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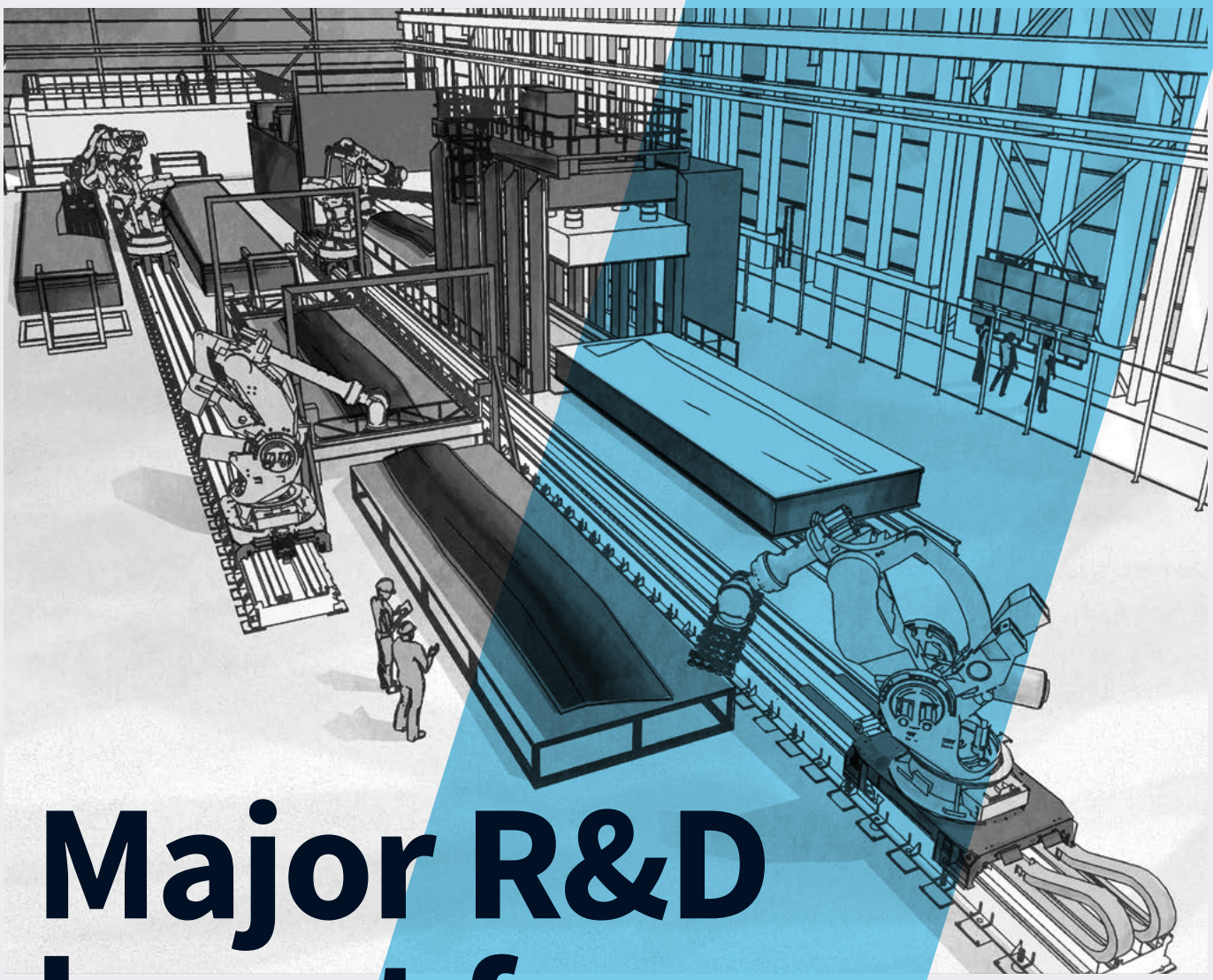

Major R&D boost for composites

Also in this issue:

AgBot – the autonomous tractor

Celebrating ten years of apprenticeships

Cultural heritage meets cutting-edge tech

CATAPULT High Value Manufacturing

UKRI Innovate UK

TOMORROW. DONE BETTER.

The three D's: data, digital and decarbonisation

Data and digital tools are star players of the Industry 4.0 team. Some say they're the Fourth Industrial Revolution equivalent to the coal and steam that powered the First Industrial Revolution. However you look at it, data and digital technologies are transforming the world around us; how we live, how we work and play, and how we make things.

For manufacturers, these star players are helping businesses to see more, to understand more and do more. Which may explain why Britain's manufacturers are said to be 'powering forward in their digital journey towards net zero', as the sector moves to reduce energy usage and costs, cut greenhouse gas emissions and boost productivity, according to the *Digitalise to Decarbonise* report.

Published by MakeUK, in partnership with Sage, the research found that manufacturers are investing in digital tools and technologies 'more than ever before', to decarbonise their business, with almost half of Britain's manufacturers having an active plan to invest in digital technologies to accelerate their decarbonisation journey, and a quarter having already made that investment.

For those who have already made the leap, they are seeing multiple gains, with reduced costs through improved productivity, improved energy efficiency, better quality of products, greater visibility of the supply chain, better quality of products and reduced carbon emissions.

But there are still barriers to wider technological adoption, particularly for smaller companies, which the report says are finding it much harder than larger businesses to take those tentative first steps on their digital journey. Some of the highest barriers cited are skills and the cost of investment – not just for equipment but the whole process of implementation, adjusting production, machinery and training. Some 64 per cent of small and medium-sized-enterprises (SMEs) said they experience skills shortages when trying to invest in and adopt new digital technologies to decarbonise, compared with just 36 per cent of large manufacturers.

That is why support for SMEs is critical, so they can overcome these barriers and begin to unlock the benefits of Industry 4.0. Every year, the University of Sheffield Advanced Manufacturing Research Centre (AMRC), works with hundreds of SMEs and medium-sized businesses, microbusinesses and individual entrepreneurs across the UK. In this issue, our SME engagement manager, Shirley Harrison, looks at why they need bespoke support to innovate, grow and thrive.

We also take a look at Composites at Speed and Scale – COMPASS – the largest research and development programme in the AMRC's history, focussed on the automated manufacture of large-scale, high-rate composite components.

It signals a major boost to aerospace research and development for the UK, helping to solve the composites manufacturing challenges needed to meet future demand for lighter commercial aircraft and help the aviation industry reach net zero. One of the best analogies we've heard so far is that the technical challenge of COMPASS is said to be like trying to park a double-decker bus within a tolerance of 1mm every single time.

Also in this issue we speak to Nikki Jones, director of the University of Sheffield AMRC Training Centre, which marks its tenth anniversary this year. Vocational education is constantly in the cross hairs of political debate for both main parties, so it's hardly surprising that the training centre has had, and continues to attract, so many visitors through its doors. Nikki talks about ten years of apprenticeship delivery and why they matter for the economy, region and industry.

Enjoy.

Katia Harston
Editor

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Sign up to our newsletter: amrc.co.uk

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Cover image: Composites at Speed and Scale: the new AMRC facility set to give a major boost for aerospace manufacturing in the UK, with Boeing as its first major research partner. See page 14.

Why COMPASS matters

By Steve Foxley, CEO, AMRC

When we look back, July 2023 will be an important milestone in the AMRC's history for two reasons; firstly for winning project COMPASS (Composites at Speed and Scale), which is the largest research development programme in the AMRC's history; and secondly, for securing the anchor project for the UK government's first investment zone, which will be here in South Yorkshire.

I'm so proud of what the project COMPASS team has achieved, but I'm especially proud of how they have achieved it. The AMRC team has battled many headwinds, picked themselves up when they hit setbacks and yet, the team has ultimately managed to secure another seed of innovation with huge potential for the UK.

I'm not exaggerating when I say this could be one of the most significant regeneration projects for the UK and that it could have an impact that is three or four times bigger than the impact the AMRC has made, so far, over the past 20 years.

The original AMRC innovation seed in 2001 was focussed on machining of aerospace alloys; this seed in 2023 is focussed on the automated manufacture of large-scale, high-rate composite components.

There is a lot of content later in this edition of the Journal that explains more about the goals of project COMPASS and what it wants to achieve, so I'm going to focus on why COMPASS is important for the planet, for the country and for the region.

For the planet, the technology will ultimately support innovation in many critical UK sectors, such as aerospace, automotive, defence and offshore wind. For example, in the aerospace sector, the innovation at the heart of COMPASS will be a key enabling technology to manufacture lighter aircraft, reduce energy consumption in manufacture and increase fuel efficiency in flight – whether electric, hydrogen or sustainable aviation fuels.

This innovation develops enabling technologies to support FlyZero – the UK government-backed programme exploring the future of zero-carbon emission air travel – addressing how we decarbonise aerospace, which is one of the hardest sectors to decarbonise.

For the country, the UK was up against stiff global competition for this opportunity from Germany, Japan and the US and so it's important to recognise the world-leading nature of the UK's composite research and innovation. COMPASS adds capability to the UK's composite assets and strengthens our national capability.

Chancellor of the Exchequer, Jeremy Hunt visiting the University of Sheffield AMRC's Factory 2050 facility, accompanied by AMRC CEO Steve Foxley and South Yorkshire Mayor, Oliver Coppard.

An artist impression of the new COMPASS facility, which will be located next to Factory 2050.

The research and equipment complements the existing world-leading capabilities which the High Value Manufacturing Catapult has in composites, in particular at the National Composites Centre in Bristol, which is one of our sister centres that makes up the incredible High Value Manufacturing (HVM) Catapult network.

For the region, this project will strengthen the growing green aerospace cluster that is developing across South Yorkshire.

The region already has world-class capabilities in aerospace, including but not limited to the Boeing and Rolls-Royce manufacturing sites that sit alongside us here on the Advanced Manufacturing Park, and the many critical supply chain companies across Sheffield and Rotherham.

But with the recent announcement from Hybrid Air Vehicles to create a manufacturing facility in the region, and now with COMPASS, the cluster is building out.

Regionally, the icing on the cake was that COMPASS was an instrumental part of the Chancellor of the Exchequer coming to Factory 2050 to announce the UK's first investment zone, right here in South Yorkshire. The Mayor of South Yorkshire, Oliver Coppard, and his team have worked hard to be the first to announce an investment zone. From the government's five key growth areas, they have selected advanced manufacturing as the anchor theme for the South Yorkshire Investment Zone.

"It is opportunities like this that are the foundations upon which we deliver the AMRC's purpose of transforming lives through innovation."

Steve Foxley, CEO, AMRC.

These investment zones are focussed around innovation clusters and their aim is to be a catalyst to create new business opportunities and jobs. We're good at this in South Yorkshire and at the AMRC; the investment zone will give us the opportunity to do more of what we've done over the past two decades in regenerating the region. As the mayor has publicly stated, the aspiration is to use the investment zone funding to leverage £1.2bn of investment into South Yorkshire and create thousands of jobs.

It is opportunities and innovation like this that are the foundations upon which we deliver the AMRC's purpose of 'transforming lives through innovation'.

So what's the next step? Well, the bidding phase is now over, and the hard work of implementation begins. By early 2025, the new facility needs to be built and the equipment in operation. Our first research programme will be with the AMRC's founding partner Boeing, in partnership with Spirit AeroSystems and Loop Technology.

The research has already started. We're excited. It's a thrilling area of innovation and our teams in composites and integrated manufacturing are more than up for the challenge.

Transforming lives one apprentice at a time

This year, the University of Sheffield AMRC Training Centre celebrates its tenth birthday. **Katia Harston** sat down with director **Nikki Jones,** to talk about a decade of delivering engineering apprenticeships.

Nikki Jones, director of the University of Sheffield AMRC Training Centre.

"Apprenticeships transform lives. They provide the workforce for the future. They are part of the bloodline that keeps industry moving."

Nikki Jones, the director of the AMRC Training Centre, doesn't pull any punches when it comes to answering the question on why she thinks apprenticeships matter for regions, for the economy and for industry.

And Nikki knows her stuff. She has spent five years at the helm of the AMRC Training Centre, which works hand-in-hand with employers to provide the manufacturing industry in South Yorkshire, and beyond, with access to a pipeline of highly skilled people, needed to drive growth and help UK businesses compete on a global stage.

This year, on October 7, the training centre turns ten – marking exactly a decade since the first cohort of apprentices started in 2013.

Since opening, it has worked with 400 different businesses and has delivered more than 1,700 apprenticeships – from advanced through to degree – alongside continuous professional development to upskill and reskill existing workforces.

"When you bring together education and industry – it is very powerful," says Nikki. "You might describe it as a marriage made in heaven. We've been doing apprenticeships for ten years now and they matter just as much now as when we started. They are so important for the education mix and providing the workforce for the future. Any industry needs to have skilled people going into their businesses, and apprenticeships give them access to that pipeline of talent.


The University Of Sheffield
AMRC
Advanced Manufacturing Research Centre

"We must continue to invest in apprenticeships nationally and continue to support all employers – large or small – to take on apprentices.

"They bring in new skills and fresh ideas, and their ability to progress within an organisation starts very early. If you start your apprenticeship at 16 and finish at 22, you have been in that industry for quite some time and can move much quicker into senior roles. We see that over and over again.

"Apprenticeships start preparing a person for their work life. When you put a young person into that environment, they really develop holistically because they have to be more than just a qualification."

It is the training centre's special blend of strong ties to industry and academia, and its tailored approach to delivery, that has made it a key ingredient in catalysing a dense clustering of high-value manufacturing companies across the Rotherham and Sheffield border. This includes significant investment from global companies such as Boeing, Rolls-Royce, and McLaren.

And, rightly, that hasn't gone unnoticed. The training centre has been cited by think-tanks, politicians and policymakers as a blueprint for how to do vocational education and training. Looking back at the list of visitors that have passed through its doors over the years, it reads like a 'who's who' of global industry and politicians. There's even been the odd TV personality and stars of the sporting world too – yes, we're talking about Sir Alex Ferguson, former manager of Manchester United, himself once an apprentice toolmaker.

"There are so many pride points to look back on, so many remarkable achievements by our students and moments in time where we can say to ourselves – 'yes we got that right'," says Nikki. "For me, it's an honour and a gift that I am able to play a very small part in the lives of other people."

Nikki hails from the Rhondda Valley in Wales and knows what it feels like to grow up in a tough, working class mining town. A place not too dissimilar from parts of South Yorkshire where the training centre is based, which is on the site of the former Orgreave Colliery and Coking works in Rotherham.

For Nikki, education was a saviour of sorts, a way of breaking through the glass ceiling and unlocking doors to a promising future. Education is now Nikki's passion. She has dedicated her professional life to the sector, racking up more than 30 years in further education (FE) provision.

Her career began as a teacher in Somerset before going on to be a curriculum manager and taking up roles as a head of department and part-time Ofsted inspector. Nikki moved to South Yorkshire in 2010, where she was assistant vice-principal at Barnsley College. It was a post she held for six years before making the move to the AMRC Training Centre to be the head of training.

"When I started out, I became very passionate about education immediately," says Nikki. "I could see I could see how it had the power to transform lives. Whatever your starting point is in life, your education is so important because it enables you to achieve the life that you want. It gives you confidence to do that. It really is the key to unlocking and opening those doors.

"Where education hits me in the heart, where it really gets me, is in what it does for other people. To do a job that I am proud to do, and to see the difference it makes, that is where the job satisfaction is for me."

She has been director of the training centre since 2018. In that time, much has been achieved. Nikki and her team were unrelenting in their mission to turn around a poor Ofsted rating into one that saw it judged 'good' overall. She was barely a year into the new role when the report came back to say there had been a 'relentless focus' on improving the quality of education apprentices receive.

"When the training centre didn't do well in 2017, it was crushing," says Nikki. "But I've seen it before with new organisations that are set up. It is hard to get apprenticeships off the marker because of the work that needs to be done.

"By 2018 I was the director and had to get my feet firmly on the floor. There was no time for blue sky thinking. We just had to get our heads down and get on with it. There was no time for licking our wounds or to feel sorry for ourselves.

"We worked really hard, focused on the priorities that would make the most difference and what we needed to do – putting our students at the heart of everything we were changing.

"I've always been relentless in everything I have done. The Ofsted inspection was no different. I put all my energy and passion into what I do; I feel a great sense of responsibility for ensuring that our students achieve and employers get what they need."

It is that attitude, and a pursuit of quality over quantity, that has seen the centre grow its offering to meet the needs of industry, with new apprenticeship pathways that include automation and controls, composites and nuclear. It is also part of the consortium behind a new South Yorkshire Institute of Technology (IoT) that launches this year, investing £500,000 in new software and technology at the training centre.

"We have grown but stayed true to who we are – it's a decision we made early on to not try and do everything but to do the right thing and to move at the right pace," says Nikki. "It's not about how big you get – it is about how good you get.

"We must balance the delivery of the immediate needs for skilled people with thinking about future horizons.

"It is clear that digitalisation, artificial intelligence, sustainability, composites and nuclear manufacturing skills are going to be critical to enable manufacturing to innovate and be productive.

"Innovation and a skilled workforce are different sides of the same coin; they are both essential to economic growth and you cannot have one without the other."

"We must continue to invest in apprenticeships nationally and continue to support all employers – large or small – to take on apprentices."

Nikki Jones, director, AMRC Training Centre.

Cultural heritage meets cutting-edge technology

By Mrudula Jadhav

The University of Sheffield AMRC has supported a major restoration project at Wentworth Woodhouse that will help preserve its 18th century Germanicus statue for generations to come and open up new ways to raise vital funds for the stately home.

Wentworth Woodhouse, near Rotherham in South Yorkshire, is the longest and one of the grandest stately homes in the UK, and is run by the Wentworth Woodhouse Preservation Trust.

The centuries-old Germanicus statue is of huge cultural significance and value to the home as it was commissioned by the Second Marquis of Rockingham in the 1750s and created by the same artist who made sculptures for the famous Trevi Fountain in Rome.

The Trust has embarked on an ambitious project to repair and preserve the Germanicus; using reverse-engineering technology to create a highly-accurate digital blueprint of the statue, so that not only can it be recreated should it ever get seriously damaged, but also to explore creating miniature replicas that can be sold to raise vital funds for the large-scale restoration of the home.

To do this, the Trust collaborated with the AMRC, which is part of the High Value Manufacturing Catapult, and PES Scanning. The company, which is part of Performance Engineered Solutions (PES) Ltd, based close to the AMRC on the Advanced Manufacturing Park in Rotherham, was responsible for 3D scanning Germanicus and optimising the digital 'point cloud' model that was created of the statue.

“Technology today is developing rapidly and it has the potential to not only make a better tomorrow but also to preserve, conserve and restore the past. Using the technology at the AMRC and PES Scanning to create a model of the Germanicus statue is the first step towards this.”

Dr Phil Yates, senior engineer for SMEs, University of Sheffield AMRC.

A hand-held 3D laser scanner was used to capture the detail of the statue to an accuracy of 0.020mm and resolution capability of 0.01mm. The scanner works by projecting lines of laser light onto the surface of the statue while two sensor cameras continuously record the changing distance and shape of the laser lines in three dimensions as it sweeps over the statue, taking up to 1.6 million measurements per second.

Once the individual measurement points are captured, specialist software meshes the points into surfaces. The meshing process calculates how the points relate to each other in order to join them together into surfaces.

