COLLATION. Trusted Data Collaboration in Complex Sustainable Supply Chains

Modern manufacturing supply chains are highly fragmented, multi-actor and international. Supply chain structural diversity ranges from simple vertically integrated systems to scaled decentralised networks (food). Irrespective of supply chain complexity, all need to exchange data, whether on the physical flow of goods, finances, environmental measures, standards and specifications. Data exchange underpins productivity across the whole of the economy; optimising just in time operational deliveries, product provenance, the monitoring of environmental, product and regulatory standards and financial transactions. Modern supply chains have to be sustainable, not only economically but environmentally. The evolution to environmental sustainability widens the scope and urgency for data sharing and needs to be informed by deeper stakeholder engagement (e.g. consumers) in supply chain function. The ongoing COVID-19 pandemic has demonstrated the vulnerability of supply chains to disruption. Supply chains are now transitioning to shorter networks with a hybrid emphasis on both “just in case” and “just in time”. This transformation requires highly flexible supply chains where data provision effects high speed decision support without additional cost (e.g. inventory, redundant capacity).

However, supply chain transformation underpinned by exchange of data is highly challenging; multiple and unresolved socio-technical barriers (behavioural, legal, technical, commercial) inhibit effective data exchange and flow. Unlocking these barriers would have transformational impacts across the whole of the manufacturing sector and increase the resilience /adaptability of UK’s supply chains in future, green and post Brexit/pandemic economies.

Our premise is that only cutting edge research developed by leading experts well-structured in centres of excellence such us COLLATION, with the engagement of industry and policy makers, will have more chance of building up more adaptative, competitive, and sustainable UK supply chains fit for the unpredictable challenges of the 21st century. Consequently, the aim of COLLATION is to create a globally leading centre of excellence that unlocks trusted and controlled data exchange across increasingly complex and more sustainable manufacturing supply chains.

COLLATION will conduct basic research across four central themes;

1. Social-legal. Collaborating with industry across UK manufacturing, key behavioural, ethical, competitive and legal (competition law, GDPR etc) barriers to trusted sharing will be explored.
2. Technical. Role of technology to expediate data exchange and interoperability.
3. Sustainable adaptive supply chains. Transition of supply chains to integrate economic with environmental sustainability.
4. Governance of data sharing. Novel structures, such as data trusts, to govern and manage data sharing.

Collaboration with industry will deliver rapid and scalable impact for all sectors of UK manufacturing and the digital economy. The outputs from the basic research will be synthesised and tested across real and diverse supply chains in industry (automotive, food and chemistry).

COLLATION is a joint initiative across leading UK-HEI’s with significant track records supporting UK manufacturing and MADE SMARTER including the Universities of Lincoln, Exeter, Cambridge (IfM,), Nottingham, and Southampton. Collaborative partners include 3 Catapults (Digital, MTC, Satellite) as well as leading industry partners across the UK food, manufacturing and chemical supply chains.

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The Materials Made Smarter Research Centre will enable the transformation of materials intensive manufacturing through the development and application of advances in cyber-physical systems, data science and artificial intelligence, and the understanding and leadership of technological change. The opportunity is very timely; the discovery of improved materials, coupled with new, lower impact, means for their production, fabrication and reuse/recycling are critical across a wide range of key technologies and sectors, and underpin the UK's goals of net-zero carbon by 2050. The materials intensive industries driving development, production, fabrication, use and reuse of materials have not yet experienced the same digital transformation as other closely aligned manufacturing sectors, however. Such transformation is essential to ensuring the future of high value materials manufacturing in the UK. By developing the means of overcoming these societal and technological challenges and understanding and driving innovation in how the required changes are led and implemented, we seek to reshape the way we think about and value the materials that shape our world and their manufacture.

The Materials Made Smarter Research Centre pools expertise and insight from four EPSRC Future Manufacturing Hubs (MAPP, LiME, SUSTAIN and Composites) together with the Turing Institute and the Institute of Work Psychology to create a stand-alone unique centre focussed on the Digital Innovation of the Materials Intensive Industries aligning novel underpinning research and collaborative user-focused R&D across all four priority areas of the call focusing on three core research themes: data centric manufacturing, cyber-physical systems, and technological change.

The essence of materials and the nuances of their processing are challenging to draw into a digital form requiring multiple complex descriptors and often the integration of huge, noisy, data sets to accomplish. Through re-imagining the internationally leading pilot-scale facilities at our disposal as experimental R&D platforms we will develop technology demonstrators to do this efficiently and effectively. Through close collaboration between manufacturing researchers, researchers in computing, AI and cyber-physical systems and our industrial user base the centre will develop common technical solution to accelerate the pace of innovation across multiple industries. Our valuable, pre-existing, relationships with key industries and the academic network will also allow us to maximise the opportunity that this new centre presents, creating a stimulating environment to nurture new talent, whilst reducing risk and lowering the barriers to participation.

Technological advances, however, only offer a partial solution – to succeed they must also be trusted and adopted. There is a need to engage on the human level, not only in terms of engaging with and managing the adoption of emerging technologies, but also in terms of understanding and managing our reactions to them. With the acceleration of technological change many sections of the present workforce will need to retrain to keep pace with those changes relevant not only to their role but also to the wider needs of their businesses. Leadership and management of such change is vital, as is understanding and developing the new business models which emerge to create and capture greater value for UK manufacturing.

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CENTRE FOR SMARTER MANUFACTURING LOGISTICS

The Centre is about conducting fundamental research to project what the future of manufacturing supply chains will be (a blueprint of future developments) and bringing companies from where they are now (i.e., the current state) to the envisaged future state (i.e., in the next 5 – 10 years).

We consolidate existing strengths and interdisciplinary collaborations currently available at Cardiff University, in the PARC Institute of Manufacturing, Logistics and Inventories (PARC: Business and Engineering) and the Centre for Artificial Intelligence, Robotics and Human-Machine Systems (IROHMS: Engineering, Psychology and Computer Science), facilitated by the outward facing nature of the ASTUTE programme (Engineering and Business), to enable the co-creation, between academia and industry, of a relevant programme of work and help resolve real world issues through relevant generalisable fundamental research. This will facilitate better responding to industry needs through a virtuous cycle between fundamental and applied work, the latter being particularly important because of the involvement of various companies. We leverage existing facilities and equipment in Cardiff University. This is complemented by considerable contribution from our industrial collaborator DSV, and substantial support from a great number of other companies.

The vision of this centre is three-fold:

i. depict the future of the UK's manufacturing logistics and supply chains to develop smarter next generation operating models;
ii. build and scaleup new smarter capabilities for managing businesses in the era of digitisation and automation which needs to be supported by advanced decision support system tools;
iii. ensure that the needs of all stakeholders, including employees and their local communities, especially those who have been 'left behind', are catered for in terms of smarter education and training.

We will achieve the above by addressing the following three research questions (RQs).

RQ1: What is the operating model needed for manufacturers, 'manufacturers without factories' and 4PLs to adapt and develop their competitiveness in the era of digitisation and automation? (Work Stream 1)

RQ2: How can we adapt our operations and introduce flexibility in our planning capabilities to deliver manufacturing logistics activities in real-time while resolving ambiguities and creating value for customers and other stakeholders (including employees)? (Work Stream 2)

RQ3: How can we build an integrative (forward and closed loop) supply chain and improve the productivity of all logistics and manufacturing activities, including warehousing, manufacturing, remanufacturing and transportation? (Work Stream 3)

The work streams (WS) above reflect an emphasis on the research prioritised by this call: Smart Connected Factories (WS1); Adaptable, Flexible Manufacturing Operations and Skills (WS2), Connected and Versatile Supply Chains (WS3). Very importantly, the proposed programme of work will also prepare (and appropriately equip) the workforce in anticipation of digitisation and automation to safeguard people's existing jobs, whilst creating news ones as well (Societal and cultural change - managing the disruptive impact of digital technologies).

The work streams contribute collectively to an innovative agenda for the manufacturing logistics industry and align with national and international priorities and EPSRC's delivery plan and priority framework; WS1: Connected Nation; WS2: Resilient Nation; WS3: Productive Nation.

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Centre for Innovation in Socio-Technical Manufacturing (CISTM)

The Centre for Innovation in Socio-Technical Manufacturing (CISTM) will deliver a programme of research that will help factory systems to extend beyond conventional factory boundaries to unlock the benefits of industrial digitisation. It will focus on issues related to the future of supply chain management with consideration of the social and cultural impacts that digitisation can bring. CISTM will pay particular attention to supply chain integration, system integrity and trust in systems. We will develop best practice around data capture, artificial intelligence (AI), and security; including both technological and social aspects.

CISTM members comprise world-leading experts at Lancaster University and Manufacturing Technology practitioners from BAE Systems Ltd. Building on our successful partnership (e.g. Productivity Through People and the Made Smarter Leadership Programme), CISTM will co-develop projects that address supply chain management from the users perspective. BAE Systems Ltd will identify user need in the context of their Factory of the Future in Warton. Indicative areas of work include:

1. Societal and Cultural Change & Smart Connected Factory:

Focused on in-depth analysis of socio-technical vulnerabilities in industrial control systems, ethical considerations around data ownership, and human-machine interactions (ergonomics, big data, human factors, connected worker, cyber-physical systems). Expertise comes from Security Lancaster- encompassing NCSC ACE-CSR and the Centre for Research and Evidence on Security Threats (CREST), who approach these areas through the lenses of Computer Science and Psychology.

2. Connected and Versatile Supply Chain:

Focused on how Industry4.0 technologies will enable improved demand management, shape management practice to proactively use data for supply chain performance optimisation and improve decision-making and AI. Integral here is understanding how the relationship of the supply chain evolves as SMEs are integrated into the manufacturing industry, such as the impact on supply chain resilience and the eco-systems ability to cope with change and disruption. Expertise comes from Lancaster University Management School.

3. Adaptable, Flexible Manufacturing Operations and Skills:

Focused on the impact of digital technologies in safety and human-machine interactions, big data, psychosocial effects, ethics and skills as a supply chain. It is crucial to maintain a supply of skills and talent to enable future factories to deal with volatility and disruption. CISTM, will link with the expertise within the collaborative Lancaster-BAE Systems Ltd Advanced Manufacturing Capital Skills Development & Employer Engagement (ACaDEmE+) Programme focussed on additive manufacturing and immersive design.

CISTM will deliver its programme of research with BAE Systems Ltd as they explore the first outside factory automatic communication system. This will provide an environment to learn about how best to implement integrated supplier communication and response capitalising on improvements in communications (5G) and Industry4.0 integration that reaches beyond the defined factory parameters. Importantly, an understanding of the benefits (i.e. productivity, efficiency and pro-activity) will be derived from testing and comparing response timelines and improvements against legacy systems and processes that exist across the different manufacturing platforms. The aim of CISTM is to provide a framework of new efficiencies and priority areas for future research, investment and deployments.

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Context of the Research

A Smart Factory (SF) is a complex system with sub-components connected to a centralised information system, gathering and exchanging data that enable intelligent decisions to produce a manufacturing system capable of reacting to changes in the local and global environment. SF benefits extend beyond the physical space of production, by enabling synchronisation of the wider logistical networks of material/information supply and demand.

Additive manufacturing (AM) technologies offer much promise as engines of SFs. However, they are often cited as being too slow and too expensive to use in a wider manufacturing context. The research centre proposed here will address these fundamental limitations and establish an AM SF testbed.

Aims and Objectives

We aim to develop a phased proof-of-concept SF based on AM of metal components. We will deliver an intelligent AM production system by establishing a combination of production, information, and communication technologies integrated across the entire SF system, incorporating key aspects of people, processes, products and plant.

Our objectives cut across 4 main themes

Theme 1: Smart Connected Factory
By exploring manufacturing process and operations, we will:

- Establish an AM SF testbed based on a new generation of high-speed metal AM production technology;
- Deliver real time in process monitoring and AM process optimisation;
- Establish powerful cloud-based modelling and simulation tools to create a robust digital twin of the AM production and SF operations;
- Establish secure digital certification and validation of production across the SF and value chain;
- Implement AI based verification of operating conditions, connecting the worker within the SF.

Theme-2: Connected and versatile supply chain
We will explore how analytics and diagnostics can provide essential insight, that enable collaborative ecosystem partners to monitor and effect control of the AM supply chain. By exploring supply chain execution, we will:

- Improve SF operations through analytics and artificial intelligence (AI);
- Establish new capabilities for production planning and scenario modelling;
- Create digital tools that provide traceability and provenance;
- Pilot secure encrypted AM build file transfer.

Theme-3: Adaptable, flexible manufacturing operations and skills
Using new AI-based vision inspection tools, we will:

- Gain greater understanding of real work using data from people and industrial AM systems;
- Capture and standardise best practice AM manual activities such as build plate preparation and post-processing;
- Establish safe human-machine interactions;
- Provide a scalable AM skills development repository.

Theme-4: Societal and cultural change - managing the disruptive impact of digital technologies
Our SF research will:

- Optimise the engagement of the individual worker in AM manufacturing;
- Fully understand the human factors in design and engagement of AM technology solutions;
- Explore the ethical and privacy considerations of AM data ownership and use.

Potential Applications and Benefits

Through the application of a new generation of SF operations, our research will find wide ranging applications across all industrial sectors by providing the benefits of increased manufacturing competitiveness. This research is conducted in collaboration with LEs and SMEs. We welcome interest from new industrial & academic partners that have interest in or can contribute to any of the above research topics.

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Focus

Themes and sub-topics: 2 (interoperability of data across value chains; supply chain design; supply chain execution); 4 (reconsidering the design of jobs; human factors; working in a technology-rich environment; ethical and privacy considerations).

Context

Industry 4.0 technologies are a means to transform UK manufacturers' competitiveness. However, the UK significantly lags global adoption levels, revenue ambitions and savings' expectations of and from these technologies. Research at the University of Liverpool and close industry collaborations have shown that SME manufacturers struggle to understand how new, digital technologies can power manufacturing and supply chain innovations. The key impediments for SMEs are investment levels, complexity of operations and skill requirements. Many larger manufacturers have the same challenges. Others are more adept at new technology adoption, but lack the strong partnerships, sufficient understanding of the social, ethical and environmental contexts and consequences, and the performance prediction capabilities to fully exploit the opportunities to transform their supply chain eco-systems.

Aims/Objectives

Our aim is to research, demonstrate and evaluate how digital technologies can best be deployed to transform the economic, social and environmental (triple bottom line – TBL) performance of the eco-systems of manufacturers, SMEs and related businesses that comprise modern industrial supply chains. The Centre will address how digital technologies can accelerate productivity and competitiveness in supply chains and their SME manufacturing operations. It will improve supply chain visibility, transparency and traceability to support ethical business practices and positive societal change. We will endeavour to thoroughly understand the interplay between digital technologies, socio-technical skills and culture by drawing on network, social value and technology acceptance theories. Utilising our state-of-the-art facilities (STFC Central Technology Hub, AI supercomputing facilities, immersive visualisation, and digital test-beds), and building on existing expertise and partnerships, we will research, test and evaluate SME and industry applications to develop new processes and skills utilising the latest technologies and data-centric insights for TBL transformations across different supply chains.

