The University of Nottingham

UNITED KINGDOM · CHINA · MALAYSIA

INSTITUTE FOR ADVANCED MANUFACTURING

Supporting UK manufacturing through innovation and collaboration

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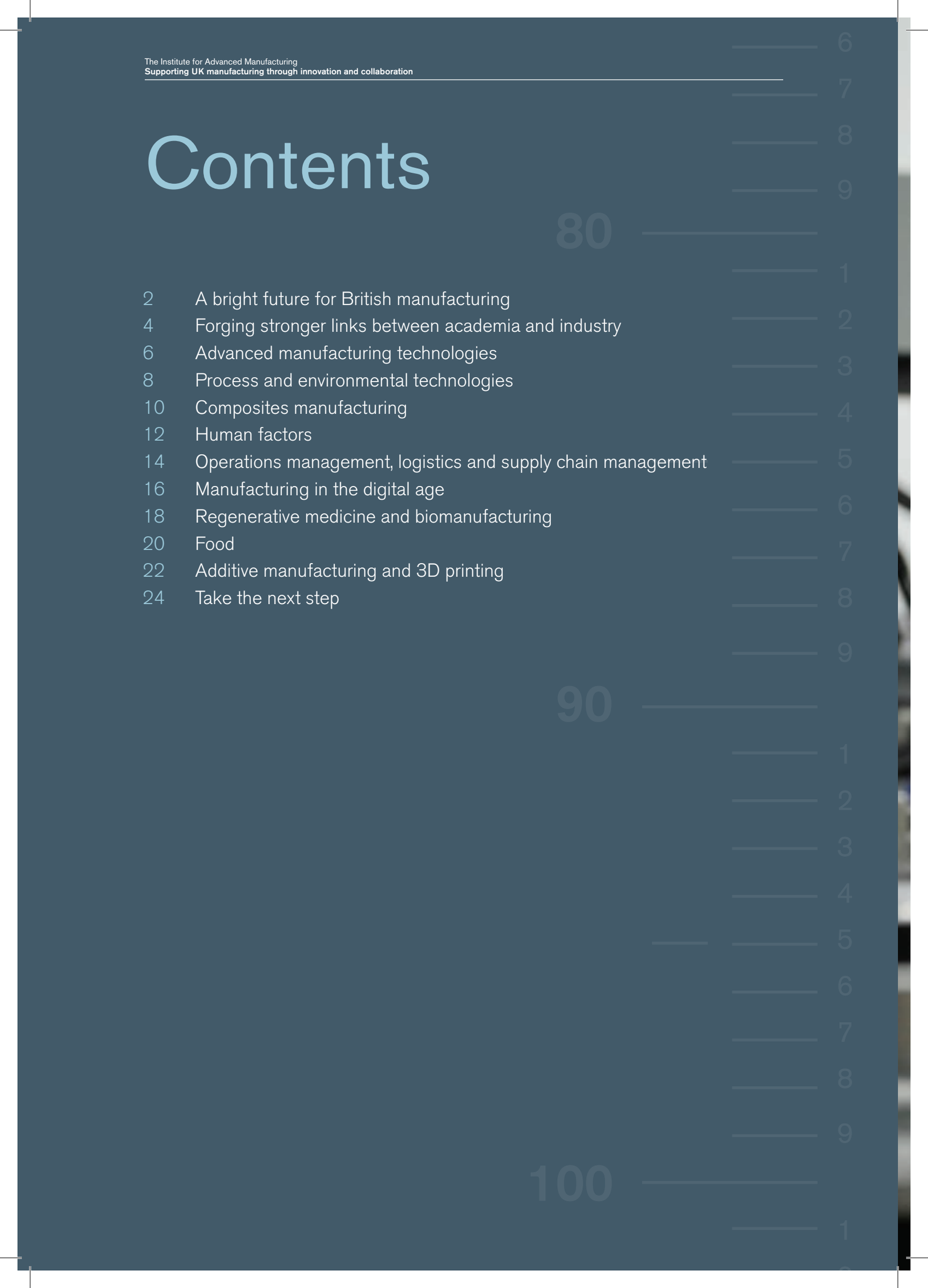


Staff member Mark Dains using the Mitutoyo-Coorinate measuring machine in one of the Advanced Manufacturing labs.

A bright future for British manufacturing

Dr Peter Standring, Dr Adam Clare and NIMRC Industrial Fellow Johannes Dedenbach, (Ford Motor Company) discussing results at the UK's first Plasmatron brazing/welding cell.

Our vision...

...is to be the leading international research centre and preferred supplier to industry of research in advanced manufacturing technology.

UK manufacturing has undergone seismic changes over the past couple of decades. And although so much mass-volume, low-cost production has moved East, there are many exciting opportunities for ambitious, British-based companies who dare to innovate.

