# Connecting a UK Digital Manufacturing Ecosystem


Delivered by Innovate UK, EPSRC and ESRC

MADE SMARTER INNOVATION

# Contents

# Foreword

**The Made Smarter Review, published in 2017, set out a clear diagnosis of the challenge facing UK manufacturing. Industrial digital technologies (IDTs) offered transformative potential to improve productivity, resilience, and competitiveness, but adoption was uneven and fragmented. Too often, innovation stalled at the boundaries between research, industry, and supply chains.**

The review concluded that the barrier was not technology itself, but the absence of a visible, connected, and effective ecosystem capable of accelerating innovation and its diffusion across industry. It called for government, industry, and academia to work in partnership to establish the institutional frameworks needed to turn digital capability into sustained industrial advantage.

The warning was explicit. Without coordinated action, the UK risked falling further behind, becoming more dependent on imports and losing high-value manufacturing capability. With the right ecosystems in place, however, digitalisation could rebalance the economy, create skilled jobs, and support a renewed industrial base built on innovation and collaboration.

That ambition underpinned the creation of Made Smarter Innovation (MSI).

Launched in 2020 and coordinated by Innovate UK (IUK), MSI was designed to do more than fund individual projects. Its purpose was to build and connect national ecosystems around IDTs, creating clear pathways from early research to industrial deployment, and from isolated innovation to shared, scalable capability.

Through Research Centres, Innovation Hubs, collaborative R&D programmes, and accelerators, MSI brought together manufacturers, technology providers, universities, and research organisations to address real industrial challenges. More than 800 organisations have engaged with the programme, directly or indirectly, forming networks that span sectors, supply chains, and technology readiness levels.

What distinguishes MSI is not simply the scale of activity, but the way innovation moves through the system. Projects are designed to connect rather than compete. Partners reappear across initiatives, allowing learning, data, skills, and trust to accumulate over time. Early-stage experimentation feeds later commercialisation. Solutions developed for one context are adapted and reused in another. In this way, MSI has created an ecosystem in which progress compounds rather than dissipates.

To demonstrate this ecosystem in practice, this document examines three case studies, each offering a different lens on the same system.

The first lens focuses on small and medium-sized enterprises, using additive

manufacturing as an example. It shows how MSI enabled SMEs, software developers, and equipment manufacturers to collaborate around shared digital infrastructure, automation, and artificial intelligence. Through connected projects, early prototypes evolved into production-ready systems, new services, and export opportunities. This case illustrates how SMEs, often constrained by risk and scale, can innovate more quickly and confidently when embedded within a supportive, connected ecosystem.

The second lens examines the role of a large manufacturer as an ecosystem anchor. Through its engagement with MSI, BAE Systems combined internal digital transformation with deliberate supply chain collaboration. By working openly with SMEs, startups, and research partners, and by sharing learning beyond its own operations, BAE helped raise digital capability, trust, and sustainability across hundreds of suppliers. This perspective shows how large organisations can use scale and influence not to concentrate innovation, but to distribute it across the wider industrial base.

The third lens explores the contribution of academia, centred on the University of Cambridge and its Institute for Manufacturing. Here, MSI provided the mechanism to coordinate long-standing research strengths, align them with national industrial priorities, and connect SMEs, multinationals, and global supply chains. This case highlights the role of universities not only as sources of technical expertise, but as ecosystem connectors, ensuring innovation addresses people, skills, ethics, and sustainability alongside technology.

Taken together, these three lenses provide a comprehensive view of the ecosystem that MSI has built. They show how MSI has delivered on the intent of the 2017 review by creating a national digital manufacturing ecosystem that is collaborative rather than fragmented, applied rather than theoretical, and enduring rather than transactional.

The impact is visible across factories, supply chains, research centres, and skills programmes throughout the UK. More importantly, it is embedded in relationships and capabilities that continue to generate value beyond individual projects. In doing so, MSI has helped ensure that industrial digitalisation in the UK is not a series of isolated advances, but a sustained and connected transformation.

**Ben Farmer,**
Deputy Director, Made Smarter Innovation

# AMFG, Photocentric and Batch.Works

## SMEs put UK additive manufacturing on global stage


### MSI set out with a bold goal to accelerate digital transformation by helping UK manufacturers and technology developers collaborate.

Nowhere has that vision been clearer than in additive manufacturing (AM), or 3D printing, where MSI projects have delivered world-first technologies and built a connected ecosystem of pioneers, suppliers, software developers, and researchers.

Through structured collaboration, shared risk-taking, and open knowledge exchange, these projects have expanded the UK's capacity and capability in AM. Crucially, they have done so in a way that engaged SMEs, long considered both the backbone and the untapped potential of UK manufacturing.

# AMFG: Building the Digital Backbone

At the apex of this emerging ecosystem sits MES developer AMFG. Its first major MSI-linked contribution came through the SPACE project (Supplier Planning And Capacity Estimation), working with Jaguar Land Rover, Angel Trains, and Paragon Rapid Technologies. Together they developed a digital platform enabling OEMs to place small-batch production orders with verified pricing and delivery dates.