These joined up points are called point clouds which once created, can be loaded into CAD platforms to enable items to be used in a number of ways, for example to be redrawn for reverse engineering or design optimisation. They can also be used, as in this case, for 3D printing.

Nathan Bailey, metrology applications engineer at PES Scanning, said: "We provide metrology and 3D scanning services for a range of different industries, from aerospace to construction.

"We're using data capturing technology to address the heritage challenges of today, from restoration to preservation. The technology allows us to visualise how these items or buildings were back when they were originally built and it helps us restore them, if needed, to their former glory.

"As a company that is constantly looking to expand the horizons and the areas that we work in, this project with the AMRC and Wentworth Woodhouse is a fantastic opportunity and we were very excited to be a part of it."

"The use of digital technologies at Wentworth Woodhouse is still in its early stages, but there's no doubt that it will have an important role to play in both conservation and entrepreneurialism."

Steve Ash, digital projects manager at Wentworth Woodhouse Preservation Trust.

The AMRC's design experts used the scans to 3D-print three miniature replicas, which weigh 348 grams and stand at just 29cm tall – a fraction of the height of the real Germanicus which is 180cm.

Suzanna Mitchell, project engineer at the AMRC, said: "The replicas were manufactured using our Photocentric LC Magna 3D Printer, which is capable of creating large, high-detail, low-cost parts. This polymer Additive Manufacturing (AM) technology uses an LCD Mask approach to fully expose each print layer instantly, allowing us to produce three statues in 31 hours.

"The print files were optimised with internal and external supports applied to ensure the fine features were printed successfully. The support was then removed after printing. Without the availability of this technology, the replicas could have been much more difficult to produce with potentially higher costs and lower detail."

Dr Phil Yates, senior engineer for SMEs at the AMRC, said: "Wentworth Woodhouse is gearing up for a major restoration of its site and artefacts and to be able to contribute to it, is a matter of great pride for the AMRC."

He added: "The collaboration gave us the opportunity to implement our design and prototyping expertise for the benefit of a national heritage organisation of great cultural significance.

"It also turned the spotlight on two important aspects that lie at the heart of the AMRC – providing opportunities for innovative SMEs, such as PES Scanning, and showcasing the need to nurture and guide young talent towards manufacturing skills and opportunities."

The project not only connected the two dots of cultural heritage and technology,

The three miniature replicas being 3D-printed using the Photocentric LC Magna 3D Printer.

AMRC Training Centre apprentice, Harry Howsen, helped scan and digitise the statue.

AMRC SME senior engineer, Phil Yates, holding one of the three miniature replicas of the Germanicus statue.

but also highlighted the role of future young generations in preserving our history and the importance of equipping them with technical skills.

University of Sheffield AMRC Training Centre apprentice, Harry Howsen, who works for PES Scanning, helped scan and digitise the statue.

PES Scanning metrology engineer, Nathan Bailey, added: "This project was a fantastic and exciting opportunity for our apprentice, Harry, to really get his teeth stuck into the world of 3D scanning and metrology and within a project that's quite interesting and outside of the usual traditional engineering situations that we see."

Talking about his experience, Harry said: "I have just completed my first year of studies at the AMRC Training Centre and coming from a family of engineers, I understand the importance of experience within the engineering field.

"I decided to choose the apprenticeship route which allowed me to have the best of both worlds, through the University as well as while working full-time at PES Performance. At the end of it, I'm also debt-free which is a major bonus for me.

"I thoroughly enjoyed this project as I got to see the full cycle of it and the final products at the end, which usually you don't get to see."

Steve Ash, digital projects manager at Wentworth Woodhouse Preservation Trust says it is looking at a range of ways in which the scans of Germanicus might be used to create merchandise that could be sold in the Wentworth Woodhouse shop.

He said: "Under consideration at the moment are ideas to sell small, museum-quality replicas of Germanicus, either as statues or as bookends. We may also create confectionary lines using the scans to create edible versions of the statue.

"The use of digital technologies at Wentworth Woodhouse is still in its early stages, but there's no doubt that it will have an important role to play in both conservation and entrepreneurialism. The project collaboration with the AMRC and PES Scanning has shown the possibilities that lie ahead, and we are very much looking forward to continuing collaborating together."

Phil added: "Technology today is developing rapidly and it has the potential to not only make a better tomorrow but also to preserve, conserve and restore the past. Using the technology at the AMRC and PES Scanning to create a model of the Germanicus statue is the first step towards this. And we hope to use our technical expertise for many such avenues, and continue our collaboration with the Trust."

History of the Germanicus statue

The white-marble statue of Germanicus that now resides in the grand Pillared Hall in Wentworth Woodhouse was commissioned in Rome by the Second Marquis of Rockingham in the 1750s. The statue was sculpted by Filippo Della Valle, who also made sculptures that can be seen on the Trevi Fountain in Rome.

Germanicus was an immensely successful ancient Roman General and politician, and he was hugely popular in his day. He was the father of the emperor Caligula and the older brother of the emperor Claudius and was regarded by many as being the 'ideal' Roman.

The statue of Germanicus originally arrived at the house in the 1760s, however it was moved to the Camellia House in 1902. In the mid-20th century, the roof at Camellia House failed, allowing water into the building which poured over the statues and explains the dirty appearance of Germanicus.

Following the disrepair of the Camellia House, Germanicus returned to Wentworth Woodhouse in the 1980s, where he took his current position. However important the statue of Germanicus is, there's no denying that it is in less than ideal condition and it needs to be conserved and protected.

COMPASS points to new opportunities for UK manufacturing

By Katia Harston

Composites research and development for aerostructure manufacturing in the UK has received an £80m boost, with a new research facility set to be built in South Yorkshire that has aerospace giant Boeing as its first major research partner.

The University of Sheffield Advanced Manufacturing Research Centre (AMRC) has secured £50m to establish the Composites at Speed and Scale (COMPASS) facility in Sheffield to enable a groundbreaking research programme with Boeing at the centre. The investment was announced in the summer by UK Chancellor Jeremy Hunt, as part of the South Yorkshire Investment Zone.

COMPASS is a major boost to aerospace research and development for the UK, helping solve composites manufacturing challenges needed to meet future demand for lighter commercial aircraft and help the aviation industry reach net zero.

It will be home to AMRC's largest ever collaborative research and development programme which will be undertaken with founder and long-standing member Boeing, in partnership with Spirit AeroSystems and Loop Technology. It aims to de-risk and develop high-rate sustainable structures, with the potential to reduce large component process times from ~40 hours to ~four hours.

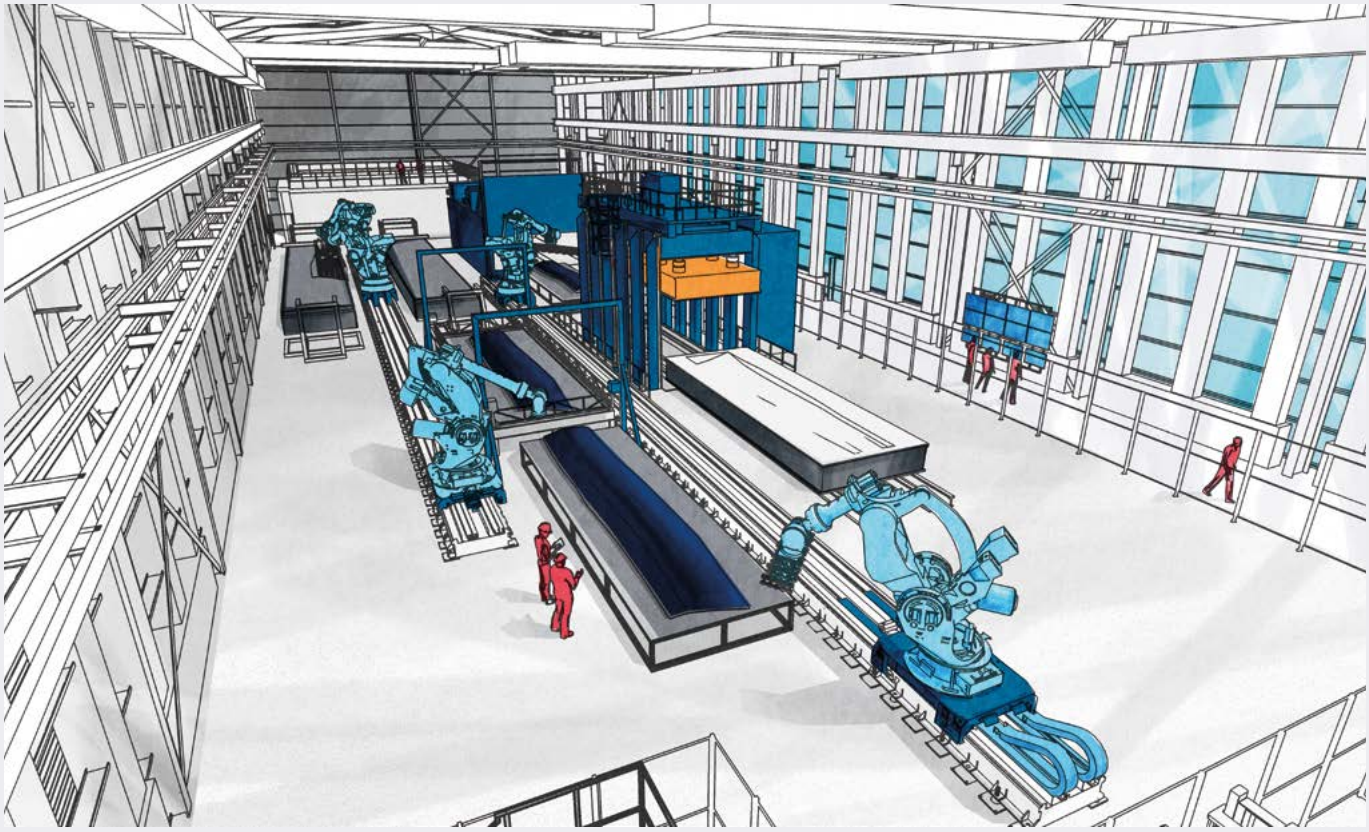
On the back of the research, Boeing has committed to procuring in excess of £2 billion of UK-manufactured goods for export per year to support the production of the company's next civil passenger aircraft — with the potential to create up to 3,000 high-skilled jobs by the mid-2030s.

COMPASS builds on the AMRC's world-class composites and automation capabilities to de-risk the development and manufacture of high-rate, large-scale composite parts, providing the wider UK industry with a unique open-access facility to develop, demonstrate, test and validate new composite manufacturing technologies and capabilities.

Slick CGI images show how the new COMPASS facility might look alongside Factory 2050.

Steve Foxley, chief executive officer at the AMRC, said it is a landmark moment for the AMRC and the region, helping unlock economic potential for South Yorkshire through new opportunities in technology and innovation, employment and investment, supply chains, skills development and training.

"COMPASS will help to establish South Yorkshire as the leading R&D centre of excellence in the manufacture of composites at speed and at scale, enabling future production capabilities that currently don't exist," said Steve.



An artist impression showing how the inside might look for the new Compass facility.

"This facility, alongside our existing pedigree and the work on hydrogen and sustainable aviation fuels in the wider University of Sheffield, are cornerstones of a future green aerospace cluster in the region.

"COMPASS and the research that will take place there, offers a step-change in UK R&D capability and provides a unique opportunity for the UK. It will support and de-risk new technologies and processes, combining composites and digital technologies to help wider UK industry adopt more efficient, sustainable and cost-effective solutions for the production of future components, including the renewable, transport, defence and urban air mobility sectors."

Professor Koen Lamberts, president and vice-chancellor of the University of Sheffield, said: "The new South Yorkshire Investment Zone builds on our region's industrial heritage and will supercharge opportunities to drive more innovation-led growth.

"We are very proud that our new COMPASS facility is the investment zone's first major announcement. It is a testament to our region's strengths, and the expertise of the University of Sheffield AMRC, that our long-standing partner Boeing has chosen South Yorkshire for this globally significant research and development project.

"Over the last two decades, we have seen how university research and innovation has helped to transform our region by attracting inward investment and creating highly-skilled jobs. South Yorkshire's Investment Zone holds enormous potential, and we look forward to working with our partners to ensure its success."

The research with Boeing builds on more than 20 years of collaboration and innovation with the AMRC, and the investment it has made into South Yorkshire with Boeing Sheffield, the company's only European manufacturing facility, and the partnership with the University of Sheffield for its Sustainable Aviation Fuels Innovation Centre (SAF-IC).

"COMPASS will help to establish South Yorkshire as the leading R&D centre of excellence in the manufacture of composites at speed and at scale, enabling future production capabilities that currently don't exist."

Steve Foxley, chief executive officer, AMRC.

Chancellor of the Exchequer, Jeremy Hunt visiting the University of Sheffield AMRC's Factory 2050 facility, accompanied by AMRC CEO Steve Foxley, Maria Laine, the president of Boeing UK, Ireland and Nordic region, and Oliver Coppard, Mayor of South Yorkshire.

Maria Laine, president of Boeing UK, Ireland and Nordic region, said: "This project is a testament to Boeing's global commitment to drive innovation and growth within the local communities in which we are proud to live and work.

"Together with our world-leading industry partners, this investment is poised to revolutionise aerospace manufacturing to meet global demand, while supporting vital jobs and growth in the UK."

The new building is being jointly funded by the South Yorkshire Mayoral Combined Authority (SYMCA), Sheffield City Council, University of Sheffield and the High Value Manufacturing Catapult (HVM). It will be home to a raft of state-of-the-art equipment secured through a £29.5m grant from the Aerospace Technology Institute (ATI) to support new capabilities, technologies and processes to reduce cost, waste, production time and associated carbon emissions.

Oliver Coppard, Mayor of South Yorkshire, said: "This groundbreaking research partnership is yet another huge vote of confidence from Boeing in South Yorkshire's future. Boeing is now adding to its footprint here – their only manufacturing base in Europe – because they know our ability to solve problems and make things is unique. That's just what we do.

"That knowledge and expertise, built on our heritage at the forefront of engineering and manufacturing, and now powered by the UK's first Investment Zone, is going to provide the foundation for a bigger, better economy, and a brighter future for anyone lucky enough to call South Yorkshire their home. Welcome to our future, Boeing."

Gary Elliott, chief executive officer of ATI, said: "The ATI investment in the COMPASS project will provide the UK aerospace industry with a path to proving new and advanced composite technologies, help develop world-first manufacturing capabilities and create an open-access facility for the broader benefit of aerospace and other industries.

"Alongside our support for Boeing's research project, this puts the UK supply chain in a competitive position to win production contracts for future next-generation aircraft."

Katherine Bennett, chief executive officer of the High Value Manufacturing Catapult, the research centre network which the AMRC is a member of, said: "This flagship facility is a real vote of confidence in UK manufacturing, building on the outstanding R&D capabilities already in South Yorkshire and within the HVM Catapult. COMPASS will create a powerful legacy that extends beyond the region and across the manufacturing sector.

"Supported by the South Yorkshire Investment Zone, and with the backing of

"Together with our world-leading industry partners, this investment is poised to revolutionise aerospace manufacturing to meet global demand, while supporting vital jobs and growth in the UK."

Maria Laine, president of Boeing UK, Ireland and Nordic region.

Chancellor of the Exchequer, Jeremy Hunt visiting the University of Sheffield AMRC's Factory 2050 facility.

Innovate UK, COMPASS can help position the UK supply chain as a key enabler for net zero aviation, create thousands of high-skilled jobs and ultimately help the HVM Catapult achieve industrial transformation for the UK."

The majority of large composite components are currently manufactured by hand, placing layers of 'prepreg' or dry-fibre material onto a tool. Once deposited the material is either cured in an oven or autoclave, or infused and cured. It is a time-consuming process, with inconsistency through the risk of human error.

In order to meet future demand and delivery projections of new aircraft, the aerospace industry needs to disrupt current production and technological limitations by building more sustainable, large-scale aerospace assemblies at appropriate rates with reduced part counts – while maintaining the quality levels and accuracies required for components within the aerospace sector.

Manufacturing industries are on the verge of a data-driven revolution – COMPASS will harness the power of data sharing to fuel innovation with manufacturing production data being a key output of the facility and its research.

It will use data, cyber-physical infrastructures and robotic automation to generate a large manufacturing data pool to help the wider business and research community develop solutions to unlock the value to become smarter and more productive.

COMPASS will push the boundaries of existing science and technology, enabling automation of layup of large-scale composite components to move beyond existing capabilities.

Drawing on relevant state-of-the-art R&D with industry, it will:

- Enable run-at-rate demonstration of large-scale automated manufacturing processes.
- Develop precise pick and place and in-line inspection technologies to support tolerances required by aerospace.
- Develop a digital twin of the facility and process. This will allow industry to start development work virtually and support our existing research into virtual commissioning.
- Use fully-sensored processes and equipment, linked together in a flexible control architecture, providing a single source of truth for the validation of parts/processes, and enabling active control responding to changing process environments.
- The data, gathered over time, will enable future research in artificial intelligence and machine learning techniques for factory-scale process optimisation.

Scan to hear more from our teams on why COMPASS matters for UK manufacturing.

Decarbonising the way we travel

Future Platforms and Propulsion Systems is a key theme in the University of Sheffield AMRC's strategic vision. But what is it, why does it matter and how is the AMRC using its capabilities to address some of the grand challenges? **James Hunt, future propulsion lead at the AMRC, writes.**

In the simplest of terms, propulsion systems comprise the various components that contribute towards providing the motive force of a vehicle, aircraft, train or boat. This encompasses everything from the onboard storage of fuel or energy, such as a petrol tank or battery pack, and the conversion of that energy into power via an engine, electric motor or gas turbine, through to propelling the vehicle forward via a gearbox, driveshaft and wheel, or by the thrust generated from a jet engine or propeller.

For the majority of the transport sector, these propulsion systems have been heavily reliant on fossil fuels for more than a century, whether that was burning coal in steam-powered trains and ships, to petrol and diesel for cars and trucks, or kerosene for aviation.

The pressing need to address the climate crisis places the spotlight on those sectors that are significant contributors to CO_2 emissions and other global

James Hunt, future propulsion lead at the AMRC.

warming effects. According to figures from 2021, the transport sector accounts for approximately 24 per cent of global greenhouse gas emissions, primarily driven by this heavy reliance on fossil fuels, compounded with a thirst for increased mobility and global connectivity of people and goods.

Future propulsion systems is a catch-all term for technologies that transition the transport sector away from fossil fuels, hence reducing emissions to either zero or net zero. These technologies include battery electric, hydrogen fuel cell, hydrogen burning engines, sustainable/synthetic fuels and hybrid systems.

The best solution for any single application will depend on many factors, such as the availability of the fuel, or charging points in the case of battery, range i.e: how far the vehicle needs to travel before refuelling, power and duty cycle requirements, purchase cost, running costs. Clearly the solution for a small passenger car commuting

short distances and only carrying one or two people will be very different to that required for a large articulated lorry travelling long distances.

There is no silver bullet solution to all applications. The pros and cons of competing technologies are not easy to define and lockdown as the landscape is constantly evolving with the development of new battery chemistries, more advanced fuel cells and greater access to sustainable fuels.

The relative sustainability of these technologies can also be contentious, with issues around mining critical elements for batteries, magnets or catalysts, or how landmass use for bio-fuels competes with food production being played off against the potential CO_2 benefits they bring. It is not the role of the AMRC to pick a winner amongst these technologies, nor provide a view on which solutions are more viable than others.

