AMRC / Journal
Issue 10

Shivan shines bright to win ‘Apprentice of the Year’

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Welcome to the

AMRC/Journal

Jewel in the crown

Earlier this year the University of Sheffield Faculty of Engineering became number one in the UK for research income and investment: eclipsing Imperial College London for the top slot, having previously overtaken both Oxford and Cambridge. That a northern university could topple such global giants was described by our President and Vice Chancellor, Koen Lamberts, as a 'monumental' achievement. He is right. And we share his view that: "Having a university in the North of England leading in engineering research income and investment is a tremendous boost for the Northern Powerhouse as we seek to boost the aerospace, nuclear and manufacturing sectors and rebalance the UK economy."

Here at the AMRC we are dedicated to expanding and enhancing the role of the Sheffield City Region as a global manufacturing R&D hub, whose skills and talents are driving economic and social renewal in an area once consigned to decline. For the university, this means that no less than 60% of the £124m research income that secured Sheffield the number one position, was delivered by the research talents of the AMRC in close collaboration its industrial partners.

A fact recognised in a recent paper by Professor David Petley: who is now the AMRC's innovation champion within the university. Prof Petley noted: The extraordinary growth in research income in the (faculty) and the role that the AMRC has played within this, is clear. (While) the faculty does show a small growth in research income, this is dwarfed by increased capture by the AMRC".

We can all be proud of the role we have played in enhancing the reputation of Sheffield as the go-to place for translational research. Nowhere is that role more celebrated than in the pages of our latest Journal. Here we see how Sheffield's collaboration with the Welsh Government is rapidly moving towards the completion of a dedicated new research facility, AMRC Cymru, with Airbus already confirmed as an initial anchor tenant. Here our researchers are tasked with pushing the boundaries of the possible in wing manufacture, using all our know-how, from machining to machine learning, to drive improvements in productivity, performance and quality. As the AMRC Cymru team grows, our role will expand to support the Welsh Government's ambitious inclusive economic strategy.

A similar picture is emerging in the North West of England, where, with the generous support of colleagues at the University of Central Lancashire, a team of AMRC researchers are already on the ground, working with strategic partners such as BAE Systems, but also the wider aerospace and automotive supply chain. This ERDF and Lancashire LEP funded project will result in the construction of a dedicated AMRC North West research facility, fully in line with the University of Sheffield's Science and Innovation Audit.

The Journal also notes the role the AMRC plays in knowledge export, along with the export of physical R&D assets. It cites the Centre for Cities Parks and Innovation report – generously commissioned by Lord Sainsbury – which shows that the cluster of global companies and their supply chains taking shape around the AMRC outperforms other similar parks in the country, with the highest share of advanced manufacturing jobs in the UK.

The report found that 66% of all the jobs on the fast expanding Advanced Manufacturing Park are in high-value added manufacturing, compared to 4% in the UK as a whole. The report says this presents both challenges and opportunities for national and regional government. They must both work with the AMRC to ensure the model developed here in the Sheffield City Region can play an even bigger role in cracking the productivity puzzle by pushing the R&D dial closer to the ambitious 2.4% of GDP. Achieving those goals would be a monumental achievement. But, as Koen Lamberts says, Sheffield is getting good at doing monumental.

Prof Keith Ridgway, CBE.

Executive Dean of the
University of Sheffield
Advanced Manufacturing
Research Centre Group

Shivan shines bright p34

Cover image: Shivan Morkar and Brian Holliday, managing director for Siemens Digital Factory.

From slag heap to the **jewel in the crown**

The cluster of global companies and their supply chains taking shape around the Advanced Manufacturing Research Centre (AMRC) in Rotherham outperforms other similar parks in the country and has the highest share of advanced manufacturing jobs of any in the UK, according to a new report by the Centre for Cities.

The Parks and Innovation report found that 66% of all the jobs on the fast expanding Advanced Manufacturing Park (AMP) in South Yorkshire are in high-value added manufacturing, compared to 4% in the UK as a whole.

The report was launched in London by the Centre for Cities' Director, Andrew Carter along with former Innovation Minister, Lord Sainsbury; the Deputy Director of Strategy at UKRI, Alex Marsh; and AMRC Executive Dean, Professor Keith Ridgway.

Addressing an invited audience of national and regional policy makers, Andrew said the report showed clearly that the AMRC is a 'nationally significant innovation asset.' Although it is located in the Sheffield City Region, he added that: "Its impact and influence extends well beyond the city region. The reach of the AMRC raises important issues about how we support it, and invest in its future – what should be the balance between national government and agencies such as Innovate UK and local government, LEPs and universities?"

Anthony Breach, author of the report, opened the event with a rapid run-through of its findings. The cluster of high-value companies in the Advanced Manufacturing Park (AMP) 'outperforms other similar parks around the country and has the highest share of advanced manufacturing jobs compared to similar industrial estates in other parts of the UK'.

Slag heap: The Orgreave coking site during its mining heyday.

He also noted that the R&D carried out on the park benefited not just the local firms and workers but was also 'exported' to other parts of country, citing the AMRC's work with Rolls-Royce in de-risking a £100m investment in its North East fan disc plant securing 300 high-value added jobs, and its ongoing work with Airbus in North Wales to secure the future of wing production in the UK and 6,000 highly skilled, high-value added jobs in the region.

"This creates a bit of a puzzle for the local industrial strategy," Anthony added. "We can see that the AMP is a concentration of highly skilled, highly productive advanced manufacturing work that is different and distinct from the existing industrial base but that many of its benefits flow outwards well beyond the city region.

"The AMP is a rare concentration of highly skilled work, with a great amount of knowledge production that can only be accessed on that site. Places like Sunderland and Broughton are engaging with Sheffield City Region to access the knowledge and research that is only being created around the AMRC. This shows the importance of place to the successful delivery of the Industrial Strategy.

"It is a key part of the transformation of the region from one where the competitive advantages of the local economy are cheap land and cheap labour, to one where the competitive advantage of the Sheffield City Region is high-value knowledge and the ability to produce exports.

"This means that the AMRC is a locally-

"It is a key part of the transformation of the region from one where the competitive advantages of the local economy are cheap land and cheap labour, to one where the competitive advantage of the Sheffield City Region is high-value knowledge and the ability to produce exports."

Anthony Breach, author of the Parks and Innovation report.

based national asset whose benefits are diffused across the entire national economy which means the national government should help support as many advanced manufacturing firms across the country to participate in the R&D outputs produced in Sheffield.

"For local government the implications are a little different. What's key for them is to ensure that the city region is able to provide the skills, the transport connections and the planning decisions that support Sheffield City Region's transition from a place of low cost production to one of high-value manufacturing based on knowledge production."

Lord Sainsbury, who secured the first public money to support the idea of the AMRC when he was Science and Innovation Minister in the Labour government, asked the Centre for Cities to look at the AMRC in more detail following a visit he made last year. He was especially impressed by the AMRC Training Centre and the full span of apprenticeship levels covered.

He told the event's audience that advanced manufacturing was crucial to solving the UK's productivity challenge. "It is very important to understand that value added per capita varies very significantly by sector and advanced manufacturing is usually a very high-value added sector because it is a place where you can use science and technology to create competitive advantage, and that is why it is vitally important to encourage the growth of advanced manufacturing jobs in a region and it has to be a key part or regional policy."

Lord Sainsbury, founder of the Gatsby Foundation, added: "The Bank of England doesn't understand that the slowdown in growth in our economy, along with other G7 countries, is not about the long tail of underperforming companies: it's the result of employment shifting from high-value added manufacturing into low-value added services.

"Innovation is absolutely key to maintaining high-value added jobs in manufacturing which is what the AMRC excels at. It is creating real production efficiencies that enable its partner companies to be high-value added. Innovation is critical to creating competitive advantage, that again allows you to have high-value added businesses."

He said recent regional policy was in an 'appalling mess.' Policy makers, he argued, 'don't seem to understand

Jewel in the crown: The transformed former coalfield site now home to the AMRC and the cluster of global advanced manufacturers taking shape around the centre.

Keith Ridgway at home on the shop floor of the machine room.

the nature of our regional economic problem'. "It's blamed on market failure, lack of enterprise and hard work. But the answer is we just have too many low-value added legacy firms in the poorly performing regions and not enough high-value added ones.

"To address this, first we need an agreed regional structure. And then we need government to recognise that it has a responsibility to support the diffusion of technology and innovation throughout the economy, which is why the Advanced Manufacturing Research Centre is so important. Diffusion is a real problem and we need to address it.

"This is especially relevant because we are at the start of a revolution in manufacturing commonly called Industry 4.0 which is essentially the digitalisation of manufacturing. This is a hugely significant revolution and will transform manufacturing: if we don't get into that field in a serious way we are just going to be left behind.

"Belatedly we have the Made Smarter initiative; but it is a bit feeble. It has some technology in it, but not enough on diffusing this technology and also the massive amount of training and skills development that will be required. This is why I think the AMRC should be part of a key national effort, as well as a local effort."

