INDUSTRY 4.0 REPORT

Institution of MECHANICAL ENGINEERS

IMechE Services Ltd

BDO

INDUSTRY 4.0:
TRANSFORMING AGILITY AND PRODUCTIVITY

"The fourth industrial revolution is being driven through connectivity and the availability of data, digitising manufacturing in a way that is transforming the agility and productivity of manufacturing businesses and supply chains.

There is a trend towards customisation and servitisation where the organisational learning derived from digitised manufacturing processes and data provides a distinct advantage to businesses at the forefront of these new business models.

The technology available today improves the productivity and quality of existing processes, using the availability of data to enact real time process control and also aggregated data sets to drive process and organisational learning. This is part of a trend that sees manufacturing engineers building digitised manufacturing systems that produce components rather than directly intervening in the manufacturing process.

Automation of decision-making is a key facet of the fourth industrial revolution with automation of processes arguably being the foundation of the third industrial revolution.

The Advanced Manufacturing Research Centre (AMRC) has built Factory 2050 as the embodiment of the digital, flexible, smart factory. A digital factory master will track the flow of components tooling and automated guided vehicles around the facility as well as monitoring the performance of highly sensored manufacturing processes and equipment. This technology creates the factory as one reconfigurable system that can respond to changes in material or components supply, equipment or process health and changing customer requirements.

PROFESSOR SAM TURNER,
CHIEF TECHNOLOGY OFFICER,
ADVANCED MANUFACTURING
RESEARCH CENTRE"

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INTRODUCTION

The next industrial revolution is being defined by one thing: cost. How can developed economies with their business rates, taxes and high labour costs, remain a competitive location in which to manufacture? What will factories here look like in the near future? Will they look like they do today?

Or will we require fewer people to work in our factories, where more automated technology is deployed, performing the repetitive work for us, to greater levels of accuracy and at higher levels of productivity? It is a rhetorical question, of course.

But how do we reach this nirvana? And what is accelerating the digital factory?

Over the last decade Germany realised that the business case for offshoring was becoming weaker, as costs in the low cost economies began to increase. But with their labour costs remaining high comparatively, something different had to be done to remain competitive. The answer was a highly integrated project, launched in 2011 by the Association of German Engineers under the banner 'INDUSTRIE 4.0', to develop and market a wide suite of technologies to affect a step change in manufacturing productivity, enabling 'future proof production'.

It was a smart move for Germany; here was a way to save manufacturing in the country, where industry represents some 22% of GDP, and simultaneously market high volumes of Made in Germany technology to the world. This would mean that other countries would have to adopt these technologies or those like them, to keep their production competitive. Such an approach provided a solution to the growing need for mass customisation, the rising consumer requirement to build variation into high volume, first complex, and then more commodity, goods.

In the five short years since the concept of Industry 4.0 emerged, the phrase has become embedded in our lexicon. Few people working in this sector today will not have heard of it. But how many really know what Industry 4.0 actually means? We know that manufacturing is under relentless pressure to be more efficient – consider the weak average productivity the UK has versus our peer countries, where levels are below their pre-2007 crisis trend.

In this report, produced in partnership with the Institution of Mechanical Engineers and drawing on findings from a survey of their members and BDO clients, we provide some answers to these questions: What is Industry 4.0? Why is it relevant to your company? What are other countries doing in this space? What are the important next developments?

Whether this is a revolution or more likely a gradual evolution of our manufacturing sector we cannot ignore the changes taking place in the way goods are produced. We are thankful to all those who shared their thoughts and experiences – I hope you find this report interesting and useful.

TOM LAWTON
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EXECUTIVE SUMMARY

WHAT IS INDUSTRY 4.0?

INDUSTRIE 4.0 is identified by the German government as one of ten 'Future Projects' as part of its High-Tech Strategy 2020 Action Plan. The INDUSTRIE 4.0 project (aka the fourth industrial revolution) began as a marketing opportunity for Germany to establish itself as an industry lead market and technology provider.

It has now subsumed into the business lexicon as a catchall covering the automation of manufacturing, machine-to-machine and machine-to-product communication, the industrial internet and technology needed for mass customisation of production.

It essentially means smart, flexible factories, where machines capture more data and convey more useful data to business operators so that they can make quicker, better decisions about how something is manufactured.

PERSONALISATION OF GOODS

In 2002, the big German electronics chain Saturn used the advertising slogan 'Geiz is geil' or 'Penny pinching is sexy'. Prof. Detlef Zuehlke of the University of Kaiserslautern and one of the fathers of Industry 4.0, says this became a more general slogan in commonplace German that people should celebrate that cheap products were made in China and were all the same, as it saved us money.

"Customers at that time had cheaper products as their major shopping goal," he says. "But over the last three to four years this has rapidly changed in favour of more emotional and customised products. Customers seem to be willing to pay more for customisation."

This is true wherever you look, from cars where even the production lines of mid-market brands like Nissan and Vauxhall rarely have two identical cars in series, to toys (the online make-your-own Makie Doll), spectacles, trainers and more.

For non-consumer goods, more flexible and automated manufacturing methods are now needed to deal with increasing complexity and product variation. Companies can still make products by hand, but they cannot make thousands of different products by hand simultaneously without technology.

> "Several disruptive elements are having a profound effect on manufacturing. Social media, no longer just for sharing selfies with your friends, is now a powerful marketing channel. And new technologies like additive, and additive + subtractive hybrid manufacturing, are reshaping the way we design products to meet the rising demands of consumers."
>
> **ASIF MOGHAL,** MANUFACTURING INDUSTRY MANAGER, AUTODESK

"Industry 4.0 gives companies a chance to out-compete their rivals by collaborating more efficiently throughout the supply chain. The ability to share real-time data with suppliers and customers gives a chance to greatly improve the overall efficiency of the whole system and not optimise locally at the expense of others in the supply chain.

The companies that do well out of the fourth industrial revolution will be the ones that recognise the business opportunities and apply the technologies in a focused way to drive the benefits. The challenge is not what technology to use but what benefits do I need in order to out-compete my rivals. The winners as always will be the companies with the best people, vision and determination to succeed."

PROFESSOR KEN YOUNG,
TECHNOLOGY DIRECTOR,
MANUFACTURING
TECHNOLOGY CENTRE

SURVEY HIGHLIGHTS

FROM THE BDO INDUSTRY 4.0 SURVEY 2016

ONLY **8%** have **significant understanding** of the term, Industry 4.0 and

56% have **little or no understanding** of the term, Industry 4.0.

44% said it would have a **large impact on their business**.

59% say Industry 4.0 will **have a big impact on the manufacturing sector**

20% of responding companies had **some level** of Industry 4.0 strategy in place.

48% admit they have **no Industry 4.0 strategy** but need to look into this.

19% said they did **not need a strategy**.

43% planned **some level of investment** in automation over the next 24-months.

10% planned to **invest £1m or more** in this technology.

64% of **Industry 4.0 investment** is focused on production, followed by:

45% R&D
25% logistics

44% cited a **lack of understanding** as the main reason for not currently investing, and

5% said **lack of external sources of finance/ grants** was the lowest barrier to investing.

73% said the **use of Industry 4.0 will increase the risk of cyber security breaches**, suggesting this side-effect is high on company agendas. Among these,

48% said their firms had **the right IT systems** to counter this threat, and

35% said they **would be OK with such breaches** with some IT upgrades.

OPPORTUNITIES AND BENEFITS OF INDUSTRY 4.0

THE MAIN DRIVERS FOR THE DIGITAL FACTORY EVOLUTION ARE:

- Higher productivity
- Product variation and customisation
- Quality control and consistency
- Traceability
- Supply chain responsiveness

PRODUCTIVITY

Economists say that average productivity in the UK economy is low compared with peer group countries like France and Germany. Productivity is typically measured as output value per man/hour worked. Logistics firm Unipart claims that 95% of all lean implementations fail and that the average worker in France can achieve the same output as a UK worker's output by Thursday afternoon.

Juergen Maier, CEO of Siemens plc, says that full factory automation and data analysis can make factories up to 50% more efficient in terms of productivity. To realise such a transformation could take a company more than ten years. This highlights the need for companies and government to have a long term strategy.

PRODUCT CUSTOMISATION

The need to vary products mildly or radically within a production line is a big driver of Industry 4.0. Car companies, especially luxury marques, have been doing this for years; the ability to manufacture in series with minor or large scale variation is now standard at many of the large automotive companies (OEMs).

Increasingly this customisation is being offered by less expensive products. Toys such as Makie Doll, and collaborative design and make projects for children such as KiDesign, where children can design and 3D-print small model 'cities' in the classroom, are examples. Companies such as plastic moulders are using Industry 4.0 technology to build variation into their lines.

A famous example is French lens company Essilor, which manufactured 320 million spectacle lenses. Many have a high degree of personalisation, achieved first by producing a range of standard blanks, and then customising the lens in stages via a network of 330 small laboratories.

QUALITY CONTROL

Quality control, or QC, and metrology is a hugely important area of manufacturing. For many industries, products must have micrometre scale tolerances to pass international quality standards. Where and when to build in the metrology (measurement) into a process is critical, to save time and resource.

The EPSRC Centre for Innovative Manufacturing at Huddersfield University, with the National Physical Laboratory and partners including Rolls-Royce, is developing techniques for measuring component tolerance in-manufacture, rather than as a post-production process. "This has profound effects on manufacturing process times", says Centre Director Professor Jane Jiang.

Hexagon Metrology in 2015 became Hexagon Manufacturing Intelligence, now offering end-to-end manufacturing technologies. Having purchased CADCAM design engineering firm Vero Software, and then QDAS, the company strapline became 'Quality Drives Productivity', to reflect this end-to-end approach including sensing and touchless measurement and software analysis all within real-time manufacturing.

TRACEABILITY

The traceability of identical machined parts has been given particular importance in some sectors like pharmaceuticals, which places a lot more emphasis on this for legal compliance. Meggitt PLC and other companies are creating a production system where the traceability of every bespoke part will match that in industries where 100% provenance is taken for granted. This remains a key requirement for all products as manufacturers need to be sure that their products are safe and certified appropriately at the point of sale. In addition to this if at a later date for any reason a product needs to be recalled for a particular fault in a part, this will improve the speed of recovery of these products.