Our role is to support the industrialisation of the key technology elements and ensure UK manufacturing companies are equipped with the knowledge and capability to exploit them.

What excites me, as an engineer, is that there are lots of clever technology solutions being developed in the UK and beyond, and many of these will provide at least part of the answer as to how we can carry on using cars, buses, trucks and aeroplanes – but in a much more sustainable way.

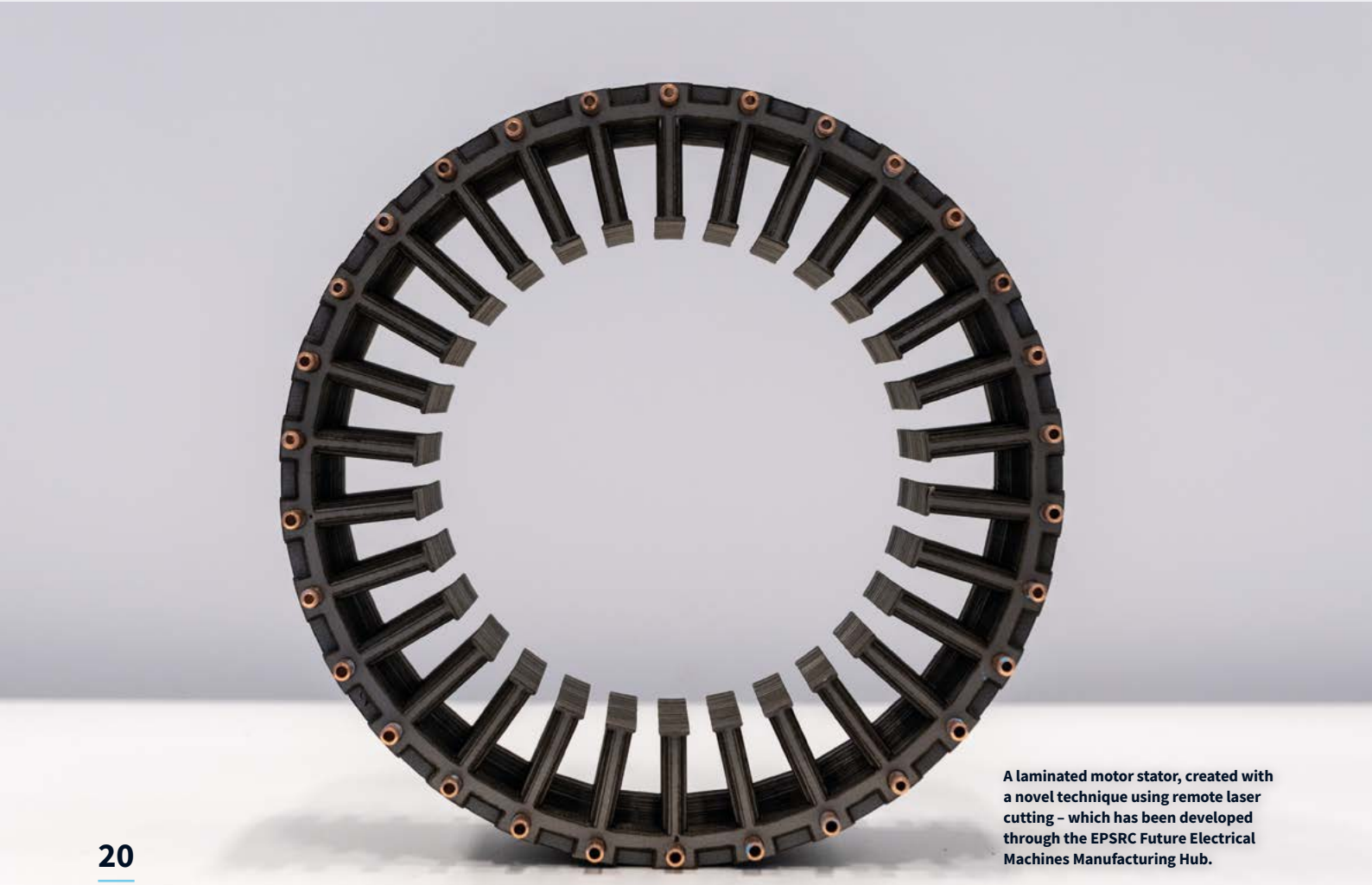
Why is this of interest to the AMRC? Well, beyond the engineering development phase, all of these solutions will need a viable method of manufacture to produce them at the scale and rate required by the transport sector, and companies are experiencing significant challenges along this industrialisation journey. The AMRC is well placed to address these challenges, with strong alignment between our core competencies and the needs of industry.

Across the AMRC we have been building specialist capability and expertise to address some of these specific challenges, these include:

- **The Hydrogen Electric Propulsion Systems Testbed at AMRC Cymru.** This facility is dedicated to carrying out research and development on the assembly of fuel cell stacks, to improve the quality and repeatability, allowing industry to de-risk production scale up. This capability, established via High Value Manufacturing (HVM) Catapult funding, and led by our future mobility lead, Lee Wheeler, has already attracted interest from several companies across aerospace and automotive, and has resulted in landing a project with Toyota UK, backed by the Welsh Government-administered Ford Low Carbon Vehicle Transformation Fund.

- **At AMRC North West,** our technical fellow for batteries and automation, Richard Heggie, has been developing a facility to assist during the development and prototyping phase of electric vehicle battery modules and packs. Technologies such as laser welding, wire bonding, ultrasonic and resistance welding, are utilised to join individual cells into connected modules.

  Our focus is on automation of battery assembly, with emphasis on greater



A laminated motor stator, created with a novel technique using remote laser cutting – which has been developed through the EPSRC Future Electrical Machines Manufacturing Hub.

> **"Our role is to support the industrialisation of the key technology elements and ensure UK manufacturing companies are equipped with the knowledge and capability to exploit them."**
>
> **James Hunt**, future propulsion lead at the AMRC.

intelligence and flexibility. In-process monitoring and testing is used to ensure quality and reliability, while also providing data to create digital passports which can be used to monitor the health of the batteries through production and during use. This will enable greater optimisation of the manufacturing processes and provide a pathway to the re-use and recycling of batteries at the end of life.

- **The AMRC is one of the collaborating research institutes in the EPSRC Future Electrical Machine Manufacturing (FEMM) Hub.** Lloyd Tinkler, our senior technical fellow for electrical machines, works closely with the FEMM Hub director and vice president of advanced manufacturing at the University of Sheffield, Prof Geraint Jewell, to establish credible manufacturing solutions for the production and assembly of electric motors.

  This ranges from laser cutting of sheet steel laminations used to produce motor stators or the machining of stator stacks to produce more complex geometries which could incorporate cooling channels – through to investigating different approaches to the forming of coils, including robot assisted winding, form winding and even the use of additive manufacturing, allowing greater coil packing efficiency to improve the power density of the motor.

Within our composites team, the existing capability in filament winding is ideally suited to the manufacture of lightweight pressure vessels that are needed for the onboard storage of gaseous hydrogen for passenger cars or trucks. We are building expertise in the design, simulation, manufacture and testing of such vessels. Working alongside our HVM Catapult colleagues at the National Composites Centre (NCC), we will develop and demonstrate a viable and scalable process for the manufacture of type IV pressure vessels that can be exploited by UK supply chains.

To fully embrace the benefits of some of the future propulsion technologies, the vehicle platforms will also need to evolve and adapt, as such future generations of cars, trucks, buses and aeroplanes will require new designs and new methods of manufacture.

For example, vehicle manufacturers have expressed a desire to have adaptable architecture that could either accommodate a large battery pack or, within the same volume, house the pressure vessels for a hydrogen fuel cell. Similarly, for aerospace, current designs are based on the principle of kerosene being stored within the wings and large gas turbine engines installed on pylons under the wing. The adoption of liquid hydrogen and distributed propulsion will force future designs to look very different. Programmes such as the ATI's FlyZero and Airbus ZEROe have indicated the direction these may take, with concepts such as belly tanks or more radical blended wing configurations.

The AMRC also has a role to play in future platforms, whether that is making efficiency improvements to existing designs, enabled by lightweighting technologies such as composites and topology optimised castings, or in developing the new methods of manufacture and assembly for truly novel aircraft concepts.

Our vision is to establish the AMRC as the UK's leading centre for manufacturing development of high-performance future platforms and propulsion systems. Supporting the transition away from fossil fuels and creating a more sustainable future for transport solutions.

A great example that showcases the AMRC's combined strengths is ROTATOR, a project funded via the EU programme Clean Sky2, that is developing a novel solution for the pitch control mechanism of an open rotor aeroengine. Safran is developing a new engine concept based around an open rotor design; these engines provide the thrust and performance of a turbofan engine, but with the enhanced fuel efficiency of turboprop engines. To maximise the thrust and efficiency of these engines for take-off and cruise, a complex pitch control mechanism (PCM) is required.

This £4m project, led by Sheffield-based company Magnomatics, a spin-out of the University of Sheffield, and involving AMRC partner Hexagon, is developing a solution based around Magnomatics' pseudo-direct-drive (PDD), this is a fault tolerant design that eliminates the hydraulic mechanism of conventional PCMs.

The AMRC is contributing by seeking opportunities to lightweight key components in the system to provide further efficiencies. This includes the use of composites for the PDD rotor, topology optimisation of the blade hub produced as a titanium casting, and additive manufacturing of the blade lever arms. This requires close cooperation across various AMRC groups including design and prototyping, machining, composites and castings, as well as working alongside our colleagues at the University of Sheffield, who are providing input on the design and sizing of the electric drive system.

Over the next 12 months, we will further enhance our capability and offerings in this theme both in terms of platforms and propulsion.

We have a strong programme of HVM Catapult projects and will continue to collaborate with industry to address their specific challenges: from battery packs to electric motors, hydrogen storage to fuel cells, turbines and gearboxes, to high-rate composites manufacture of aerostructures to deliver on our vision for a tomorrow, done better.

Electrification research produces promising outcomes

By Mrudula Jadhav

AMRC engineers are developing new manufacturing solutions for the production and assembly of electric motors, as part of a seven-year research programme to help bring UK manufacturing to the forefront of the electrical revolution.

The University of Sheffield Advanced Manufacturing Research Centre (AMRC) is one of the collaborating research institutes on the EPSRC-funded Future Electrical Machine Manufacturing (FEMM) Hub programme that aims to develop new manufacturing techniques and technologies to improve the reliability, performance and efficiency of high-value electrical machines, which recently passed the midpoint of the programme.

As part of the wider FEMM Hub programme, the research team at the AMRC's flagship Factory 2050 facility is working on two research projects. The AMRC has successfully produced an electric motor component using remote laser cutting technology that's three times faster than its conventional counterpart; and is testing robotic winding that allows greater coiling flexibility for more efficient motors.

Lloyd Tinkler, AMRC senior technical fellow for electrical machines, said: "Electrification is central to the AMRC's future propulsion core research theme, and the FEMM Hub has given us the opportunity to tap into expertise in the electrical machines research community with the hub acting as a central point from which we've now built a large portfolio of activity across the whole AMRC."

The trend for increasing speed and operating frequency in electric machines is driving a push towards thinner laminations in the stator and rotor core, which presents manufacturing challenges to conventional processes such as stamping or laser cutting without causing degradation in mechanical or magnetic properties.

The AMRC has developed a novel remote laser cutting process for electrical steels, from experimental proof-of-concept by other researchers, to producing a complete laminated stator core. The technology is up to three times faster than conventional laser cutting, with the potential to tune process parameters to avoid damaging the steel properties.

Remote laser cutting had previously been demonstrated on a representative stator tooth geometry (c. 50mm x 50mm).

Dr Alexei Winter, technical lead in electric machines at the AMRC, has led research that builds on previous laboratory demonstrations, creating a bespoke remote laser cutting system that is capable of producing 600mm x 600mm parts using

AMRC technical lead for novel robotics, Gianmarco Pisanelli, demonstrating robotic coil winding technique.

a 2kW laser, scanned at up to 8m/s, and overcoming manufacturing challenges, such as cleanliness of the optics and handling thin-gauge electrical steel sheets, to produce hundreds of laminations for a full stator.

The stator demonstrated the inherent flexibility of laser cutting to allow each lamination to be customised, such that when stacked, it approximates three-dimensional features such as radii, chamfers or holes which could incorporate additional functionality into the stator core. This stator is currently being wound and prepared for testing in the Electrical Machines and Drives Group at the University of Sheffield.

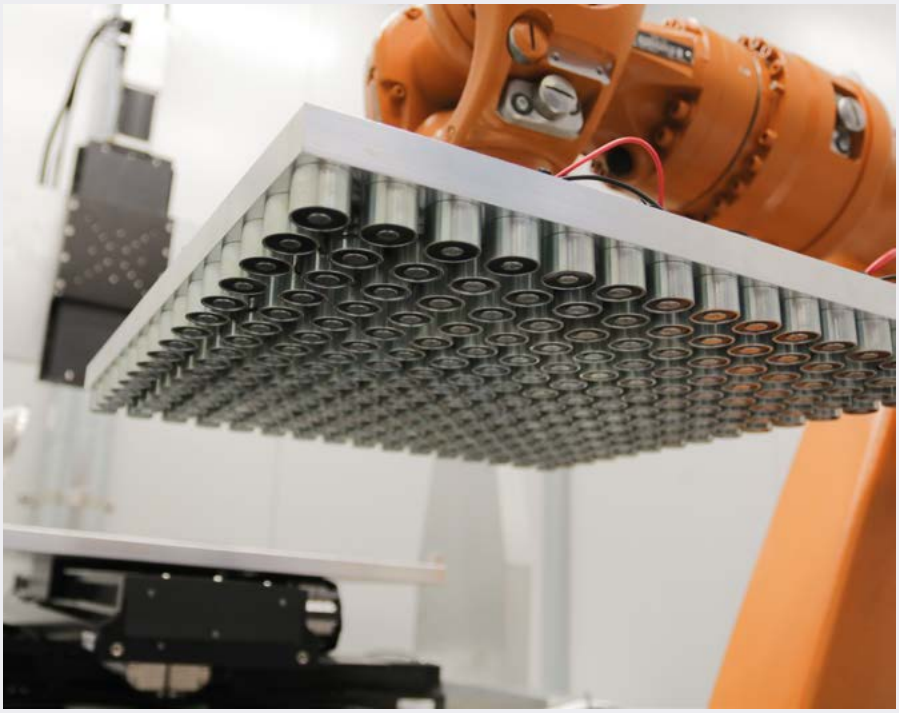
As part of the other research strand, Gianmarco Pisanelli, technical lead for novel robotics at the AMRC, has developed robotic coil winding as a more flexible alternative to conventional winding machines, using the large working volume and dexterity of the robots to accommodate a wide variety of coils.

He said: "The research demonstrates the precision winding of coils to maximise the fill factor, i.e. the number of copper wires placed within the slot, and has quantified the influence of friction in the needle and wire tension pulling the robot from its planned trajectory.

"The ongoing research focuses on compensating for these effects to minimise fluctuations in wire tension which could influence the quality of the resulting coil."

Last year, Pisanelli presented his work to an audience of industrial leaders in the field of coil winding and machine manufacture at the *Coil Winding, Insulation, Electrical Machine Exposition* (CWIEME) in Berlin, one of the largest industrial events in the world.

FEMM Hub director Prof Geraint Jewell said: "I'm delighted that the quality of research and the impact that our work under FEMM Hub is having has been commended by the mid-term review panel.



The AMRC used a bespoke remote laser cutting system to produce hundreds of laminations for a full stator.

We have many strands of research on electrical machine manufacture on-going across the consortium with real momentum, and the innovative work on next generation laser cutting coil winding being undertaken at the AMRC is one of the highlights."

In 2019, the AMRC received a £1.7m grant from the Engineering and Physical Sciences Research Council (EPSRC) for research, to establish credible manufacturing solutions for the production and assembly of electric motors. The AMRC is hosting the majority of FEMM Hub's capital investment at Factory 2050, part of which has seen two winding robots and a remote laser cutting facility established. Apart from the £1.7m funding, the hub also kick-started a portfolio of electrification projects, worth £2m.

"Electrification is central to the AMRC's future propulsion core research theme, and the FEMM Hub has given us the opportunity to tap into expertise in the electrical machines research community."

Lloyd Tinkler, AMRC senior technical fellow for electrical machines.

FEMM Hub fact sheet

FEMM Hub is a £28m, seven-year programme, which began in 2019 and is core-funded by the Engineering and Physical Sciences Research Council (EPSRC), with supporting contributions from a range of industry partners.

The programme focuses on research that addresses key manufacturing challenges in the production of electrical machines, motors and generators for high value sectors, such as aerospace, renewable energy and automotive.

The hub is a consortium of five research groups from three institutions: the University of Sheffield's AMRC and the Electrical Machines and Drives (EMD) group from the Department of Electronic and Electrical Engineering; and the Department of Automatic Control and Systems Engineering (ACSE); the Electrical Power group at Newcastle University; and the University of Strathclyde's Advanced Forming Research Centre (AFRC), part of the National Manufacturing Institute Scotland.

Exploring wire arc additive manufacturing for aerospace

By Chloe Rothenburg

Additive manufacturing experts from the University of Sheffield AMRC North West are exploring an innovative technique to produce hydrogen storage tanks for aerospace applications.

Dr Evren Yasa, head of additive manufacturing (AM) for the AMRC, led a team of researchers on a project using Wire Arc Additive Manufacturing (WAAM) – a production process used to 3D-print metal parts that uses an electric arc to melt a metal wire, depositing layers of melted metal on top of each other, until a desired 3D shape is created.

WAAM is used in many industrial sectors, including energy, defence, automotive, construction and aerospace, to produce large and complex structural components - reducing the need for assembly and joining technologies, as well as waste material. Moreover, WAAM has been deployed for repair and re-manufacturing purposes in aerospace, saving time and costs. In addition, it has the advantage of greater supply chain flexibility, enabling on-demand production in small quantities.

Dr Yasa said: "This project was initiated to utilise our in-house WAAM capability to construct a demonstrator storage tank for liquid hydrogen using an aluminium alloy for use in the aerospace sector – and showcase the complete value chain for producing finished AM parts."

Hydrogen is a highly sustainable energy carrier and is considered as a key to achieving climate neutrality in the EU by 2050. However, challenges around how to store hydrogen limit its full potential, says Dr Yasa.

Muhammad Shamir, technical lead within the AM team at AMRC North West, measuring height of the wire arc additive manufactured (WAAM) wall to control layer height and process parameters.

"The main challenges of storing hydrogen for use as a fuel source in aerospace are the additional storage requirements, along with the complicated geometry needed for integral tanks as well as operation at cryogenic temperatures when it is stored in liquid form," she said.

"These challenges make AM technologies one of the promising manufacturing routes for hydrogen storage tank demands, which is also supported by the Cryogenic Hydrogen Fuel System and Storage Roadmap Report published by the UK's Aerospace Technology Institute in 2022."

Currently, sheet metal forming, machining and welding are used for metallic tank production. However, these conventional techniques do not offer the design freedom to make novel shapes. WAAM provides design freedom, which resulted in the AMRC team being able to make an array of more complex shapes, compared with the standard cylindrical/spherical shape – opening up the opportunity, particularly in aerospace, to have the potential to store hydrogen in more compact areas.

Dr Yasa's team wanted to explore the feasibility of using WAAM for metallic storage tanks by identifying the process parameters, as well as the deposition strategies, for good mechanical properties. Furthermore, the aim was to investigate and counteract the residual stresses occurring due to the high heat input generated during the WAAM process.

