All-Party Parliamentary Group
on the Fourth Industrial Revolution

appg

The Fourth Industrial Revolution

THE FUTURE OF MANUFACTURING

Advancing Manufacturing in the Fourth Industrial Revolution

With Foreword by the Minister for Business and Industry

4IRappg.com

Founder and Chairman: Alan Mak MP

This is the fourth in a series of reports the 4IR APPG will publish in the coming year to raise awareness of how emerging and enabling technologies are transforming various sectors of the economy, from financial services to energy and manufacturing. They will draw on a range of perspectives from across industry and Parliament, including issues raised at our regular cross-party events, to promote engagement with the Fourth Industrial Revolution.

In this edition, we look at the impact of technology in the manufacturing sector, including contributions from the Nadhim Zahawi MP, Minister for Business and Industry. Our sponsors – all leading players in the development and implementation of technology in their sectors – also share their insights alongside leading figures from academia, industry and beyond.

This report provides valuable information to Ministers, MPs, Peers, advisors and others working in Westminster, Whitehall and beyond who want to understand the powerful influence of technology in shaping our economy and society. We are grateful to the APPG's members, supporters and sponsors for their continued backing.

Contents

The views of the contributors listed above are their own, and are not necessarily shared by the 4IR APPG or the MPs and Peers who are its members.

Foreword

The Covid-19 pandemic has disrupted and changed the way of life in the UK, for its citizens and for industry.

It has presented challenging trading conditions for many of our leading sectors. But UK manufacturing has delivered on this Government's call for support in managing the response to Covid-19, including meeting increased demand for essential goods.

Manufacturing has shown its capability and its adaptability. The pandemic has also been a test of **how enabling and transformative technologies of the Fourth Industrial Revolution** can help industry and society overcome challenges and deliver opportunities.

For me there is no better example of manufacturing and technology in action than the **Ventilator Challenge**. It saw manufacturers, large and small, collaborate in the virtual world to develop and manufacture the parts needed to scale up fully functioning, tested and accredited ventilators in four weeks.

In the first week, scanning technology was used to digitally capture the component geometry and create prototype parts to prove the engineering.

In the second week, a new supply chain of 120 UK and global suppliers was established, made possible by sending the digital representation of components to manufacturers to confirm their ability to make parts, and programme their manufacturing and inspection machines.

By week four, an ERP system was set up to support the digital contracting, delivery tracking and receiving of parts. This enabled 3.5million parts to be ordered and 3million parts to be delivered. Virtual simulation was used to design and optimise the manufacturing facilities, while virtual reality was used to train the manufacturing teams.

13,437 ventilators were built in just 12 weeks! This is testament to the might of UK engineering and manufacturing capability, enhanced and supported by digital technology, to save lives.

Manufacturers tell me how technology has helped them maintain production while operating safely.

Whether through the adoption of basic technology for remote working or the application of remote sensing to monitor production or to demonstrate product and capability to potential new customers, technology has provided resilience, new business models and new opportunity. Manufacturers who were reluctant to innovate before the crisis have realised what technology can do for their business.

Technology is helping UK manufacturing to be more competitive and to transition to greener production process and products- supporting the UK to deliver Net Zero by 2050.

To make this happen, we are investing £167m in Made Smarter, the UK's industrial digitalisation initiative that aims to boost UK manufacturing productivity and competitiveness through the development and adoption of industrial digital technology. It is fantastic to know that so many of the contributors to this booklet recognise the value of Made Smarter and want more manufacturers to access the programme to embrace digital technology.

Through the Made Smarter North West Pilot we are working with manufacturing SMEs to help them adopt digital technology to grow greener. Across the manufacturing value chain, digital technology has the potential to drive down emissions. Whether through better visibility of waste streams, more efficient production processes, or even new approaches to working with customers. The Pilot is working with firms like Wirral-based Parity Medical, to help develop virtual demonstration of their products to reduce their travel time and shrink their carbon footprint by up to 11 tonnes per year.

Digital technology is enabling the transition to the next generation of electric vehicles. Funded through the Advanced Propulsion Centre and industry partners, including Ford and McLaren, the Virtual Vehicle Integration and Development (VIVID) programme uses state of the art simulation technology to reduce the reliance on serial engineering and physical prototypes. This lowers overall carbon emissions by accelerating time to market of a desirable electrified product.

Digital Technology helps manufacturers to supply critical products to UK citizens. Universities and industry partners including Pfizer Ltd, Astra Zeneca and GlaxoSmithKline PLC are working together through the **ADDoPT (Advanced Digital Design of Pharmaceutical Therapeutics)** project to deliver new, higher quality medicines to patients faster and more cost effectively. Data analysis, digital twinning and predictive models facilitate targeted experimentation and better design and scale-up for robust products and processes.

Some people will argue that jobs are at risk from digital technologies like AI and automation, fuelling fears of "technological unemployment". But these technologies can enhance and boost skills of the workforce, replacing mundane or dangerous tasks, and freeing up capacity to focus on higher value activities and opportunities for growth. We ignore technology at our peril if we want the UK to maintain and excel beyond its position as the 9th largest manufacturing nation.

The manufacturing sector's response to aiding the country during the Covid-19 pandemic has left me in no doubt about the capability of UK manufacturers and what technology has helped them to achieve. **The adoption of digital technology will enable more of our manufacturers to compete, to pivot to new opportunities and to grow a greener manufacturing future for the UK.**

Nadhim Zahawi MP
Minister for Business and Industry

Introduction

The Fourth Industrial Revolution (4IR) is rapidly transforming the manufacturing sector. From the Internet of Things (IoT) to Artificial Intelligence (AI), we are witnessing innovation at an unprecedented speed and scale. Such innovation is delivering much-needed growth and allowing our manufacturing sector to become more environmentally sustainable.

During the First Industrial Revolution, new machines were produced to respond to the increase in demand for mechanisation. From the spinning jenny to the steam engine the machinery of the First Industrial Revolution allowed us to speed up the production of manufactured items. In this digital age, AI, the IoT and robotics are the new spinning jennies and steam engines, allowing us to produce items with greater consistency, more quickly and more cost effectively. As in the Victorian era, there remains today fears that machines may replace human workers; that data may be misused; and that artisan skills may become obsolete, as the hand of the robot becomes more efficient than its creator. However, as we saw in the First Industrial Revolution, legislative changes followed to create a balance between the innovation that comes from allowing market freedoms and ensuring that there are new safeguards and high workplace standards for workers.

Today, advancements in manufacturing have only been possible due to the upskilling of the workforce – a theme that is high on the agenda of all those contributing to this report and who have a stake in the success of the Fourth Industrial Revolution. Advancements in technology do not have to equate to job losses. In fact, technology is now advancing so quickly that a report by the World Economic Forum recently highlighted that 65% of children entering primary school today will ultimately end up working in completely new job types that don't yet exist. Therefore, the upskilling and continued reinvention of the workforce must remain paramount if we are to fully realise the opportunities of this Fourth Industrial Age.

Modern technology is driving forward the UK's commitment to delivering Net Zero by 2050, whilst allowing us to remain competitive internationally. Digitalisation is delivering a boost to our nation's productivity, distributing growth and strengthening SMEs throughout the supply chain. To further this work and unlock the full potential of the Fourth Industrial Revolution in the manufacturing sector, a national debate is now needed on how we can enable businesses of all sizes to completely digitalise.

From the rapid production of PPE to the advanced manufacturing of lifesaving instruments for Intensive Care Units, throughout the COVID-19 pandemic we saw how quickly traditional manufacturing processes could be adapted to support the national effort to defeat Coronavirus. The pandemic has caused manufacturers of all sizes and sectors to consider the importance of innovation to grow their businesses. With this transformation policy makers now have a responsibility to ensure that businesses have the legislative freedom and financial incentives to seize these opportunities, particularly as we restructure and rethink our economy in the wake of COVID 19.

Thanks to the Fourth Industrial Revolution the UK's manufacturing sector is playing a key role in generating new jobs and innovative products, helping our country respond to the pandemic and position itself strongly for the future.

Alan Mak MP
Founder & Chairman of the 4IR APPG

The fourth industrial revolution should also be a green industrial revolution

Britain is built on industry. When I was growing up in Newcastle, it was the greats of our industrial past such as Stephenson, Armstrong and Parsons, Rachel Parsons, the first woman naval engineer, who inspired me to study electrical engineering. I wanted to build and make things which made the world better. Today, as shadow minister for Industrial Strategy, it is my job to consider how we can grow British industry so that it is not only our past but our future prosperity.

The fourth industrial revolution is about smart factories, utilising intelligent and flexible automation, making manufacturing cheaper, quicker and more efficient at its heart. However, technology underpinning automation cannot be done to people, it must be done for people, with working people in mind, creating high skill, high wage jobs not destroying them.

We are seeing incredible technological changes that herald astounding new opportunities; increased connectivity, boosted productivity and social reach. Technological advancements that inspire creativity, bringing together previously separate areas of the economy and empowering citizens. We have the use of 3D printers and ever more advanced computer software, enabling manufacturing at home making us work faster and create more, which is vital for the UK to stay competitive in the 21st century. When I visited the Advanced manufacturing Centre in Sheffield last year I was impressed by the range of technological change and how it was being integrated into modern day manufacturing. It is essential that employers and industry groups work with trade unions and policy makers to makes ensure that workers feel empowered by change and not scared of it.

The fourth industrial revolution should also be a green industrial revolution.

Some may say that the two driving forces behind a green industrial revolution, environmentalism and industry, are incompatible. That to support our industrial base we must abandon our role as guardians of the planet – or vice versa.

Well, I disagree. I believe that by being bold and ambitious, investing in sustainable manufacturing methods as part of a circular economy we can build the industrial economy we want while safeguarding our planet.

This means recognising the economic, environmental and social problems that current methods of production can create and fundamentally changing the way we make things. In other words industrial revolution.

Greater energy and resource-efficiency could generate an extra £10 billion per year for the UK economy, 300,000 new jobs and a 4.5 per cent reduction in our total annual greenhouse gas emissions.

It took close to a century for the workers to feel the economic benefits of the first Industrial Revolution. So much wealth was generated by the North that was only shared more equally thanks to the conception of the Labour movement. Well with the green industrial revolution we have the opportunity to bring well paid secure jobs to the areas that most need them. The green industrial revolution will require a massive mobilisation of finance and labour towards decarbonisation. However, in return we will see a rebalancing of our economy, 'greening' production to create new jobs in high skill, high wage, high productivity industries.

Ensuring that the fourth Industrial revolution is a forward thinking, digitally literate, green industrial revolution we can generate the kind of growth we want to see an economy for the many, and a future that is sustainable. We are approaching an immense change to our way of life, together we can take control of the narrative and maximise the potential of the fourth industrial revolution. It is urgently important that not only politicians and engineers, but trade unions, financiers, bosses and workers in equal measure unite behind a green future. We must not suffer from the faults of the first industrial revolution, we do not want the modern-day equivalent of nine-year-olds going down mines, or of limbs being lost in the unguarded looms of the workplace.

I look forward to working with you to achieve that.

Chi Onwurah MP
Shadow Minister for Science, Research & Digital

How Hydrogen is powering innovation in manufacturing

The Fourth Industrial Revolution often encompasses technologies such as artificial intelligence, quantum computing, 3D printing and the internet of things, but what is often left out is something that will invariably fuel this revolution and the future – Hydrogen.

It is without a doubt that the Fourth Industrial Revolution will come to be powered by the Hydrogen Revolution. When it comes to the future of our energy sector it is no doubt that the most abundant element in our universe will and must pave the way.

Hydrogen serves as a potential resource for heating, electricity generation, industrial processes, vehicular power, and energy storage just waiting to be tapped into. Over the next decade, the cost of creating hydrogen from renewable resources or low carbon sources is expected to drop by up to 60 per cent. The opportunity in front of us is immense. It is the chance to be both a global leader and an innovator in this new fuel industry.

With a strong global and U.K. resolve against climate change the time to make the case for hydrogen is now. According to Clare Jackson, manager of Hydrogen Hub, "public perception of hydrogen is a blank sheet of paper." This means that the industry is not plagued by poor perceptions. It also shows that work remains to be done in raising awareness on the infant industry and new fuel source.