Asked about the success of the AMRC, Professor Ridgway, said: "Our unique strength was that we knew how to cut aluminium faster than anyone in the world because we knew how to tune machine tools. That was taking a factor of five out of machine times. We are now at the point where Boeing are making gears in Sheffield at a level of improved productivity, which means you don't need to offshore to the Far East, because you can do it faster in the UK.

"And we should never underestimate the importance of Boeing. Their influence on us was huge, they were a father figure and a guiding hand to us. They knew we were the best in the world at cutting aluminium, but they were moving to composites and that meant machining a much more difficult material: titanium. From that we developed a composite centre and a world-leading expertise in titanium with the support of Boeing staff embedded in our teams."

Prof Ridgway said the AMRC's early development was founded on two key strengths in the region: cutting tool technology and weaving. "When we set up the Composite Centre we knew that the best place to weave carbon fibre would be Lancashire and Yorkshire which have been weaving material for 300 years. Let's not do cloth, let's do carbon fibre.

"With the support of the ATI we have just invested in a big Jacquard loom which might have been thought obsolete years ago, but we can use it to weave 3D carbon shapes for high-value aerospace and automotive markets. We then asked, can we assemble these products better? And Boeing again put people in to help us understand the problem and develop R&D projects to find the best solutions. The result is AMRC Factory 2050, a fully reconfigurable research and development facility that is leading the UK in Made Smarter and industrial digitalisation."

Questions then turned to whether policy makers were looking for a critical mass of expertise in a region before deciding where to invest. UKRI's Alex Marsh said this was the 'the killer question and we haven't bottomed out the answer yet.' He said that the Strength in Places fund is 'looking at investments of a certain

Keith Ridgway, Alex Marsh and Lord Sainsbury at the Centre for Cities launch.

range that informs the critical mass needed to justify a scale of investment'.

Asked whether there was a critical mass in Sheffield when he approached Lord Sainsbury for funding the AMRC, Prof Ridgway replied: "No. We just had an SME and a slag heap (referring to the former colliery at Orgreave). But we did have Boeing. From that we have built an innovation eco-system where ideas are shared, people transfer across companies, people get together and support one another. I think success comes down to a unique capability and an absolute commitment to innovation."

Professor Ridgway noted that the Centre for Cities report identified the remarkable rise in the value of land around the AMRC over the last decade. "When the first plot of land was purchased it was offered to us at £1 an acre. Today, prime land around the AMRC is now selling for in excess of £600,000."

One negative consequence of this is small and medium firms in the region like Technicut, whose then sales director, Adrian Allen, co-founded the AMRC with Professor Ridgway, are being priced off land owned by the university and the private sector. "What we urgently need in the region is a clear strategy of how we develop the Advanced Manufacturing Innovation District and that requires a big shift from seeing things solely from a developer perspective to one that drives the formation of an R&D intensive cluster of high-value added industries."

When Alex was asked would he have invested in the AMRC almost two decades ago, despite the lack of a cluster, he said: "The AMRC has evolved over time and now it's the jewel in the crown. Would we have backed it? There's an important point to be made here about leadership. It's not enough to have a good idea and an evidence base behind it. You need to have a crack team. You need to know about the people you are investing in; you need a core of people with the expertise and the passion and the drive you can then trust, without putting shackles around them, to go and do the right thing to realise the opportunity."

In concluding the session, Andrew Carter was clear: "There's no argument that, when you look at the performance and the impact of the AMRC, this is truly a world-class success." But it is also poses a challenge in the current policy landscape. "When you look at the success of the AMRC you can see it in the region, but also well beyond the region. This raises interesting questions about whose responsibility is it to maintain and develop that success? What is the role of the local policy maker and the role of the national policy maker in ensuring that we can maintain and build on world-class assets in places like Sheffield City Region? And what needs to be done to induce and encourage more success stories of this type in more places."

The Parks and Innovation report, along with the discussion that followed its launch, makes a powerful case for greater collaboration and coordination between national and local government, and national and local agencies to ensure that we accelerate and diffuse the innovation outputs of assets like the AMRC for the benefit of the locality in which they based and the country.

A regional launch of the report is being planned.

We have a name: **AMRC Cymru**

The advanced manufacturing centre under construction in Broughton will be officially known as AMRC Cymru, Minister for Economy and North Wales Ken Skates announced.

Construction is progressing well on the centre which will provide a new level of support to business and facilitate collaboration between industry, academic partners and entrepreneurs. It will be a catalyst for economic growth by driving innovation, commercialisation and development of cutting-edge skills.

The Welsh Government has invested £20m in the centre which will have a strong focus on advanced manufacturing sectors including aerospace, automotive, nuclear and food with Airbus confirmed as the first major tenant.

It is scheduled to be completed in the Autumn and it is predicted that the benefit to the Welsh economy could be as much as a £4bn GVA increase.

Ken Skates also announced that current Principal of Coleg Cambria and Chair of the Deeside Enterprise Zone, David Jones OBE, will chair the Local Advisory Board which will oversee activity related to AMRC Cymru, including advising on projects. Mr Jones will chair the board for an initial period of six months, allowing time for a permanent chair to be appointed.

The Minister said: "As construction work on the centre in Broughton is progressing well and is on schedule, I'm pleased to be able to announce that it will now be known officially as AMRC Cymru.

"I'm also very grateful to David Jones who has agreed to chair the Local Advisory Board and provide leadership for the initial six months. This is an important role in the governance of the centre, providing advice on projects and ensuring they deliver against the priorities of our Economic Action Plan.

"I have said previously that AMRC Cymru is a game-changer. It will ensure a thriving industry base that will be a catalyst for economic growth across the supply chain, increasing productivity and supporting competitiveness of Welsh industry at home and around the world.

"As we prepare to leave the EU, developments such as AMRC Cymru are more important than ever.

"I'm pleased to see the good progress which has been made to date, and I look forward to the completion of the centre later this year."

Professor Keith Ridgway, Executive Dean of the University of Sheffield AMRC, said: "It's great to see the new AMRC Cymru R&D facility in Broughton take shape. We share the Welsh Government's bold ambition to enhance North Wales' reputation for manufacturing excellence, creating secure, high-value jobs and wealth for the whole of Wales by acting as a magnet for inward investment.

"Our mission is to drive world-class manufacturing innovation for Wales. The focus will be to extend open access to our research expertise and capabilities in automation, digitalisation, design for manufacture and product and process verification to assist Welsh industry to develop new capabilities.

"Airbus is a longstanding partner of the AMRC in a key sector of the Welsh economy. By building on the research relationships we have with them we will ensure the company remains at the forefront of aerospace development, supporting skills in the area and

upskilling its manufacturing supply chain partners.

"We will also be working closely with other universities in Wales to maximise our impact, drawing on their research expertise to develop new projects showing how partnerships with industry and government can accelerate big improvements in economic and social wellbeing."

David Jones said: "The Deeside Enterprise Zone (DEZ) was formed in 2011, and I have been very pleased to Chair the Board with senior industrialists from the region and beyond. Realising AMRC Cymru, as part of the DEZ's suite of recommendations to the Welsh Government, is a pivotal moment for Wales.

"I am looking forward immensely to leading the Local Advisory Board's initial phase, working with other Board members and stakeholders, to meet the needs of the advanced manufacturing sector."

UCLan partners with AMRC North West

A new partnership between one of the North West's leading universities and the AMRC has been sealed to drive growth among the region's small and medium sized companies and support innovation across a range of sectors including aerospace, automotive and low carbon energy.

The new partnership between the University of Central Lancashire (UCLan) and the University of Sheffield Advanced Manufacturing Research Centre North West (AMRC NW), will deliver collaborative R&D projects, develop graduate talent and engage with regional industry to cement Lancashire's reputation both as a hub of engineering innovation and as a top destination for high-value manufacturing inward investment.

UCLan is now working with the University of Sheffield AMRC NW on a number of research projects, including the world's first graphene-skinned plane, Juno, and a range of R&D activity with the UCLan's prestigious new £35 million Engineering Innovation Centre (EIC).

It is an important and significant partnership for Lancashire and the North West, which will ensure the region is an attractive destination for inward investment and the creation of new businesses.

The AMRC NW, whose research facilities and specialist equipment are currently located on UCLan's Preston Campus, plans to open a purpose-built £25m facility at the Samlesbury Aerospace Enterprise Zone in 2021, funded through the ERDF, the High-value Manufacturing Catapult and the local Growth Fund.

UCLan Chief Operating Officer, Michael Ahern, said: "This is an important and significant partnership for Lancashire and the North West, which will ensure the region is an attractive destination for inward investment and the creation of new businesses, in addition to providing the highest level of support for existing engineering and manufacturing companies.

"It also means the area will be home to some of the best learning and applied research facilities in the world. From staff and students, to SMEs and large businesses, it's an exciting time for all who are set to benefit."

