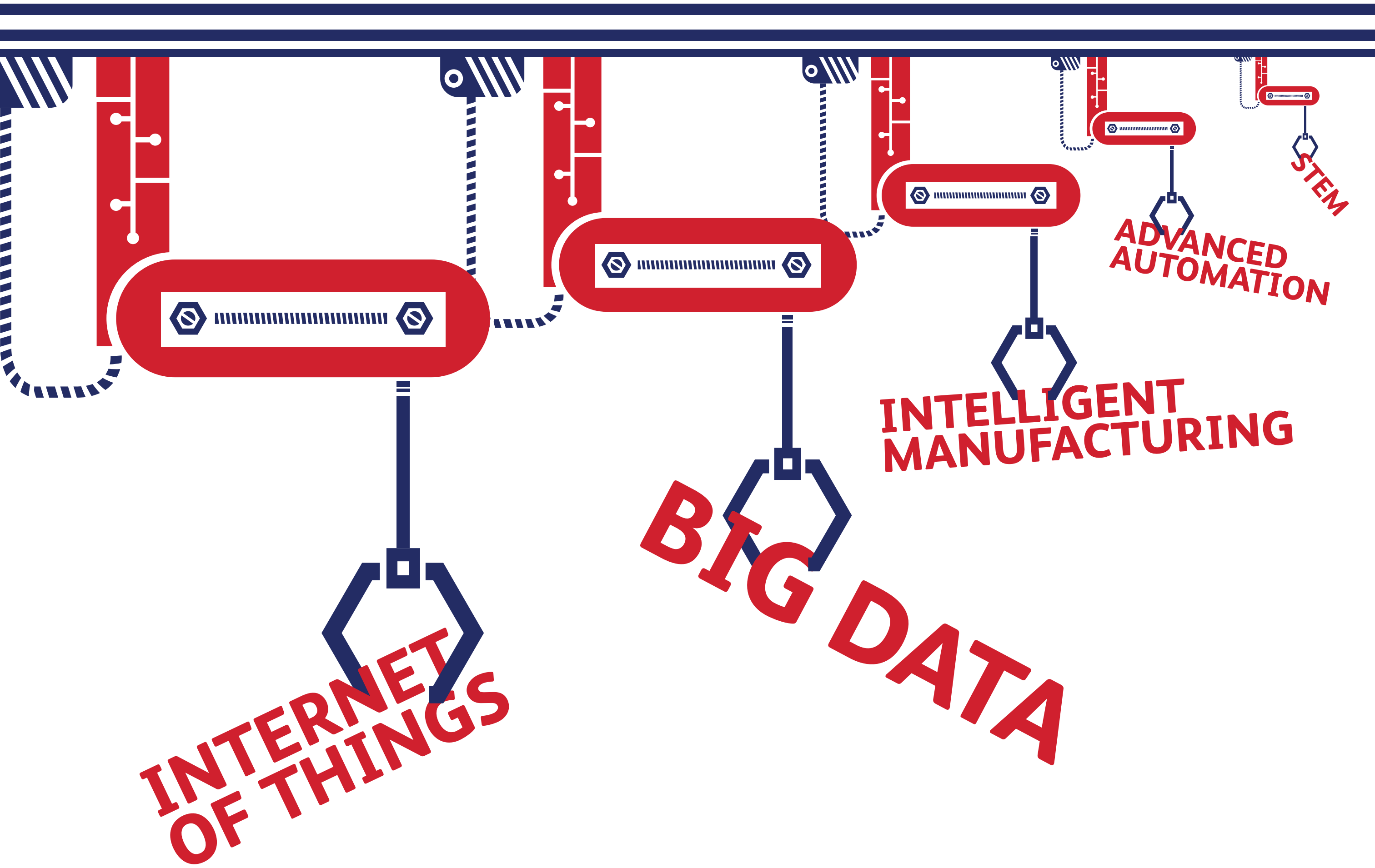
eef The manufacturers' organisation

MAKE IT BRITAIN

EEF - CAMPAIGNING FOR A STRONGER MANUFACTURING BASE



MANUFACTURING BRITAIN'S FUTURE

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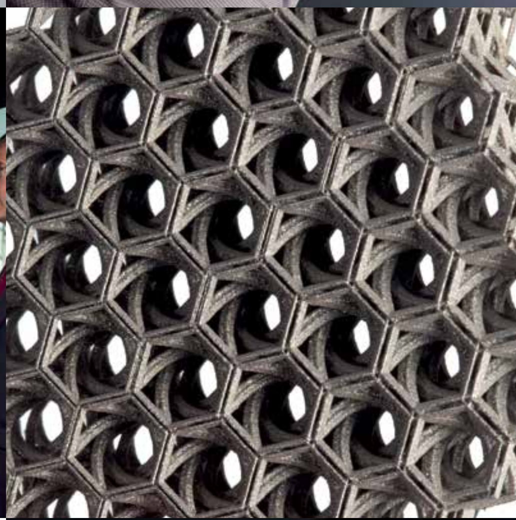





RENISHAW
AM 250
LASER MELTING SYSTEM

Contents

FOREWORD

Pam Murphy
Chief Operating Officer, Infor

We now face the dawn of a 4th industrial revolution (Industry 4.0) as digitisation takes hold. But what makes digitisation so special? It opens up new ways to respond efficiently to customer needs with methods that can fix problems (almost) automatically. How is this done? By converging a specific set of new technologies and strategies, grounded in a customer-centric approach.

Firstly, the development of the Internet of Things and cyber-physical systems such as sensors and wearable technology has enabled machines, computers and even data itself to have an active role in the manufacturing and production processes.

Secondly, the development of Big Data and powerful analytics means that these systems can process huge data sets and that information can be quickly translated to intelligent courses of action.

Lastly, the communications infrastructure on which these 'conversations' rely has become so secure that it can be trusted with business-critical aspects such as production.

Over-arching all of this there are two notable pressures on manufacturers. Firstly, speed: the timeframes for innovation are getting shorter. Secondly, complexity: due to the increased automation and networking, every process has far more 'moving parts'.

From a business perspective there is also the need to recruit, retain and develop a specific set of collaborative problem-solving skills. If Industry 4.0 is grounded in identifying customer requirements and the issues they face, it becomes an inherently collaborative process to solve those challenges. Sadly, many of those skills are still very difficult to find.

Broadly speaking, there are three categories of these challenges: market, business and technology. Market challenges could include the entry of a new competitor or a new geography opening up. Business challenges are typically more 'internal' – a change to the business model, or threats and opportunities presented by partners and suppliers. Challenges presented by technology itself are simply a consideration of the benefits that can arise from better management of the digital components of existing systems.

That management is dependent upon the solid, flexible integration of systems. A standards-based framework that provides the technological foundation to build business processes and workflows throughout and beyond the Smart Factory is critical. Likewise, the interface between people and technology has to be quick, intuitive and reliable.

In addition, change management will be a vital part of Industry 4.0 success. Employees' areas of responsibility need to change from the management of standard tasks to tracking automated processes, detecting errors and fixing them, in order to be able to solve complex problems proactively.

These are challenging goals. Thankfully, Industry 4.0 is less of a 4th revolution and more of an evolution in many small steps that will truly change how manufacturing and industry does business.

Pam Murphy
Chief Operating Officer, Infor

FOREWORD

Terry Scuoler
CEO of EEF, The manufacturers' organisation

In an election year, when thoughts inevitably turn to the future, this report is unashamedly forward looking. Rather than focusing on where British manufacturing is today, this report challenges us all to envisage our sector in 10, 20 and even 30 years' time.

It sets out how the 4th industrial revolution – dubbed Industry 4.0 – is upon us, and how innovative firms can take a lead and help position the UK as a global manufacturing and technology hub. It reminds us that the clever implementation and speedy adaptation of new technology will be a key weapon for our sector in the global battle for dominance.

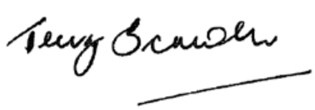
I would go further. The 4th industrial revolution has the potential to change British manufacturing beyond all recognition. It will impact how we make things, where we make things, the relationships we have with our customers and suppliers, and how well we are able to compete. This report provides a powerful vision of our sector's future and the issues we must tackle today if British manufacturing is to remain relevant and continue to be a force to be reckoned with over decades to come.

Some companies, many of which are included in this report as case studies, are at the forefront of this revolution. Their stories are inspirational, but more importantly they will help others to understand the benefits new technology will bring. They are the pioneers of our sector, but many more need to follow, and this will require stakeholders to pull together as never before.

Make no mistake, Industry 4.0 will be a challenge. It will require business leaders to drive change, to invest and to innovate. It will rapidly impact on our industry's skills requirements and will find us potentially competing with the likes of Google and Microsoft for the brightest, most creative and innovative people. The manufacturing landscape will change beyond all recognition and, instead of playing catch-up, government and policy makers must ensure they are ahead of the curve.

We can no longer afford to be short term in our thinking. A visionary future requires a visionary approach. We can no longer think of skills or innovation funding in terms of today or tomorrow – we have to think in terms of our requirements to 2050 and beyond.

Britain is on the threshold of a new industrial age – and the decisions taken by our future successive governments, and indeed by manufacturers themselves, will determine our success or otherwise. This report serves to open up that crucial debate and it is clear that many of its key themes will undoubtedly remain high on the agenda in coming years as the reality of Industry 4.0 sets in.



Terry Scuoler
CEO of EEF, The manufacturers' organisation

INTRODUCTION

EEF's report, 'Manufacturing, Britain's Future', launched at our annual conference on 26 February 2015, is part of our 'Make it Britain' campaign. The report sets out how the 4th industrial revolution is upon us, and how, in the global battle for dominance, innovative firms can take the lead and help position Britain as the manufacturing and technology hub of Europe. Some companies, including those featured in our report, are at the forefront of this revolution. Many more need to follow. Britain is at a crossroads – and the decisions taken now will determine the future success of the sector.

The recent Foresight 'The Future of Manufacturing' report[1] has outlined some high-level issues that will affect manufacturing in the lead-up to 2050, including the implications for the UK government. Together with our sponsors, Infor and IBM, we at the manufacturers' organisation feel it is vital to draw attention to these issues and to raise awareness of the challenges ahead.

We live in a fast-paced, changing world with increasing consumer demands, a need for more efficient sustainable manufacturing and growing competition from the global economy. Advances in technology in recent years are also driving change. Networked and digital systems, increased automation and cloud computing are already transforming our world. The enormous possibilities, offered by the Internet of Things and Big Data, are yet to be taken advantage of.

As the UK continues to grow, a desire to see a rebalancing of the economy means that Britain is currently enjoying a manufacturing renaissance. Our heritage of making things, our innovative outlook, our improving education system and world-class universities, together with our inventiveness, make Britain ideally placed to lead the 4th industrial revolution, also commonly referred to as Industry 4.0. A key consideration, however, must be the education and development of our future workforce, to ensure we have the skills and mind set required, to make the leap forward.

Part one of this report explores each of the drivers for change and the developments that will enable this transformation. In part two we introduce organisations that are already working on sophisticated technologies and are considered to be leading the way. The aim is to demonstrate innovations which are truly in a position to revolutionise the future of manufacturing and to provide knowhow and impetus to companies, government and policymakers, to ensure they create the right skills that will be the foundation of the 4th industrial revolution.