Organisations such as Hydrogen Hub are doing just that by providing educational resources to young pupils, creating local partnerships with companies within the hydrogen industry, or those simply interested in exploring hydrogen's potential. While we must support these sorts of organisations, we must also pledge to demonstrate to the general public how making the switch to hydrogen heating makes practical sense. Concrete pilot programs showing hydrogen's viability are key to ensuring we have the public's support in pursuing this opportunity.

The government pledge to meet net zero emissions by 2040 demands that hydrogen fuel cells, which only emit water, play a massive role in revolutionizing our transportation industry. An industry which accounts for a third of our carbon dioxide emissions already.

Last May, Transport for London ordered 20 new double-decker hydrogen buses. These new buses emit nothing, except water, and their fuel is sourced renewably from the North Kent offshore wind farms. Along with that, these buses can be refuelled much more quickly than their conventional battery-electric bus counterparts, have a longer range, can run on one five-minute refill a day, and their performance is not impacted in colder climates (unlike battery technology). On a total cost of ownership basis, fuel cell electric buses can be more competitive than current and next generation battery electric options. In many markets diesel buses will not be allowed, which means the fuel cell bus can become the lowest cost option; whilst being zero-emission. In early February, the Department for Transport confirmed £48m is to be committed to a variety of ultra-low emission bus projects across the U.K. This proposal included 20 new hydrogen buses for Brighton and Hove. A great step in the right direction.

A prime example of an industry leader in the hydrogen bus arena would be Jo Bamford and particularly his work with Wrightbus. The company has already begun work providing the 20 hydrogen-fuelled buses for London, 15 for Aberdeen, with Birmingham expected to order some as well. This is only the beginning; we must work to extend hydrogen into public transport for cities across the entirety of the United Kingdom.

Hydrogen and fuel cell buses must be produced at a large enough scale in order to capitalise on their potential. At a manufacturing scale of only 3,000 buses built over 4 years (10% of U.K. bus market), the total cost of operating hydrogen buses will not only have fallen below battery buses, but will be competitive with conventional diesel technology and will continue to fall further. At this scale, hydrogen infrastructure will directly save 238,000 tonnes of CO_2 each year and directly remove emissions from 10% of the U.K. bus fleet, which will be deployed on the "hardest to convert" bus routes thereby improving air quality in cities. The net present value of avoided CO_2 and air pollutants alone equals £152m.

When it comes to hydrogen production Bamford stresses that obtaining a wind farm and a hydrogen electrolyser would make the cost the same as diesel and would only bolster production. Wind farms are not the only method of producing zero carbon production hydrogen. Solar, nuclear, gas, and carbon capture and storage systems are all paths to producing hydrogen without creating more carbon. When it comes to Wrightbus, aiding in the funding for the acquisition of a windfarm is a concrete, effective action we must take to support this organisation and others in the industry. Pursuing more hydrogen mobility will also support technology built in the U.K. which will in turn develop a local supply chain for hydrogen production and fuel cell equipment.

When it comes to hydrogen versus battery power, even Bamford, whose Ballymena-based company Wrightbus offers battery buses as well, acknowledges the fact that when it comes to longer distances hydrogen is vastly superior. Imagine the new distances ships, trucks, and aeroplanes could reach when running on this clean fuel. Hydrogen will therefore enable the decarbonisation of industry and heavy transport. There is also a dependency on imports when it comes to batteries, along with major grid expansion costs, operational issues due to limited range, and poor cold weather performance. Not to mention, batteries are simply wasteful as 50% of their components end up in a landfill. They may produce zero carbon, but they also make zero sense to produce long term.

Even the motorsport industry, the epitome of competition, has begun to turn toward hydrogen. The FIA World Endurance Championship organisation has begun to look at hydrogen as an alternative fuel. President Jean Todt acknowledges that "hydrogen technology is the next, important, step on the road to a cleaner and sustainable future." Hydrogen mobility can become as affordable as diesel vehicles are today by as early as 2024. With comments such as these coming from an industry leader, in a sector where petrol and diesel have dominated, and the competitiveness of hydrogen against diesel, it is obvious that hydrogen may be the true alternative to traditional fuel sources.

Transportation is just the start, just earlier this year the U.K.'s first live pilot to inject zero-carbon hydrogen into a gas network is now fully operational. The pilot program, HyDeploy, is a serious trial at Keele University, Staffordshire, that may help Britain greatly cut its carbon emissions. The pilot is directly injecting up to 20 per cent of hydrogen into the existing natural gas framework. This blend of hydrogen and gas is the highest in all of Europe. If this program and 20 per cent blend were pursued across the entirety of Britain's natural gas framework, it could save around 6 million tonnes of carbon dioxide emissions every year. That is the equivalent of taking 2.5 million cars off the road. It is evident that this is a policy area that must be pursued and must be enacted throughout the United Kingdom if we are to meet our net-zero goal.

Often it is the case that innovation and visionary pilot programs are stifled because most subsidies go to more established energy sources. We must look to creating an effective subsidy framework in order to create an environment where hydrogen can prosper so we may prosper in the long run.

Looking outward, other nations around the globe have taken interest in hydrogen technologies. Germany is planning a new €2bn hydrogen fund and has already installed tens of electrolysis facilities along with nearly 100 fuelling stations. In the U.S. there are already over 5,000 fuel cell passenger vehicles operating on the road in California. In Korea, their government and Hyundai have partnered to accelerate the production of fuel cells and hydrogen vehicles to the tune of 10,000's per year. Japan is also planning to make hydrogen a centrepiece of the 2020 Tokyo Olympics. It is time we not only take interest in hydrogen as the world has, but we must also invest and support hydrogen and its surrounding industries in all aspects.

In summary, we must take these steps to ensure we harness hydrogen to its maximum potential.

First, we must take the opportunity to convince the public of the practical, long-term benefits of making the switch to hydrogen. We will do this by working with and supporting organisations such as Hydrogen Hub, along with concerted concrete pilot programs.

Second, we must take the opportunity to invest in hydrogen technologies. The potential for a new green energy source and a new industry would not only lead us toward net-zero emissions, but also create quality jobs in a long-term and forward-thinking sector.

Third, we must further our efforts in introducing hydrogen into the transportation sector. Investing in a new hydrogen-fuelled brigade of buses would serve as an excellent means to both reduce the U.K.'s carbon emissions and to introduce the public to these new technologies. Working with and supporting industry leaders like Wrightbus specifically will be the key to ensuring we create carbon-free public transport systems across all U.K. cities.

Lastly, we must have a holistic hydrogen approach from Westminster. A sustained effort in creating an effective subsidy framework will further catapult the potential of hydrogen and our potential as a leader in reducing carbon emissions throughout the globe.

Ian Paisley MP
Shadow DUP Spokesperson
(Culture, Media and Sport)

Cloud -> A Key Foundational Technology for Business

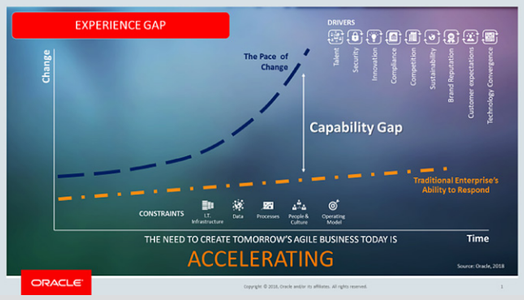
Experience Gap and Why – Most organisations face an experience gap. The expectations of the employees, customers, communities and even governments etc. have dramatically changed over recent times especially with the consumerisation of technology. From employees' perspective, they want healthy and safe, including psychological, environment. From communities' perspective, they want manufacturers to adhere to high social responsibility standards including control over carbon footprint. From a customer perspective, they expect an outcome and accordingly pay only for that. Many manufacturers see that in the form of the shift to service-oriented business model e.g. Train being sold as a service or printer being sold as a service.

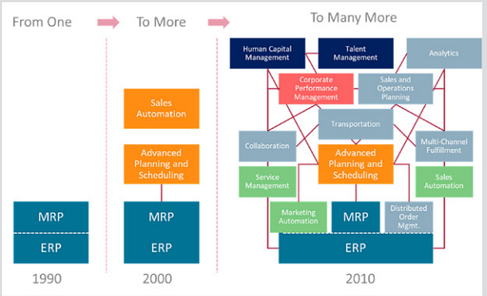
However, many organisations struggle to close this gap, let alone be ahead of the curve and outpace change. The primary reason is that the existing pillars e.g. operating models, culture, business processes and technological landscape etc. are just not fit for purpose. While incremental changes are being tried, the real and hard solution is to inherently design these pillars to deliver the modern expectations of various stakeholders.

Cloud -> Foundational Technology to Retire Technical Debt

From a technology perspective, the key issue with the current systems is the inability to be always current. And this is primarily down to how the systems have evolved over the years as per the picture below. This creates a technical debt that stops companies from automating a business process end-to-end and hence freeing up the people to focus on understanding the data to impact decisions. Hence modern applications inherently designed to support end-to-end cross functional business processes consumed through cloud mechanism is a key foundational requirement to retire technical debt.

Emerging technologies (AI/ML, IoT etc.) embedded into these applications then take the process automation/ data insights to next level to drive a data driven organisation.





Policy Recommendations – Creating the best environment for innovation adoption

A recent CBI/Oracle study on large company digital transformation identified the policy recommendations. These are applicable to manufacturing sector too.

Investors must promote digital transformation to ensure the firms they invest in stay competitive

Investor and senior executive engagement is crucial when justifying the initial cost of transformation projects that may impact ROI. Investors can use diagnostics tools to understand and communicate at board-level where transformation is most needed.

Government has a role to play in providing insights into what questions investors should ask themselves, and companies, within their portfolios. This will increase the knowledge base on digital transformation and simplify future conversations on the topic.

Regulation must adapt to match the changes in the business ecosystem

To become a tool to stimulate innovation, regulation must be pre-emptive in its outlook, with greater focus on horizon scanning. This will be key as businesses create new products and services within a clear forward-looking framework.

Many members pointed to the Financial Conduct Authority (FCA) and its 'sandbox', as a positive model of the interplay between regulation and business development. This could act as a foundation for future governmental regulatory interventions.

Large firms must support innovation throughout their supply chain

By offering smaller companies within their supply chain significant support, large firms can incentivise innovation in a way that benefits everyone in the chain.

Many members said in order to achieve their business goals they cannot wait for others to reach a certain level of digital maturity and therefore had to take proactive steps to address the issue. This could be by providing data management training or using additional capital to embed necessary systems that ensure continuity and reduce disruption. This can be extremely resource intensive and thus is an area where government could help through sector-specific interventions.

To summarise, while most organisations need to close the experience gap, there are progressive companies who are taking the action today to move ahead.

A Case Study - Precision Group

The Precision Group U.A.E., is a pioneer and market leader in the manufacture of aluminium extrusion dies, tools, press tools, blow moulds and injection moulds, precision moulded plastic products and thermo-formed industrial packaging. They recently embarked on technology modernisation to outpace change. Here is extract from an interview with their CIO.

Why Change? - Precision was running on a legacy system for more than 25 years, which resulted in many process inefficiencies. We were not able to manage our reporting since many reports were in silos, and we were lacking an integrated system. We did not have visibility on our shop floor, nor in our inventory organization and that did not allow us to scale and support new processes.

Why Cloud? - To address these challenges and make sure that we are ahead of the competition, it was very critical for us to modernize our systems, so we decided to kick off a digital transformation program across our organization. Oracle had the best offering in the cloud, in terms of the breadth of applications, how they are seamlessly integrated, and the use of advanced technologies embedded in the solutions (like IoT, artificial intelligence and machine learning). It is all integrated, and the beauty is that it comes in a SaaS model: an architecture that continually updates itself without the need for upgrades that are costly and risk business continuity. So, with this subscription model, we are constantly upgraded with new functionality. All these features helped us select Oracle Cloud for our entire Digital Transformation program. We were one of the early adopters of R13 (release), which we think that made the whole project a grand success by this time.

