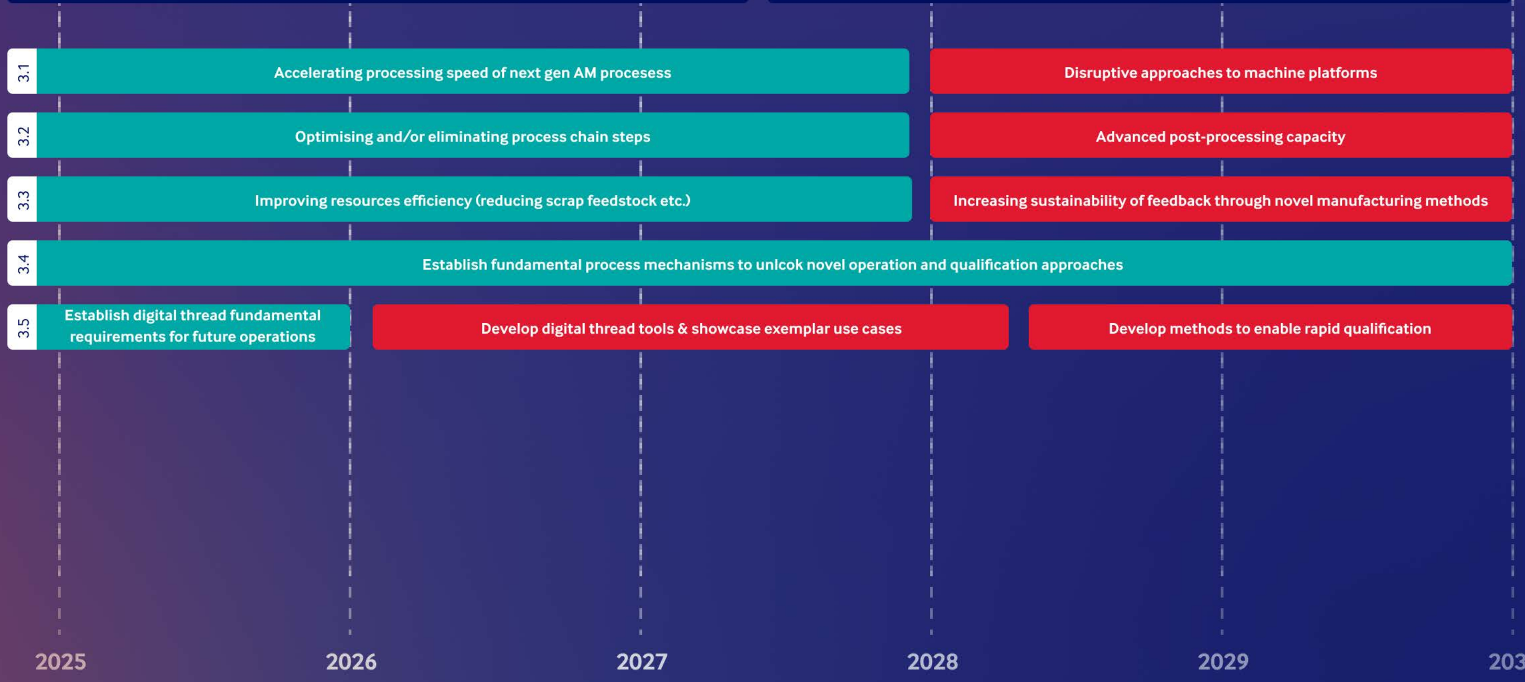
Establish fundamental process mechanisms to unlock novel operation and process qualification approaches

- Establish & share fundamental process mechanisms for both PBF-LB and DED processes, recognising that there may already be work carried out in this topic area that can be pulled through into future work. Tackling areas such as:
  - Establish underlying relationships between materials, process, structure, properties, and performance.
  - Establish understanding of primary and secondary key process variables to process implications.
  - Establish "neutral language" proxy variables between technologies and processes.
  - Establish machine to machine variability and develop methods to reduce part variation with aim of improving yield, part quality, and supply chain agility.
  - Develop methods to provide users with access (and if required control) to process inputs (Such as parameters or scan strategies) to provide full traceability of process inputs to manufactured output.
  - Developing methods to make machine platforms, software, and/or build data interoperable to increase agility within the supply chain.