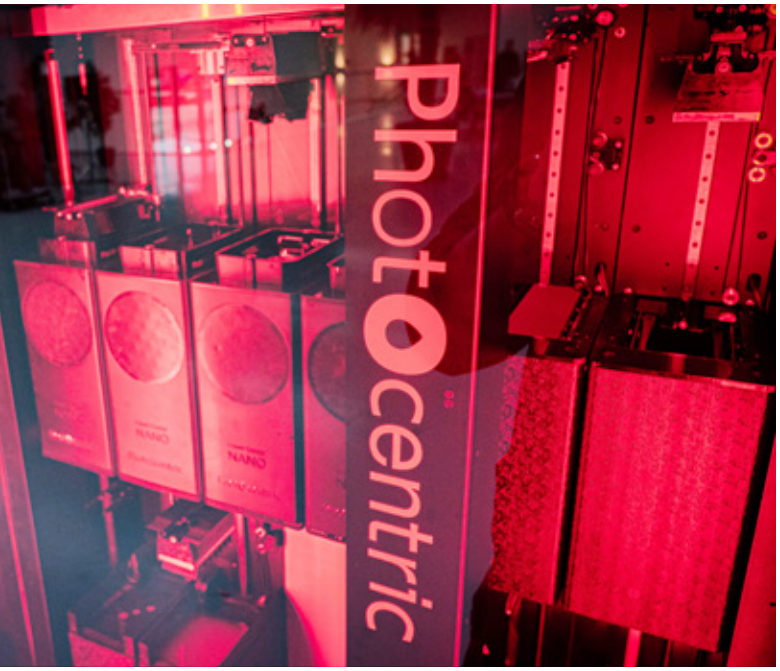
For SMEs, SPACE created new market access. For OEMs, it reduced lead times and increased flexibility. More importantly, it proved how a digital workflow backbone could bridge the gap between additive suppliers and industrial customers.

The insights, infrastructure, and relationships built in SPACE seeded a series of follow-on projects. Some were funded directly by Innovate UK, others under the MSI banner. Each pushed technology readiness further: from early workflow integration, to production-scale automation, and eventually towards market-ready services. This progression showed how lower TRL research and prototypes were not dead ends but stepping stones, feeding directly into higher-level applications across multiple projects.


Sven Hinrichs,
Head of Technology at AMFG, said:

> ***"Programmes like MSI are vital because they bring together the right mix of partners to tackle challenges that no single company could solve alone. Through projects like SPACE, we were able to connect with manufacturers, researchers, and other technology developers in ways that accelerated our ideas far beyond their original scope. What began at an early stage has now matured into solutions with real industrial impact. That tapestry of collaboration is what has allowed TRLs to advance so quickly and take on a momentum of their own."***

# Photocentric: Prototype to Production




Photocentric's journey exemplified this progression. Its first foray with MSI came through the LEAD (Low Energy Autonomous Digital) Factory project, working with Games Workshop, Essentra Components, Unipart, Authentise, and the Manufacturing Technology Centre (MTC).

The result was JENI: a fully autonomous 3D printing line that uses robotics to transport parts through printing, washing, and curing without human input. CAD files replaced injection mould tooling, enabling unlimited design variations. Integrated with MES and ERP systems and supported by Authentise's slicing and nesting tools, JENI can produce parts every 20 seconds, up to two tonnes a day, with 86% less carbon footprint than injection moulding. It is now a disruptive product, bringing new opportunities to digital manufacturing.

MTC's sustainability toolkit added real-time monitoring of energy and emissions. The outcome was not just a machine but a blueprint for scalable, smart, low-carbon production.

With LEAD's success came new challenges: how to optimise over 50 parameters across a complex process, especially when materials or designs changed frequently.

The next step, IntelliJeni, paired Photocentric with AMFG and Cambridge AI spinout Intellegens to integrate machine learning. Alchemite™ software trained on real-world print data, cutting experimentation cycles by 80% and reducing production times by three days in a test case for 100,000 dental aligners. This was not just a productivity boost, it was proof that AI-enabled additive manufacturing could match traditional methods on quality, cost, and scale.

What began with early workflow integration in SPACE had now evolved into AI-enabled production, with AMFG's platform providing the glue.

Photocentric then shifted focus to accessibility. Through MSI's Smart Manufacturing Data Hub (SMDH), it launched Plastic Parts On Demand (PPOD), an online tool enabling SMEs to upload CAD files, get instant pricing and carbon data, and trigger fully automated production through the JENI system.

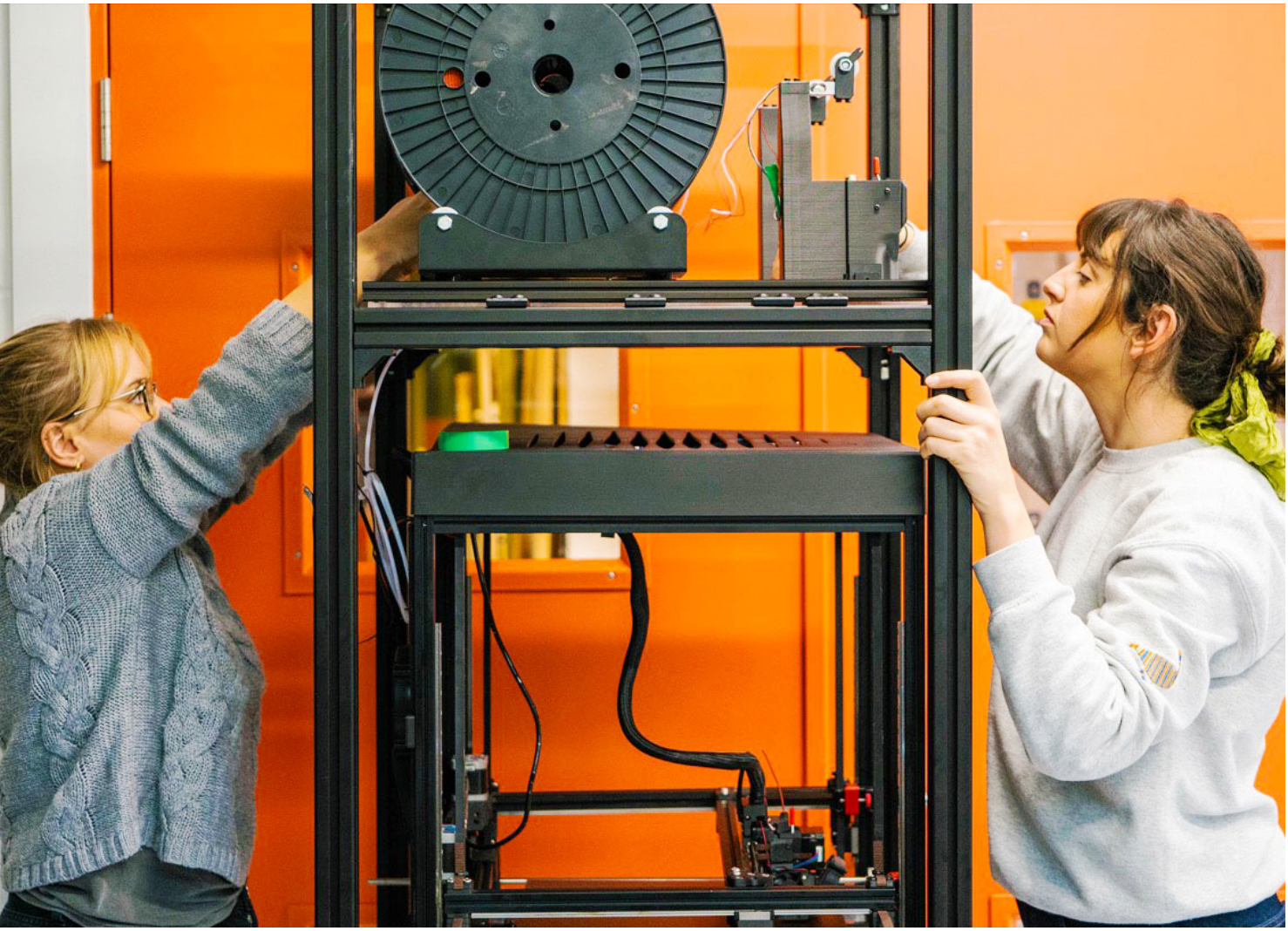
For smaller manufacturers, this eliminated costly tooling and long lead times, providing sustainable, just-in-time production without large upfront costs. PPOD was not just a service, it was the culmination of multiple innovations across the MSI journey. It also inspired Project Nexus, a new Innovate UK initiative, developing sustainable bioprocessing equipment with partners including Imperial College, CPI, and Sartorius.