Benefits so far - By having this system right now, we were able to achieve increased efficiency and end-to-end visibility into the supply chain. We have real time visibility of our orders and thereby the entire cycles of order-to-cash and procure-to-pay have been completely streamlined. We have complete visibility of our business with advanced analytics in simple dashboards, enabling better collaboration and faster decision-making. This is brilliant, and from day one, we could use all the dashboards. Oracle Manufacturing Cloud helps us streamline our manufacturing operations and get actionable insights in our factories to drive efficiency, flexibility, and speed. Also, everything is available through mobile. Therefore, our employees can stay connected and work seamlessly from anywhere, enhancing overall work efficiency. This was a major transformation from the 25-year-old legacy system.

Key Learnings - I think one of the key messages that we can pass on to other companies is the need to have a proper governance structure in place to embark on a digital transformation journey. Manufacturing companies are reluctant to change, because change is not easy in a manufacturing set up and it may cause disruption. We actually had change agents, process champions, who empowered the rest of the organization and made sure we addressed all the challenges and effectively drove the change in the organization.

Connecting Smart Factories

"The challenge with manufacturing now is not advancing devices, but connecting those devices to each other and to the shop floor as a whole."

Richard Conway, CEO of Elastacloud

Data fidelity

The key to advancing factories and hence manufacturing processes is to gather data regarding the generative machinery and distribute the data to enterprise software. Data can be gathered at a variety of frequencies (how often a sensor is checked) and granularities (how many engine revolutions per minute/how far the engine has powered a vehicle). Whilst it is tempting to abstract the data gathering, to a higher level of granularity or frequency (i.e. miles per day rather than revolutions per second), it is by gathering as much data as possible and looking for correlations in other low-level data that we discover the raw materials for our intelligence.

To solve this challenge, an approach to contemplate is the use of data discrimination; data can be compressed to its most significant components and streamed in a hot path that is immediately investigated by the analytics system and the remaining data can be bulk uploaded in a cold path that runs in an asynchronous and preemptible fashion.

Information Security

In order to do this, we must securely connect our devices to the cloud remote processing capabilities and stream our results to it. The importance of security in this scenario should not be underestimated. The original approach taken to this was to hard-code connection information into the devices, which provides a low level of security with significant drawbacks: the device manufacturer needs to know the connection information so must be trusted with sensitive credentials. Any credentials burnt into the firmware are hard to change, and also difficult to vary from device to device, which may lead to many devices using the same credentials. The credentials are also only as secure as the physical device, as if it is compromised virtually or physically (perhaps stolen or hijacked) the device will have credentials within it that allow it to send messages to the analytical systems which may be very hard to revoke, particularly if they are shared between devices.

The key technique to consider for device infosec is the notion of a device registry which allows the device to store a unique identifier and authentication token which is registered with a middleware and this middleware can also store state as to whether the devices registered remain trusted. IF they are trusted, the middleware may hand out time window restricted keys for access to remote resources of messaging, storage and command.

Network bandwidth and intermittency

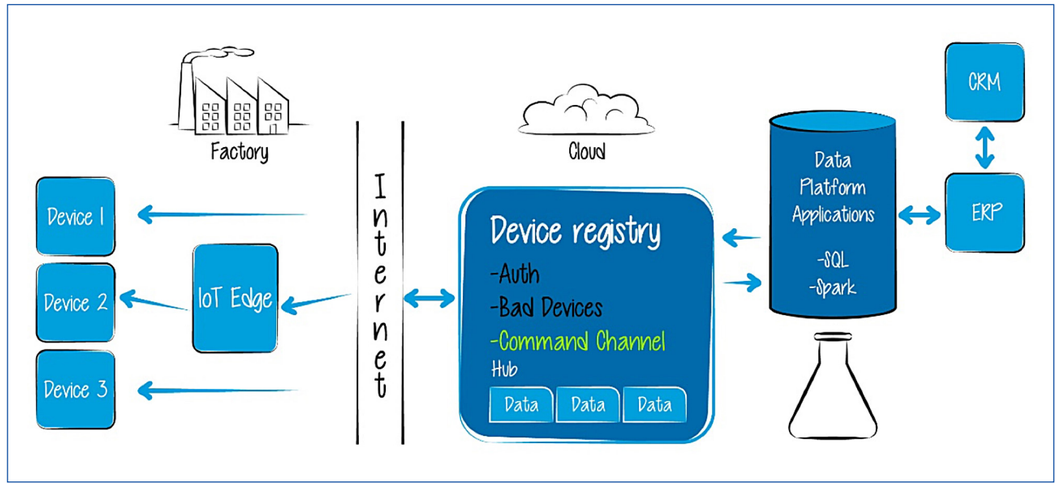
If we have a trusted connection to the analytical processing systems, we may begin to send our gathered data to our remote processing capabilities. A challenge which you may face is the ability of your network to support the weight of data with a low enough latency to fulfil your timeliness of query requirements.

To solve this challenge, an intelligent Edge device can be placed inside the factory infrastructure that facilitates the aggregation of data so that the most immediate data is sent and aggregates can be utilised then replaced in order to remove these types of bottleneck.

Through Elastacloud's experience with the intelligent edge and hybrid connectivity, including with 5G and interplexed networking, the restrictions on bandwidth, partial connectivity and latent intellectual lag can be alleviated by bringing the intelligence closer to the devices. This edge based smart router approach allows for near instance contextualisation and actuation.

Data Platform Applications and the Command Channel

The culmination of the advancement of devices and the intelligent shop floor is the use of a command channel for receiving guidance direct to the device to manifestly alter operation in order to meet a goal requirement. This may be to optimise productivity, prevent an outage through avoiding or reducing the need for maintenance, and so on. The method we utilise to affect the operational change is called the Command Channel and it is a connection opened from the device to the remote application which the device listens on and the remote application may write to. This allows the remote application to send updates, configuration changes and other commands to change the operation of the device for the holistic benefit of the overall system.



As we will learn later, the remote applications that we have been alluding to are data applications that process, contextualise, augment and visualise data feeds from singular devices with the sole goal of providing insight and automating action based on the insight garnered. These data applications are typically based around technologies that can provide scale, flexibility and complexity in a modern cloud environment and can combine technologies from a diverse catalogue into a single orchestration of computational intent over input data.
www.elastacloud.com

A Case Study
Johnson Controls Use the Connectivity of Smart Chillers to Save Energy

Johnson Controls are involved in the manufacturing and engineering of batteries, buildings, and distributed energy storage. As providers of heating, ventilation and air cooling solutions and maintenance to companies around the globe, Johnson Controls were very interested in how to help reduce the amount of energy used by their chiller systems in order to reduce the spending and carbon footprint for their customers.

Johnson Controls began working with Microsoft to connect their Smart Chillers to the Microsoft Azure IoT Suite, enabling them to track and store the vast amounts of data coming from their machines. Chiller maintenance technicians became able to monitor machines remotely, responding to any issues visible in the Chillers' outputs quickly before costly problems occurred.

On top of this, the Azure IoT Suite enabled them to create a scalable platform to connect the Smart Chillers to the other components of the buildings they're in, integrating building sensors, thermostats, and any other Smart-Enabled device. This means ultimate visibility and insight for predictive maintenance, while at the same time using this data to regulate temperature across their client's sites and find other areas in which to be more energy efficient, all with data coming straight from sensors and into the cloud.

Covid-19 isn't the only meteor that's landed on our lawn

Harvey Nash.

There has never been a more important time to shore up the UK manufacturing sector and shape it for the future. The Covid-19 crisis has emphasised the need to bring our supply chain closer to home, and hinted that our economy, so focused on the services sector, may benefit from having a broader base. In an altogether more unpredictable world, we need an economy that can weather the storms.

But Covid-19 isn't the only meteor that has landed on our lawn.

In the last decade technology has begun to transform how organisations operate. As a technology recruitment and solutions company we have witnessed its evolution closely - it began with cloud, then data and analytics, and more recently artificial intelligence, automation and IoT. In a sector so keen on buzz words, it's tempting to shrug off the impact of such advances, but we have seen its effect first-hand. We have witnessed creative destruction; old jobs being radically changed or retired, new roles created, often with exotic job titles. And it won't stop.

In fact, Covid-19 has served to accelerate this process. One CIO recently said to me that more digital transformation has occurred in her organisation in the last four months, than has happened in the last ten years. The crisis has acted as a catalyst for all of those 'one for next month' decisions that have been discussed in boards for years. For many, the driver of digital has not been the CIO, CTO or COO - it has been COVID.

With such leaps in technology, manufacturing, like so many other sectors has had an opportunity to remodel itself and make step changes in productivity. It's an exciting time and Harvey Nash Group has had the privilege to work with many organisations seizing upon this chance to redefine themselves through the lens of technology.

Organisations rating their digital strategy very or extremely effective

- **All organisations globally 31%**
- **Manufacturing Germany 23%**
- **Manufacturing globally 15%**
- **Manufacturing UK 8%**

Source: Harvey Nash / KPMG CIO Survey 20191

But whilst there are success stories, manufacturing as a whole has been relatively slow to adapt. The Harvey Nash / KPMG CIO Survey 2019 reported that UK manufacturing tends to lag behind other sectors in the effectiveness of their digital strategy.

But if the manufacturing sector is playing catch up to other sectors, perhaps of more concern is that UK manufacturing is playing catch up to other countries. Less than one in ten manufacturing organisations in the UK rated their use of digital technology Very or Extremely effective; that's half the global average, and a third of Germany.

Of course, a key driver behind technology investment and adoption is people. A technology strategy is not worth the paper / PowerPoint deck it's written on if there aren't the people there who can innovate, architect, implement, deliver and support it. And for manufacturing there is a problem. The CIO Survey reported that 73 per cent of technology leaders in manufacturing said they were suffering a technology skills shortage that was holding them back on their strategy. Or put that another way, three-quarters of organisations would be doing more with their technology if only they could find the right talent. Manufacturing was the fourth most affected sector out of the twenty-three we reported on.

The top two areas where skills were most lacking were the emerging and increasingly critical areas of artificial intelligence and data analytics. It seems then that one of the biggest barriers to the UK navigating its way through the Fourth Industrial Revolution is gaining access to the right skills.

In many senses, the challenges are similar to other sectors needing technology talent: how can we develop the right STEM skills for building entry level talent in the sector? How can we develop the right skills in emerging technology? How can we create a more inclusive and diverse workforce?

But for manufacturing the hill to climb extends further. Compared to sectors like financial services, technology and media, manufacturing has not always been seen as a prime destination for technology careers. Even more so for women.

For the large part this is a perception issue. Ask someone outside manufacturing whether the sector is a growing, and they would probably say not. And yet manufacturing output was actually higher in real terms in 2018 than 1993. Not the stratospheric rise of services of course, but growth all the same.

All the evidence we have suggests a career in manufacturing technology is just as rewarding and fulfilling as a career in other sectors, women progress as fast as men. We clearly need to get that message out more loudly.

Cross-training could be part of the answer. For instance, in our Belgium business we have been highly successfully training motivated individuals wishing to learn new technology skills. They are placed on client sites where they gain valuable work experience and insight and continue to learn their new craft. Most people successfully complete their first year and are rewarded with a permanent job and a new career.

The challenge for manufacturing will be to position itself as a key sector to work in, a sector that is driving innovation and playing an important part of the UK economy. As the Fourth

Industrial Revolution progresses, and as the UK re-assesses what's important for its economy, this is a perfect time to make that case.

Key areas of focus:

- Invest in building home grown technology skills, for instance for the unemployed or people who wish to cross-train into the sector.
- Keep the UK's door open to Europe as a source of highly skilled technology labour.

  Around a quarter of technology jobs in the UK are filled by EU nationals.
- Incentives for businesses to work with local suppliers in their supply chains. Securing jobs and growing the economy whilst de-risking supply chains exposed to global suppliers unable to fulfil demand.
- Showcase UK manufacturing strongly both within the UK and as part of trade deals as we exit the European Union.

Bev White
CEO, Harvey Nash Group

Industrial Revolution in Defence Manufacturing

As the fourth industrial revolution continues to transform aerospace manufacturing, Lockheed Martin is implementing industry 4.0 technologies at manufacturing facilities around the world to speed up production, reduce costs, and improve quality. These technologies include a 'digital thread', laser instruments, robotic systems, the internet of things and drones.