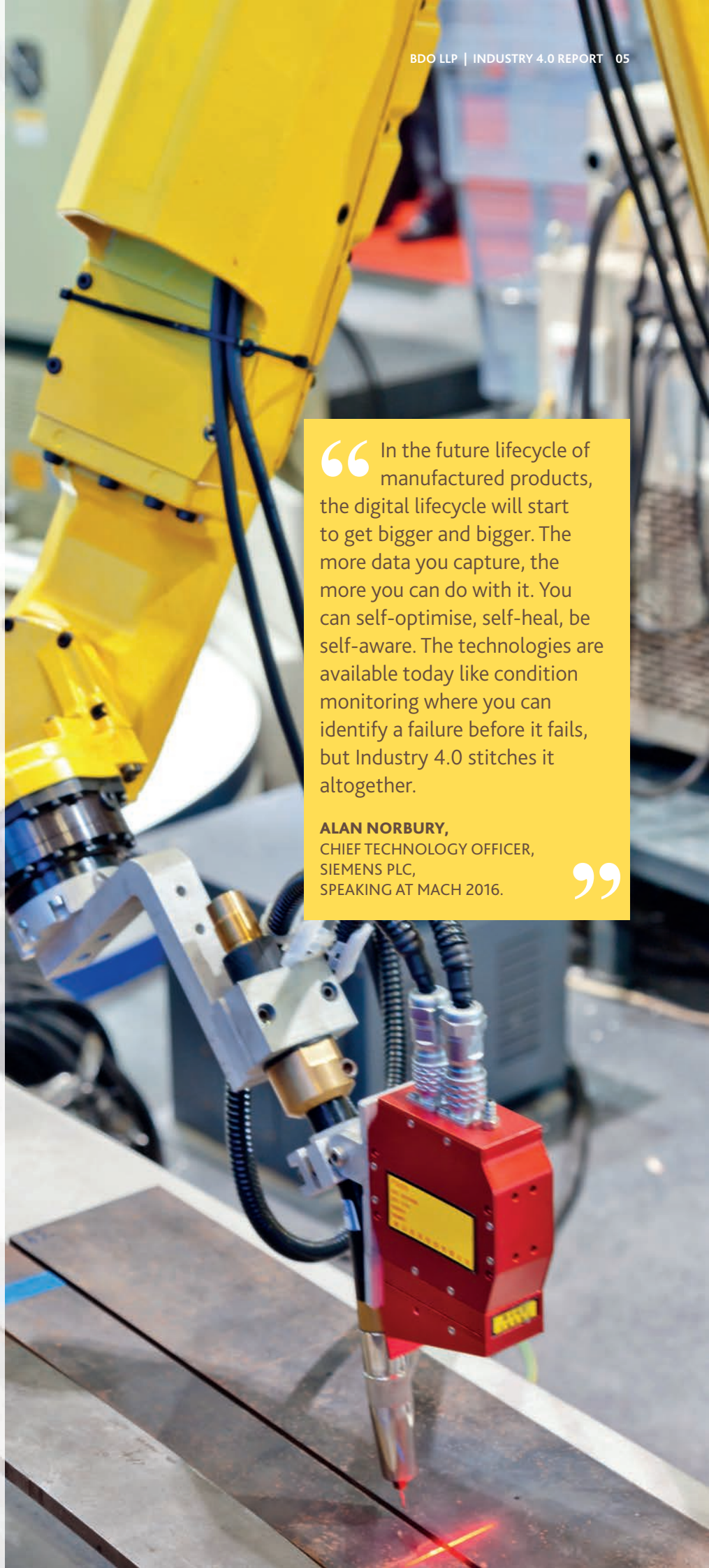
SUPPLY CHAIN RESPONSIVENESS

One core benefit of Industry 4.0 is to improve data communication within a supply chain. Think of the example of data shared between engineers in a complex assembly by a shared Product Lifecycle Management (PLM) system. Sharing sensitive data between customer and suppliers in reality is complicated and one of the biggest barriers to Industry 4.0 uptake, as SMEs are cautious about 'giving their crown jewels away'.

Adoption of this technology throughout the supply chain will enable the whole product chain to become more responsive; in terms of changes in design, manufacture, volumes, rework and through-life service provision. This will enable those countries within the more developed economies to become more competitive in terms of time to market and cost.

But Professor Ken Young of the Manufacturing Technology Centre says this data-enabled supply chain benefit is fundamental to a manufacturer's success. "Industry 4.0 gives companies a chance to out-compete their rivals by collaborating more efficiently throughout the supply chain. The ability to share real-time data with suppliers and customers gives a chance to greatly improve the overall efficiency of the whole system and not optimise locally at the expense of others in the supply chain. The companies that do well out of the fourth industrial revolution will be the ones that recognise the business opportunities and apply the technologies in a focused way to drive the benefits.

"The challenge is not which technology to use, but what benefits do I need in order to out-compete my rivals."



> "In the future lifecycle of manufactured products, the digital lifecycle will start to get bigger and bigger. The more data you capture, the more you can do with it. You can self-optimise, self-heal, be self-aware. The technologies are available today like condition monitoring where you can identify a failure before it fails, but Industry 4.0 stitches it altogether."
>
> **ALAN NORBURY,**
> CHIEF TECHNOLOGY OFFICER,
> SIEMENS PLC,
> SPEAKING AT MACH 2016.

CASE STUDY
MEGGITT PLC

DIGITAL MANUFACTURING AT MEGGITT PLC

The physical world is changing, becoming intertwined with the digital world through a network referred to as the Internet of Things. Physical objects, embedded with digital capabilities, including sensors, software and network connectivity, are enabled to collect and exchange information. This change is happening everywhere from intelligent homes and cars to 'smart cities'. Now manufacturing is catching up.

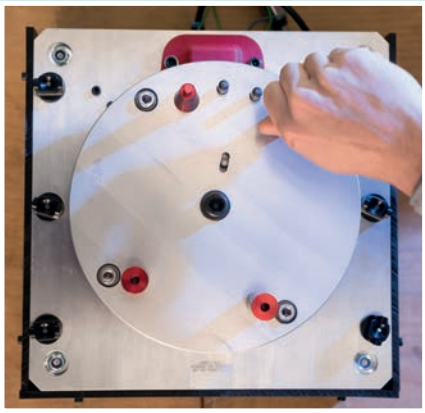
The potential of the Industrial Internet of Things (IIoT), to improve productivity by introducing cyber-physical systems is vast, hence the creation of various digital factory initiatives from 'Industrie 4.0' in Germany to the 'Industrial Internet' in the USA.

Global engineering group Meggitt PLC has its own IIoT initiative, called M4 – Meggitt Modular, Modifiable, Manufacturing. It seems appropriate that a company whose slogan is 'smart engineering for extreme environments' has developed a digital factory strategy. It remains one of the few UK-headquartered companies to embrace the concept. Tasked with developing its own digital factory framework, part-funded through the Aerospace Technology Institute (ATI), Meggitt has a dedicated team researching different technologies, from data analytics to intelligent automation, which can be deployed to improve efficiency across its wide manufacturing network.

Meggitt's business is the design and manufacture of high value, low volume and highly complex products for aerospace, defence and energy markets. Achieving these characteristics amongst the diversity of Meggitt's output — aircraft braking systems, avionics, thermal systems, fluid controls, sensors and piezoceramic components to name a few — creates a number of manufacturing challenges.

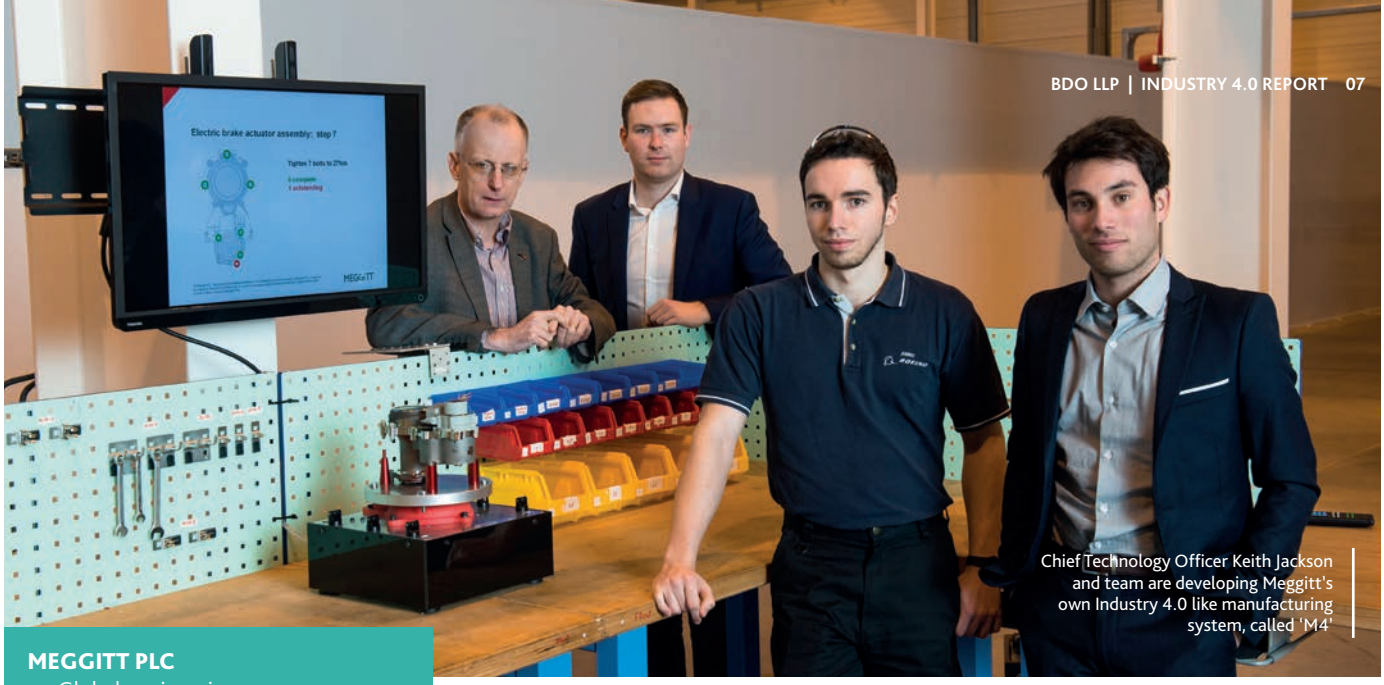
Left: Meggitt International Graduate Programme Engineer, Remy Trang examines a flexible fixturing solution, a product of Meggitt's Closed Loop Adaptive Assembly Workbench (CLAAW) project, the aim of which is to achieve a quantum leap not only in production output but quality, repeatability and traceability using guidance via lasers and display screens and 'smart' tools. The sample part is Meggitt's electric brake.

Below: CLAAW's fixture includes targets to guide the calibration of an overhead laser. A shaft is encoded to enable precise rotation measurements. A power-on brake provides stability for torque operations. Product assemblies can be mounted and removed swiftly using a pneumatic easy-click clamp.



Take the need for dedicated product lines, for example. Today, similar products are manufactured at specialist factories dedicated to specific technology areas. This is where M4 comes in.

"The ideology of having dedicated product lines can be broken" says John Borton, M4's Analytics Leader. "Different products will not only be able to share machines within the same factory but across a wider manufacturing network." A company's best equipment is that which is used regularly. Assets must be sweated and the major advantage of a flexible factory is high equipment utilisation. M4 will enable such flexibility. The system will be able to track all machines, in use and resting, across the Meggitt network. It will enable the company to calculate where spare capacity can be deployed and understand the implications of using each and every machine before deciding where a product will be made.



Chief Technology Officer Keith Jackson and team are developing Meggitt's own Industry 4.0 like manufacturing system, called 'M4'

MEGGITT PLC

- Global engineering company, £1.65bn revenue, 12,000 employees. Headquartered Bournemouth, Dorset.
- Key sectors served: Aerospace, defence, energy.
- Manufacturing facilities in Asia, Europe and North America and regional bases in Brazil, India and the Middle East.
- 25 true capabilities, with 100 or more specific technologies per capability.
- Meggitt components are fitted to 66,000 aircraft in service.
- Proprietary digital manufacturing system called 'M4'.

