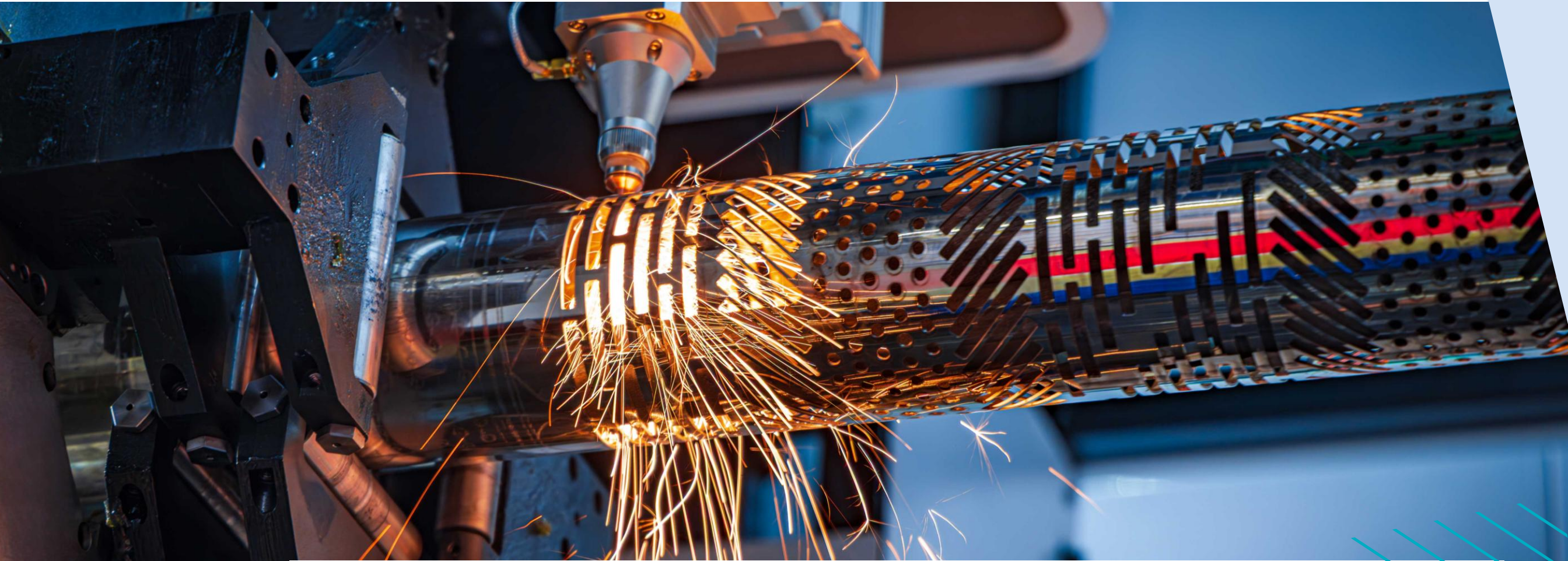


Subtractive manufacturing **CATAPULT**

High Value Manufacturing

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Connect with us

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Subtractive manufacturing

Achieving net-shape geometry through controlled material removal, delivering the strict dimensional precision and surface integrity required for high-performance applications.

Why: Demand drivers

- Addressing the digital deficit in manufacturing process optimisation
- Mitigating supply chain fragility and securing strategic investment
- Overcoming barriers in advanced material development and qualification
- Transitioning to sustainable and circular subtractive manufacturing models
- Scaling industrial infrastructure to support national energy systems.

What: Priority industry capability needs

- Disruptive and non-traditional material removal processes for challenging environments
- Data-centric subtractive frameworks and digital passports for life cycle transparency
- Integration of sustainable principles for circular economy within subtractive manufacturing operations
- Deployment of reconfigurable subtractive systems within connected and responsive future supply chains
- Capability for design for subtractive manufacture, repair and component re-use
- Harmonisation of physical autonomy with human-in-the-loop for robust subtractive operations.