The revolution is well underway for the F-35 Lightning II, Lockheed Martin's largest production programme. The UK is the only top-tier international partner in the system development and demonstration phase of the programme, and it is a key industrial partner. Around 15 percent of each F-35 built comes from a UK supplier, contributing to a global network of more than 1,900 suppliers, supporting many thousands of jobs and seeing returns for UK businesses in excess of $1bn annually.

Key components of every F-35 built are produced in the UK. These include the actuators which open and close the weapons bay doors on the aircraft and are high value components manufactured in the West Midlands. The ejection seat and life support systems are critical safety systems which are made in the UK, along with the lift fans for the F-35B short takeoff and vertical landing variant.

A digital thread helps link the global F-35 network. The thread is established by creating and consuming 3D engineering models and data for use in manufacturing, supply chain and sustainment. It provides partners and suppliers around the world with secure access to engineering data, greatly reduces the number of changes and supports factory automation. Mechanics and maintainers use the 3D data for graphics in work instructions and maintenance orders, optical projection of data onto the aircraft surface and augmented reality training and collaboration. Plus, the digital thread allows direct comparisons of as-designed to as-built digital twin configurations using technologies like structured light and laser scanning.

Automation on F-35 initially consisted of gantry robot systems which were able to drill 80% of the exterior wing and fuselage holes accessible to these large robots. Drilling capability has expanded with more flexible robotic arms, and in many cases, laser tracking is used to help position robotic systems for improved measurement accuracy.

Robots also apply the F-35's stealth coatings taking advantage of the precision, quality and labour savings compared to manual applications. In another area of the production line application, robots place tools on the aircraft and inject coatings between the tools and the aircraft surface – a process called mould in place.

Beyond manufacturing, the fourth industrial revolution is introducing new technology for aircraft inspections during production and sustainment. It is critical to control aircraft surface features such as gaps, mismatches and fastener flushness to enable stealth. Laser instruments used to measure these features can be tied directly to IT systems for automated reporting of any defects – a great example of the fourth industrial revolution's internet of things and the convergence of IT and operational technology.

As a global technology leader, Lockheed Martin is experimenting with drone-based production and post-flight inspections. Flying and crawling drones eliminate the need for platform and stairs, reducing time for external inspections and improving safety for the workforce.

While the fourth industrial revolution is creating huge transformational benefits, people will still play a major role in our work and fully automated aircraft production is not planned. The industry will continue to depend on highly trained, highly skilled men and women throughout the supply chain to perform critical operations and inspections – with the help of technology.

AI powered manufacturing

braintree
nature of intelligence

When asked during the Q&A session– "what will the future bring us?", a speaker might struggle to provide one with a coherent and structured answer, failing to develop on 'how and why' certain future events will take place. Which drove me to an idea of dividing my answer into three parts: 'Why' 'How' and 'What'.

'Why'

While observing the development of humankind from a high-level of abstraction, one might see a pattern of human species using their intellect to survive in our natural habitat – Earth; Solar System, the Universe (in the nearest future).

The more impact humanity has on ecosystem, the more intellectually challenging solutions a relationship between 'nature and humankind' requires.

Our planet's natural habitat creates a naturally challenging environment, where humankind has to fight for its' survival. Which, in turn, creates a need to use our intellect to overcome the so-called 'challenges' and with a help of civilization and constant development change the natural balance of things and not be in a constant fight for survival. In addition, it helps us to create a more relaxing, comfortable environment, with better facilities and a new 'balance of power', creating more and more opportunities to evolve. This tendency to evolve in order to change the balance of power is relevant and be observed at every stage of human evolution: from the stone age to the space age, when idea of colonizing other planets emerged.

Our natural habitat is a very complex system. In order not to upset the existing balance, one must possess a certain level of intelligence. The more one uses it resources the more careful one should be. Failure to follow this approach led to natural disasters caused by human activity. That is 'WHY' humanity has encountered a need to improve intellectual development of our civilization. Which leads us to an urgent need of the next step in AI development.

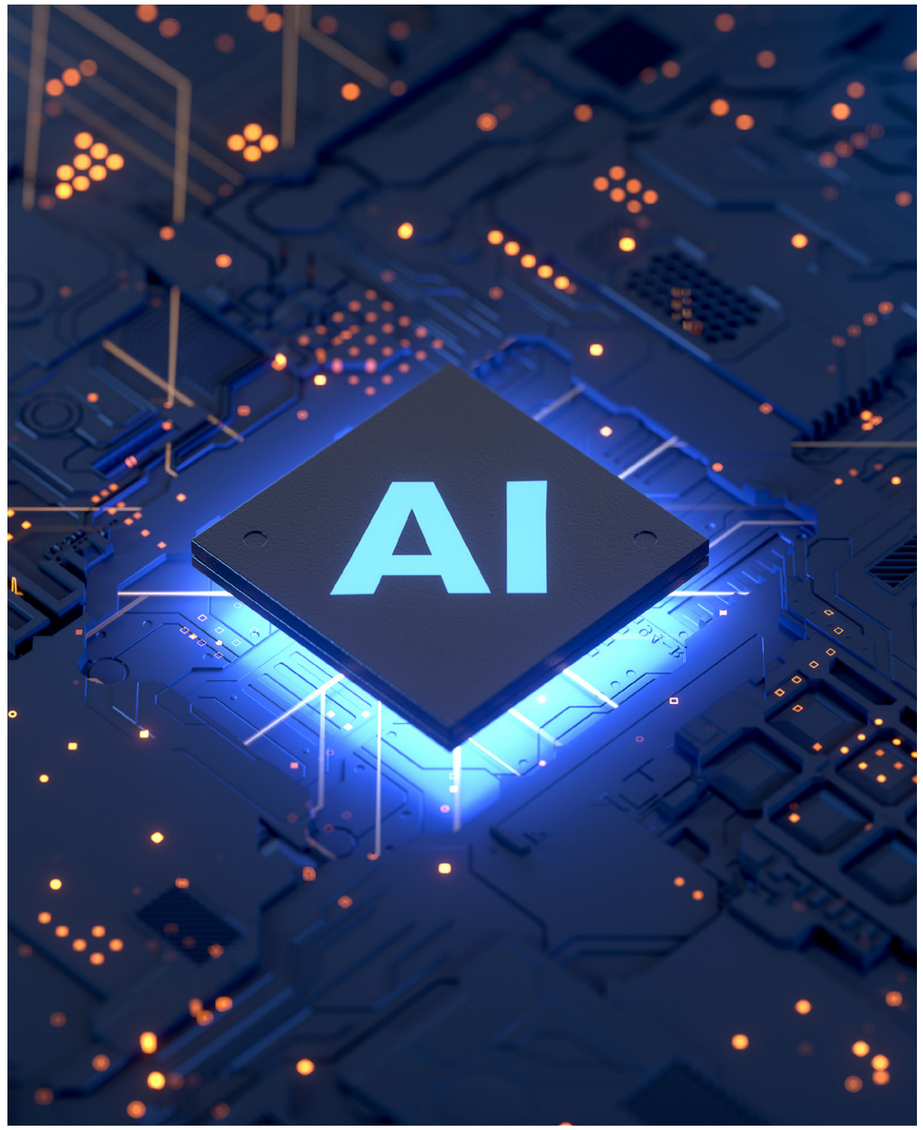
'How'

We have identified a logical link between humankind and intelligence/civilisation and nature. Though it's hard to prove that there were any civilizations before ours or be certain that there will be any future ones or how there going to be categorized; or civilization can be categorized and described as 'digital'. What used to be precepted as 'science fiction' became our reality, meaning that all the components that one's life consists of, either already exist as data, or will soon be converted to data. This concept is going to be called – 'Very Big and Complex Data'. In order to continue developing our civilization we urgently need to learn how to understand and control such data. There is only one tool we can use to overcome those challenges – Artificial Intelligence. AI shouldn't be associated with our society, as we know it, coming to an end. On the contrary, it's an already chosen path towards a modern era and our only chance to enter it is through AI. The answer how to do it explicitly is to combine human intelligence with artificial intelligence, producing a unique and powerful concept called – Hybrid Intelligence (HI). The aforementioned 'new era' will see AI as a so-called 'navigator', leading us towards better understanding and new knowledge and helping us out in a digitalized world. The HI isn't something that aims to replace human intelligence, it's something that helps us further develop it. From what it follows, that we will have a better ability to understand our natural inhabitant and take better care of it, as well as find most efficient and effective ways of developing our civilization. The answer to keeping a healthy balance between humankind and nature is a formula that combines three factors, that reinforce each other's strength: Human Intelligence + Digitalized Civilisation + Artificial Intelligence = Hybrid Intelligence. Hybrid Intelligence is not only the key technology of the Fourth Industrial Revolution, it's also a technology that is going to be used in every aspect of one's life.

'What'

Finally, let's discuss manufacturing and address a question - "what will happen".

Hybrid Intelligence is inevitably going to change the nature of manufacturing, as it's going to evolve and become 'smart manufacturing'. The complex production process is going be optimized by being perfectly aligned with market demand. We already know what we need to align (market demand, logistics, etc), what we currently lack is a platform to help us structure, converge and control data there is on it. Once that's solved it will be much easier to create an optimised and effective model of the so-called 'smart manufacturing'. For instance, technology can be used to help create a safer environment in a workplace, help achieve better results by combining human and artificial intelligence and being more proactive, rather than reactive to emerging issues. To sum up, HI will help to restore world's economy, by providing with additional resources and intelligence where needed and ourselves with more time to spend on what we consider important.



Future Computed: AI and Manufacturing

We are fortunate—but also challenged—to live in one of the rare periods in human history when technology innovation sets the stage for dramatic transformation. Fortunate because the rapid emergence of artificial intelligence is creating incredible opportunities to make our lives more productive and address some of humankind's most pressing issues. But challenged because we face difficult new questions about how technology will change our lives and our communities.

While there's no doubt that AI will have a significant impact on every industry, here in the UK, the opportunities are particularly promising for manufacturing. According to "Made Smarter Review," an independent review of the impact of digitalisation on manufacturing published by the Department for Business, Energy & Industrial Strategy, adoption of AI and other key digital technologies could expand economic output by more than £450 billion, improve industrial productivity by 25 percent, and generate more than 175,000 new jobs within the next decade. But because manufacturing is so technology-driven, it is also likely to find itself grappling with the challenges that AI raises sooner than other industries.

Earlier this year, Microsoft published Future Computed: AI and Manufacturing, the second book in our series looking at the current and future implications of AI. Through interviews with manufacturers, workforce experts, and policymakers around the world, we found that the industry is embracing AI but concerned about a growing shortage of workers with the right skills. We also heard that companies want guidance from regulators on the ethical and responsible use of AI, and that governments see vast potential for AI to create jobs and promote competitiveness.

Since the First Industrial Revolution, the UK has been a pioneer when it comes to applying technology innovation to the manufacture of goods. Today, we're in a strong position to lead the world forward in the productive and ethical use of AI in manufacturing once again. Our universities are among the best in the world. According to the Made Smarter Review we have more companies working on AI than Germany, France, and the Nordic countries combined.

So where do we go from here? The Made Smarter Review offers a solid blueprint. It recommends a national skills programme co-funded by industry and government that will enable 1 million workers to improve their digital skills over five years. It also proposes measures to eliminate barriers that slow the adoption of AI and other key digital technologies, including the creation of secure data trusts that can serve as a foundation for AI research and development.

These recommendations are closely aligned with that we learned in researching Future Computed: AI and Manufacturing. Ultimately, to take full advantage of the opportunities that AI presents for UK manufacturers, it will depend on fostering trust that AI solutions are safe and secure, and that the disruptions that AI creates are balanced by the benefits it delivers. Collaboration between industry and government through efforts like the Made Smarter Review is essential to creating the trust that will enable this technology revolution to move forward to the betterment of all.

How Industry 4.0 is advancing Defence Manufacturing

BAE SYSTEMS

Industry 4.0 and the digital revolution are transforming how organisations operate, providing opportunities to realise and apply technological innovations more rapidly, work more productively and efficiently and connect with like-minded organisations across the globe.