M4 AT A GLANCE

The brainchild of Chief Technology Officer, Keith Jackson, M4 is founded on a top-down approach to Meggitt's data needs. "If you understand what data you need and when it is needed, rather than capturing everything in the blind hope that it might be useful one day, your business will perform better."

The M4 factory framework embraces many different IIoT concepts. For instance, it will have smart boxes, kitted up with all the parts needed to make a product. Components, fittings and specialist tools will be packed logically, arriving at and leaving each workstation via a flexible delivery system. It could even be self-delivered by autonomous vehicles or by a person who has been given optimal delivery routes and digital instructions from the M4 'brain'. Computers will assist assembly operators through detailed work instructions provided automatically on screens at workstations, through laser guidance and wearable devices, including virtual and augmented reality systems.

OTHER M4 CHARACTERISTICS:

- Optimised scheduling to ensure products are manufactured in the most efficient way possible, leveraging historical data collected from factory floors
- Increased machine flexibility to ensure maximum utilisation of assets
- Dynamic load balancing within the factory enabling products to be rerouted to avoid delays ahead
- From their workstations, operators in touch with colleagues globally to receive advice and share information
- M4 factory management supported by scheduling algorithms and simulation tools
- A place where new machines, technologies and methods can be commissioned and tested virtually before they are introduced to factory floors, reducing risks and enhancing understanding of how the system will respond.

BENEFITS OF M4

M4 will give complete insight into how the shopfloor is performing, delivering what the team calls the Factory DNA. "Without the burden and cost of manual data collection processes, we will increase the accuracy of our simulation models, supporting Meggitt engineers, planners and managers to make informed decisions," says Kostas Efthymiou, the M4 project architect. "Sensors deployed on the shopfloor will capture operational data which will be stored in the cloud after cleansing."

Data analytics algorithms based on descriptive statistics methods will make factory operations highly visible, allowing a more detailed view of key performance indicators.

Simulation models used to evaluate alternative planning strategies and different production line configurations will utilise the clean data stored in the cloud to predict critical performance indicators for decision-makers.

According to Borton, one of M4's biggest benefits is traceability, a key requirement for the safety-critical nature of aerospace products. "All manner of product DNA will be captured, from individual operation times and operator identifiers to the environmental conditions of parts in transit." Again, this will be stored using a cloud repository system based on the M4 manufacturing data model. "Combining these with a user-friendly web portal will allow Meggitt employees to find, analyse and visualise the correct product data with minimal effort. This will be a giant step forward in productivity. On top of this, the aggregated build data for a mass of products will enable us to understand the strengths and weaknesses in factory performance."

Efthymiou observes: "No factory is an island. The most sophisticated algorithms cannot unlock the full potential of a factory without considering suppliers." Similarly, the M4's holistic approach will help the exchange of critical planning information about material and part deliveries between Meggitt factories and their suppliers through a web portal. High value assets, such as state-of-the-art CNC or metal additive manufacturing machines will be connected via the cloud, allowing factories to share facilities.

And this, in Meggitt's view, is what M4, the power of intelligent manufacturing, is all about.

INTERNATIONAL COMPARISONS

GERMANY

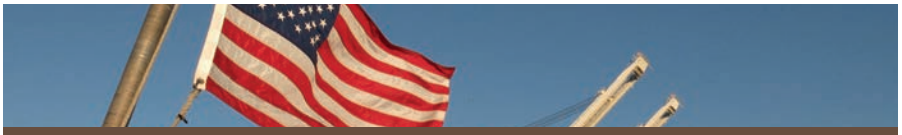
Germany coined the term INDUSTRIE 4.0 and its government has it as one of ten 'Future Projects' which forms its High-Tech Strategy 2020 Action Plan. This strategy has led to Germany now having a wide and deep network of organisations promoting the concept placing them at the forefront as an integrated industry lead market and provider. Big technology partners are engaged with their programmes, with The Fraunhofer Institute, and companies including Siemens, Bosch, SAP, DMG Mori, Festo, Trumpf, Wittenstein and Wibu Systems leading the way.

One programme is Platform Industrie 4.0. While all four main German machine trade associations have their own approaches to Industry 4.0, Platform Industrie 4.0 is the only independent platform for dialogue between companies, their employees, trade unions, associations, the science community and politicians.

To help smaller companies decipher the Industry 4.0 miasma, the German government funded by the Ministry for Economic Development and Energy launched a programme 'Mittelstand 4.0 Centres of Competence' in autumn 2015. The first five centres are active in Berlin, Hannover, Dortmund, Darmstadt and Kaiserslautern. Another five centres will follow in late 2016. These centres will offer:

1. Information gathering and sharing
2. Demonstration of technologies
3. Consulting with SMEs
4. Training, mostly for factory floor people.

Each of these centres is funded over three years between €5m and €7.5m.



THE UNITED STATES

The US is advanced in its version of Industry 4.0 'the Advanced Manufacturing Partnership', which was introduced as part of US industrial strategy in 2011. The updated version, AMP 2.0, promotes a suite of capabilities 'to maintain U.S. leadership in the emerging technologies that will create high-quality manufacturing jobs and enhance America's global competitiveness.' One of three prioritised Manufacturing Technology Areas is Visualisation, Informatics and Digital Manufacturing. There are many components to this: one is to create a Manufacturing Centre of Excellence for, among other things, the Digital Thread, including tools for digital design and energy efficient digital manufacturing. Another is to create a Big Data Manufacturing Innovation Institute focused on secure analysis of and decision-making via large, integrated data sets for manufacturing processes.

The Industrial Internet Consortium was founded by the US multinationals IBM, Cisco, GE, AT&T and Intel. Today the independent consortium has over 150 members, including many European and Asian hardware and software providers including Bosch, Siemens and Huawei Technologies. It has 19 working groups that coordinate and establish the priorities and enabling technologies of the Industrial Internet in order to accelerate market adoption and drive down the barriers to entry.

Founding member IBM has recognised that this 'industrial revolution' is not all about spending millions of dollars on new capex. "Analytics tools are enabling organisations to aggregate and get more value out of what was once perishable and isolated data sets. Typical use cases being around predictive asset failure and quality issues leveraging real time data. With many clients we also see a strong desire to get more value out of existing brownfield assets being equally as important as new greenfield investments, this varies depending on stages at investment cycles within organisations and countries", says Robert Heys, Associate Partner, Global Business Services at IBM in the UK.

On June 2, IBM and Cisco partnered to make IBM's powerful Watson analytics tool and Cisco's Edge Analytics more accessible to operations in remote locations or with no highspeed broadband. This helps firms by processing more data locally, at the point of collection. "With the ubiquity of connectivity, with more sensors, their reduced battery life, and ease of retrofitting sensors you can start to take a lot more data out of assets you are trying to connect," says Heys. "It can be about processing more data on the edge rather than moving petabytes of data to the cloud every second and churning it. You are processing more of the data in the devices local to the assets."

Establishing international standards took a big step in March when representatives of Platform Industrie 4.0 and the Industrial Internet Consortium met in Zurich, to explore the potential alignment of their two architecture efforts – the Reference Architecture Model for Industrie 4.0 (RAMI4.0) and the Industrial Internet Reference Architecture (IIRA).

The US also has the MT Connect Institute, an organisation working to create open standards to foster greater interoperability between devices and clients, by defining the structure used in communications in the discrete parts manufacturing sector, rather than process manufacturing.

THE NETHERLANDS

Smart Industry is the Dutch action programme to implement the fourth industrial revolution bottom-up. Prof. Dr. Ir. E.J. Egbert-Jan Sol at the Netherlands innovation agency, TNO, explains:

"It is all about the acceleration of the digitalisation of our industry. This will lead to new technologies on the factory floor, to the need of training the existing workforce in understanding digital technologies and how to apply them most effectively.

"We knew this, but we found that the problem is within the companies; when asked they said no-one knows how their manufacturing business will look like five years from now. Developments are moving so fast, no-one can innovate on their own. We need to cooperate between small and larger companies, with government and with knowledge institutes.

"In the Smart Industry action programme we start with an awareness call to action, or actionline, 'Eat or to be eaten', followed by a field lab action line. A field lab is close to or within the operational environment, where new technologies and innovation are tried and where people can learn how to apply them. Lastly we have the conditions to support actionline with skill and ICT topics. The end goal is to deliver products to customers in single or small series for the same cost of mass produced products; not produced in China, but around the corner, in the next town and delivered almost overnight."

CHINA

The Made in China 2025 initiative launched in 2015, designed to upgrade Chinese industry, will spur a new robotised industrial revolution where it is planned that intelligent manufacturing may upgrade 'Made in China' to 'Created in China' – China wants to shift its reputation as a copier to an innovator.

Fifteen innovation centres will be established by 2020 and 40 by 2025 focusing on IT, intelligent (digital) manufacturing, additive manufacturing, new materials and biotech. All will be supported with funding from the government.

Research spending will be increased to 1.68% of all manufacturing revenues by 2025 from 0.88% in 2013. China aims to raise the percentage of core components and materials sourced locally to 40% by 2020 and 70% by 2025.

Intelligent (digital) manufacturing will be targeted with reducing costs by 30%, the development cycle shortened by 30%, and the number of faulty products cut by 30% by 2020 and 50% by 2025.

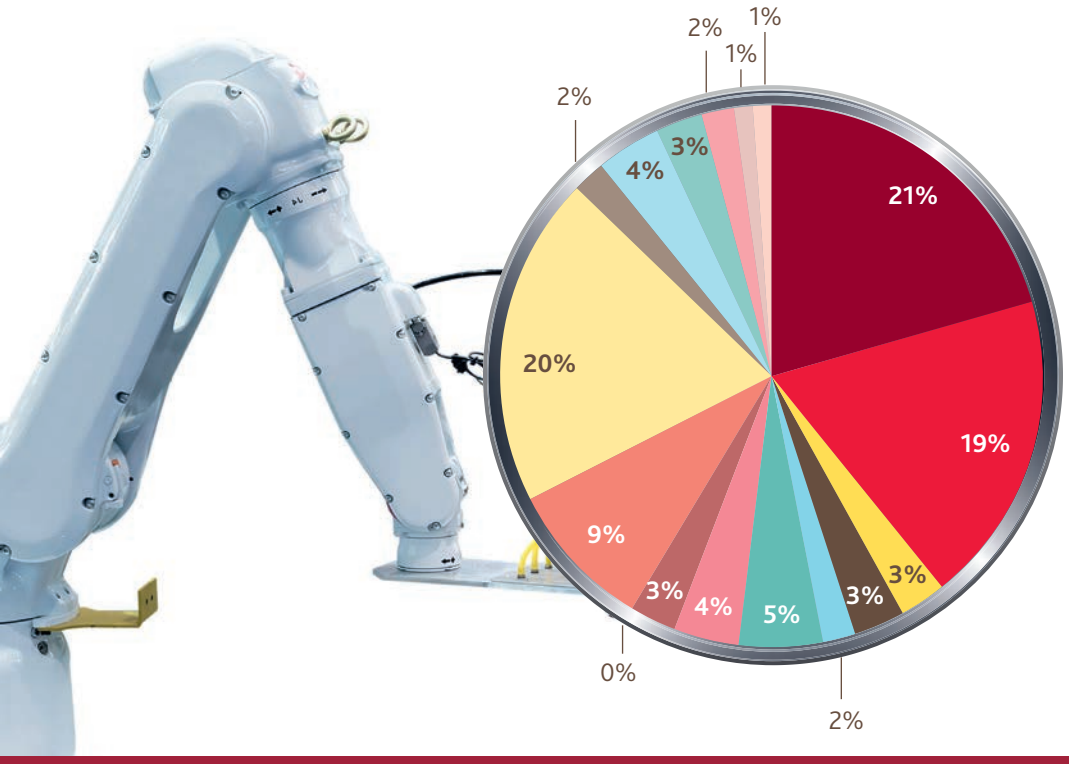
THE UNITED KINGDOM

Currently the UK Government is working on its National Innovation Strategy which will include its approach to Industry 4.0.