How: Priority innovation requirements

- Establishing a centralised national database to validate properties and accelerate new material introduction
- Developing AI-driven tools to assess manufacturability and verify processes via high-fidelity digital thread simulations
- Engineering technologies to capture, separate and reprocess waste for circular resource recovery
- Prototyping scalable hybrid systems and reconfigurable robotics for large-envelope in-situ machining operations
- Implementing standard data protocols to enable fully optimised and resilient supply chains
- Fostering collaborative innovation ecosystems and upskilling the workforce for human-centric manufacturing.



Subtractive manufacturing strategies underpin the creation of the UK's most critical, high-integrity infrastructure. By exploiting advancements in autonomous machining, adaptive process control and digital twins, we are cutting waste and energy use to boost precision, productivity and UK capability. These rigid, high-accuracy technologies have diverse applications, spanning from nuclear energy to complex defence systems. The High Value Manufacturing Catapult is pushing the boundaries of what is possible – transforming legacy mechanics into a data-driven science.

Key HVM Catapult capabilities in subtractive manufacturing

Flagship subtractive manufacturing capability, AMRC (Rotherham)

The AMRC's Factory of the Future has world-leading equipment and expertise covering a wide breadth of subtractive processes enabling technology development and routes to implementation across a number of high value manufacturing sectors. Working across all material systems and conditions of supply from established production routes through to emerging near net shape and additively manufactured approaches. Established foundational experience in subtractive manufacturing science and engineering with a pull through across technology readiness levels.

Large-scale subtractive manufacturing capabilities, AMRC (Rotherham)

The Future Energy Factory leverages world-class equipment at scale with the engineering expertise to process oversized, high-value components with precision – optimising complex operations and reducing cost and lead-times.

National Manufacturing Institute Scotland (NMIS), (Renfrew)

Precision subtractive manufacturing of composite materials, addressing tool wear, delamination and process optimisation to support high-rate production for aerospace, energy and transport sectors. Integrated additive and subtractive manufacturing workflows, enabling complex geometries, material efficiency, repair solutions and flexible production.

Laser processing centre of excellence, MTC (Coventry)

The UK's most comprehensive laser subtractive manufacturing and surface engineering capability, enabling cutting, texturing and cleaning applications, scaling applications from laboratory development to industrial deployment.

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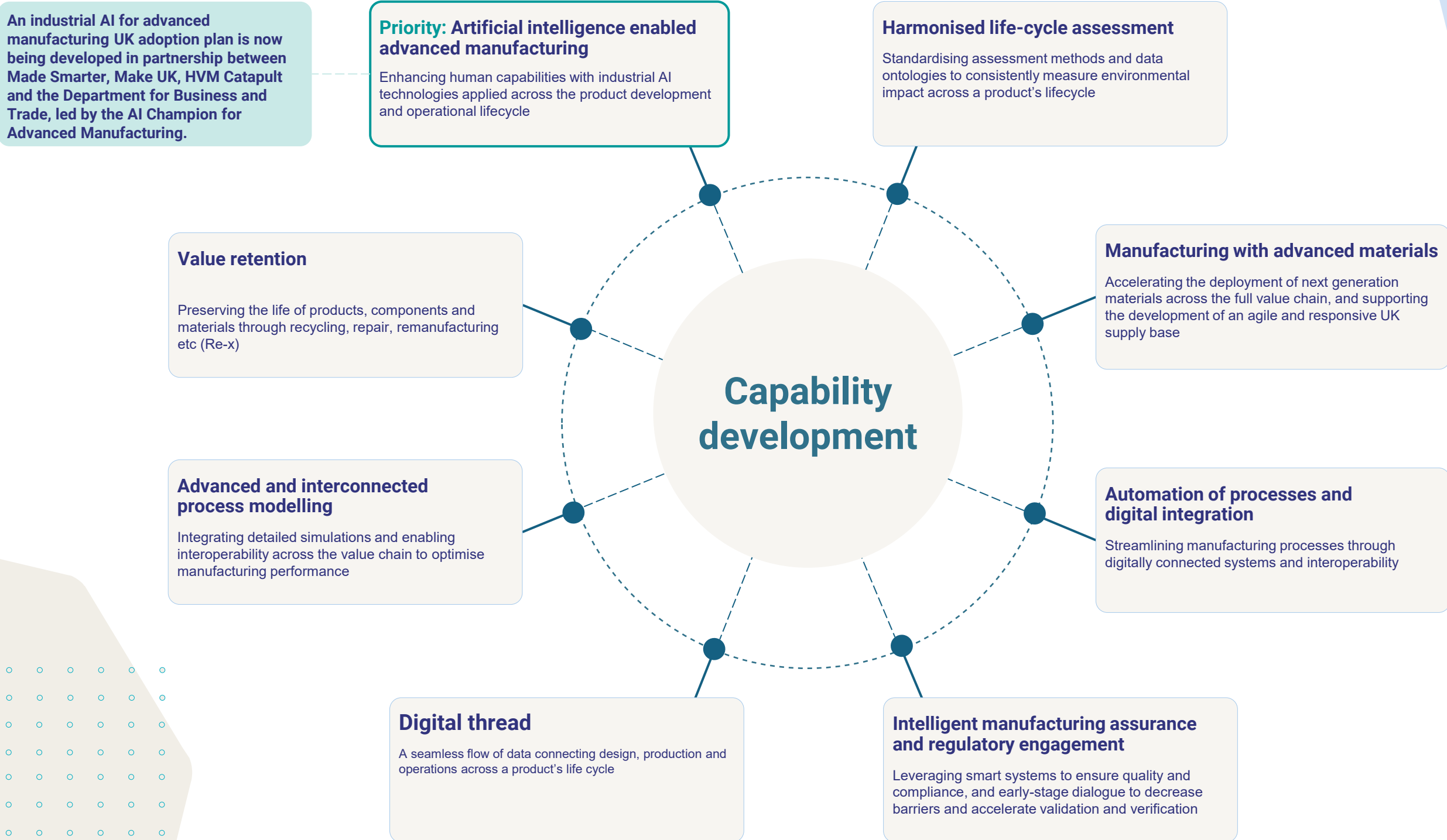
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Connected technology platforms