University of Sheffield President and VC Prof Koen Lamberts at Factory 2050.

Talking about **a revolution...**

Leading figures from academia and industry gathered at the AMRC for the official launch of the university's new research hub, which aims to put UK manufacturing at the forefront of the electrification revolution in aerospace, energy, high-value automotive and premium consumer sectors.

The £28 million Engineering and Physical Sciences Research Council (EPSRC) Future Electrical Machines Manufacturing Hub is the first of its kind to bring together leading research expertise in electrical machines and manufacturing. Researchers will work closely with industry to address key manufacturing challenges in the production of high integrity and high-value electrical machines.

Held at Factory 2050, part of the University of Sheffield Advanced Manufacturing Research Centre (AMRC), the launch event was attended by 120 people from academia and industry. This included Professor Koen Lamberts, President and Vice-Chancellor, at the University of Sheffield together with leading academics and industry figures from Rolls-Royce, Airbus, Siemens-Gamesa, GKN Aerospace and funding partners.

Society is witnessing a huge global shift towards cleaner growth and more resource efficient economies, with electrical machines at the heart of the move towards electric cars, aircraft and the use of renewable energy such as offshore wind. However, there are significant manufacturing challenges, particularly around new materials and the application of digital

approaches, and how to overcome these economically while ensuring reliability and quality.

Guests at the event heard presentations from the Future Electrical Machines Manufacturing Hub industrial and academic partners on the opportunities and challenges in electrical machine manufacturing and the research activities proposed to address and overcome these challenges. They also participated in networking sessions and attended demonstrations of new industrial digital technologies within the advanced manufacturing facilities of the AMRC's Factory 2050.

The initial research plans within the hub cover a number of topics, including: the use of the latest manufacturing processes to enable the lightweighting of electrical machines, understanding and demonstrating how digital tools can support skill intensive manual manufacturing tasks and exploring how robotic systems can be applied to tasks such as the winding of coils in electrical machines.

Professor Geraint Jewell, Director of the EPSRC Future Electrical Machines Manufacturing Hub, said: "The University of Sheffield has recently been named the number one university in the UK for income and investment in engineering research which positions us as a global leader. This new hub exemplifies this in action – we are bringing together world-leading researchers with industry to deliver real impact in the manufacture of electrical machines.

"The hub will not only address the key manufacturing challenges mentioned but also assist UK manufacturing to capture significant value in the supply chain, improve productivity and deliver the cleaner growth at the heart of the UK's industrial strategy."

Ben Morgan, Head of Integrated Manufacturing at AMRC, said: "Factory 2050 is at the forefront of research into digital assembly and flexible manufacturing. We are developing and delivering new technologies for partners across aerospace, automotive and construction. We have an opportunity with the EPSRC Hub to apply novel digital approaches to the manufacture of electrical machines and help to secure future production in the UK across high-value markets."

Researchers in the new hub will work closely with industry to address key manufacturing challenges in the production of high integrity and high-value electrical machines.

Dr Arwyn Thomas, Head of Generator Design at Siemens-Gamesa, said: "The new hub is an exciting development in the partnership between Siemens-Gamesa and the University of Sheffield. Our partnership with Sheffield supports the development of new technologies including the latest generation of generators for offshore wind turbines. As the generators grow in size they present new manufacturing challenges and working with the hub will be essential to addressing these."

Simon Taylor, Chief Engineer for Hybrid and Electric Aircraft at GKN Aerospace, said: "For future hybrid and electric aircraft, GKN are exploring the potential for electrical propulsion systems in order to solve the environmental challenges due to the growth in air travel. This work expands upon our capabilities on electrical drivetrains, systems integration, propulsion and structures to invest in the future of sustainable aviation. Working in partnership with UK research activities such as the hub will be an essential part of development for those organisations which will be manufacturing high integrity and high-value electrical machines as used in aerospace."

Ruaraidh McDonald-Walker, Chief Engineer for Hybrid and Electric Drives at McLaren Applied Technologies, said: "McLaren Applied Technologies have been supplying high-performance components into motorsport and automotive for over three decades.

"In particular, developing technologies for Formula 1 and Formula E has given us the unique opportunity to work with the latest technologies, long before these technologies are mature enough for adoption into even niche automotive applications. As we continue to develop our technologies, including electric motors, engaging with the hub will be essential to understand optimum designs and the new manufacturing processes which enable these."

The £28m investment is underpinned by a £10m award from the EPSRC and funding from industrial partners including Rolls-Royce, Airbus, Siemens Gamesa, GKN Aerospace, McLaren and Dyson and the University partners. The team, led by the University of Sheffield's Faculty of Engineering and AMRC, will work with academics at Newcastle University and the University of Strathclyde's Advanced Forming Research Centre (AFRC).

For more information on the Hub, visit: **electricalmachineshub.ac.uk**

The Prodrive team with the AMRC Composite Centre's Hannah Tew and Rob Hewison, Technical Manager.

Foot down to accelerate composites recycling

One of the most respected and successful names in motorsport is working with lightweighting and materials researchers at the AMRC to advance its processes for manufacturing recyclable composite components that extend useful lifetimes and reduce tooling costs.

Prodrive, founded in 1984 and employing almost 500 in the UK, develops innovative engineering solutions for automotive, aerospace and marine industries. It also designs and manufactures advanced lightweight composites for a wide range of applications across automotive, motorsport, aerospace, marine, defence and other specialist sectors.

The company has been working in collaboration with research engineers at the University of Sheffield Advanced Manufacturing Research Centre (AMRC) on its P2T (Primary To Tertiary) philosophy, which is used for manufacturing recyclable composite components that can satisfy end-of-life requirements (specified in Directive 2000/53/EC) without any compromise in the performance of the original parts.

It not only simplifies recycling, but endows a composite material with the potential to fulfil three or more useful lifetimes.

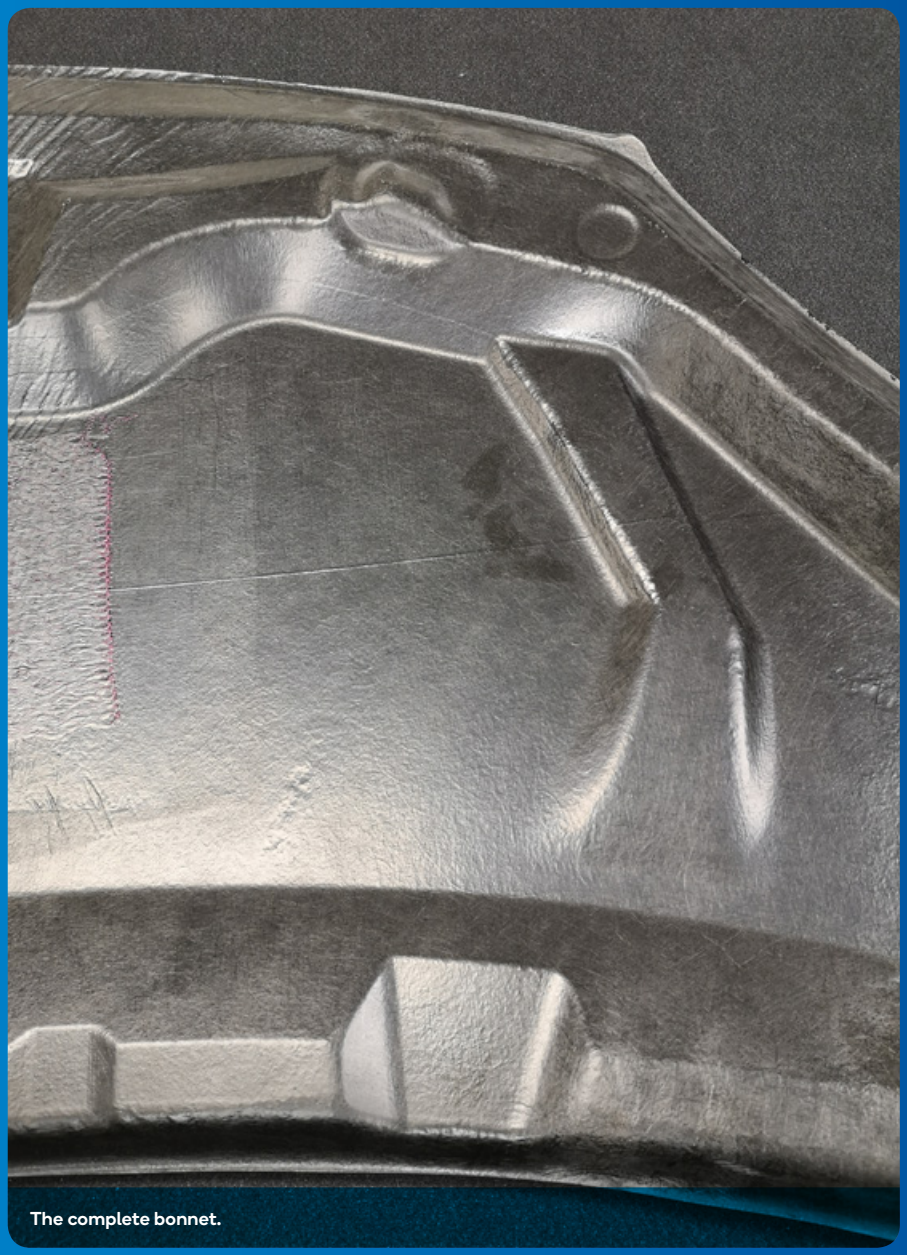
Hannah Tew, Partnership Lead at the AMRC Composite Centre, said her team has been working with the company to further advance its recyclable composite process closer to full production. This has primarily focused on allowing for automation; making it possible to achieve medium to high volumes at substantially lower costs; looking at the recyclable nature of the materials used and increasing the technology's attraction to other industries

Hannah said: "The results from our initial press trials look promising and we're very much looking forward to supporting Prodrive in automating the process going forward."