# Batch.Works: Parallel Innovation in Sustainability

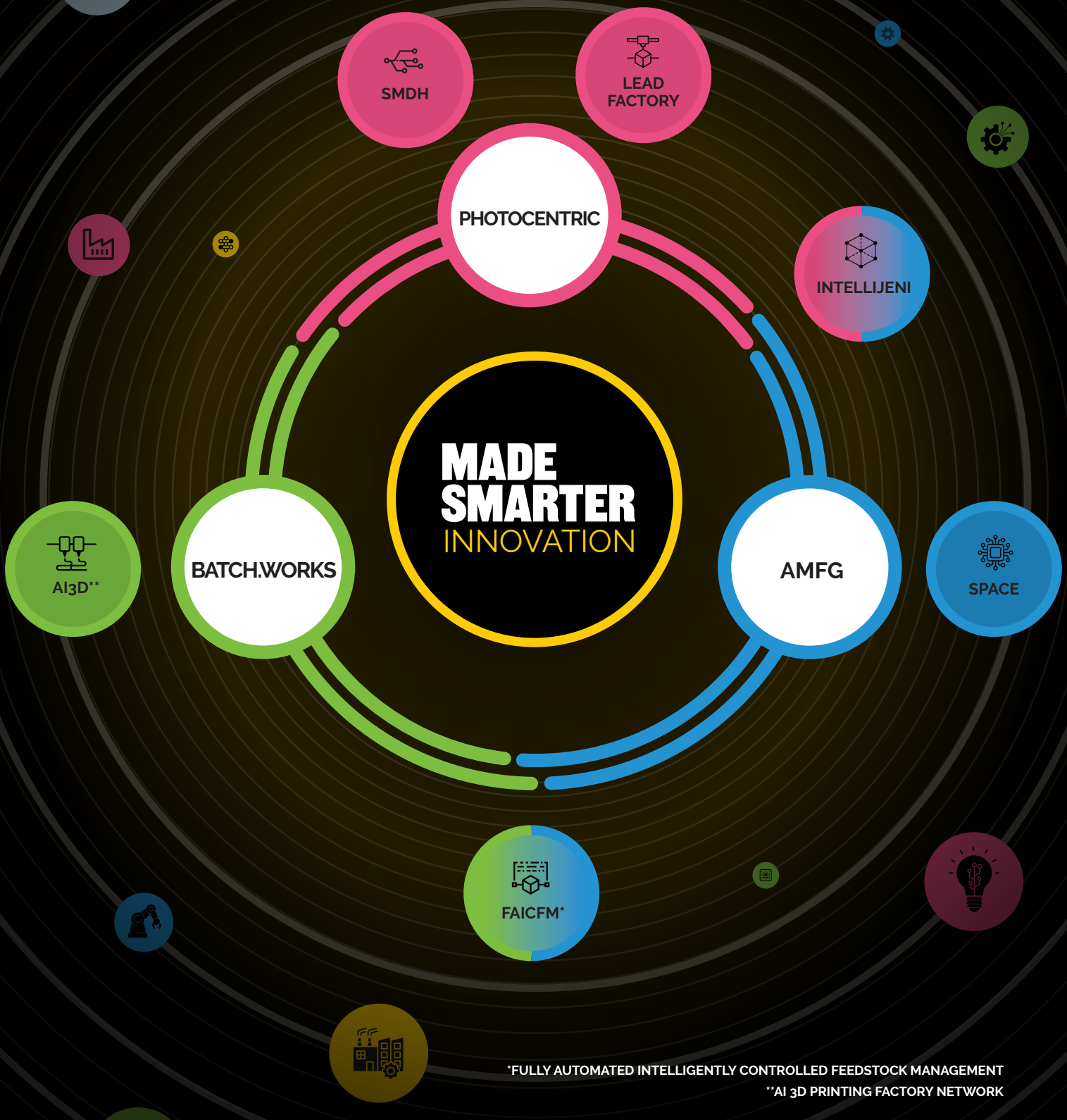
While Photocentric scaled resin-based AM, Batch.Works pursued complementary innovations in fused filament fabrication (FFF). Its first MSI-supported project focused on automation and AI. Partnering with AI startup Matta and workspace provider Plus X Innovation, it built an autonomous printing facility with robotic part handling and real-time optimisation.