Through cross-domain analysis, eight connected technology platforms have been identified. They underpin both the core advanced manufacturing process technologies and the cross-cutting enabling technologies set out in this strategy.

They provide a shared foundation of insight and collective capability, showing where coordinated effort across our domains can best strengthen, connect and accelerate the technologies that matter most to UK industry.



Interpreting our roadmaps

The strategy structure

Why: Demand drivers

External pressures or opportunities that create the need for new or improved manufacturing capabilities.

What: Industry capability needs and priorities

The practical abilities industry must have to remain competitive in the future and the priorities for HVM Catapult.



Priority industry capability needs

The most critical capability gaps identified through industry consultation that must be addressed first to deliver impact.

How: Innovation requirements and priorities

The specific technologies, tools, processes, data, skills or system enablers that must be developed, improved or integrated to meet future industry capability needs, and the priorities for HVM Catapult.

Connected technology platforms

Highlight where coordinated effort across our domains can best strengthen, connect and accelerate the technologies that matter most to UK industry

Roadmap activity examples

Establish test beds to develop, integrate and validate novel inspection, measurement and test techniques and processes.

Demonstrated the trustworthy comparative robustness of emerging inspection, measurement and test technologies

The above 'what' items are linked and dependent – denoted by the overlapping boxes

Deployment of increased mechanization to remove variability and increase standardization linked to respective process specifications

Standardised digital weld procedures, reusable qualification libraries, harmonised standards

The above 'how' discrete items that are not linked and occur in different time horizons

IUK Strategic imperatives



Alignment with the Innovate UK vision

Each demand driver is colour-coded to align with the four imperatives of the Innovate UK materials and manufacturing vision 2050.

Innovative and digital

Businesses drive continuous and transformative innovation and create, adopt and export advanced digital technologies

Resource-efficient and regenerative

Sectors maximise circularity of materials, energy and water and aim for a net positive impact on the environment

Resilient and responsive

Mitigating risks from supply chain disruptions, national/global crises, and climate change.

Skilled and empowered

Workforces are highly skilled in executing advanced tasks and are empowered by configurable, open technology stacks

Subtractive manufacturing



Further details of the demand drivers, industry capability needs and innovation requirements are available online. Follow the QR code or [click here](#).