The network of High Value Manufacturing (HVM) Catapult technology and innovation centres are working on disseminating Industry 4.0 knowledge and technologies to industry (both large member companies and SMEs). With two of the centres, The Manufacturing Technology Centre (MTC), forging a path as a thought-leader in Industry 4.0 and the Advanced Manufacturing Research Centre (AMRC) with Boeing adopting the new Factory 2050, modular factory approach. The Digital Catapult is helping to explain to companies how they can find and interrogate big data.

Details of the government's grasp of Industry 4.0 is summarised on page 20.

SURVEY RESULTS

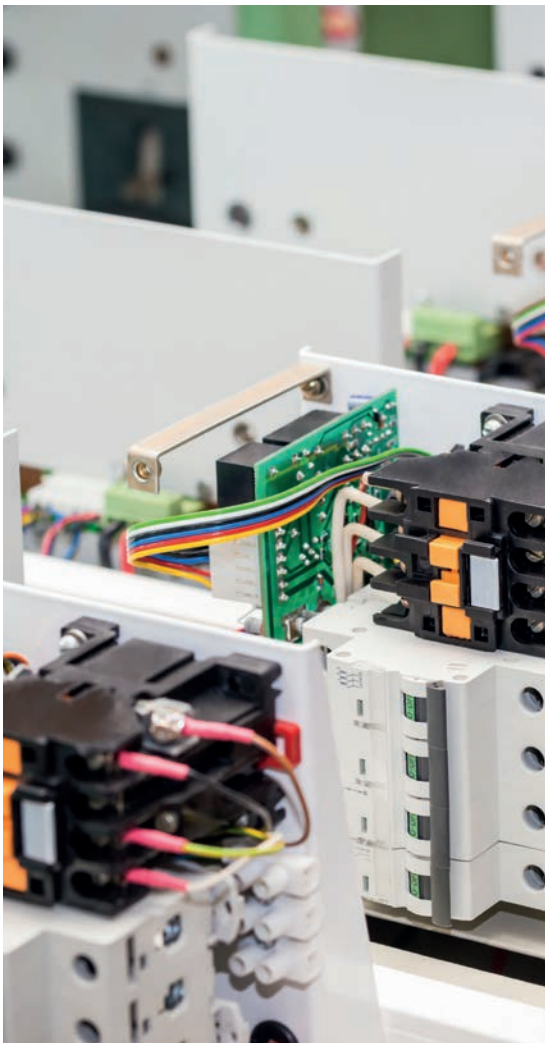


WHICH OF THE FOLLOWING BEST DESCRIBES THE SECTOR FOR THE COMPANY/ORGANISATION YOU WORK FOR?

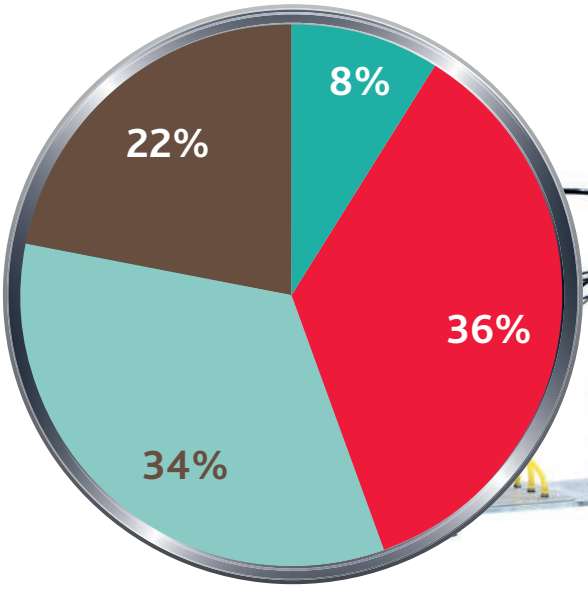
The BDO and the Institution of Mechanical Engineers (IMechE) Industry 4.0 survey received 318 responses from engineers in management-level and director-level positions across a wide spectrum of industry sectors (see chart above). Nearly one third (30%) were engineering or manufacturing managers whose jobs are the most relevant to applying digital technologies to the plant or factory.

The survey had a wide distribution of responses across the entire UK. The South East comprised the biggest group (19%), followed by the East Midlands (16%) second and then West Midlands (14%). A healthy proportion were also from the South West, North West, Yorkshire and Scotland.

The chart shows the distribution by industry sector. Aerospace, automotive and oil and gas dominated, with a good selection of respondents from the defence, electronics, chemicals, food and drink and rail industry. All these sectors can and will be affected by a transition to a more connected, digital *modus operandi*.

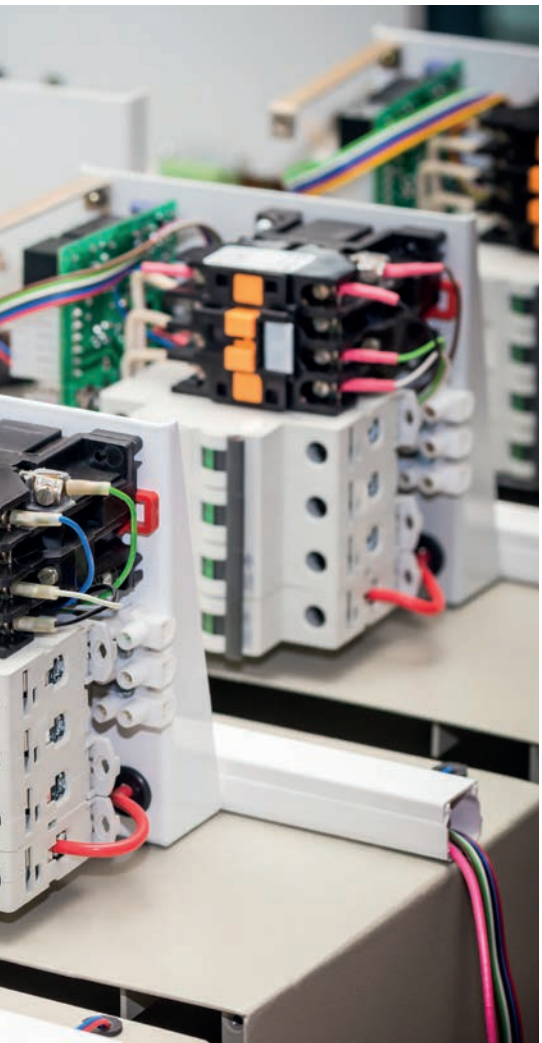


AWARENESS OF INDUSTRY 4.0 IN THE UK MANUFACTURING COMMUNITY



- Significant understanding
- Some understanding
- Little understanding
- No understanding

HOW WOULD YOU DESCRIBE YOUR LEVEL OF KNOWLEDGE OF INDUSTRY 4.0?



If you accept that Industry 4.0 is the future business model for manufacturing, awareness generally is very low. Over half of those surveyed (56%) had little or no understanding of the term 'Industry 4.0' and 8% had 'significant understanding' of it. A more respectable 36% have 'some understanding' of it.

By region, the survey revealed that Yorkshire had the highest significant understanding of Industry 4.0 (24%). It also performed well on an overall basis with over half being familiar with the concept (43% having some understanding and 24% having significant understanding). Followed by London, East Midlands, North West and West Midlands.

By industry sector, understanding was perhaps surprisingly low in the aerospace and automotive sectors. 55% in automotive and 55% in aerospace had little or no understanding. This is perhaps surprising given that arguably automotive has driven Industry 4.0 more than other sectors, because of the relentless drive for productivity and increasingly, customisation of product. This smaller figure for automotive could be explained in that more supply chain companies that make components completed the survey than large OEMs.

The remaining manufacturing sectors covering chemicals and pharmaceutical, oil and gas, electronics, food and drink, construction, power generation and others had generally low awareness; the numbers of respondents with significant understanding of Industry 4.0 were almost all in single figures. For defence, building products, plastics, steel and textiles, nobody had significant understanding.

The results highlight that there remains an opportunity to educate large tracts of the manufacturing sector about what Industry 4.0 is and, more importantly, its benefits.

OPPORTUNITIES AND BENEFITS

HOW WILL INCORPORATING INDUSTRY 4.0 INTO YOUR BUSINESS IMPACT YOUR BUSINESS PROCESSES? (RESPONDENTS WERE ASKED TO SELECT ALL THAT APPLY)

Survey respondents largely showed a good understanding of how Industry 4.0 would affect their business processes.

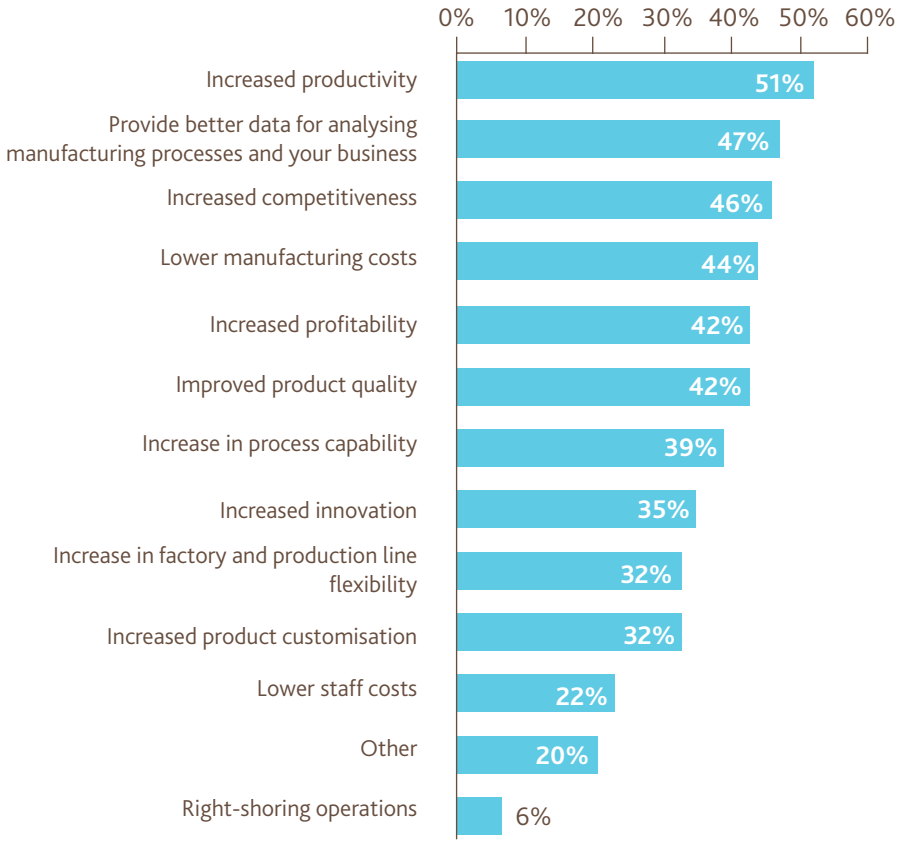
More than 40% said that Industry 4.0 would affect:

- Increased profits
- Increased productivity
- Improved quality
- Lower manufacturing costs
- Increased competitiveness
- Provide better data for analysing manufacturing processes and the whole enterprise.