The impact was transformative: new R&D teams, four spinouts, and a £3 million funding round. For Matta, the project validated their AI platform, unlocking opportunities in CNC machining, powder-bed AM, and even food extrusion.

The follow-up project, Fully-Automated, Intelligently Controlled Feedstock Management, tackled a key bottleneck: material handling. Working again with AMFG, Batch.Works developed a smart microfactory capable of autonomously switching between filament types. Using robotic gantries, API-integrated storage, and dynamic scheduling, the system enabled continuous, multi-material production. It is now progressing toward a 1,000-unit production run with global 3D printing component specialist E3D.



# AMFG, Photocentric and Batch.Works Ecosystem




*FULLY AUTOMATED INTELLIGENTLY CONTROLLED FEEDSTOCK MANAGEMENT
**AI 3D PRINTING FACTORY NETWORK

## The triangle of collaboration

Taken together, these journeys form a triangle of collaboration. At the top sits AMFG, providing the digital backbone first proven in SPACE. At the base are Photocentric and Batch.Works, developing complementary hardware and process innovations.

The strength of this triangle lies in the flow between them. Early-stage experiments informed later factory automation projects. AI and workflow tools developed with one partner were reused with another. Lessons from resin-based AM influenced filament-based microfactories. What began as separate projects evolved into a shared ecosystem, with MSI funding and facilitation ensuring technologies, skills, and insights bled across boundaries.

## A cultural shift

This convergence was no accident. MSI deliberately encouraged projects to involve multiple partners across disciplines: machine builders, software developers, manufacturers, researchers. Innovate UK and Made Smarter leaders like Chris Needham played a crucial role in spotting synergies, offering continuity, and ensuring promising ideas progressed rather than stalling at early stages.

As Batch.Works CEO Julien Vaissieres put it: "We were wrapping up our second AMFG project when someone mentioned Photocentric. It turned out AMFG was working with them too. That realisation, that we're all part of an emerging ecosystem, was a lightbulb moment."

Ed Barlow, Head of Engineering at Photocentric, added: *"These projects have allowed us to engage with companies we'd never reach otherwise. Through these funded collaborations, we've been able to say: 'You may not be interested now, but give us the chance to show you how this idea could transform your manufacturing.' And then we take them on that journey."*

## Looking ahead

With successful exports, expanded networks, and new investment, the additive manufacturing ecosystem seeded by MSI is now bearing fruit. Batch.Works and Photocentric continue to push forward, AMFG is embedding its software into more systems, and spinouts like Matta are scaling across new sectors.

But the deeper impact is cultural. Companies that might once have worked in silos are now part of a shared effort. They build on each other's ideas, accelerating progress toward cleaner, faster, more flexible manufacturing.

In the words of Ed Barlow: *"Made Smarter Innovation was not just a funder, it was a catalyst. The projects created a network of innovation where one idea sparked another. It has advanced digital manufacturing in the UK and made the AM sector here stronger, increasing our capabilities on the world stage. We have only just begun to see what it can do."*

# BAE Systems

## Anchoring Supply Chain Collaboration


### Large manufacturers play a critical role in turning digital innovation into system-wide change, and for BAE Systems.

Made Smarter Innovation provided the platform to do exactly that. As one of the UK's largest aerospace and defence manufacturers, the programme was more than a source of funding. It created the partnerships and structures needed to explore Industry 4.0, trial new technologies with SMEs and startups, and share the benefits across a supply chain of more than 2,000 UK companies.

Through projects funded by MSI, from Collaborative R&D to the Digital Supply Chain Hub and a series of accelerator programmes, BAE has transformed its own operations while also acting as an anchor organisation, helping SMEs, startups, and academics translate innovation into real-world impact.

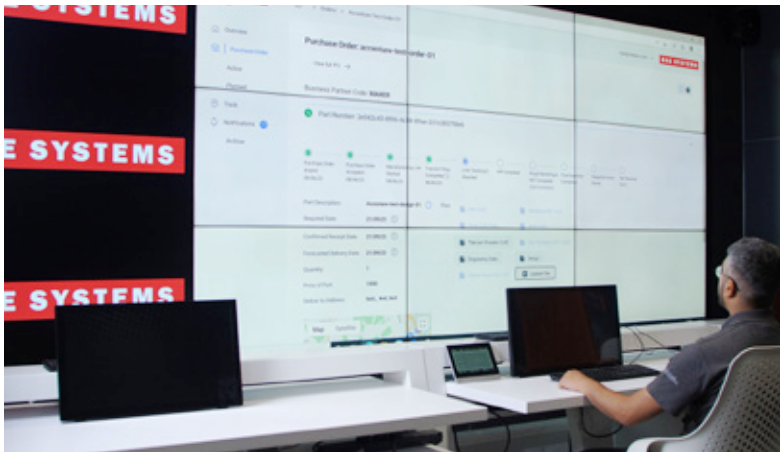
## Laying the foundations: Smart Connected Shop Floor

BAE's journey began in 2019 with the Smart Connected Shop Floor (SCSF) project, which brought major partners including GKN Aerospace, Nissan, Rolls-Royce, Airbus, and GlaxoSmithKline together to test digital technologies in live environments and share learning.

The project began with an inward focus. Engineers trialled different connectivity models, learned from both successes and failures, and built the foundations for the Factory of the Future at Warton. Alongside this, BAE created its own customised set of Operational Technology Architecture Security Controls. These standards, developed through repeated iterations linking shop floor assets, factory management systems, and enterprise networks, reduced operational risk and strengthened security while demonstrating the benefits of a connected facility.