Vision

Leading innovation for subtractive manufacturing processes and technologies by pioneering autonomous precision, digitalisation and circularity, enabling resilient, high-integrity production across the UK's critical supply chains.

2026

2030

2035

2040

Addressing the digital deficit in manufacturing process optimisation

Mitigating supply chain fragility and securing strategic investment

Overcoming barriers in advanced material development and qualification

Transitioning to sustainable and circular subtractive manufacturing models

Scaling industrial infrastructure to support national energy systems

Development of educational frameworks for next-generation subtractive manufacturing engineers and machinists

Deployment of reconfigurable subtractive systems within connected and responsive future supply chains

Capability for design for subtractive manufacture, repair and component re-use

Deploying embedded 3D metrology and sensors to drive real-time adaptive control for zero-defect production

Data-centric subtractive frameworks and digital passports for life cycle transparency

Realisation of zero-defect subtractive processes and precision finishing of complex near net shape routes

Developing AI-driven tools to assess manufacturability and verify processes via high-fidelity digital thread simulations

Harmonisation of physical autonomy with human-in-the-loop for robust subtractive operations

Implementation of digital autonomy and digital twins for intelligent process planning

Implementing standard data protocols to enable secure sharing and performance benchmarking across supply chains

Creating modelling toolkits that prioritise energy efficiency and carbon reduction in process parameter selection

Engineering technologies to capture, separate and reprocess waste for circular resource recovery

Embedding sustainable subtractive principles and energy efficient machine tools for circular operations

Advanced subtractive processing capabilities for next-generation materials and future complex components

Defining robust subtractive strategies and tooling parameters for novel alloys and difficult-to-process materials

Prototyping scalable hybrid systems and reconfigurable robotics for large-envelope in-situ machining operations

Disruptive and non-traditional material removal processes for challenging environments

Designing application-oriented training programmes to upskill the workforce in human-centric automation and digital skills

Formalising partnerships between research centres and industry to facilitate knowledge exchange and de-risk R&D

Key

- Demand drivers**
Why change is needed.
- Industry capability needs**
What capabilities industry needs to respond to these changes.
- Innovation requirements**
How capabilities must develop.
- Priority industry capability needs**
The most critical capability gaps identified through industry consultation that must be addressed first to deliver impact.

Subtractive manufacturing – Demand drivers

Mitigating supply chain fragility and securing strategic investment

The subtractive manufacturing sector faces volatile raw material availability and high capital costs for advanced equipment that stifle growth.

Strategic supply chain mapping: lack of visibility requires mapping to foresight high-priority sectors facing critical feedstock and tooling shortages.

De-risking capital investment: high capital costs demand new mechanisms to de-risk investment in high-capacity, multi-axis CNC machinery.

Strengthening local ecosystems: global disruption risks necessitate distributed, reconfigurable subtractive manufacturing networks and clustered factories to ensure national resilience.

Securing critical component supply: sovereign capability is essential to secure the supply of complex critical components.

Addressing the digital deficit in manufacturing process optimisation

A reliance on disconnected legacy machine tools hinders the sector's ability to adopt precision, data-driven manufacturing.

End-to-end connectivity: siloed legacy assets require end-to-end connectivity to ensure seamless data flow from computer aided methods to inspection.

Scalable flexible manufacturing: static production lines must become reconfigurable cells to adapt to varying complex part geometries.

Predictive process control: unpredictable tool wear demands in-process sensing to optimise surface finish, quality and dimensional accuracy.

Virtualising smart machining: legacy equipment limitations require virtualisation to enable smart design, process verification and automated correction.

Overcoming barriers in advanced material development and qualification

Innovation is bottlenecked by the difficulty of processing next-generation materials and the slow pace of regulatory validation.

Next-generation material machinability: unknown cutting characteristics of next-generation materials hinder applications in hydrogen, nuclear and high value sectors.

Accelerating product validation: slow certification speeds require rapid verification of processed surface integrity to accelerate manufacturing readiness.

Agile standardisation methods: rigid specifications necessitate agile standards and open access data to enable wider material re-use.