As P2T composites do not require heat or pressure during manufacture, there is


A blank bonnet in the pre-press stage.


The pressed bonnet.


The complete bonnet.

no need for an autoclave - thus reducing costs and enabling the scaling up of production without major investment.

The process uses a reactive thermoplastic resin instead of a thermosetting type; a plastic monomer is reacted with a catalyst in the presence of the fibres to produce a cured laminate.

Prodrive Composites believe they are the first to develop this technique with recycled fibres, which emerged through a development programme with an automotive OEM customer who required a high-performance structural material with lower environmental impact than conventional composites.

"End-of-life recycling is one of the biggest debates in the composites world today," said John McQuilliam, Chief Engineer at Prodrive Composites. "The issue affects automotive manufacturers and wider industries too, such as marine, where old fibreglass boats are often broken up and sent to landfill. The main barrier to recycling has been the type of resin used; thermosetting resins predominate but these cannot be readily recycled.

"We have been working with the AMRC and a series of large trial panels have been produced using an innovative process which can readily be automated. These trials have demonstrated that recyclable composite panels can be produced at a rate and cost to suit many industries.

"The unique feature of the P2T process is the reduced tooling cost and lead time compared to existing metallic or composite solutions."

Traditionally, the composites industry has been based on the supply of rolls of 'pre-preg' (woven fibre sheets pre-impregnated with resin) which customers then lay up in moulds to produce 3D parts, curing through heating and pressurising to fix the final shape. Thermosetting resins are considered convenient materials to support this supply chain but, as tighter end-of-life regulations are introduced, better alternatives are required.

The advantages of composites produced by the P2T process is that they can be recycled multiple times. The highest mechanical properties are obtained during first use of the virgin fibres, enabling highly-loaded structural items to be manufactured.

At the part's end-of-life, the fibres and potentially the resin can be recycled, supplying much of the raw material for a secondary part, such as a body panel. When the secondary part reaches the end of its life, being thermoplastic, it too can be chopped and remoulded into new parts with properties suitable for 3D solid components. This tertiary part can itself be recycled several times into lower grade parts.

The ongoing research between the AMRC and Prodrive Composites is set to expand considerably over the coming year and is being closely monitored by numerous companies in various industries looking to improve their environmental impact with high performance, light-weight components.

Okuma opens **new opportunities**

Okuma, a manufacturer of CNC equipment, has joined the University of Sheffield AMRC to further develop its extensive aerospace expertise and partner on research to increase aircraft drive efficiency while reducing noise and pollution.

The Germany-based subsidiary of the Okuma Corporation, a world leader in CNC machine tools and machining process optimisation, joined as a Tier One member of the Advanced Manufacturing Research Centre (AMRC), which is part of the High-value Manufacturing Catapult and a network of world-leading research and innovation centres around the globe.

Okuma specialises in exploring advanced machining, manufacturing and materials of practical use to the aerospace industry. With the new membership, Norbert Teeuwen (President Okuma Europe) and Stefan Vielsäcker (Senior Manager Okuma) will sit on the AMRC management and technology board.

Okuma will participate by developing machining applications for new types of material. Other research focuses on new components for more efficient drives like future solutions for conventional drive arrangements in fields like electro, hybrid or gear-driven systems. Advanced manufacturing processes like skiving for new materials and other cutting-edge gear manufacturing technologies will also be the focus of new research. The overall goal of these projects is to increase the efficiency of aircraft drives while reducing noise and CO2 emissions.

Prof Keith Ridgway, founder and Executive Dean of the AMRC, said: “Okuma has a rich history in the machine tool industry, but are constantly looking to the future. Like us, they have a deep tradition of innovation and have a mission to speed the evolution of advanced manufacturing. They consistently push the boundaries of machining, opening new possibilities in terms of quality and productivity. We are proud to have a company with such a remarkable manufacturing pedigree join us as a partner and look forward to working with them on pushing the boundaries of the possible in the future.”

The collaboration will help expand the AMRC’s research capabilities with the new CNC machine tool and put Okuma at the forefront of new advances, further developing its extensive aerospace expertise.

Okuma said one benefit of being part of the research projects is that its machines will be used for certifying innovative materials and manufacturing processes. This allows Okuma to immediately offer solutions that are recommended and licensed by the process developers when a new material or manufacturing process becomes ready to go into production. In addition, the cooperation will bring researchers, aerospace manufacturers and machine tool builders closer together at an early stage.

As a member of the AMRC, Okuma will provide know-how and support for the latest research in the form of a MU-8000V-L, a versatile CNC machine tool that combines turning and 5-axis multitasking machining, making it the ideal solution for highly complex aerospace components.

In cooperation with UK distributor NCMT, a Tier Two member of the AMRC, Okuma will also accompany the research with constant application support and service free of charge.

Pryor engagement with AMRC

World-leading marking, identification and traceability specialist Pryor Marking Technology has become a member of the University of Sheffield Advanced Manufacturing Research Centre (AMRC).

The AMRC is part of a network of world-class research and innovation centres working with advanced manufacturing companies around the globe including Boeing, Rolls-Royce and BAE Systems.

As part of being a Tier Two member, Pryor has placed an advanced integrator laser marking system in the AMRC's Factory 2050, the UK's first state-of-the-art factory dedicated to research into reconfigurable digitally assisted assembly, components manufacturing and machining technologies.

The integrator laser is the first laser marking equipment in Factory 2050. It will be integrated into a fully automated robotic cell for marking parts and components to demonstrate part traceability and data capture in production assemblies.

The demonstration will involve two robots that will load the parts of a pen into the laser cabinet for marking and then assembling the parts into a working pen. Visitors will also be able to sign their name on a tablet linked to the system and the laser will engrave their signature on the pen.

David Ray, Technical Director at Pryor says, "This is an exciting collaboration sharing best practice in traceability. Product identity and data capture is becoming essential in modern manufacturing for multiple reasons including efficiency, quality assurance, anti-counterfeiting, recall actions and to meet increasing regulatory requirements. We're delighted to be members of the AMRC and look forward to showcasing our solutions and contributing to research projects that will help develop the next generation of traceability systems for the smartest factories in the world."

The two organisations already partner on Pryor's apprenticeship programme, through the AMRC Training Centre, and Professor Keith Ridgway, AMRC founder and Executive Dean, said they are a welcome addition to the AMRC's 100-plus member companies.

"Pryor is a world-leader in product marking and traceability and we're very much looking forward to working with them on collaborative research projects to advance traceability systems for manufacturers," he added.

Pryor is leading the way with proven fibre laser marking technologies to address the growing need to mark components moving at high velocity through its range of 'on-the-fly' standalone and integrated laser systems. The software links manufacturing data to uniquely identified components. Traceability is provided throughout the component manufacture and the product lifecycle, not just for materials but for all manufacturing variables that need to be monitored.

An added smile: Mark Cocking with his Formlabs bank.

Banking on **additive manufacturing**

A bank of powerful 3D printers linked to easy-to-use software has been built by AMRC engineers to show that the batch-printing of bespoke polymer components is an affordable option, even for smaller manufacturers who are keen to accelerate their design processes, shorten lead times and drive improvements in productivity and quality.

Using a fleet of 12 Formlabs Form 2 desktop 3D printers for the stereolithography (SLA) of polymer components, four Form Cure post-curing stations, four Form Wash cleaning stations and buffing capabilities, AMRC Development Engineer and AM Specialist, Mark Cocking, believes the new capability will spur the adoption of AM technology across a range of industrial sectors.

"This unique capability will be of great benefit to industry, especially to SMEs looking to explore AM as an alternative production method, and to larger companies who wish to work with us to conduct research projects into the batch-production of additively manufactured components," Mark said.

"For firms dealing in lower-volumes of production, with special print runs or runs of multiple sets of bespoke components with small but significant changes, the bank system we have constructed provides the perfect opportunity for them to explore quickly and efficiently making design changes, producing batch volumes of multiple sets of components on the same printers," Mark added.