Aerospace, automotive, defence, healthcare, food, power engineering, instrumentation, textiles and consumer goods are just some of the sectors where so many businesses recognise that staying competitive in the global market means pushing the boundaries of what is possible.

But innovation is not easy and demands vision, talent and capability. Which is why so many turn to the Institute for Advanced Manufacturing at The University of Nottingham.

We are dedicated to supporting UK manufacturing to revitalise the British economy. The Institute pulls together internationally renowned academics in a diverse range of fields. Working collaboratively across disciplines and countries, these commercially focused researchers thrive in a stimulating culture of innovation and experimentation and are developing the technologies, processes and concepts that give manufacturers a competitive edge.

Key to our success is research that is directly applicable to industry. We work closely with many organisations – from determined young start-ups and regional SMEs to powerful multinationals such as Airbus, Rolls-Royce and BAE Systems. We are proud to meet the needs of these companies, tackling challenging briefs and bringing tomorrow's products closer to today.

We invite you to find out more about the areas in which we work and how we could benefit you…

Discover our multidisciplinary research

The Institute for Advanced Manufacturing is a dynamic research centre that provides a fertile environment for some of the world's leading researchers in a number of areas. These include:

- Advanced manufacturing technologies
- Process and environmental technologies
- Composite manufacturing
- Human factors
- Operations, logistics and supply chain management
- Manufacturing in the digital age
- Regenerative medicine and biomanufacturing
- Food
- Additive manufacturing and 3D printing

You can find out more about these topics in this brochure and at **www.nottingham.ac.uk/research/priorities/advancedmanufacturing**

Forging stronger links between academia and industry

The Institute for Advanced Manufacturing is part of The University of Nottingham, one of the world's leading universities.

Described by The Sunday Times University Guide 2011 as 'the embodiment of the modern international university', Nottingham has award-winning campuses in the UK, China and Malaysia. We are ranked in the UK's top 10 and the world's top 75 universities by the respected Shanghai Jiao Tong University.

Fundamental to the University's success is the pursuit and dissemination of knowledge for the benefit of society and the economy. Collaboration with industry is central to this mission, and we have a long and proud record of knowledge transfer and making our expertise and facilities widely accessible to organisations of all sizes.

About the University

- Over 40,000 students
- Campuses in the UK, China and Malaysia
- Ranked 7th in the UK for research power
- 90% of research of an 'international standard'
- Over 200 industrial sponsors of research

PhD student Liam Evans on site at Airbus.

Advanced manufacturing technologies

In highly competitive global industries such as aerospace, defence, healthcare and energy, customers demand products that are stronger, lighter, more flexible, more cost-effective and deliver better performance.

Often, commercial pressures and financial constraints mean it is not possible for manufactures to spend millions on equipment or to give their own R&D teams limitless time to develop new ideas. And that's where a strategic partnership with the Institute for Advanced Manufacturing can provide significant benefits.

We offer a wide range of cost-effective services to UK and international industrial partners and other global research centres. These range from design concepts and simulation to developing new technologies and processes. We also develop new manufacturing techniques, providing long-term strategic thinking and tackling some of the most challenging engineering problems on the planet.

Areas of research include:

- intelligent automation and assembly
- laser processing
- machining and condition monitoring
- metalforming
- micro- and nano-manufacturing
- precision manufacturing
- responsive manufacturing
- robotics

How we benefit industry

We work with hundreds of companies across the supply chain. A major collaborator is Rolls-Royce, which has set up two of its global University Technology Centres here at Nottingham. The UTC in Manufacturing identifies, assesses and aids the delivery of new and emerging technologies to support the company's strategy. This includes tackling current manufacturing challenges as well as identifying areas for future research.

In collaboration with Airbus we have established an international research hub dedicated to developing future technologies in assembly systems, tooling and fixturing. This will help the company develop more advanced, high quality and lower-cost aircraft wing structures. The hub activities have led to further partnerships with BAE Systems and other major aerospace companies.

Our research in smart reconfigurable assembly systems and devices has attracted significant amount of research finding and has benefited major international companies including Philips, Bosch, Festo, Mikron and others.

Building on our expertise in high precision technologies, we have led the development of the European Micro- and Nano-Manufacturing Strategic research agenda MINAM, informing policy makers and funders on future research priorities.

BAE, along with a number of other international companies, has benefited from our development of novel machining techniques, such as using water jets to mill complex shapes. Other technologies include the development of miniaturised machine tools and more efficient grinding techniques.

‘Spider’ robot carries out repairs

Working with Rolls-Royce, our researchers have developed a spider-like machine to carry out in-situ repairs and maintenance in cramped conditions.