Dr Muhammad Shamir, technical lead within the AM team at AMRC North West, explained how different types of heat sources can be employed in WAAM, for example, an electric arc or a plasma arc to melt the wire feedstock material, adding: "For our research, we focused on an electric arc process using a special technique to minimise heat input."

The project took the team on a steep learning curve, as the equipment used was new to them, said Dr Yasa, adding: "The material was also difficult to work with as aluminium alloys are susceptible to oxygen and hydrogen pick-up. If the material is left in ambient air for too long, it begins to pick up moisture, leading to excessive porosity during processing – deteriorating the mechanical properties."

Showing the tank after it has been manufactured using wire + arc additive manufacturing.

Other challenges surfaced during the project included the narrow process window giving a limited range of suitable process parameters, and five-axis programming for complex geometries.

However, overall, Dr Yasa said the research work was beneficial as it enabled the team to explore these challenges of WAAM processing aluminium alloys.

The seven-month project was funded through the High Value Manufacturing (HVM) Catapult, of which the AMRC is a member alongside six other national research centres.

Dr Yasa and her team now want to push the research to a second phase and are awaiting the result of a further funding bid to explore the effect of AM on the cryogenic mechanical properties, as well as hydrogen permeability to ensure that it is a feasible route for liquid hydrogen applications.

"We have applied for funding to carry out more work on the process optimisation, as well as having the opportunity to test WAAM materials at cryogenic temperatures in a collaboration with the University of Southampton," Dr Yasa said.

"Moreover, AM for hydrogen storage tanks in aerospace presents challenges, including regulatory approval, standardisation, cost, and industry acceptance.

"Our future projects will focus on overcoming these challenges by collaborating with industry stakeholders, ensuring compliance with standards and regulations, establishing additive manufacturing guidelines, conducting cost-benefit analyses, and fostering acceptance through engagement and knowledge-sharing with the aerospace industry.

"The goal is to showcase the economic viability and competitiveness of this solution."

"These challenges make AM technologies one of the promising manufacturing routes for hydrogen storage tank demands."

Dr Evren Yasa, head of additive manufacturing at the AMRC.

Advancing space applications through AM

Evren Yasa

Abdul Haque

Abdul Haque, technical fellow for additive manufacturing and **Dr Evren Yasa**, head of additive manufacturing, at the University of Sheffield AMRC, discuss the potential of AM technologies for the space sector.

Additive manufacturing (AM) has revolutionised the manufacturing landscape, offering unprecedented design freedom, material efficiency, and the ability to produce complex geometries. The space industry, with its need for lightweight, high-performance and bespoke components stands as one of the most promising sectors for AM application.

The University of Sheffield Advanced Manufacturing Research Centre (AMRC) is at the forefront of this technological revolution. With its expertise in AM, the AMRC supports the space industry in the design, manufacturing and testing of new AM components. Focusing on performance enhancement and the ability to create components not possible with conventional manufacturing methods, the AMRC is well-positioned to drive innovation in space-focused applications.

The AMRC's work aligns with the growing industry demand for more efficient and cost-effective space systems. As the space industry expands with an increasing number of satellites, probes, and potentially manned missions, the need for lightweight, durable and efficient components is paramount. AM offers the potential to meet these needs, reducing the mass of components, optimising design for performance and enabling rapid prototyping and testing for a wide range of applications from satellite components such as antennas to launcher sub-systems.

Here at the AMRC, we have been involved in several key projects that showcase the potential of AM in space applications. These include the development of novel fuel tanks for microsatellite propulsion systems, initially in Ti6Al4V, now a bulk metallic glass, and a collaborative project to develop metal optics for Earth Observation (EO) and exploration missions in space.

We also supported students at the University of Sheffield in developing a 3D-printed liquid rocket engine, similar to those used by pioneering space companies such as SpaceX. However, this was not the first time. The AMRC was also involved in a collaboration with Airborne Engineering and Alloyed, which led to the manufacture and first hot-firing of a complex combustion chamber made from a new nickel superalloy (ABD®900). This was developed for a liquid rocket engine, requiring combustion components as an alternative to Inconel 718. Furthermore, the AMRC has been working on a project to develop a new type of lightweight composite fuel tank for spacecraft and inventing a patent-pending AM technology allowing for the embedding of electrical, optical, and structural elements during print.

However, the adoption of AM in the space industry is not without its challenges. One of the primary concerns is the alignment with standards to ensure safe and reliable space-focused applications. The AMRC is actively addressing this issue, closely aligning activities with industry and regulatory bodies to ensure that AM processes and parts meet the stringent safety and performance standards required for space applications.

Specifically, NASA 6030 outlines the qualification and acceptance testing for metallic and non-metallic materials used in high-reliability applications. This standard covers key aspects like mechanical properties, chemical composition and

"As the space industry expands with an increasing number of satellites, probes, and potentially manned missions, the need for lightweight, durable and efficient components is paramount. AM offers the potential to meet these needs."

Abdul Haque, AMRC technical fellow for additive manufacturing.

manufacturing processes. On the other hand, ECSS-Q-ST-70-80C is a European standard that provides guidelines for the qualification and acceptance of AM processes for space applications, encompassing material selection, process control, post-processing and testing. It is crucial to align with these standards in the end-to-end AM process chain, ensuring that the components meet the stringent safety, reliability and performance requirements of the space industry.

Another AM challenge of paramount importance for space applications is part qualification, which necessitates comprehensive testing and validation of AM components. The AMRC is tackling this through its state-of-the-art testing facilities and expertise in AM process simulation, Finite Element Analysis (FEA) and physical testing, ensuring that components perform as expected under the harsh conditions of space. Quality inspection is another challenge that comes with complex AM parts.

No matter how complex the geometry can be manufactured, without a reliable inspection method, the output is not fit for purpose. Therefore, the AMRC is working on benchmarking different non-destructive testing methods aiming specifically at complex AM components with internal features to provide a deeper understanding of the current limitations and applicability.

We're also working to increase the productivity and reliability of AM processes to enable a more viable option for large-scale part production using technologies such as Wire Arc, Directed Energy Deposition and Additive Friction Stir Deposition.

The AMRC is playing a contributing role in advancing the use of AM in the UK space industry. Through our expertise in AM, commitment to addressing industrial challenges, and close collaboration with our partner companies, UK High Value Manufacturing Catapult centres and regulatory bodies, we're helping to exploit the full potential of AM for space applications.

Much like that first exploration by humans into the world beyond our own, the journey is complex and filled with challenges, but with the ongoing research and innovation, the future of AM in space looks promising.

Blast off for 3D-printed rocket engine

A liquid rocket engine has been built using 3D printing by students at the University of Sheffield, supported by engineers from the AMRC. The 'SunFire' engine, developed by a team of Sheffield engineering and science students, is the first metallic 3D-printed liquid rocket engine to be built and successfully tested by students in the UK.

It's the most powerful student-built engine of its type – an engine that uses both fuel and an oxidiser, rather than breathing in oxygen like a jet engine. It's also the first that is regen-cooled – an engine that uses fuel to cool the combustion chamber before it is burnt, which increases the engine's efficiency and saves weight.

The Sheffield students successfully hot fired – or tested – the engine as part of a week-long competition called Race to Space, in which teams of students from universities across the UK tested rocket engines they have built over the last two academic years.

There are only a handful of liquid rocket engines made by students throughout Europe and even fewer regen engines worldwide, and until now, none in the UK made by 3D printing or as powerful as the engine built at Sheffield.

The University of Sheffield's Royce Discovery Centre - a research centre developing the next generation of materials to meet the needs of UK manufacturing – was instrumental in trialling the laser-powder-bed metallic 3D printing that was used to build the engine. The University's Advanced Manufacturing Research Centre (AMRC) and Faculty of Engineering machined the engine post printing.

Yun-Hang Cho, who works in the AMRC's space sector engagement team, said the AMRC supported the SunFire project in realising the AM parts into finished components ready for assembly.

"Moving forward into the near future, we are continuing to support the rocketry programmes at the University of Sheffield by further leveraging our expertise in design, sensing and additive manufacturing methods such as laser powder bed fusion," he said.

"This includes exploring using more exotic materials designed for high temperature, high pressure environments; simultaneously printing with different materials for better heat transfer/cooling; and finally working with the Sheffield team to optimise the design, simulation and testing.

"Ultimately, this will also further develop the AMRC's capability and demonstrate our centre as the place for space manufacturing."

The Sheffield students built the engine over the last two years outside of their studies as part of the University of Sheffield's Space Initiative – a programme to help STEM students use their skills to tackle some of the space industry's biggest challenges and help them develop careers in the industry after graduation.

Students in the team – known as Sunride – hope to eventually use the engine to power one of their own rockets to the edge of space and become the first UK student-led team to launch beyond the Kármán line, which borders Earth's atmosphere 62 miles above sea level.

The team already holds the UK altitude record for an amateur rocket, which they achieved in 2019.

AI: Oracle or ogre?

Katia Harston explores the buzz around artificial intelligence technologies and talks to the AMRC's director of industrial digitalisation, **Professor Rab Scott,** on what AI means for UK manufacturing.

Professor Rab Scott, AMRC director of industrial digitalisation.

‘I warned you guys in 1984. And you didn’t listen.’

That was the stark warning from Terminator filmmaker James Cameron, the director and writer behind the cult movie about the risk posed to humanity by the ‘rise of the machines’ when a cyborg assassin is sent from the future.

You know a topic is hot when people like Cameron line up alongside tech experts and media magnates, academics and researchers, to join in on the global conversation about artificial intelligence (AI). It’s fair to say interest in the technology has seemingly exploded of late, which is due, in no small part perhaps, to the emergence and popularity of platforms like ChatGPT.

So, it’s official. AI is the latest buzzword. And while many might not truly understand what AI is or what it actually does, the chances are they’ve talked about it with friends and work colleagues, heard it mentioned down the pub, or even at family gatherings. It’s the tech talk on everyone’s lips. And we’re all riding the AI wave, whether we like it or not.

But what actually is AI? It is defined as ‘the ability of machines to replicate or enhance human intellect, such as reasoning and learning from experience’.

Artificial intelligence has been used in computer programs for years, but is now applied to many other products and services. And although the concept of AI has been around since the 19th century, when Alan Turing first proposed an ‘imitation game’ to assess machine intelligence, it only became feasible to achieve in recent decades due to the

increased availability of computing power and data to 'train' AI systems.

AI seems to be everywhere – it is talked about in the news, on TV and touches almost every part of our lives. Most people use it everyday without thinking about it. How? Well, when you reach for your smartphone and open it up using face recognition – that's a form of AI called machine learning that is based on algorithms. Emails sent to your spam inbox – AI. Google search – that's enabled by AI. Security transaction and fraud checks for your banking – AI. The commentary you hear on non-show court matches for Wimbledon? AI. Those recommendations you get on Amazon? You guessed it – AI.

Even celebrities can now be brought back from the dead as digital clones powered by AI. In fact, it is this development that has put Hollywood in hot water, opening up a dark void of uncomfortable questions on who owns the rights to a face, voice or persona that sits behind some of the concerns from actors and screenwriters who recently went on strike. And it's not just concerns about how the dead are affected, but the living too.

And these ideas and fears are creeping into the wider social consciousness through pop culture. Take the new series of TV show Black Mirror – spookily released just weeks before the standoff between actors and studios – where one episode sees Hollywood A-lister Salma Hayek unwittingly signing away her AI-generated digital likeness to a studio for them to do what they like with her AI-powered clone.

AI continues to pose the global question on whether the technology is a friend or foe. The rapid progress being made by AI seems to raise fear and excitement in equal measure; and answers seem to bring more questions – how do we define AI, how do we use it, what is the impact of automation on industry, on society? And that's without touching upon the moral and ethical dilemmas circling around the subject of AI.

As digital technologies continue to transform the world we live in, should we see AI as an opportunity or a threat for manufacturing? We put that question to the AMRC's director of industrial digitalisation, Professor Rab Scott, who shared his thinking around this hot topic – starting with the current use of AI technologies by UK businesses.

Prof Scott says that – according to Capital Economics – which was commissioned by the government to report on current future use of AI by UK businesses – the use of the technology is limited to a minority but is more prevalent in certain sectors and larger businesses.

"There is a clear moment for manufacturers to harness the power of AI in several ways to enhance their operations and drive innovation."

Prof Rab Scott, AMRC director of industrial digitalisation.

"Overall, about 15 per cent of the UK's 2.8 million private businesses have adopted at least one AI technology – that equates to 432,000 companies – spending a total of £16.7 billion," says Prof Scott.

"As businesses grow, they are more likely to adopt AI. About two per cent of businesses – 62,000 – are piloting AI while ten per cent – 292,000 – say they plan to adopt at least one AI technology in the future. That could see spending grow to as much as £35bn by 2025."

Prof Scott says that currently, AI solutions for data management and analysis are most prevalent, followed by natural language processing and generation; machine learning; AI hardware; and computer vision, image processing and generation. The IT and telecommunications, and legal sectors have the highest rate of adoption, hovering at about 29 per cent.

The next highest sectors in terms of adoption rate are finance and accounting as well as the media, marketing, and sales. Health and retail are the lowest, nudging 12 per cent.

So where does manufacturing fit into all of this? "The Capital Economics report showed that about 17 per cent of the manufacturing sector has adopted AI technology, with a further 14 per cent saying they plan to do so in future and about two per cent already piloting AI technologies," says Prof Scott.

"What this shows is a huge opportunity for growth. Government is investing heavily in support for AI and in developing an appropriate regulatory framework with the aim of increasing the type, frequency and scale of AI discoveries developed and exploited in the UK and diffusing AI across the whole economy to drive the highest amount of economic and productivity growth. There is a clear moment for manufacturers to harness the power of AI in several ways to enhance their operations and drive innovation."

Prof Scott outlines a number of ways for how AI tools might be used, including to:

- **Aid product design and development:** by training the models on existing product information, customer preferences, and market trends. Manufacturers can utilise AI to generate new product concepts, optimise designs, and simulate product performance. This can accelerate the innovation process and reduce time-to-market;
- **Support quality assurance and predictive maintenance** by identifying patterns and anomalies to predict potential issues, recommend preventive maintenance, and improve quality control processes;
- **Create comprehensive knowledge bases**, training materials and interactive tutorials;
- Process and analyse vast amounts of textual data to gain valuable insights. AI applications can help with sentiment analysis, trend identification, market research, and competitive intelligence, empowering manufacturers to make data-driven decisions;
- **Automate customer support with chatbots, and virtual assistants**. These applications can improve customer experience, streamline communication and provide personalised assistance;
- **Optimise supply chains** by processing and analysing unstructured data like supplier contracts, purchase orders, and logistics documents. By automating document processing, AI can help identify bottlenecks, optimise inventory management, and improve overall supply chain efficiency;

- **Deliver better market intelligence and customer insights** by analysing vast amounts of publicly available data, including news articles, social media posts and online reviews, to deliver real-time market intelligence, track consumer sentiment and identify emerging trends. This information can drive product development, marketing strategies, and customer engagement initiatives.

According to Prof Scott, these are all valuable functions, but he says it is important to remember that AI is not a panacea.

"Even the most sophisticated machine learning tools will lack true understanding, or consciousness" he said. "They will also carry any shortcomings or bias from the data on which they are trained into the outputs they deliver.

"More than that, there may also be ethical considerations to bear in mind. Generative-AI models will confidently produce inaccurate, plagiarised, or biased results, without any indication that its outputs may be problematic. That's because the models have been trained on data often sourced from the internet, which is hardly a universally reliable source."

So – artificial intelligence – oracle or ogre? Prof Scott has a view.

"As the author Mark Twain once said: 'To the man with a hammer, everything looks like a nail' and to some extent that is where it feels we are with AI," he said.

"It is just a tool, but everyone wants to solve all their problems with it. But, as with all tools, training in their use is needed, and there must be recognition that tools used wrongly can cause harm.

"However, as with every tool in manufacturing, used responsibly and in the right way and in the right place, AI can be a tremendous aid for good, allowing us to move towards net zero, improving productivity and making lives better."

Know the lingo

Artificial intelligence (AI) is the ability of machines to replicate or enhance human intellect, such as reasoning and learning from experience. Artificial intelligence has been used in computer programs for years, but it is now applied to many other products and services. Although the concept of AI has been around since the 19th century, when Alan Turing first proposed an 'imitation game' to assess machine intelligence, it only became feasible to achieve in recent decades due to the increased availability of computing power and data to 'train' AI systems.

Machine learning is a form of artificial intelligence based on algorithms that are trained on data. These algorithms can detect patterns and learn how to make predictions and recommendations by processing data and experiences, rather than by receiving explicit programming instruction. The algorithms also adapt in response to new data and experiences to improve their efficacy over time. The volume and complexity of data that is now being generated, too vast for humans to reasonably reckon with, has increased the potential of machine learning, as well as the need for it.

Deep learning is a type of machine learning that can process a wider range of data resources (images, for instance, in addition to text), requires even less human intervention, and can often produce more accurate results than traditional machine learning. Deep learning uses neural networks to process data through multiple iterations that learn increasingly complex features of the data. The neural network can then make determinations about the data, learn whether a determination is correct, and use what it has learned to make determinations about new data. For example, once it 'learns' what an object looks like, it can recognise the object in a new image.

Generative AI describes algorithms that can be used to create new content, including audio, code, images, text, simulations, and videos. Following huge media interest, ChatGPT is perhaps one of the most well-known generative AI tools and has prompted a noisy public debate about the extent to which AI tools have the potential to drastically change the way we approach content creation and have the potential to change how a range of jobs are performed.

"Used responsibly and in the right way and in the right place, AI can be a tremendous aid for good, allowing us to move towards net zero, improving productivity and making lives better."

Prof Rab Scott, AMRC director of industrial digitalisation.

AMRC Cymru rolls into agri-tech with autonomous tractor

By Chloe Rothenburg

AMRC Cymru has taken delivery of the UK's first commercially available fully-autonomous tractor – enabling the research centre to plough new ground in the agriculture industry.

The AgBot has been designed to create a smaller, lighter and more efficient tractor unit, which can run non-stop and unsupervised for up to 23 hours, saving not only time, but can enable farmers to plan ahead with daily operations in order to help them drive forward their sustainability footprint, improve farming precision and provide traceability data to support vital business decisions.

Harry Collins, senior manufacturing research engineer at AMRC Cymru, said the AgBot is important as its autonomy provides many advantages, including having a lower weight which provides less ground pressure and soil compaction and has the ability to run for longer periods of time unmanned, helping to fill gaps in current labour shortages.

"The idea behind it is being able to put the AgBot in a field and set it off running with tasks via a phone, laptop or tablet," said Harry.

"If it encounters a medium risk, such as coming into contact with a tall weed, the online system sends you a notification outlining the problem and provides a list of options of how to fix it and quickly allows you to set it back off again.

"Or if it comes across a major risk, including someone standing in front of it, the tractor automatically comes to a stop – and in that scenario, the individual will need to physically go out and address the problem."

AMRC Cymru has purchased the UK's first commercially available fully-autonomous AgBot tractor.

Andrew Martin, head of food and drink at AMRC Cymru, said the impact of agri-tech plays an important role to help the research facility be at the forefront of agricultural change within Wales.