The bank is installed on custom racking which connects each printer to Formlabs' Dashboard software which gives users visibility of printer utilisation, allowing them to select a printer using the appropriate material for their print build with just a couple of clicks.

After a short 45-minute training course and completing their first print, engineers have remote access to SLA capabilities and 20 different polymer materials for a range of applications including prototyping, engineering resins and beta test materials such as ceramics for specialist applications.

The bank has already been used by AMRC research projects for global aerospace companies who want to explore the feasibility of investing in batch-printing technology to produce

components of the necessary quality, within very short time-frames, and worked with them to demonstrate how designing for AM can streamline their manufacturing processes.

"The bank has been a great success with staff across the site and we are printing well over 700 print runs every month, with over 1,000 components already processed," said Mark.

Creating open access for all was critical to the system's success he added. "If you give engineers means to develop their own design and AM skills needed to use the print stations, they naturally develop their own use-cases for the use of AM in their research projects, from concept demonstrators to the creation of components like jigs and fixtures.

"Once those skills and knowledge are shared and embedded, the engineers are able to draw on their wider experience and capabilities toolkit to service projects, encouraging innovation.

"Using the new capability to share knowledge and best practice with our supply chain resellers means we will be able to provide a comprehensive service to our industry partners by advising them on how they are able to access and build systems to their specification with scalable options.

"The kind of organic knowledge transfer that has come from the open-access scheme for our own engineers, could be the catalyst for our industry partners and local businesses developing valuable skills, accelerating innovations in AM for their own product lines or processes.

"Much like the large-scale SLS High Speed Sintering machine being developed by the AMRC and the University of Sheffield's AdAM Centre, the bank of 3D printers allows multiple parts to be built in each print run for shorter lead times and quick turnaround on component builds," explained Mark.

Formlabs – who started out of MIT in 2011 and now have over 500 people across Boston, North Carolina, Hungary, Germany, Japan, and China – have been following Mark's ambitious project with keen interest and recently came to witness how it was stimulating innovation and productivity improvements across the AMRC itself.

The projects the company saw included the batch production of 500 high-precision drilling caps that were critical to prevent cross-contamination during aerospace drilling trials; the 3D printing of highly intricate brackets for a pick-and-place robot that automates composites' manufacturing; fixturing for a sensor-mounting system for an autonomous welding project; and the printing of customer rollers for a composite filament winding machine.

All of these are now featured in a series of short films that can be seen on the AMRC website.

"We often hear about companies that try to adopt 3D printing, but purchase expensive machinery that ends up standing idle in a corner—because of its complexity and limited accessibility, only a select few can use it. The AMRC's open access bank with the Form 2 3D printers and post-processing units is a brilliant model that other companies can easily replicate to solve this challenge and empower hundreds of engineers to support their work. The wide range of applications we saw across multiple AMRC sites proves that once equipped with these versatile and easy to use tools, engineers will find ways to integrate them into their workflows, savings time, costs, and increasing efficiency", said David Lakatos, Chief Product Officer at Formlabs.

"The projects are really great examples of the breadth of applications AM can be used for," said Mark. "But we also want to show industry how accessible this technology is for even the smaller companies we work with and demonstrate how batch-quantity bespoke AM is possible right now, at a good price point."

For companies interested in engaging with the Formlabs 3D printing bank at the AMRC, please contact Mark Cocking on **0114 222 6244** or **m.cocking@amrc.co.uk.**

Case study:
Batch volume cost reduction strategy for additive manufacture

Engineers within the University of Sheffield Advanced Manufacturing Research Centre's (AMRC) Design and Prototyping Group (DPG) have developed a cost reduction strategy to batch produce additive manufactured components. This is compared against traditional manufacturing techniques.

Challenge

Additive manufacture (AM) has the potential to disrupt conventional processes for the production of polymer components. AM doesn't require tooling and is now able to produce complex geometry components in relatively high volumes. The project challenge was to identify and create a cost reduction strategy suitable for AM which would reduce the manufacturing cost per part when compared directly with injection moulding. The initial brief specified selecting a component suitable for AM using the Stereolithography (SLA) system Formlabs Form 2 machines. The DPG developed a solution for producing high volume AM polymer components using a part stacking and nesting technique, maximising the build volume available within the Formlabs Form 2 machines.

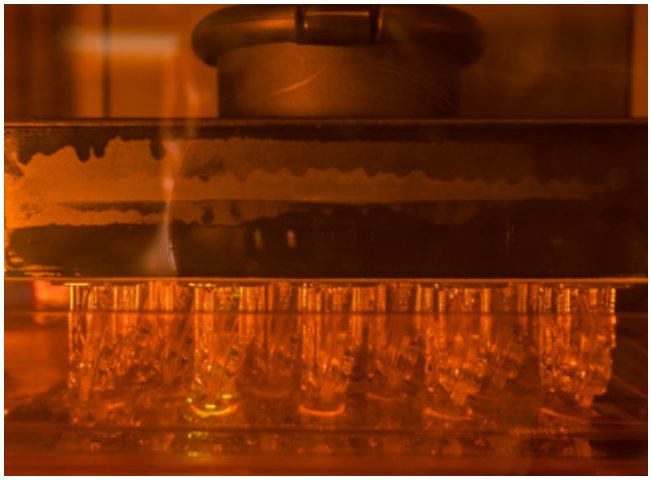
SLA process

SLA machines produce polymer AM components using a vat polymerisation process using a laser to cure solid isotropic parts from a liquid photopolymer resin (Formlabs 2019). The SLA Form 2 machines work with the build platform lowered into the resin. The UV laser then draws a cross section of the part which hardens the resin. The part is built in layers until complete. Post processing involves the part removed from the Formlabs resin tank then transferred into an isopropyl alcohol (IPA) solution and agitated removing any uncured resin. After washing, the part is placed into a post-curing unit with a turntable exposing the part to light and heat, improving overall strength.

Solution

A generic cap was selected as the candidate component for the study. Its end-use function is to seal apertures within a composite part. The cap was chosen due to its small size and that it would be typically volume injection moulded rather than additively manufactured. The cap has an OD of 36 mm with a volume of 5.34 cm^3. A trial batch of caps were prepared using the Formlabs Form 2 software PreForm, with the caps oriented at a 25 degree angle allowing the maximum batch of caps to be positioned on the build platform. PreForm is a print preparation software used in conjunction with Form 2 AM machines, allowing users to prepare, orientate, apply supports and upload the files to the Form 2 machines ready for additive manufacture. An initial batch of 27 caps were trialled and produced taking under nine hours, including preparation, build and post-processing time.

A method was developed to vertically stack the caps, maintaining overall part quality and close fit part geometry whilst maximising the available build volume. The parts were nested to maximise the quantity that could be produced within the build envelope. Using PreForm, these nests were then duplicated to produce 90 caps in a single build. The caps were then additively manufactured using the Form 2 machines, followed by washing in an IPA solution and curing within the curing station. The final stage involved removing the breakaway supports manually and any excess support material needing to be trimmed down so as not to cause detriment to the overall part quality or function.



As part of this study, it was noticed that the caps nested further apart with more supports between the caps resulted in radial distortion. Reduction of length supports between the caps within the nest resulted in less distortion. To understand the part quality and dimensional accuracy, the caps were inspected using a CT scanner. These scans highlighted that the caps tended to overfill during AM causing the part to be oversized. The cap geometry was measured with 98% of the cap being within 0.30 mm of the nominal value. The Form 2 machine ran the 90 cap build with the addition of preparation, build and post processing time in just over five days.

Material properties AM vs Injection Moulding

The caps were produced using Formlabs clear resin (predominantly acrylic compound). The injection moulded material could use a comparable material of acrylic. The injection moulded component may typically present with a witness line and potentially flash but could have a high polish. The AM components retain support touchpoints which can be removed using an abrasive for a smooth finish. To improve the appearance further, an acrylic cleaner and microfiber cloth can be used for a well-polished transparent part.