Potential applications/benefits

Led by a multi-disciplinary and experienced team of researchers from UoL, and building on the Siemens/Hartree Industrial Digitalisation Accelerator and Virtual Engineering Centre (LCR4.0 lead), we will develop a research and practice community trained to fuse technical, ethical, environmental, social and post-COVID thinking to design, plan and provide people with the requisite skills for the adoption of ground-breaking, supply chain solutions. We will work in three, broad, economy-driving sectors (textiles; process/FMCG; automotive) and be responsive to emerging challenges in these sectors and positive spillovers from them. Our cross-cutting research applications are exemplified by:

- fibre-to-floor platforms in the textile sector in which complete product provenance, ethical credentials and authenticity can be verified at the point-of-sale;
- commodities' transactions and supply chain, inventory-movement visibility in the process/FMCG sector to mitigate price and demand volatility, and support real-time, TBL-driven decision-making, sustainability and waste minimisation, and ethical reporting;
- connected, interoperable, decision-support environments in automotive supply chains to enhance data visibility to support product customisation, performance optimisation and human-centric design.

Partner information

Further application opportunities to support our sectoral and TBL focus, and partners with complementary strengths are of interest.

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Focus: Borrowing inspiration from “software defined environments” research in distributed systems, this Centre proposal aims to create a “Software Defined Factory” (SDF), borrowing from a recent vision that “a factory is itself a dynamically reconfigurable machine, whose function can be monitored, analysed, extended and adapted in real-time”. The Centre will, in particular, focus on supply chain adaptation and resilience for the food processing sector using the SDF concept.

Context: The manufacturing industry is increasingly embracing automation and control to improve product experience and customisation. This is paving the way to a paradigm shift that is gradually transforming factories consisting of passive to dynamically operated assets that respond to various stimuli (both demand/ market/ experience-driven and operational change in the factory) – taking into account a wide range of environmental and operational technology changes. Factories can involve complex interacting systems that exhibit dynamic and non-linear behaviour in a continuously changing environment. Increasingly, factories are equipped with Internet of Things (IoT) sensors that monitor and observe the manufacturing process, worker productivity, product quality and which increasingly contribute to operations on automated systems (robot controlled in many instances). Such a complex manufacturing environment necessitates real-time harvesting and integration of data from internal and external sources (both from within the operational processes and subsystems and from other connected, externally managed, information sources). Managing and adapting these interactions through a programmatic interface could change factory operation and resilience.

Aims and objectives: The fundamental premise of “SDF” programming paradigm is to combine simulation (e.g. via “digital twins”), real-time sensing, inferencing, and prediction as part of one holistic software system – with the key aim of investigating control parameters and undertaking “what-if” investigations on the SDF prior to validation in the real environment. Specifically: (1) To investigate how SDFs can be used to support data collection and analysis within the multi-factory manufacturing supply chain – building on similar efforts in this area in built environments; (2) To develop a taxonomy of known events/stimuli that affect operations and automation of a manufacturing environment, and devise a system (hardware and software) architecture for interpreting their impacts on the performance of the systems concerned. (3) To identify research and implementation challenges in supporting data management capability within an SDF, enabling various analytics and digital twin capabilities (e.g., simulation) to be realised within and across manufacturing environments; (4) To investigate how SDFs can be scaled, securely, across multi-factory manufacturing environments – such within the food processing supply chain, and validate their resilience under cyberattack using a realistic testbed.

Applications and benefits: This project will be of benefit to the manufacturing engineering, supply chains within a multi-factory environment, factory control/operation technology systems engineers and the computer science research communities. The SDN simulator and sensor ontology will be released for general use and can be used to support a number of other types of investigations.

Additional info.: This proposal aligns and extends work on the “Internet of Production” efforts in Germany, with strong collaborations with existing groups in Germany in this area.

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Imagine a world where outcomes of complex engineered assets such as HS2 and Hinkley Point can be predicted and optimised throughout the lifecycle, even as early on as the inception of ideas. In this world, people can share their knowledge within the wider digital technological landscape with better interaction to an integrated digital platform. By taking a holistic approach across the lifecycle, we will cost effectively maximise output, enable new value creation, ensure job security, and reduce environmental impact.

In pursuit of this goal, we must address numerous challenges as the UK transitions to an outcomes-based economy. Today, there is no platform that can optimise outcomes with integrated data, models, and visualisation capability across the asset lifecycle. However, there is a demand to move away from the isolated view of phases. In detail, the following is needed: firstly, a much greater comprehension of the harmful events that may arise during and after realisation of assets. Secondly, limiting uncertainties to enable effective management of outcomes early on. Thirdly, harvesting knowledge across the value chain to sustain an evolving workforce. Fourthly, centring technology design around humans individually and socially. Lastly, effective resilience through cradle-to-grave monitoring and optimising the asset.

The Through-Life Digital Manufacturing Centre will bring together a consortium of academics, companies and non-governmental organisations with multi-disciplinary expertise over several industrial sectors. The proposed Centre aligns with the EPSRC ISCF MMS calls' remit in the following four novel ways. 1) Create smart connected factories across the lifecycle through developing an ambitious, and transformative digital ecosystem called 'The Interface' that will be able to monitor and predict outcomes, using even imperfect datasets. 2) Create a structure to integrate diverse dataflows in 'The Interface' to connect versatile supply chains and ensure resilience across diverse sectors. 3) Create a self-adapting digital replica of the complex engineered asset through 'The Interface' that will offer adaptable and flexible manufacturing operations and skills. 4) Create secured information channels that enable real time co-working and collaboration opportunities between the workforce via 'The Interface'. This project will enhance human contribution, broaden skillsets, ensure the positive impact of digital technologies on the workforce through societal and cultural change.

Project partners are crucial to the success of our proposed Centre and we have already secured support from major organisations and will attract additional partners via centre co-creation activities. The solution of creating 'The Interface' will be applicable in sectors that are reliant on the availability of major assets and benefit organisations ranging from SME to multinational. Accordingly, we have already identified case studies in the gas turbine, rail, FMCG and defence sectors. The benefits will take economic, environmental and social dimensions. As a target, this proposal sets a 20% improvement in each of the areas of; asset performance, overall costs and environmental impact. Additionally, we aim to create a dynamic workforce, where each individual may influence the future of manufacturing. By allowing individuals to have oversight of the entirety of the manufacturing process, their long-term position is secured as job roles evolve.

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BEING SMART TODAY – INVEST IN PEOPLE

Imagine you are responsible for the digitisation journey of your company's manufacturing. You know by embedding digitisation throughout the whole manufacturing value chain will bring success. However, your manufacturing portfolio is diverse e.g. high volume fast moving white goods, novel pharmaceutical biological drugs, automotive components, chemical synthesis and aircraft avionics. You also design, manufacture and operate nuclear facilities. Each of the sectors claim they are unique; however, your experience evidences the underlying challenges are common – although often articulated in different ways!

You have learnt lessons from the 1980's where companies adopted automation because 'it was the new shiny technology" but productivity savings were not always realised, and the Made Smarter Review evidenced that in 2017 productivity challenges, still remain - even though the technology is available. You know that people are the critical element. You have seen manufacturing systems fail to deliver because of employee pushback, lack of engagement/skills/leadership as well as poor change management (Made Smarter Review 2017, Vander Luis Da Silva, et al. 2020). You recognise to create value in manufacturing through digitalisation needs investment in people. It is your view that the right combination of current technology, data and people can deliver SMART manufacturing today i.e. if we have the right people, we can be responsive, reactive, make smart decisions to maximise manufacturing value using live data and information. However, to achieve digitally engaged people, especially in manufacturing you believe there needs to be a process for manufacturing companies to follow, regardless of sector and size.

The vision of this centre is to enable 'UK Manufacturing to improve their productivity year on year by investing in their biggest assets – people"". This investment will lead to the uptake of digitalisation.

As part of our ambitious centre, Theme 4 - "Societal and cultural change: managing the disruptive impact of digital technologies." i.e. achieving digitally engaged people is core and will account for up-to 65% of our activities. Around 56% of UK manufacturing (Q2, 2019) are SMEs which are critical to UK Manufacturing. To meet our goal of digitally engaged people our research will engage the whole manufacturing value chain through Theme 3 – "connected and versatile supply chain" our second core theme.

However, we recognise investing in people will 'touch' all of the themes and our networking activities will be crucial in leveraging value from the Made Smarter investments.

In summary, our hypothesis is that regardless of manufacturing sector and company size a common process leading to digitally engaged people is achievable in practice i.e. in industry. Impacts from embedding our research into aerospace manufacturing demonstrated the data/information engineers believed they needed, was not the data/information they used to make decisions. We were able to increase their productivity by 47% through a combination of manufacturing digitalisation and human factors. This was achieved through a step-by-step process, using data analytics, human factors and observing people in action which our centre will build on and create a generic process for use across UK manufacturing.

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Non-Destructive Evaluation (NDE) underpins the manufacture and operation of safety-critical engineering structures across multiple industries (aerospace, nuclear, defence, oil & gas, rail, renewables). However, all aspects of current NDE practice, from inspection design and validation to the physical acquisition and analysis of inspection data, are reliant on skilled human operatives. This limits the capacity and capability of NDE and will severely impede progress to Industry 4.0 in key sectors. COVID has catalysed the industrial need for automation, and it is now the number one NDE priority in many organisations. We therefore propose an NDE for Industry 4.0 Research Centre with the following aims:

- automation of NDE data analysis to enable step changes in NDE capacity and capability that can address the increased volume and complexity of data in Industry 4.0;
- automation of the inspection design and validation process so that it can be performed in silico before a component is physically made, thus reducing design/production time and enabling manufacturing agility;
- design of NDE methods for minimally-invasive inline deployment during advanced manufacturing processes to provide process feedback and integrity information for archival in digital twins;
- design of NDE methods for automated in-service monitoring of assets to provide up-to-date integrity information for an asset's digital twin.

The work programme maps to Innovation Themes as follows.

Theme 1: SMART CONNECTED FACTORY

To support MANUFACTURING PROCESS AND OPERATIONS, we will develop NDE methods for inline inspection of components made using advanced (e.g. additive) manufacturing. Inline NDE will provide both the integrity guarantee of the finished component and real-time process feedback. NDE results will be archived in the digital twins of both the finished part (providing digital traceability) and the production facility (enabling future process optimisation).

To support ASSET MANAGEMENT OPTIMISATION, we will develop NDE methods tailored for robotic deployment or permanent installation on assets to provide integrity data for the asset's digital twin. We will also develop robust processing tools to analyse these vast streams of complex, heterogeneous data and extract predictive analytics to support asset maintenance.

(Theme 2: not addressed)

Theme 3: ADAPTABLE, FLEXIBLE MANUFACTURING OPERATIONS AND SKILLS

To realise the full benefits of production agility enabled by new manufacturing techniques, we will develop the tools that enable a new component's NDE to be automatically designed and validated in silico. This requires extensive use of high-fidelity, multi-physics numerical simulations and robust design of (virtual) experiments to map multi-dimensional parameter spaces.

Theme 4: SOCIETAL AND CULTURAL CHANGE

We will drive innovation in NDE to increase UK competitiveness in Industry 4.0. The innovations are disruptive steps that will have a profound effect on the industrial perception of NDE and the training of NDE personnel. We will work closely with industry to address potential barriers to implementation (social, cultural and organisational). We will engage with the British Institute of Non-Destructive Testing to advance their professional training programmes and the CDT in Future Innovation in NDE to evolve the taught elements of their doctoral programme.

Additional industrial partners are welcome to the programme.

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The Digital Centre for Integrated Additive Manufacturing Technologies aims to digitise Additive Manufacturing (AM) for engineering and high performance polymers (HPPs) together with their composites, as a stand-alone solution and as part of wider hybrid manufacturing technologies. This will allow industry to fully capitalise on the outstanding combination of properties offered by these materials (lightweight replacement for metals, high operating temperatures, resistant to sterilisation, corrosion, abrasion and stress-fatigue, low toxicity and mechanically tough). It will create an end-to-end digital twin from polymerisation to part production and optimise manufacture through tailoring of polymers and processes, guaranteeing quality and improving performance.

The objectives are to:

- Develop an end-to-end digital twin from polymerisation to part production.
- Integrate AM technologies into hybrid manufacturing processes and models and design a framework for incorporation in production networks
- Deliver tailored solutions that will evolve to meet industrial requirements with customised materials and processes.
- Provide accurate predictions for part performance through visualisation and modelling and guarantee parts performance
- Understand the impact of digitalisation of AM with relation to both changes to industry and society, putting in place the necessary systems and policy recommendations to ensure that the benefits are realised.

The Innovation themes will include:

Smart connected factory – Using AM to accelerate processes through multiple hybrid applications and creation of a complete digital twin from polymerisation to part production, with real time, in-process monitoring for embedded certification and validation.

Connected and versatile supply chain – Understanding obstacles and developing unique collaborative working arrangements with secure multi-party sharable databases to ensure an end-to-end supply chain for both the virtual and real world. A new landscape for the evolving data models will be created, including integrity and confidentiality features.

Adaptable, flexible manufacturing operations and skills - AM can add flexibility to manufacturing operations and production networks. True customisation with rapid and flexible manufacturing will be made feasible through hybrid processes and integration of AM in conventional manufacture. This will be an enabler for new distributed manufacturing models and expand the use of AM into areas such as repairs, embedded sensors, composite manufacturing.

Societal and cultural change - The impact of all aspects of the project will be investigated in collaboration with industrial partners considering multiple multi-disciplinary aspects, from training and re-skilling, gender balance, to the understanding of human factors and integration with technology at various stages of the process.

Initial target markets will be aerospace, automotive, oil and gas, medical (non-implantable) and industries working in the advanced manufacturing sector. The Centre will create an AM ecosystem, combining technological advancements from the last decade with the large volumes of data gathered. It will produce new systems and processes for designing and manufacturing high value engineering components (taking advantage of the outstanding combination of properties offered by HPPs), whilst providing a technological and societal roadmap for the UK's evolution into a flexible, digital manufacturer of the future.

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Focus: Our proposed research centre focuses on digitalisation to transform industry practices and productivity through pre-competitive cross-sector collaboration. With a social value and societal impact remit, 60% of our activities will focus on innovation theme 4 (societal and cultural change - managing the disruptive impact of digital technologies). 40% of activities will cover aspects of innovation themes 1-3 that drive societal and cultural change. We will co-create projects with industry and policy actors to address user needs.