"AMRC Cymru, part of the University of Sheffield, is leading the way in driving forward agri-tech solutions in Wales by conducting a landscape review," Andrew added. "The review is helping us to understand how we can aid Wales in achieving a reduction in emissions within the farming and food supply chain, as the UK pushes for a zero carbon supply chain within the agriculture industry.

"We hope such an investment will help the UK drive forward the next global rural/industrial revolution in green growth, through new technology deployment. It will also help us to develop research in global climate change, advance capabilities and new

"Purchasing this new technology shows the public and the farming community that we are serious about investing in the latest equipment and having the opportunity to test it in order to help farming adapt for the future."

Harry Collins, senior manufacturing research engineer at the AMRC.

relationships – we are already being proactive in developing international partnerships across Wales, Canada and Japan."

AMRC Cymru has led in the development of new technologies, using digital twins and robotics within the food and drink sector. Engineers are now using this business-focused research to develop new areas of horizontal innovation from food and drink into the agriculture supply chain.

Harry said the landscape view of the sector came about at the research facility, after engineers had listened to the farming community about what needed change – and that this new technology would help aid and de-risk future investments by the farming community.

"Purchasing this new technology shows the public and the farming community that we are serious about investing in the latest equipment and having the opportunity to test it in order to help farming adapt for the future," Harry added.

"I think there is a massive unknown in the market with the significant reviews being undertaken by Governments and a lot of changes are coming. It is unclear what the future holds for farming, around the latest agri-tech, but it's great to be in a position to be able to test the equipment, do research in this area and be ready for the change when it comes, so we can help the farming community in Wales that will be most affected."

Currently, an AgBot costs about 75 per cent more than a conventional tractor, but could provide long-term savings in terms of fuel consumption, labour costs and has the capacity to switch out its diesel generator for the potential of future greener non-fossil fuels, such as hydrogen. This could drive forward a different view of how sustainability should be considered within the farming environment.

It has the standard three-point linkage, meaning the tools and equipment hitched on the front and back are compatible with those currently available in farming, can tackle adverse weather conditions and run for almost a full day before the need to refuel. In addition, it is able to plot out the most efficient route on the field, which takes into account headlands and navigating predefined obstacles such as trees – all of this is done through an online portal of the farm and mapped field.

The AgBot, which costs around £380,000, was funded through a £1.5m capital purchase grant that AMRC Cymru secured from the Welsh Government. The funds are being used to buy multiple pieces of equipment to help enhance the research facility's capabilities and use on future collaborative research projects.

Harry has a pivotal role to play in the centre's agri-tech research, bringing with him a wealth of experience in design and manufacturing engineering, as well as being involved in agricultural design.

He also revealed how AMRC Cymru's new work in agriculture brings about a personal connection – Harry enjoys sheep farming as a hobby and has a small holding with 90 acres of land and is home to a small flock of commercial sheep, as well as a group of pedigree sheep.

"I think it's great to work on things in your professional career that you are passionate about and interested in away from the day job," he added.

"I am excited to work with the AgBot and intrigued to see what comes out of it. There's also plans to present this capability at a number of roadshows over the coming months. We are still ironing out our plans in terms of future project work and how this agri-tech comes in through our landscape review.

"But we have signed a memorandum of understanding (MoU) with Coleg Glynllifon (Grwp Llandrillo Menai), and our plan is to use the AgBot on its farm. That is going to provide us with a great test window and help us get lots of data as to how successful it is with varying parts of the Welsh landscape."

AMRC Cymru is actively looking for new partners within the agricultural sector. To find out more, visit amrc.co.uk/cymru.

A digital mock-up of how the AgBot will soon look in the AMRC's colours.

Building smart production lines for aerospace

By Mrudula Jadhav

A revolutionary new manufacturing process for the production line of global aerospace giant, Collins Aerospace, has been developed by AMRC Cymru.

AMRC Cymru, part of the University of Sheffield Advanced Manufacturing Research Centre (AMRC), was tasked with developing a Smart Assembly and Inspection Demonstrator (SAID) for Collins Aerospace's state-of-the-art factory in Wolverhampton.

Having been given a deadline of just ten weeks, AMRC Cymru, based in Broughton, North Wales, successfully achieved its objective, utilising and uniting computer-aided design (CAD) with existing technological systems such as the LightGuide Smart Workbench – including projector, monitor and camera – and DIOTA augmented reality software.

The result was a hi-tech Smart Workstation which can operate in any language, enabling workers of all experience and abilities to assemble a gearbox via a much simpler, paperless method.

Collins Aerospace implemented a demonstration station at its Midlands site, housed in its technology development area, and hosted a number of sessions with people throughout the organisation.

The Smart Workstation solution is designed to analyse processes to improve efficiency and provide insight into alternative, more efficient paths forward. The programme-controlled build process helps maintain compliance with the approved manufacturing and assembly method.

From a training and flexibility perspective, a person can operate the Smart Workstation with limited experience and be taught the build process step-by-step, which ensures process outputs are consistent. Being very intuitive, the potential of the technology can also help improve operations efficiency and quality while improving health and safety of operators.

The Smart Workstation has the potential to remove potential barriers. With many companies looking to incorporate more inclusive methods of work processes, this will play a vital part in supporting employees, particularly with a learning or physical disability. If someone has dyslexia or is partially sighted, for example, the technology will help make the instructions as clear as possible. Eventually, the workbench can be at different heights so it can be operated by someone in a wheelchair, and set-up for people who are left or right-handed.

With direction from the LightGuide, and such an easy-to-follow process which logs time and every step and movement of the manufacturing process, the general consensus among users who tested the demonstrator was that it would have a 'significant and beneficial' impact.

Gareth Towlson, senior manufacturing research engineer at AMRC Cymru, a member of the High Value Manufacturing (HVM) Catapult network, led the team at the Broughton facility, to ensure the workstation has the capacity to be tailored to a variety of requirements.

"To see the Smart Workstation already in use in real time in Wolverhampton is fantastic, it's testament to how hard we have worked in partnership to find a solution, within budget and deadline," said Gareth.

"We had a vision, but ultimately it is their product, their factory and their workforce, so we had to ensure it was bespoke to their needs, and through collaboration we have done so successfully."

He added: "We've already had interest from other sectors and high-value manufacturers as the technology can be applied in many different ways.

"Through our dedicated and experienced team of research engineers we have the skills and expertise to work with customers in any arena, to meet critical timescales and exceed their goals.

"For Collins Aerospace to purchase the equipment and for it to have such a positive effect commercially, and on health and safety, training, and quality, is incredible, and a real honour for us.

"It's something we will be looking to achieve with other organisations in the future."

Images (clockwise from top): The Smart Workstation incorporates animation videos for more complex stages of the build to show the part being assembled in the correct orientation, alongside a highlighted graphic for the operator to follow; the Collins Aerospace team using the Smart Workstation at AMRC Cymru, Broughton; The Smart Workstation uses DIOTA augmented reality system to create a simpler process in terms of training and inspection.

"To see the Smart Workstation already in use in real time in Wolverhampton is fantastic, it's testament to how hard we have worked in partnership to find a solution, within budget and deadline."

Gareth Towlson, senior manufacturing research engineer at AMRC Cymru.

MediTel: A prototype of passion and perseverance

The AMRC made worldwide headlines with game-changing robotics technology developed to provide remote medical treatment to casualties in high-risk emergency environments. **David King, the AMRC's head of digital design,** took **Chloe Rothenburg** behind the scenes to reveal the design and prototyping blueprint for success on this first-of-a-kind project.

From concept to prototype, the AMRC played a leading role in successfully creating a mobile, robotic, uncrewed ground vehicle (UGV), using medical telexistence (MediTel Technology) – all in just nine months.

King said this work was his most rewarding project since starting at the AMRC seven years ago and was the most challenging in terms of timescale delivery and complexity.

"The MediTel project was definitely a thrilling and demanding experience," added King. "Our team had to learn a lot, including some new technologies that were completely unfamiliar to us. Despite the challenges, we were able to gain a solid understanding of these technologies and successfully implement and demonstrate them within a very tight timeframe.

"It was certainly a challenging project, but it was also incredibly rewarding to see our hard work pay off in the end. The project was a huge team effort."

The AMRC team initially consisted of 10 engineers from the design and prototyping group. Later increasing to 15 at the peak of the project, who all worked tirelessly to bring it to fruition. They used skills across the AMRC, utilising the expertise in digital communications from AMRC North West, as well as robotics developers from the AMRC integrated manufacturing team and Sheffield Robotics.

King said: "Our team successfully created and built a mobile telepresence robot designed to navigate rugged terrain and assist those in need. We developed and integrated a dual robot arm system located on the front of the platform near the injured party and a virtual reality interface that allows the operator to feel present in remote locations.

"The team also oversaw project management throughout the entire process, ensuring that every task was completed to the highest standard. We take pride in our design and engineering skills, which resulted in the development of a successful prototype that was fit for purpose. We built a consortium of partners to work with us on the project, which included world-leading academic researchers from Sheffield Robotics, part of the University of Sheffield, who helped to develop the robot's bi-manual control software.

"In addition, we had further support from two industrial partners who provided us with key technology to deliver the project. I3D robotics in Kent, provided a stereo camera system for mapping the environment mounted on the front of the UGV – and Digital Concepts Engineering from Hinkley, Leicestershire, supplied the all-terrain tracked base of the UGV platform."

The team had some previous experience in this area in terms of machine building, systems integration and virtual reality (VR) development, but King says it was the first time they had needed to scale up for a fully-integrated mobile robotics platform.

With help from the consortium, the MediTel team was able to deliver the first-of-its-kind, fully-integrated medical telexistence solution, which boasts virtual reality and could effectively remotely operate medical tools to perform a critical initial assessment of a casualty within 20 minutes, including temperature, blood pressure and pulse rate checks; carry out a palpation of the abdomen and administer pain relief through an auto-injector – all while streaming real-time data to the remote operator.

MediTel was one of three novel telexistence technologies funded through a two-phase £2.3million innovation competition run by the government's Defence and Security Accelerator (DASA), on behalf of joint funders, the Defence Science and Technology Laboratory (Dstl) and the Nuclear Decommissioning Authority (NDA).

Despite other project work running parallel to MediTel, King puts a spotlight on the team's perseverance to make sure the work was delivered on time, recalling seven-day working weeks and a final 2am finish on the day of the main demonstration day for the funders.

"We found ourselves in a situation where you're immersed in the work, your heads are down, you're in the zone, and you don't have the time to really step back and reflect on the potential impact it will have," said King.

"It wasn't until afterwards, when we reached the demonstration day, that we realised how much we had achieved. We had been working flat out, especially during those final four weeks. But the tough deadline pushed us to the limits; it was a date we couldn't move – so it really brought out everything we had to give, pushing us to deliver like never before.

"MediTel was a massive project in terms of complexity and was one of the toughest things we've ever done. It pushed us into the unknown, but we thrived on it and enjoyed learning new skills and technology.

Dr Jonathan Gomez Palomino, technical lead at the AMRC, checking over the functionality of the robot's wireless optical tactile sensor, which can be used to carry out a palpation of the abdomen.

"A lot of our design projects involve a small team or even a single engineer with a specific design skill – but this one involved every aspect of what we do: design, additive manufacturing, electrical design, software design and also included us pulling from the wider AMRC for knowledge – a resource we are very fortunate to have on our doorstep. It was a real team effort across multiple groups and a testament to their skills and commitment to pull it off successfully in that short amount of time.

"I can look back and say I am very proud of what we as a team achieved. Everyone pulled together when it counted and without this, we would have never got the work done."

What more could have been done with the initial MediTel project if the AMRC team had more time? King said he would have liked to have spent longer on testing with the end users, adding: "Given more time, it would have been great to have pushed the technology further and improved the user experience.

"The robot has a lot of sensor technology on it that we didn't get the time to utilise. This is still just a prototype and needs more work to make it deployable, making it a robust product and suitable for manufacturer – but there has been interest from our original funders and stakeholders to develop it further and integrate it with other systems rather than be a purely standalone unit, so we're hopeful there may be more work to come."

King started working at the AMRC in 2016 as a senior project engineer, coming in originally to set up the electronics arm of the design and prototyping group. He was blown away by all of the technology he saw at the AMRC and really wanted to work for the organisation.

"It's certainly been an interesting seven years," said King. "When I started, I was one of just two in the team, which I helped to grow and establish our digital design lab – from there, I progressed within my career, became a digital design manager for three years and for the last two I have been head of digital design. MediTel was 100 per cent my favourite project from my 20 years of working in industry and was the most rewarding technically, but also in terms of the team working together. I'm excited and eager to see where this work will lead us."

"MediTel was a massive project in terms of complexity and was one of the toughest things we've ever done. It pushed us into the unknown, but we thrived on it and enjoyed learning new skills and technology."

David King, head of digital design at the AMRC.

Sustainability: everything, everywhere, all at once?

Ahead of the AMRC Summit 2023 to discuss the future pathway for moving UK manufacturing to a net zero environment, the **AMRC's sustainability lead Dr Andy Bell**, takes a closer look at the United Nations sustainable development goals and their implications for industry.

Dr Andy Bell, sustainability theme lead for the AMRC.

In 2015, the United Nations (UN) member states agreed a path forward to achieving, in their words, a shared blueprint for peace and prosperity, for both people and planet, adopting 17 sustainable development goals (SDGs). It recognised that our future depends upon not only tackling the climate crisis, but also on reducing other inequalities that pervade society. It is for this reason that I find the idea of selective engagement with the 17 SDGs problematic.

When we undertake sustainability discussions, we typically cherry pick SDGs based on a skewed perception of the reality of its problems and our perceived control over it. No one would argue that we need to address goal 12 – responsible consumption and production, but goal three – zero hunger, is abstract in relation to what is in our perceived control. This results in a kind of sustainability tunnel vision that we see across sectors with clear net zero goals but a weaker, wider agenda. The truth, in fact, is that if you are engaged with one of the SDGs you are engaged with them all.

Whilst this is a fairly new idea in the literature, dating back only to the late 2010s there is a sound logic that supports it. The SDG wedding cake from the Stockholm Resilience Centre, shows visually how the SDGs can be organised into broad interrelated themes of biosphere, society and economy and goes some way in defining the prioritisation of these activities in relation to reaching the goal of a sustainable future. Yet, this is a broad brush that does not specifically consider the application of the high-value manufacturing sector.

As part of my current exploration of sustainability within the AMRC, I have been considering the implications of the SDGs for our industry and manufacturing organisations – particularly how these SDGs interlink and should be approached by a manufacturing business, a concept we will be exploring at the AMRC Summit 2023.

By understanding only a little of the complexity of the SDGs, the SDG interaction diagram I've created proposes an approach to understanding how they are linked in our context.

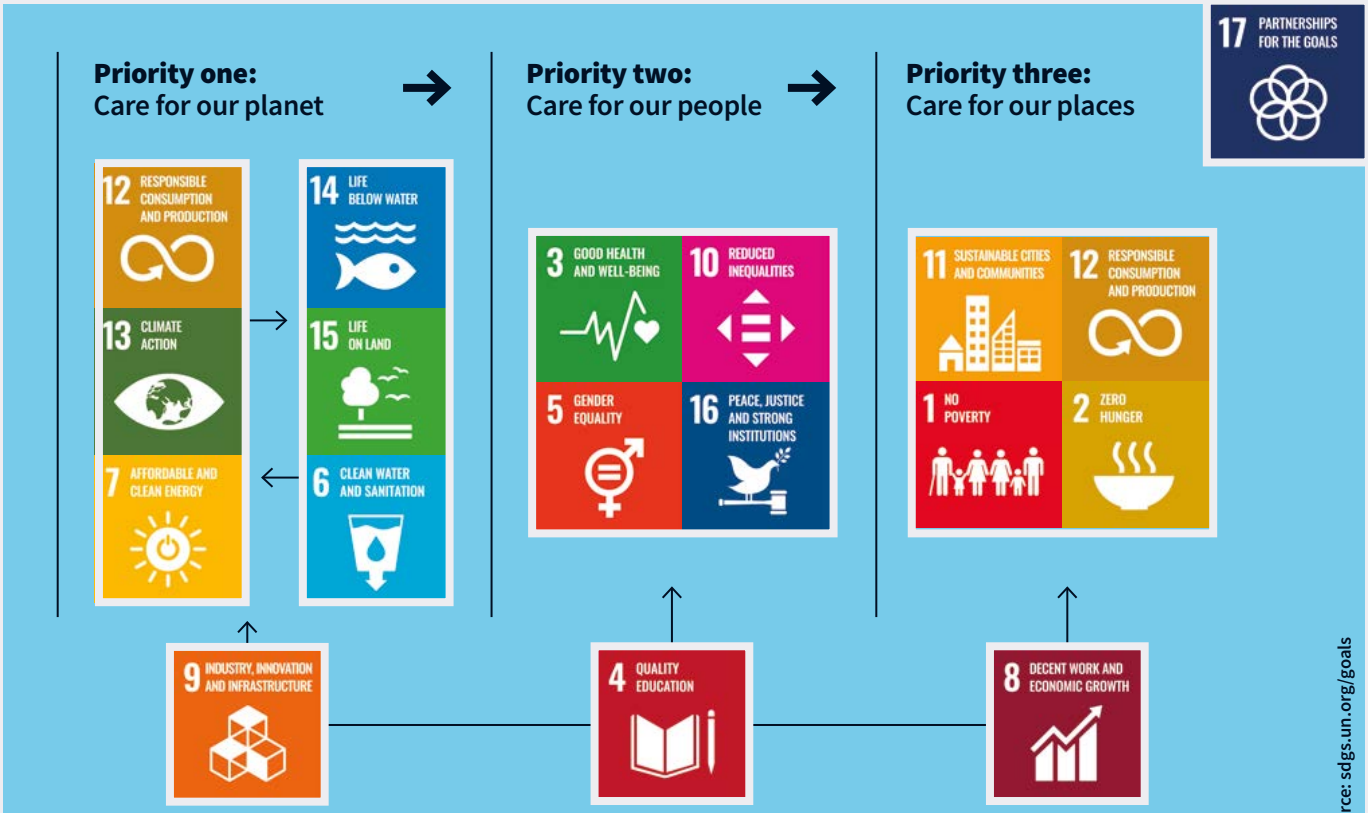
By separating the SDGs into four groups, encapsulated within the concept of creating the necessary partnerships to achieve these goals, we can chunk the problem and better understand our place in the story. My proposal is simple: we have a set of key enablers that create the backdrop for achieving a sustainable future, supporting three priority areas that we must act on to realise the vision of the SDGs.

So, what is a key enabler? The key enablers provide a foundation upon which to build a response to the rest of the SDGs. The three elements under this cover our ability to innovate and create wealth, which is built on the strength of world class education systems and will generate the necessary funding to support sustainable transitions. We cannot, in truth, realise innovation and growth without the people to support it, which is driven by higher educational standards. What this also says is that the three elements are linked. For example, by focussing on SDG nine and four, SDG eight must be a natural byproduct.

This interlinking is also true for the proposed priority areas. Caring for our planet, aligned with the Stockholm Resilience Centre's perspective of a foundation built on the biosphere, is critical and needs an immediate response. Interestingly, I believe that the six elements of caring for our planet are also being undertaken together, whether intentionally or not. We cannot, for example, reduce plastic consumption – SDG 12 – without unintentionally or otherwise impacting on SDGs six, 14 and 15. The reduction of plastic waste that follows sees an associated reduction in plastic, reaching both landfill sites and the oceans and has the necessary impact of improving land and water quality.