[1]Foresight (2013). 'The Future of Manufacturing: A new era of opportunity and challenge for the UK'. Project report. The Government Office for Science, London.

PART 1

OUR CHANGING WORLD

THE DRIVERS OF CHANGE

The 4th industrial revolution is upon us. In future, resource scarcity, competition from an increasing number of emerging economies and a lack of highly skilled employees could threaten to hamper the success of British manufacturing, in what will be a significant period of change.

Exactly what life will be like in 2050 is, of course, impossible to predict, although we do know that technology is moving at a tremendous pace and we live in a constantly changing world. This is as true for business and industry as it is for consumers. Manufacturers must take a global lead to ensure Britain reaches its full potential and secures our industry's future.

Forecasts suggest that by 2050 the world will be more densely populated, people will live longer and a greater proportion of the earth's population will be wealthier. Inevitably, needs will change, and demand for goods focused on the individual will increase.

OLDER, WEALTHIER AND WISER

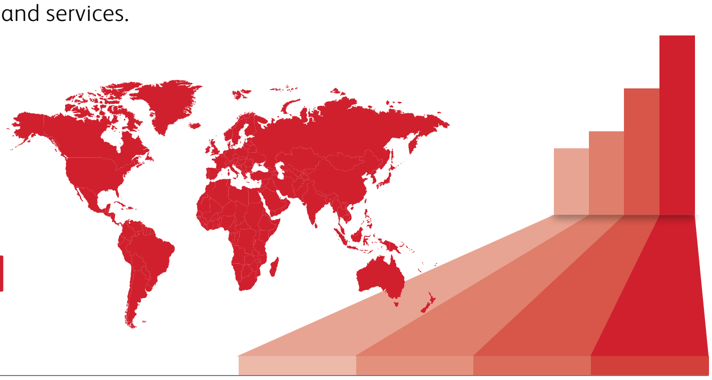
Our population is changing and growing, impacting the way people live and how they demand and consume goods and services. British manufacturers need to be in a position to respond. It is our duty to ensure that future generations have the necessary skills, yet it is critical that we also retrain the existing workforce to meet the continually shifting skills requirements.

The United Nations (UN) predicts that the world's population will grow by 2.4 billion by 2050. It is projected that by 2050, 32% of people in developed countries will be aged over 60, compared to 23% in 2013. However, in the developing world this trend is predicted to be even greater. In 2013, only 9% of the population in these countries was over 60, but this is expected to more than double to reach 19% in 2050.[2]

Across the world, 54% of the population is already living in urban locations, and this tendency is expected to continue: the UN predicts that two-thirds will reside in towns and cities by 2050.[3]

A rise in the middle classes is anticipated, but this trend is expected to be more significant in developing countries. The global middle class population is forecast to rise from 1.8 billion in 2009 to 4.9 billion in 2030.[4] This will result in more people with disposable income to spend on goods and services.

THE WORLD'S POPULATION IS PROJECTED TO GROW BY 2.4 BILLION BY 2050[2]



PEOPLE POWER

The successful manufacturer of the future will be flexible and capable of responding to rapidly changing consumer demand.

As we move towards 2050 we will see a shift towards the creation of individually specified goods. Pressure from consumers means manufacturers will be further driven towards the provision of more personalised products as standard.

A detailed understanding of target audiences will be critical, as knowledge of consumer preferences allows manufacturers to differentiate their products from those of competitors and provide innovative solutions. Going further than this, companies will increasingly need to utilise technology to gain feedback, embedding sensors into goods to collect data on usage and help influence the future development of manufactured products.

Decisions on what to buy either personally or commercially are no longer decided by cost alone: factors such as functionality and quality are considered. Today's customised goods tend to fall into two categories: novelty objects at one end and high-end, high-value at the other – for example, luxury cars. Research suggests consumers in developed countries would be prepared to pay a premium of up to 10% for individualised goods.[5]

We constantly seek improvement, and the more access there is to technological solutions, the higher our expectations.

IN THE FUTURE THE PROVISION OF PERSONALISED GOODS WILL BECOME STANDARD

SECURING OUR FUTURE

Soaring demand from rising populations, resource extraction challenges, climate change and competing demands for land threaten to pose huge water, energy and material risks in the medium to long term. Some commentators claim that to avoid severe climate change impacts, 80% of coal reserves and a third of oil reserves may have to remain in the ground.[6] Meanwhile, the UN estimates that half of the world's population will live in water-stressed regions by 2030,[7] and global demand for water will increase by 55% by 2050.[8]

These pressures threaten to undermine the resilience of supply chains and increase commodity price volatility. Chatham House warned at the end of 2012 that in the future, "resource politics, not environmental preservation or sound economics"[9] will dominate the global agenda.

Governments are already putting in place regulations forcing companies to adapt the way they operate. In the UK, the Climate Change Act commits us to reducing carbon

[2]United Nations, Department of Economic and Social Affairs (2013). 'World Population Prospects. The 2012 Revision. Highlights and Advance Tables'. (Population growth based on the medium-variant projection).
[3]United Nations, Department of Economic and Social Affairs (2014). 'World Urbanization Prospects 2014 revision. Highlights'.
[4]OECD Observer (2012). 'An emerging middle class'. (http://www.oecdobserver.org/news/fullstory.php/aid/3681/An_emerging_middle_class.html), accessed November 2014.
[5]Foresight (2013). What are the significant trends shaping technology relevant to manufacturing? 'Future of Manufacturing Project, evidence paper 6', Government Office for Science, London. (*Research undertaken at Loughborough University*).
[6]McGlade, C & Ekins, P (2015). 'The geographical distribution of fossil fuels unused when limiting global warming to 2°C', Nature 517, 187-190.
[7]UN Water website. 'Water Scarcity'. (www.un.org/waterforlifedecade/scarcity.shtml), accessed 7 August 2013.
[8]WWAP (United Nations World Water Assessment Programme). 2014. The United Nations World Water Development Report 2014: 'Water and Energy'.
[9]Chatham House (2012). 'Resource Futures'. (www.chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20and%20Development/1212r_resourcesfutures.pdf), accessed December 2014.

emissions by at least 80% below 1990 levels by 2050, and the EU is looking to achieve similar cuts. Rules on recycling, pollution and the chemicals found in products are also being progressively tightened. This will affect companies' own operations and bring fundamental changes to the electricity market and wider operating environment. Some institutional investors are already beginning to ask how companies intend to operate under these new conditions.

The successful manufacturers will be those that prepare and adapt to the challenges posed by these trends. The focus so far has been on driving inefficiency from manufacturing processes, but in future companies will need to consider more radical changes to remain competitive in the face of resource constraints and tighter regulation. New feedstocks and business models, and the need for more resilient supply chains, will change manufacturers' relationships with their suppliers and customers.

This might mean products that are designed with reuse, remanufacture or recycling in mind,[1] so that materials are kept in productive loops under manufacturers' control. It could also mean offering services in place of products, changing contractual terms and vertical integration of supply chains. Products might be leased to other companies, maintained, repaired and upgraded through their life and then remanufactured and given a new warranty, using substantially less energy and material than the generation of entirely new products.

For companies that can evolve and develop new products and ways of doing business, these challenges should prove to be an opportunity rather than a threat.

SUCCESSFUL MANUFACTURERS WILL BE THOSE THAT ADAPT TO THE ENVIRONMENTAL CHALLENGES AHEAD

SOPHIE THOMAS
Director of Design, RSA

Our investigations at The RSA Great Recovery have indicated that future manufacturers will need to be nimble and knowledgeable in areas where they have not needed to be in the past. In a time when resource prices are highly volatile and unpredictable, coupled with increased demand from new consumer bases in developing countries, building workforces costs and disappearing skills, things will not be easy. However, opportunity lies in models that move away from the 'take, make, waste' mentality towards more circular systems for manufacturing which the UK has the creativity and ingenuity to develop.

Future thriving businesses will be those that really understand their products' whole life cycle chain; from the materials being dug out of the ground all the way through to the end-of-life, and crucially beyond.

Those that embrace disruptive thinking in the search for new environmentally efficient methods and processes will also benefit. New technologies and additive printing will play a key role for rapid prototyping and reactive testing in markets.

More will be offering services and leasing options that enable the recovery of valuable resources and reusable components and get them back into the manufacturing processes and help build stronger and longer-term consumer relationships.

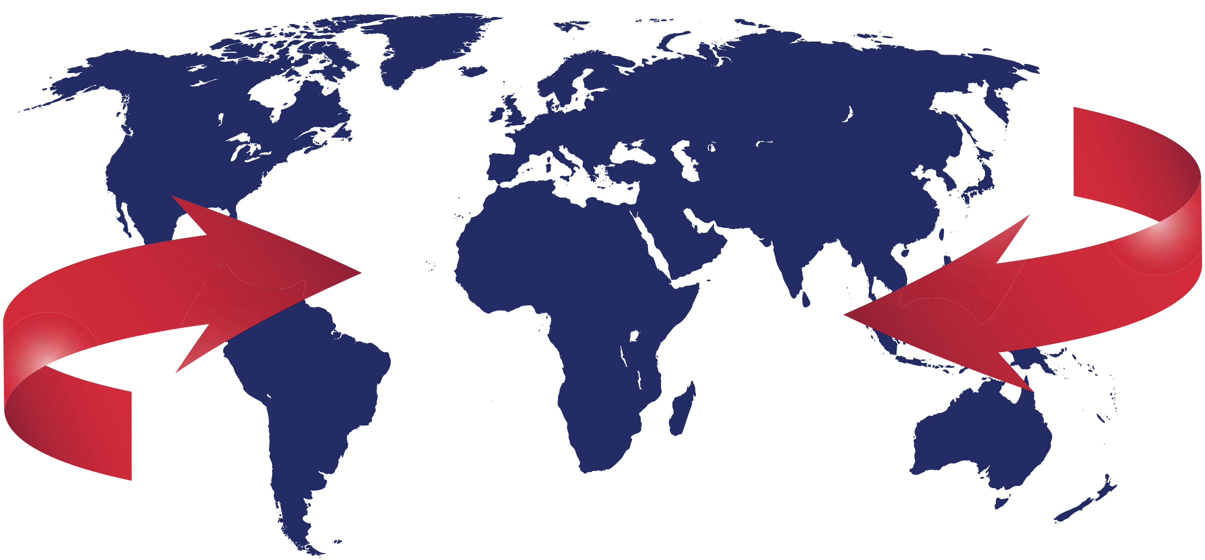
We hope to see a growing number of joint ventures within manufacturing groups and an increased appetite for industrial symbiosis in non-sector-related businesses where companies work together to increase value from their waste streams.

IT IS A GLOBAL MARKETPLACE

The ongoing risk of global competition means British manufacturers must work to stay ahead.

Emerging markets are set to grow at a much faster rate than advanced economies. It is an accepted fact that many emerging economies, such as the BRIC countries (Brazil, Russia, India and China), have become increasingly competitive locations for manufacturing over the past decade. However, these economies also bring opportunities in terms of markets to sell to, as fast growth shifts their economic model away from exports and towards consumption-led growth. For example, British exports to China have increased by 500% since 2003.[10] The ability to target high-demand countries and the flexibility to diversify export markets will be key for British manufacturers going forward.