Another one third of people expected innovation (35%), process capability (39%), factory flexibility (32%) and product customisation (32%) to increase with Industry 4.0 investment.

Only one fifth (22%) said that lower staff costs were a benefit, and just 6% thought it would lead to 'right-shoring' or reshoring of manufacturing operations.

While reshoring is a driver of Industry 4.0, it makes sense that this effect is subordinate to productivity and other key benefits.



CASE STUDY
WILO (UK) LIMITED / WILO SE

Wilo SE is one of the world's leading manufacturers of pumps and pumps systems for Building Services, Water Management and Industry. With 16 production sites, more than 60 subsidiaries and approximately 7,500 employees worldwide.

The company has an uncompromising customer-driven mindset and a culture of innovation, and as such has digitised many business processes that one could say are "en route to Industry 4.0".

It uses live-KPI reporting on the factory floor, including live machine and shop order status. There is also live monitoring of critical process data including alarm messages if a process does not meet specific quality controls, and machine allocation/availability monitoring. This data is all looped back to production planning. The production system can predict the remaining shop order process time to schedule work, and there is Master Data Exchange with Wilo's enterprise resource planning (ERP) system.

The company has an uncompromising customer-driven mind-set and a culture of innovation, and as such has digitised many business processes that one could say are "en route to Industry 4.0".

Self-regulated Pick & Place machines which are linked to the MES system

PERSONALISED MANUFACTURING AND PRODUCT QUALITY

Wilo deploys a Manufacturing Execution System (MES)-based component management to handle product variation, with active and automated component setting by the MES. There is automated shop order transfer from the ERP via MES to the machines.

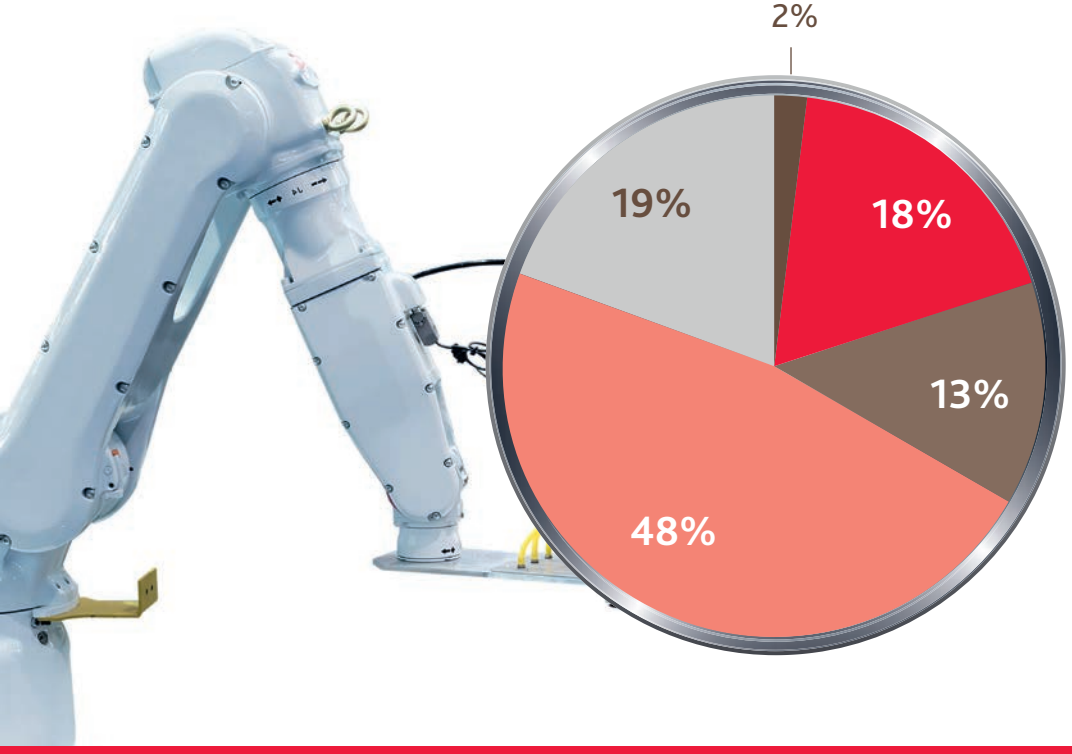
For quality control, Wilo has integrated its production and test equipment including live KPI-dashboards and alarm messages. To provide process control, its processes have interlocking (fail-safe mechanisms) based on quality data and technical restrictions. Bill of materials are automated between the machine and ERP system. Among other processes, Wilo also uses predictive maintenance based on machine performance and quality data.

ROLE OF PARENT COMPANY AND BENEFITS

The Industry 4.0 project at Wilo (UK) Limited is part of a corporate digital transformation approach led from the headquarters in Germany. Teams at different sites are defined and budget is made available. "Almost everything is being piloted before it will be deployed towards the main factories," says Georg Weber, Senior Vice President, Group Electronics & Motors at Wilo SE in Dortmund. The main ultimate benefits from investing in digital manufacturing include improved quality performance, inventory reduction, higher flexibility towards customers and traceability.

"The ROI is definitely long term," says Mr Weber. "The payback period matters in an investment decision, however given the expected long term effect, there is hardly any alternative."

STRATEGY



- Yes - we have adopted it via our parent company's advice
- Yes - we have a strategy in place and have started implementing changes
- Yes - we have drafted a strategy but are yet to implement
- No - but we need to look at this
- No - we don't need one

DOES YOUR BUSINESS CURRENTLY HAVE A STRATEGY IN PLACE TO IMPLEMENT INDUSTRY 4.0 INTO YOUR BUSINESS?

Are companies implementing Industry 4.0 into their business strategies?

Only 20% of responding companies had some level of Industry 4.0 strategy in place, while a handful of these (2%) had adopted this from the parent, foreign-owned company. 19% of companies had nothing in place and said they did not need one. Nearly half (48%) of companies had no Industry 4.0 strategy but said that they needed to look into this, showing that while awareness is generally low, those engineers and managers who are aware of Industry 4.0 know that it requires real action and is not just the 'next big fad' in manufacturing.

Regionally, the highest group who did not need a digital factory strategy came from Wales (40%), followed by the North East (34%) and Scotland (33%). Of those who had no strategy but said they needed to look into one, the highest proportion came from Northern Ireland (67%), followed by Wales (60%) and the North West (60%). 23% of those in the South East said they had a strategy in place and had started implementing changes. This suggests that as a region, the South East is fairly advanced with smart factories, where a large proportion of firms either needed to look at this (51%) or were implementing a strategy (23%).

By industry activity, defence had the highest proportion of detractors, 41% saying their company did not need an Industry 4.0 strategy. The lowest scoring sectors for having started to implement a strategy were construction, oil and gas, steel and test and measurement.

Of the 48% of all the companies who said they did not have a strategy but needed to look into this, the highest number came from aerospace, followed by other engineering then automotive. As a proportion of those responding, 64% from the electronics industry, and about 45% each from aerospace and automotive said their company needed to look into this. The lowest scorers of needing to look at a strategy was test and measurement. For those beginning to implement a strategy, automotive (29%) was highest, followed by other (23%) and aerospace (21%).

The stand-out results for an Industry 4.0 strategy are:

- Started implementing: highest = Automotive (29%)
- Need to investigate: highest = Electronics 64%
- Don't have one, don't need one = Defence 41%

Overall it is a positive that a majority of the respondents understand that Industry 4.0 is an important step change for businesses with over 80% of respondents either already implementing a strategy or understanding that they needed to find out more to ensure their businesses remain competitive.

INVESTMENT

One third of respondents' companies had invested no money in automation systems and Industry 4.0-related technology in the last 24-months, and about a quarter (24%) said they do not plan to invest in this capex in the next 24-months.

This suggests that the Industry 4.0 revolution has not precipitated a wholesale investment drive across UK manufacturing. Also this question has a high proportion of 'Don't knows'. But 16% of companies are expected to spend over £500,000 on this technology in the next 24-months, a significant number given the size of investment. This was nearly double the number which had spent this sum in the previous 24-months.

Combining those no-investors, both last and next 24-months, 50% of the survey were not investing in automation or manufacturing IT, and yet more than 80% had also said they were either implementing an Industry 4.0 strategy or needed to do so. This suggests a high proportion of firms are not making a connection between 'Industry 4.0' and automation, which prompts the need for better education of these terms, and a role for trade bodies and institutions to do this.

In addition, 9% had invested more than £5m in these technologies in the last 24-months and 7% planned to invest more than £5m in the next 24-months.

Such large investments were planned by companies with +£450m turnover, so in proportion to their size the investments are not vast.

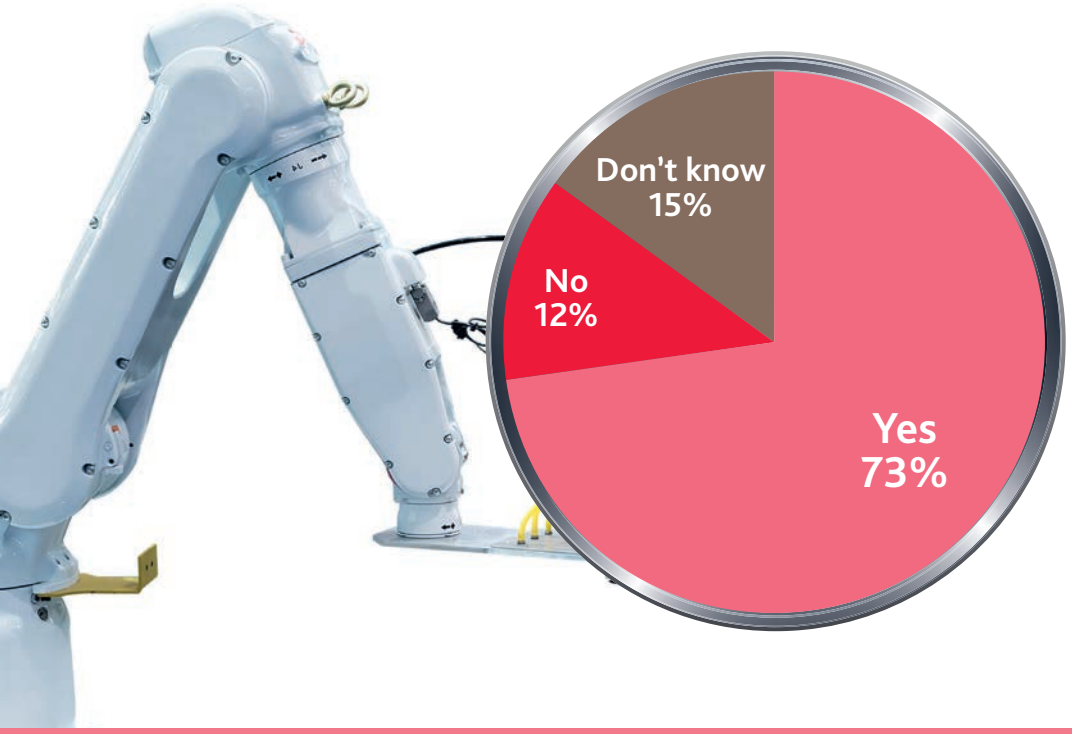
WHAT ARE YOU INVESTING IN?