James Leadbetter, Senior Engineer at BAE, said:

> ***"We could not credibly help and integrate with our vast supply chain partners until we understood Industry 4.0 ourselves. The Factory of the Future now runs a secure-by-design manufacturing network based directly on these learnings."***




## Building trust in digital supply chains: INTELI

The next stage of BAE's MSI journey tackled one of aerospace's most pressing challenges: ensuring speed and trust across thousands of suppliers. In 2021 the Intelligent Trusted Supply Chain (INTELI) project brought together BAE with partners including Accenture, Intellium AI, Digital Catapult, Maher, and Codegate.

At the time, supply chain communication still relied on phone calls, spreadsheets, and even encrypted CDs. INTELI reimagined this landscape, creating a system where the supply chain could operate as if it were inside the factory with BAE, with problems flagged instantly, schedules re-optimised, and responsibilities confirmed in real time.

The breakthrough lay in trust. By applying blockchain and distributed ledger technology, the project proved that suppliers could depend on tamper-proof, verifiable data shared simultaneously across the chain. This enabled rapid collaboration, reliable updates, and resilient replanning. Crucially, it gave suppliers direct visibility of operations and access to trusted, up-to-date data, strengthening accountability while empowering them to act.

## Project Butterfly: from internal efficiency to supply chain engagement

Building on the lessons of SCSF and INTELI, BAE launched Project Butterfly in 2022 with partners including Leonardo, Accenture, the University of Sheffield, and the University of Lincoln.

One strand focused inward, targeting autoclaves, the high-pressure ovens used to cure carbon fibre composites and among the most energy-intensive assets in aerospace. Traditionally, operators relied on experience to decide how to load them, balancing space, cycle time, and quality. Working with AI startup Digica, BAE developed a tool that uses sensor data and thermal simulations to recommend optimal packing strategies. The solution shortened curing cycles, cut energy use, and forged a lasting partnership between BAE and Digica that continues today.

The other strand looked outward, supporting suppliers to adopt connectivity and data-led approaches. A&G installed sensors across its machines to calculate the carbon cost of every part, Campbell optimised its compressed air systems to prove efficiency gains, and Hyde Group piloted both leak detection and machine-level monitoring. To make the results accessible, savings were standardised in terms of the number of homes powered for a year: Campbell's improvements equated to 32 houses, Hyde's 12, and A&G's 7.

BAE compiled the outcomes into a publicly available report and ran webinars to share learning across its supply chain. The approach set a new model of collaboration in which a large company uses Innovate UK funding not only to solve its own challenges but also to raise the capability of its suppliers and provide tools that can be replicated across UK manufacturing.

## Digital Supply Chain Hub: mapping what matters

BAE's role extended further through its involvement in the Digital Supply Chain Hub, a national initiative funded by MSI and developed by Digital Catapult. Working alongside organisations such as Rolls-Royce, Sainsbury's, Deloitte, and the International Chamber of Commerce, BAE helped create digitally empowered supply chains that are more efficient, resilient, and sustainable.

In one project, BAE partnered with Versed AI to deliver bill-of-materials-based mapping. Previously considered too complex, the solution combined automatically generated bills of material with multi-tier visibility to produce highly focused supply chain maps. In some cases, up to 95% of irrelevant relationships were filtered out, giving customers a clearer view of upstream risks and dependencies.

The project met a specific client demand and showed how MSI collaboration gave BAE access to agile startups capable of delivering solutions that would have been difficult to achieve internally.

## Accelerators: connecting to the startup ecosystem

BAE also participated in several MSI Accelerator programmes, which pair large manufacturers with SMEs and startups in rapid, challenge-led sprints.

Through the Technology Accelerator, BAE partnered with Machine Intelligence to tackle the limitations of visual inspection in aerospace. Unlike the automotive sector, where millions of images can be used to train machine learning, aerospace production involves small volumes, high complexity, and limited datasets. By combining expert "paint by numbers" guidance with AI, the team created a system that supports rather than replaces skilled operators. This generated novel intellectual property now being applied across multiple areas of BAE's operations, and even led the company to redirect small internal funds away from synthetic datasets and towards deploying this proven method.

The same year, BAE joined the International Supply Chain Accelerator, supporting the Seamless Trade Across Borders project. Backed by Leonardo UK, the International Chamber of Commerce, and BT Group, the initiative underpins the UK Government's Electronic Trade Documents Act, a reform expected to unlock £25 billion in economic growth at a time when more than 60% of trade transactions are expected to be digital within five years.

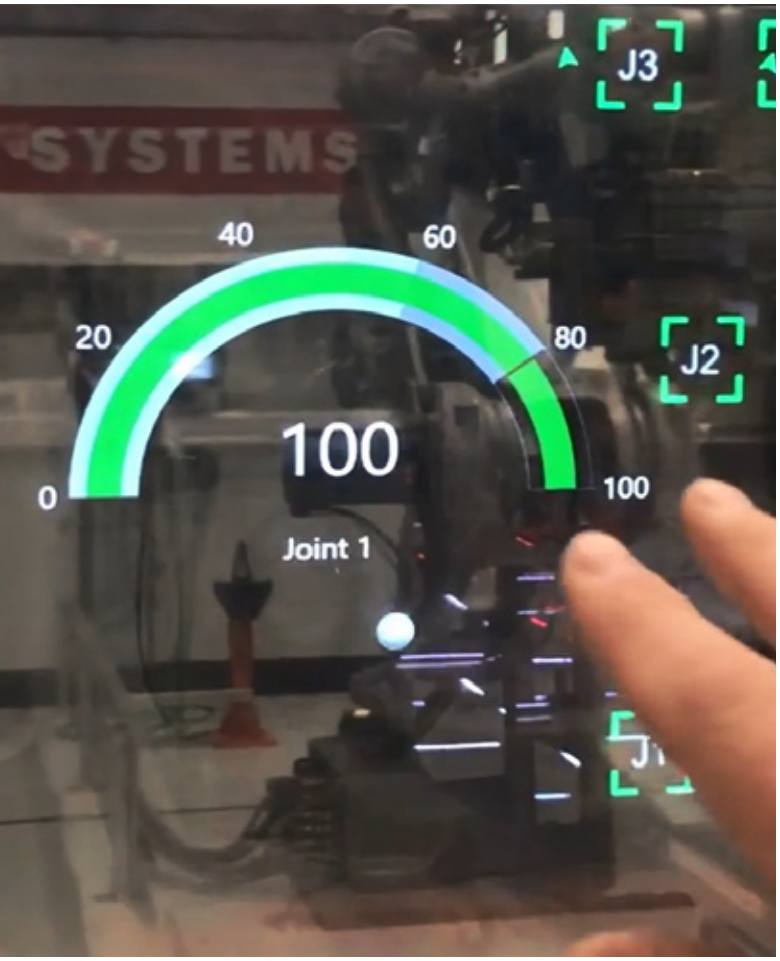
Through the Sustainability Accelerator, BAE partnered with Quaisr to develop a platform that combines physics-based models with machine learning. This enables operators to use verified simulations to decide when to execute assembly jobs and how to run building management systems, cutting energy use and waste. In parallel, BAE worked with Digica to create a digital twin of the Factory of the Future, using AI to optimise composite curing and improve performance.