But today's fast-growth emerging markets will become tomorrow's developed economies. British manufacturing must retain its competitive edge in the production of R&D-intensive high-value-added goods against the emergence of new low-cost manufacturing locations such as the MINT countries (Mexico, India, Nigeria and Turkey). Ultimately it will be our high-end, high-value manufacturing that keeps Britain in the lead.



[10]UKtradeinfo (https://www.uktradeinfo.com/Statistics/BuildYourOwnTables/Pages/Table.aspx), accessed January 2015.

TECHNOLOGY TURNS SCIENCE FICTION INTO FACT

The 4th industrial revolution will be technology driven. Manufacturers must engage with academia, government and each other to embrace these changes. In addition, the ability to capture and effectively utilise data to enhance knowledge and understanding will be key for British manufacturers. Advanced automation, intelligent manufacturing, the use of innovative approaches, such as virtual reality and additive manufacturing (also known as 3D printing) are all gathering pace in our sector. Embracing and using these technologies to their advantage will ensure that manufacturers can meet the challenges ahead. This, combined with a focus on digitisation, the Internet of Things and Big Data will act as an enabler to drive the changes needed in industry in the decades to come.

Looking ahead to 2050 and beyond, our industry's future will also depend on a highly skilled, technologically advanced workforce to propel it to success.

AUTOMATION AND COMMUNICATION

It has been 56 years since the first industrial robot, Unimate, was developed by a US company.[11] Two years later the 2 ton robot was used on a production line at General Motors to perform the repetitive job of moving hot sections of diecast metal. From the outset, robots have been used in manufacturing for repetitive tasks and those that require a high degree of consistency and performance, as they do not get tired and they do not lose concentration. They are ideal for employment in areas of work deemed unsafe for humans, such as moving heavy objects or working in harmful environments.

It did not take long for robots to infiltrate the factory. According to the International Federation of Robotics[11] by 1973 there were around 3,000 industrial robots in operation globally. By 2011 that figure had hit 1.1 million.

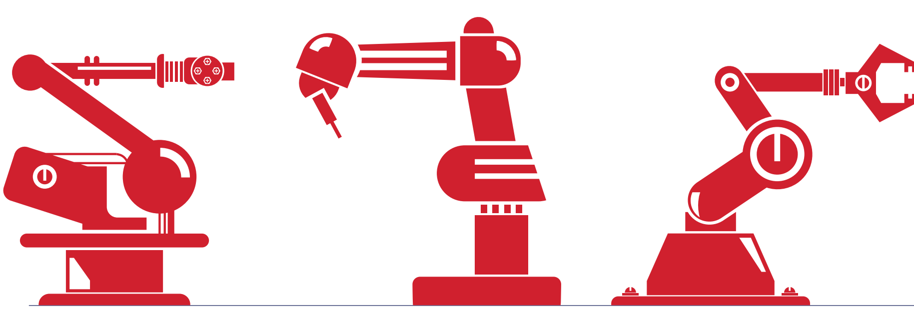
Advances in robotics are moving at a fast pace. We are already building robots to be more focused on human capabilities, with the ability to sense, feel and recognise objects. The next generation of robots is likely to be easier to train, having the ability to learn and remember. Like humans, they will learn from physical demonstration[12] and be able to share their knowledge and interact with one another.

Circuit Board Manufacturing, taken by Simon Mackney at Peak NDT in Derby, shortlisted for the Professional Photographer category in the EEF Photography Awards 2012 in partnership with Canon, Lombard, ERA Foundation.

Already as robots are advancing they are being entrusted with more intricate and complex tasks. In future they will be capable of communicating among themselves and working autonomously. Although the next generation of robots will inevitably replace some of the human workforce, additional jobs will be created to develop, programme and maintain these robots. Furthermore, the increasing sensitivity of collaborative robots means they will be suitable and safe enough to work alongside human colleagues.

Perhaps unsurprisingly, the automotive industry is "the most important customer of industrial robots",[13] with more than 69,000 installed worldwide across the sector in 2013. However, it is likely that Britain's wider manufacturing industry will get in on the act and start considering how they can use these new breeds of robots to improve their processes.

[11]International Federation of Robotics (2012). 'History of Industrial Robots'. (*The first industrial robot was developed by Unimation in 1959*).
[12]PwC (2014). 'The new hire: How a new generation of robots is transforming manufacturing'.
[13]World Robotics (2014). 'Industrial Robots', Executive Summary.



ROBOTS ARE ALREADY BEING BUILT TO BE MORE FOCUSED ON HUMAN CAPABILITIES

SENSING A CHANGE

Sensors are already built into most products that form part of our everyday lives, and go unnoticed. Defined in the Foresight 'The Future of Manufacturing' report as "miniaturised devices which measure a physical, chemical or biological variable and convert it, usually into an electronic signal,"[1] they monitor performance, report on conditions, control our environment and feed back on usage. These are just a few examples of the things sensors help us to achieve.

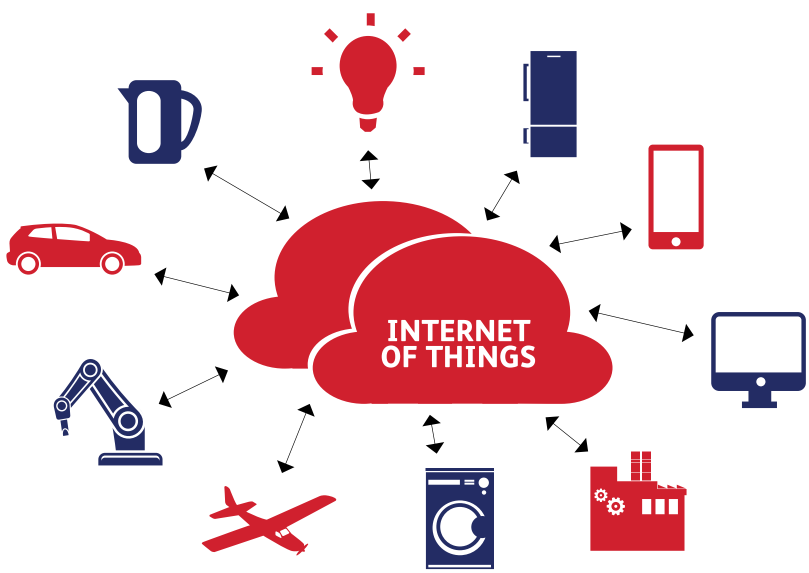
The connection of all of these embedded sensors to the internet and the linkage of these devices so that they can communicate with one another, opens the door to a whole range of exciting possibilities. Commonly referred to as the 'Internet of Things', this is a world where physical objects are connected and communicate with one another via networked systems.

British companies are already putting embedded smart sensor technology to use – for example, aerospace giant Rolls-Royce has embedded sensors into their jet engines. These sensors feed back real-time data about their condition and status to the manufacturer. Rolls-Royce are then able to advise airlines of any potential maintenance issues, improving safety and operating efficiency and preventing breakdowns.[14]

Another example is that of British technology developer ARM which has implemented its own chip technology at its headquarters in Cambridge. Hundreds of sensors enable them to control and maintain their heating and adjust the external lighting, thus saving money and energy.[15]

We will see real change and development in the coming years, with more collaborative working, wide-scale adoption of the Internet of Things and increased ability to connect. However, the speed of change is reliant on finding cost-effective, energy-efficient sensors that take advantage of new ways of harvesting energy. Progress is underway – for example, British company TTP Group is already developing battery-free ultra-low-power sensor technology to "…add connectivity and intelligence to everyday dumb objects such as medical implants, supermarket labels and engineering components."[16]

EMBEDDED SMART SENSOR TECHNOLOGY OPENS THE DOOR TO A WHOLE RANGE OF EXCITING POSSIBILITIES



THE BIG DATA CHALLENGE

There are also other challenges which must be overcome. Firstly, the ability to manage and effectively utilise the vast volumes of data that these sensors collect. Connected objects will gather huge amounts of information which will be too large to be handled by today's data-management tools. The creation of algorithms will be essential in order to manage and analyse this Big Data, thus enabling companies to understand the information, interrogate it and further optimise performance and processes.

Secondly, like people, machines need a common language to communicate effectively, so standards need to be developed and agreed.

Once all of this data has been collected, the next challenge is to ensure that it is kept secure. Improved data security and encryption technology is required to safeguard against cyberattack. Regulations and legislation must also protect intellectual property rights. Finally, for networked manufacturing to succeed, we must have international cooperation on the freedom and sharing of information across borders.

The future is a networked world where billions of devices will be connected. In fact, the possibilities are infinite, to the extent that it is difficult for us today to even contemplate the opportunities of tomorrow. According to Gartner, there could be 26 billion devices networked on the Internet of Things by 2020,[17] compared to the predicted 7.3 billion smartphones, computers and tablets expected to be online.

At the next level, the technology could allow factories to be established anywhere in the world and elements of an operation to run independently without the need for human interaction.

Ultimately, the Internet of Things will bring greater knowledge and influence to British manufacturers. It will allow them to understand the journey of a product from supplier through to the end customer. Just imagine sitting in an office in Britain and being able to monitor and control whole manufacturing operations across the world.

THE ABILITY TO MANAGE AND ANALYSE BIG DATA WILL BE A KEY CHALLENGE FOR THE FUTURE

[14]Royal Academy of Engineering. Innovation Now. 'Rolls-Royce: Trent Engines'. (http://innovationnow.raeng.org.uk/innovations/default.aspx?item=15), accessed December 2014.
[15]ARM (2013). 'ARM to bring the Internet of Things to life at its Cambridge Campus'. (http://www.arm.com/about/newsroom/arm-to-bring-the-internet-of-things-to-life-at-its-cambridge-campus.php), accessed November 2014.
[16]TTP Group (2013). Press release. 'TTP connect the Internet of Things'. (http://www.ttp.com/news/2013/06/TTPandIOT), accessed November 2014.
[17]Gartner (2013). 'Gartner says the Internet of Things installed base will grow to 26 billion units by 2020'. (http://www.gartner.com/newsroom/id/2636073), accessed November 2014.

PAM MURPHY

Chief Operating Officer, Infor

The last few years have witnessed an impressive resurgence for UK manufacturing. The 11th largest manufacturing nation in the world, the UK is seeing average productivity increases of 3.6% – two and a half times greater than the UK economy as a whole. Global demand for quality UK-built products is currently at an unprecedented level in the automotive industry, according to the SMMT, as investments from government and industry continue to boost the sector.

In parallel with this, manufacturing technology has advanced at a rapid rate, and in its wake is creating even greater opportunities to expedite this growth. Only a few years ago the Internet of Things and 3D printing were viewed as more sci-fi than factory floor. Today they are recognised as tangible disciplines, with 2014 representing a stage for an increasing number of high-profile examples. Few could fail to be impressed by NASA sending 3D printed tools up into space, and by Infor customer BAE Systems creating 3D printed parts for its Tornado fleet, or by another Infor customer Renishaw 3D printing a metal bike and metal parts for the BLOODHOUND supersonic car. While these might seem a far cry from the day-to-day operations of a manufacturing plant, they highlight the enormous potential for manufacturers to reduce maintenance and distribution costs, speed up production and drive innovation.