At the more granular level, the highest number of companies were planning to invest in technology in production (64%), research & development (45%) and logistics (25%). A high proportion in logistics shows that digital technologies are also relevant to transportation and material handling, not only pure manufacturing.

The Industry 4.0 concept takes into account the 'entire manufacturing value chain'. With pockets of Industry 4.0 technology investment in non-production areas like warehousing (17%), procurement (13%) and sales (11%), this survey proves that Industry 4.0 is being considered, and applied, across the whole value chain in UK manufacturing, although core production is still the biggest beneficiary.

The main reason for not investing in Industry 4.0 technology is a lack of understanding (44%). Only 5% said it was due to lack of external finance or grants, and just 8% said their infrastructure was unsuitable.

CYBER SECURITY RISKS



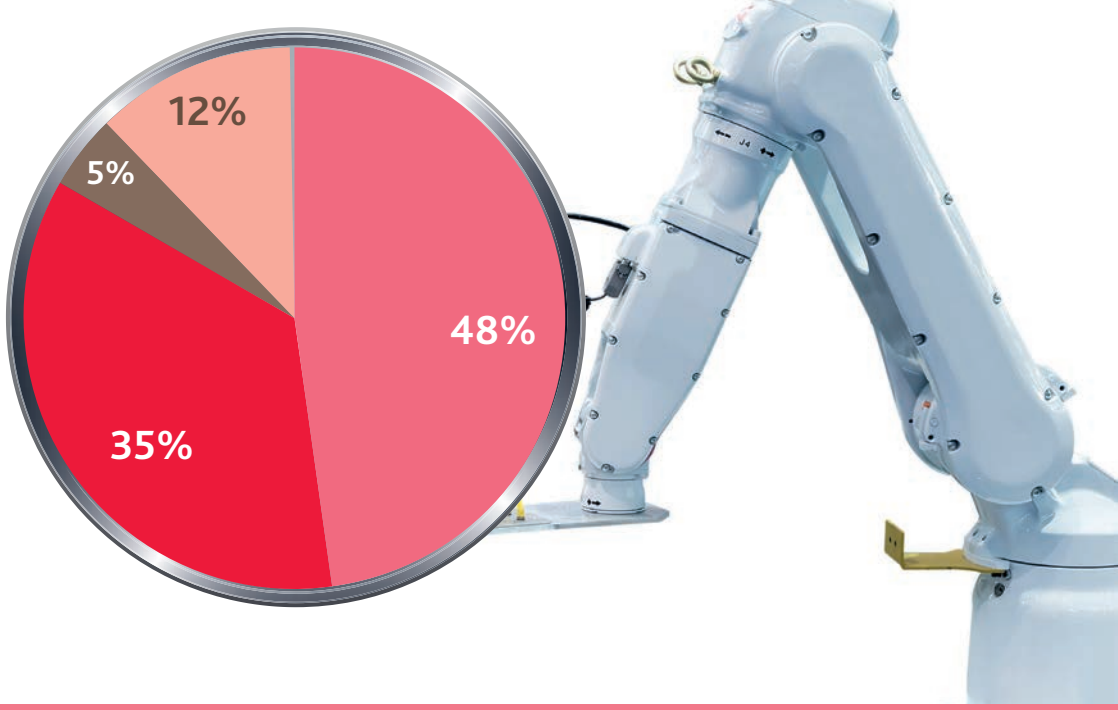
INCREASING DIGITISATION WILL LEAD TO BUSINESSES NEEDING TO MANAGE LARGER QUANTITIES OF DATA (BIG DATA). DO YOU THINK INDUSTRY 4.0 WILL INCREASE THE RISK OF CYBER SECURITY BREACHES FOR MANUFACTURING BUSINESSES?

From a security perspective, this hyper-connectedness of systems – both within the organisation and over the internet – increases an organisation's 'attack surface' allowing attackers to target systems through new vectors. The threat includes attackers trying to disrupt manufacturing processes or those trying to exploit systems in order to get their hands on intellectual property.

73% of the survey respondents believe Industry 4.0 will increase the risk of cyber security breaches for manufacturing businesses.

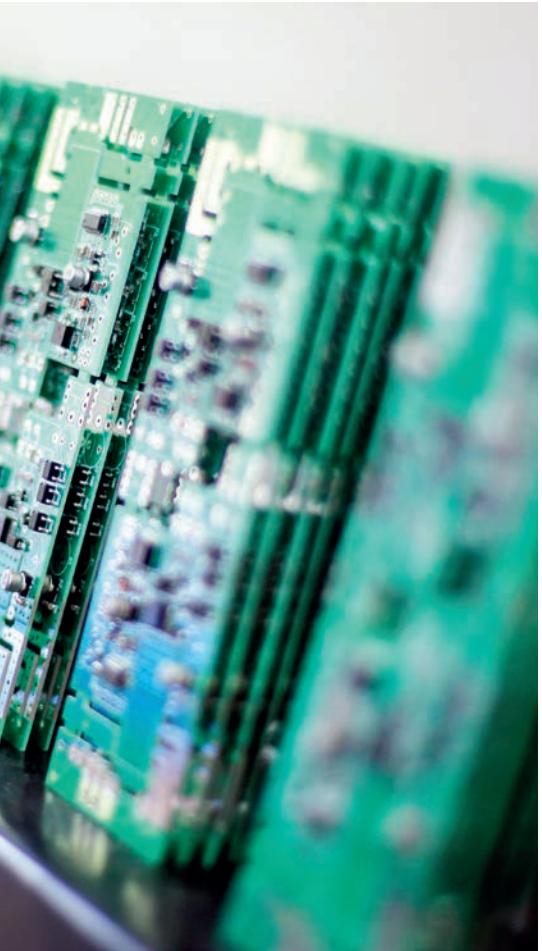
Manufacturers of industrial control systems have traditionally not focussed on security of these systems. This was primarily because such systems worked in isolation from the corporate network infrastructure and were not connected with the internet. Such systems usually also have a long lifetime, often exceeding the vendor support periods for the platforms they are built on. There is a risk of use of unsupported systems which increases the likelihood of unaddressed security vulnerabilities on the systems.

Anti-virus and anti-malware software is not typically designed for industrial production machinery. Installing anti-virus software can have an impact on machine performance. In addition to this the software may require future updates so need access to the internet which is typically not in place for such systems.



- Yes - we have adequate systems
- Partly - it will require some updates
- No - we will need to install new IT systems
- Don't know

DOES YOUR BUSINESS HAVE A SUITABLE IT INFRASTRUCTURE WHICH COULD PREVENT CYBER SECURITY BREACHES?



Cyber security is a challenge for organisations in the manufacturing sector today. High-profile sophisticated attacks, known as advanced persistent threats (APTs) have included attacks like Stuxnet and Flame which have specifically targeted industrial control systems.

Our survey results show that over 50% of organisations are not convinced they have the suitable infrastructure to prevent cyber security breaches. What is interesting in the results is the 12% of respondents who said they did not know if they had adequate security controls or not. Both results above point to a need for cyber security governance and risk-based security framework to implement and monitor appropriate internal controls to address the risk of a cyber security breach.

The significance of this need increases with the adoption of Industry 4.0 as the board and management need to ensure they have adequate controls in place against new challenges.

All risks relating to cyber security should be covered as part of a risk assessment which should be periodically revisited. Regular threat intelligence should be carried out to inform on emerging risks relating to the industry, sector, sub-sector and company. Appropriate controls need to be put in place in each of the four areas – prevent, protect, monitor and respond – to address the associated risks.

CASE STUDY
KÄRCHER UK LIMITED / ALFRED KÄRCHER GMBH & CO. KG

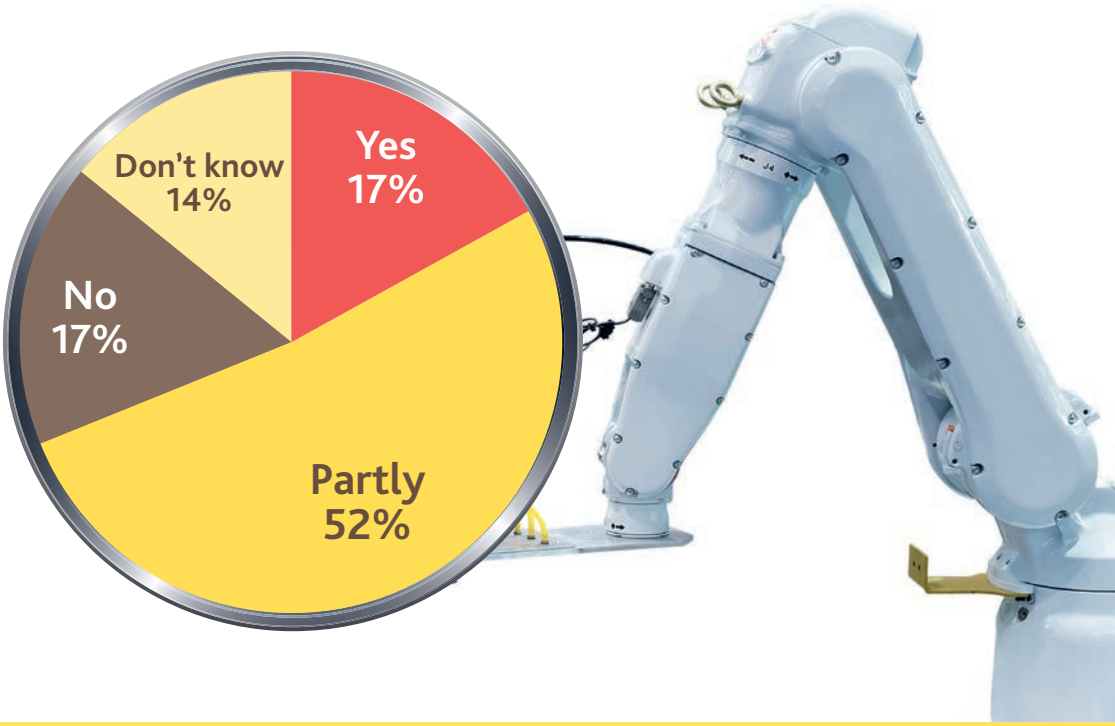
Industry 4.0 is central to cleaning technology company Kärcher's thinking for its global production lines. "Especially our larger Floorcare machines, and we are looking to continue developing 3D printing and digital work instructions, also known as automated pick by light," says Mark Venner, Chief Operating Officer at Kärcher UK Limited.