Context: In major research programmes (EPSRC; non-EPSRC; International), we have observed three digitalisation pathways where digital innovations are being managed: 1) by experimenting with innovation theme 1 (smart factory concepts) first, then addressing supply chain issues; 2) by focusing on innovation theme 2 (connected and versatile supply chain concepts) first and then addressing product/process (smart factory) issues; or 3) simultaneously tackling innovation themes 1 and 2 together with other issues (e.g., skills gap), which relates to innovation theme 3 (Adaptable, flexible manufacturing operations and skills).

While both sequential (pathways 1 and 2) and simultaneous (pathway 3) approaches are being tried, it is not clear how operational risks are mitigated in each pathway. What is clear is ‘going it alone’ is too tortuous and risky a route to take for speedy digital execution when industry-first breakthroughs, impossible to imitate using conventional methods, are at stake. What is also missing is the impact of pathways on societal and cultural change (a 4th pathway consequent to paths 1, 2 and 3), where managing the disruptive impact of digital innovations (in transitioning) is even riskier (e.g., in terms of consequential effects on regional inequalities in skilled jobs), often underplayed, or not considered at all.

Aim and objectives: Our aim is to better inform firms on how to organise for their digital innovations, in terms of new manufacturing technologies and digital supply chains, and to inform policy makers to encourage innovations that provide fairly distributed societal benefits. We will integrate technological and societal aspects of manufacturing research, with a people-focus, in order to improve adoption and acceptance of new ways of working. For example, better decision-making by incorporating considerations of how transformative technologies can be used to reduce inequalities between groups (i.e., age, gender, ethnic group) and regions.

As well as targeted applications linked to proposed WP1 (incorporating innovation themes 1 and 2) and WP2 (incorporating innovation theme 3), WP3 will focus on the 4th pathway with benefits arising from ‘Smarter Transitions’. The overall focus of WP3 is to ensure the concerns of those affected by digitalisation pathway decisions are incorporated into decision-making at the firm level. In proposed WP3a, we focus on individual decision makers. In WP3b, we focus on organisational values framed in terms of creating social value. In WP3c, we focus on smart collaboration within and across sectors (where risks are pooled, commercial interests protected and common interests served e.g. clusters), mutually beneficial cooperation with government (taskforce, enterprise councils etc) and engagement with local communities.

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While there is significant ongoing investment in digital manufacturing, few industries have achieved adoption levels and maturity necessary to fully leverage Industry 4.0. Further, within supply chains there exists a divide between levels of adoption, maturity and cultures in terms of digitalisation, digital infrastructure and connectivity. In addition, industries face tough economic challenges which, when combined with the lack of methodologies for effective digital transformation, mean commercial risks are just too great.

We will address this fundamental challenge through the co-creation and co-delivery of the digital transformation of a High-Value-Manufacturing (HVM) facility provided by our partners. This transformation will include product, process, people and infrastructure-led (digital) changes. A key tenet of our approach is the consideration of the facility and extended enterprise as a whole-system represented as a continuously evolving holistic and interoperable Digital Twin. The paradigm of Digital Twins is being adopted by software vendors in the engineering sector, and it is therefore timely and feasible to research and create a multi-scale, holistic Digital Twin covering product, processes, production system, infrastructure and enterprise. To transition from legacy facility to future factory, both facility and twin will be stepped through a series of discrete and continuously evolved states (transitions) e.g. new process/process control, improved connectivity or design change. Because of the complexity of HVM systems, these states cannot be fully understood in advance and will be investigated and characterised using the Twin. For example, in the case of composites assembly, a poor performing transition, or emergent property thereof can compromise quality/rate, and the extreme prevent production. To overcome this, the Twin will evolve with the Facility and be extended and 'twinned' at each transition to provide the understanding and confidence to design, specify and implement the next transition. In this way, the holistic Digital Twin will enable an agile, fully informed and business resilient transitional pathway from legacy to industry 4.0 facility.

The technical pillars that constitute the Digital Manufacturer of Tomorrow are reaching a level of capability and financial viability that make them affordable and attractive. In accord, academic research into these technologies has matured to a level where we can begin to implement and integrate them into a set of complementary interventions across the breadth of the sociotechnical system (facility, supply chain, infrastructure and operators). These interventions encompass Digital Engineering tools; Manufacturing technologies; Digital Connectivity, Infrastructure and Services; Data Science; Supply Chain Models; Legal Systems and Security; as well as paradigms for Digital workers of the future. The concomitant maturation of these fields means that a whole-systems approach guided by an evolving Digital Twin is now possible.

The UoB is uniquely placed to convene a trans-disciplinary team of world leading researchers and industry partners – many of which are located within the region and who are respectively world leading in Digital Engineering, Digital Manufacturing and High Value Manufacturing. This Centre will leverage our portfolio of CDTs and the regional investments in Digital Futures (Temple Quarter Enterprise Campus), Digital Engineering (DETI funded by WECA) and HVM (NCC and GKN's GTC).

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Centre for Digital Manufacture of Customised Consumer Formulations

Formulated consumer products - which include cosmetics, creams, gels, emulsions, beverages, and many food products are ubiquitous in everyday life2. Consumers in the UK spend £154bn per year on these product categories alone1. The UK is a major exporter in a growing overseas market worth £1000bn annually. The UK supply chain comprises significant centres, including Unilever, Nestlé, Mondelez, Kellogg's, P&G and Premier Foods, a vast number of smaller manufactures and a diverse international supply base2. However, the first wave of the COVID19 pandemic unveiled the sensitivity of this supply chain to disruption with a classic example the hand gels which where impossible to purchase for several weeks. Furthermore, there is an increasing demand for customisation. Recent research by the applicants (EP/K001965/1) and some of these manufacturers revealed that customisation will drive future growth in this industry.

The customer-as-co-creator production will disrupt the traditional practice of mass-manufacturing for the idealised consumer, and poses fundamental questions on the manufacturing processes, business models and the role of the consumers in such products. Imagine a future where manufactures and consumers are so aligned they co-create products that are customised to a level where consumers regard them as an extension of their lifestyle, well-being and ultimately health.

The two manufacturing challenges to address are (i) the ability to identify market segments that have different needs, performance requirements and preferences, and (ii) the ability to respond quickly, accurately and flexibly to these segments. There is uncertainty and risk surrounding the level of success of new product development due to the limited access to consumers, current market research techniques afford. Meanwhile, the ability to re-configure manufacturing lines and supply chains to quickly respond to emerging market segments is largely dependent on how information is managed and the level of flexibility and adaptability of manufacturing processes to handle very small batch sizes economically.

The research thrust is in the ability to elucidate and translate the largely unstructured set of consumer preferences and needs and synthesise them into a set of product attributes to translate into specification and flexibly accommodate in production. This means integration of design with manufacturing and the alignment of systems and processes with people. The Centre will:

- Develop a digital twin of the manufacturing system that maps processes to product families and the formulation space translating consumer needs to manufacturing instructions.
- Research whole-systems models for the rapid reconfiguration and alignment of manufacturing lines and supply chains to consumer needs
- Introduce manufacturing automation and process intensification for modular and flexible digital manufacturing formulation systems
- Establish large-scale interaction models and privacy-compliant protocols between brands and consumers to elucidate needs. With a big-data approach consumer profiles and market segments will be built and define future products. Exploiting edge computing devices and consumer electronics (e.g. smart home appliances), uninterruptable data streams will support product design and supply chain alignment
- Understand the impact to skills, behaviours, regulatory compliance and product safety, in this disruptive manufacturing environment
- Network with other Centres with complementary objectives

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Design to centralise project complexity (design, frame manufacturing, tools/operations etc.) within a central virtual 'hub'; thereby supporting SME-operated 'spoke' factories near to the point of need/demand. The H&S approach would also leverage economies of scale (common components at the hub, and bespoke customisation at spokes) to deliver distributed solutions. This will be underpinned by Artificial Intelligence (AI), Industrial Internet of Things (IIoT), 4D BIM-integrated simulation modelling and Machine Learning. SWIFT will be the first centre of its kind aligned to support and accelerate Smart, Adaptable and Flexible manufacturing practices in the UK. The focus and objectives of SWIFT include:

- Mechanisms for addressing variances (site, end-user needs/demand, customisation etc.), including the concept of low latency and high device synchronicity to: optimise mass customisation/mass production in the housing construction lifecycle. This will embrace design through to site assembly, using AI capabilities, robotics, additive manufacturing and digital twins to optimise design-production-construction;
- A central smart hub to wrap ‘intelligence’ around data to turn it into actionable intelligence using IIoT to facilitate robotisation/automation with cloud computing, advanced analytics and people;
- Provision of new off-site manufacturing workflow processes to minimise inefficient procedures, capacity attrition, waste, volatility, disruption and performance bottlenecks. This will incorporate advanced simulation modelling and lean philosophies within the production process;
- Incorporation of new IIoT-based systems to improve visibility (design, production, logistics, assembly processes etc.), with advanced real-time monitoring capabilities (assets/inventories/performance);
- Provision of new skills and knowledge sharing to deliver conjoined specialist knowledge through organisational learning-driven value chains (engaging smart manufacturing, integrated partnerships, innovation hubs and business delivery platforms);
- Application of progressive Design for Manufacturing and Assembly (DFMA) protocols aligned to the H&S to deliver optimised housing solutions through advanced stage-gates methodologies. This will integrate data drop points with design, simulation, production and logistics (supported by cyber-security protocols, occupant criteria, AI, IIoT and Big data solutions);
- Detailed strategies for harnessing skills, knowledge and technical solutions (in line with organisational capacity/maturity). This will support the paradigm shift in thinking needed for working in smart manufacturing environments. SWIFT will be at the forefront of this by engaging a smart teaching factory and bespoke training simulator.

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Centre for Smart Manufacturing Systems

Focus and Innovation Themes
The Centre will deliver a programme of fundamental and transformative research to enable the next generation of high-performance factories based on a new class of smart manufacturing systems that can adapt their configuration and behaviour to maintain and continuously improve their performance in response to product, process and demand variations.

The Centre will address the following innovation themes:

- T1: Develop new factory solutions based on cyber-physical architectures and autonomous cognitive control; human-oriented digital systems; production-integrated 3D printing; sensing, IoT, in-process monitoring and certification; data analytics and AI.
- T3: Development and integration of smart adaptable processes and equipment including rapidly configurable machining processes; smart fixtures and digital technologies supporting one-way assembly; metrology driven smart assembly processes, systems, tooling and fixturing.
- T4: Rethinking the role of people in modern production via human-centred digital systems and human-digital interfaces; investigating the impact of digital technologies on human behaviour.

Context of the research
The research is defined by the future production needs for high-value, high-complexity low-volume products in terms of:

- Speed: Reducing overall production cycle and lead times;
- Flexibility: Ability to rapidly reconfigure, repurpose and adapt processes, equipment and systems for cost-effective high-value manufacturing;
- Quality: Digital technologies to eliminate rework and waste and improve product and process traceability.

Aim and objectives
We will develop and demonstrate the science and technologies required to equip the UK industry with a blueprint for future resilient smart manufacturing systems, that can be repurposed and redeployed to cost-effectively produce new complex products on demand. The aim will be supported by the following objectives:

- Deliver a step change in industrial practice by developing new lines of research in manufacturing systems science, industrial cybernetics, machine learning, manufacturing data analytics and human-in-the-loop technologies;
- Develop, validate, de-risk and demonstrate a suite of smart manufacturing solutions and technologies using experimental testbeds and industrial pilot cases;
- Work with key stakeholders to maintain national community of practice and international leadership in smart manufacturing systems and technologies;
- Train the next generation of digital manufacturing engineers and future leaders.

Potential applications and benefits
The research results will be demonstrated through industrial pilot projects addressing specific industry requirements, guided by use cases and validation scenarios developed with project partners and other stakeholders. The smart systems concept will be validated and demonstrated through several experimental testbeds including: ISCF FA3D2 national digital aerospace assembly demonstrator (Nott); a formulation and packaging smart cell (Nott); intelligent machining and RAEng-Airbus digitisation labs (Sheff); Distributed Information& Automation and Cyber-Human Labs (Camb); low-cost SME focused digital technology testbeds (Camb, Nott).

The Centre will underpin the growth potential of key UK industries by providing them with solutions to double productivity by reducing new product introduction and ramp-up times by 50%, production (door-to-door) times by 50% and manufacturing cost by 50%. It will support the growth of a UK-based smart manufacturing industry and supply chain.

Engagement
The centre will act as on open innovation ecosystem welcoming new industrial partners, addressing national and regional priorities and providing specific support to SMEs.

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The Made Smarter Review (2017) set out the predicted benefits of increased adoption of automation technologies across UK manufacturing, and highlighted the need to support greater uptake by SMEs. Adoption has accelerated amid the Covid-19 pandemic, as this major incident has acted as a key driver for companies to push towards greater responsiveness and resilience. With disruptions to supply chains and workforce availability, collaborative robot sales have more than doubled over the last 6 months. While there is clearly an appetite for the benefits of industrial automation, equally important is the ongoing need for research innovations to overcome fundamental barriers to wider adoption.

Smart collaborative industrial robots could transform traditional large manufacturing enterprises and enhance the competitiveness of small and medium sized innovative businesses. They will address many of the current barriers to adoption, including lack of specialist robotics skills, expectations of performance, need for effective transfer of human skills, flexibility required for bespoke products, challenges of gaining operator acceptance and trust and perceived speed of return on investment.

Aim:
This centre will advance smart manufacturing by eliminating barriers and accelerating widespread use of smart collaborative robotics technology for a significant improvement of productivity (40%), quality and agility.

Objectives:

- Increase adaptivity: Enable automation to adapt to expected and unexpected disturbances and variations with minimal effort.
- Enhance resilience: Minimise the impact and time to respond to sudden shocks and system failures.
- Simplify automation: Reduce the costs and expertise required to introduce, changeover and use a wide range of automation technologies.
- Improve collaboration: Eliminate the social and technical boundaries separating people and automation systems.
- Enable validation: Develop a methodology to verify and validate the emergent behaviour and safety of complex human-robot systems before deployment.

Innovation Themes:
Adaptable, flexible manufacturing operations and skills:

- Methods to reduce robot programming, integration, and changeover effort.
- Sensors and algorithms to flexibly respond to product and process variations.
- Less product specific workpiece interfaces.
- Natural human-robot collaboration approaches.
- Validation and safety methodologies for more human-machine systems.

Smart connected factory and versatile supply chains:

- Reference architecture for large human-machine systems.
- Visualisation and decision support methods.

Societal and cultural change:

- Skills for the future of manufacturing work.
- Sociotechnical impact of smart automation on workers (ethics, acceptance, trust, safety).
- Training for future jobs, roles, and organisational structures.
- Regulatory, standardisation and policy frameworks for smart automation.