The miniature free-leg hexapod operates in small spaces with uneven surfaces. It is computer controlled for precision positioning and in its current configuration has a high-speed spindle for milling, drilling and deburring.

Traditionally, computer-controlled machine repairs are completed in a workshop or in-situ using large, bulky machines that are difficult to operate and require hours to set up. This leads to long down times and high costs. The FreeHex is extremely mobile and can be set up in minutes.

Dr Joel Segal and Professor Svetan Ratchev discussing microtool project results outside the Precision Manufacturing Centre’s clean room.

Process and environmental technologies

Research within this theme focuses on the development of innovative and sustainable technologies for manufacturing processes, with particular expertise in three areas:

- fluid and particle processing
- industrial microwave processing
- biorenewables and bioprocessing

Fluid and particle processing

A vast range of materials can be classified as fluids (such as water and petroleum) or particles (like pharmaceutical powders, minerals and soils). It is these complex mixtures of fluids and particles in various phases that create such a huge range of products, from food to paint.

A similarly vast amount of processes are involved when it comes to engineering and manufacturing these products. Our manufacturing research explores how these types of materials, systems and processes behave. We cover almost every area of chemical engineering and environmental engineering for sectors as diverse as energy, mining and pharmaceuticals. We help companies improve their processes, identify new materials and design new products.

Industrial microwave processing

Sustainable microwave technologies can improve manufacturing process efficiency and operability. Using microwaves to process materials can be a thousand times faster than traditional processes, saving companies time, money and energy. Faster processing can also mean more portable equipment, ideal for remote locations.

Microwaves are produced from an electrical power source, with up to 95% conversion efficiency from electrical to microwave energy. Using microwaves allows the heating process to be powered efficiently from an electrical source, rather than rely on natural gas like most conventional heating processes. Electrical energy can be supplied from renewable sources, meaning that microwave technologies not only improve process efficiency and operability, but can create a more sustainable heating process.

We have world-leading scientists in this field, working closely with industry for a huge range of applications. These include using microwaves as an efficient way to extract valuable minerals and ores and to turn biodegradable waste into energy.

Biorenewables and bioprocessing

Around 5-10% of the world's oil is used to make the base chemicals so widely used in global industry. But what happens when the oil runs out? Scientists within the Institute are leading the way in the development of chemicals made from plant biomass and agricultural waste.

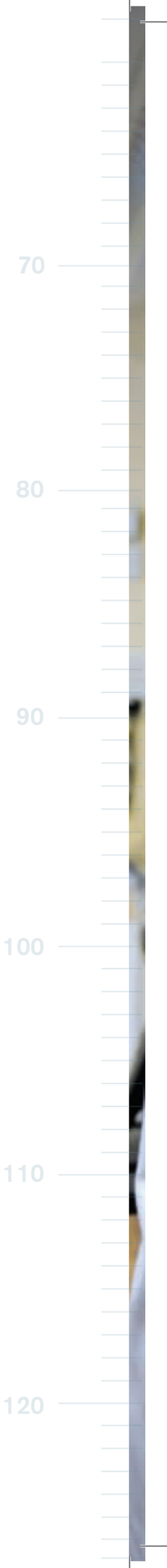
Applying fundamental discoveries in biosciences and chemistry, researchers are using a combination of cutting-edge techniques – including the use of genetic manipulation and enzymes – to create the chemicals.

Changing the cells in the raw material is incredibly challenging, so research in this area is pushing biology to new boundaries. Scientists are working with a host of UK-based companies looking to move into this area within the next few years.

Other strands of research in this theme include using biorenewable cellulose to create sustainable construction materials.

Mineral extraction

Around 5% of all global electrical energy generation is used to grind rocks to liberate valuable minerals. This is because of the large amount of material being processed and the inefficiencies of existing processes. Our cutting-edge research explores how using microwaves to induce micro-fractures within the rocks can significantly reduce energy requirements and the costs of grinding.



Researcher in bioprocessing lab.

Composites manufacturing

Composites – two or more materials combined – are increasingly popular in manufacturing due to their good strength-to-weight ratios, performance benefits and ability to form complex shapes, which saves on assembly costs.

The applications for such products are hugely varied, ranging from high-volume, low-cost parts for the automotive sector, through to specialised, high-performance components for aerospace and satellite manufacturers.

The challenge for many companies is to develop the right type of materials which will push performance and deliver a competitive advantage. More specific challenges include understanding manufacturing variables and their influence on components and reducing environmental impact.

The Institute for Advanced Manufacturing supports industry by developing new, economical processes to make composite components and structures, while ensuring they are more efficient and sustainable. It also offers access to specialist equipment that organisations may not otherwise have access to.