He points out there are no "ready-for-use" Industry 4.0 solutions or products on the market yet. "Industry 4.0 is more than just networked machines, for example logistics is a key aspect. Lean and Industry 4.0 are not opposites, but complement each other." Kärcher also recognises that data security is a high priority in the evolution of digitised manufacturing business, and personnel and HR flexibility are also integral parts of Industry 4.0. The company says an overall understanding of business processes in IT departments is essential to develop this strategy.

SOME OPPORTUNITIES FOR INDUSTRY 4.0 THAT KÄRCHER HAS IDENTIFIED:

- Efficient customer-specific production will be possible, i.e. the 'batch size of one' without incurring extra costs by using highly flexible production cells and logistic value streams
- Smart products communicate with each other via the internet or with databases (the customer and/or Kärcher)
- Traceability through entire value stream is possible
- The speed of changes (customer, engineering and more) increases
- Highly increased resource-efficiency by interlinking environmental data with data of Kärcher's value stream.

SKILLS



DO YOU HAVE THE RIGHT STAFF/SKILLS TO INCORPORATE INDUSTRY 4.0 INTO YOUR BUSINESS?

Over half the survey (52%) said that their company had some of the right skilled people to implement Industry 4.0 into their business. 17% said yes they had the correctly skilled people for Industry 4.0, and 17% said they did not. On balance this seems a stable position for digital factory skills as the evolution progresses.

HOW IS BRITAIN PREPARING TO TRAIN EMPLOYEES FOR THE DIGITAL FACTORY?

Two technology and innovation centres of The High Value Manufacturing Catapult – the Advanced Manufacturing Research Centre and the Manufacturing Technology Centre – have training centres where apprentices and post-graduate students can learn more about the requirements of the technology used within a digital factory.

At the Lloyds Bank Advanced Manufacturing Training Centre near Coventry (part of the MTC), 40 engineering apprentices per year train in subjects including informatics and PLC programming. They expect the intake to increase.

At the AMRC Training Centre they offer courses including machine programming training, manufacturing IT and the centre is developing more courses.

The Edge Foundation, which helps run the system of University Technical Colleges (UTCs) in the UK, published a report (May 2016) The Digital Revolution, The impact of the Fourth Industrial Revolution on employment and education, to demonstrate that the UTCs are preparing for the needs of future factories.

The Aston UTC is using Festo mechatronic equipment and plans to teach some digital manufacturing programmes, but there is not much detail on the UTC courses and lessons for Industry 4.0.

UK GOVERNMENT POLICY

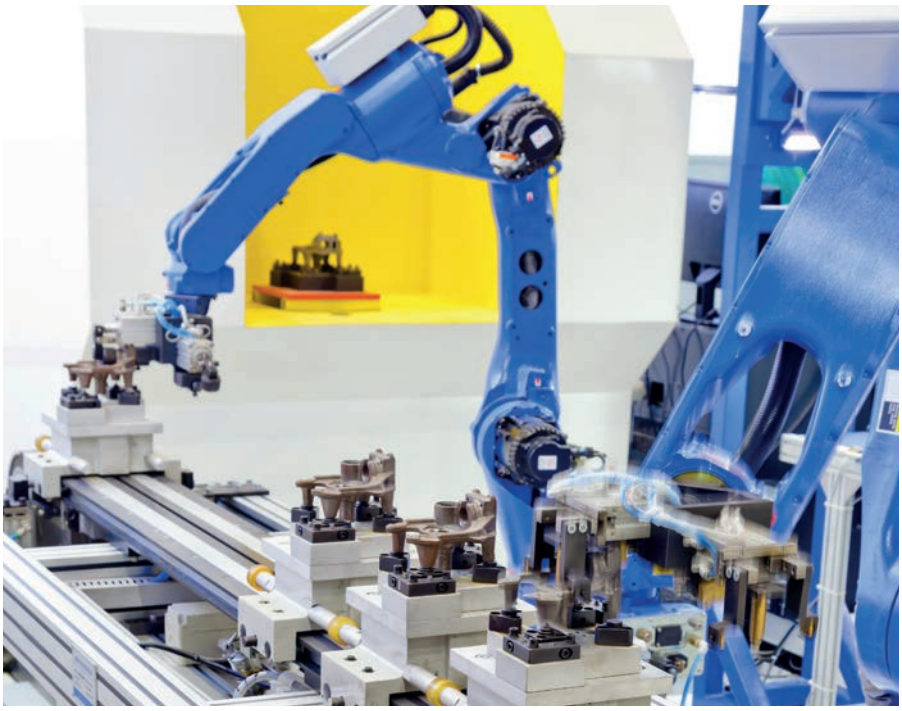
How is the government responding to digital future factories?

Since the Conservative Government took office in May 2015, it is safe to describe the government's attitude to a UK Industrial Strategy as underwhelming. Business Minister Sajid Javid made some lukewarm noises about the importance of manufacturing at the EEF National Conference in February, where he also warned against "picking winners", a hackneyed phrase linked to giving money to big companies, which many thought the UK had got past, where we are now appropriately "backing winners".

The UK's response to Industry 4.0, given its primary launch in Germany in 2011, has been slow. Until now, no formal policy making has reflected the rise of the digital industry. Meanwhile, our neighbours in the Netherlands – with a much smaller manufacturing sector - have been coordinating an integrated programme, Smart Industry. Perhaps sensing we were behind the international curve, later this year, government will launch **The National Innovation Plan**, a framework for the government's approach to getting the UK to the forefront of the fourth industrial revolution. The plan 'will set out the whole government approach to ensure the UK exploits the opportunities of this by creating the conditions for innovative businesses to flourish.'

Innovate UK, revised 2016 strategy – has a focus on digital manufacturing and support for commercialising underpinning technologies, including 3D printing/additive manufacturing.

High Value Manufacturing Catapult – these innovation centres have positioned themselves as thought leaders and delivery agents in Industry 4.0, taking on a role in Britain similar to the Fraunhofer Institute in Germany – helping companies cross the tricky Technology Readiness Levels 4 to 7 en route to product commercialisation.



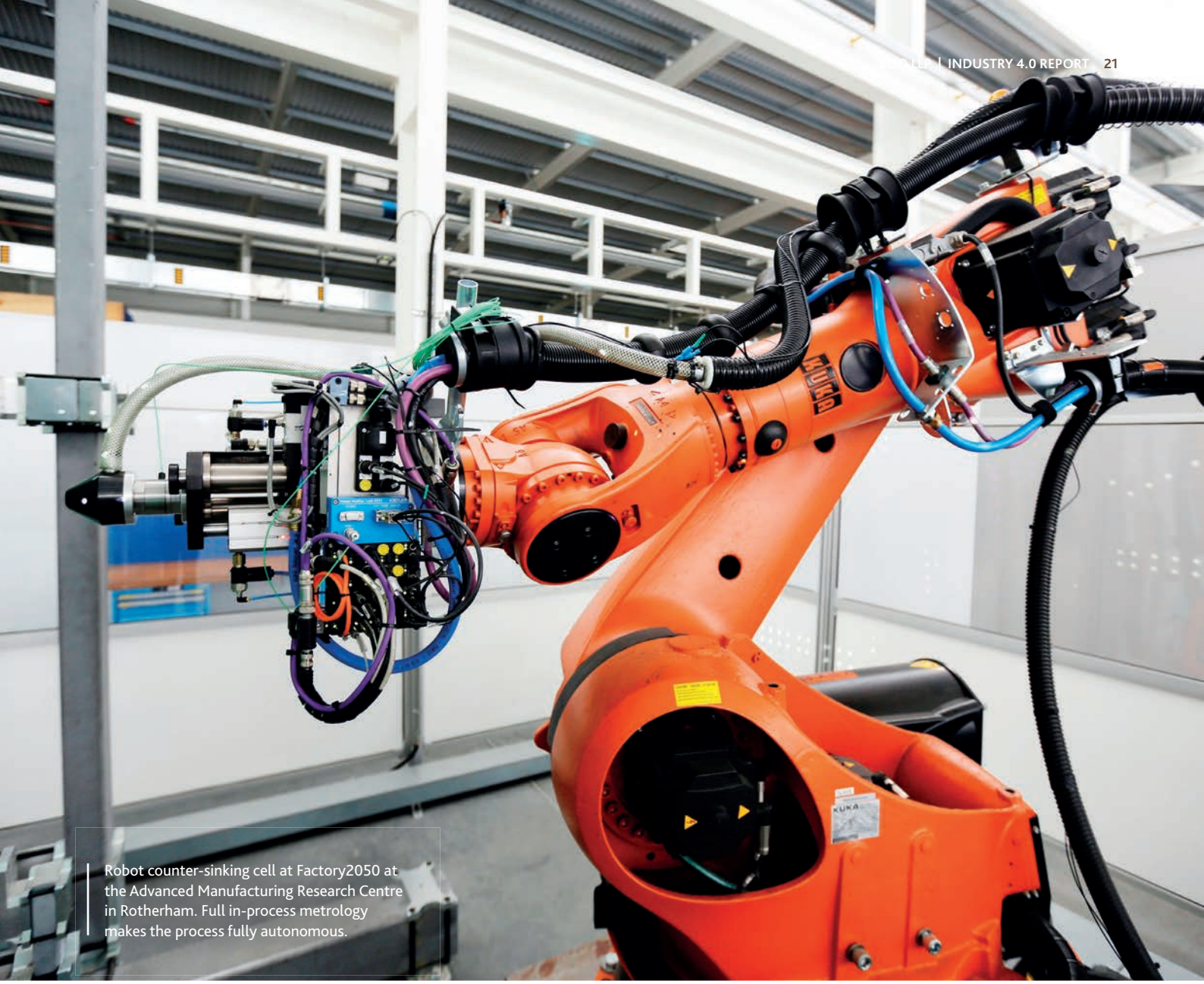
The National Institute of Coding - in the Autumn Statement speech in November 2015 on cyber security support, The Chancellor outlined the creation of a new Institute for Coding to help support digital skills. There is a competition to attract joint collaborations between universities and businesses to establish the Institute which will focus specifically on delivery of higher level digital skills and computer sciences. The Government has committed a total of £20m in capital to help fund the Institute for Coding, alongside an expected further contribution to the costs by the winning bids.

Meanwhile, the BBC has launched the micro:bit, a new computer to be given to every 11-year-old in the country. Children must code as an essential life skill, the prevailing wisdom says, if they are to participate in business in the future.

As shown earlier in this report, the governments of other nations are making serious long term plans to address the opportunities offered by Industry 4.0.

"Government needs to listen to industry leaders about what they need and set a long term industry strategy. The implementation of Industry 4.0 is not going to happen overnight and government needs to recognise and support businesses through this change. Embracing these new technologies will enable our manufacturers to drive productivity growth whilst ensuring they are developing sustainable business models and delivering products that consumers want."