Industry benefits and opportunities:
Smart collaborative industrial robots will enable manufacturers to quickly respond to disruptions and fast changing markets, to enhance productivity, to augment capabilities and improve wellbeing of their existing workforce, to reduce economic batch sizes and to significantly reduce investment risk. SMEs will especially benefit from automation that is easier to deploy and repurpose.

This Centre will work closely with a wide cross section of industry to understand underpinning business needs and formulate strategies and policies to facilitate the uptake of smart automation. We are looking for partners with disruptive new technologies to explore or adaptive/flexible manufacturing challenges.

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This Centre will be a smart robotic hub for the development of new molecules and drug formulations to accelerate speed-to-market for new drug and to onshore the UK pharmaceutical industry. Building on our recent work on intelligent mobile robotic chemists (Nature, 2020, 583, 237;), we will build a smart, connected factory for drug development. The overall aim will be to create a unique and flexible approach to accelerate new product development by leveraging the state-of-the-art in artificial intelligence, chemistry automation, and robotics. A related objective will be to create a new approach to this problem that uses low-cost and commoditised mobile robots to network existing facilities, rather than to design bespoke and highly expensive automation solutions, as has been done with some other 'factories of the future'. The Centre also addresses the challenges of operating research facilities under social distancing (see BBC News feature, https://www.youtube.com/watch?v=WBwZp5Bg2L8), and will create a transferable blueprint for activities that extend beyond pharmaceuticals; for example, we will tackle core questions relating to safety and logistics of autonomous operation that have relevance other areas of manufacturing, such as materials synthesis, home & personal care products, and a range of other chemical processes.

The long-term benefits will be to create a UK centre for drug development that is faster, more flexible, more modular / expandable and, ultimately, much more cost-effective than could be achieved using traditional technologies. This will only be possible through the fusion of a range of technologies that span the disciplines of chemistry, engineering, robotics, computer science, and artificial intelligence - as such, we will seek partners that extend well beyond the core partnership in chemistry and pharmaceuticals. As a reflection of this, the Centre will be staffed by a variety of roles in the following approximate proportions: chemists / chemical engineers (30%), roboticists & engineers (25%), software engineers (20%), computer scientists & AI experts (15%), safety / logistics specialists (10%). This will create a unique interdisciplinary hub that could not be assembled by any of the partners working alone.

Contact details not provided

Across manufacturing sectors as diverse as bulk chemicals, pharmaceutical, agrochemicals, oil and gas, personal care products, food and beverage, the factory and product life cycles are characterised by an evolution from data paucity in early design and innovation, to increasing data knowledge wealth through years of operation. Data paucity hinders innovation and productivity and favours conservative strategies. As more data become available, this is rarely turned into tools that support long-term decision-making; experience is instead relied upon to handle any unusual situation, resulting in inconsistent performance. Digitalisation offers an exciting opportunity to accelerate innovation by overcoming early data gaps, deploying data rapidly to improve operations and sustainability.

The Centre will focus on creating innovative digital tools and deploying these across process industries to enable decision-makers to derive maximum value from the combination of large datasets and mechanistic understanding and to identify what new data need to be acquired to complement limited data sources. It will address all four themes:

- how best to create digital twins to improve design and operations in smart connected factories;
- how to optimise manufacturing processes, enabling flexible and distributed manufacturing across whole supply chains;
- how to use data to support more robust and automated decision-making in safety-critical or infrequent situations;
- how to establish new innovation-and-training ecosystems and business models to enable the adoption of these digital tools.

The Centre's aims are (i) to develop new digital tools and workflows that accelerate innovation and enhance sustainability of factories and products across their life cycle and to identify strategies to overcome barriers to change (ii) to demonstrate applicability to use cases relevant to our multi-sectorial partners. To achieve this, we will develop:

i. new methods to build predictive capabilities from data quickly: extracting the most value from data, e.g., targeted experiments for hybrid modelling or new tools for analysing large datasets.
ii. systematic approaches to design and operate flexible processes, resilient across operating conditions, using operating envelopes and design spaces (not nominal operating points),
iii. automated, data-driven, approaches to critical activities such as HAZOP studies, optimised maintenance scheduling for plant turnaround or fault detection
iv. new insights into the barriers to the adoption of digital tools, leading to recommended business models and new innovation-training ecosystems.
v. set of use cases exemplifying these approaches, drawing on the evolving needs of industry partners and academic pilot facilities.

The new methodologies to improve design, risk assessment, operation, maintenance and supply chains will deliver significant benefits:

- Better processes faster - Speed to market is critical in extending production within patent life-time. This will increase yield, sustainability and reduce time for complicated multi-stage synthesis and waste.
- Improved design through risk assessment and optimisation- Critical with declining experience levels in industry.
- Optimised operation within process envelopes – Reduce variability, the main source of production loss, quality and process safety issues.
- Optimised maintenance turnarounds (costing typically $1M-20M) reducing cost, accidents and enabling social distancing.
- Improved supply chains leading to increased resilience and agility.
- Increased uptake of digital tools.

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Data+Design-Driven Smart Manufacture for AppaRel and Textiles (DDD-SMART)

The clothing, retail and the wider textile industry, currently contributes £32 billion to UK GDP. Meanwhile, recent world events are significantly disrupting UK Apparel and Textiles industries, affecting nearly every aspect of the global supply and manufacturing chain and calling for a “great reset”. Data-driven design connected to smart manufacturing methods is required to address the accelerating demand for cost-effective mass customisation, shorter lead times, transparent manufacturing supply chains, as well as improved environmental sustainability through reduced levels of waste. This is at a time when increasing numbers of SMEs and PLCs seek to improve their resiliency by reshoring and developing smart manufacturing capability in the UK.

Data is increasingly driving product design and manufacturing as well as expanding retail opportunities by providing better understanding of what consumers need/want. Data-driven insights include development of new forecasting systems based on deep learning and natural language processing techniques. These predictive techniques are needed to sit alongside smart factory developments as part of the Fourth Industrial Revolution (4IR), particularly large-scale machine-to-machine communication and the Internet of Things.

The DDD-SMART Centre will co-create projects with industry to address this challenge. It willintegrate technological and societal aspects of industrially defined problems and take a human-centred approach to minimise the risk of late-stage failure. The key objectives will be to:

- Enhance SME-led R&D across Data+Design-Driven Smart Manufacture
- Establish a SOA technology network to enable Onshoring/Reshoring
- Improve sustainability by optimising made-on-demand, local production, efficiencies of systems and scale, improved quality and value
- Embed agile, flexible, bespoke and lean production and remanufacturing capability that is accessible and distributed
- Advance greater international competitiveness of the UK apparel and textile industry

Informed by the network of UK companies (approx. 4-500) engaging with two Industry Strategy funded Creative Industry Cluster Programmes (Future Fashion Factory and Business of Fashion, Textiles and Technology) the Centre will convene academic expertise from the fields of Design, Manufacturing, Robotics, Materials Innovation, Business, and Anthropology.

The Centre will bring together expertise in AI/Machine Learning, Design, Manufacturing; Materials Innovation, Robotics, Business, and Anthropology, and will work with a multidisciplinary growing network of 400 UK companies - assisted by two AHRC Creative Industry Cluster Programmes (Future Fashion Factory and Business of Fashion, Textiles and Technology - to bridge the gap between basic research and its application in manufacturing. Projects will be co-created with industry to bring real change to the sector and to ensure real unmet needs are directly addressed. By focusing on the UKFT sector there is potential to test viability and embed skills across a complex infrastructure which could be transferred to other sectors – a testbed for others and a valuable blueprint for a smarter industrial paradigm.

Post Brexit / Covid19, the DDD-SMART Centre will provide a vehicle for UK SMEs to develop resilience in their operations at all levels based on advances at the core of the 4IR, enabling new agile and bespoke design and manufacturing systems to be developed, increasing competitiveness in international markets.

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Digital Urban Manufacturing Research Centre (DRAMAR-Centre)

Socially and environmentally responsible manufacturing in urban areas is very timely and will achieve a step change in inclusive economic development. This research centre will enable novel urban smart factories that utilise city resources and improve population health.

The research will design novel, net zero emission smart factories and autonomous manufacturing technologies suitable for cities, and develop digital twins capable of predicting the health of the factory, and that of its equipment. The factories will protect the identities of its users and system components and assure trust, privacy, and security.

A crucial component of the Centre is inclusivity. DRAMAR Centre will develop new assistive and immersive technologies to support employees with visual, communication or physical impairments. Given urban manufacturing challenges we will develop holistic, circular approaches to business modelling, cultural and community impact assessments and regulatory frameworks pertinent to emergent digital technologies.

Novel trusted supply chain models will be developed to support business models in an adaptive and efficient manner. Sustainability of digital supply chains will be enhanced through a collaborative model of engagement in a very dynamic environment.

The degree of urbanisation in the UK was 79% in 1950 and is expected to grow to 92.2% by 2030. Recent research reveals that the three cities with the highest percentage of employees concerned about job loss in 2020 are Cardiff (60%), Norwich (59%) and Sheffield (56%). In London, 45% of employees are concerned about the loss of their job. The distributed and city-based manufacturing model(s) will create new job opportunities in all cities, add revenue to local economies and provide significant social value. Urban manufacturing will develop a new sector in UK manufacturing that will help meet the social and economic challenges during and after COVID-19. The social and cultural impact of this new urban manufacturing will improve the wellbeing of city dwellers.

The aim of the Research Centre is to conduct world class cross-disciplinary research, enhancing industry practice to develop digital manufacturing (DM) technologies and systems for urban production. The key objectives of the DRAMAR Centre are:

- Lead transformative research in socially responsible DM technologies and models as a Centre of Excellence.
- Study social value creation by the technologies and its cultural impact.
- Redefine job roles and support models for an inclusive workforce in the cities.
- Develop DM supply chain models, collaborative platforms and circular business models to support the manufacturing.
- Develop demonstrator smart factories for urban areas.
- Develop digital intellectual properties for commercialisation.

The research will be validated through three application domains and demonstrators across London and at least five other UK cities:

1. Design and prototyping of customised wearables and AI for the assessment of mental health in cities,
2. Assistive technologies for the three types of disabilities,
3. A modular platform for gene therapy process intensification.

Along with the medical products, the urban smart factories will also benefit other sectors such as customised food, eyewear, furniture and smart garments.

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The Centre for Data-Driven Manufacturing will develop advanced digital twinning technologies to underpin engineering decisions-making tools, across the breadth of manufacturing and supply chain processes. Our research will develop novel human-centered research in digital twins, driven by our industrial partners' needs across the manufacturing sector. A digital twin is a complex simulation of an engineering system, product or user experience which through continuously evolving data, proactively learns to replicate and predict behavior to transform the future of engineering decision-making.

The development and adoption of advanced digital technologies will enable the UK to lead the way in industry 4.0 and ensure UK manufacturers, of various sizes, can thrive in the current uncertain economic climate, and longer term ensure the UK are international leaders in Digital Manufacturing Technologies, a market expected to grow to $30Bn by 2025.

The Centre will develop digital twin technologies across three research themes:

1. Rapid Prototyping of High Value Products – develop digital twins of complex manufacturing processes (e.g. high temperature forming, additive manufacturing and composite deposition) to enable intelligent integration of design software and historic data with simulations to generate virtual prototypes of complex products.
2. Smart Manufacturing Systems - develop and harness digital twins of manufacturing systems to optimise the design and execution of current and future products and manufacturing systems, to deliver agile manufacturing strategies, customised products and support business' sustainability agendas.
3. Resilient Supply Chains – develop new agent-based digital twins to configure and optimise robust global supply chain networks which are sustainable, resilient and responsive to challenges. The design of novel rapid decision tools for sourcing and inventory decisions will reduce cost, carbon emissions and delivery time.

Each theme includes cross-cutting integrated interdisciplinary research to critically explore and ensure technologies are human-centred; fully capture the impact on end-users and the organisation, including skills requirement and ethical and privacy considerations of data through a responsible innovation approach.

The Centre will assemble a diverse portfolio of researchers to meet the challenging needs of these research domains, including manufacturing simulation & data-centric engineering (Dodwell), smart manufacturing (Sucala), design engineering (Ahmed-Kristensen), machine learning (Everson) and responsible innovation (Hartley). Building on Exeter's considerable experience in innovative engineering education, the Centre will develop and deliver world-class training in new digital technologies.

Partnerships with internationally leading research centres: Turing Institute (AI and Data Science), Royce Institute (Materials), University of Heidelberg (Scientific Computing), Fraunhofer (Human-Technology Interaction) and the Oden Institute (Computational Engineering), and High Value Manufacturing Catapults. These connections will facilitate a bi-lateral exchange of research talent, provide access to large scale manufacturing, testing and computing facilities and expand industrial partners.

The Centre will be housed within the Institute of Data Science and AI, supported by capital investment in Project North Park, a £70M purpose-built facility, and the Exeter Digital Enterprise Systems lab, a new interactive human-cyber research capability.

After this EoI stage, a transdisciplinary workshop will further develop the set of partnerships, co-create research themes and engage early career researchers.

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Our DMI vision is to create a digital platform for the UK metals industry and enable agile, interconnected through process supply chains. The metals industry, from raw materials to final products, is a vital component of the UK's manufacturing economy. It comprises 11,100 companies, employs around 230,000 people, and directly contributes £10.7bn to UK GDP, and supports a diversity of companies across sectors including shipbuilding, automotive, aerospace, defence, infrastructure and construction. The industry is characterised as highly capital intensive with long investment cycles and consequential legacy equipment, and faces current and future challenges for UK plc. However, despite significant investment in process control, data capture and analysis, this industry continues to lag behind other sectors in engaging with Industry 4.0.

Digitalisation offers the ability to meet the Manufacturing Made Smarter Challenge Objectives, transforming productivity, increasing cross-sector collaboration between UK manufacturing sectors and driving the creation of common digital solutions, helping the industry to meet UK Industrial strategy Industry 4.0 aspirations and regain a world-leading position. The DMI Centre will:

1) Develop retrofit sensor and data-driven processing technologies, to augment legacy systems with modern digital technologies and in turn, transform the industry's productivity and global competitiveness;
2) Build an engineering competency-based digital tool to design and optimise connected metals supply chains (OEMs & SMEs), enabling smart interconnected factories and reshoring; DMI's digital supply chain platform will incorporate data-driven throughput-process simulations of primary processes, down-stream processes and the final product performance to achieve efficient transfer of trial results to upstream and downstream processing stages, enabling flexible manufacturing operations, planning and scheduling;
3) Create high-throughput process simulations with dynamic predictive capability to: enable rapid low-carbon manufacturing of metal processes and products using a data-driven holistic multi-level materials and energy evaluation framework; design and optimise new robotic additive and other manufacturing processes using data-driven high throughput process simulation to accelerate the R&D process;
4) Network with other ISCF Manufacturing Made Smarter Research Centres, investments and activities to transfer technologies and best practice and harness recent advances in data-driven tools;
5) Drive societal impact of digitisation and promote Responsible Research, ED&I balance, explore the impact of disruptive digital technologies (jobs, training, education & public perception), provide a platform to incorporate stakeholder voices facilitating societal engagement and opportunities for supply chain design.