Over the past 25 years, our experts have earned a reputation for providing internationally recognised composite materials research across sectors such as automotive, aerospace, wind energy and healthcare.

Areas of research include:
- process development
- multiscale modelling
- end-of-life and recycling
- biomedical products

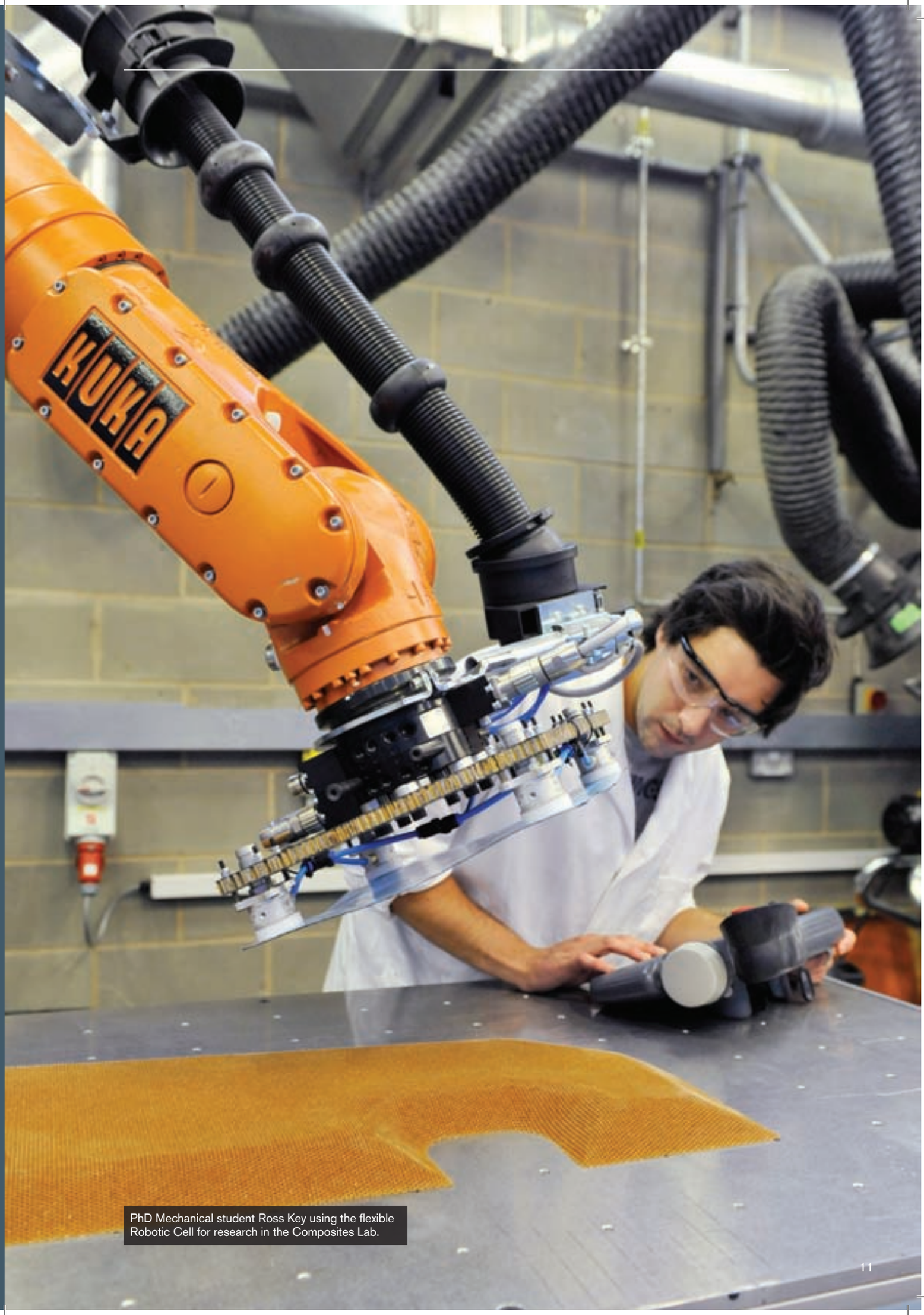
How we benefit industry
We work closely with a number of global organisations including Boeing, BAE Systems, Rolls-Royce, GE Aviation, Gamesa, Aston Martin, Lotus and Bentley. We also collaborate with a large number of SMEs, who are able to cost-effectively tap into our expertise.

In particular, we have a long and successful history of working with the automotive sector. Our scientists have been instrumental in developing materials, modelling and processing techniques for a range of components including transmission tunnels and low-cost carbon fibre panels.