Similarly, the volume of data being created worldwide is exploding into numbers we don't even recognise, and while managing it poses something of a conundrum for many, the opportunity offered by harnessing and contextualising this data within an organisation is immense. Better information means more informed decisions, which inevitably leads to greater insight and control over the direction of a business.

But some barriers continue to prevail. While the UK has become a beacon for global manufacturing, its adoption of technology doesn't necessarily follow suit. For example, it is the lowest user of industrial robotics among the technically developed nations in Europe, and many hold the view that even greater potential could be realised if greater investment were to be channelled into this area alone. Similarly, while some eagerly embrace the benefits that new technology offers, others take a short term view, or dismiss these as fads which are distracting to the core business of production.

Of course, a degree of caution is important. These are big initiatives, and prudence must be exercised in making decisions about how to invest, and what and where to invest in. But we are at a key tipping point whereby revolutionary new technology is available to create large-scale leaps in exploiting growth. 'Business as usual', or simply doing nothing, just aren't options.

The winners will be those who deploy considered strategies as part of cultural change which embraces technology as part of the DNA of manufacturing. Those manufacturers who sit back and dismiss new technology will gradually become less competitive, lose their edge and ultimately fall behind in this new technological race.

VIRTUALLY HERE

Manufacturing is tangible, involving people, machines and materials. However, some companies are undertaking an ever-increasing range of tasks in the virtual world, going beyond techniques such as computer-aided-design to a world more familiar to those who play online games. As a result of collaborative working with academia and innovation centres, manufacturers are benefiting from the huge advances in virtual reality that have been developed in the gaming industry.

The factory environment is an ideal place to use this technology as it can really harness the benefits of this approach. A simulated world allows companies to interact with 3D objects or virtual situations using sensor fitted helmets and glasses, or even gloves and suits. Companies' designs can be honed virtually pre-production. This can reduce the need for physical testing of products and the development of expensive prototypes. It also provides the opportunity to examine the consequences and impacts of various 'what if' scenarios without having to create the situations in the real manufacturing environment. Therefore, flaws and potential issues can be spotted pre-implementation.

Virtual reality has the potential to be used in other ways – for example, to map alternative factory layouts and work out the optimum location of equipment. Material flow can be simulated to understand how it will move through the system and if there might be bottlenecks to address or improvements to be made. These simulations provide an alternative to real-life disruptive and costly experimentation on the factory floor.

The technology also provides companies with a new way to train staff, allowing individuals to learn in a virtual environment.

Technology is advancing all the time, and organisations are investing in fully immersive virtual laboratories or suites. These environments enable users to enter a virtual factory and interact with and manipulate the created world or objects in a very realistic way. Some are even using this method to create avatars to act out the processes and procedures.

This innovative approach has already become standard in the UK automotive sector (an example of which you will see in our case study of Jaguar Land Rover's Virtual Innovation Centre), and is increasingly being implemented in other industries such as aerospace and defence. BAE Systems has built 'visualisation suites' across their sites in Glasgow, Portsmouth and Bristol. These suites enable the engineering teams to virtually build and test the design of Royal Navy warships before construction.[18]

In terms of costs and safety, the benefits of virtual modelling and simulation are clear. They can save time, save money, increase efficiency and reduce risk. Another advantage that users are seeing is the ability to engage with their suppliers and customers at an earlier stage of development. Stakeholders therefore have greater involvement in the process, which creates a better relationship and arguably a better, more customer-focused product.

Every British manufacturer needs to prepare for a future that will increasingly involve virtual as well as physical realities as a means to develop and test products and even train their workforce.

THE FACTORY ENVIRONMENT IS AN IDEAL PLACE TO UTILISE VIRTUAL REALITY

[18]BAE Systems (2014). 'Virtual reality technology transforms design of UK warships'.

FACTORIES' FLEXIBLE FUTURE

As we move into the 4th industrial revolution and beyond, factories will need to become more flexible and reconfigurable in order to enable manufacturers to meet changing customer demands and requirements. Manufacturing operations are going to need to be able to switch between the production of different components and one-off parts efficiently and effectively with the minimum loss of time.

The Foresight 'The Future of Manufacturing' report[1] suggests that factory locations are set to become more diverse. They believe that in the UK this is likely to include smaller hubs, with factories increasingly located in urban areas, thus nearer to their markets. Additionally, technology such as additive manufacturing will allow operations to become more mobile and to locate closer to demand. At the other extreme, there will also be larger "more capital intensive super factories"[1] which will produce complex products.

PRINTING SHAPES UP MANUFACTURING

Already, additive manufacturing is a game changer. Did you know, for example, that more than 30 different components on the Boeing 787[19] are produced using additive techniques, or that there are more than 10 million hearing aids in circulation[20] made using these technologies? The global market for additive manufactured products and services is growing rapidly. It was worth just over $3 billion in 2013,[21] and it has been predicted that the sector could be worth in excess of $100 billion per annum by 2020.[22] Yet this is only the start.

Additive manufacturing, also known as 3D printing, has been born off the back of rapid prototyping and is where objects are built up gradually layer by layer. It differs from many traditional subtractive manufacturing techniques, which remove material to create objects. Materials that can currently be used within additive manufacturing include polymers, ceramics and metals, typically in wire and powder formats. The process generally starts with a 3D CAD model of the part to be produced. This is then sliced into layers before being sent to the additive machine for manufacture.

However, 3D printing is for more than just prototypes. Although yet to be used in mass production, it is being utilised to create both parts and finished goods. In one process, extremely complex shapes can be produced from scratch. As the designs are printed, little or no extra material is used in the creation,

$ IT IS PREDICTED THAT THE ADDITIVE MANUFACTURING SECTOR COULD BE WORTH IN EXCESS OF $100 BILLION PER ANNUM BY 2020[22]

Stand Proud, taken by Kristofor Green of the BLOODHOUND Project visiting Walsall College, shortlisted in the Amateur category of the EEF Photography Competition 2014 sponsored by Lombard, Canon and The ERA Foundation. 3D printing has been used to produce parts for the BLOODHOUND supersonic car.

allowing the objects to be as lightweight as possible, significantly reducing waste and over-production.

Unlike traditional manufacturing techniques, no tooling is required, resulting in further cost savings. Additionally, companies can print to demand, so fewer spare parts will need to be stored or purchased.

A real bonus of this approach is the ability to make complex and customised parts. Components can be manufactured in hours rather than weeks, thus enabling a speedy response to customer demand. The 3D printer can also be placed at any location, as the data files of the objects can be sent electronically.

According to the Royal Academy of Engineering, 3 of the fastest-growing areas for this technology are automotive, aerospace, and medical and dental.[23]

British defence manufacturer BAE Systems has produced metal and plastic parts for RAF Tornado aircraft[24] using additive manufacturing processes. This has the potential to significantly reduce the RAF's maintenance and service bill. The production of protective plastic covers for radio equipment, for example, could save £1.2 million in manufacturing costs over a 4 year period.

Recognised standards, improved software and increased speed of high-volume production are all needed to ensure that 3D printing becomes widely commercialised. However, these hurdles will undoubtedly be overcome, and there is no doubt that 3D printing will be an integral part of manufacturing's future.

[19]MIT Technology Review (2011). 'With 3-D printing, manufacturers can make existing products more efficiently and create ones that weren't possible before'. (http://www.technologyreview.com/featuredstory/426391/layer-by-layer/), accessed November 2014.
[20]Forbes (2013). '3D printing revolutionises the hearing aid business'. (http://www.forbes.com/sites/stevebanker/2013/10/15/3d-printing-revolutionizes-the-hearing-aid-business/), accessed November 2014.
[21]Wohler's report 2014. '3D Printing and Additive Manufacturing state of the industry'. Media release (http://wohlersassociates.com/press63.html), accessed November 2014.
[22]Additive Manufacturing Special Interest Group (2012). 'Shaping our national competency in Additive Manufacturing'. (Data extrapolated from Wohler's report 2012)
[23]Royal Academy of Engineering (2013). 'Additive Manufacturing: opportunities and constraints'.
[24]The Institution of Engineering and Technology, Engineering and Technology Magazine (2014). '3D printing to transform aerospace manufacturing'. (http://eandt.theiet.org/news/2014/jul/3d-aerospace.cfm), accessed November 2014.

NOW YOU SEE IT; MANUFACTURING MATERIALISES

As manufacturing moves into the future, its progress is intrinsically linked with improvements in material sciences. New developments mean we are a step away from the use of highly advanced and innovative materials. For example:

Graphene: a 2-dimensional material that consists of a single layer of carbon atoms arranged in a honeycomb structure. It is almost one million times thinner than a human hair and a far superior electrical conductor than copper. Incredibly lightweight, strong and extremely elastic, it is also waterproof and can conduct heat better than any other known material. The first samples of pure graphene were produced at the University of Manchester in 2003. Potential uses for graphene are in flexible electronics and lightweight composite materials. Graphene paint could provide an impermeable and chemically resistant coating to protect metals against corrosion.

Metamaterials: engineered materials, created to have properties that do not exist in nature. The atomic structure of the material is engineered so that it interacts with electromagnetic waves (e.g. light, radio waves and microwaves) in a different way. These metamaterials could theoretically be used to guide light around an object, which would render the object invisible to the eye, potentially making cloaking devices a possibility. They could also be used to manipulate microwaves, which could help conceal planes from radar.

Nanomaterials: typically defined as having at least one measurement below 100 nanometres (one nanometre is one millionth of a millimetre). They are developed to have modified or enhanced properties over materials without nanoscale qualities. This encompasses things such as increased or improved magnetic or optical performance, strength, conductivity and chemical reactivity. Nanomaterials are already in use. They include water-repellent, antibacterial, wear and scratch-resistant surface coatings. Active nano-coatings could also be applied to products which are sensitive to factors such as PH, temperature, light and chemicals.

BRIAN HOLLIDAY

Managing Director, Siemens Digital Factory

The long-term opportunities for our manufacturing sector are significant. In the next 20 years there will be a productivity revolution which will manifest itself through the greater uptake of digital and automation technologies. Advanced manufacturing, and the high levels of investment that have been spearheaded by the automotive and aerospace industries, will take root in sectors that have traditionally underinvested. With that we will see the arrival of smart supply chains and even greater domestic production – which in turn will result in the reshoring of more manufacturing to Britain.

The biggest change in the way we as industry need to work will be the need to embrace the full effects of mass customisation – which will be fuelled by the growth of a global middle class that will crave increasingly tailored manufactured products – from phones to cars.

What will this mean? It will mean factories need to mass produce different goods on the same production lines – which will require a huge shift in how we do this, not just in the UK but globally, too. Why is this exciting? Because if we get it right, we could be in the driving seat of a new industrial revolution which could create skilled jobs, build on domestic design strength and help us capitalise on the new production paradigm.