All industries will need to take advantage of this revolution and the UK's defence industry is no exception. Successful implementation of Industry 4.0 will support businesses in the defence sector in delivering the most technically advanced and integrated battlespace systems for the land, sea and air domains with more agility, flexibility and at lower cost. Appropriate sharing of timely, accurate and trusted data, information and therefore insight across the defence environment from government, allied nations and with industry is critical to increasing operational effectiveness. This 'force multiplier' could make the difference between winning and losing on the physical or virtual battlefield.

Harnessing Industry 4.0 will also enable the UK's defence industry to continue its critical role in maintaining the UK's sovereign defence capability and freedom of action. This will be achieved through advanced engineering and manufacturing skill-sets and technological-know which are held within a complex and interconnected supplier ecosystem comprising prime contractors, small and medium sized enterprises, start-ups and universities. The digital revolution has already led to significant time reductions in the engineering process – the use of advanced tools we can evaluate numerous designs for components in a matter of hours rather than days in order to find the best design possible. And in the manufacturing process, BAE Systems has been using 3-D printing in Typhoon aircraft production for several years in addition to trialling collaborative robotic (cobot) processes in its shipbuilding and aircraft facilities. These sorts of developments will help maintain the UK defence industry's role as a national asset in a fiercely competitive global marketplace. According to the trade body ADS, the UK's defence and security sectors exported £14bn of goods and services in 2018. On a rolling 10 year basis, the UK remains the second largest global defence exporter after the USA.

So, much is at stake and there is much to gain in delivering Industry 4.0 across the defence sector's ecosystems. Clearly there is some good work underway already - at BAE Systems we are involved in several successful engineering and manufacturing initiatives including Brunel Challenge, MadeSmarter and the High Value Manufacturing Catapults, as well as the Defence Growth Partnership which sees Government and industry striving to enhance the competitiveness of the UK's defence industry in the global market.

We believe however that the time has come to instigate a co-ordinated and concerted strategic plan that is bespoke to the UK defence sector and embraces the needs of Government and the military.

This plan could consider:

- The opportunities that the digital revolution offer to military, MOD, industry and others
- A holistic approach to the implementation of Industry 4.0 across the industrial sector, areas of competitive advantage and critical gaps
- Collaboration with and bringing in best practice from other industries so the Defence Sector isn't "reinventing the wheel"
- The investment needed by Government , industry and universities in necessary technologies and capital equipment
- Requirements for training, reskilling and upskilling
- The alignment of the Defence-as-a-platform (DaaP) initiative which will help to position the UK Defence Sector for continued excellence and growth on the world stage.

The UK defence industry is vital in ensuring our continued security and economic prosperity. We should not take it for granted. A co-ordinated and concerted plan to harness and deliver Industry 4.0 is necessary and we should not delay.

Case Study - Factory of the future for military aircraft manufacturing

Work is underway to create a digital 'Factory of the Future' at BAE Systems' military aircraft sites in Lancashire. Digital work stations will be brought into Typhoon production in 2019, proving the technology in an operational environment and paving the way for future aircraft manufacture. The new digital factory is a result of close collaborative working with a number of academic and industry partners including the University of Sheffield's Advanced Manufacturing Research Centre and Siemens and it builds on existing investments in robotics and aims to drive further productivity, quality and safety improvements into the company's manufacturing capabilities for future fighter aircraft.

The collaborative workstation is fitted with a range of digital technologies that allows engineers to focus on highly-skilled tasks, adding greater value to the manufacturing process. Integrated sensors will identify each worker and automatically load optimised individual profiles using wireless technology – delivering cues and instructions to suit the working expertise of each user and ensuring the role is carried out safely.

The workstation features light-assisted assembly, with 'pick by light' technology prompting the user towards the correct components or consumables during the manufacturing process. It also features a sensor-enabled cobotic arm, to work safely and seamlessly alongside manufacturers building high-tech systems for cutting-edge combat aircraft.

Whilst some of the technologies are already in use today, it is the level of integration that really sets this facility apart. This facility demonstrates a real step change in our manufacturing capabilities that ensure we, as a company and on behalf of the UK, maintain our position as a world-class manufacturer."

Case Study - Augmented reality (ar) and artifical intelligence (ai) in naval combat systems management

BAE Systems is investing £20m investment in augmented reality and artificial intelligence developments to the critical systems that give warships their combat capability. These innovations will help naval personnel improve decision making in the future battlespace and support upgrade of combat systems, helping to maintain operational effectiveness for many years to come and reducing through-life support costs.

Part of the investment will see the integration of AR into the bridges of naval ships, through products such as wearable AR glasses. This will allow an Officer of the Watch, who is responsible for the ship's safety, to work outside of the operations room and still be able to see tactical situation data and other vital information from anywhere on the ship.

This ability could result in information such as the location of friendly vessels or other data being overlaid onto a real world view, giving crews enhanced situational awareness. The use of AR would allow the officer to spend more time maintaining a 'heads-up' visual lookout without the need to refer to a console or rely on clarifications from his crew – instead, taking control of situations with increased effectiveness and adaptability.

The Company is also enhancing the Shared Infrastructure technology it develops on behalf of the Royal Navy by introducing 'open systems' architecture. Open architecture technology will work in a similar way to a consumer 'app store', allowing crews to deploy new capabilities, increasing their flexibility and ability to respond to emerging situations in the future battlespace.

Frank Cotton, Head of Technology, Combat Systems, BAE Systems, said: "These technologies have the potential to transform maritime warfare and greatly increase the situational awareness and efficiency of crews on board Royal Navy ships. Our combat systems expertise and investment in future technologies will ensure we continue to deliver innovative capabilities to navies.

How Banking is Supporting the Manufacturing Sector

Manufacturing is integral to the success of the UK economy, accounting directly for around 10% of UK GDP. Despite the challenges facing the country due to the coronavirus pandemic, manufacturing continues to be a significant contributor to the long-term sustainable success of the UK economy, creating 2.7m direct and around 5m indirect jobs and delivering almost half of all UK exports. Manufacturers are delivering growth and demonstrating agility and resilience.

The July UK Manufacturing PMI from IHS Markit has brought positive news with further signs of stability and output gradually moving into a recovery phase. Our own analysis supports this, with the Lloyds Bank Business Barometer in July seeing an increase in sector confidence of 14 points to -21%, the highest level since March. Additionally, our UK manufacturing export index saw early signs of international demand returning at the end of the second quarter, after falling to an all-time low. It remains difficult to gauge exactly how the sector is performing but it's clear that factors including the easing of lockdown measures and reopening of factories during June and July undoubtedly aided recovery and improved business prospects.

Manufacturing and the Fourth Industrial Revolution

In the current environment, the Fourth Industrial Revolution presents a real opportunity for businesses, whether through digitalisation; the use of big data; or the development of new technology. Initiatives such as the 'Future of British Manufacturing' and 'Made Smarter' and exhibitions like MACH bring together businesses, technology experts, industry leaders and engineers to explore and use specialist technology and digital tools that can, and will, make an everyday difference.

It is essential that businesses are thinking about the importance of the Fourth Industrial Revolution – to invest in these new technologies; improving productivity through better use of data, becoming more innovative and exploring new export opportunities – by doing this they will help drive a sustainable and growing economy.

There is a wealth of support out there. The High Value Manufacturing Catapult (HVMC), built on the German concept of the 'Fraunhofer Institute', aims to bring businesses and experts closer by providing access to seven world-class research centres across the UK. The centres operate some of the most advanced manufacturing equipment in the world and employ teams of highly skilled engineers, many of whom are leading experts in their field. This creates a high quality environment for the development and demonstration of new processes and technologies on an industrial scale.

Recognising that businesses don't stand still in an ever competitive environment, the HVMC centres offer a range of services to accelerate business performance with dedicated experts who can directly assist manufacturers to improve quality, cost and delivery performance. They can introduce a business to tomorrow's technologies and help to de-risk their implementation. This ensures rapid and sustainable growth for businesses by delivering end-to-end manufacturing systems solutions.

Supporting the Manufacturing Sector

Financial support for the sector is vital to allow businesses to invest in these new technologies. As at the end of May, Lloyds Banking Group has provided £3.18 billion cumulative funding against a 2018 – 2020 target of £3 billion. This is in addition to £4.6 billion delivered in the four years to 2017. This funding supports a variety of manufacturing businesses and has been even more important in recent months due to the impact of Coronavirus on the economy.

We have supported a family run business, Quest88, in Shropshire that specialises in manufacturing orthotic equipment and whose products include equipment for the NHS, charities and children with cerebral palsy. When the lockdown started, the business saw a 50% reduction in orders and our £200,000 funding package ensured that they have been able to continue to trade and protect jobs.

Support goes beyond finance to businesses however. We work with the University of Warwick and the Warwick Manufacturing Group (WMG), one of the HMVC centres, to provide manufacturing accreditation to our relationship teams which provide expert support for the sector. So far, over 400 Lloyds Bank and Bank of Scotland colleagues have received the accreditation which provides training in supply chains, operational efficiency and the future of manufacturing. This enables them to help drive innovation with their clients, helping to shape the future of the sector.

We are delighted to be a patron member of the 'Made in Group', and we will be exhibiting at their Backing Britain expo between 17 and 28 August. This year, the expo will be going virtual with webinars, round table discussions as well as many other events. We are working closely with the Made in Group to ensure that the UK manufacturing sector continues to promote itself and share best practice. You can find out how to be one of the 5,000 digital delegates by visiting www.backingbritain.com and register to attend here.

We also continue to support MHA, one of the largest accountancy associations in the UK. MHA's annual report on Manufacturing and Engineering is the go-to review of the sector, benchmarking SMEs across the country to provide a detailed picture of the sector.

Developing Skills in the Sector

Skills shortages remains one of the biggest challenges faced by the sector. That's why we are committed to our sponsorship of the Advanced Manufacturing Training Centre (AMTC), which will train and develop 3,500 engineers, graduates and apprentices by 2024. So far, we have seen 1,508 trained since we started our partnership in 2014.

As one of the seven HVMC centres, the Manufacturing Technology Centre (MTC) develops and proves innovative manufacturing processes and technologies in an agile, low risk environment, It operates in partnership with industry, academia and other institutions and focuses on delivering bespoke manufacturing system solutions for their clients.

Apprenticeship Levy

Attracting and keeping new talent in the sector is essential for its long term survival. In 2019 we announced our commitment to support SME apprenticeships through the government backed Apprenticeship Levy scheme. Between 2019 and 2022 we will transfer up to £3 million to allow small businesses to recruit and train apprentices in sectors such as digital, technology and manufacturing.

We have partnered with the West Midlands Combined Authority, the Greater Manchester Combined Authority and the AMTC to help small businesses find partners who will provide ongoing co-ordination, support and training. These additional levy funds should help small businesses to develop their existing workforce and improve career opportunities for young people.

We're delighted that a second year AMTC apprentice has been named as one of the top 50 women in engineering in the UK. Melissa Chigubu aged 19, has been given the accolade by the Women's Engineering Society at a ceremony at the Royal Academy of Engineering. The award was founded by the Women's Engineering Society in 2016 and aims to address the skills shortage in engineering and highlight the discrepancy between genders entering engineering and manufacturing. Melissa came to the UK in 2012 and was the first female to complete the Foundation Gateway in the AMTC's new Apprenticeship Engineering Standard programme.

Clean Growth

We believe that low carbon growth must be at the centre of the post-pandemic economic recovery. Which is why we're supporting the call from over 200 UK businesses to ensure that economic recovery plans align with the UK's wider environmental goals.

The focus on a green and sustained recovery is driving investment and innovation across the sector, creating new opportunities for growth. Clean Growth Financing allows businesses to invest in smaller improvements with a positive environmental impact, right through to large-scale renewable energy infrastructure.

Dave Atkinson
UK Head of Manufacturing, SME & Mid Corporates, Commercial Bank

Michelle Blayney
Group Ambassador for the South East

Using the power of digital to increase manufacturing productivity

The Institution of Engineering and Technology

Industrial digital technologies offer manufacturing firms step changes which will enable them to create better products, offer customers greater personalisation and differentiation, and get their productivity and profits up.