Researchers also work closely with the renewable energy sector, where advancements in low-cost materials and high deposition automated manufacturing have helped to make wind energy more competitive against traditional forms of energy production. The technologies developed in any one sector are supportive or transferable to growth in various other industrial applications.

Composites for bone reconstruction

Institute for Advanced Manufacturing researchers have created a special composite that is intended to be implanted into the human body to aid with bone reconstruction. The biocomposite is compatible with the properties of the bone and cleverly degrades at a specific rate tailored to the patient's needs.



PhD Mechanical student Ross Key using the flexible Robotic Cell for research in the Composites Lab.

Staff and students during a Human Factors workshop in the ITRC buidling.

Human factors

All manufacturing processes and systems, no matter how automated, interact with people as operatives, controllers, supervisors, planners and end users. Successful manufacturing, therefore, depends on human-centred design processes.

The human factors discipline provides the knowledge, tools, methods and developments needed to make the best use of capabilities, meet stakeholder needs and match the outcomes from manufacturing to the needs of end users.

Our human factors researchers conduct world-leading, interdisciplinary research into the behaviours and performance of people, user-centred design and systems design. Our goal is to help manufacturing organisations understand human-systems interactions in order to improve their organisational systems, manufacturing processes and the end products.

Areas of research, include:
- virtual and augmented reality systems
- rail systems engineering
- in-vehicle and road infrastructure design
- location aware and geographical systems
- systems safety, security and risk assessment
- consumer product design and safety

How we benefit industry
We work with a wide range of companies in sectors such as automotive manufacturing, aerospace and air traffic control, rail, medical devices and systems, virtual and interactive technologies, and construction. Key contributions that the group makes within these sectors are user needs and requirements analysis, system specification, testing and evaluation, organisational systems design and implementation support. Industrial partners include the Highways Agency, Network Rail, Honda, Jaguar Land Rover, Opel, Volvo, Eurocontrol, Triumph Motorcycles, EADS Innovation Works and TAS Alenia Spazio.

Research highlights in support of manufacturing include:
- designing and evaluating technologies to support manufacturing operations design
- using visualisation technologies to understand passenger perceptions of aircraft interiors
- using virtual technologies to simulate and test automotive prototypes
- developing tools and techniques to evaluate work systems in transport control
- developing tools to understand functions and identify human factors risks in infrastructure work
- supporting the development of products for the elderly and people with special needs

Improving human-centred manufacturing across Europe

The University is one of several European partners involved in a series of large multimillion-euro manufacturing-related projects.

ManuVAR is developing an innovative technology platform and framework to support high-value manual work throughout the product lifecycle. Technologies connect experts at different stages of the lifecycle, including designers, factory workers and maintenance personnel. The project focuses on spacecraft assembly, remote maintenance for trains, heavy machinery assembly and maintenance design, assembly line design for SMEs and training for power plant maintenance. The groundbreaking virtual and augmented reality tools include on-site and remote support for maintenance, ergonomics analysis for designing workplaces, designing and reviewing systems for complex assembly procedures and skills training.
You can find out more at **www.manuvar.eu.**

VISTRA is using a series of virtual models to integrate process planning, product design and training. Models of the production process and the products being manufactured and assembled are used to form the basis of operative training programmes. In turn, feedback from training sessions is inputted into a knowledge centre, and subsequently informs improved manufacturing system and product designs, especially in terms of their ergonomics, safety and efficiency.

VR-Hyperspace is building a series of virtual environments to assess aircraft passengers perceptions of and reactions to aircraft interiors and, consequentially, passenger behaviours. Subsequently, VR applications will be examined for their value in-flight, to modify and improve passengers' perceptions of the aircraft interior and of the flying experience.

Professor Kulwant Pawar in the stairwell of the Business School South building, Jubilee Campus.

Operations management, logistics and supply chain management

In a competitive global environment, manufacturing companies need to minimise design-to-market time, while keeping costs low and maintaining high levels of quality.

The Institute for Advanced Manufacturing works with a wide range of companies to advise in all areas of operations management, improving the way they work and increasing productivity and profitability.

Areas of research include:

- operations strategy
- systems design
- collaborative design and new product development
- logistics and supply chain management
- mass customisation
- planning, scheduling and control
- outsourcing logistics and supply chains
- quality management
- modelling and simulation technology
- knowledge management

How we benefit industry

The Institute works with a number of organisations in the UK, Europe and Asia, including those in the aerospace, consumer goods, pharmaceutical and telecommunications sectors.

There is a particular focus on looking at how companies design products and the interrelations with manufacturing, supply chain and logistics. Researchers explore the benefits and disadvantages of how teams are located, whether physically or virtually, across different disciplines and how they interact. An important aspect of this is so-called 'concurrent engineering', a systematic approach to integrate product design and manufacture that considers all elements of the product lifecycle from a very early stage. This can significantly reduce cost and time to market and is being increasingly used by major manufacturers.