Sphere Inspection, taken by Stephen Allen at MBDA Lostock, shortlisted in the Amateur category of the EEF Photography Awards 2010 sponsored by Canon. An MBDA apprentice. MBDA is a high-tech innovation-seeking company whose successful future depends on its young people.

BRITISH MANUFACTURING’S FUTURE SUCCESS WILL STEM FROM SKILLS

Highly skilled individuals are vitally important to the future of British manufacturing, and technological developments are likely to have a particular impact on skillsets within the industry – for example, advances in technology will lead to the automation of many manual processes. Increases in productivity means that manufacturing employment is predicted to decline by around 170,000 by 2020.[25] That said, the retirement of aging workers alone will result in a need for nearly 800,000 jobs[25] to be filled across the same period. The challenge will be to find highly capable individuals to fill the future jobs in the sector.

The demand for STEM[26] qualified individuals is well reported and is set to increase in prevalence as job roles evolve and adapt to advances in technology. A report by the Royal Academy of Engineering, for example, identified a requirement for more than 100,000 STEM graduates per year until 2020.[27] The new and emerging technologies will also require a workforce with advanced skills to engineer in both the virtual and the physical worlds. Roles in supporting areas, such as cyber-security, will become increasingly important as manufacturing becomes ever more digitised.

MANUFACTURING NEEDS:

- Knowledge based workers with hybrid skills encompassing commercial and technical as well as problem solving capabilities
- Highly skilled employees with in-depth product and advanced ICT knowledge
- Individuals with skills in cyber-security
- Increasing numbers of technicians, engineers and scientists
- Increased diversity across the sector, allowing manufacturing to draw on the huge pool of untapped talent

If Britain is to lead the 4th industrial revolution there is no time to delay. It is essential that future skill needs are considered today. Without the right skills and people in place, there is a risk that British manufacturing will not be able to take full advantage of future opportunities. As The Institution of Engineering and Technology points out, “Without the skills today, the chance of creating the jobs of tomorrow is substantially reduced.”[28]

[25]Foresight (2013). ‘What type of future workforce will the UK need?’. Future of Manufacturing Project: Evidence Paper 36, Government Office for Science, London
[26]STEM: Science, Technology, Engineering and Mathematics
[27]Royal Academy of Engineering (2012). ‘Jobs and growth: the importance of engineering skills to the UK economy’.
[28]The Institution of Engineering and Technology (2014). ‘Ones to watch. Six fast growing industries that will drive the future employment of engineers and technicians in the UK’.

VERITY O'KEEFE

Employment and Skills Policy Advisor, EEF

While it is difficult to predict the exact requirements beyond 2020, we can already identify the range of issues that are likely to influence the demand for skills in the future. These factors can help us build up a picture of the potential skills requirements beyond 2020.

The implementation of new technologies and the ongoing trend towards high-value goods and services mean that lower-level jobs will continue to diminish. Manufacturers will need to increase investment to retrain existing employees and keep up with new processes. Companies will be seeking employees who have more than just technical competencies and generic skills: they will require them to have both in-depth product and advanced ICT knowledge. Moving towards high-value goods will mean at least a continued, if not increased demand for technicians, potentially in a management capacity. Acquiring skills through apprenticeships will become even more important, with the focus on ensuring that training provision meets the changing demands of manufacturing.

Developing the right talent pipeline will be crucial. With a focus on higher-level skills to fill professional roles, we will need scientists, technologists and engineers as well as technicians. Employers will demand a mix of vocational and academic prowess from prospective candidates. We are already seeing an increased focus on programming and coding within the national curriculum: these skills will be essential to the future manufacturing sector. From school to college to university, employers need to input into the development of the syllabus. This way we ensure that the needs of our fast-moving industry are met. Only by being one step ahead can manufacturers prevent skills shortages from hampering their growth ambitions in the future.

PART 2

COMPANIES REVOLUTIONISING THE FUTURE OF MANUFACTURING

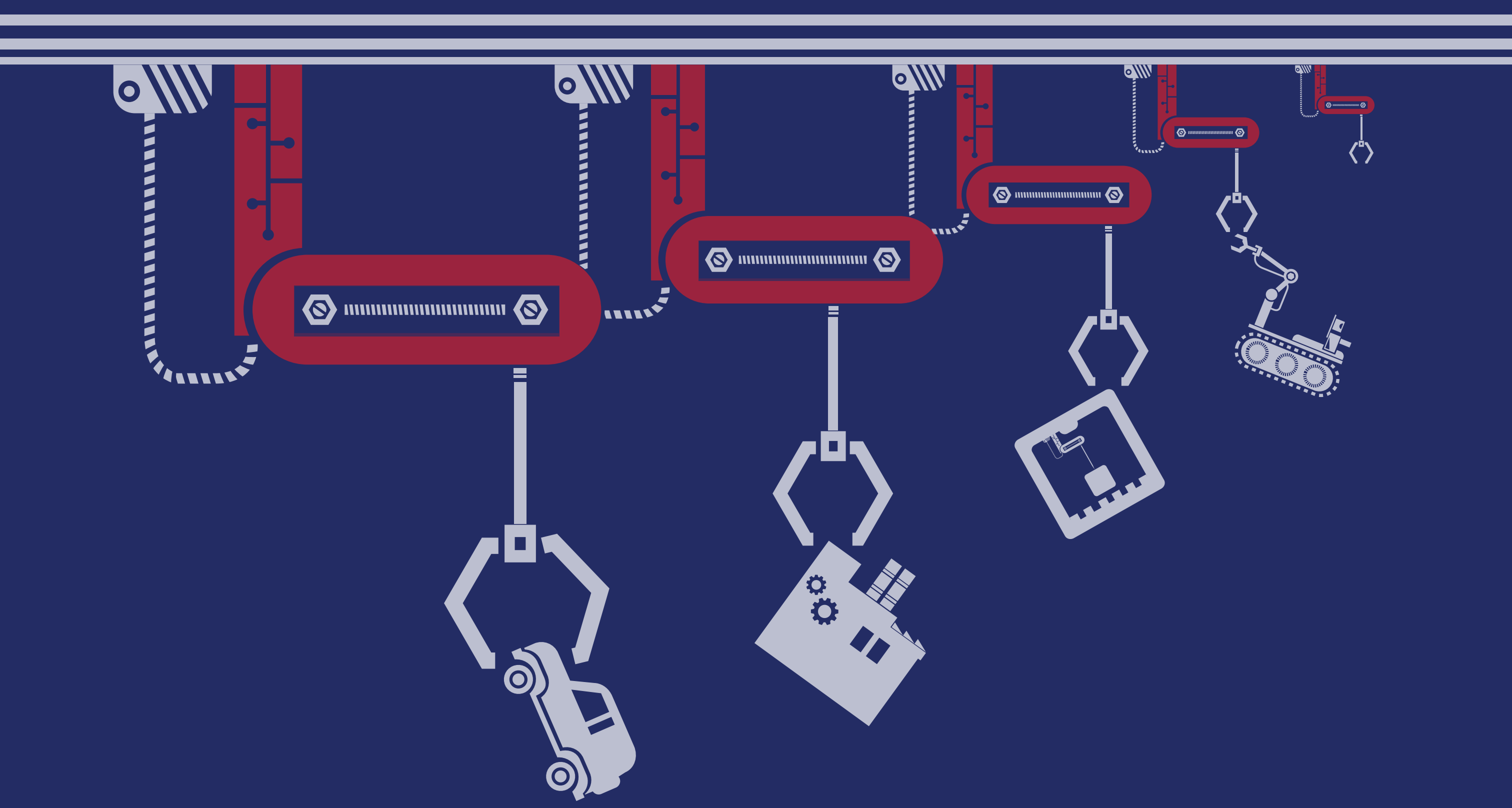


Image courtesy of Jaguar Land Rover

JAGUAR LAND ROVER DRIVES VIRTUAL REALITY

State-of-the-art simulations herald a new era in car manufacturing.

Designing and engineering all of its vehicles within the UK, Jaguar Land Rover (JLR) is the country's largest automotive manufacturer. Employing nearly 30,000 people in the UK, across six locations, the company has a long history of manufacturing with its two iconic British brands: Jaguar and Land Rover.

JLR created its first virtual environment in 2008 and in 2013 invested another £3 million to further the capabilities of its Virtual Innovation Centre, based at its engineering, design and test facility in Gaydon. Incorporating knowledge from areas such as aerospace and Formula 1, virtual technologies have led to a transformation of design and engineering processes.

As the country's largest manufacturing research and development investor,[29] it is no surprise that JLR is taking advantage of these technologies. It now leads industry in this field and utilises some of the most advanced equipment available. The Virtual Innovation Centre is made up of the 3D Virtual Reality CAVE, the Driving Simulator and the Virtual Reality Ergonomics Laboratory.

CAVEman

The modern CAVE could not be further from the place where early man lived. A Computer Aided Virtual Environment (CAVE) forms a key part of JLR's Virtual Innovation Centre.
It is known as a cave also because the 3D imagery is projected on to three walls and the ceiling of an empty room, surrounding the user in the virtual world. Eight projectors powered by 16 computers are used to display images which are four times the quality of a high-definition television. Most of us are aware of 3D virtual reality through gaming and films, but these fully immersive spaces take the concept much further.

VIRTUAL TECHNOLOGIES HAVE TRANSFORMED DESIGN AND ENGINEERING PROCESSES AT JLR

3D GLASSES PROVIDE A GLIMPSE INTO THE VIRTUAL WORLD

JLR's CAVE allows designers and engineers to see and interact with full-size representations of components and the vehicles themselves. Manipulating the images using a wand, similar to a games console controller, the user wears 3D glasses to view the virtual simulations. Tracking head movements, the glasses allow the user to look at the projected image from any perspective. With a turn of your head and the click of a button you can even look through solid panels, right into the engine: something that is clearly not possible in the real world.

WHY SIMULATE REALITY?

Designers and engineers no longer have to wait for prototypes to be developed: they can view and assess new or innovative ideas in the CAVE. Improvements can be made to aerodynamics and ergonomics, in addition to appearance and function.

JLR is taking advantage of this virtual space for an increasing number of tasks that used to be undertaken in the real world. It even uses it to consider the practicality of fitting parts in an engine so that it can be serviced with ease. However, the CAVE is about more than just vehicles. It has the ability to display anything, providing CAD data is available. JLR also uses it to model elements of its production lines to ensure that workers can operate safely and that new machinery will fit into the planned location.

[29] In the year to March 2015 Jaguar Land Rover will invest £3.5 billion in R&D and CAPEX.

Image courtesy of Jaguar Land Rover

Image courtesy of Jaguar Land Rover

HOW'S MY VIRTUAL DRIVING?

While the CAVE has proven to be an invaluable tool for making many engineering and design decisions, it is not set up to test how a vehicle will drive. JLR's state-of-the-art virtual driving simulator has been specifically built for this task. It features a customisable cockpit with an actual production seat and steering wheel, three display screens and surround sound.

The full-motion simulator allows engineers to hone how a vehicle will drive as well as to measure things such as noise and vibration in a realistic driving environment. Difficult driving conditions such as snow, ice and rain can be replicated in order to evaluate their impact on the vehicle's performance. There is also the option of selecting specific routes for these tests.