Prototypic material research: high innovation risks demand joint research to de-risk subtractive manufacturing of novel materials and protect intellectual property.

Transitioning to sustainable and circular subtractive manufacturing models

Subtractive processes inherently generate waste; the industry must urgently pivot to reclamation and energy efficiency to meet net zero.

Material reclamation systems: high material waste necessitates systems for swarf recovery and separation to improve material security.

Circular lifecycle design: linear consumption models require designing components for efficiency, remanufacturing and sustainable decommissioning strategies.

Energy efficient machining: rising energy costs demand optimised tool paths and plant operations to drive manufacturing cost reduction.

Sustainable process inputs: environmental impact must be lowered by developing sustainable coolants and extending tooling life.

Scaling industrial infrastructure to support national energy systems

The UK currently lacks the large-scale subtractive manufacturing capacity required to deliver heavy energy infrastructure and grid modernisation.

Grid modernisation strategy: grid expansion demands defined supply chain options and capabilities to manufacture future component configurations.

Clean energy scale-up: capacity gaps require developing heavy subtractive manufacturing skills specifically for hydrogen production and nuclear decommissioning.

Strategic sector foresighting: strategic gaps necessitate foresighting applications that support the industrialisation of large-scale critical structures.

Decommissioning and compliance: regulatory pressures demand compliant processes for sustainable decommissioning of offshore structures and nuclear waste.

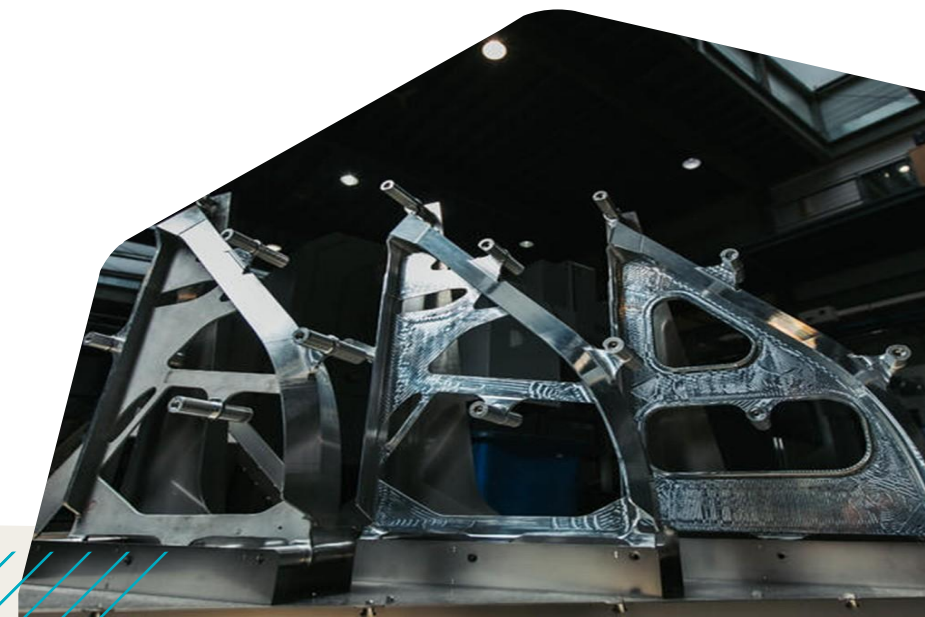


Strategic summary

There is a critical demand for resilient supply chains, scalable energy infrastructure, and resource-efficient production. To secure this future, we must position the UK as a global leader in data-driven subtractive manufacturing and circular value recovery, enabled by a skilled and empowered workforce capable of delivering these complex, critical systems.