Researchers work closely with companies to assess their operations, helping them create tailored strategies that lead to measurable improvements.

Effective order fulfilment in the automotive sector

Volume car producers face many challenges in delivering a very high number of variants, or buildable vehicle combinations, to the marketplace. We have worked with Ford of Europe to develop analytical and simulation models to understand how best to match customers with appropriate vehicles from anywhere in the pipeline. Vehicles may be in dealership networks, in vehicle holding compounds, in assembly plants, or be 'virtual vehicles' planned for production.

Understanding how the number of variants offered affects the performance of these open pipeline fulfilment systems has provided many new insights for effective systems design, management and control.

Analysing teamwork

A wide range of companies can improve the way they design and manufacture products through close collaboration with our academic consultants. One such example is one of Europe's largest kitchen appliance manufacturers.

The company wanted to experiment with co-locating multifunctional design teams in order to improve the development process and bring products to market more quickly.

We were able to analyse how this worked, exploring the efficiencies and inefficiencies and make recommendations for improvements.

Manufacturing in the digital age

Personal computers, the internet, wireless networks and mobile devices have transformed the way we live and work. And as devices become cheaper and increasingly interconnected, digital technology is becoming increasingly embedded in all areas of our lives, from public spaces and buildings to kitchen appliances, furniture and even clothes.

This shift towards a world of ubiquitous computing and a convergence between the digital economy and traditional manufacturing, opens up exciting and profitable areas of increasing interest to many companies.

Helping those organisations to understand these new opportunities are researchers at the Institute for Advanced Manufacturing. Our research into digital technology, and how it is designed and used in manufacturing, is crucial for delivering economic and societal benefits.

Areas of research include:
- the 'Internet of Things'
- ethics
- localised manufacturing

How we benefit industry
In the aerospace industry, each component that makes up an engine or aircraft is tracked and monitored digitally, creating a whole life history that can be used to improve performance and safety.

As technology becomes more affordable, these digital services are creeping into everyday consumer products as well. With this technology, manufacturers could, for example, monitor washing machine use, gaining a better understanding of energy use or predicting potential problems. This connected technology even in the most mundane objects could lead to a future that some call the 'Internet of Things'.

Obviously, such widespread monitoring creates legal and ethical debates around privacy, which is an important element of our researchers' work. Companies' understanding of this critical dimension is vital for their reputation.

Another area of interest for researchers that could have significant benefits for manufacturing organisations in the not-too-distant future is the concept of cloud manufacturing. Setting up a manufacturing business is expensive, but greater digital connectivity could lead to a world where businesses can design and make products across shared cloud-based resources, creating a much more fluid and cost-effective supply chain.