Using simulator assessments to make engineering decisions helped JLR save £750,000 in retooling costs when developing the award-winning Jaguar F-Type, the first model to be evaluated in the simulator.

PEOPLE POWER

Virtual technologies are used by JLR not only to guarantee that vehicles are well engineered: it is also using this approach to ensure that designs take account of customers. The Virtual Reality Ergonomics Laboratory enables engineers to consider a range of everyday ergonomic issues, including whether buttons on the dashboard are easy to reach or in the right place. They can also assess whether a driver's view is obstructed and consider space issues, such as comfort for the passengers.

All these considerations and design features can be addressed and optimised in the laboratory well before physical prototypes are produced.

DRIVING HOME THE ADVANTAGES

The Virtual Innovation Centre has saved JLR more than £8 million in vehicle development costs since 2008. The benefits of the virtual technologies, however, extend far beyond cost savings and include:

- a reduction in physical prototypes and real-world testing
- the ability to perfect designs, ensuring that when physical prototypes are produced they are correct first time
- more reliable results when compared to traditional physical engineering, design and testing
- greater flexibility in design, allowing engineers to customise designs to cater for different tastes across markets

Most importantly, the Virtual Innovation Centre has enabled JLR to get vehicles to market faster as a result of shorter development times.

INTO THE FUTURE

JLR has plans for the Virtual Innovation Centre to unite the virtual world with augmented reality by combining the 3D simulations with real imagery such as live video, to make the testing and simulation even more realistic and accurate.

Virtual technologies will also become commonplace within cars themselves. JLR is developing industry-leading technologies that will provide drivers with an enhanced virtual view of the road. The Jaguar Virtual Windscreen, for example, displays information such as speed, navigation and warning icons across the entire screen to aid the driver. It has a clear benefit in that the driver never has to take their eyes off the road.

It is not just sight and sound that affect reactions and responses. JLR also wants to consider things such as smells within the virtual world in order to imitate the driver and passenger experience as closely as possible. The incorporation of smell into simulations is one of the components of a 5 year £10 million research programme that JLR is leading, along with the Engineering and Physical Sciences Research Council and 4 leading UK universities (Cambridge, Leeds, Loughborough and Warwick). The research, entitled 'Programme for Simulation Innovation', is intended to improve the quality and capabilities of simulation in the automotive industry.

JLR is investing for the future. It is also working alongside the Warwick Manufacturing Group and Tata Motors and investing in a new £130 million National Automotive Innovation Centre, which is due to open in 2017. The state-of-the-art research facility will house 1,000 advanced research engineers working on projects to progress automotive technologies.

JLR is a trailblazer in this area, continually looking to enhance its virtual capabilities to stay ahead of the competition.

VIRTUAL TECHNOLOGIES HAVE SAVED JLR MORE THAN £8 MILLION IN DEVELOPMENT COSTS SINCE 2008

RENISHAW ADDS A NEW DIMENSION TO MANUFACTURING

Engineering leader combines the strengths of laser technology and 3D metal printing.

Renishaw is a FTSE 250 engineering business with more than 3,700 employees across the globe. It specialises in the design and production of measurement and inspection equipment and has expertise in motion control, spectroscopy and precision machining. A leader in the field of metal-based additive manufacturing, Renishaw is the only British company to make additive manufacturing machines that can print metal parts. In fact, it is one of very few companies worldwide that has the capability to print using metal.

Until recently, the focus of additive manufacturing has been on using materials such as polymers and ceramics. However, this form of manufacture is constantly evolving, and metal parts and objects are now also being printed.

Renishaw has had expertise in additive manufacturing for many years. For more than a decade the company has operated an in-house Rapid Manufacturing Centre which is used in the product development process and utilises additive manufacturing technology. It chose to focus on enhancing its presence in 3D metal printing from 2011 onwards, as it could see that this emerging technology was likely to become a game changer.

POWERFUL PRINT TECHNOLOGIES

Renishaw has used its engineering expertise and has combined the strengths of two powerful technologies – lasers and 3D printing – to become a pioneer of laser-melted metal additive manufacture.

Although the Renishaw AM250 additive manufacturing machine is not particularly exciting to look at, it has massive capabilities. It is able to print precise metal parts which are denser than traditionally cast metals, making each individual part potentially stronger and more durable.

RENISHAW IS ONE OF VERY FEW COMPANIES WORLDWIDE WITH THE CAPABILITY TO PRINT IN METAL

Image courtesy of Renishaw

Based on 3D CAD data that is 'sliced' into layers, the machine prints parts using an additive technology known as laser melting. Currently, the company can use a number of metal powders in its machines such as titanium, aluminium, stainless steel, cobalt-chrome and Inconel, and is working to develop further materials for use.

The process begins with the deposition of a thin coating of metallic powder, about one twentieth of a millimetre thick, onto a metallic substrate inside the machine. A high-powered laser is then guided, using a dynamic optical system, to fuse the powder particles together in a two-dimensional layer that represents a slice of the part. The process is then repeated by indexing from layer-to-layer to form a three-dimensional object.

Typically, components can be produced at a rate of $5cm^3$ to $20cm^3$ per hour, although the speed depends on the material used and on the complexity and density of the parts.

TRANSFORMING THE INDUSTRY

Renishaw promotes the potential of additive metal manufacture. It is also utilising the technology to improve some of the products it makes. More than an alternative way to make a part or component; it is a revolution that could change manufacturing. Here are just some of the advantages that Renishaw's customers have already seen:

- Parts can be fully customised to suit customers' requirements
- Designs can be optimised to produce parts that are as lightweight as possible
- An increasing amount of design freedom: 3D printing allows extremely complex objects with detailed geometries to be produced from scratch in one process, requiring no tooling or casting
- The flexibility to make design changes right up to the point of production
- A vast reduction in the amount of waste product – for example, more than 98 % of the metallic powder used in the AM250 system is reusable
- Lower costs, as it is possible to produce only the parts needed and to consolidate multiple components into one
- The ability to quickly and cost-effectively build specialist components for niche applications where there is little demand for large volumes

RENISHAW IS A PIONEER OF LASER-MELTED METAL ADDITIVE MANUFACTURE

Image courtesy of Renishaw

RENISHAW IS AT THE CUTTING EDGE

Renishaw's laser melting technology is currently used for a range of tasks, including the manufacture of custom medical implants and lightweight aerospace and automotive components, as well as efficient heat exchangers and specialised injection moulding inserts.

Printed bicycle

Working with Empire Cycles, Renishaw produced the world's first 3D printed metal bike frame and seat post.

The work came about following a request from the Managing Director of Empire Cycles to build a stronger yet lighter bike. He already had a 3D printed full-size plastic version, but Renishaw took and adjusted the bike design to take advantage of the benefits of 3D metal printing.

Through a process of 'topological optimisation', excess material in areas of low stress were removed, resulting in a lighter product that maintained structural integrity.

The seat post bracket was tested using the mountain bike standard EN 14766. After successfully repeating the test 6 times, both Renishaw and Empire Cycles were delighted with the results.

The titanium alloy frame was printed in sections and bonded together. The frame is 33% lighter than the aluminium alloy original and the seat post weighs 44% less.

Rebuilding a face

Further demonstrating the diversity and value of metal printing, the technology has been used to rebuild the skull of an individual who suffered severe injuries in a motorcycle accident. Renishaw produced cutting and placement guides printed in cobalt chrome alloy for surgeons at the Morriston Hospital in Swansea.

3D printing helps build the fastest car

In 2015 the BLOODHOUND supersonic car will attempt to break the current land speed record of 763 miles per hour (mph). If successful, it will then attempt to exceed

Image courtesy of Renishaw

3D METAL PRINTING IS A REVOLUTION THAT COULD CHANGE MANUFACTURING

Image courtesy of Siemens NX

1,000-mph in 2016. Renishaw has worked with the BLOODHOUND team using the capabilities of 3D printing to produce complex parts that can cope with large amounts of stress and force.

Renishaw has produced a prototype titanium nose tip for the car, and the BLOODHOUND team will use the data from the record attempt to evaluate manufacturing processes. This is a one-off car, therefore this medium of production is ideally suited. It is an example of where creating complex production methods to build a single part would be wasted.

Printing our future

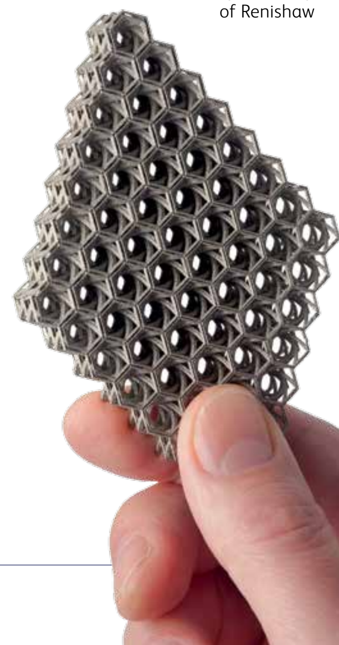
In November 2014 Renishaw unveiled a new metal-based additive manufacturing machine that has been purposely designed for industrial production. Provisionally named EVO Project, the machine, which is the first to be designed and engineered entirely in-house by the company, should be available during the second half of 2015.

The EVO Project machine has been designed for single material production. According to Renishaw the new machine will have a heavy focus on automation, monitoring technologies and reduced operator interaction. Powder handling, for example, will be nearly completely hands off, while the machine will also feature 'intelligent workflow' to minimise the need for user interaction.

Renishaw is already seeing strong signs that 3D printing will be used in main stream manufacturing, particularly where the process can add value to the component which will continue as a performance benefit while the product is in use. In years to come, aircraft will be lighter, fuel systems will be more efficient and patients will benefit from customised implants, all because of the capabilities of 3D metal printing. The company is looking to a future with wide-scale 3D metal printing of 'smart' components that adhere to globally recognised production standards.

Clearly, additive manufacturing has a key role to play in the sector's future. Renishaw expects that most organisations will utilise this technology, whether for flexible tooling, product development or reduced lead times. Furthermore, it could be used for 'smart' designs that could only be successfully produced utilising this new technique.

Image courtesy of Renishaw



SIEMENS' INTELLIGENT APPROACH TO MANUFACTURING

Industry and academia are working together to develop technologies that will revolutionise manufacturing.

Siemens is a global engineering and technology services company that has operated in the UK for more than 170 years, employing around 14,000 people in this country alone.

As a leader in industrial software, automation and drive technologies it should be no surprise that Siemens is leading the 4th industrial revolution. Often referred to as 'Industry 4.0', this new industrial revolution is driven by embedded technologies which enable objects to interact intelligently.

We already take for granted a world where many things are connected and the internet forms an integral part of our lives. However, this is just the start. In the factory of the future, and in the manufacturing supply chain, physical objects such as machinery, computers and even the components that are being made will contain embedded smart sensors and transmitters that will connect via networks.

But why is this Internet of Things so important? The answer is that the future potential to connect all of these things

EMBEDDED TECHNOLOGY IS SET TO BRING A FUNDAMENTAL SHIFT IN HOW PRODUCTS ARE MANUFACTURED

will revolutionise manufacturing. Physical objects will be able to remotely manage and collect data, understand their own condition, exchange commands and react appropriately.