These accelerators helped BAE cut through the crowded AI startup landscape. By engaging through structured programmes, the company identified a trusted set of partners for long-term collaboration, while startups gained access to one of the UK's largest industrial players.

## Beyond projects: spreading learning across industry

BAE's collaborative projects with initiatives such as Made Smarter are pivotal in extending learning and best practice beyond the company to benefit the wider UK manufacturing sector. By combining internal R&D with external partnerships, BAE accelerates innovation while embedding valuable knowledge and skills across industry.

One example is the company's industrial IoT-driven cybersecurity policies. First developed through the Smart Connected Shop Floor project, these have since become baseline standards across BAE's divisions. Shared through communities such as the Digital Manufacturing Working Group, they have demonstrated practical application across Air, Land, Maritime, and Submarines.




This dual focus on internal and external collaboration is also central to developing future talent. The Academy for Skills and Knowledge has integrated an Industry 4.0 syllabus derived from Made Smarter projects, giving apprentices and graduates essential skills in areas such as AI and cybersecurity. These trainees strengthen BAE's workforce, but the benefits extend further: when individuals move on, they carry these capabilities into other parts of UK manufacturing, raising digital maturity across the sector.

BAE is also working with industry peers and education partners to update apprenticeship standards, co-developing new qualifications for specialist roles including Aerospace and High Integrity Software Engineers. By embedding Industry 4.0, ESG, and sustainability themes into these programmes, BAE is helping ensure the next generation of engineers enter the workforce with skills aligned to industry needs.

Gareth Howell, Principal of the Academy for Skills and Knowledge, said: *"Through our work with Innovate UK and Made Smarter Innovation we are not only advancing BAE's own capabilities, we are helping to raise the bar for UK manufacturing as a whole. By embedding Industry 4.0 skills into our apprenticeship programmes and sharing the outcomes of collaborative projects across our supply chains, we are building a stronger, more digitally enabled workforce. This is about future-proofing both our business and our industry."*

BAE also sat on the Strategic Advisory Group for two Research Centres, Connected Factories and Smart Cobotics, providing oversight and helping to guide programme development to ensure it met the needs of UK manufacturers while fostering collaboration between industry and government.

# BAE Systems Ecosystem

## A cultural shift

BAE's involvement in MSI demonstrates the ecosystem effect in action. What began as internal experiments with connectivity has evolved into projects that improve SME sustainability, create trusted digital supply chains, and accelerate the adoption of AI-driven tools.

MSI provided the impetus to think bigger. Supplier-facing pilots such as Butterfly Work Package 4 were only possible because of the programme's support. Digital sprints with startups produced novel IP and lasting relationships. Research Centre collaborations ensured continuity and rigour.

In addition to the direct benefits BAE has experienced, the company expects to see increasing engagements into a growing selection of the 6,000 organisations across its Tier 1, 2, and 3 supply chains benefit from this work over the coming years. Knowledge and learning are also being shared with hundreds of organisations outside BAE's network, extending impact across manufacturing sectors well beyond aerospace and defence.

As Leadbetter reflected:

*"These programmes are enablers. They give us the space to test new approaches, build trust with SMEs and startups, and share results across UK industry. The outcome is not just BAE getting better, but the whole ecosystem moving forward together."*

# The University of Cambridge
## An Ecosystem of Ecosystems


**For over half a century, the University of Cambridge has been at the forefront of manufacturing research, bringing together engineering science, operations management, and industrial practice to tackle real-world challenges.**

This work was consolidated in 1998 with the creation of the Institute for Manufacturing (IfM), a division of the Department of Engineering dedicated to combining research, teaching, and industrial engagement. The IfM quickly became a convener between academia and industry, with specialist groups spanning advanced materials, automation, operations strategy, innovation management, and global supply chains.

As digital technologies began to reshape industry, Cambridge was among the first to explore their implications. Projects such as Digital Manufacturing on a Shoestring (Shoestring) gave SMEs affordable entry points into digital adoption, while new centres and labs addressed supply chain resilience, information systems, and sustainability.

When the Made Smarter Review was published, Cambridge was ready to play a pivotal role. MSI provided the mechanism to bundle its wide-ranging capabilities, align them with national priorities, and connect them into the ecosystems of SMEs, large companies, and global supply chains.

Two academic leaders were central to this activity: Professor Duncan McFarlane, Professor of Industrial Information Engineering, and Professor Jagjit Singh Srai, Director of Research in the Department of Engineering. Their complementary focus, McFarlane on SMEs and assembly industries, Srai on multinational supply chains, enabled Cambridge to support both ends of the spectrum.