Manufacturing SMEs seizing the opportunity within these so-called 'industry 4.0' technologies also stand to gain from improved processes, reducing costs, and increased sales.

The Made Smarter Review, set out an excellent blueprint for UK manufacturing to go digital. The Made Smarter North West Pilot is delivering support to manufacturers in the region to do just that.

We at the IET encourage manufacturers to grab this singular opportunity to use the power of digital to specifically target an increase in resource productivity, at the same time as increasing labour and capital productivity. It really is a win-win and will further enhance UK productivity.

Benefits like the 4.5% reduction target in Co2 emissions over the next decade, as anticipated in the Made Smarter Review, will not be achieved automatically, just because we go digital.

Focussing on resource productivity will help us deliver on the Government's commitment to reduce greenhouse gas emissions to net zero.

Our report 'sustainable manufacturing – the next steps' set out an exciting post-Brexit opportunity for UK manufacturing firms to create significant financial, environmental and social improvements.

We fervently believe in the power of collaboration and have been working to encourage manufacturing engineers to come together with environmental and sustainability managers to identify and drive reductions in energy, water, materials and other consumables.

Action on resource efficiency through better data, a skills-based approach and sharing current good practice, are three vital prerequisites to investment in digital manufacturing. Taken together, we passionately believe they will deliver massive gains for the UK economy.

Steve Evans, Chairman, IET Manufacturing Policy Panel with Peter Ball, Sustainable Manufacturing Lead, IET Design and Production Sector Executive Committee.

The IET is an independent charitable institution working to engineer a better world by advancing the engineering community for the benefit of society.

Recommendations to Government

The Institution of Engineering and Technology urges the Government to ...

- Roll-out the Made Smarter programme across the rest of the UK.
- Increase provision of advisory services, peer-to-peer-based industry collaborations and upskilling
- Appoint Government Champions for Industrial Sustainability.

Transforming Manufacturing by Digital Technology and Skills

Part of the High Value Manufacturing Catapult supported by Innovate UK, the Manufacturing Technology Centre is an independent research and technology organisation bridging the gap between university-based research and the development of innovative manufacturing solutions.

Digital technology is improving businesses NOW

Digital technologies are having a real-world impact on British businesses now. Digital solutions developed at the Manufacturing Technology Centre are driving productivity, efficiency, cost reduction and waste reduction in factories around the UK.

Harris RCS, a precision engineering company in the Midlands supplying the aerospace sector, has achieved a 10 per cent increase in its forward order book and made double-digit productivity gains with the help of experts from the MTC.

MTC engineers, working with Harris RCS employees, began by replacing manual set-up processes with a digital solution. They captured data already available and made it visible to all operators so every machine could be monitored in real time. Machines are being connected digitally and a culture of continuous monitoring has been encouraged.

Harris RCS managing director Graham Harris said the solutions arrived at added to the company's reputation for quality and efficiency.

"They took the big data we already had, made it more visible and linked our existing machine assets, building digital assets to make the processes more efficient. We are now able to handle more orders without having to bring in more resources. More importantly, they encouraged a culture of constant improvement. There is a real buzz about the place with our people coming up with new ideas all the time. Now working with the MTC forms an integral part of our strategy for improvement and innovation to meet our customer's evolving needs," he said.

The MTC has also been working with one of the UK's leading packaging companies to develop a revolutionary wrapping system for heat sensitive products from food and perishables to aerosols.

Leading IA and robotics development - even remotely

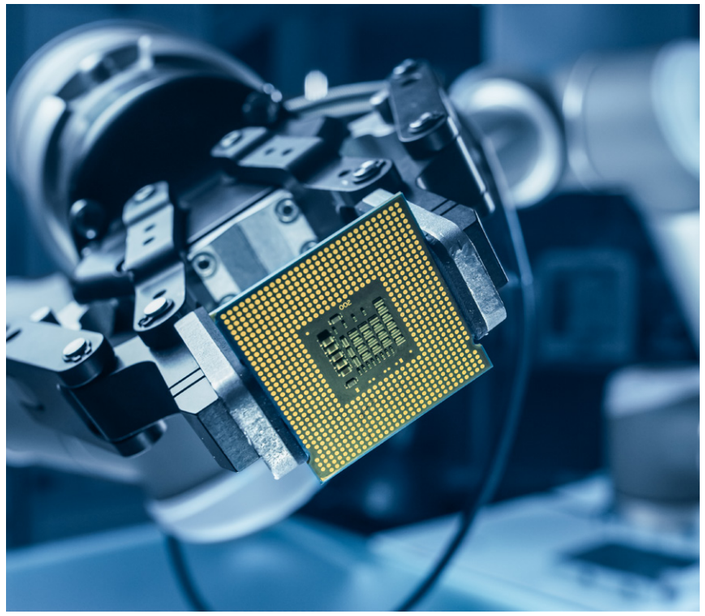
These are just two examples of how the MTC's digital capabilities are transforming businesses now. But the work carries on to develop these technologies further. The MTC has a team of experts to help small and medium businesses get their innovative products to market with the latest technologies and improved productivity. The team helps entrepreneurs and SMEs move from the drawing board to full-scale manufacture, improving their efficiency and productivity along the way.

The MTC is a leader in the application of intelligent automation and robotics, working with companies to apply digital technology to a wide range of sectors including construction, food and agriculture, and much of the MTC's expertise can be accessed by SMEs remotely, saving valuable time and cost. The MTC is recognised as a leader in the field of digital manufacturing, applying tools such as virtual or augmented reality, simulation and factory planning to de-risk investment decisions early in the design process. Overlaying digital designs onto real-world scenarios allows the simulation of complex processes and operations, demonstrating how people interact with machines. MTC staff are working with SMEs, using this technology remotely. It effectively gives those SMEs their own visualisation laboratory connected to a remote expert who they can access on demand

Since its establishment in 2010, the MTC's manufacturing and engineering experts have worked with hundreds of companies to smooth the path of digital transformation, from increasing awareness to delivering full blown solutions. They have introduced businesses to appropriate and innovative manufacturing processes and technologies in an agile, de-risked environment.

Dr Clive Hickman
Chief Executive, Manufacturing Technology Centre

Transforming Manufacturing by Digital Technology and Skills



Long-term initiatives to help the digital journey

MTC technologists are working with companies on a daily basis to help them introduce technology into their factories to help them flourish. One way of helping this process is the "Factory in a Box" developed by the MTC, the University of Birmingham, Loughborough University and a team of industrial partners. The "Factory in a Box" is a modular, remotely-controlled, rapidly deployable demonstrator showcasing how advanced industrial technologies can benefit manufacturers and their supply chains, speeding up their route to market and taking advantage of new business models. The Factory in a Box is also a real world example of how a range of digital technologies can be combined in a system to drive productivity or quality gains in future factories of all sizes.

The MTC has the ability to help companies make big strides in adopting advanced technologies, underpinned by digital systems and appropriate skills. This is helped by the fact that the MTC itself is a leader in the development and application of many of these technologies. An example of this is additive manufacturing, or 3D printing, which is one of the fastest growing areas of advanced manufacturing. The National Centre for Additive Manufacturing (NCAM) is housed at the MTC, bringing together one of the most comprehensive combinations of equipment and capability in the UK. The MTC also leads the £15 million DRAMA project which looks at how digital technologies can help reduce the time it takes to bring a new 3D-printed product to market - particularly in the aerospace sector.

In addition, the MTC has recently launched a national initiative "Artificial Intelligence Hub in Manufacturing", which is a collaborative ecosystem to generate foresight and increase uptake of AI in manufacturing. This Hub will provide a platform to help UK industry understand and demonstrate the future need for AI as a service for manufacturing.

Digital transformation is about technology AND people

Of course the digital factory revolution isn't just about new machines or software. Critically it's also about people with the skills to drive technological transformation. The world's major manufacturing companies need a digitally-enabled supply chain staffed by employees who have the technological skills and knowledge to support an end-to-end digital strategy - a talent pool of people prepared for the changes that technology brings. This is where the MTC's Advanced Manufacturing Training Centre comes in.

This is all part of the MTC's digital strategy; bringing a manufacturing eco-system together that embraces skills, disruptive processes, innovative technology and thought leadership, which combine to fulfil the MTC's stated aim of inspiring Great British manufacturing on the global stage.

Benefits to the UK Economy

Digital technologies don't just benefit manufacturing industries. The technology is transferable and can be applied across almost every sector of the UK economy.

The UK has traditionally struggled to keep up with other industrial nations in terms of productivity. Digitalisation has been clearly shown to increase productivity, as well as improving competitiveness and reducing waste and cost.

Digital technologies require 21st century skills which, when rolled out across schools, colleges, universities and apprenticeships, will result in a highly-skilled UK workforce, further improving the competitiveness of British industry.

Policy issues for consideration:

- Digital transformation is daunting for many small and medium-sized companies. It is important that help is available - both financial and experiential - to aid them on their digital journey.
- New technology requires new skills. Training and re-skilling are vital and the earlier they begin in schools and colleges, the more they will become embedded.
- Disruptive solutions and large-scale collaborative efforts will be required to put the UK at the forefront of future manufacturing

TrakRap

Skelmersdale-based TrakRap has developed an innovative cold-wrapping system which replaces traditional heat shrink-wrapped packaging. Working with the MTC and other partners, the company has made huge savings in energy and material use, and by using digital technology has developed a new machine to cold-wrap aerosols - removing the potential hazard of heat wrapping a flammable product.

MTC engineers, including simulation experts, worked with the company to develop an orbital cold wrapping process which applies a special ultra-thin stretch film to packs which are themselves designed to use less material. The machines to carry out the process were designed, tested and built at the company's premises, working with MTC engineers.

The MTC used Siemens software to inform the design of the machines and simulate their operation in a digital twin. Through the creation of a digital twin they were able to get accurate and detailed information and carry out virtual production runs. TrakRap plans to pair physical machines with their digital twins to allow 24 hour monitoring of performance and efficiency, and enable predictive maintenance. By monitoring constantly, potential issues will be identified early, and it is forecasted this will deliver a 72 per cent reduction in machine downtime.

TrakRap chief executive Martin Leeming said the digital twin approach had been very successful.

"We know the machines work in a way that delivers exactly what we want. In addition to the manufacturing predictability we have gained, time to market has been reduced by 40 per cent and development costs cut by 30 per cent because the physical prototype stage has been eliminated," he said.

He added, "Simulation is the answer and the MTC has all the software necessary, along with the expertise. We now think of our machines not so much as physical entities, but as flexible software platforms that can adapt to different types of environment, product and set-up, enabling us to predict quality, throughput and timescales.

Impact of Fourth Industrial Revolution on manufacturing – Industrial Digital Technologies Making it Smart/Green

Our economy is undergoing a profound digital transformation, powered by a new source of energy: data. This Fourth Industrial Revolution has the potential to transform our lives and our economy, making it more productive, resilient and sustainable.

As we rally together as a nation to address the economic, social and public health impacts of the COVID-19 pandemic, we are seeing at first hand the critical contribution of our manufacturing sector to this effort. Whether it is making the medical devices and protective equipment our hospitals need or keeping us all fed, the UK's makers have played their part.

And this speedy and flexible response has largely been made possible by digital manufacturing technologies. When new medical devices were needed, they were designed remotely and collaboratively. They were tested virtually, using digital twinning techniques. And when disrupted supply chains meant a shortage of critical components coming from overseas, we turned to additive manufacturing processes to 'print' replacements in the UK. This sort of resilience will play a role in the future manufacturing recovery post-COVID-19. There are many lessons we can, and should learn from this.

It is critical that our manufacturing sector isn't left behind in this digital revolution. As with many longer-established sectors, this transformation produces specific challenges for manufacturers – and profound change is required. These challenges are further amplified by the fact that most manufacturers are SMEs: often located in the parts of the country with weaker regional economies, and where the Government is concentrating its efforts to 'level up'. As part of these efforts – quite rightly – the Government and the wider public sector is funding a range of innovation-led programmes to help promote industrial digitalisation. Some of these flow from the 2017 Made Smarter review, including a regional adoption pilot for SMEs in North West England.