DEMONSTRATING A DIGITAL FUTURE

As a major player in British manufacturing, Siemens is keen to work with industry and academia to ensure that the sector is at the forefront of the great technology race.

Led by Siemens, a range of industry partners (including the Electronic Systems Community (ESCO), GAMBICA, Hewlett Packard, Shadow Robotics and Ubisense) have worked with the Manufacturing Technology Centre (MTC) to create Britain's first 'digital factory demonstrator'.

Developed to make the design of new manufacturing processes easier, the 'digital factory demonstrator' (which is also known as the Industry 4.0 demonstrator) is designed to showcase how a 4th industrial revolution could influence the future of manufacturing. Both industry and academia can take advantage of this new facility, which is located at the MTC near Coventry. Launched in September 2014, its purpose is to create, test and showcase new ideas and technologies.

The demonstrator is made up of a virtual 3D factory and a physical production line.

THE FACTORY GOES VIRTUAL

Based on a sister demonstrator already operational in Germany, the virtual 3D factory has been created in the MTC's immersive virtual reality CAVE.[30]

Utilising this environment, Siemens has developed a simulated copy of a real machine that mimics a continuous production environment.

THE DIGITAL FACTORY DEMONSTRATOR IS ONE OF A KIND IN BRITAIN

[30]CAVE: Computer Aided Virtual Environment


Image courtesy of Siemens

The virtual factory enables manufacturers and other stakeholders to use this test bed to innovate production processes, utilising the latest technologies to improve areas such as productivity, quality and even energy efficiency.

The virtual 3D factory is connected to its sister demonstrator in Germany. This allows greater collaboration and sharing of ideas across borders on the latest technologies.

SMART PRODUCTION LINE

Separate to the 3D factory is a physical production line. The purpose of this element of the demonstrator is to show the potential for the mass customisation of goods.
The production line contains a range of robotics, including Kuka robots with local cell control, a collaborative arm from Universal Robots and a Shadow Robotics dexterous hand. Utilising a range of Siemens specialist-built technologies, they have linked all the machinery so that there is real-time control, while a multi function touch screen shows condition monitoring, status and diagnostics for the entire line.

By using smart machinery that is capable of communicating, components or goods on the production line can be customised to demand, allowing companies to understand how this would work in a real factory environment.

By implementing these smart sensors and networks between machines they are also working to understand and address the challenge of how the Internet of Things can develop into the future.

VIRTUAL MEETS REAL IN THE 'LIVING LABORATORY'

Calling on industry and the government to now take the next steps and match fund the £6 million needed to create a 'living laboratory', Siemens believes that investing in smart factories could boost British manufacturing's productivity by up to 30%,[31] as well as increase the sector's competiveness.

A physical clone of the virtual 3D factory would be built at the MTC and linked to its simulated parent, thus facilitating two-way data transfer. This would result in virtual actions being transmitted to the real production line. Bi-directional smart data communications will enable it to become a self-learning, self-healing, self-optimised manufacturing process.

The existing 'digital factory demonstrator' and the future development of the 'living laboratory' will ensure that British manufacturers have the opportunity to define, test, refine and ultimately lead the standards that will be needed globally for intelligent manufacturing.

INVESTING IN SMART FACTORIES COULD BOOST BRITISH MANUFACTURING'S PRODUCTIVITY BY UP TO 30%[31]

[31]Siemens (2014). 'UK's first digital factory demonstrator launched'. (http://www.siemens.co.uk/en/news_press/index/news_archive/2014/uks-first-digital-factory-demonstrator-launched.htm), accessed December 2014

AMRC CATAPULTS SCI-FI INTO 2050 REALITY

The AMRC's Factory 2050 is designed to be the most advanced factory in the world

The Advanced Manufacturing and Research Centre (AMRC) with Boeing is an excellent example of how collaboration between business and academia can benefit all. An endorsement of its success is that it has been heralded as a role model for technology and innovation centres by Prime Minister David Cameron.

Established in 2001 by the University of Sheffield and Boeing, the AMRC's work concentrates on finding ways to overcome the challenges faced in advanced manufacturing. Its focus has been on finding cutting-edge ways to improve the machining and materials for aerospace and other high-value manufacturing sectors, enabling industry to decrease the time and costs involved in production while enhancing performance.

Through its proven success, the AMRC has developed and grown. Its existing Factory of the Future building, sponsored by British aerospace company Rolls-Royce, now extends to more than 6,000 square feet of space that also houses the AMRC Composite Centre. The later addition of the AMRC Design Prototyping and Testing Centre contains the Advanced Structural Testing Centre and the new Design & Prototyping Group.

CATAPULTED FORWARDS

The AMRC's accomplishments were further recognised when it was chosen to be one of the 7 centres in the network that makes up the High Value Manufacturing (HVM) Catapult, in 2011. The catapults are a government initiative designed to ensure that the achievement of Britain's existing research capabilities is translated into industrial success.

The HVM Catapult was the first of the original 7 catapults to be established, backed by a mixture of private and public funding, forging stronger ties between business and academia. The research projects are currently undertaken in both AMRC centres and focus on machining, assembly, composite materials and structural testing, as well as design and prototyping.

THE AMRC IS ONE OF 7 CENTRES THAT MAKE UP THE HIGH VALUE MANUFACTURING CATAPULT

2001	AMRC set up
2004	Moved to Advanced Manufacturing Park
2008	Opened the AMRC Rolls-Royce Factory of the Future
2011	Nuclear AMRC opens on the Advanced Manufacturing Park
2012	Factory of the Future extended to encompass Composite Centre
2012	AMRC acquires the National Metals Technology Centre
2013	AMRC Training Centre opens
2014	Secure go ahead for Factory 2050
2014	AMRC acquires Castings Technology International
2014	Work starts on Factory 2050
2015	Factory 2050 opens


Image courtesy of the AMRC

RESEARCH PAYS DIVIDENDS FOR BUSINESS

The AMRC has more than 70 members and has worked with hundreds of businesses to enhance the industry's performance. A good example of this is the development of a new manufacturing method, which has dramatically reduced the machining time and increased the quality of the gas turbine discs used in Rolls-Royce jet engines.

Further testimony comes from the Performance Engineered Solutions (PES) Ltd and Teks UK collaboration with the AMRC Composite Centre to devise new bio composite materials for use in motorsport vehicles. These environmentally friendly composite materials are being developed and tested to replace traditional composites such as carbon fibre, to manufacture significantly lighter panels for motorsport vehicle bodies.

Through commissioned projects companies can use the facilities and expertise at the AMRC to try out new innovations or resolve production problems. They can undertake this research without having to change their day-to-day factory operations and therefore benefit from fewer risks and significantly lower costs.

A NEW ERA FOR MANUFACTURING

Not content with addressing today's manufacturing challenges, the AMRC is building a new Factory of the Future, Factory 2050, which is designed to be the most advanced factory in the world. It is being developed in response to the Foresight 'The Future of Manufacturing' report[1] which highlighted the importance of a reconfigurable factory designed for one-off manufacturing of production parts.

Currently under construction and set to open towards the end of 2015, Factory 2050 is aiming to become Britain's only completely reconfigurable assembly and component manufacturing facility for cooperative research. The £43 million investment in the building is being funded by academia, industry and government. A grant of £10 million has come from the Higher Education Funding Council for England, with further money coming from the European Regional Development fund. Additionally, companies including Boeing, Rolls-Royce, Airbus, BAE Systems and Spirit AeroSystems have contributed to its development.

IT'S A FACTORY, BUT NOT AS WE KNOW IT...

Factory 2050 will be circular in design, with its office space at the centre, surrounded by the manufacturing area. There will be extensive use of glass, to create a transparent and open feel, thereby providing a clear view to the clean environment within.

The hope is that this level of visibility will inspire the next generation, help change traditionally

IN 2007, AMRC WITH BOEING WON THE QUEEN'S ANNIVERSARY PRIZE FOR HIGHER AND FURTHER EDUCATION

Image courtesy of the AMRC

held views of the sector and attract future talent into the industry, thereby addressing one of the conclusions of the Foresight 'The Future of Manufacturing' report.[1,32]

As with the first Factory of the Future, Factory 2050 will be built with the environment in mind and designed to meet BREEAM[33] 'Excellent' environmental standards.

SMART FACTORY FOR SMARTER WORKING

However, it is not all about how the building will look; a major feature of the new space will be its adaptability. It will be possible to quickly and easily reconfigure the layout and the machinery to meet changing demand as the drive for customised products increases.

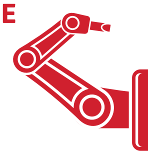
Factory 2050 will do this by using flexible, reconfigurable and Big Data technologies, linking actual and virtual environments in real time, together with advanced robotics and machinery that can communicate and function with limited human involvement. Advanced sensor technology, including 3D safety scanners, will be used to detect human presence and motion and will react by adjusting or stopping activity so that man and machine can work alongside one another safely and efficiently.

Factory 2050 will encompass many of the other features of a smart factory, such as virtual environments for design and testing, automation, unmanned work areas and 3D printing. The AMRC is also looking to install other ultra advanced tools, such as the augmented reality technology found in Google Glass, where a computer image is laid over the real-world view, allowing the user to see both scenes as one. It will be home to the AMRC Integrated Manufacturing Group, which will work with industry to develop a range of flexible manufacturing projects, covering areas such as automation, robotics, large-volume metrology and digitally assisted assembly.

The ultimate aim is to provide the manufacturing industry with the systems, technologies and innovative capabilities that it will need in order to respond to those drivers of change in the industry, such as rapidly changing customer demand.

The AMRC says that Britain's manufacturers will increasingly need to be flexible, automated and digitally driven to enable them to remain globally competitive and take them to 2050 and beyond.

AUGMENTED REALITY AND AUTONOMOUS ROBOTS WILL FEATURE IN THE FACTORY OF THE FUTURE



[32]The Foresight (2013). 'The Future of Manufacturing: A new era of opportunity and challenge for the UK'. Project report. The Government Office for Science, London. "It will also be crucial to address the current image associated with manufacturing. Here government and industry should work together to further promote and market the opportunities for careers in manufacturing industries at all levels of education".
[33]BREEAM: is the Building Research Establishment Environmental Assessment Method for buildings and large scale developments.

DICK ELSY

CEO, High Value Manufacturing Catapult

Continuous improvement is a mantra in modern manufacturing. It's part of a daily process to flush out small changes and improve efficiency incrementally.

It's much tougher to make radical change and introduce completely new processes which change the rules and the game. We shy away from these radical ideas because they are risky – risky to implement and risky in outcome and therefore risky to finance. The irony for the UK is that we have world class technology research and yet we are culturally risk averse to commercialise it.

This is where the catapults come in – to help to overcome these risks by giving access to equipment, skills and collaboration to help develop out these risks and to provide the confidence to invest.

We are currently working with industrial partners on collaborative projects with 5-10 and 20-year horizons. As an example of the type of work we are doing, we have found ways to reduce the machining time of challenging aerospace components by 50%, making the new process by far the most dominant driver of cost. This makes the production of these components in the UK globally competitive and beyond the reach of low-labour-cost or energy-cost offers.