DMI has already engaged with an impressive range of industry players, from primary manufacturers to end users. DMI will drive impact using an industry needs driven approach to:

i. Develop co-designed R&D feasibility studies with metals industry (flexible fund), to include a balance of 'quick wins' (to demonstrate value), fundamental studies, and interconnectivity projects to enable technology pull on supply chains;
ii. Industrial partner case studies to test and prove our digital supply chain platform in; New product development; Low-carbon manufacturing; Acceleration of R&D processes and operational manufacturing viability.

Digital/Industry 4.0 is recognised as potentially a relatively low-cost option for the UK Metals Industry, to meet many of the challenges of the industry and transform competitiveness, UK supply security, and sustainability of the industry.

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In a turbulent world what will manufacturing's role be? The challenges are clear: a lack of productivity born from endless uncertainty, the increasing threat of business closures, a serious shortage of skilled labour, a lack of investment in digital solutions and all set against the prospect of working with unfamiliar technologies.

The Centre for Smart Manufacturing, Automation and Robotics Technologies (SMART) will gather a unique coalition of research expertise to tackle these pressing challenges. Focused on increasing productivity - but also on addressing associated ethical and societal issues - it will undertake co-created, industry-led research to facilitate the deployment of automated, connected and responsible digital manufacturing solutions.

SMART will be led by an experienced team at the University of the West of England (UWE) and will include researchers in AI, VR, Big Data, Cybersecurity, Robotics and Digital Ethics from Cranfield University, University of Bristol, University College London and the Institute for Manufacturing, Cambridge.

The National Composites Centre and Toshiba's Bristol Research and Innovation Laboratory will support the research, while providing a 5G infrastructure. Additional referrals, support and networking opportunities will be offered by the Digital Engineering Technology & Innovation initiative and the National Nuclear User Facility.

Through a combination of collaborative research, co-created with large and multinational companies, and smaller-scale projects developed with a diverse cohort of SMEs, SMART will deliver 'real world' impact and help UK Plc to exploit new commercial avenues.

Our manufacturing partners have already highlighted areas they would like SMART to address, primarily aligned with three Innovation Themes:

- Smart connected factory
- Connected/versatile supply chain
- Societal and cultural change

The application of digital manufacturing technologies and processes will influence the future prosperity and well-being of UK citizens. Current levels of adoption, however, are poor – and the opportunity to adapt and super-charge UK productivity is clear.

Alongside obvious commercial and social benefits, however, this adoption presents potential ethical and societal challenges – from job losses resulting from the implementation of robotics and automation, and longer-term, structural and cultural ramifications for the people and communities affected, to issues around freedom, security and privacy emerging from the use of big data, AI, track-and-trace, etc.

The development and deployment of digital manufacturing solutions will be the driving aspiration for SMART, but researching the human impact of this activity will also be a cross-cutting theme, led by the UK's foremost academics in this field, from both UWE and UCL.

Smart will be led by UWE's Robotics Innovation Facility – a specialist arm of the Bristol Robotics Laboratory (the UK's most comprehensive centre for multi-disciplinary robotics research). Awarded Digital Innovation Hub status by the European Commission, its expertise spans robotics, automation, mechanical and electronic engineering, simulation and mechatronics. It also has a track record of collaborating with SMEs and large industrial partners (Rolls Royce, Numatic International, Jaguar Land Rover, etc.) through consultancy, CPD, KTPs and collaborative research.

Partner institutions will contribute similar levels of research expertise and industrial linkages (incorporating artificial intelligence, machine learning, augmented/virtual reality, big data, machine vision, leadership, strategy, ethics, sociology, etc.).

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Several high-level reports continue to highlight UK construction sector inefficiencies, including failure to meet its housing shortage. Where for example, an additional 3.1 million new social homes are needed in the next 20 years (Shelter, 2019). Challenges also include the need for greater productivity and efficiency. Given this, offsite manufacturing and modern methods of construction have been proffered as a tangible solution (HMSO-CCS0819942756, 2019). This proposal aims to address these challenges through the creation of a new research centre of excellence: Smart Wolverhampton Innovative Future Technology (SWIFT) Centre for Manufactured Construction. This will purposefully harness additive technologies and nuanced production methodologies to connect, integrate and enhance supply chain operations using a new distributed production model (Hub and Spoke) which seamlessly aligns house manufacturing companies' and supply chain partners' synergy and expertise to deliver optimised solutions.

The Hub and Spoke (H&S) model will enable bespoke customisation by applying the principles of Generative Design to design/frame manufacturing/tools/operations using a virtual 'hub'; thereby supporting SME-operated 'spoke' factories near to the point of need/demand. The H&S approach will leverage economies of scale (common components at hub, and bespoke customisation at spokes) to deliver distributed solutions. This will be underpinned by Artificial Intelligence (AI), Industrial Internet of Things (IIoT), 4D/5D BIM-integrated simulation modelling and Machine Learning. SWIFT will be the first centre of its kind aligned to support and accelerate Smart, Adaptable and Flexible manufacturing practices in the UK. The focus, aim and objectives of SWIFT include:

- Mechanisms for addressing variances (site conditions/constraints, end-user needs/demand, customisation etc.), including the concept of low latency and high device synchronicity to: optimise mass customisation/mass production in the housing construction lifecycle. This will embrace design through to site assembly, using Generative Design, AI capabilities integrated with digital twins, robotics and large scale additive manufacturing to optimise design-production-construction;
- A central smart H&S which 'wraps intelligence' around data to turn it into actionable intelligence using IIoT to facilitate robotisation/automation, underpinned by cloud computing, advanced analytics and people;
- Provision of new off-site manufacturing workflow processes to minimise inefficient procedures, capacity attrition, waste, volatility, disruption and performance bottlenecks. This will incorporate advanced simulation modelling to develop a cyber-physical factory with lean philosophies and production processes;
- Incorporation of new IIoT-based systems to improve visibility/analysis throughout the design, production, logistics and site assembly processes (using advanced real-time monitoring capabilities: assets-inventories-logistics);
- Provision of new skills and knowledge sharing to deliver conjoined specialist knowledge through organisational learning-driven value chains (engaging smart manufacturing, integrated partnerships, innovation hubs and business delivery platforms);
- Application of advanced Design for Manufacturing and Assembly protocols and advanced stage-gates methodologies to deliver H&S optimised solutions. This will integrate data drop points with: design, simulation, production and logistics, cyber-security protocols, occupant criteria, AI, IIoT and Big Data analytics);
- Creation of a smart teaching factory and bespoke training simulator to deliver operational and strategic skills - aligning knowledge and technical solutions with organisational capacity/maturity. This will support the paradigm shift in thinking needed for working in smart manufacturing environments.

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The focus of “the Smart Factory at Your Fingertips Centre” is to create and leverage cross-sector digital manufacturing solutions to UK industry to establish Social-Centred Smart Factories (SCSFs). Co-created with industry and covering three key Innovation Themes, the Centre’s research programmes are:

- Closed-loop digital twins (Industrial Internet of Things (IIOTs); smart sensors; data integrity; cyber-physical system integration; and intelligent control)
- Intelligent and adaptive automation and collaborative machine/robotics manufacturing systems (real-time production planning; autonomous quality control; flexible collaborative machine/robotics manufacturing systems and processes)
- Social-centred factory (Redesign of jobs; human factors; social security; and employability)

Context: The UK manufacturing industry stands on the threshold of a technological revolution and a digital transformation that is considered a key driver for the improved productivity which has long lagged behind that of its competitors. In recent years, the IIOTs, Big Data and Artificial Intelligence (AI) technologies have been applied in advanced manufacturing systems to gain a high-level of connectivity. However, there is a clear technology gap in bringing these separate aspects under one umbrella to address productivity challenges for the benefit of the UK manufacturing sector. In addition, research on societal and cultural changes, which is very important for managing disruptive impact of digital technologies is largely absent.

Aim and objectives: The project aims to develop cross-sector digital manufacturing solutions and a novel system engineering “fingertips” approach to bring together the proposed innovative solutions for the creation of SCSFs with significantly enhanced productivity to ensure UK’s global leadership in industrial digitalisation by 2030.

The project’s principal objectives are:

- To research and develop underlying technologies for the SCSFs, including closed-loop digital twins, intelligent machine/robotics manufacturing systems, social-centred factory (by addressing the societal and cultural change in the way humans work) and the “fingertips” approach;
- To assemble UK’s dispersed digital manufacturing, robotics, management science, economics and psychology leaders into a unified Research Centre to form an agile response to emerging industry needs through a number of co-founded mixed TRLs research projects;
- To establish a well-connected UK digital manufacturing network to accelerate the uptake of innovative digital technologies and to create a highly-skilled workforce.

Applications and benefits: The SCSFs will be affordable, reliable, resilient and scalable to various production scales, possessing a high level of social security and sustainability. Therefore, they will be widely accepted by the society, individuals, industry and easily-accessed by the whole value chain. The beneficiaries include aerospace and defence, advanced manufacturing, construction, medical devices and photonics sectors which are well represented by the consortium. It is envisaged that the SCSFs will create a step-change in the current manufacturing systems to achieve significant productivity gains of up to 30%.

Exploitation: Routes to impact will include the National Manufacturing Institute Scotland and Northern Ireland Technology Centre as flagship Factory-of-the-Future facilities and with open-access to industry for small-scale trial runs, through their well-connected catapults (AFRC, MTC and AMRC) and industrial networks. The Centre’s key advanced manufacturing industrial partners will be granted licenses to take the SCSFs to market within two years of the project’s completion.

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EPSRC MMS Research Centre for Advanced Manufacturing through Intelligent Process Analytical Technologies (iPAT)

The chemistry-using industries are fundamental to UK manufacturing supply chains from raw materials to end products. It is estimated that over 96% of all manufactured goods have chemical industry content and the sector generates £17.8Bn GVA, with a turnover of £48.7Bn. It provides direct and indirect employment for ~400,000 people throughout the UK, and the Data Economy is at the heart of the industry's strategy for Clean Growth (Chemistry Council, 2020).

The aim of iPAT is to provide a pipeline of advanced technologies for future chemical manufacturing through development of a new generation of integrated, digitized and versatile PAT platforms. These will pave the way for data-driven, efficient, sustainable and adaptive manufacturing across sectors that is intrinsically compliant with future data management standards (GoFAIR).

Currently, various PAT are used separately at different stages of process development and manufacturing, by different technology groups with different objectives. Managing and merging these disparate data streams is difficult as techniques have different file formats, information contents and temporal resolutions. This data fragmentation prevents knowledge transfer, resulting in rigid manufacturing processes confined to specific conditions that are difficult to automate and digitize. Achieving data integration will improve the efficiency of R&D and manufacturing processes, allow late-stage variation of scale and reactor types, and, crucially, pave the way for exploitation of data for advanced manufacturing (Industry 4.0) through connected supply chains, digital twins, machine learning and artificial intelligence. This step is vital for the international competitiveness of UK manufacturing and onshoring post-Brexit and post-Covid.

Centred around the University of Bath's Dynamic Reaction Monitoring Facility (https://www.bath.ac.uk/research-facilities/dynamic-reaction-monitoring-facility/) within the Centre for Sustainable & Circular Technologies (www.csct.ac.uk), iPAT will bridge the gap between fundamental research and applied manufacturing by combining a multidisciplinary academic team with key industries including pharma, fine chemicals, commodities, personal care and materials. New iPAT capabilities and projects will be co-created respondingto emerging manufacturing industry needs. Societal, cultural and regulatory considerations will be fully integrated to ensure digital technologies are deployed productively and holistically from the outset.

The iPAT RC will focus on Innovation Themes 1 (Smart Connected Factory, 60%) and 4 (Societal and Cultural Change, 20%) with contributions to Themes 2 and 3 (Supply Chains and Operations & Skills, 10% each). The core team comprises University of Bath academics with expertise in reaction monitoring & PAT (Hintermair), sustainable catalysis & materials (Davidson), synthesis of fine chemicals (Cresswell), reaction engineering & process modelling (Castro-Dominguez), mathematics, machine learning & AI (Kyprianou), biologics & therapeutics (Larijani), and transdisciplinary engineering (Newnes). We have identified strategic links to other manufacturing-focused centres, including the UK Catalysis Hub, CMAC, CPACT, SPECIFIC and the iPRD. Key industrial partners include analytical instrument manufacturers (Bruker UK), PAT software specialists (Optimal), PAT design consultants (MWC), reactor manufacturers (Syrris), process development specialists (CatSci), and pharma & fine chemical manufacturers (Almac). This consortium will grow and evolve in proposal development and over the lifetime of the Centre.

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Advances in 5G network technology, e.g. enhanced Mobile Broad Band (eMBB), Ultra Reliable Low Latency Communications (URLLC) and Massive Machine-Type Communications (MMTC), will transform smart connected factories. There is widespread acknowledgement that these important technologies must be implemented to meet future manufacturing data needs, however, there are significant knowledge barriers that must be overcome to enable large-scale adoption.

The Interoperability Smart Manufacturing (5G-ISM) Centre is focused on smart connectivity, and generating the knowledge required to harness frontier technology such as 5G connectivity in smart manufacturing. The centre will provide foundation support to the wider Made Smarter Community, addressing four fundamental system integration challenges:

- How do companies design and implement interoperable factory systems with 5G, integrate with legacy systems, embed 5G within processes and machines, monitor, understand and have confidence in their smart communications?
- How do companies manage the integration and interoperability of hardware, what balance of embedded/ edge/ cloud computing approaches are appropriate?
- How do companies manage cyber security and resilience, what is the cost of security and how can resilience and risk be quantified and modelled?
- What Societal, Legal, Ethical and Industrial policies and frameworks are needed to promote, optimise and govern the responsible deployment of highly connected smart manufacturing ecosystems?

To address these, a concerted focus on industrial communications infrastructure is urgently needed. The factory data network is a core factory service, such as water, air or power, that is necessary for efficient manufacturing operations. As factories strive to become, smarter and even more connected, factory networks and the tools to manage, optimise and secure the network, will be either a performance bottle neck or, if implemented correctly, an important enabling technology.

The aim of the 5G-ISM centre is to remove the barriers that prevent the uptake of advanced manufacturing communications technology and demonstrate the transformative potential of ‘tactile’ manufacturing networks, that combine ultra-low latency with extremely high availability, reliability and security; across enterprise scales, from the factory cell to the global supply chain.