The table identifies the mechanical properties of the materials for both processes:

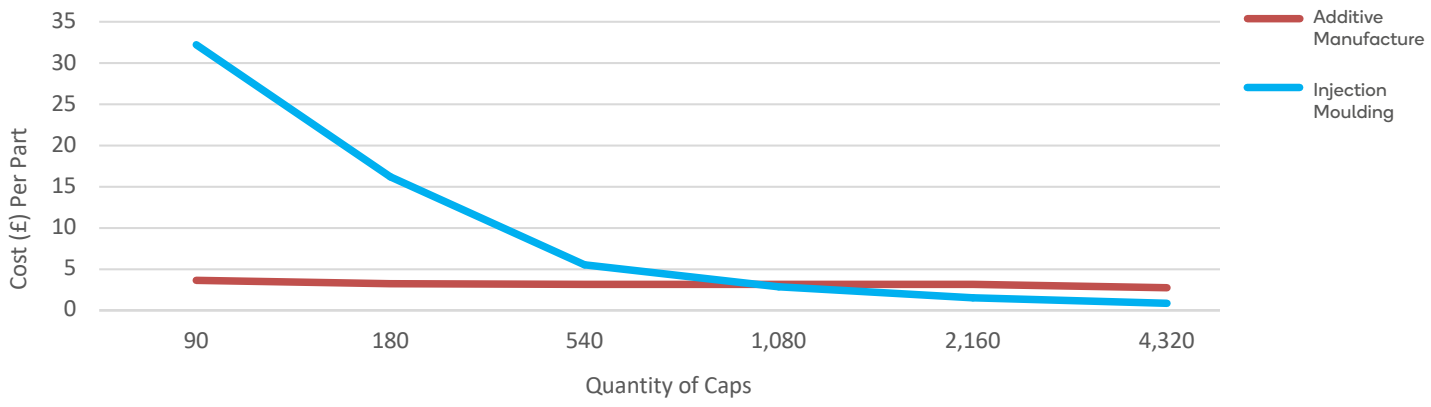
	Injection Moulding	Additive Manufacture
Ultimate Tensile Strength (MPa)	64.9	65
Elongation at Failure (%)	10.1	6.2
Flexural Modulus (GPa)	2.9	2.2
Deflection Temperature at 0.46 MPa (°C)	97.2	73.1

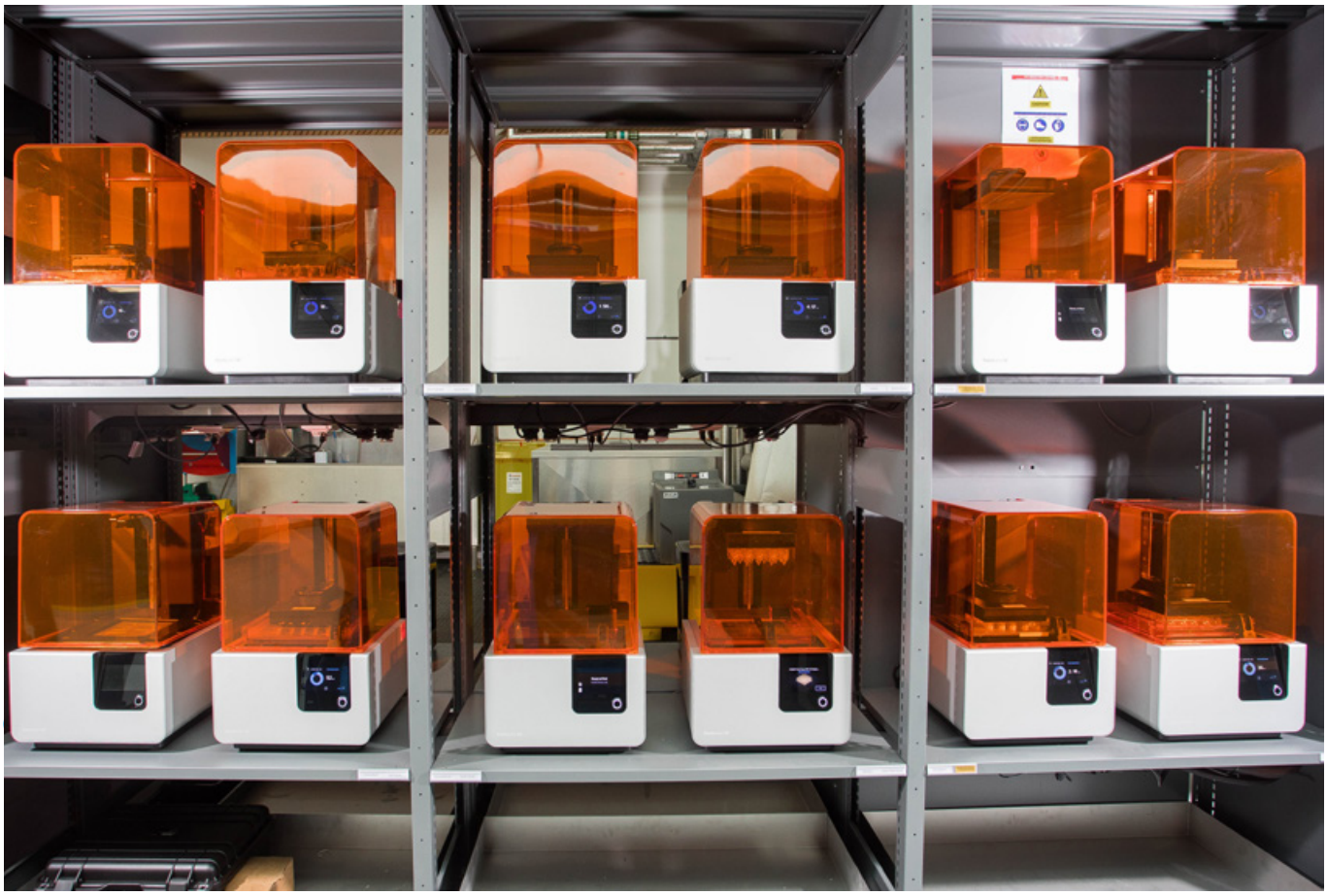
Cost saving benefit

The injection moulding process and cost calculations included the design, manufacture and polishing of the tool, and production of the parts. The AM calculations included the software preparation, build and post processing time, material and machine costs. We identified that the production of 1000 caps in AM would have a lead time of 4 weeks using just one Form 2 machine, wash station and curing unit with the machine running at 90% capacity. This lead time could be reduced with the use of another Form 2 machine and associated equipment. Injection moulding the same quantity would take an estimated 4 weeks, this lead time would not be incurred every time parts are ordered.

The table below shows cost per part with the cost of the injection moulding tooling amortised. The cost per part when injection moulding in quantities of 1000 is £2.86 whereas the same quantity in AM would cost £3.16. We found that to additively manufacture parts in quantities under 1000 is more cost effective when compared to the same quantity if injection moulded. We also identified that there was a cost saving benefit to adopting the strategy of optimising the building techniques.

Additive Manufacture vs Injection Moulding Cap Production Part Cost





We have shown that in this instance applying the stacking technique, AM is a more cost effective method of producing batch volumes of small components when compared to injection moulding. The scope was to compare one type of AM machine with injection moulding and one type of component geometry. AM is suitable and advantageous in this instance, but larger components or other types of AM equipment may differ in cost benefits.

AM enables the production of low quantity custom, complex shapes for a minimal cost when compared to injection moulding. Clearly the novel AM solution offers benefits in terms of fast turnaround, high accuracy parts. This solution could offer advantages to many companies looking for a cheaper alternative with this type of development in AM potentially disrupting existing manufacture technologies utilising this readily accessible technology.

Clearly the novel AM solution offers benefits in terms of fast turnaround, high accuracy parts. This solution could offer advantages to many companies looking for a cheaper alternative.

Anna Whiteley, AMRC Design and Development Engineer

Helping drones lose weight

A lightweight airframe design for an autonomous drone has been developed by Sheffield Robotics with help from engineers at the University of Sheffield Advanced Manufacturing Research Centre (AMRC).

The project was part of the EPSRC Brains on Board programme to develop a series of autonomous drones capable of processing sensor data in real time to control their own flight.

The AMRC's Design and Prototyping Group (DPG) opted to use additive manufacture (AM) techniques to meet strict weight limits imposed on the airframe and the requirement to test multiple iterations of the design.

The completed frame comprised AM and carbon fibre components, producing a final drone weight of 600g – about the same as a pet hamster - meeting the exact required specification.

The flight control algorithm of the drone is based on that of a honey bee. In previous versions of the drone, Sheffield Robotics have successfully achieved real time processing of sensor data by performing all necessary computing tasks on a remote base station and sending the data wirelessly.

The goal of the Brains on Board project is to perform all required computing tasks on-board, eliminating the need for a remote base station. To perform data processing on-board, additional computing modules need to be housed within the drone, which add to its flying weight. To maintain the required thrust to weight ratio of the drone, while still housing these additional computing modules, significant weight savings were required to the airframe.

AMRC DPG collaborated with Sheffield Robotics and Malloy Aeronautics to develop the lightweight drone for the project. AMRC DPG were required to design a quadcopter type airframe to house components selected by the collaborating partners.

To maintain the required thrust-to-weight ratio for the selected motors, a strict upper weight limit of 600g was imposed. In addition to this, there was little flexibility in the selection of components. This meant that the maximum airframe weight was restricted to 98g. By comparison,

commercially available airframes for similar sized quadcopters are normally in the 200-400g range. In addition to the weight limit, there was a requirement for the frame to protect the electronic components in the event of a hard landing.

As with most new design projects, AMRC DPG started with an idea generation activity which identified two preferred design approaches. The first approach was a strut-and-node type design, where a framework of lightweight tubes were connected by nodes. The second approach was the use of laser cut carbon fibre plates connected by a series of rigid fasteners.