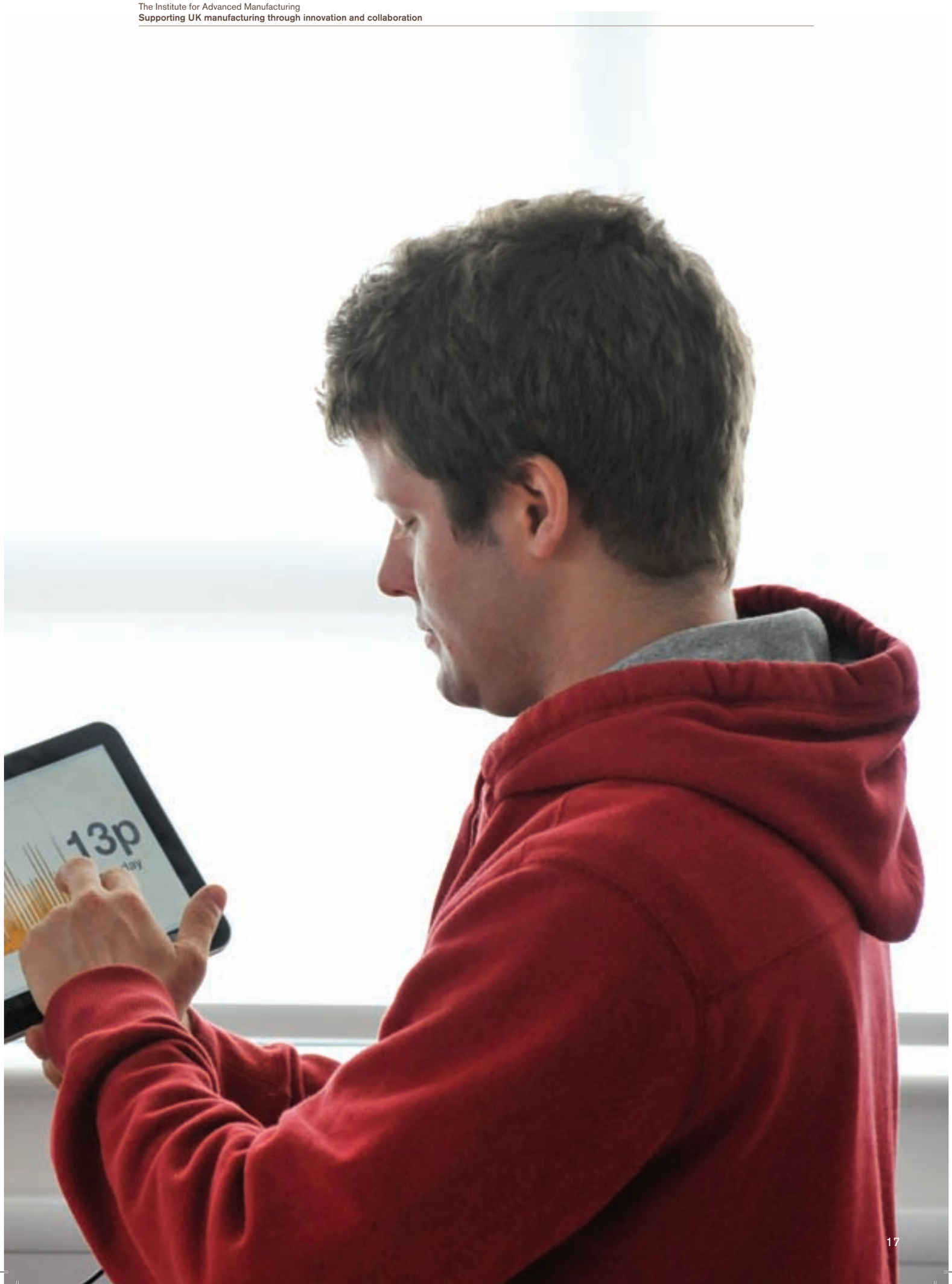
Manufacturing on your doorstep

Manufacturing is about the creation of products, which have to be stored and transported around a country or even the whole world. This can be costly, environmentally hazardous and difficult to manage.

Researchers at the Institute for Advanced Manufacturing are working in collaboration with Horizon Digital Economy Research, a research institute at The University of Nottingham funded by RCUK, which focuses on the role of '*always on, always with you*' ubiquitous computing technology. Horizon investigates the technical developments needed if electronic information is to be controlled managed and harnessed to develop new products and services for societal benefit. **www.horizon.ac.uk**

Researchers at the Institute for Advanced Manufacturing are looking at opportunities for creating smaller-scale, localised manufacturing. Thanks to advances in technology, companies may in the near future send their designs to local manufacturing plants who will make their products closer to consumers as and when they are needed. This could revolutionise the way consumers shop – making goods more readily available and greatly reducing the need for transportation.

PhD Computer Science student, James Colley uses a energy monitor in the Geospatial Buidling.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Regenerative medicine and biomanufacturing

The fascinating field of regenerative medicine could revolutionise healthcare. Combining stem cell treatment and tissue engineering with pharmaceutical therapies and surgical techniques, this research looks to develop new treatments for damaged, diseased or defective tissues.

Scientists at the Institute for Advanced Manufacturing are currently developing minimally invasive, injectable materials that stimulate a patient's own cell growth. This could help treat patients with a range of conditions, particularly in the area of orthopaedics.

The manufacturing of regenerative products is right at the cutting-edge of medical research; the materials being developed are composed of live cells and are extremely complex to make.

How we are benefitting industry

Regenerative medicine is of great interest to pharmaceutical and biomaterials companies, yet there are many challenges to widespread use. Alongside material complexity, there are also issues around development costs and clinical trials, which can see a product take years to reach market.

The Institute's multidisciplinary approach, involving world-class engineering, rapid prototyping and stem cell research, is well positioned to tackle these challenges. We are working closely with industry and other leading universities in order to further develop the materials, technologies and manufacturing processes that could see regenerative medicine treat some of society's most serious health conditions.

The future of medicine

One example of where regenerative medicine could benefit patients is in hip surgery. Our researchers are developing material that could be injected into a patient's leg that would bond with cells and repair the damaged area. This could replace the need for invasive surgery and the use of metals to replace the hip.

Postgraduate Researcher Glenn Kirkham using the Stereo-confocal microscope in the Culture Facility.

Food

The availability of food is a growing concern for much of the world. Issues such as booming populations, climate change, water shortages and competition for land mean food security is a critical global issue.

Over half the world's food comes from just three crops: rice, wheat and maize. So possible solutions lie in the wider use of under-utilised crops, new crop varieties and parts of crops previously wasted.