Key objectives will be:

- Design: New quality of service metrics for connected manufacturing; new ontological structures and architectures for 5G-ISM systems; frameworks for human centred design, and standardisation activities.
- Security and resilience: Frameworks to define risk, model cost and quantify security; models to test scalability manufacturing environments; utilisation of emerging technologies including distributed ledgers and smart device service contracts for flexible, secure networks.
- Performance and management: real-time AI algorithms for network, service and resources management; tools for flexible and effective network function virtualisation and software defined orchestration.
- Enabling ecosystems: legal and ethical frameworks for data sharing, ownership, collection, storage and distribution; roadmaps for skills, societal impact and the future workforce; a framework for Industrial strategy in the context of 5G-ISM to drive manufacturing policy.

These objectives will be delivered by Loughborough University (intelligent manufacturing, and smart embedded devices), University of Surrey (smart communications, 5G), Birmingham (systems, cyber security); in collaboration with The Digital and High Value Manufacturing Catapult Centres, and a diverse set of industrial partners.

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The proposed Applied Digital Manufacturing and Engineering Research Centre (ADME) will focus on the following Themes:

1. Smart connected factory
- Manufacturing process and operations
- Robotics and autonomous systems in manufacturing operations to improve productivity
- Connected worker – X-Reality solutions for task assistance, training, safety

2. Connected, versatile supply chain
- Data interoperability across value chains
- Digital supply chain design
- Supply chain execution

3. Adaptable, flexible manufacturing operations and skills
- Enabling customisation: adapting processes to smaller batch size production, rapidly configurable processes.
- Safety and human-machine interactions - ergonomics, sensing, big data, and psychosocial effects.

4. Societal and cultural change
- Reconsidering the design of jobs, roles and organisations
- Developing people with broader skills for more diverse and flexible teams.
- Acceptability of working in a technology rich environment
- Ethical and privacy considerations of data ownership and use.

The manufacturing industry is continuously subject to market pressures and is now faced by threats related to Brexit, Covid 19 and the forthcoming net-zero regulations. Digital manufacturing technologies can improve resilience to external shocks and support skills development to achieve the UK's net-zero targets.

As manufacturing businesses digitalise and integrate their value chains, their business models are transformed giving rise to a new range of emanating challenges and opportunities related to technologies, services, processes, products, operations, people and management.

ADME will impact the three themes preventing the UK from achieving the digitalisation vision highlighted in the Made Smarter Report in 2017.

1. Lack of effective leadership of industrial digitalisation in the UK;
2. Poor levels of adoption, particularly among SMEs;
3. Under-leveraged innovation assets to support start-ups/scale-ups.

ADME will utilise a multi-disciplinary team of leading researchers and practitioners in high-value digital manufacturing, ICT, supply chain management, innovation, business management, technology transfer and socio-technical approaches.

The research centre will bring together businesses of all sizes from multiple manufacturing sectors (transport, energy, food, machinery, electronics...) across the value chain with academics to:
- co-identify common challenges;
- co-create research plans and the new digital solutions based upon them;
- create methodologies to assess the suitability of digital technologies;
- create new and expanded business networks, identify and transfer experience and best practice, recognise and adapt to emerging innovations and needs, and connect to the Made Smarter community;
- pilot, roll-out and evaluate the impact of digital solutions on businesses, people and society.

The ADME, modelled upon the Institute for Advanced Manufacturing and Engineering, will be a physical facility focused on industry led technology development, skills and business growth, to close the gap between technological and social capability to increase adoption of digital technology and ultimately productivity.

Key applications areas include:
- Integrate soft and hard systems to develop intelligent and [people-centred] digital solutions e.g. integrating human knowledge and data-driven AI models to improve productivity.
- Create smart and connected products, processes and value chains to provide real time data to inform and optimise the entire product lifecycle.
- Rethink behavioural traditions and rules to foster a culture of innovation and trust to enhance organisational capacity and people's resilience to cope with new challenges.

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The University of Manchester (UoM), Manchester Metropolitan University (Manchester Met) and Salford University (SU) are partnering in a bid that is being co-designed with a consortium of our industrial partners, as well as other key stakeholders such as the Made Smarter North-West Pilot, MIDAS, GMCA and the GM Chamber of Commerce to capitalise on the wide range of capabilities and opportunities in the region, in addition to other national or cross-sectorial bodies to maximise the relevance and impact of the Centre.

Our mission is to bring key stakeholders in UK manufacturing together in an innovative ecosystem that adds unique value to UK products, processes and services, and inspire the creation of globally competitive and sustainable manufacturing. Together with our partners, we have identified a number of imperative sustainability, growth and resilience challenges, and we will co-develop innovative solutions underpinned by our combined research strengths, knowledge transfer expertise, and educational prowess.

Our proposal will be propelled by the three universities' Industry 4.0 and digital capabilities including the societal and human-centric aspects, particularly:

- Advanced Materials and Additive Manufacturing
- Artificial Intelligence and Digital Twin
- Intelligent Automation and Robotics.

Our Centre will act as a focal point for industry to engage with expertise addressing their sustainability and productivity challenges through a holistic approach spanning: digitalisation, automation and optimisation of manufacturing processes; utilising revolutionary materials and digital technologies; instigating the required fundamental changes in business models; upskilling the workforce; and addressing the organisational and wider societal impact of Industry 4.0.

Our work packages are being designed to address research challenges in a way that is applicable to multiple manufacturing industries, across which we seek additional partners to inform and co-develop them. These sectors may include, but are not restricted to: Energy & Nuclear, Materials, Construction, Food & Drink, Coatings, Aerospace & Automotive, Stratified Healthcare, Chemicals and Process Industries, and Textiles.

We believe implementing sustainability through innovation in one sector or in one part of the supply chain should not shift unsustainable elements to another sector or a different part of the supply chain. Instead, we will champion a circular and holistic approach where sustainability and digitalisation underpin the entire manufacturing paradigm including its impact of society and workforce.

The combined ecosystem of our three universities offers access to a range of interdisciplinary institutes, centres and incubators that will allow us to leverage substantial and highly relevant and innovative R&D activities and industrial partnerships. Examples include:

- The Henry Royce Institute (hub in UoM)
- PrintCity (Manchester Met)
- Centre of Excellence in Intelligent Automation & Robotics in the United Kingdom (SU)
- The Productivity Institute (hub in UoM)
- Research Centre for Autonomous Systems and Advanced Robotics (SU)
- The AI Foundry and Cyber Foundry (led by Manchester Met)
- The Thomas Ashton Institute (UoM)
- Centre for Applied Pharmacokinetic Research (UoM)
- Manchester Fuel Cell Innovation Centre (Manchester Met)
- Tyndall Centre for Climate Change Research (UoM among partners)
- The Alan Turing Institute (UoM among partners)
- The Dalton Nuclear Institute (UoM)

We invite organisations interested in our bid to contact us and explore possible opportunities for collaboration.

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Data+Design-Driven Smart Manufacture for AppaRel and Textiles (DDD-SMART)

The clothing, retail and wider textile industry currently contributes £32 billion to UK GDP. Meanwhile, recent world events are significantly disrupting UK Apparel and Textiles industries, affecting nearly every aspect of the global supply and manufacturing chain and calling for a “great reset”. Adoption of data-driven design connected to smart manufacturing methods is essential to address the accelerating demand for cost-effective mass customisation, shorter lead times, transparent manufacturing supply chains, and improved environmental sustainability through reduced levels of waste. This is at a time when increasing numbers of UK SMEs and PLCs seek to improve their resiliency by reshoring and developing smart manufacturing capability.

Data is increasingly driving product design and manufacturing as well as expanding retail opportunities by providing better understanding of what consumers need and want. Data-driven insights include, for example, development of new forecasting systems based on deep learning and natural language processing techniques. Such predictive techniques are needed to sit alongside smart factory developments as part of the Fourth Industrial Revolution (4IR), particularly large-scale machine-to-machine communication and the Internet of Things.

The DDD-SMART Centre will co-create projects with industry to address this challenge. It will integrate technological and societal aspects of industrially defined problems and take a human-centred approach to minimise the risk of late-stage failure and resistance to technological innovation. The key objectives will be to:

- Enhance SME-led R&D across Data+Design-Driven Smart Manufacture
- Establish a SOA technology network to enable Onshoring/Reshoring
- Improve sustainability by optimising made-on-demand, local production, efficiencies of systems and scale, improved quality and value
- Embed agile, flexible, bespoke and lean production and remanufacturing capability that is accessible and distributed
- Advance greater international competitiveness of the UK apparel and textile industry

Informed by an existing network of UK companies (approx. 400-500) through two Industry Strategy funded Creative Industry Cluster Programmes (Future Fashion Factory and Business of Fashion, Textiles and Technology) the Centre will bring together expertise in AI/Machine Learning, Design, Manufacturing; Materials Innovation, Robotics, Business, and Anthropology, to bridge the gap between basic research and its application in manufacturing. Projects will be co-created with industry to bring real change to the sector and to ensure real unmet needs are directly addressed. The UKFT industry spans an extremely broad range of manufacturing sectors from material developers and suppliers, to the design and production of apparel, furnishings, healthcare and automotive components (and other adjacent sectors). Focussing on this industry will provide the potential to test viability and embed skills across a complex infrastructure and to create a valuable blueprint for a smarter industrial paradigm across other sectors.

Post Brexit / Covid19, the DDD-SMART Centre will provide a vehicle for UK SMEs to develop resilience in their operations at all levels based on advances at the core of the 4IR, enabling new agile and bespoke design and manufacturing systems to be developed, increasing competitiveness in both UK and international markets.

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UK remains one of the most under-roboticized industrial nations, with only 70 robots per 10,000 employees (300 in Germany, 700 in Korea). UK's factories remain heavily reliant on low-wage manual labour for numerous handling tasks, especially SMEs manufacturing small batches with frequent product changeovers. Ordinary human tasks can be extremely complex, far exceeding the capabilities of conventional automation. However, there is now a rapidly escalating labour shortage in the UK, accelerated by Brexit and Covid19.

To deliver a Smart Manufacturing revolution, we must increase the use of robots in UK's factories. This necessitates a dedicated robotics-focused centre – the Smart Robotics for Manufacturing Centre (SRMC) – led by specialist robotics experts: providing advanced robotics technologies to support the other Smart Manufacturing Centres; developing critical robotics advances needed to efficiently automate UK businesses for economic growth.

Smart Robotics provides the essential physical link, between the software of digital manufacturing design, scheduling and logistics, and the real materials and components on production lines.

SRMC leverages world-leading robotics infrastructures of: National Centre for Nuclear Robotics, Faraday Institute, EPSRC wire-arc Additive Manufacture Programme and the Catapults, and synergistic links to National Quantum Technology Hub, Birmingham Energy Institute, HTRC.

We initially focus on:

1) Advanced robotic manipulation, driven by computer vision, multi-sensor fusion and AI, enabling: i) smart handling of small batch sizes, with uncertainty in product geometry and positioning, and frequent product changeovers, e.g. ceramics industry; ii) handling odd-shaped and deformable components, e.g. food manufacturing; iii) robot-deployed tooling with complex trajectories e.g. cutting, welding, and robotic wire arc Additive Manufacturing (Co-I Pierce is NDT leader in EPSRC wire-arc AM programme, and Co-I on KUKA-led RobbWAAM).
2) Human-robot co-working on production lines – introducing intelligent, human-safe ""cobots"" as a means to: i) incrementally insert automated tasks into previously/mostly manual lines; ii) provide assistance to human experts assembling high-value bespoke products or prototypes (e.g. remote handling for clean-room assembly of prototype Quantum Technology sensors).
3) Robotically deployed, in-process NDT inspection for quality assurance of components during each stage of manufacture including: physical sensing (e.g. high temperature ultrasonic wheel probes for metal AM); real-time robotic sensor deployment; automated data interpretation, exploiting computer vision, multi-sensor data fusion and AI.
4) Autonomous warehouse and logistics robots, increasing efficiency in supply chains. These robots provide physical links between digital scheduling software and physical warehoused components, while removing humans from hazardous environments.
5) Adaptive Digital Twins – virtual robots interacting with virtual objects, with models updated in real-time as real robots and sensors interact with objects exploratively.
6) Wider issues of societal and cultural change, socio-technic analysis, ethical, safety and regulatory issues.

The above forms underpinning research (50%), co-created with national manufacturing catapults, and both large and SME end-user manufacturing companies, spanning diverse industries. We reserve funds (45%) for agile allocation, meeting evolving industry needs. SRMC will also provide specialist assistance in advanced robotics to the other Smart Manufacturing Centres (5%).

We primarily address Theme 1 (Smart factory) and Theme 3 (Adaptable, flexible manufacturing) with substantial contributions to wider societal issues of Theme 4.

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Centre for Smart Manufacturing Ecosystems

Whilst spanning the relevant aspects of all the innovation themes, the focus of the centre will relate to digital systems optimisation both within individual Smart Factories and across wider Connected Supply Chains.

Currently, digital manufacturing systems are siloed and this lack of effective integration solutions inhibits the potential of Industry 4.0. Enabling this connectivity and integration will unlock the potential of smart digital systems within and between supply chain organisations and enable inherent resilience, sustainability, agility, and energy efficiency towards net-zero.

The centre will focus on visionary research to create safe, secure, optimised, yet unconstrained environments, deployable from the shop floor through to inter-connected Smart-Factory ecosystems. Our novel approach will aim to realise an integrative platform that can be utilised by both academia and industry across multiple sectors (food and drink, automotive, electrification, aerospace, foundational industries) and at various operational levels (production, internal logistics, supply chain operations).

We aim to co-create with industry such an ecosystem of autonomous connected components through:

1. An ambitious transformative research programme addressing trust, secure information sharing, coherent communication frameworks, and the utilisation of open standards.
2. Foundational capabilities in manufacturing processes and technologies to enable relevant business-driven, problem-oriented functionality.

The academic partners from Warwick, Sheffield, Swansea, and Strathclyde have an excellent track record of innovative research with industrial impact.

WMG will lead the research centre, using its embedded cross-sector manufacturing research expertise and industrial network. WMG brings broad capabilities spanning all aspects of automation, digitalisation, and supply chains. The thrust of WMG's role is related to systems integration, supported by WBS and Computer Science.

Sheffield will focus on the areas of data science, autonomous systems, control and digitalisation for resilient, sustainable, and pervasive manufacturing supply chain and innovative business models.

Swansea's inter and multi-disciplinary research in engineering and computer science will focus on improving understanding of complex production processes, and on increasing operational efficiencies of manufacturing processes and connectivity, human-machine interaction, model-driven software development and data science.

Strathclyde will focus on adaptation to new technology and new market conditions to address the societal and cultural issues around awareness, investment, risk, skills, employment, and new business models for manufacturing productivity.