In May we published a report Make It Smart: delivering improved resilience and productivity by digitalising our manufacturing base, which looks at the progress made by Made Smarter and other initiatives, and sets out a blueprint for how we can help SMEs right across the country move more quickly to embrace a digital future. In short, we found that the patchwork approach to this issue outside the North West was selling SMEs short – with both gaps in coverage in some places and overlapping, competing initiatives in others. Given this confusion, it's not surprising that SMEs continue to struggle to access the advice, support and finance they need to modernise.

So we think that – as part of the upcoming stimulus package – the Government should commit to supporting all parts of the country to develop co-ordinated, integrated initiatives to help manufacturing go digital. The blueprint is there, and regional bodies such as growth hubs and LEPs are ready and waiting to deliver. What's needed are the dedicated resources to make it happen.

MSM Aerospace, an aerospace fabrication company based in Greater Manchester, is a good example of the Made Smarter Pilot support having a big, practical impact. Having outgrown their current factory it needed to move to new premises, taking the opportunity of the move to redesign and overhaul its production processes. With an integrated package of support from the pilot, it received advice and financial support to develop and invest in a digital twin virtual reality simulation of its new factory. This enabled the company to quickly and easily simulate different options for the layout and operation of the premises, and identify solutions before a single physical alteration was made.

A range of small-scale financial incentives remains important to helping SMEs digitalise, although grants and loans need to be seen as part of the wider picture alongside, for example, fiscal incentives such as tax credits or investment allowances. There are particular issues around the longevity of some of the funding mechanisms currently used.

However, finance is often less of a barrier than, for example, technical awareness or concerns about change management. One good example of a way manufacturers were able to overcome them, is the Knowledge Transfer Partnership programme (KTP).

Brandon Medical, a company based in Leeds manufacturing medical equipment for operating theatres and exporting globally, worked together with The University of Huddersfield through the KTP to implement a fully functioning Smart Cell. The Smart Cell uses bespoke semi-automated hand

assembly, allowing shop floor data collection with zero Quality Control (QC) paperwork required.

The KTP opened up opportunities for the business that were previously not present. It involved attaching a postgraduate student to the company for two years, as well as making available the expertise of relevant academics and the world-leading technology that the University has on site.

Another example is Numatic, a Somerset-based company that produces the famous Henry vacuum cleaners. In 2017, it began a two-year Knowledge Transfer Partnership with the Bristol Robotics Lab (BRL) and the University of the West of England (UWE). At the time they were building the devices entirely by hand. The research and development carried out through the KTP allowed them to introduce a semi-automated production line, using two collaborative robots, or 'cobots'. This increased productivity by 50%, helping to expand exports and pave the way for future product innovation. Key to this success was access to the expertise at BRL, which provided support in design, testing and implementation of the project, and UWE, which provided an electrical engineering graduate to work at Numatic for the duration of the project.

Digitalisation and decarbonisation

The link between industrial digitalisation and the transition to a net-zero carbon economy is increasingly well documented. Technology and data capture and analysis, for example through smart metering, is one of the methods that manufacturers can use to reduce their carbon footprint and energy costs. But too often these agendas are pursued separately – by businesses and government. A greater understanding of the synergies would help with effective implementation of both the industrial decarbonisation and digitalisation agendas.

There is widespread enthusiasm for, and commitment to, increasing the pace and scope of our national efforts to promote industrial digitalisation. And the COVID-19 pandemic has brought home to us all the importance of having a flexible, modern, productive and resilient manufacturing base in this country. So we need to redouble our efforts, ensuring as we recover from the COVID crisis we don't simply return to the status quo ante, but instead take this great opportunity to build back better.

As the organisation representing 20,000 manufacturers across the country, many of whom are SMEs, Make UK is committed to playing its part in ensuring we create a sector which is digital, global and green: able to play its part in delivering prosperity and high-quality jobs right across the UK.

Make UK

Finding manufacturing's digital disruptor

Our entry into the digital age has revolutionised our lives and business operations. While we as consumers have quickly become accustomed to the ease and efficacy of conducting our lives through a smartphone, for businesses, the transition has been more difficult. Many sectors have been radically disrupted by one or two new digital entrants, who have turned well-established industries and business models on their heads. Those slow to innovate are being faced with a stark choice; modernise or die.

While this enforced digitalisation has presented an uncomfortable ride for many businesses, those who have embraced the transformative effects of embracing advanced digital technologies have come out the other side much more efficient – and probably quite thankful in hindsight for being made to consider the benefits of data and technology, and their new found position at the forefront of the fourth industrial revolution.

Identifying and applying the benefits of advanced technology

UK manufacturing is in much the same place that the majority of industries were in before their digital disruptors came along. Manufacturers are still focussed on the same production centric business models that they've been using for decades, and despite a range of new technologies that have the potential to revolutionise their offering to the market and their operations, manufacturers are being slow in realising, and opening up to, the potential benefits that technologies like virtual and augmented reality, 5G and the internet of things, or artificial intelligence, machine learning and blockchain technology can have on their operations.

Listening to those within the sector, there seem to be two dominant reasons for this.

Firstly, the lack of existing use cases. Without compelling proof of ROI, manufacturers still view adoption as high risk. Digital Catapult is working with a range of organisations to help prove the value of these technologies. The Industrial 5G Accelerator for example aims to showcase tangible and relevant examples of 5G in an industrial setting to better demonstrate the business case for 5G in manufacturing and the supply chain.

Secondly, there is some scepticism over whether the solutions currently available are appropriate. Every manufacturing business is unique and can comprise several different systems. To gain manufacturers' trust, technologists need to concentrate on demonstrating how digital adoption can benefit their businesses, rather than pushing a specific technological concept. Digital Catapult's role here, as a technology agnostic innovation centre, is to show the potential of one technology, or cross technology applications, in creating new market opportunities. Our recently launched partnership with TWI Ltd to establish the Industrial Net Zero Innovation Centre in Cambridge is doing just that: boosting regional research and technology innovation, exploiting domain expertise, and demonstrating the benefits of increased efficiency, better optimisation and reduced emissions.

Manufacturers need to stick their necks out and be more ambitious and innovative about how they think of technology, and what it means to be a modern manufacturing business.

The benefits of doing so are manifold. Advanced digital technologies have the potential to verify supply chains, improve trust in the sector, and optimise the value of existing data within manufacturing businesses. They can also assist in improving sustainability by gathering data around the environmental impact of products. Adoption will drive efficiencies that will help keep the UK's manufacturing sector competitive, while bringing a net benefit to end consumers.

Breaking the status quo

Manufacturing is in desperate need of its own digital disruptor to shake up the industry. This disruptive influence will use technology to explode existing business models, leaving competitors no choice other than to follow suit or face extinction.

At present there's a high level of complacency in the manufacturing sector, but manufacturers need to be brave, daring and willing to take on a level of risk if they're to break out of their current digital stalemate. And they don't have to do this alone. Made Smarter is just one example of this; chaired by former Siemens CEO Juergen Maier, it provides businesses in the North of England with access to facilities, funding and expertise, to better understand the impact and benefits of adopting advanced digital technologies.

Finding manufacturing's data disruptor One project that Digital Catapult has recently worked on is the Connected Factory Demonstrator. In partnership with two medium sized manufacturers - Dyer Engineering and Special Metals Wiggin, this project uses IoT technology to improve asset tracking – just one area where there is big scope to improve efficiency.

Tracking a particular asset around a factory (in particular if spread across multiple sites) can be a tricky and manual process, especially if it's a single component of a much larger structure. Finding it involves manually checking records for the location of the asset, which even then is only as accurate as the last piece of data that was recorded. It's only inevitable that parts go missing, especially when there are multiple projects on the go.

In the same way you can now check on your smartphone that a taxi is en route, asset tracking within a factory cuts out the manual coordination of trying to find where an asset is, instead showing its location in real time through a central dashboard. Having access to this information helps to avoid the severe delays that can hold up a project when parts go missing, significantly improving factory output.

Through this activity, amongst others, we aim to supercharge progress towards the technical disruption of manufacturing. Manufacturers are sitting on the brink of digital adoption. Our mission is to remove the fear-factor from taking the leap by demonstrating the incredible value that these technologies can add. You can find out more about Digital Catapult's work in the manufacturing sector at www.digicatapult.org.uk

Nick Wright
Head of Manufacturing Industries, Digital Catapult

Support SMEs, by Supporting Start-ups

Since the Made Smarter report was published in 2017 1, there has been a concerted push from both Government and industry to increase the adoption of industrial digital technologies (IDTs) by the 98.5% of UK manufacturers that are SMEs 2. Before this, the early adopters of IDTs had been large manufacturers (with over 250 staff members) with the resources and capacity to trial new and expensive technologies, to little or no risk to the company. So when the next wave of middle adopters (that have typically been medium-sized manufacturers; 50-250 staff) started to express an interest in adopting Industry 4.0 in the factories, they found that the available technologies were largely unsuitable as they had been developed for the significantly larger early adopters, with little consideration for themselves and other SMEs.

This is a problem, as SMEs as a group have very little in common with large blue-chip manufacturers. They typically have less working capital, less available time, and fewer technical staff available to set-up and utilise new technologies; meaning that technologies that requires months of integration, and weeks of training are unlikely to be adopted, no matter how much they can benefit a business. Employees of SMEs (in particular small and micro manufacturers which make up 91.5% of all manufacturers) typically work to capacity, with little or no time available to perform anything other than their central job roles. So whilst a large manufacturer may be able to trial a technology for several months with a team of engineers, SMEs will only be able to implement a technology once they are sure that it will bring a benefit to their business, without disrupting their production. Technologies for SMEs must therefore be particularly attentive to reducing disruption; by being quick to install or setup, and requiring little or no training where possible. Put simply, IDTs should be plug and play, easy to use, and configurable to manufacturers of all sizes.

An arguable criticism of the current strategy has been to focus on the SME manufacturers as a problem to be fixed, rather than looking at the technology providers and the solutions they offer. We cannot expect SMEs to adopt technologies that are not suitable for them. Instead we should be challenging tech providers to develop more 'adoptable' solutions for SMEs, rather than just focusing on getting SMEs to adopt what is available.

An example of this is the current approach to bridging the skills gap. This gap could be approached in three different ways: by upskilling the workforce, simplifying the technology, or by doing both. Surprisingly, the current single-pronged approach within Industry 4.0 has been solely to upskill workers to use complicate technologies, whereas no real push has been made to encourage technology providers to make their technologies easy to install and use.

Much of the UK population already interact with consumer technologies; 87% of UK households access the internet daily 3, and most of the population own a smartphone (88%), laptop (78%) and tablet (65%) 4. So, if people are successfully using technologies away from their workplace, then why is there such a need for upskilling at work? Put simply, it's because most Industry 4.0 technologies are overly and unnecessarily complicated.

As so many people are comfortable using smart devices and simple internet-based software, we should therefore be looking for solutions that utilise them wherever possible. These are technologies that are already plug-and-play, intuitive and configurable to manufacturers of all sizes, so can bring digitisation to a factory environment without the scare-factor that often comes with new and complicated devices and systems.

Unfortunately however, there is currently a lack of products that follow these principles, and instead provide solutions consisting of bespoke hardware requiring expert installation, and complex software that is clunky to use. There therefore needs to be work done to increase the number of IDTs that can be adopted by SMEs; technologies that are plug-and-play, intuitive and configurable. This is going to become even more pertinent when the next wave of late adopters, that will likely be small and micro manufacturers, begin to explore the possibilities of Industry 4.0 in the coming years.

Part of the problem is that it's the default for new Industry 4.0 start-ups to target the glamorously large automotive and aerospace giants; with few of them even considered the surprisingly large, albeit arguably less glamorous market of SMEs. There therefore needs to be incentives to steer technology providers towards developing SME-friendly products.