The team believed the strut-and-node type design was likely to be the lightest airframe design, this approach was further developed. Prototype designs were constructed for the purposes of review (Figures 1 and 2) which revealed that a number of complex node geometries would be required. Calculations showed that, due to the number of nodes required, it was unlikely that this type of design would be capable of achieving the weight requirement. As a result, the second design approach was given further consideration.

A basic prototype of the airframe, designed to make use of laser cut carbon fibre plates was manufactured.

To reduce development time, AMRC DPG used the Markforged fused deposition modelling (FDM) printer to manufacture the bespoke carbon fibre connectors. The Markforged printer is capable of printing components in a proprietary ABS and chopped carbon fibre material called Onyx. The strength of Onyx components can be enhanced by inlaying strands of carbon fibre into them as they are built, this results in components with very similar material properties to carbon fibre. The remainder of the airframe was manufactured using standard carbon fibre components such as sheet and box section (Figure 3).

Initial flight tests were conducted using the prototype in Figure 3. While thrust and hover performance were satisfactory, significant flex was noticed in the frame as the drone changed direction. While maximising the stiffness of the frame was not a requirement of the original design specification, it was known that significant movement in the frame would cause unacceptable issues with the control algorithms. After investigation it was determined that the frame had insufficient torsional rigidity and a re-design was required. A second version of the airframe design was produced (Figure 4) which had increased frame depth. Test flights of this frame showed it was sufficiently stiff during flight.

In parallel with the frame design activities AMRC DPG also designed, prototyped and tested various structures capable of cushioning the frame during impact. Figure 4 shows a version of the frame with a compressible landing gear structure, which was proven to protect the airframe and all attached components from a drop of two metres. This landing gear was trialled in a number of materials and geometries to optimise its compressibility (Figure 5 shows these variations). A landing gear manufactured in Nylon using a FDM process was found to be optimal. However, due to the severe weight limitations these structures could not be included on the final airframe. Smaller landing feet, manufactured in Formlabs tough resin, were found to give a good balance of impact protection and lightweighting.

Further details of the Brains on Board programme can be found by visiting **brainsonboard.co.uk**

For details of the AMRC's Design and Prototyping Group's additive manufacturing capabilities, please visit: **amrc.co.uk/capabilities/additive-manufacturing**

Figure 1: Prototype designs constructed using strut-and-node method.

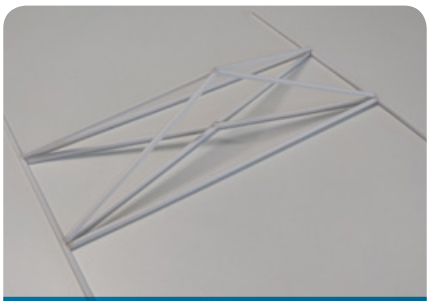


Figure 2: Prototype designs constructed using strut-and-node method.

Figure 3: Airframe made using carbon fibre components.

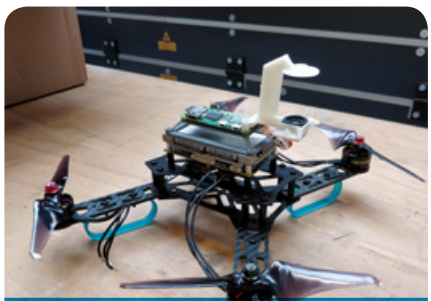


Figure 4: Frame depth increased on the airframe design.

Figure 5: Landing gear variation that were trialled.

Figure 6: The final airframe created using AM technologies.

Conquering new horizons with additive manufacturing

The University of Sheffield AMRC has successfully manufactured and delivered component prototypes for a mobility device that visually resemble those made by mass manufacture methods.

The Design and Prototyping Group (DPG) was asked to develop a mobility aid with the capability to raise the user to 'social height' - eye level - as part of the Conquering Horizons project, set up by former Royal Marine Commando Phil Eaglesham, wife Julie and businessman Brian Meaden.

Phil contracted a rare fever during active service in Afghanistan and as a result relies on wheelchairs and similar devices for his mobility. These traditional devices restrict his mobility and independence. The aim of Conquering Horizons is to create a mobility device for the modern age with none of the drawbacks of conventional wheelchairs and scooters.

The prototype for this project was codenamed VICTOR and two completed prototypes were required that closely resembled final production models. The DPG used additive manufacture (AM) technologies to quickly manufacture and develop components for these prototypes.

A range of post-processing operations were carried out allowing the appearance of the AM components to mimic that of components made using traditional mass production methods, specifically injection moulding, as Samuel Rees, Senior Project Engineer at the DPG, explains.

"As part of the design and development process, we identified that the likely mass manufacture method for two key components, the fairings and headlights, would be injection moulding.

"Creating prototype injection moulded fairing components was not possible as their large size meant the required tooling would take too long to manufacture and would be very costly.

"It was decided that the prototype fairing components would be made using the AMRC's in-house capability of the Fortus 900mc machine which manufactures components via Fused Deposition Modelling (FDM)."

FDM produces components by depositing molten plastic material in a highly controlled pattern using a nozzle. Because of this, the surfaces of FDM components can appear highly textured.

To ensure that a smooth surface finish was achieved, the exterior of the fairings were filled and sanded, several coats of base paint and final finishing coat were then applied. Samuel, technical lead on the project, said the result was a component visually indistinguishable from an injection moulded panel.

He added: "The headlight units were also designed to be injection moulded but the material for this needed to be transparent. Again, it was not possible to produce prototype components using injection moulding due to time and cost limitations.

"We manufactured these components using a streolithography (SLA) process, using the in-house SLA capability to print the components in clear resin with a Formlabs Form2 machine.

"Although SLA components are smoother and require less finishing than FDM parts, some further processing was needed as the headlights needed to have a high optical transparency."

Samuel used abrasives of decreasing coarseness to smooth and polish the surface of the printed component before a final coat of lacquer was applied. This resulted in a highly transparent material which closely mimics traditional headlight mouldings.

Again, the most likely method for the manufacture of the handles was thought to be injection moulding, due to the low cost and high strength requirement of these components. Samuel said: "We manufactured them in SLA using the Formlabs Form2 machines. The handle components were then painted in a matte black colour, resulting in a handle which visually resembles one manufactured using injection moulding."

By making use of the AMRC's in-house AM capability, the DPG has been able to produce high-quality prototypes in a very short space of time. As the AMRC expands its in-house AM capability through the addition of more technologies and materials, it is expected that it will be possible to simulate more manufacturing processes beyond injection molding.

Constructing a better future

An ageing workforce, the end to the free movement of EU labour, and a poor recruitment image are creating a perfect storm for UK construction. John Yates hears how Mark Farmer and the AMRC can help the industry ride out that storm.

When Rolls-Royce was exploring the possibility of building a £100 million manufacturing plant in the North East to make high performance jet engine discs, it turned to its partners in the University of Sheffield Advanced Manufacturing Research Centre (AMRC) to help in de-risking the venture.

What engineers at the Rotherham-based centre did for the world-leading jet engine manufacturer may be cloaked in commercial secrecy, but the outcome was very clear: existing operating times were halved; productivity doubled; and quality increased by 15%.

Productivity gains of this magnitude have reinforced the AMRC's reputation as the go-to place for aerospace and defence manufacturers and their supply chains. But the last two years have seen a very different sector beating a path to the AMRC's door: construction. So what brings bricks and mortar to an R&D centre focused increasingly on bits and bytes?

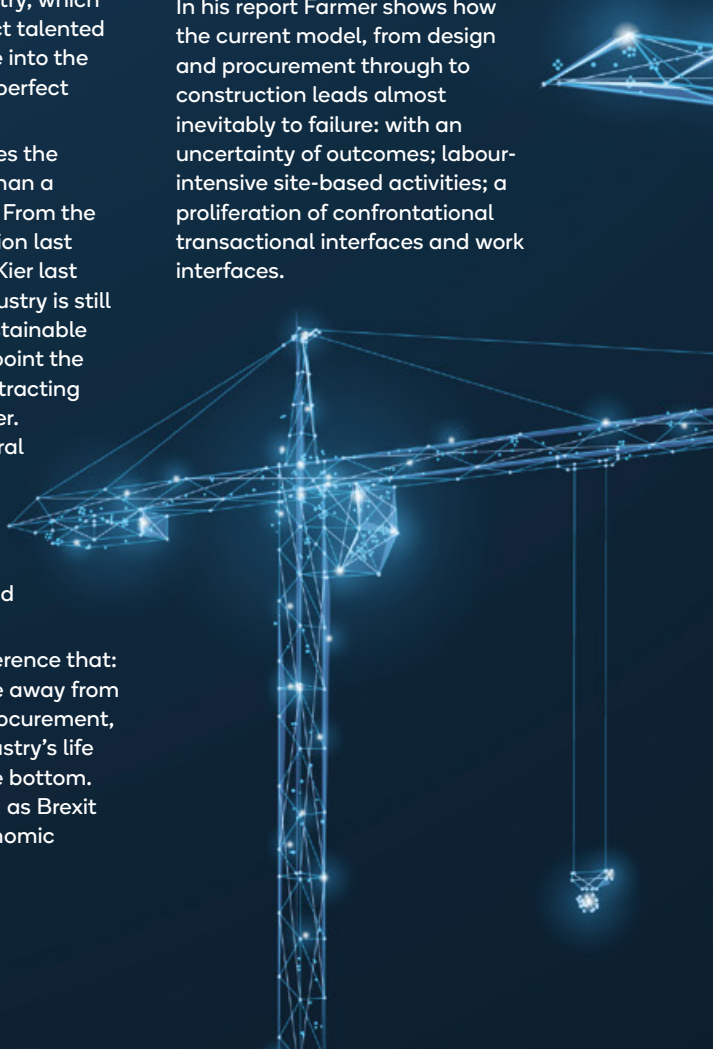
For off-site modular evangelist, Mark Farmer, the answer can be found in his report to Government on the state of the UK construction industry: Modernise or Die. "Construction is a labour intensive industry and we have an ageing demographic that we ignore at our peril," Farmer told the Modular Offsite Construction and Digital Manufacturing conference held at the AMRC with Imperial College London, earlier in the year.