The research will be oriented around sector-specific scenarios within the supply chains of the industry partners, cross-linked to projects such as ASTUTE, IMPACT, and SUSTAIN, and to the HVMC, NMIS, and DMIW organisations. Outcomes will be incorporated into a generic integrative platform, working with leading vendors and driving implementation with major OEMs in addition to providing low-cost solutions to SMEs throughout England, Scotland and Wales,

The philosophy of this centre is to:

- Encourage co-investment
- Accelerate adoption by industry of research outputs
- Create cross-sector applications through open connectivity
- Increase digital skills uptake and capabilities

In the context of an open research platform, which is integrative and widely applicable, we would welcome new partners. We intend to make available a proportion of funding available to enable additional partners to engage throughout the life of the centre.

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Centre for Data-driven Innovation in Manufacturing (CDiM)

Vision

Exploitation of data has potential to catalyse transformative changes in manufacturing, increasing efficiency, productivity, resilience and future-readiness to promote economic growth and global competitiveness. However, existing cultural and technical approaches to data have meant few companies have fully exploited this opportunity.

Data platforms in investment banking have successfully enabled a culture where quants (quantitative analysts) and developers can explore large amounts of data for insights, then rapidly develop and deploy algorithms to solve business problems. Our central research question is: can this successful approach to data, skills and culture be adapted to transform manufacturing?

Challenge

The 2020 Annual Manufacturing Report highlights over 90% of consumer goods manufacturers see digital transformation as a top three priority, however, 43% of UK manufacturers report digital transformation fatigue due to the many roadblocks encountered. Our research challenge is to address these roadblocks, and determine how a culture of data-driven innovation can underpin agile, effective deployment of digital technologies in manufacturing. PwC state that manufacturers need to go beyond the promotion of new technology and embracing the whole journey of business transformation: learning new habits, acquiring the right talent and implementing organisational changes.

Aims and Objectives

The Centre aims to show that a data-enabled culture yields significant business benefits across whole value-chains and significantly increases the exploitation of digital technologies. The objectives are: (a) to develop an easy-to-adopt data ecosystem: platform, best practices, new behaviours, investment in digital skills and workplace/job design; (b) demonstrate using prototypes developed with industrial partners.

Sectors

Current partners include: manufacturers operating in aerospace, marine and defence sectors (others being sought in pharma, automotive, industrial equipment, food and drink); IDT vendors.

Research programme

WP1 Underpinning: provide an easy-to-adopt data platform and best practices

A. Socio-technological systems approach to work organisation/design, semi-autonomous work groups, versatile teams, career systems, problem solving methodologies to provide the cultural innovations needed to data-enable manufacturers (Theme 4), will be exemplified with case-studies from (WP2).
B. Develop a specialised manufacturing data platform, drawing on best practice from other sectors, addressing relevant data-structures, machine learning, AI, cyber-security and data governance. Industry support from investment banking technical advisor and IDT partner expert in data platforms.

WP2 Responsive: prototypes developed, tested and deployed with manufacturing partners on common and emerging manufacturing challenges to enable future-readiness and resilience.

A. Common challenges: discussions with industrial partners have identified common challenges across Innovation Themes 1-3. (Theme 1) Predictive analytics for asset management; dynamic, real-time production planning & scheduling; digital twin of facilities; (Theme 2) improved decision making in supply-chain through analytics & AI; (Theme 3) modelling of network of supply and skills to manage volatility/disruption post-Covid.
B. Emerging challenges: engage with existing and new partners and their supply-chains to identify and solve emerging challenges through application of our toolset. Identify opportunities to apply solutions from WP2A to other manufacturers.

WP3 Networking. We will collaborate with the Research Centres, other Challenge investments and exploit industry networks to expedite cross-sector adoption, and disseminate best practice and thought-leadership.

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Improving Productivity in SME High Mix Precision Manufacturing

The UK holds a leading position in high technology products for niche and emerging markets, a sector dominated by SMEs who face many similar challenges. These SMEs use sophisticated equipment to manufacture high value, low volume components and sub systems, but have limited data-based decision-making infrastructure or capability and often rely on individual operator and engineering input to maximise manufacturing performance. They do not have the budget, expertise, or risk appetite to transition their range of legacy and new manufacturing tools to interface to data systems they do not understand and are largely unproven in similar high mix SME environments. As a result they cannot benefit from the huge productivity opportunities offered by current data analysis and AI technology.

The University of Glasgow's James Watt Nanofabrication Centre and Kelvin Nanotechnology Ltd manufacture low-volume, high-mix, photonics, power electronics and quantum products for a global customer base while supporting diverse R&D programmes. They are an exemplar of this issue.

This proposal creates a Centre using JWNC/KNT as a demonstrator that will

- Apply the principles of Industry 4.0 to high-value, high precision, high mix manufacturing, demystifying these technologies and evaluating their ability to remove individual operator and engineer dependencies
- Demonstrate data based real time process control and feedback to achieve a step change in manufacturing performance
- Quantify the effort and return on investment of deploying industry 4.0 approaches in a typical SME environment
- Provide evidence-based investment case studies and learning for industry deployment by a company's existing production engineers.

The Centre will also evaluate the social and cultural issues arising from transition to a Digital Manufacturing environment. It will assess barriers faced by SMEs in making this transition including culture, upskilling, data ownership and privacy, and attitudes to cyber security. It will demonstrate solutions that overcome these hurdles and address political, societal, economic and ethical concerns (data regulation, low-carbon processes, privacy and cyber security policy). It will enable SMEs to develop evidence-based business cases for investment.

The Centre comprises academics from the Universities of Glasgow and Strathclyde (Engineering, Communications, Computing Science, Business and Management), SMEs, large established companies, Centres of Excellence (NMIS and CENSIS), and enablers of economic development.

This will be achieved through the development of a continuously evolving and updating digital twin model of the key manufacturing processes in the Centre. The activity will bring together the research themes below:

1. Models of manufacturing system that are smart, reconfigurable, resilient, sustainable and transferrable.
2. Digital twinning techniques giving real-time control in data-sparse environments and using stochastic modelling for tasks such as prioritisation, conditioning and scheduling of production and maintenance. This will include AI-driven, physics-based modelling of task-, productivity- and efficiency-oriented human-machine H2M and human-human H2H interactions tailored to technology-intensive environments.
3. Robust communications and remote sensing infrastructure with appropriate EMC for specialised environments.
4. Data regulations, privacy and security policy.
5. Assessment of barriers to digital adoption that consider political, management, business model, environmental, societal, economic and ethical aspects.

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High Value Manufacturing is a key economic activity in Wales and the UK, complemented by recognised world-class manufacturing expertise in Welsh universities, and skills provision from apprenticeships to doctoral training.

The proposed Centre will build on a strong, recently established, partnership of industry working with an academic and RTO network to deliver the Made Smarter Test Bed for a digital supply chain project (DAUPHIN). It will cross-link into successful support mechanisms, such as:

- the well-established, Swansea led ASTUTE project with four other Welsh universities, an extensive industrial network and a strong track record of successful collaboration with a diverse range of Welsh manufacturing companies,
- co-location opportunities provided through the state of the art Institute for Materials, Processing and Numerical Technologies (IMPACT),
- the Computational Foundry as a platform for industry partners to collaborate and test new ideas in ICT working with digital innovators of the future.

The Centre proposal is for an operation mainly under Innovation Themes 3 and 4; with around 50% match funding from participating industrial and academic partners. The aim is the transformation of the regional manufacturing industry, driving a culture change for new production paradigms, where new machines (co-bots, VR/AR, automation) converge with digital transparent supply chains and digital marketplaces, underpinned by machine learning and AI, working with existing and newly emerging UK networks to apply best practice across the UK. This will be achieved by means of responsive support in the form of industry demand-led collaborative RD&I. The Centre's objectives are:

Objective 1. Develop and deploy state of the art and newly emerging Technical Tools to adopt more innovative manufacturing techniques:

- Data Centric Process Systems Engineering to exploit digital processes, data analytics, connectivity and integrated physical processes with information,
- Computational Modeling for understanding, visualising and improving complex manufacturing processes and systems, and for customised manufactured products.

Objective 2. Develop Non-Technical Tools and drive the creation of a resilient, sustainable, digitally informed and driven manufacturing ecosystem in Wales and wider:

- Skills development from early learners to leadership: up-skilling and re-skilling current workforce through degree apprenticeships with FE partners; linking to Doctorate/Masters (M2A, SU UKRI CDTs), graduate (METaL 2) and leadership (ION) programmes
- Business model re-/design support with techno economic modelling tools; socioeconomic modelling tools for policy
- Ethical and fair B2B collaboration framework through servitisation, working closely with Legal Innovation Lab Wales.

At the heart of the Centre will be co-creation of strategy and projects with regional partners, building on the success of extensive EU, Welsh and UK government investments in infrastructure and operations. The Centre will connect with other Made Smarter Centers, and will be crosslinking with other strategic initiatives in the region, for instance AMRC Cymru, and wider in the UK.

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The formulated products sector is worth over £180 bn to the UK economy including home and personal care, paints and coatings, fuels and lubricants, pharma and agrochemicals. There is a continuing drive to reducing the lead time of new products and with reduced costs. However, the sustainability challenge is central to this, requiring sustainable processes, products and packaging in order to reduce water and energy use, reduce the carbon footprint and to use more recycled materials to drive the circular economy. This sustainability challenge requires the tools of digital manufacturing to achieve these aims in a rapid and economical manner enabling flexibility, agility and adaptability in operations and skills.

The overall aim of the centre is to develop experimental and modelling tools to enable managers and engineers to use digital manufacturing tools and information to make better and quicker decisions to transform manufacturing sites into smart factories. How can we incorporate sustainably produced and recycled materials into new manufacturing processes and products?

For the smart connected factory innovation theme, the underpinning scientific challenge is to produce mechanistic or first principles models for the new sustainably sourced materials in parallel to validating these models with measurement data. Currently, any change to manufacturing is extremely slow due to the amount of physical testing that is required before processes and products can be scaled with confidence. The solution is modelling from first principles combined with data driven models to enable the exploration of new space such as the impact of scale up and processing options, to model ‘what if’ scenarios and to have an informed and genuine risk analysis that directs where more data is required. The mechanistic models are multiscale in nature from molecular to microstructural to computational fluid dynamics (CFD) which adds to the challenge. In the smart factory soft sensor data from the ‘digital twin’ will be combined with real sensor and analyse data in a data-driven model for real-time optimisation and control to realise the product critical quality attributes.

The development of mechanistic and data driven models will enable increased flexibility and adaptation to variability in the supply chain. Variations in the feedstocks can create significant changes to functionality, aesthetics and stability that would otherwise require extensive manufacturing trials. This is also important to increase the use of recycled materials in products and packaging such as the use of post-consumer resin (PCR) where characterisation in the supply chain is key to develop accurate processing models leading to greater confidence in final product specifications.

For the societal and cultural change innovation theme we aim to promote behavioural change within the new digital environment so identify how leaders can use digital information to make better, quicker decisions and how team members can use data visualisation techniques and data analytics/mining to enhance knowledge sharing within teams and manage knowledge transfer between large distributed teams within companies. This will provide a holistic framework across the whole centre.

We welcome partners involved in the manufacture of formulated products.

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Value Added Additive

Establishing the rules that drive cost. Enabling the design of valuable AM parts to feed the top of the digital manufacturing supply chain.

Research Vision

The current adoption of Additive Manufacturing (AM) for production, across all manufacturing sectors and scales, is hampered by a lack of understanding as to how to design objects valuable enough to justify the application of it. The vision for this proposed AM focussed centre is to develop and then disseminate the understanding of designing for value with AM. This will accelerate adoption across all sectors of UK manufacturing of all scales.

Call Alignment

AM technology has tantalised manufacturers with the promise of "design freedom." To some extent this is true but to exploit this in terms of new commercial applications, designers must understand the rules that drive the production cost and the entire supply chain. These rules provide the commercial framework within which designers can profitably deploy this freedom.

Without valuable products, the complimentary potential of smart connected factories, robotics, versatile supply chains, adaptable manufacturing and societal change, remain hypothetical. Understanding how to purposefully and valuably make things at the outset is the key objective of this project.

Research Challenge

Manufacturers are encouraged to adopt AM for production with all its compelling advantages including; customisation, low volume production, agile methodologies, and previously unattainable geometries. This all requires a firm commercial starting point.

Additional emphasis is placed on the technology being for "high value" applications, which many interpret as it being for "tier one" manufacturers exclusively. Manufacturers below this level often believe that AM has nothing to do with their scale of endeavour and dismiss AM as prohibitively expensive.

Proposed Programme

AM encompasses a broad range of technologies. Initially, this application proposes focussing on powder bed fusion technologies which are the most versatile, mature and readily available, with applications across all sectors of manufacturing. This provides manufacturers with a gateway to the principles of all AM technologies and the ability to start their adoption journey with some relatively "easy wins." These will foster confidence in the technology and stimulate progressively more ambitious applications.

This understanding will be augmented by an appreciation of the complexity of supply chains, which are constantly adapting as new technologies and materials are developed and tracing technologies become increasingly sophisticated. Additionally, the dynamic material properties of powder bed fusion materials can be applied to further maximise value.

AM research projects tend to be sector specific and confront roadblocks which others have already resolved. The centre will bring cross-sector manufacturers together with the genuine interdisciplinarity reflected in the consortium. This will provide a centralised base, where lessons and solutions can be identified, consolidated and shared.

Transformative Potential

The provision of valuable product designs is the vital success criterion for any Smart Factory as these form the very start of the digital, connected supply chain. This centre will drive valuable AM into the top of digital supply chains and establish complimentarity with all other digital systems within the Smart Factory.

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Medicines Manufacturing Data Centre (MMDC): levelling up the UK's digital medicine manufacturing capabilities.

To exploit the potential of industrial digital technologies (IDTs) to transform medicines manufacturing productivity and drive patient-centric supply, we must first deliver access to data and information for analysis, interpretation and decision making. Data must be consistent, standardised and validated to enable AI, big data, advanced analytics, prediction and automation to be deployed between and across organisations, sites, departments, supply chains and different users, from regulators to operators.

Clinical trials are a growing element of UK medicines innovation and present major opportunities to manufacture-to-demand at speed direct to patient/clinic whilst delivering major cost, timeline and waste reductions. Current approaches are outdated leading to huge write-offs (up to £100m per provider) and long lead times (6months from order) resulting from complex production processes, demanding timelines and uncertain supply requirements whilst assuring regulatory compliance and patient safety.

MMDC will deliver multidisciplinary foundational and demand-led research programmes to realise widespread benefits of IDTs across organisations, sites, processes, products and people. The Centre will tackle issues head on to assure the right data, right format, right time to deliver value to patients' health and UK plc from smarter, digitally enabled UK adaptive clinical trial manufacturing, regulation and supply.

Together with industry, the core MMDC team will work with expert partners to deliver a cross cutting, data-centred research ecosystem to strengthen UK manufacturing via:

I. Foundational Data Platform (Themes 1,2,3&4): Establish a world first centre for data enabling digital medicines manufacturing and supply; develop standards and interfaces across materials, production, testing and supply. Deliverables = Modular, plug and play, FAIR data; new science and AI; industry wide database of information and tools underpinning new skills, multi-scale digital twins, automated future product manufacture and supply.