The simplest, and most attractive way to do this is to provide early-stage funding, and a robust support network. Furthermore, if these start-ups were located close to a centre of excellence such as the Advanced Manufacturing Research Centre (AMRC), a package of support and access to SMEs could be provided to help tech providers to hone their offering. For example, just £2m could provide eight technology start-ups with a year's funding to develop and launch a product for SMEs; and if they were clustered in or around Sheffield City Region they could be provided with a package of support and contacts from the AMRC, Sheffield Digital, local universities, and even local manufacturers. This would be a neat way to create a small collection of solution providers, that could then flourish into an eco-system of novel IDT providers with SMEs as their focus.

If you want to SMEs to adopt technology, you must ensure that there are the appropriate technologies available for them to adopt. To support SMEs, you must support start-ups.

Dr Joe Handsaker
CEO of Elements Technology

[1] Made Smarter Report (2017), Juergen Maier.
[2] Business Population Estimates (2019), Office for National Statistics.
[3] Internet Access – Households and Individuals, Great Britain (2019) Office for National Statistics.
[4] Deloitte Global Mobile Consumer Survey (2019) Deloitte

One-size does not fit all: How the Fourth Industrial Revolution is making personalised medicine manufacture a reality

The biopharmaceutical industry is undergoing a shift away from "one-size-fits-all" medicines towards personalisation, where treatments are targeted to particular groups of patients or even to individuals. This requires a corresponding shift in manufacturing from large batches to small-scale made-to-order production. Embracing the Fourth Industrial Revolution will enable the biopharmaceutical sector to produce high quality products which meet the strict regulatory standards required when manufacturing complex biological medicines.

What are personalised medicines?

The current approach to drug development assumes that patients respond similarly to a given drug so that all patients receive the same first-line treatment, even though it may only have a 30-60% chance of working for each individual due to differences in the way we interact with medicines. Thanks to advances in genetic sequencing and initiatives such as the 100K Genomes Project, we are moving closer to a future where different groups of patients with the same condition can be identified, and treatment can be tailored to the underlying cause for those groups (stratified), or even to the individual patient (personalised), see Figure 1. A shift to personalised medicine will improve outcomes for patients and enable smarter management of limited resources within the NHS.

Targeted biological medicines

Biological medicines, or biopharmaceuticals, are ideal therapies for personalised treatment of patients since they are designed to interact with very specific targets in a patient's body. This leads to a greater chance of the medicine having the desired effect against a disease and results in fewer side effects as compared to traditional pharmaceuticals. Since targeted biological medicines are structurally much larger and more complex than traditional "small molecule" pharmaceuticals, they are more challenging to make. Potential hurdles to their commercialisation include the time and cost of manufacture, manufacturing efficiency, lack of appropriate large-scale facilities and supply chain costs.

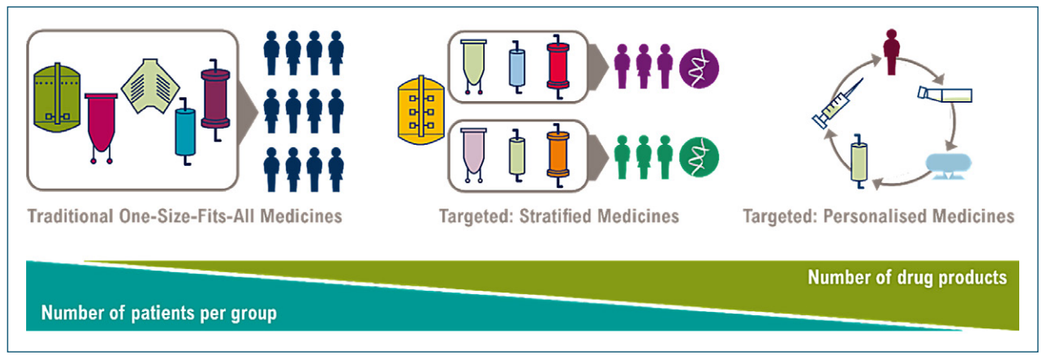


Figure 1: Moving from one-size-fits-all to targeted medicines (stratified and personalised). Source: Future Targeted Healthcare Manufacturing Hub.

[1] Improving Outcomes through Personalised Medicine; NHS England; 2017. See: https://www.england.nhs.uk/publication/improving-outcomes-through-personalised-medicine. [2] For more information on the Genomics England 100K Genome Project, see: https://www.genomicsengland.co.uk/about-genomics-england/the-100000-genomes-project/

Case study - manufacturing personalised cancer treatments

The field of oncology has seen great leaps forward following the availability of targeted biological medicines. New and exciting treatments using antibody and cell therapies are leading to better outcomes for patients and providing options for patients whose cancer would have previously been untreatable. Personalised cell therapies in particular have dramatically improved the prognosis for some patients and have cured some patients of cancer after traditional treatments had failed.

- Product: CAR T-cells for Acute Lymphoblastic Leukaemia
- How do they work? Gene-modified cell therapies are used to treat certain types of blood cancer. Cell therapies work by engineering immune cells (e.g. T-cells) acquired from the patient or a suitable donor and training them to recognise and kill cancerous cells.
- Manufacturing Challenge: The current process for manufacturing cell therapies is long, labour-intensive, prone to contamination and struggles to deal with patient-to-patient variability. This can result in a poor quality product that may not meet regulatory standards.
- How will the Fourth Industrial Revolution address this challenge?: Digitisation can facilitate more responsive processes based on enhanced product and process understanding. Feed-forward and feedback control algorithms will enable us to cope with variability – for example, if a patient's source material cell concentration is lower than expected, an automated system could increase the cell culture time in order to produce the required final number of cells for treatment. Advances in product quality assurance are particularly important for cell therapies, given the serious implications of having a failed batch of therapy – it is often difficult or impossible to obtain a second set of the patient's T-cells to engineer due to the fact the patients are generally significantly immunocompromised.

How does the Fourth Industrial Revolution apply to personalised medicine manufacture?

The Fourth Industrial Revolution envisages factories and supply chains where goods and machines are all connected to the internet, communicating with each other, exchanging, collecting and analysing information, and co-ordinating processes in a distributed fashion. This data-driven integrated system will enable improved responsiveness in manufacturing and will unlock the potential for personalised treatment of patients using biological medicines.

Existing manufacturing strategies and supply chains were designed for one-size-fits-all drugs that utilise large-scale production. Moving to a future with many more drug products targeted to relatively small patient populations (or even individuals) will require new manufacturing and supply chain strategies. To meet patient demands for personalised medicine manufacture, facilities will need to be "scaled out" (several parallel production lines) rather than scaled up and manufacture may even take place in hospital settings "at the bedside". This means that sample traceability, release testing, and facility planning will be critical.

These challenges can be partially resolved through technology; optimum personalised medicine manufacturing processes of the future will be digitally integrated and fully automated, with real-time release testing, standardised procedures, real-time traceability and agile processes . The Fourth Industrial Revolution will act as an enabler for:

- **Quality by Design (QbD)**. The QbD approach aims to ensure the quality of medicines by employing statistical, analytical and risk-management methodology in the design, development and manufacturing of medicines. Digitalisation that leverages big data analytics will facilitate QbD and result in more flexible processes based on enhanced product and process understanding that can be used to adapt the process to manage critical sources of variability (see above).
- **Smart and responsive supply chain management**. Many personalised biological medicines require the use of temperature-sensitive ingredients and their manufacturing takes place on a global scale requiring complex shipping and real-time temperature reports to ensure they are kept cool. Solutions from the Fourth Industrial

[3] Branke, J., Farid, S.S., Shah, N, (2016) Industry 4.0: a vision for personalised medicine supply chains? Cell and Gene Therapy Insights, 2(2), 263-270. http://dx.doi.org/10.18609/cgti.2016.027. [4] See: https://www.ema.europa.eu/en/human-regulatory/research-development/quality-design
[5] For more information on the EMVS, see: https://emvo-medicines.eu/mission/emvs/

revolution will provide real-time visibility and control across complex supply chains from material sourcing through to manufacturing and temperature-controlled transport to patients.

• **Product release processes**. The trend towards more patient-specific therapies will result in an explosion in quality data, batch manufacturing record reviews and an increase in the number of release tests that must be completed. Quality control and assurance functions will need to be more automated, with continuous real-time release methods, to handle larger numbers of patients per year so as to avoid becoming a bottleneck.

• **Enhanced track-and-trace capabilities**. Enhanced track-and trace capabilities enabled by the Fourth Industrial revolution will ensure that patient-specific therapies are tracked needle-to-needle, guaranteeing the chain of custody and ensuring that the correct therapy returns to the correct patient, avoiding potentially fatal errors in shipping. In the European Union, medicines are now packaged with a Unique Identifier (embedded in a barcode) which is uploaded to the European Medicines Verification System (EMVS) along with information on the contents. This means that medicines can be tracked as they make their way from the manufacturer into the supply chain, and finally to the patient.

• **Increased industrialisation**. Technological innovation approaches from the Fourth Industrial Revolution will facilitate a shift from batch processing of biologics to continuous bioprocessing. A "continuous" process is composed of physically connected units with minimal hold volume in between. This means that the process is capable of processing a continuous flow input for a prolonged period of time and remove the need for holding times in between processes that can lead to product degradation in batch processes. Switching to continuous processes will lead to smaller footprint facilities, lower capital investment costs, lower production costs and consistent product quality.

• **"Connected" patients**. Using monitoring devices worn by the patient, real-time patient data would allow automatic adjustment of their treatment (such as time and dosage), or would notify a doctor if it detected that an intervention would be beneficial. It would also allow a much better monitoring of efficacy and could detect potential side effects more rapidly. Reminders sent to the patient could lead to better treatment compliance and medicines could be automatically re-ordered as needed, alerting the manufacturer. Such approaches not only promise improved delivery of the drug, but also lead to higher customer loyalty and retention. With many more possibilities enabled by a connected patient, and radically new business models, this clearly has the potential to change the healthcare industry substantially.

Conclusions

The creation of automated and connected manufacturing solutions, standardisation of procedures across the supply chain as well as real-time traceability has the potential to be game-changing and a critical lever for survival and success for the personalised medicines industry. The willingness of manufacturers, suppliers, hospitals and patients to embrace the Fourth Industrial Revolution will be a key factor in ensuring increased patient access to novel biological therapies in an affordable manner.

About the Hub

The Future Targeted Healthcare Manufacturing Hub is a multidisciplinary EPSRC-funded 7-year project addressing the manufacturing, business and regulatory challenges to ensure that new targeted biological medicines can be developed quickly and manufactured at a cost affordable to society. The Hub forms part of a strategic Government investment to prepare the UK to respond to future manufacturing opportunities.

• For more information about the Hub visit: www.ucl.ac.uk/biochemeng/hub

• To find out more about biomanufacturing, you can read our policy briefing published earlier this year at: https://www.ucl.ac.uk/steapp/sites/steapp/files/biomanufacturing_briefing_jan_2020.pdf

• To find out more about how the Fourth Industrial Revolution will transform the field of bioprocessing, read our paper published in 2016, which was the source for much of this article: Branke, J., Farid, S.S., Shah, N, (2016) Industry 4.0: a vision for personalised medicine supply chains? Cell and Gene Therapy Insights, 2(2), 263-270. http://dx.doi.org/10.18609/cgti.2016.027

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appg

About the APPG

As technologies like artificial intelligence, the internet of things, robotics and process automation, additive manufacturing, augmented and virtual reality, social media, and other emerging innovations continue to converge, our economy and society will become highly networked and increasingly dependent on data.

The All-Party Parliamentary Group on the Fourth Industrial Revolution was launched to encourage pro-active engagement with the policy implications of new and emerging technologies, and to raise awareness of the corresponding challenges and opportunities for Britain's economy and society.

Founded in 2017 by Alan Mak MP, it is now one of the fastest growing and most active All-Party Groups in Parliament. The group exists to bring together Government, parliamentarians, academia, the private sector, and other stakeholders to consider how technological advancement is changing our economy and society, and how political and business leaders can and should respond.

The group also seeks to build a large non-parliamentary community of business leaders, academics, and other individuals interested in technology policy, to connect politicians and advisors in Westminster with industry and academic expertise around the country.

The APPG will continue to reinforce the message that Britain has a once-in-a-generation opportunity to harness emerging technologies to boost economic growth and raise living standards, and that this should be a priority for policymakers.

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