PHILIPPA OLDHAM,
Head of Manufacturing, Institution of Mechanical Engineers



Robot counter-sinking cell at Factory2050 at the Advanced Manufacturing Research Centre in Rotherham. Full in-process metrology makes the process fully autonomous.

CASE STUDY
BAE SYSTEMS

ROBOT COUNTER-SINKING CELL

Engineers have been developing a roboticised counter-sinking cell at the Advanced Manufacturing Research Centre, and now the Factory 2050, for several years. It is now deployed into production at BAE Systems Samlesbury. It takes in pre-drilled panels, one robot counter-sinks the panel while the other robot acts as a fixture, supporting the panel.

The AMRC's work to date has included complete reprogramming of the PLC to be more efficient, removed as many moving parts as possible, non-contact laser metrology. For Industry 4.0-like analytics, the centre is now doing process monitoring and controlling, control of the spindle and the encoders driving the spindle. "We can effectively listen to the spindle to when it engages and finishes the cut," says Ben Morgan, Head of the Integrated Manufacturing Group/Factory 2050 at AMRC. "By fusing that data with the encoder data we can ascertain if we have a counter-sink at the right depth as the tool comes away. This is full in-process metrology, it means we don't then take precious seconds to image or manually check the counter-sink."

The amount of information the team can get from thousands of holes per wing section, or tens of thousands per day, is 'big data'. This can start to reveal trends such as what cutting patterns affect the machine performance.

CASE STUDY
LAMBERT ENGINEERING LIMITED

Lambert Engineering is a leading provider of automation systems, equipment engineering and precision components, employing 185 people at its factories in North Yorkshire.

The company has enjoyed rapid growth over the last three years by investing in the latest technology and a personal development programme that develop multi-discipline engineers of the future. 80% of turnover is from exports.

The company builds bespoke high-end factory automation for the medical device and fast-moving consumer goods sectors, targeting blue chip organisations focused on productivity and Overall Equipment Effectiveness.

Warren Limbert, Managing Director of Lambert Engineering, explains its digital factory journey:

"Our factory has changed dramatically in the last decade, with an increasing amount of CNC machines in the precision engineering department, installation of Enterprise Resource Planning (ERP) and data terminals in our build and test areas, investment in the latest 3D modelling software in our design room and almost a complete overhaul in inspection and quality.

What we thought were top of the range measuring capabilities in 2005 are now a distant memory to the co-ordinate measuring machines (CMM) and laser measuring systems we now have at our disposal. Access to data around our factory has become the norm, with computer terminals being installed in all manufacturing, assembly, commissioning and test departments. This access to data goes way beyond the technical support that staff require, but also allows full business communication through our company SharePoint site.

Warren Limbert, Managing Director at Lambert Engineering

Training:

Our employees have the ability to navigate around our business management systems, submit continuous improvement ideas through our suggestion scheme and read all up-to-date company news. The benefits of this data communication are massive compared to even five years ago.

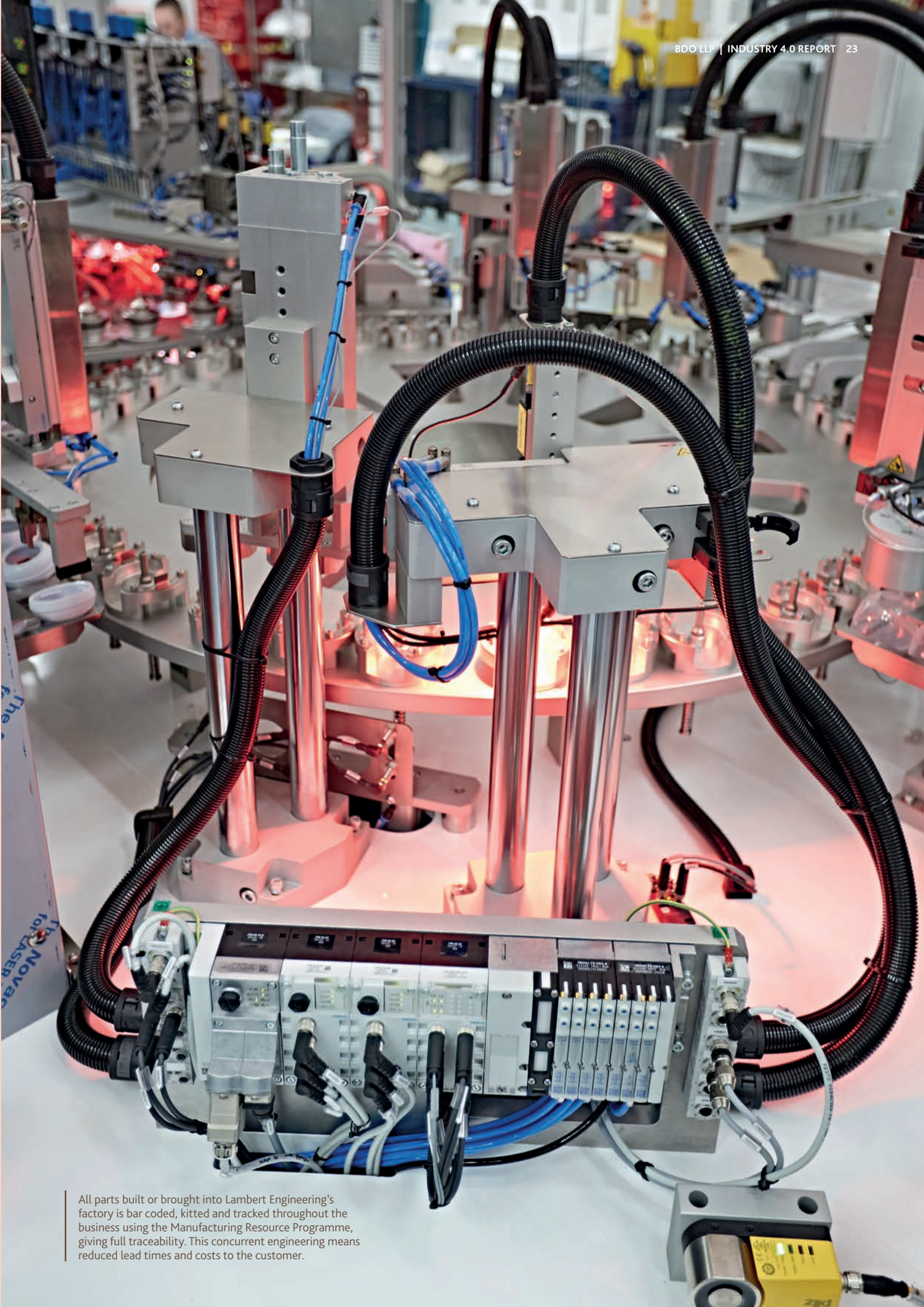
Everything built or brought into our factory is now bar coded, immediately kitted and can be tracked throughout the entire business on our Manufacturing Resource Programme, giving us full traceability of the job and ensuring we can design and build more effectively. What this concurrent engineering means to the customer is reduced lead times and costs, for highly sought after commodities. This is no small feat when you consider the tens of thousands of individual bespoke components that are being managed at any one time.

It's not just the machinery and technology that has changed, you have to also invest in the skills of your staff to ensure you are getting the most out of them. This has seen a general move towards all our employees in the manufacturing and inspection areas being able to programme CNC machines and, by giving them access to component 3D models, the ability to manipulate components around geometrical planes and surfaces.

In the machinery build division we have always had highly skilled engineers in mechanical build and the electrical assembly who would work together. Now we are moving more towards mechatronics, where engineers need to be proficient in both areas (along with the ability to interface through the machine PLC's Human-Machine-Interface) so they can build and set-up, while also fixing the automation parameters of the equipment.

Momentum is increasingly growing around big data, internet of things and Industry 4.0 as manufacturing strives for 'Factory of the Future'. This will be driven by our end customer, but SMEs cannot be left lagging behind, there has to be a co-ordinated approach so that we can support and benefit from the fouth industrial revolution."

Lambert Engineering won The Manufacturer of the Year Award, Overall Winner, at the 2015 TMMX Awards run by The Manufacturer and the Institution of Mechanical Engineers.



All parts built or brought into Lambert Engineering's factory is bar coded, kitted and tracked throughout the business using the Manufacturing Resource Programme, giving full traceability. This concurrent engineering means reduced lead times and costs to the customer.

GLOSSARY

Augmented reality – wearable technology to assist with visualizing a simulated product or system.

Batch of one – linked to mass customisation and personalised manufacturing. One product in series production can be a variant of every other product in the series.

Big Data – that are so large or complex that traditional data processing applications are inadequate. Challenges include analysis, capture, data curation, sharing, visualization, and information privacy. The term often refers simply to the use of predictive analytics or certain other advanced methods to extract value from data, and seldom to a particular size of data set.

Cyber-physical systems (CPS) – enabling technologies that bring the virtual and physical worlds together to create a truly networked world in which intelligent objects communicate and interact with each other.

Digital or 'smart' factory – a factory where products, machines and people are 'connected' wirelessly, where the data transmitted will assist in identifying productivity improvements. These might include self-organisation and autonomous navigation of parts around the facility.

Digital Twin – broadly, an interchangeable term for cyber physical systems.

Fast data – a term being used to describe 'big data' delivered in real-time.

High-Tech Strategy 2020 Action Plan – Germany has a high-technology strategy. The Action Plan identifies ten 'Future Projects' – including Industry 4.0 (INDUSTRIE 4.0) – which are considered as being critical to addressing and realising current innovation policy objectives as the focus of research and innovation activity. Within these lighthouse projects, specific innovation objectives will be pursued over a ten to 15 year time frame. The INDUSTRIE 4.0 project has been allocated funding of up €200m within the High-Tech Strategy 2020 Action Plan.

Industry 4.0 – aka the fourth industrial revolution. Industrial production has passed through three revolutions involving mechanisation, electrification, then mass production, electronics and IT to further automate production. The fourth phase is based on the use of cyber-physical systems, where machines, products and logistics equipment communicate with each other, reducing repetitive human labour and enabling mass customised production.

Industrial Data Space – a platform founded by the Fraunhofer Insitute for more secure and self-determined exchange of data. The Industrial Data Space helps enterprises in accessing more business potential by providing basic data services such as anonymisation of data, integration services and management of 'expiration dates' for data.

Industrial Internet – the development, adoption and widespread use of interconnected machines and devices and intelligent analytics, within the industrial environment.

Mass customisation – the ability to produce goods in high volume, with small or large modifications to each individual unit, without a significant change in the efficiency of manufacturing in those volumes. See 'batch of one'.

Standards and protocols – standards for electronic communication are vital to digital factories. Standards include universal ones including Ethernet, Profinet and Profibus. Countries and jurisdictions can set their own communication standards. One advantage of European Union membership is, arguably, that member countries have more control over setting universal standards in a group of partners, rather than being obliged to adopt the standards chosen by other countries.

(VR) CAVE – Computer Aided Visual Environment. A virtual reality environment where the user/s can view a 3D simulated product or assembly in immersive 3D, seeing around and 'inside' the assembly.

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