Whilst I appreciate that our priorities of caring for people and places are more abstract, the logic also follows that they are linked back to our pursuit of priority one and the proposed key enablers.

Investment in education is always an investment in people and although abstract, we know that improving educational standards, whether in pursuit of innovation and economic growth or not, improves outcomes for the people involved. The same is true of priority one: a clean and healthy planet



Key enablers to realise the sustainable development goals

means healthy people, closing the loop between the key enablers, goals under priority one and the goals of priority two.

Priority three is the priority that I have the most difficulty in giving a title. I've referred to it as caring for our places, but what it really means is that we make sure that the places we inhabit can support the people that live there fully. Perhaps being the most abstract of the priorities, it is also difficult to visualise the links for it. But when we pursue priority one and draw on the key enablers, we inadvertently create the conditions for priority three to take place.

A planet that has a clean environment, is innovating through education and providing people with the greatest opportunities, will naturally deliver zero hunger and poverty in a sustainable community.

Looking back to my previous article in the AMRC Journal discussing Sir Titus Salt's mill and Saltaire, gives a glimpse of what this idea of fully interlinked SDGs could be. There are significant benefits to be had from simply understanding that if we are targeting only one SDG we are effectively beginning to enable them all.

This is something that I believe can be seen in Saltaire and the approach that Sir Titus Salt explored 150 years ago. However, there are natural differences between the 1800s and today, not least the idea that an individual could simply build a town to support their manufacturing plant.

Today sees a new dawn of ever accelerating digital technologies. So, do the ideas presented hold true for a digital future? I would argue that yes, they do. The sustainability agenda will be driven over the coming decade by our ability to embrace the benefits of digital technologies, such as artificial intelligence and machine learning. These technologies will be used to isolate areas of waste in our systems that were previously invisible or ill understood, driving the environmental efficiencies of our manufacturing plants and new products to previously unthinkable levels. They will support us to create new and novel solutions, and quickly assess target areas for intervention. Digital will be the key to unlocking the vision of the SDGs.

Take for example, the benefits seen at AMRC Cymru, through the implementation of a digital framework under the Ffatri 4.0 project. The simple act of monitoring, digitalising and assessing energy usage across its research building has resulted in a near 20 per cent reduction in electricity consumption. This is without the benefit of any advanced analytics to really explore the full potential of energy savings using optimisation approaches.

A digital future will require education, innovation and investment – our key enablers and the foundation of achieving our priority areas. It will specifically support the minimisation of material consumption and target interventions on health and wellbeing. In fact, we are already seeing some of this happen today as apps and wearable devices begin to take over control of our insulin delivery, nutrition and sleep quality to name only a few.

Digital technologies will also provide the ability to predict where interventions may be needed to support agricultural outcomes, for example, to ensure food supplies, avoid pandemics and shuttle energy supplies to where they are needed at the right time.

Understanding the SDGs and the way in which they interlink is critical to achieving net zero and more so by 2050. The AMRC is now recognising this as a problem area that needs to be addressed. Educating our partners in the interactions of the SDGs will become a critical part of our future as we build towards not just net zero, but on impacting on all inequalities globally.

So, look again, are you just targeting a handful of the SDGs, or are you unavoidably engaging with them all?

Paperless shop floor becomes an AMRC first

By Chloe Rothenburg

AMRC Cymru is set to become the first facility in the University of Sheffield AMRC cluster to have a completely paperless shop floor.

The innovative idea, which uses computer software and an interlinked touch screen kiosk to house all the necessary documents for a shop floor to function safely, was devised by AMRC Cymru's senior manufacturing research engineer, Anmar Al-Qutayri.

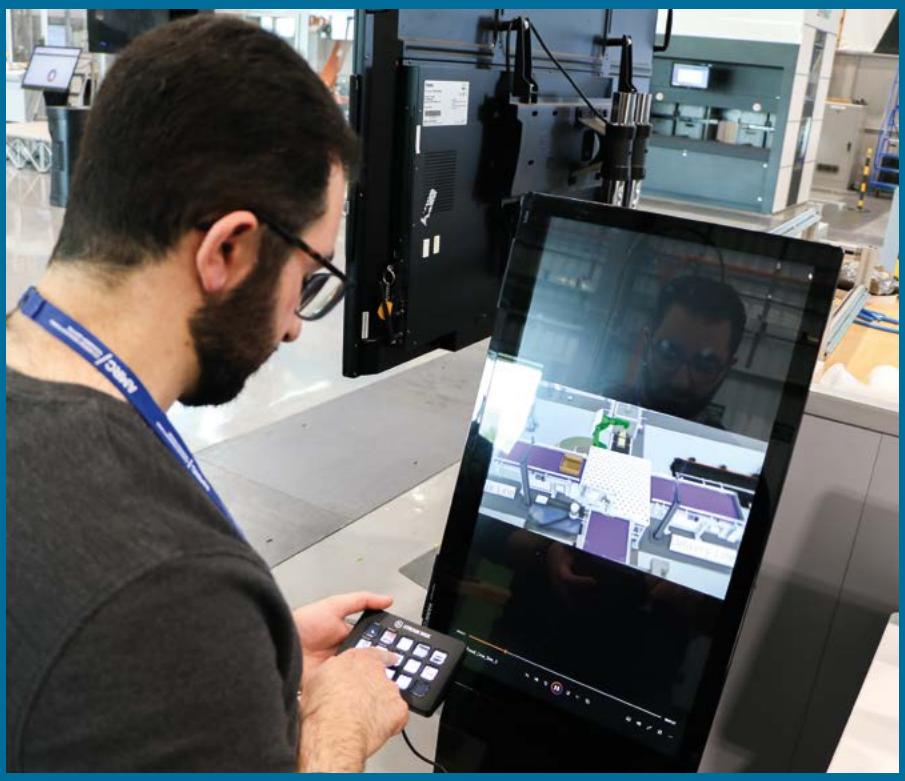
Anmar's avid interest in gaming and computers inspired him to devise the concept and he hopes to roll out the software to all AMRC shop floors – cementing the opportunity for the organisation to strengthen its long-term sustainability footprint.

He highlights that the system is very easy to use and said one of the best things about it is you can store as many documents as needed, all in one place, and can be updated quickly without the need to use countless sheets of paper.

"Sustainability is big on the agenda for the AMRC's future and AMRC Cymru has a key role to play it that vision," said Anmar. "Our workshop manager, Matt Booth, was searching for ideas on how we could make the workshop more sustainable and going paperless seemed like a good place to start that would not only benefit the AMRC, but also all the companies we support so I started to look at how we could actually do it.

"The stream deck, an interactive touch pad with tailored buttons that can be programmed to display images and documents, is an integral part of the system and was something I was using at home when gaming – this sparked my idea to use the software to enable our shop floor to go paperless. I pitched the idea to Matt and he was on board, so we decided to run with it.

"Buttons on the stream deck can be customised and take you to any videos or documents you use most frequently. It may be a small touch pad, but it's simple and works very effectively."

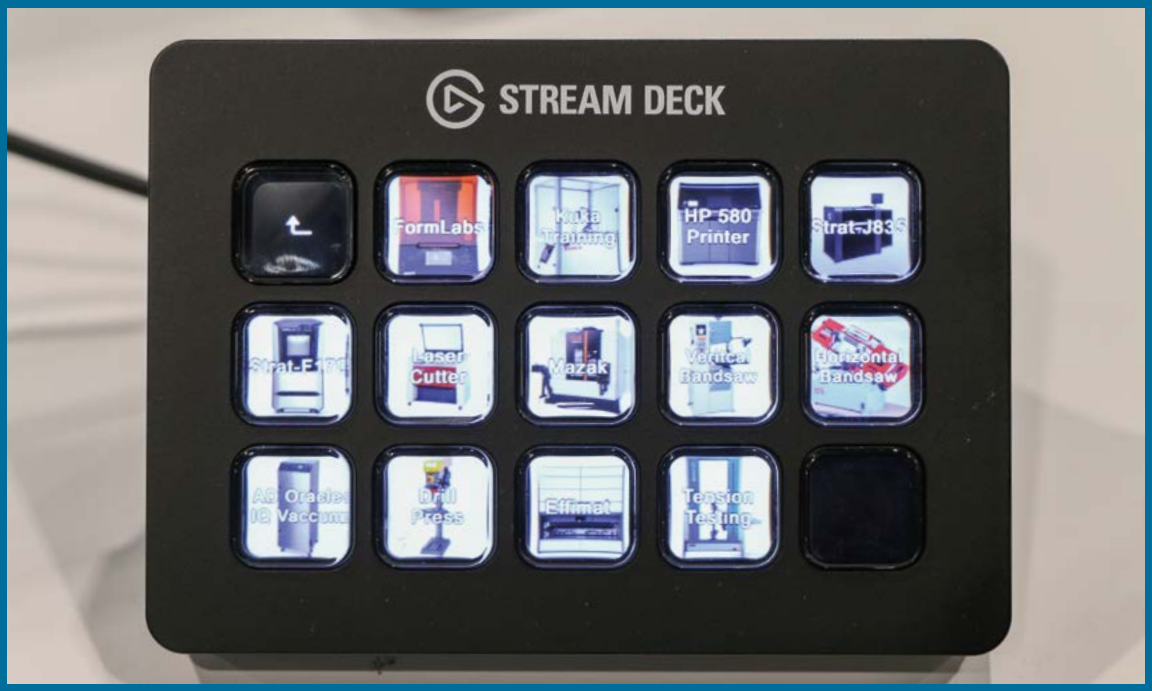


Anmar Al-Qutayri, senior manufacturing research engineer at AMRC Cymru, pictured with the interlinked touch screen kiosk – which houses all of the necessary documents needed on the shop floor.

Anmar highlighted that the impact of having this system in place helps to save paper, time, energy and money associated with having to manually create and use documents. It can also help to familiarise staff with machinery they're not used to, can add a further element of interactivity to the shopfloor and enable engineers to keep up-to-date with safety documents and amend them at the touch of a button.

Andy Silcox, research director for AMRC Cymru, said the interactive systems gives engineers easier access to vital work documents, assessment check sheets and work instructions, rather than having to find the relevant documents in a paper format next to the machine.

He added: "As we develop the system at AMRC Cymru, the management team will have a greater assurance that the up-to-date information has been seen and understood by all users of the shop floor equipment."



The stream deck provides shortcut links to the main system.

Matt Booth, workshop manager at AMRC Cymru, said feedback on the system so far from staff and other companies visiting the site has been very positive.

He added: "Since introducing this system into our workshop, we have been able to not only demonstrate the benefits to the AMRC team, but have also demonstrated it to numerous visiting SMEs and large companies. They provided great feedback relating to its sleek look, how easy it was to use and the versatility of this system – more importantly they commented on how they could all see how this system could benefit their organisation."

Matt and Anmar began the task to set up the stream deck software system to work alongside a computer and touch screen, to be housed on a metal frame within close proximity of any machine on the shop floor at AMRC Cymru, based in Broughton, North Wale in February.

Fast forward six months and four separate set-ups have been successfully created and are ready to be implemented at the research facility, which is managed by the University of Sheffield and is a member of the High Value Manufacturing (HVM) Catapult.

The user-friendly system can store all mandatory documents needing to be displayed next to any machinery on the shop floor, including method statements, risk assessments and demo videos of the machines in action and how they can be used.

Anmar added: "Most people think of the big-ticket items, including energy consumption, solar and wind – but this project, despite being smaller, will have a great impact, both in the short term and for the future. Everyone at AMRC Cymru has been really positive about this project and it has spurred me on even more to get the project operational in the fastest time possible."

The full set up, which cost about £1,700 each, was funded from a £1.5m capital purchase grant secured through Welsh Government, which is being used to help enhance the research facility's capabilities and use on future collaborative research projects.

"I am really passionate about the work we are doing in sustainability and I want to help leave a lasting impact in my job – not just at AMRC Cymru, but across the whole organisation," Anmar said.

"I want to help AMRC Cymru become stronger in its sustainability footprint and work towards achieving more in this space. I also want this system to become a useful tool to help new engineers coming into the business to get to grips with the machinery, how they are used and the correct safety procedures to use without them worrying or feeling intimidated."

Anmar hopes that in the future the system could be used across other departments that rely heavily on paper documentation and have the need to keep it updated.

"Since introducing this system into our workshop, we have been able to not only demonstrate the benefits to the AMRC team, but have also demonstrated it to numerous visiting SMEs and large companies."

Matt Booth, workshop manager at AMRC Cymru.

Ffatri 4.0 saves enough energy to power 60 homes for a year

By Mrudula Jadhav

The Airbus UK team based at the AMRC Cymru facility in Broughton, saved enough energy to power 60 homes for a year as part of a pioneering future factories project to help businesses boost productivity while meeting net zero targets.

As part of Ffatri 4.0, over a five-month period, AMRC Cymru and aerospace manufacturer Airbus, who share a research facility in Broughton, saw electricity savings equivalent to powering 41, three-bedroom homes for a year, and gas savings equivalent to powering 21, three-bedroom homes for a year.

Ffatri 4.0, which launched last year, is a collaboration between the Welsh Government and AMRC Cymru, part of the University of Sheffield Advanced Manufacturing Research Centre (AMRC) and a member of the High Value Manufacturing (HVM) Catapult network.

Through implementation and use of Industry 4.0 digital technologies, the project has already delivered tangible results and proven to increase business resilience, productivity and cut emissions for Welsh manufacturers in the aerospace and food and drink industries, including Airbus and The Pudding Compartment.

Luis Rivera, wing accelerator industrial leader at Airbus, said the collaboration between Airbus and the AMRC has been positive at many levels. By connecting its network of Airbus process experts with the AMRC team, the collaboration allowed for shared learnings, as well as guidance and feedback on needs for future product introduction.

The AMRC Cymru facility is a £20m state-of-the-art applied research centre in Broughton, North Wales, funded by the Welsh Government and managed by the University of Sheffield.

He said: "The AMRC in turn used its research and innovation core knowledge to explore and discover new possibilities beyond our day-to-day activities, expanding our area of interest to new topics that will help the introduction of any future line of production."

By tuning the building management system to the actual use requirements both in offices and on the shop floor, specifically in terms of temperature and lighting control, the significant gas and electricity savings seen by Airbus have been achieved with minimal additional equipment and costs.

The Pudding Compartment's data and analytics results were more fact-based.

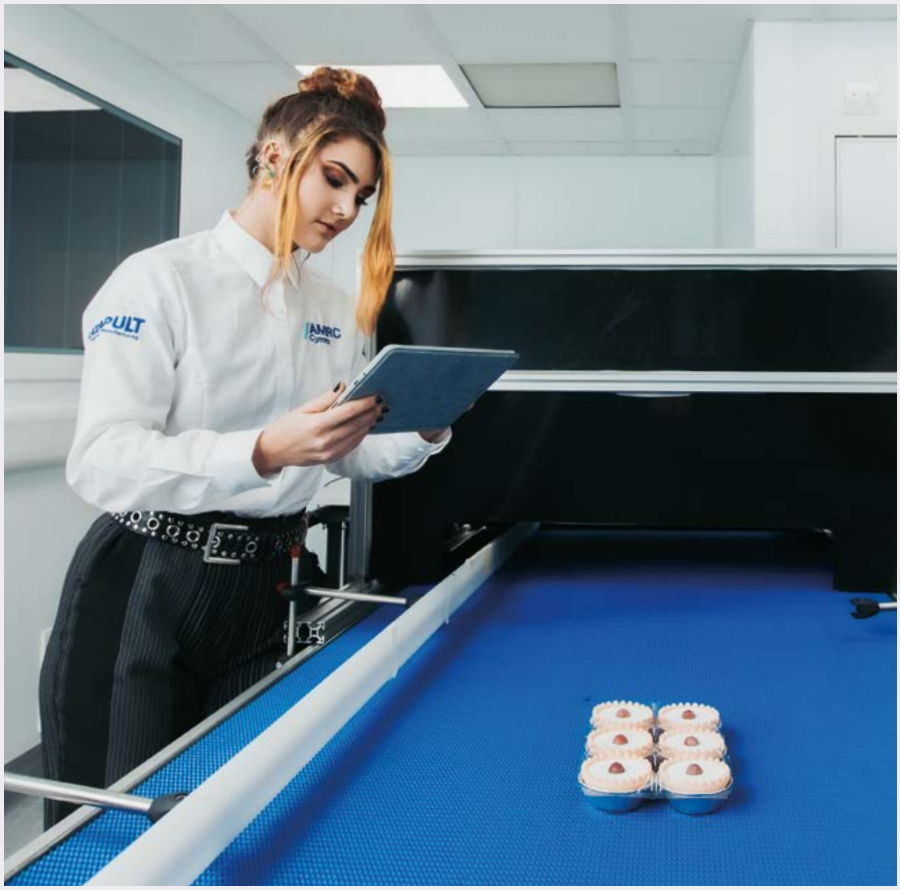
By implementing advanced digital tools, they were able to get a holistic view of their business with real data. This helped highlight key areas for improvement and led to a stronger strategic transformation plan for business growth.

Steve West, director at The Pudding Compartment, said he was interested to see how a big project like Ffatri 4.0 could help an SME like his company.

For The Pudding Compartment, digital data gathering using low-cost temperature sensors is helping to optimise their production/storage area temperatures. Energy sensors help to understand the equipment better; faults can be identified before they result in machine breakdowns, and scheduled production is reducing energy consumption of the equipment.

"The work at The Pudding Compartment combines the robotic processing of food produce with a complete intelligent manufacturing system that harnesses and processes data from a host of industrial sensors."

Jason Murphy, operations director at AMRC Cymru.



AMRC Cymru is using artificial intelligence (AI) to help drive manufacturing improvements in the food and drink sector.

A VR digital model and simulation tool of the production area has helped to model a new layout digitally before moving equipment around – saving the time and cost of installing power and compressed air outlets in the wrong place, allowing them to try various layouts digitally before optimising their process flow.

All digital interventions are being 'joined together' to create a whole system that'll act as a comprehensive digital planning tool.

Steve said: "We're currently installing our first automation equipment (robots) and setting up a system that'll give us a comprehensive digital planning tool. All the digital interventions are being 'joined together' to create a whole system that'll be displayed on a PC dashboard – this'll enable us to remotely monitor, understand, and improve all aspects of our processes from start to finish in a way that we could never achieve previously."

Ffatri 4.0 is a ready-to-go framework with proven success that will create a blueprint for future manufacturing companies and their associated supply chains. It is based on the premise that the sustainability and productivity goals of the manufacturing sector can be accelerated through the successful adoption and integration of digital manufacturing technologies.

The research programme focuses on two work packages:

- **The Sustainable Manufacturing and Assembly project** demonstrates the universal nature of sustainability assessments across two extremely different business sectors; in aerospace with Airbus – pioneers of sustainable aerospace – and in food and drink with The Pudding Compartment – an award-winning manufacturer of tray bakes, cakes and wrapped goods.
- **The Future Production Lines** project focuses on methods and technologies to establish smart production lines for The Pudding Compartment in the food and drink sector. This project investigates how novel, innovative technology can benefit industry to achieve improved production line output.

Jason Murphy, operations director at AMRC Cymru, said: "The Ffatri 4.0 project offers the Welsh manufacturing sector a window into the future. The work at The Pudding Compartment combines the robotic processing of food produce, with a complete intelligent manufacturing system

As part of Ffatri 4.0, the Airbus team saw a reduction in electricity usage of almost 20 per cent at the joint AMRC Cymru facility.