II. Digital Medicine Supply Chain Platform (Themes 1&2): Agile, flexible, demand driven supply of digitally networked operations connecting product, process and supply data. Deliverables = New JIT adaptive supply business model; reconfigurable operations for multi-dose time-critical clinical trials, based on demand sensing and clinical trial flexibility needs, driving faster customised production for patients and reduced inventory and waste.

III. Digital Manufacturing & Release Platform (Themes 1&3): Demand, material, process and performance data to drive real-time control, scheduling and operation; adapt product performance and predict QC. Deliverables = Autonomous, microfactory platform operations; digital twin enabling scalable or distributed multi-dose oral solid-dosage form production; methods for AI-enabled smart experimentation and self-optimising manufacture-to-demand and release.

IV. Digital Regulation and Skills Toolbox (Themes 3&4): Integrated data, digital twins and immersive tools to support regulation, process verification and predictive release of product. Deliverables = Connect users with data and models across the value system to inform decisions; faster regulation; improved skills, adoption and acceptance of IDTs.

V. MMDC Network: Connect academic centres, organisations and businesses to collaborate, share data, training, best practices and learning across sectors. Deliverables = integrated digitalisation activities, translated via a UK Digital Medicines Manufacturing community accelerating impact of IDT research across pharma and process industry value chains.

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Enabling domain specific intelligence for economic and social purpose.

How is manufacturing best purposed in the face of global change? A novel distributed information infrastructure will overcome current barriers to collaboration, innovation and creativity. This will support regional economic renewal based on specialisation in supply chain clusters. Economic networks, information infrastructure and local geography and history will complement each other to renew the skills base, delivering a step change in meaningful employment, productivity and innovation. Quality, creativity, sustainability and resilience will be the watchwords of a new production economy.

The nature of this infrastructure offers up an alternative to a short term, market driven reactive mode of manufacturing where market share is achieved at any cost and by any means. An opportunity that is collaborative by nature and innovative by design. The design of jobs, firms, industries and business models that will thrive in this new ecosystem, will require a greater intelligence of that which they are designing for. Sight of this future potential may help inform its current acceptability.

The capability of UK manufacturing is distributed at the nodes of a mature ecosystem that gave birth to the industrial revolution, much of which is bound up in the knowledge, skills and systems that have resisted automation. To fully exploit this, and to avoid becoming customers to our own capabilities, we aim to quantify the unquantifiable. The proposed centre will develop two connected lines of research:

1) The distributed synthetic twin: AI and data collection technologies will process data and inform domain specific models at individual nodes in the manufacturing ecosystem. We recognise the demands on robotics, monitoring, analytics and human interaction differ at every node. As an alternative to a standardised, centralised information model, this will enable each stakeholder more appropriately and fully to represent their own domain, with greater agility and resilience to unforeseen change.
2) The adaptable communication framework: enabling effective data transfer between nodes, and systems ensuring traceability and trust, allow the nodes of the distributed twin to function together. The ethics and privacy of data, human-machine interaction, and the optimal employment of skills will depend on this infrastructure.

We commonly identify “known challenges in unknown systems”. In supporting a strategy of not addressing these challenges individually, but holistically we mitigate destabilising significant dependencies and opportunities. Connected technologies offer significant solution spaces that markets are calling into use with little attention to broader impact beyond their immediate environments. Opportunities presented by these technologies require context.

The research will explore and inform the information systems efficacy through:

1. Intelligent and Connected Manufacturing societal ecosystems
2. Computation as enabler of resilience
3. The role of Corporate Governance and “The culture of the firm.”

Incorporating exemplar use cases around construction and fashion/textiles as they offer scale diversity and are heavily skill dependent and employ a high number of people relative to GVA. Working towards enabling distributed accumulative value and embedded intergenerational assets, will need a shared risk and reward system for innovation through access to domain specific intelligence.

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REMATCH – Centre for Responsive Manufacture of Target Chemicals

Key global shifts, including carbon net zero ambitions, reshoring policies, e-commerce, and new generation digital tools, are driving the smart manufacture of high value chemicals. To maintain and increase competitiveness in this dynamic context, the UK high value chemicals industry needs to increase its agility and responsiveness. As SMEs and micro businesses make up 97% of this industry, they will play a pivotal role in providing the innovative solutions needed to respond.

The goal of the Centre for Responsive Manufacturing of Target Chemicals (REMATCH) is to catalyse and facilitate a paradigm shift in the UK high value chemicals manufacturing space. REMATCH will act as an honest broker between core stakeholders: UK technology SMEs, the national Flow Chemistry R&D community, UK-based process design/development expertise, UK-based CROs and CMOs, multinational corporations, and global supply chain actors. This will enable SMEs to engage directly with Flow Chemistry and process design academics to digitise novel reactor and separator concepts. Novel process ideas utilizing these can then be evaluated efficiently in silico by CROs, CMOs and multinational corporations, leading to smarter manufacturing solutions. Supply chain actors will be able to explore new markets, and offer a more transparent value chain (of increasing importance to consumers) and quicker business transactions.

Specifically, REMATCH aims to:

- Reinvent the manufacture of high value chemicals through continuous processing and the implementation of digital tools – particularly, the creation of digital twins - in the automation/control and process design space, thereby bridging the innovation gap between TRL3 and TRL6. Digital connectivity throughout the manufacturing, supply and value chain will enable new levels of end-to-end visibility, traceability, transparency and data-driven insights;
- Provide a forum, platform and repository for the creation and utilisation of digital twins for the in silico assessment of process design options and their techno-economic feasibility, leading to rapid translation from laboratory to manufacture;
- Provide a physical test bed for the detailed analysis of manufacturer-developed unit operations for the subsequent creation of digital twins;
- Support the standardisation of unit operation interfaces and control protocols;
- Integrate process design across the entire value chain from ideation to techno-economic/business modelling to supply chain formulation;
- Train the next generation of engineers and scientists in the application and implementation of digitally augmented chemicals manufacturing technologies.

Beneficiaries:

SMEs will benefit from exposure to new markets, clear identification of performance indicators, design feedback and digital twin(s) of their product(s); CROs and CMOs will access faster and more accurate design and techno-economic evaluation of potential processes and direct vendor contact; multinational corporations will gain process insight and quick business potential analysis; and supply chain partners will be able to explore new markets and increase the transparency of their value chains.

Opportunities to engage with REMATCH include product provision for the creation of digital twins, pilot projects, advisory board membership, and application note development for new technologies.

REMATCH will be a flagship programme of the DigiFAB Institute (Digital Molecular Design and Fabrication), a strategic initiative of Imperial College.

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Made Smarter Research Centre: Robotics for manufacturing and production

--Context--
UK manufacturing trails in adoption of robotics, with 91 per 10,000 workers (Singapore (831), Korea (774), Germany (338), and the European average (114)) [1]. Reasons include attitudes toward robotics, risk aversion, skills shortages, and conservative investment strategies [2,3,4]. Comparable levels of investment in the UK offer a 10-year Value at Stake of £183.6bn to UK industry [2] and productivity improvements of 22% [5].

--Aims and Objectives--
Our digital research centre proposal in manufacturing robotics responds directly to the Made Smarter review [2]. It will increase adoption and innovation by developing simpler, more cost effective technologies and implementation processes, increasing autonomy, collaboration with other machines, and developing the UK skills base. Research will take a broad, interdisciplinary approach addressing technical and societal challenges of adoption.

--Innovation Themes to be Addressed--
1. Smart connected factory
  1.1 Manufacturing process and operations
    1.1.1 Accelerating processes via robotics or additive manufacturing
    1.1.2 State or design optimisation via Digital Twins
  1.2 Improving productivity or worker safety via robotics and autonomous systems in manufacturing or warehouse operations
  1.3 Augmented & virtual solutions for task assistance, training or safety
2. Adaptable, flexible manufacturing operations and skills
  2.1 Safety and human-machine interactions - ergonomics, sensing, big data, and psychosocial effects
3. Societal and cultural change - managing the disruptive impact of digital technologies
  3.1 Fully understand the human factors in design of technology solutions, including safety, cybersecurity and ethical issues.
  3.2 Developing people with broader skills in order to thrive in more diverse and flexible teams.
  3.3 Acceptability of working in a technology rich environment.

Our cross-sector approach emphasises:
1. Flexible & reconfigurable autonomy (IT1.1.1;1.1.2;1.2;1.3) - improving small-batch processes; improving the ease and speed of deployment, setup, programming, use, and reconfiguration
2. Increasing trust (IT2.1;3.1,3.3) - safety, security, verification, and testing of robots and processes; user acceptance; physical and psychological safety
3. Human and organisational factors (IT2.1;3.1;3.2;3.3) - skills and education, ergonomics, organisational behaviours, impact on jobs and processes

--Applications and Benefits--
The centre will translate interdisciplinary, cross-domain academic research, exploiting considerable academic robotics research expertise, expertise in establishing startups, and the huge translational experience, expertise and resources of the Advanced Manufacturing Research Centre (AMRC).

We will co-create responsibly with industrial partners to ensure relevance and increased adoption, with immediate benefits to industry and low-adoption sectors (e.g., SMEs, food & beverages, construction).

--Additional Information--
Interested partners from across sectors, regulators, and policy makers are invited to make contact to participate in the proposed centre and shape activities.

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We launched The London Digital Twin Research Centre (LDTRC) at Middlesex University London in March 2020 (https://dt.mdx.ac.uk/). The Centre targets the development of state-of-the-art technology in digital realisation of the physical world, whether it is in 5G, infrastructure, structure, healthcare or transportation, using concepts and complementary technologies from the notion of a “digital twin”. The initial work in the LDTRC, supported by external fund, focused on two core aspects: Structure Health Monitoring (SHM) and Industry 4.0 (I4.0).

The first, supported by Newton Fund, has been conducting Digital Twin (DT) research to support early detection of infrastructure damage with partner from University of Transport and Communications (Vietnam). Particularly, the project focuses on development of DT for SHM and prediction systems to enable continuous monitoring of bridges and other vital infrastructures. It also aims to develop translational techniques to implement the technology for various infrastructure elements.

A second project, funded by the UK India Education and Research Initiative (UKIERI), has been fostering research in DT modelling for automation, monitoring and maintenance in Industry 4.0 smart factory concepts, in collaboration with the Indian Institute of Information Technology, Sricity (India). The aim of this work is to develop more sophisticated tools to enable high productivity, lower running costs, product quality improvement, minimized maintenance and shutdown to keep up with rapid advancements in manufacturing technologies and industry transformation in the 4th Industrial Revolution.

However, we aim to expand the Centre's research activities and sustain their impact beyond the current short-term projects. Hence, we are looking for additionally substantial funding and other partners to join us in building on the foundation we have laid and developing more industry-driven solutions to meet the following medium- and long-term objectives for the Centre:

1) Develop digital twins of facilities and processes to optimise future designs or optimise current state of manufacturing process and operations;

2) Develop artificial intelligent tools for asset management optimisation, including predictive analytics and augmented support for maintenance;

3) Develop digital twin tools for smart connected networks in 5G wireless systems and beyond, including simulation and understanding of 5G IoT data from users and industrial systems, efficient transfer of virtually trialed results to the actual workplace (e.g., network slicing concept);

4) Helping manufacturing industries to redefine and redesign the roles and jobs to incorporate new technologies (e.g., 5G, Artificial Intelligence, Internet of Things) to optimise the future of work.

With the support of industrial partners (Siemens, Festo, Ericsson, Ansys, Schlumberger, Viavi Solutions) and possibly more to come, the Centre will help address the industry-identified needs and challenges in digital manufacturing and digital transformation, bring benefits specifically to the partners involved. The digital manufacturing solutions will have potential to be easily transferred to other workplaces. Particularly, we will work with the partner Ansys on Objectives 1 and 2, and with Ericsson on Objective 3, with Schlumberger on Objective 1. All partners will also help us on Objective 4. We welcome other academic/industrial partners to join us on this exciting project.

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This is an opportunity to dispel the myths; UK imports 14.3% from Germany and 9.13% from China, (Origins, 2018) cost of Labour is not the issue.

Currently (IFR, 2019) identify that the UK has 85 robots / 10,000 employees, this leaves the UK significantly behind others. Germany recording 322 robots / 10,000 employees. Robotics, Automation and further process technology development all have a role to play in helping close the current, and growing productivity gap in Wales, as identified as the 'productivity problem' (Nesta, 2020)

Technology platforms applied with cross-sectorial learning. Something that has been experienced pre-Covid-19 and something that can be expedited in a post-Covid-19 environment with the networking of the assets to build relationships between individuals, companies and institutions to accelerate the advancement and deployment of these technology platforms across sectorial boundaries. Encouraging the cross-sector deployment of these technologies through secondments, scholarships and industrial / academic appointments and engagement.

A large choir of mixed industry voices will enable curriculum challenge and development to ensure they fully support the future needs of society; from Psychology, Business Management, Human Resource, Engineering through to Digital Technologies.

Contrary to widespread concerns about worker displacement, a (McKinsey, 2017) report suggests that fewer than 5% of occupations consist of activities that are 100% automatable with today's technology, while 62% of occupations have at least 30% of automatable tasks. Successful adoption of these technologies, bringing authentic economic impact relies on delivering democratised technology and engagement.

UWTSD's extensive experience of working with Industry over many years, through a variety of engagements has led the University to identify how, in Wales, the Tier 1, 2 and 3 supply chain companies can be supported to help them keep pace with the larger global companies. Current programmes include the MADE Cymru (https://www.madecymru.co.uk) programme which part of which is designed to support the upskilling of individuals and deployment of advanced Manufacturing technologies.

Through partnership with CBM Wales, there is a portfolio of experience using the latest additive manufacturing techniques, accelerating product and process development. (Several case studies are available at www.cbmwales.co.uk)

Recent activity, through Industrial Case Studies has highlighted the benefits of using Virtual Reality tools to model, simulate, optimise and validate automation and productivity improvements within the Manufacturing sector. Currently further work in this area is focused on a pilot to demonstrate the potential benefits of Augmented Reality to the manufacturing sector and progress its use within products use and maintenance.

There is a need to optimise equipment efficiencies and deliver productivity improvements within the SME network of Wales, identifying key areas of opportunity, bridging the gap for industry that will increase private sector investment.

Previous experience with a number of projects co-created with industry, particularly the example with Aston Martin Lagonda Ltd (https://businesswales.gov.wales/innovation/aston-martin-university-wales-trinity-st-david) has shown that projects which take such a co-creation approach, driven by industry need, are the ones that address and meet the needs of the customer i.e. industry.

This is an opportunity to deliver a place-based solution to support, nurture and grow manufacturing in Wales.

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