IUK Strategic imperatives

- Innovative and digital
- Resource-efficient and regenerative
- Resilient and responsive
- Skilled and empowered



Subtractive manufacturing – Industry capability needs

2026

2030

2035

2040

Technology domain specific

Disruptive and non-traditional material removal processes for challenging environments

Mastering adaptive machining strategies to precisely finish variable components produced via casting or additive routes

Rapidly industrialising disruptive material removal physics to continuously redefine subtractive manufacturing possibilities

Development of educational frameworks for next generation subtractive manufacturing engineers and machinists

Cultivating a next-generation workforce combining traditional metallurgical expertise with modern data science competencies

Engineering next-generation machine tools that significantly increase productivity while drastically reducing operational energy

Automation of processes and digital integration

Implementing modular hardware-agnostic machining cells that allow rapid reconfiguration for high-mix batch-of-one production

Harmonisation of physical autonomy with human-in-the-loop for robust subtractive operations

Capability for design for subtractive manufacture, repair and component re-use

Integrating digital subtractive capabilities into wider supply networks to enable dynamic resilience and load-balancing

Deployment of reconfigurable subtractive systems within connected and responsive future supply chains

Value retention

Codifying design rules that optimise components for initial machining, future repair, and subtractive re-manufacturing

Embedding sustainable subtractive principles and energy efficient machine tools for circular operations

Digital thread

Standardising machining data protocols to embed manufacturing history permanently within a component's digital lifecycle passport

Data-centric subtractive frameworks and digital passports for lifecycle transparency

Implementation of digital autonomy and digital twins for intelligent process planning

Advanced and interconnected process modelling

Utilising physics-based virtual prototypes to accurately simulate and predict cutting performance before physical production begins

Implementing algorithmic planning tools to automate toolpath generation and reduce manual CAM programming dependency

Manufacturing with advanced materials

Advanced subtractive processing capabilities for next generation materials and future complex components

Aligning subtractive readiness levels with emerging product architectures to ensure immediate manufacturing viability upon design

Intelligent manufacturing assurance and regulatory engagement

Realisation of zero-defect subtractive processes and precision finishing of complex near net shape routes enabled by in-process monitoring

Subtractive manufacturing – Innovation requirements

2026

2030

2035

2040

Technology domain specific

Developing optimisation mechanisms to enhance the resilience and efficiency of subtractive manufacturing supply chains

Formalising partnerships between research centres and industry to facilitate knowledge exchange and de-risk R&D

Building a cohesive partner ecosystem to accelerate the development and adoption of subtractive technologies

Creating a dedicated platform to facilitate the exchange of technical knowledge and best practices

Automation of processes and digital integration

Designing application-oriented training programmes to upskill the workforce in human-centric automation and digital skills

Developing flexible robotic manufacturing cells capable of performing precision in-situ subtractive machining operations

Prototyping scalable hybrid systems and reconfigurable robotics for large-envelope in-situ machining operations

Delivering application-oriented training programmes to upskill the UK workforce in advanced subtractive techniques

Designing human-centric automation workflows that augment operator capabilities rather than replacing the workforce

Digital thread

Establishing data-centric shop floors that securely capture and share real-time process performance analytics

Implementing integrated management systems for validating and distributing critical material and process capability data

Creating AI-driven tools to assess manufacturability and verify processes via high-fidelity digital thread simulations

Manufacturing with advanced materials

Defining robust cutting strategies and tooling parameters for novel alloys and difficult-to-machine materials

Establishing a centralised national database to validate properties and accelerate new material introduction

Value retention

Engineering technologies to capture, separate, and reprocess swarf and fluids for circular resource recovery

Engineering integrated systems for the efficient recovery, separation, and reprocessing of coolants and swarf

Embedded artificial intelligence for advanced manufacturing

Deploying AI-driven design analysis tools to automatically assess component geometry for subtractive manufacturability

Utilising machine learning algorithms to enable adaptable manufacturing systems driven by historic data pools

Establishing open-access data frameworks to accelerate artificial intelligence research within the subtractive domain

Advanced and interconnected process modelling

Integrating low-cost sensor networks for real-time monitoring of machining stability and vibration dynamics

Developing high-fidelity physics-based simulations to accurately predict subtractive process outcomes and behaviour

Creating modelling toolkits that prioritise energy efficiency and carbon reduction in process parameter selection

Developing optimisation toolkits to balance productivity rates against environmental impact and resource consumption

Implementing standard data protocols to enable secure sharing and performance benchmarking across supply chains

Intelligent manufacturing assurance and regulatory engagement

Embedding integrated 3D metrology systems within machine tools to enable zero-defect closed-loop verification

Deploying embedded 3D metrology and sensors to drive real-time adaptive control for zero-defect production