MORE ABOUT THE CATAPULT CENTRES

In 2010 the government announced that £200 million would be spent on creating technology and innovation centres across Britain. The aim of these centres, now known as catapults, was to give businesses access to both the expertise and the resources they would need to develop and innovate by forging stronger relationships between academia and industry.

The original plan was for the following catapults to be established:

- **High Value Manufacturing** (https://hvm.catapult.org.uk/)
- **Cell Therapy** (https://ct.catapult.org.uk/)
- **Offshore Renewable Energy** (https://ore.catapult.org.uk/)
- **Satellite Applications** (https://sa.catapult.org.uk/)
- **Connected Digital Economy** (https://cde.catapult.org.uk/)
- **Future Cities** (https://futurecities.catapult.org.uk/)
- **Transport Systems** (https://ts.catapult.org.uk/)

All 7 of the original catapults are up and running and now there are plans for another 2:

- **Precision Medicine**
- **Energy Systems**

FELICITY BURCH

Senior Economist, EEF

Whatever happens in the next couple of decades, one thing is clear: innovation will be critical to the competitiveness of UK manufacturing. Indeed, if manufacturers are going to maintain a competitive edge, the need to innovate – and to do so quickly – is only likely to intensify, particularly as companies in emerging markets seek to move up the value chain and innovate more themselves.

The UK's manufacturing SMEs are already highly innovative. But innovation can be more challenging for SMEs than for larger companies as they can be more resource constrained, limiting access to the necessary skills and facilities to innovate successfully.

The network of catapult centres therefore offers a real opportunity for SMEs to increase the success of their innovation strategies by providing access to cutting-edge equipment and highly skilled researchers. As the catapult centres represent a partnership between researchers and industry they will also deliver research that is specifically focused on meeting industrial needs. Reflecting their value to the sector, already 1,500 manufacturers have engaged with the High Value Manufacturing Catapult.

In some centres, large companies play a leading role, but they are there to support manufacturers of all sizes. SMEs may wish to join a catapult centre to take advantage of unique opportunities for collaboration with key customers, or they may wish to engage a centre's researchers on a contract basis. However a company chooses to engage, the catapult centres represent an ambitious policy measure from government, and a real opportunity for SMEs to advance their ideas from drawing board through to market.

THE HIGH VALUE MANUFACTURING CATAPULT

The HVM Catapult started in October 2011 with the ultimate aim of ensuring that the UK has a growing, successful manufacturing sector. As the CEO Dick Elsy outlines: "the HVM catapult's long-term goal is to stimulate growth in the manufacturing sector and more than double the sector's contribution to UK GDP."

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The Oracle Building
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info@hvm.catapult.org.uk
https://hvm.catapult.org.uk/

THE SEVEN HIGH VALUE MANUFACTURING CATAPULT CENTRES

1. ADVANCED FORMING RESEARCH CENTRE

Based next to Glasgow International Airport, this centre is a joint venture between the University of Strathclyde, the Scottish government, Scottish enterprise and industry. The purpose of this centre is to focus on making technological advances in the manufacturing areas of forming and forging. It is working on subjects such as:

- Materials utilisation for economic and environmental benefit
- New materials with improved metallurgical properties
- New product designs demanding ever more accurate and repeatable formed components
- Mass customisation requiring adaptable and flexible processes

Contact Details:
Advanced Forming Research Centre
University of Strathclyde
85 Inchinnan Drive
Inchinnan
Renfrew PA4 9LJ

Tel: 0141 534 5200
info@afrc.org.uk
http://afrc.org.uk/

2. ADVANCED MANUFACTURING RESEARCH CENTRE

As featured in our case study, the centre is situated on a research site in South Yorkshire, its work concentrates on finding ways to overcome the challenges faced in advanced manufacturing.

It defines its key areas for research as:

- High-performance machining to significantly improve production efficiency
- Assembly for low-volume, high-value systems and difficult-to-handle components
- Innovative manufacturing techniques for composite materials
- Advanced structural testing of components and assemblies
- Design for manufacturing

Contact Details:
AMRC with Boeing
The University of Sheffield
Advanced Manufacturing Park
Wallis Way
Catcliffe
Rotherham S60 5TZ

Tel: 0114 222 1747
enquiries@amrc.co.uk
http://amrc.co.uk/

3. CENTRE FOR PROCESS INNOVATION

Based in Redcar, North Yorkshire, the purpose of this centre is to drive innovation in manufacturing, by offering companies access to the expertise and facilities to try out new ideas. It gives them a place to test, develop and refine innovations outside of their own factory, meaning there is no time or cost impact on the day-to-day running of their operations.

Contact Details:
CPI Head Office
Wilton Centre
Wilton
Redcar TS10 4RF

Tel: 01642 455 340
info@uk-cpi.com
http://uk-cpi.com/

4. MANUFACTURING TECHNOLOGY CENTRE

Located at Ansty Park, Coventry, this centre is a collaboration between three universities (Birmingham, Nottingham and Loughborough) and The Welding Institute (TWI). Home of the first 'digital factory demonstrator' in the UK, its aim is to develop specific manufacturing processes, namely:

- Intelligent automation
- Advanced tooling and fixturing
- Electronics manufacturing
- High integrity fabrication
- Manufacturing simulation and informatics
- Metrology and NDT
- Net shape and additive manufacturing

Contact Details:
MTC Limited
Ansty Park
Coventry CV7 9JU

Tel: 02476 701600
http://the-mtc.org/

5. NATIONAL COMPOSITES CENTRE

Located on the Bristol and Bath Science Park and operated by the University of Bristol, the purpose of this centre is to advance the development and manufacture of composites.

Contact Details:
The National Composites Centre
Feynman Way Central
Bristol & Bath Science Park
Emersons Green
Bristol BS16 7FS

Tel: 0117 370 7600
info@nccuk.com
http://nccuk.com/

6. THE NUCLEAR ADVANCED MANUFACTURING RESEARCH CENTRE (NUCLEAR AMRC)

Operated by the University of Sheffield and the University of Manchester and based on the Advanced Manufacturing Park in South Yorkshire, its aim is to improve and develop the civil nuclear manufacturing sector. It therefore focuses its research into:

- Machine tool optimisation and process development
- Robotic machining
- Large-scale welding and cladding using robotics and adaptive control
- Production-scale demonstrators for innovative technologies and processes
- Non destructive evaluation
- Large-scale metrology
- Virtual simulation and design for manufacturing and assembly

Contact Details:
Nuclear AMRC
The University of Sheffield
Advanced Manufacturing Park
Brunel Way
Catcliffe
Rotherham S60 5WG

Tel: 0114 222 9900
enquiries@namrc.co.uk
http://namrc.co.uk/

7. WARWICK MANUFACTURING GROUP (WMG)

Located in Coventry at the University of Warwick, this centre is working on the task of Low Carbon Mobility, focusing on two specific areas:

- Lightweight technologies
- Energy storage and management

Contact Details:
WMG centre HVM Catapult
International Digital Laboratory
University of Warwick
Coventry CV4 7AL

Tel: 024 7615 1667
wmghvmcatapult@warwick.ac.uk
http://www.wmghvmcatapult.org.uk/

ABOUT INFOR

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ABOUT US

EEF is dedicated to the future of manufacturing. Everything we do is designed to help manufacturing businesses evolve, innovate and compete in a fast-changing world. With our unique combination of business services, government representation and industry intelligence, no other organisation is better placed to provide the skills, knowledge and networks they need to thrive.

We work with UK's manufacturers from the largest to the smallest, to help them work better, compete harder and innovate faster. Because we understand manufacturers so well, policy makers trust our advice and welcome our involvement in their deliberations.
We work with them to create policies that are in the best interests of manufacturing that encourage a high growth industry and boost its ability to make a positive contribution to the UK's real economy.

Our policy work delivers real business value for our members, giving us a unique insight into the way changing legislation will affect their business. This insight, complemented by intelligence gathered through our on-going member research and networking programmes, informs our broad portfolio of services; services that unlock business potential by creating highly productive workplaces in which innovation, creativity and competitiveness can thrive.

The EEF Information & Research Team is in a unique position to provide insight into the trends and behaviours that shape the UK manufacturing sector. The team is able to provide invaluable research data, assisting with daily business needs while also providing the intelligence to help businesses compete, innovate and grow.

CONTACTS

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THE INFORMATION & RESEARCH TEAM

Michèle Fordyce, Head of Information & Research

Michèle has been involved in Information & Research in the City for more than 25 years. Professionally qualified in information, Michèle has led information teams in both law and investment banking. She took up her position as Head of Information & Research at EEF 6 years ago. As part of the wider remit of this role, Michèle is responsible for ensuring the delivery of high-level, tailor-made information and research projects, built around clients' individual needs. With their specialist experience of the manufacturing sector, Michèle and her team can offer individual research and an integrated quality product.

Amanda Norris, Survey Manager

With more than 15 years' experience in the field of surveying and benchmarking, backed up by a Master's in Research. Amanda manages all the surveys conducted by EEF, including advising on questionnaire design and the compilation of results. In addition, Amanda has experience in a range of research methods from interviewing through to case study work and has delivered high-quality projects for blue-chip clients.

Oliver Kelly, Information Specialist

Oliver joined EEF in April 2012. Prior to this he spent 3 years working in market research and economic development. He has experience across a wide range of sectors and an appreciation of numerous research techniques. Oliver works on bespoke 'intelligence' projects for clients as well as assisting in the management and processing of benchmarking and surveying.



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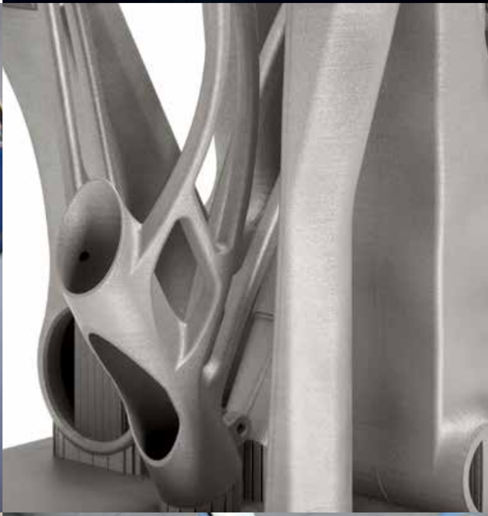

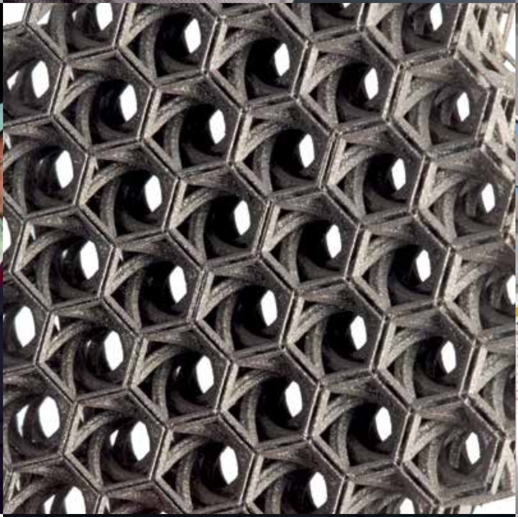




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