3.5

Establish digital thread fundamental building blocks for future operations and qualification requirements

- Work through CoP to identify key digital thread blockers and future requirements.
- Develop methods to provide/access relevant data to and from machines and supplementary data steams (Such as providing secure build files to suppliers or receiving testing results) throughout the AM process chain. Considerations should be placed in understanding and implementing best practice in data security.
- Utilise data streams (Including links to material databases) either through data science, Artificial Intelligence (AI), and/or machine learning methods to enhance predictability, stability, and quality control of production.
- Develop showcases of complete digital traceability of parts through end to end process chain to provide high fidelity data streams for digital qualification requirements that match with future qualification and certification requirements.
  - Including capturing original design and manufacturing requirements
- Utilise prior digital information to develop methods of rapid qualification and certification, whether improving design iteration phase (predicting behaviour of AM properties) or end to end for qualification and certification



3.1 Accelerating processing speed of next gen AM processes | Disruptive approaches to machine platforms

3.2 Optimising and/or eliminating process chain steps | Advanced post-processing capacity

3.3 Improving resources efficiency (reducing scrap feedstock etc.) | Increasing sustainability of feedback through novel manufacturing methods

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4.1

Large AM - Large PBF-LB and DED

- Support the development and adoption of current AM processes and platforms that enable larger parts to be manufactured. Development activities could include:
  - Developing design and simulation tools that reduce risk of build defects such as distortion compensation.
  - Tackling key uncertainties with multiple energy sources being used on same part such as overlaps, gas flow, build pauses, calibration, etc.
  - Developing suitable methods to join multiple parts to create large assemblies, including design considerations.
  - Developing suitable post processing methods for larger parts including such as cost-effective metrology & NDE, cost-effective surface finishing techniques, machining, heat treatment, hybrid DED etc.
- New approaches to machine platforms should be considered as and when required. Preference should be placed on existing platforms initially before moving to lower TRL alternatives if existing platforms do not meet collective market demands.

4.2

Adopting Novel Materials

- Accelerate the adoption of existing industrial metal alloys to unlock new applications in areas of aerospace where previous materials were not suitable.
  - Actions could include developing UK feedstock production capability, utilising collective purchasing power, developing material data, developing modelling & simulation tools to evaluate future material suitability, etc.
- Accelerating the use of high performance polymers (Including fibre reinforced) in novel applications utilising improved polymer mechanical properties such as fatigue life and/or temperature resistance.
- Create and industrialise future materials such as ceramics, polymers, metal alloys that meet the requirements of future platforms (for example requirement for higher temperature resistance or higher conductivity).
  - Preference should be placed on existing materials initially before moving to lower TRL alternatives if existing materials do not meet collective market demands.
- Consideration should be given to potential for the recycling of materials for future feedstock. However, it is unlikely this would immediately be used within aerospace products though could be used in other industrial sectors.

4.1 Enable large parts using next generation AM processes

4.1 Disruptive approaches to machine platforms

4.2 Accelerate industrial of novel materials that unlock new applications areas in aerospace

4.2 Create and industrialise future materials

11 Acronyms

AIRLIFT	Additive Industrialisation for Future Technology
AI	Artificial Intelligence
AM	Additive Manufacturing
AMUK	Additive Manufacturing United Kingdom
ASTM	American Society for Testing and Materials
ATI	Aerospace Technology Institute
CoP	Community of practice
DED	Directed Energy Deposition
DfAM	Design for Additive Manufacturing
DRAMA	Digital Reconfigurable Additive Manufacturing for Aerospace
EAAMIRG	European Aviation Additive Manufacturing Industry Regulator Group
EASA	European Union Aviation Safety Agency
FAA	Federal Aviation Administration
GCAP	Global Combat Air Programme
GE	General Electric
GKN	Guest, Keen & Nettlefolds
GTC	Global Technology Centre
HVMC	High Value Manufacturing Catapults
ICAM	International Centre for Advanced Materials
IP	Intellectual Property
LMDw	Laser Metal Deposition by Wire
MPBF	Metal Powder Bed Fusion
MRL	Manufacturing Readiness Level
MTA	Manufacturing Technologies Association
MTC	Manufacturing Technology Centre
MTU	Motoren- und Turbinen-Union
NCAM	National Centre for Additive Manufacturing
NDE	Non-Destructive Evaluation
NNS	Near Net Shape
NRE	Non-Recurring Engineering
OAAM	Open Architecture AM
OEM	Original Equipment Manufacturer
PBF-LB	Powder Bed Fusion – Laser Beam
PBF	Powder Bed Fusion
R&D	Research & Development
RTO	Research Technology Organisation
SAE	Society of Automotive Engineers
SLM	Selective Laser Melting
SME	Small to Medium Enterprises
TAMPA	Not available
TCT	Time-Compression Technologies
TRL	Technology Readiness LevelUAS: Unmanned Air System
UK	United Kingdom
UKRI	UK Research and Innovation
US	United States
XWB	Extra Wide Body

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