Through research such as the Crops for the Future initiative at our Malaysia campus, our researchers are exploring how new crops can be converted for food.

Food science at the University has a long history of successful innovation and commercial partnerships. We have long-standing industrial relationships with some of the most prominent food manufacturers including Unilever, Pepsico, Mars, Nestlé, McCain and Premier Foods. We also work with a broad range of SMEs who can access state-of-the-art facilities at our Sutton Bonington campus. This rural setting is home to our farm, Bioenergy Innovation Centre and Food Innovation Hub, along with several spin-out companies.

Professor Tim Foster working with a rapid fisco analyser (RVA).

How we benefit industry

One area of interest to manufacturers is making the manufacturing process more efficient, using less water and energy, and cutting down on global transportation. The key lies in creating more concentrated products that can be 'made' at point of use.

Our researchers are exploring technology that could see certain foods thicken without the need for heat, or create dehydrated products like ice creams, sauces and soups that could be rehydrated close to the consumer – therefore cutting down on the heavy transportation of water. Semi-hydrated products are also easy to ship and can be stored for a long time.

We also work with companies to improve their processing. Increasingly, manufacturers are asked to produce many different lines of food products. Our researchers work with these companies on improving the way they process raw materials and in setting up flexible, efficient operations.

Understanding products and processes

Working with a major producer of potato crisps, we were able to demonstrate how the company could recover the washed away starch generated in the manufacturing process. The starch was salvaged and used in other types of snack products. This project demonstrated our researchers' ability to understand a food product, improve a manufacturer's processes and save waste.

Additive manufacturing and 3D printing

Imagine a manufacturing technology that can be used to flexibly and locally create complex products, which are also tailored to user requirements. Such technology could one day remove the need for the long supply chains found in modern manufacturing, routinely spanning several countries. Also, due to an ability to create far-reaching customisation, a new generation of products with unprecedented levels of functionality would be the result.

Additive manufacturing, which is sometimes referred to as 3D printing, is such a technology. In additive manufacturing, products are built up layer by layer, using computer-aided design (CAD) data and raw materials as production inputs. No moulds, tools or dies are needed in the process.

At the Institute for Advanced Manufacturing, this technology is evolving into multi-material, multifunctional additive manufacturing. Instead of being limited to the manufacture of single material components and products, the additive approach is extended to create end-use functionalised 3D structures and complete working systems.

At the forefront of next-generation, multi-material and multifunctional additive manufacturing research, our academics host the EPSRC Centre for Innovative Manufacturing in Additive Manufacturing.

How we benefit industry

Our research is built on firm foundations, with a legacy dating back to the mid 1990s and a current portfolio of research worth in excess of £10 million. The investigation of multifunctional additive and 3D printing processes represents a new direction which is inherently multidisciplinary and fully integrative of design and manufacturing.

The majority of our activities are fundamental and blue-sky research projects, with individual projects being carried out as commercial contract research. However, some research is undertaken in collaboration with industrial partners. These partner companies come from a diverse range of sectors including aerospace, automotive, motorsport, power generation and medical devices.

Initial flagship projects include:

- the development of new design systems that are suitable for the development of multifunctional components
- investigating the development of novel reactive materials for additive manufacturing, for example materials that are biodegradable for medicinal purposes
- speeding up multifunctional additive processes through new area sintering techniques
- the direct jetting of conductive materials to additively create circuitry within the parts
- the development of a new generation of models that can accurately simulate the delivery, deposition and post-deposition behaviour of materials
- additive manufacturing of functional structures at the nano-scale, for example for sensing applications

Multifunctional additive manufacturing

Fundamental to multifunctional additive manufacturing are jetting deposition techniques. Using technologies derived from printing, these processes are able to deposit multiple materials in 3D structures in a single production step.

In simple terms, additive manufacturing is moving beyond creating single components, such as a mobile phone case. Instead, the process now aims to print the whole phone, complete with working electronics. The initial advantages of the additive approach remain, allowing the efficient realisation of complex and tailored products.

Research student Lukas Ruff supervising the build process on a selective laser melting system.

Take the next step

With a wealth of expertise, state-of-the art facilities and a sharp, commercial focus, the Institute for Advanced Manufacturing is well placed to benefit your organisations.

Whatever the challenge, whatever your size or sector, we can help you grow, evolve and become more competitive, with access to cost-effective research and consultancy.

To find out more about industrial collaborations and funding possibilities, please contact **Anthony.smith@nottingham.ac.uk** or call **+44 (0)115 67232**. You can also visit **www.nottingham.ac.uk/research/priorities/advancedmanufacturing**

Chris Dodds Engineering Project officer working on a bench scale flow rig.

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