Professor Duncan McFarlane said:

> ***"When MSI launched, Cambridge already had digital capabilities, but they weren't yet coordinated. MSI gave us the mechanism, the trigger, to bring them together."***

*"Jagjit's work has long focused on global supply chain challenges, while mine centred more on SMEs and large-company connectedness. On their own, they evolved differently, but Made Smarter Innovation created the bridge between them. Some outputs from SME-focused projects have fed into multinational networks, and vice versa, creating real complementarity. Different contexts demanded different tools, but together they formed a library of capabilities that can be applied across industries."*

Alongside them, colleagues including Dr Mukesh Kumar (industrial resilience), Dr Sebastian Pattinson (computer-aided manufacturing and AI), and Thomas Bohné (cyber-human systems) brought further expertise. MSI gave these teams the chance to engage with large industrial ecosystems in ways they might not have initiated alone, extending Cambridge's reach and impact.

# Creating a connected factory

One of the first opportunities to apply this know-how was through the MSI Research Centre for Connected Factories. Led by the University of Nottingham with Sheffield, AMRC, and Cambridge, the Centre built on the Omnifactory, a national demonstrator and testbed for smart manufacturing systems.

Omnifactory integrates robots, automation, sensors, and connected digital architecture to show how low-volume, high-complexity sectors can rethink production, making better use of assets and space while sharing digitally enabled approaches with industry.

Cambridge contributed by exploring barriers to data integration across robots and AGVs, and by identifying the skills required to adopt reconfigurable systems. The project delivered 33 technology solutions (more than double the target) and established itself as a living lab for adaptable manufacturing.

An Industrial Advisory Board including Airbus, BAE Systems, Rolls-Royce, BMW, Beckhoff, Kuka and several SME manufacturers, kept research aligned with real-world challenges and accelerated transfer to live operations. Open sharing meant manufacturers beyond the Board could adopt the outputs, with extensions into sectors such as automotive already in scope.

Cambridge led a project to explore how augmented reality (AR) can enhance manual assembly within industrial digitalisation. By overlaying digital instructions and safety alerts onto physical tasks, AR helps workers complete processes more accurately and efficiently.

Researchers identified four main types of AR visualisation and tested their effectiveness through crowdsourcing and field trials with manufacturing apprentices.

The results showed faster task completion, fewer errors, and improved user confidence, underscoring the value of testing AR tools in real-world industrial settings where their productivity impact is most visible.

## Accelerating pharmaceutical innovation

Cambridge's expertise in supply chains ensured it was a key partner in the Digital Medicines Manufacturing ($DM^2$) Research Centre, led by the University of Strathclyde's CMAC with Loughborough and more than 30 partners including AstraZeneca, GSK, and UCB.

The aim was to show how IDTs could transform pharmaceutical development and production. Across five platforms, partners created a suite of innovations including collaborative robotics, AI, and digital twins. The flagship output was a Tableting DataFactory, a table-sized unit capable of cutting tablet development from months to a single day, reducing waste by 60% and costs by 50%.

$DM^2$ also delivered the Skills-Factory, an online resource to accelerate adoption of IDTs across the pharma sector. As a research partner, Cambridge helped ensure that outputs were designed for scalability across complex supply chains. The success saw the project secure additional funding to continue to progress research into industrial impact.

## Creating a digital backbone for pharma supply chains

Alongside $DM^2$, Cambridge contributed to the Smart Pharma Supply Chain (SmartPSC) project, tackling the manual review of Certificates of Analysis (CoAs) for raw and packaging materials. The consortium, led by GSK, included AstraZeneca, CPI, SME partner Wyoming Interactive, and Cambridge.

Cambridge's whole-supply-chain perspective helped the team avoid focusing solely on local efficiency. Instead, the solution ensured digital interventions reduced inventory, improved approval times, and unlocked wider productivity benefits.

The project delivered impressive results. CoA verification in under 10 seconds (30–40% faster); manual effort cut by up to 50%; and potential to reduce rework and inventory by 25%. SmartPSC demonstrated how digital tools can strengthen productivity and resilience, creating a blueprint for supply chains well beyond pharma. Like $DM^2$, the project has progressed through additional grant funding.

Dr Ettore Settanni, a member of the research team on the project, said:

> ***"This project shows that by introducing digital processes, review-to-approval times can be cut significantly, reducing inventory and associated costs."***

## Supporting SMEs through low-cost digitalisation

Cambridge also played a pivotal role in the Smart Manufacturing Data Hub (SMDH), a £50 million programme (2022–2025) designed to help SMEs capture and use data more effectively. The consortium included 12 partners ranging from universities (Ulster, Edinburgh, Dundee) to industry groups (Manufacturing NI, MEGA, Industry Wales) and national centres like STFC Hartree and Energy Systems Catapult.

At Cambridge, the project was led by the Distributed Information and Automation Laboratory (DIAL). Over three years, Dr German Terrazas and his team engaged with more than 150 SMEs across 15 sectors, with over 100 adopting 290 low-cost digital solution kits based on the IfM's pioneering Shoestring architecture.

These kits, for power monitoring, air quality, temperature, scrap, and machine downtime, delivered measurable cost savings, efficiency gains, and safety improvements. SMEs reported significant progress in digital maturity, moving from no data collection to dashboards and semi-automated systems integrated into daily operations.


Shoestring and SMDH's momentum continues through a dedicated IfM business unit, ensuring that MSI's ecosystem for SME digitalisation leaves a lasting legacy.

## Understanding the human side of industrial digitalisation

Alongside its work on digital tools and supply chains, Cambridge has been instrumental in exploring the human and societal dimensions of industrial transformation. Through the InterAct programme, led by Loughborough and Strathclyde universities, researchers from the Institute for Manufacturing (IfM) have led and contributed to multiple projects examining how people, ethics, and inclusion shape the future of manufacturing.

Dr Nikolai Kazantsev, Dr Bethan Moncur, Russell Goh, and Professor Chander Velu developed an immersive industrial metaverse prototype designed to reveal hidden sustainability and ethical factors within global supply chains. The research demonstrated how emerging virtual environments can support better decision-making by visualising the environmental and social impacts of production systems.