The AMRC used its research and innovation core knowledge to explore and discover new possibilities beyond our day-to-day activities, expanding our area of interest to new topics that will help the introduction of any future line of production."

Luis Rivera, wing accelerator industrial leader at Airbus.

that harnesses and processes data from a host of industrial sensors.

"The data is channelled into the Siemens Mindsphere platform for storage and interpretation, finally being utilised to create a true digital twin of the factory.

"The digital twin offers numerous opportunities for improving efficiencies across the plant through production replays, real time monitoring and forward planning – allowing optimisations and efficiency savings that improve both productivity and sustainability performance.

"The system architecture also creates a platform for the AMRC to develop artificial intelligence (AI) driven manufacturing improvements – a field in which the AMRC have been supporting the food and drink sector, and Airbus with AI roadmaps. The dissemination of lessons learned through AI adoption across aerospace and food and drink, two important sectors to manufacturing GDP in Wales, is exciting and hugely appealing.

"The Ffatri 4.0 project involved collaboration across a number of industrial partners, such as CAD-IT, EBS Automation, Siemens and Small World Consulting. As a consortium, these partners delivered excellence across a broad spectrum of technologies to help to deliver this cutting-edge example for Wales."

Vaughan Gething, economy minister at the Welsh Government, said: "Ffatri 4.0 is an innovative project which supports research and development in Wales, while also carrying out important work to advise the factories of the future. Businesses want and need to increase productivity while taking the environmental impacts into account.

"It's great to see AMRC Cymru being used for this important research, which will be of particular benefit to the aerospace and food and drink sectors and is a key contributor to our Economic Resilience and Reconstruction Mission, which sets out how the Welsh Government is rebuilding the Welsh economy, so it is more prosperous, equal and greener."

Lesley Griffiths, minister for rural affairs and North Wales at the Welsh Government, said: "I'm pleased to see the results from Ffatri 4.0 during its first year. It's great to see the impact Ffatri 4.0 has had on food and drink businesses taking part, such as the Pudding Compartment. The lessons learnt from this project can be shared with the wider industry, so all can benefit.

"This also shows what AMRC Cymru can deliver, and what an asset it is to have this state-of-the–art facility here in North Wales."

With an increasing focus from the manufacturing industry on its own sustainability objectives, coupled with a potential sustainability legislation being brought in by the government setting new targets for air quality, water, biodiversity and waste reduction, the success of Ffatri 4.0 can help other SME manufacturers identify key focus areas within their own supply chains.

If you're an SME manufacturer looking to better understand your energy usage, increase productivity, reduce your carbon footprint and improve sustainability in your supply chain, scan the QR code below to find out how Ffatri 4.0 can help your business.

Discover more about Ffatri 4.0 and how it can help your business.

Want to save costs and be more sustainable? Stop the chatter.

An AMRC spin out story: **Dr Erdem Ozturk, founder of Productive Machines,** writes about the company's journey from AMRC origins to a successful startup.

Productive Machines is on a mission to maximise productivity of machine tools. We use our unique digital twin to simulate millions of combinations of machine settings to arrive at the optimum feed rate and spindle speed setting for a given process prior to manufacturing. This eliminates chatter vibrations and provides machining optimisation, preventative maintenance and part quality that may not be achieved by a human operator, even with years of continuous improvement.

We formed in 2021 as a spin-out from the University of Sheffield Advanced Manufacturing Research Centre (AMRC) – but the journey of Productive Machines began long before that.

During my undergraduate studies and master's degree, I found a key problem blocking the path to truly efficient Computer Numerical Control (CNC) machining: chatter vibrations. The issue of chatter has been a serious frustration in machining for many decades, but until now, the only solution has been trial-and-error iteration for most manufacturers; experiments to reach a set of machine settings that minimise these vibrations.

As Frederick Winslow Taylor, an American author widely known for his methods to improve industrial efficiency, wrote in 1907: "Chatter is the most obscure and delicate of all problems facing the machinist."

In the realm of CNC machining, the issue of chatter poses significant challenges. Like an unruly guest at a finely orchestrated event, chatter disrupts the smooth flow of operations, demanding attention. It leads to slower cycle times and increased waste.

Chatter – the vibrations arising from unstable interactions between the cutting tool and workpiece – leads to surface irregularities and dimensional inaccuracies. These jeopardise the quality of machined components, leading to increased rework, inefficiency, scrap, and compromised customer satisfaction.

Why does this matter? It matters because the environmental costs of chatter are significant. Left unfettered it can lead to:

- **Waste materials and parts.** Workpieces with chatter damage are unusable, significantly increasing waste. This scrapped metal was hugely energy intensive to get to a usable state; now it is useless, thanks to chatter. Chatter also wears down tools faster, leading to increased costs and unnecessary waste. Frequent tool changes not only add to expenses but also consume valuable time that could be dedicated to productive machining.
- **Hugely increased energy usage.** Machinists lose much time as they experiment to get to a spindle speed that eliminates chatter. This experimentation time is hugely costly in the wasted energy that is drawn down. Chatter means excess energy consumption, resulting in higher operating costs and increased carbon emissions.

So, as the global focus on environmental responsibility grows, manufacturers must take measures to minimise waste and energy usage associated with chatter. That means prioritising the optimisation of machining parameters, tool selection, and machine rigidity. Changing parameters is easy to implement as it doesn't involve buying extra tools or buying a new machine tool.

Chatter is a crucial problem that successful, sustainable manufacturers should be tackling head-on.

The optimisation of milling processes figured heavily in my research and by 2005, I had started my PhD on the stability of five-axis, ball-end milling processes culminating on a published predictive model[1] against chatter vibrations in the Journal of Manufacturing Science and Engineering. Using this model, a process planner was able to predict the optimum cutting depth and spindle speed combinations that would avoid chatter vibrations.

Erdem Ozturk, CEO and founder of Productive Machines.

The University of Sheffield AMRC: a nurturing environment

In 2010, I had the opportunity to work for the University of Sheffield Advanced Manufacturing Centre (AMRC) and put my theory into large companies in the aerospace industry. The AMRC's world-class manufacturing facilities and steady flow of machining challenges introduced by its partners and clients, created the perfect stage.

The AMRC is a beacon of innovation in the manufacturing industry, connecting leading manufacturers with research, consistently driving advancements and fostering promising startups.

I formed a research team and together, we worked to push the boundaries of the machining dynamics field using specially developed digital twins and simulations to improve productivity, extend tool life and eliminate chatter.

During my time at the AMRC, the team continued to grow and I had the privilege of working with lots of amazing individuals who supported the machining dynamics team, from staff members and PhD students, to MSc students and visiting researchers.

A lot of the simulation techniques we were using to overcome our partners and clients' machining challenges simply weren't available to most manufacturers, who still broadly used trial-and-error to achieve desired levels of productivity and quality.

The research team developed digital twins for the machining processes that had unique selling points, compared with commercially available products and I was able to go beyond reports and publications to form a successful startup with industrial impact.

With access to cutting-edge research, state-of-the-art facilities, a pool of internationally significant expertise in machining at the AMRC, and the network of companies looking at the AMRC for innovative solutions, a research project rapidly formed into a highly promising startup – Productive Machines.

Thanks to the support of the University of Sheffield, the AMRC, and the ATI Boeing accelerator programme, Productive Machines was formed to bring the results of this groundbreaking innovation to every machining workshop and to make the technology and techniques we had developed through the AMRC's machining dynamics team available commercially.

Today, the company has already impacted leading manufacturers from a variety of sectors, from medical to construction. Productive Machines has raised a cumulative £3m investment and grown an amazing team of 19 exceptional staff. We continue to work closely with and enjoy the support of the AMRC and have exciting growth plans for 2023 and beyond.

"We were creating a future where every manufacturer and machine operator can elevate quality, productivity and sustainability."

Dr Erdem Ozturk, founder, Productive Machines.

Why was Productive Machines formed?

There was an opportunity to bring cutting edge technology and offer it as a straightforward Software as a Service (SaaS) product; to create a future where every manufacturer and machine operator can elevate quality, productivity and sustainability. We wanted to make cutting optimisation technology accessible to all, regardless of the scale of operation or expertise.

Productive Machines' vision extends beyond mere technological advancement; it's about empowering manufacturers and machine operators to excel, to save costs – and to help save our planet.

Our technology plays a crucial role in boosting sustainability and productivity in manufacturing. By finally solving the old and frustrating problem of machine tool chatter, this technology could save a staggering 2.5 gigatonnes of carbon dioxide emissions by 2050. To put this into perspective, 2.5 gigatonnes is equivalent to the UK's total CO_2 emissions – every factory, fire, car, flight and light – for six years.

How can this be achieved? In short, by making big changes to two sides of the sustainable manufacturing triangle: optimising machine settings to cut waste and reduce energy used.

Why does CNC matter for sustainability?

In modern manufacturing, one technology stands as a cornerstone: CNC machining. It produces everything, from aerospace parts to the casings of Apple Mac computers to jewellery. And even where it does not directly produce the finished product, as in, say, the food industry, it is CNC machining that makes the machines that produce almost everything else.

CNC manufacturing has driven the advanced manufacturing processes that have redefined efficiency, accuracy, and cost-effectiveness. Its level of precision has revolutionised industries, ranging from aerospace to healthcare, enabling the creation of cutting-edge products that were once only imaginable.

Its versatility empowers designers and engineers to explore new frontiers, unleashing unprecedented creativity in fields as diverse as custom prosthetic limbs to engine parts and chassis components. It is the tool that is building the 21st Century world.

CNC machining is a huge industry (estimated at $96 billion in 2022 according to a recent research study by Contrive Datum Insights), and it is growing fast. Five-axis machine tools have brought radical improvements in capability and cycle times, and alternatives such as additive manufacturing are not always

Key benefits for manufacturers

Accelerated time-to-first-part: achieve faster production cycles, reducing lead times to deliver the first part swiftly.

Lower production costs for the first part - attain the bulk quantity price faster.

Cut energy costs by up to 25 per cent

A stand alone solution. Rely on our technology to analyse for optimal results without the need for PhD-level experts of your own.

We can optimise milling machining processes in minutes instead of weeks, at a fifth of the cost and without expert engineers

Proven technology: it is already deployed at ten major manufacturers, including Renault and MASA Aerospace.

Huseyin Celikag, CTO and co-founder at Productive Machines.

> **"By finally solving the old and frustrating problem of machine tool chatter, this technology could save a staggering 2.5 gigatonnes of carbon dioxide emissions by 2050."**
>
> **Dr Erdem Ozturk**, founder, Productive Machines.

the best commercial or technical option. So optimising machining for efficiency and sustainability matters.

CNC machining and sustainability

CNC machining has a crucial role to play in environmental sustainability. Every day across the globe, CNC machine tools turn energy and raw materials into the components of vehicles, computers and just about everything else we use every day.

There are around four million CNC milling machines globally, drawing down huge flows of energy. At that scale, improvements in efficiency can have a huge net effect. This is the promise offered by technology like that of Productive Machines.

Because of the huge scale of CNC machining, we can have a big effect fast. Groundbreaking innovation like that from Productive Machines can therefore pave the way to a greener and much more sustainable manufacturing future.

How does our technology work?

With our unique technology, customers get to the best part, faster, the first time.

Using artificial intelligence (AI) and digital twins of the milling process, we identify parameters that will be vibration-free, automatically personalising the process to eliminate chatter. This dramatically cuts cycle times, which in turns dramatically cuts energy consumption and CO_2 emissions.

It's a little like producing noise-cancelling headphones for milling machines. As with advanced headphones, we model the situation electronically and put in place a solution that cuts out the noise or chatter we don't want.

This enables us to bypass the iterative process of getting to chatter-free settings that holds up, and adds cost to, manufacturing. By eliminating chatter vibrations, machining companies get to the best part, faster, first time with reduced cost, energy usage and waste.

We do this by simulating millions of combinations of machine settings to find the optimum – an optimum that humans would never reach, even with five years' continuous improvement.

Using these mathematical models and simulations we see remarkable results. For example steel firm Ficep UK saw the productivity of their process increase by 110 per cent, with cycle time cut by 53 per cent while reducing the magnitude of vibrations five times.

Unlocking potential: the workshop results of anti-chatter technology

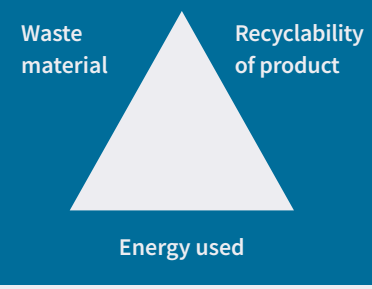
In our work with global manufacturers including Ficep, Renault and MASA Aerospace, this technology has shown it can:

- Cut the machining design and set-up time by 20 per cent;
- Cut cycle times by 10 to 53 per cent;
- Cut operational and maintenance costs by 25 per cent;
- Reduce cutting tools costs by 11 per cent;
- Reduce cutting noise by five times.

So, the technology offers a huge increase in productivity, massive reductions in cost and a very significant sustainability impact.

References:
[1] Ozturk, E., Budak, E., (2010), Dynamics and Stability of Five-axis Ball-end Milling, Journal of Manufacturing Science and Engineering, 132, 021003-1-13, doi:10.1115/1.4001038

The sustainable manufacturing triangle



Six reasons to eliminate chatter in CNC machining for sustainability

1. Waste reduction
Chatter elimination optimises cutting, reducing material waste and supporting sustainable manufacturing practices.

2. Resource efficiency
The longer cutting-tool life achieved through chatter reduction means less need for frequent replacements.

3. Energy conservation
Reduced vibrations lead to lower electricity consumption during machining.

4. Enhanced product quality
Chatter elimination results in improved product precision, reducing defective parts.

5. Extended equipment lifespan
Smoother machining operations reduce machine wear, prolonging the life of CNC equipment.

6. Safer work environment
Reduced cutting noise improves workplace safety and contributes to a healthier workplace.

Keeping SMEs on the rise

The UK is home to more than 5.5 million small and medium-sized enterprises (SMEs) that contribute to more than half of the nation's economy. The **AMRC's SME engagement manager, Shirley Harrison,** explains the diverse nature of these businesses and why they need bespoke support to grow.

Shirley Harrison, SME engagement manager at the AMRC.

“The AMRC, including our 500-plus specialist staff, state-of-the-art facilities and 22 years of acquired knowledge, is accessible to all businesses in the manufacturing sector.”

Shirley Harrison, SME engagement manager for the AMRC.

I love my job. Pretty much every day I speak with entrepreneurs taking the first tentative steps in developing their ideas; young, innovative micro businesses with cool new products and services; established manufacturers reliably plying their trade; and generations-old family firms who have been core to their local communities for decades. Each one is unique, interesting and – for the people who run them – highly personal.

As the SME engagement manager at the University of Sheffield Advanced Manufacturing Research Centre (AMRC), I feel privileged that business owners choose to freely share their hopes and fears, their dreams and nightmares with me. My role then is to help businesses find the right solution for them.

As someone who finds manufacturing endlessly fascinating and loves hearing people’s stories to understand their successes and struggles, factory visits remain one of the most fun parts of my job. It is an absolute highlight to walk out of a factory having shared my technical knowledge, network or personal experience to provide some immediate help to solve a problem or move forward with a plan, as required.

It’s a common misconception that the only answer to a SME’s problem is undertaking new research or making eye-wateringly expensive investments in the latest kit. However, in reality, many new and brilliant solutions are commercially available and are often offered by other innovation-led SMEs specifically set up to provide specialist low-cost technical solutions. An introduction to the right tech business or access to a specialist who can share expert knowledge on a technology is frequently the most useful action that can be taken.

SMEs play a vital role in the UK economy, despite often being overshadowed by large corporate entities. It seems bizarre that small businesses can possibly be overlooked when 99.9 per cent of all UK businesses are SMEs. These 5.5 million businesses employ more than 60 per cent of all private sector workers and contribute to more than half of the UK’s turnover.[1]

While there are more than 5.5 million SMEs in the UK, three-quarters of all businesses don't employ anyone apart from the owners – these four million businesses contribute around £280 billion to the economy. This substantial contribution to the national economy makes the significance of SMEs undeniable.

At the other end of the scale, there are only around 7,600 large businesses – surprising then, that special policies are put in place for SMEs as though they are a minority.[1] Presumably, this is because big businesses are experts at lobbying local and national governments.

For me, this really strengthens the case for becoming active within a business organisation or trade association that can amplify the collective voice of SMEs. Currently, the British Chambers of Commerce[2] is probably the first group which Whitehall turns to for opinions and representation from the private sector. However, there are many more heavyweight sector-specific bodies.

SMEs are the business community. So one could make a strong argument that the default position should be that all business policy is appropriate for SMEs and that the special policies for exceptional cases really should be for firms with more than 250 employees.

When SMEs are considered, they are often treated by policymakers as one homogenous mass – giving the impression that all firms with fewer than 250 people share the same characteristics and experience the same problems. In reality, these businesses are as diverse and individual as the people who own and run them.

The culture and decision-making in SMEs is significantly driven by the personalities and values of the owners, in a way that is vastly different from larger, corporate entities.

In practice, this means that firms which look the same from the outside – for example, two machine shops employing 40 people in West Yorkshire – are likely very distinct organisations. The diversity, age and skill profile of the workforce, the level of automation in the operation, the hierarchy within the business, the level of investment in new technology are just a few of the very obvious characteristics that can vary dramatically from business to business.

In my experience, a key driver of culture is the business owner's attitude to risk. There is no right or wrong approach to this: an entrepreneur's attitude to risk is likely at one end of the scale – someone who has eschewed the stability of a salaried job to start their own company – as against the directors of a generations-old family business who may be more risk-averse because they feel duty-bound to protect their staff and maintain the company for future generations. Both groups are ambitious but how they approach investment, innovation and finance will be quite different. These differences need to be recognised and appreciated; unfortunately, it seems local and national policies rarely acknowledge that a variety of approaches might be required across the sector.

These factors also influence a company's likelihood of successfully innovating, be it something new to the world, new to the sector or new to the firm. Firm-level innovation often addresses internal business processes, and lack of cash, awareness and technical skills are often cited as the main barriers for adoption of new technology.[3]

At the AMRC, part of the High Value Manufacturing (HVM) Catapult network of research centres, we help businesses to address these issues by sharing our knowledge, finding low-cost solutions and training the next generation. The AMRC, including our 500-plus specialist staff, state-of-the-art facilities and 22 years of acquired knowledge, is accessible to all businesses in the manufacturing sector.

Last year, we carried out more than 1,000 engagements with SMEs, and the vast majority of these were at no cost to the business. We did everything, from creating concept designs for a camera casing for a bird box, to building a low-cost cell to demonstrate the capability of robots to mix cocktails.

The AMRC is often cited as a great resource for big businesses – and that is certainly true – it is also a great resource for small businesses. All our work is custom-fit, based on the specific needs of the business. One size most definitely does not fit all.

References:
1 Business Population Estimates 2022
2 British Chambers of Commerce
3 *Digital Britain: How Small Businesses are turning the tide on tech*

The UK has more than

5.5m SMEs

More than

half **of the UK's economic turnover is from SMEs.**

UK SMEs employ over

60%

of all private sector workers.