Subtractive manufacturing: Priority pathways

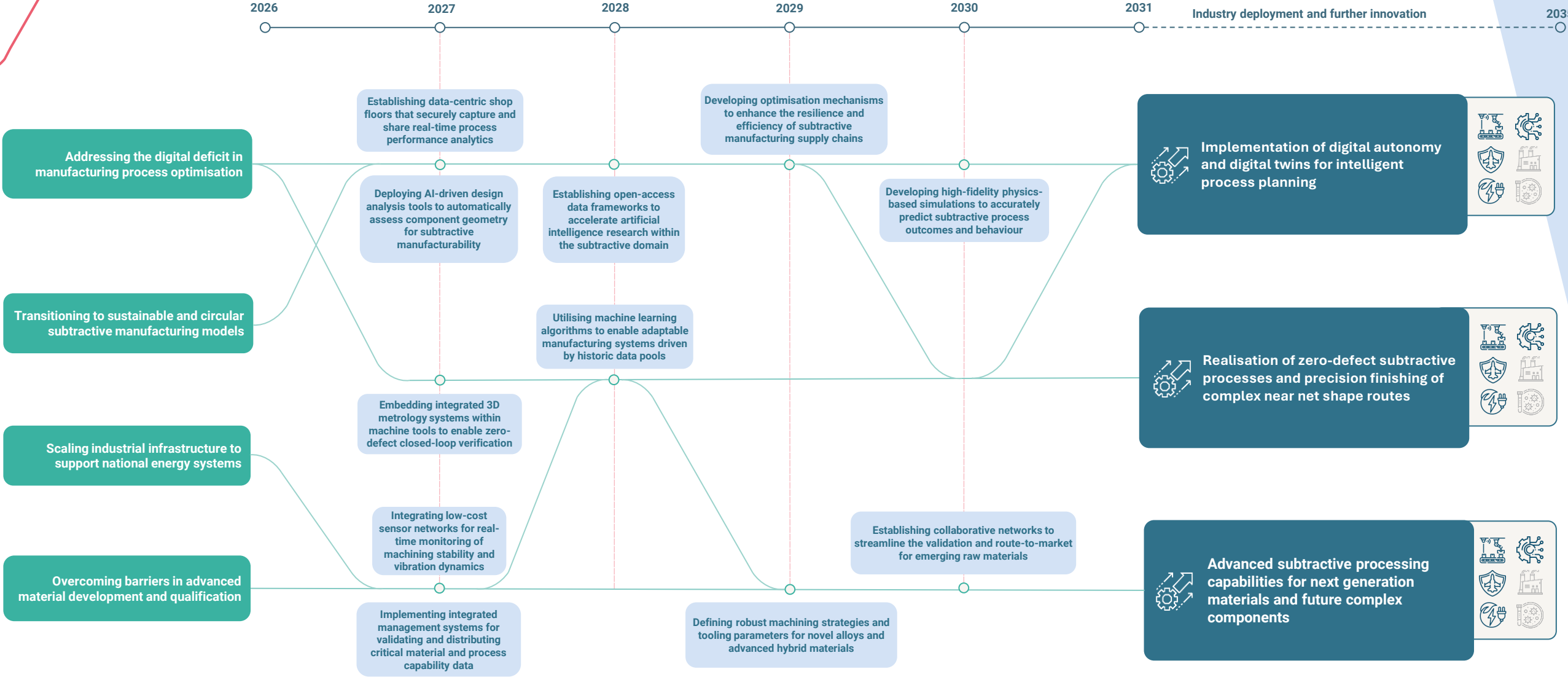


Diagram Legend

- Demand drivers** (Green box): Why change is needed
- Innovation requirements** (Light blue box): How capabilities must develop
- Industry capability needs** (Dark blue box): What capabilities industry needs to respond to these challenges
- Priority industry capability needs** (Dark blue box with gear icon): The most critical capability gaps identified through industry consultation that be addressed first to deliver impact

Industrial strategy growth-driving sectors

- Foundation Industries
- Clean Energy Industries
- Digital & Technologies
- Life Sciences
- Advanced Manufacturing
- Defence