Elsewhere, Dr Daqiang Guo investigated how human-robot teams can work safely and efficiently in aerospace manufacturing, contributing valuable insights into the design of collaborative workspaces that enhance both safety and productivity.

Dr Kazantsev also worked with international partners to model how digital platforms and Industry 4.0 technologies are reshaping supply chains into more connected and transparent manufacturing ecosystems. Complementing this, Dr Guendalina Anzolin and Dr Jennifer Castañeda-Navarrete examined how manufacturing is perceived across seven countries, while Dr Castañeda-Navarrete also led research into how digitalisation can advance gender diversity and inclusion in the sector.

Together, these studies highlight Cambridge's commitment to shaping a more ethical, inclusive, and digitally enabled manufacturing future, one that places people at the centre of technological innovation.


## Gamifying sustainability

Cambridge's people-first research was central to S3, a collaborative R&D project with Raynor Foods, Software Imaging, and the University of Lincoln. The project integrated AI, digital twins, and real-time tracking with a gamified interface that rewarded staff actions cutting emissions, from reducing waste per pack to lowering electricity use.
Raynor achieved a 19% reduction in energy use and emissions, removing over 400 tonnes of $CO_2e$, the equivalent to 1.4m cheese sandwiches.

Cambridge, through the IfM, ensured S3 went beyond technical delivery. Its expertise in gamification and sustainability translated complex carbon data into clear KPIs that staff could act on. Trust-building measures such as renaming "tags" to "game links" encouraged buy-in, and participation was voluntary and positive.

The results were cultural as well as technical: 95% of staff actively engage with the system, embedding carbon-saving behaviours into daily routines and even suggesting new KPIs. The success has since been spun out into a venture to deploy S3 across UK manufacturing.

## Building trust in critical mineral supply chains

Cambridge also addressed one of manufacturing's most complex challenges: critical minerals. The Critical Minerals: Network Insight Collaboration Environment (CM-NICE) project, part of the Digital Supply Chain Hub, brought together Teesside University, Chainvine, the World Business Organization, and Cambridge.

Led by the Supply Chain AI Lab, Cambridge developed a platform that combined privacy-preserving techniques such as zero-knowledge proofs, cooperative AI agents acting across systems, value-attribution models to reward data providers, and a trusted governance framework. Together, these innovations showed that supply chains do not need to choose between privacy and transparency, both can be achieved while creating commercial incentives for collaboration.

Strategy and community building
Beyond projects, Cambridge has shaped MSI's strategic direction and culture. Through the MSI Advisory Group, it influenced programme priorities. Through the MSI Sustainability Strategy, it helped link digital adoption with emissions reduction. And through the Women in Manufacturing UK conference, in partnership with MSI, the university has championed inclusivity and diverse leadership in industrial innovation.

## An ecosystem of ecosystems

Cambridge's role in MSI illustrates the power of universities not just as research partners, but as ecosystem anchors. By convening global players, bridging SMEs and multinationals, transferring knowledge between sectors, and supporting capability-building across TRLs, Cambridge has amplified the programme's reach and impact.

MSI provided the mechanism to coordinate capabilities and connect them to real industrial needs. Cambridge's networks ensured the right partners were in the room, projects were grounded in practice, and outcomes could travel, from pharma to food, from SMEs to multinationals, and from research into lasting change.

Professor Jagjit Singh Srai said:

> ***"MSI and the wider Made Smarter landscape is an important ecosystem in its own right, but for us the real story is about an 'ecosystem of ecosystems'. Cambridge's role has been to connect those ecosystems, convening global players, bridging SMEs and multinationals, and transferring knowledge across industries. We're not simply chasing the next grant opportunity, by being embedded in leading networks, we can spot challenges as they emerge and design projects grounded in real industrial needs."***

# University of Cambridge Ecosystem

# Conclusion

**The UK's Modern Industrial Strategy recognises that long-term growth, resilience, and competitiveness depend on the successful adoption of digital technologies across manufacturing. At its core is a commitment to back the ecosystems that turn innovation into productivity, skills, and industrial capability.**

Made Smarter plays a central role in delivering that ambition. Through MSI, the programme has demonstrated how coordinated investment in research, collaboration, and industrial deployment can connect SMEs, large manufacturers, academia, and technology providers into a functioning national ecosystem.

The impact is already clear. Digital solutions are moving more quickly from research to application. Supply chains are becoming more connected and resilient. Skills, data, and trust are accumulating across sectors. It is also creating commercially scalable ventures, with Cambridge spin-outs Versed AI and Matta both securing significant follow-on investment after their Made Smarter Innovation-backed work. These outcomes directly support the objectives of the Modern Industrial Strategy, strengthening productivity while building the foundations for future growth.
Recognising this success, the government has pledged to extend MSI with up to £116 million of further investment, reinforcing its role as a critical national mechanism for industrial digitalisation. This commitment signals confidence not just in individual projects, but in the ecosystem model itself.

The challenge now is to build on this momentum.

Future success will depend on sustaining and expanding the ecosystems that MSI has helped establish. That means continuing to support collaborative research, ensuring clear pathways from innovation to industrial deployment, and embedding people, skills, sustainability, and ethics alongside technology. It also means maintaining strong alignment between industry, government, and academia so that innovation remains focused on real-world challenges.

The case studies in this document show what is possible when these conditions are in place. The call to action is clear. To secure the UK's position as a globally competitive manufacturing nation, stakeholders must continue to invest in, participate in, and champion the connected digital manufacturing ecosystem that MSI has proven can deliver lasting impact.

**Check out the Made Smarter website**
**www.madesmarter.uk/made-smarter-innovation**

You can read more case studies **here**

Read the Made Smarter Innovation Celebration brochure **here**

Read the final, independent evaluation report **here**

Or use our Linktree where you can find lots of resources about Made Smarter Innovation, including announcement of future funding expected from 2025 Innovate UK **here**

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