More than

1,000 **engagements with SMEs, carried out by the AMRC last year.**

99.9% **of all UK businesses are SMEs.**

3/4 **of all SMEs don't employ anyone apart from the owners – these four million businesses contribute around:**

£280 billion **to the economy.**

Saving costs and enhancing operations for leading precision engineers

A South Yorkshire-based SME, Tyzack Machine Knives, has adopted new ways of manufacture that help reduce production time from two weeks to a matter of days, supported by the AMRC's machining expertise.

Tyzack Machine Knives, is part of Sheffield's long heritage of excellence in steel and engineering, with its products used throughout the world by leading manufacturers. When one of its components was in particularly high demand, the company approached the AMRC, part of the High Value Manufacturing (HVM) Catapult, to explore new ways of working.

Russell Crow, group engineering and development director at Tinsley Bridge Group, which includes Tyzack, said: "Before spending money on new machinery, we wanted to challenge how we were using our existing machines and see if we could increase capacity and reduce energy costs."

The AMRC team visited Tyzack to see its existing component models and operations. Following this, the AMRC ran a series of simulations to optimise the machining process and show different ways of increasing capacity. This included using different cutting methodologies and switching to pre-hardened material to remove the need for Tyzack to carry out the costly and energy-intensive hardening process in their factory, allowing large energy cost-saving for the company.

Funded by Innovate EDGE, the project developed new ways of working, while introducing a potential step change in the process. The AMRC team reduced the machining process from six stages to two – significantly reducing lead times – and also demonstrated the new process to Tyzack staff for better understanding.

Russell said: "It was great to challenge our conventional wisdom of how we've always done things. The AMRC's ideas have the potential to reduce production time from two weeks to a matter of days, so we could offer reduced lead times when estimating for new business.

"The AMRC isn't tied down to a particular manufacturer or supply base, so we got a completely impartial review of machines, cutting inserts, feed speeds and methods of manufacture. It's a wonderful resource to be able to draw upon."

Brian McIntyre, a manufacturing engineer in the AMRC's machining team, said: "The AMRC worked with the team at Tyzack to improve their process, leading to more efficient operations among other benefits for the company.

"Machining the material in a hardened state can be challenging but it enables a real step-change reduction in process time and energy costs. It was great to collaborate with an SME manufacturer like Tyzack and to be able to support them in their process advancement journey."

Digital technology is the missing ingredient

AMRC Cymru helped a family-owned bakery to help identify and implement low-cost digital opportunities that could save production time up to two hours a day for the Denbighshire-based manufacturer.

Henllan Bakery, which has about 130 staff and a fleet of 24 delivery vans, has been producing bread since it was established in 1908. While there has been significant site development and growth over the past 100 or more years, fundamentally the product remains largely unchanged.

The project with AMRC Cymru aimed to identify opportunities to adapt digital technology while maintaining the craft credentials which are key in terms of Henllan Bakery's identity and operations. It was delivered through the DIMAS programme, which saw the AMRC Cymru team deliver three-month individualised digital transformation support to ten small-to-medium sized enterprises (SMEs) in Denbighshire county, in partnership with

The operations line of Denbighshire-based Henllan Bakery, received digital transformation support from AMRC Cymru, saving production time.

Denbighshire County Council and funded by the UK government through the UK Community Renewal Fund.

The AMRC Cymru team, following a visit to the bakery to undertake a review of its existing manufacturing processes, developed a process flow diagram to identify opportunities and facilitate discussion about modifications to the manufacturing process on the bread lines.

From a number of potential opportunities that were recognised, the project focused on identifying a suitable method for conveying ordering information from the office to the shop floor. At the time, this information was printed and delivered by hand to the shop floor at various stages of the day, making it a time consuming and human intensive activity.

The identified solution utilised digital screens strategically positioned throughout the production and packing lines, enabling information to be shared directly from the office to the relevant parts of the production line.

In order to ensure this could be achieved in a cost effective way, Chromecast – costing approximately £30 – coupled with screens was identified as a suitable technology, which also has the advantage of being flexible and re-deployable.

Ed Moore, director of Henllan Bakery, said: "The team at AMRC are highly skilled in many fields. They came to see our process and quickly got to understand us as a business and our needs.

"Once they had identified where we could improve our efficiencies and productivity, a quick trial was set up which worked perfectly. Now screens project production figures to various departments and the needs to go to the office for data has been eliminated.

"The time saved is, we believe, up to nearly two hours a day."

Mike Booker, head of innovation at AMRC Cymru, said: "This collaboration exemplifies how a perfect balance can be struck between preserving heritage and embracing innovation, through the deployment of strategic and cost-effective digital technologies. Through this, we were able to optimise Henllan Bakery's operations but also support them to uphold their craft bakery identity."

Boosting competitiveness and efficiency for world-leading tech SME

AMRC North West helped a Colne-based tech company relocate to bigger facilities, expand the list of specialist services they offer and forge new partnerships with other advanced manufacturers.

ELE Advanced Technologies, houses a world-leading set of cooling hole drilling and multi-axis grinding equipment, capable of machining very tough materials, that produces parts for a wide range of sectors, including: aerospace, power generation and military components.

ELE Advanced Technologies was in the process of moving into a bigger factory when it was introduced to the research team at AMRC North West.

The company wanted to make sure its new factory floor was organised optimally to work as efficiently as possible. With a business that was constantly growing and evolving in response to the rise in demand for their specialist services, the company wanted to increase its competitiveness by broadening their skills, knowledge and contacts to stay up-to-date with the future of digital working and advanced manufacturing methods.

The project by AMRC North West, part-funded by the European Regional Development Fund (ERDF), was part of its assist programme to help small-to-medium sized enterprises (SMEs) offering bespoke, high-value manufacturing support to businesses in the North West.

The team at AMRC North West, which is part of the High Value Manufacturing (HVM) Catapult, provided ELE Advanced Technologies with a virtual reality (VR) demonstration simulating its new factory. This massively helped ELE Advanced Technologies to decide what equipment to place where.

The project team also advised the tech company to explore additive manufacturing (AM) as one way of enhancing its competitive advantage. This led to the AMRC North West team introducing ELE Advanced Technologies to potential additive manufacturing partners; sparking the idea for a National Aerospace Technology Exploitation Programme project, which has ultimately led to one job being safeguarded.

David Dudley, technical director at ELE Advanced Technologies, said: "The additive manufacturing expertise we received was very valuable because we realised that if we didn't learn more about it and align ourselves to this disruptive technology, it could be a potential threat to our business."

ELE Advanced Technologies was the recipient of the Lancashire Business View's Red Rose Award for Innovation in 2022.

Iain Martin, senior engagement manager at AMRC North West, said: "It is extremely rewarding working with companies like ELE and to see the impact our support can have. Small and medium-sized manufacturers are the backbone of UK manufacturing, playing a vital role in the supply chain.

"It is critical that AMRC continues to help these companies to innovate and de-risk investment in R&D."

Design expertise helps bird box camera company fly to new heights

AMRC's product design expertise helped introduce a step-change for Bristol-based tech SME company, Green Feathers, as they move towards commercialisation.

Green Feathers, is a tech manufacturer that specialises in bird box cameras – tiny recording devices that can be fitted into bird boxes and nests to allow people to watch garden bird activity from their phone or TV. At the time, the company had been growing as specialist traders for some time, but wanted to create a product to move into the mass market.

Green Feathers approached the AMRC for help with a new camera case design, on account of its excellent design and prototyping capabilities.

"We wanted a case that stood out, so you could tell instantly it was one of ours," said Chris Barrell, operations director at Green Feathers.

The AMRC team undertook a 'design for manufacture' review of the company's existing products and came up with several concepts for injection-moulded camera cases — all with striking egg-based designs. The company then chose its favourite design, which was worked up further to make it computer-aided design (CAD)-ready.

The project, funded by the High Value Manufacturing (HVM) Catapult, the network of research centres which the AMRC is a member of, allowed Green Feathers to introduce a new product into the market, preparing the company for the next steps in their business journey and accelerating growth opportunities as it expands its market offerings.

Chris said: "It is a big step for our business to have a mass-market product that we can sell through the big retailers. I've been kicking this idea around for two years, and the project with the AMRC has given us a step-change in concept and design. A product like this will be necessary for our business to grow and open up to new, mass consumer markets."

Craig Roberts, who heads up the AMRC's design and prototyping team, said: "The AMRC is here to support SMEs in developing new products and bringing them to market.

"Our team of expert product designers and mechanical engineers worked with Green Feathers to offer practical solutions for their challenges.

"By collaborating with us, SMEs can access our wide range of resources, technical knowledge and experience to realise their potential for advancement and enable business development and growth."

Chris Barrell, operations director at Green Feathers, pictured with one of the company's products.

Apprenticeships: Braving change to keep industry alive

Apprenticeships matter. They are important to so many for a variety of reasons. As the University of Sheffield AMRC Training Centre celebrates its milestone tenth year, **Chloe Rothenburg** speaks to apprentices past and present, the tutors who teach and train them, and the employers who support them to find out what apprenticeships mean to them.

'Being brave', 'having a sense of pride', 'making life-altering moments' and 'helping to secure South Yorkshire's industrial heritage', are just some of the ways in which people talk about the AMRC Training Centre.

It has a lot to be proud of as it marks its tenth year – delivering more than 1,700 apprenticeships, working with more than 400 different businesses, big and small – as well as bringing additional educational opportunities into a region with areas of deprivation.

The building in Rotherham, which opened on October 7, 2013, sits on the former Orgreave Colliery and Coking works – a gateway to the Waverley residential community that sits alongside the thriving Advanced Manufacturing Park, just metres away. And the AMRC Training Centre's success story and the lives transformed, show no signs of slowing.

Apprentices past and present, are the ones to watch in the future. It is they who will be part of finding the solutions to tomorrow's problems.

Alumni apprentice Bethany Cousins, was part of the first cohort of students to undertake an apprenticeship at the AMRC Training Centre, aged 18. Starting with her advanced apprenticeship, Beth went on to complete a degree apprenticeship, both in manufacturing engineering. Completing her degree in 2019 with first-class honours, she has since described the moment as one of her career highlights.

During the past ten years, Beth, now 28, has won awards both locally and regionally for being a role model for young engineers and remains a beacon of encouragement for women thinking about a career in engineering.

"My apprenticeship at the AMRC Training Centre paved the way to my career, I wouldn't have got both the practical and theoretical experience in any other way," added Beth, who works as a manufacturing engineer at the neighbouring University of Sheffield Advanced Manufacturing Research Centre (AMRC).

"I enjoyed meeting other apprentices, especially those who were based in other companies. It enabled me to hear about how others applied the theory

and perhaps did things a little differently, it was a great additional learning experience.

"South Yorkshire sits in a heavy manufacturing-based area and it's fantastic to have the AMRC Training Centre sit in-between, having my place of work next door really helped in getting that hands-on experience, and enabled me to network with key industry contacts I would keep for years to come."

Along with Beth, Josh Woodward, 20, also works at the AMRC and started his apprenticeship at the AMRC Training Centre in September 2020, in mechatronics maintenance, covering electrical, mechanical, pneumatics and hydraulic devices and systems.

It was thanks to the fantastic number of resources available, including the many different capability groups which make up the AMRC, that Josh was able to complete the first part of his apprenticeship a year early.

"By working with all the different groups at the AMRC, I was able to gain lots of knowledge and cross off most of the criteria needed for this part of my apprenticeship quickly," Josh said.

"This progression has enabled me to start my Higher National Certificate (HNC) in controls and automation a year early and I hope to progress onto a degree level apprenticeship in the future."

Josh said that while he was at school, the staff had 'down-played' apprenticeships, saying they were for people who wanted to be an electrician or bricklayer, adding: "It wasn't until I undertook some work experience at an engineering company close to home, that my eyes were opened to the world of engineering – and it wasn't until this point that I really started to think about this industry, and about an apprenticeship and what it could offer me.

"I feel very lucky with where I work and it has helped me massively with my confidence – and having the AMRC Training Centre right next door, it works together perfectly."

Former apprentice Connor Blades, 22, who completed his degree apprenticeship in maintenance engineering, spent almost five years working for hand tool and storage solutions manufacturer Stanley Black & Decker, but for the past six months, has been working as a methods process analyst for aerospace giant Boeing at its Sheffield facility, which is the only one in Europe.

"An apprenticeship to me has been very valuable as you're being taught by people who have had experience in industry, so you learn firsthand how it all works," Connor said. "From there, you meet people at work and together, it's these people who have helped me understand how industry works, not just in the UK, but on a global scale.

"Rotherham has a rich industrial heritage and I feel it's important to uplift people's knowledge and skills, whatever age, and keep these valuable jobs in the UK, instead of seeing engineering progress and advancements be lost to other countries. We need to keep the UK industry alive."

New apprentice Iola Jones, 19, is less than a year into her advanced apprenticeship in metallic machining. She is employed by McLaren Racing, home to the Formula 1, IndyCar, Formula E, Extreme E and esports teams.

"I decided to look for engineering-based courses at university and apply for apprenticeships," Iola said. "I was set to take up an offer at university but turned it down after receiving a call from McLaren Racing with an offer. It was the opportunity of a lifetime and something I couldn't turn down.

"Working at McLaren, while undertaking my studies at the AMRC Training Centre, was the best thing that could have happened for me. I'm taught by the best and apprenticeships help to transfer the vital skills of others in industry, to prepare the next generation."

Helping to mould and shape our future engineers are the academics and trainers, the ones who know the industry like no other. Gareth Wilkinson, head of skills at the AMRC Training Centre, has been there from the start and helped to build up the facility we see today.

"I was one of the first to be employed by the University's AMRC Training Centre," Gareth said. "We built everything from the ground up, started to deliver engineering frameworks and were the early adopters of the new apprenticeship standards.

"It's been a journey of development and we've consistently improved year-on-year – and we have continued to build relationships with our employers, even working with a number of them that we worked with from the start, so we must be doing something right."

Gareth says the training centre team have never rested on their laurels, always striving for better, adding: "I don't think there has been an intake year over the last decade where we've had the same recruitment strategy for more than one year. Each time we've made tweaks and adjustments and I think that has brought out a better calibre of apprentices every year.

"We have had to be brave, try new things and break the mould, but we've never been afraid to try."

Where does Gareth see the AMRC Training Centre in the next ten years? "I'd like for us to move into new things, build on what we've got, as well as exploring food and drink and nuclear, robotics and Industry 4.0 more," Gareth said. "These are all massive areas where we'll see growth and change in the future, all connected to net zero and sustainability – and it's here where we really need to ramp up over the coming years to help our apprentices solve the problems of the future and keep on top of the needs of industry."

"My apprenticeship at the AMRC Training Centre paved the way to my career, I wouldn't have got both the practical and theoretical experience in any other way.

Beth Cousins, AMRC Training Centre alumni.

Gareth Wilkinson, head of skills at the AMRC Training Centre.

In action teaching is Animesh Anand, one of the academic engineering tutors for advanced apprenticeships at the AMRC Training Centre.

Animesh Anand is quite new to his post and is one of the academic engineering tutors for advanced apprenticeships. Despite having just one year under his belt, he brings with him passion, fresh ideas and high hopes.

"Coming into teaching, compared to industry, I like the fact that everyday is different – the people you interact with, the way lessons are taught – I can teach the same lesson to four different groups, but are not taught the same way, as each group is different," he said. "I try to tailor my teaching to the individual as best I can.

"I believe apprenticeships are vital to how engineering should be developed."

Animesh is also a big advocate for bringing more diversity and inclusion into engineering, adding: "I've worked a lot with the UK's Institute of Materials, Mining and Minerals (IMO3). I'm vice chair of its ably-different and LBGT+ committees. One of the biggest things I talk about when it comes to diversity in engineering is encouraging diverse discussion, something I always try to bring to my teaching and be open with my students.

"It's great to see the AMRC Training Centre carrying that diversity message too and being open to expand on it more in the future."

As well as the apprentices and trainers, it too is the hundreds of employers the AMRC Training Centre works alongside which help to make apprenticeships possible – from the world's well-known household names such as McLaren, Boeing and Rolls-Royce, to the smaller companies that are the lifeblood of the UK economy and supply chains. It's companies like these that play a part in not only keeping British manufacturing alive but restoring its reputation as a world-leader.

Boeing was the first major partner of the AMRC when it was established in 2001 and has been a big advocate of the AMRC Training Centre.

As the global giant marks its fifth anniversary later this year since opening its own production facility in Sheffield, Gabriella Stannah, early careers lead for Boeing UK, described the difference its apprentices make to industry. "We are hugely proud of the contributions our apprentices make every day to our UK operations, while also gaining key skills and qualifications," she said.

"At Boeing, we are committed to supporting the UK aerospace industry's expansion, and with partners including the AMRC Training Centre, our apprenticeships are helping to build the skills needed to drive future growth. They also support our goals to build a diverse, productive workforce, by creating opportunities for people who may not previously have considered a career in aerospace."

SME Penny Hydraulics, based near Chesterfield, has been working with the AMRC Training Centre for seven years.

Martha Penny, human resources manager for Penny Hydraulics, said in that time, 38 per cent of its staff started via an apprenticeship – with 59 per cent of those having been employed via the AMRC Training Centre.

She added: "Five of these staff now have permanent roles and six are at various stages of their apprenticeship journey, ranging from advanced through to degree apprenticeships – and we plan to take on another AMRC Training Centre apprentice this year, so the relationship continues.

"The apprenticeship standards consist of key knowledge, skills and behaviours, ensuring that not only are our apprentices firmly introduced to the competencies required by their roles, but are guided by intersecting subjects such as health and safety, workplace management, respectful and conscientious attitudes and equality, diversity and inclusion.

"Apprentices are a vital part of the employee fabric and ensure the longevity of our company within the engineering and manufacturing industry."

It's clear to see the AMRC Training Centre matters, echoed by the apprentices who describe the need for growth and to keep manufacturing alive in the region – made possible thanks to the trainers who instil confidence and teach the talent of the future, using cutting-edge machinery and provide the skills needed by employers, both regionally and nationally, as we all strive for a more sustainable, prosperous future.

Together, they become the jewel in the apprenticeship crown. And you cannot create a tomorrow, done better, without the people to do that.

New members at the AMRC

RAZOR®

Razor is a Sheffield-based digital technology consultancy. They apply passion, innovation and commitment to solving some of the hardest issues organisations face globally. They pride themselves on starting everything they do with people, using cutting-edge technology to achieve this, including integrations, mobile apps, web applications, artificial intelligence and machine learning.

Events at the AMRC

Go to **amrc.co.uk/events** for the most up-to-date AMRC events information.

October 3
Ffatri 4.0 – Showcasing the future for Welsh industry
AMRC Cymru

October 11
Yorkshire Cyber Security Cluster
AMRC Factory 2050

October 12
OT Community Club Connect (Fortinet Workshop)
AMRC Factory 2050

October 16
Wales Tech Week
International Convention Centre, Wales

October 17
Medical Supply Chain and Medical Manufacturing Showcase
AMRC Cymru

October 19
Business Inspiring the Next Generation
AMRC Cymru

November 1
Advanced Engineering
NEC, Birmingham

November 23
Re-use and recycling of composites conference (RECOMP)
AMRC Knowledge Transfer Centre

April 15-19
MACH 2024
NEC, Birmingham

CPD courses at the AMRC Training Centre

To book your place on any of the courses, email **cpd@amrctraining.co.uk** or call **0114 222 9958**

For more information visit

October 2-5
City and Guilds 18th Edition IEE Wiring Regulations (2382-18)
AMRC Training Centre

November 7-8
Stainless Steel Metallurgy
Online

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