Couple this with the still unresolved issue of Brexit, which almost certainly means an end to the free movement of people across the EU to the UK, and the scale of the problem is magnified. "The shortage of construction workers is a big issue in London and the South East, but we are also seeing it in the Midlands and the North. Add to this the very poor image of the industry, which is making it difficult to attract talented and ambitious young people into the business, and we can see a perfect storm on the horizon."

Bad as this is, Farmer believes the problem goes even deeper than a dysfunctional labour model. From the spectacular demise of Carillion last year, to the restructuring of Kier last month, the construction industry is still struggling to find a more sustainable operating model. "At some point the penny will drop that the contracting model is broken," says Farmer. "Construction is in a structural skills decline, cannot deliver predictability and is no longer able to hold commercial risk. Until then it will be death by a thousand cuts."

Farmer told the AMRC conference that: "The industry needs to move away from transactional lowest cost procurement, which is the bane of our industry's life and all about the race to the bottom. And it has started again. So, as Brexit is starting to impact on economic confidence in London, we are seeing contractors trying to buy work. Despite all of the assertions that the industry would never do that again after the financial crash, Tier ones are looking at their order book and thinking they need to get that filled, even if it means compressing margins or taking a lost leader."

In his report Farmer shows how the current model, from design and procurement through to construction leads almost inevitably to failure: with an uncertainty of outcomes; labour-intensive site-based activities; a proliferation of confrontational transactional interfaces and work interfaces.



The solution? Change the way the industry designs and constructs.

For Farmer, the answer lies in what he calls horizontal innovation: bringing manufacturing ideas from automotive and aerospace into construction. This, of course, means industrial digitalisation. "The biggest lever for change in construction is around digital," says Farmer. "The pace at which this technology is moving is unprecedented, but if we are smart we can harness it to augment what we do, and how we do it. This is much more than a shortage of bricklayers and trade based skills; it is an industry-wide challenge that includes planners, architects, engineers, surveyors and all the professional services.

"Our industry doesn't think programmatically; it just takes one job at a time. There's very little use of the standardisation backbone that you see in manufacturing. Instead we have fragmentation, which is vertical disintegration with each layer adding transactional costs and risk around the interfaces which become adversarial. Unfortunately, the construction industry is massively incapable of collectively deciding to follow a different path.

"The industry is under pressure and that is now coming to a crescendo. Construction productivity has flat-lined over the last two decades, while manufacturing has improved. We need to see step changes in productivity of the kind the AMRC is delivering for aerospace. But to do that we need to change the labour model and we need to stop thinking short term about bespoke projects."

"The AMRC, is at the forefront of augmented reality which creates a much more resilient digital thread from design and manufacture to on-site delivery and construction."

Mark Farmer, author of the government commissioned state-of-the-nation review of the construction sector: Modernise or Die

To do this the construction sector needs to design with manufacturing, installation and quality in mind. This reduces the transactional interfaces, supports standardisation, changes the value chain, and creates greater predictability. "We need to pre-manufacture more value (PMV) away from the final workface.

The more we can move production off site, into a controlled manufacturing environment, the higher the PMV and the better the productivity.

"A typical residential project done by a house builder at the moment will have a PMV of 40%, which is a material value that is bricks, cement, sand, joinery and 60% is the on-site labour. By moving to the manufacture of a volumetric modular home, where all that fitting out is being done in the factory you could move PMV up nearer to 80%."

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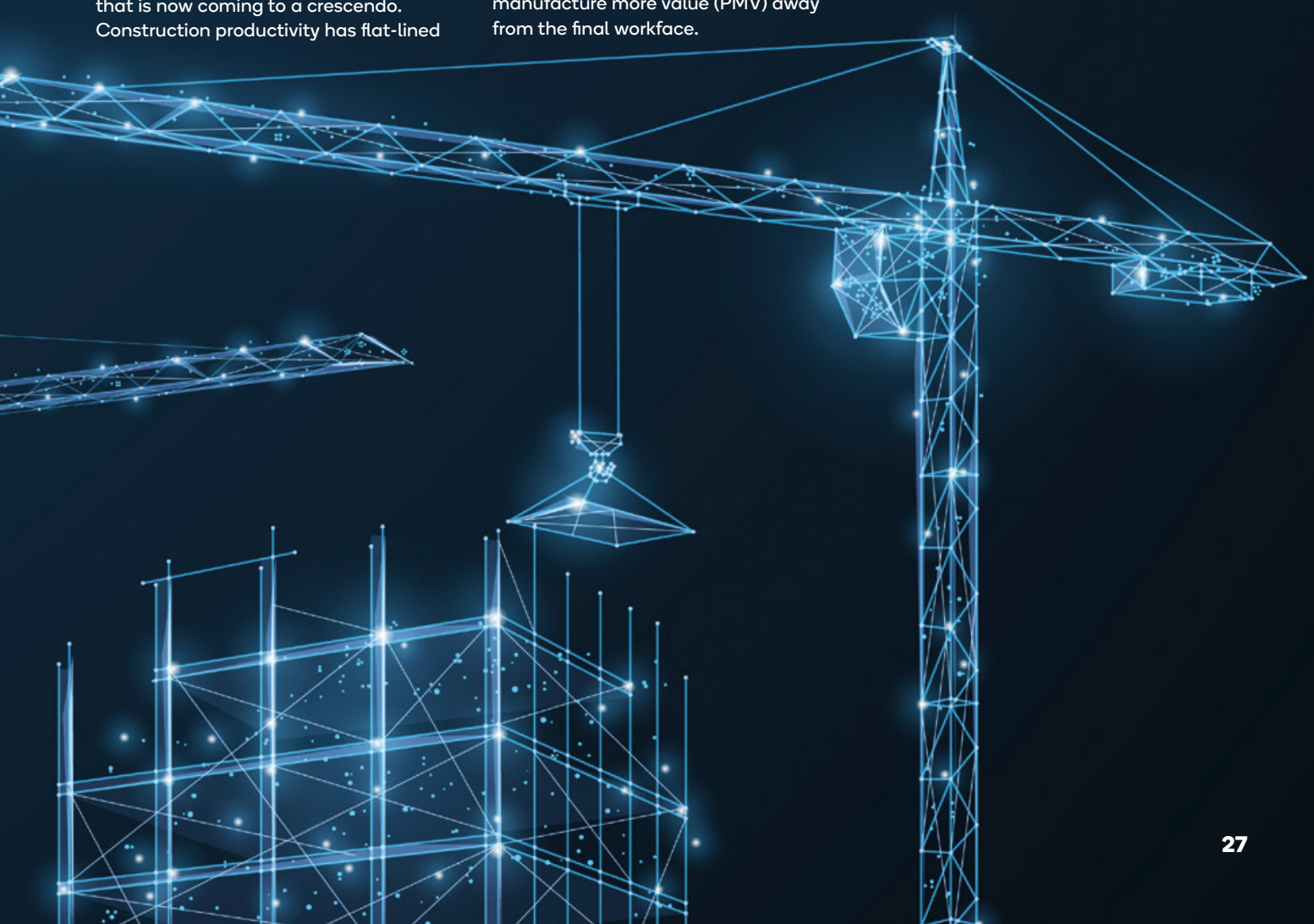


Factory 2050's Operations Manager Chris Greaves has a captive audience in George Clarke and Mark Farmer.

The PMV concept is being picked up by the government and will be a metric used to judge success in the various waves of the £170m construction industry sector deal. "PMV is referenced as being an outcome that the government is going to judge the sector on in 2021, with the intention to increase PMV across assets," says Farmer who is currently chairing a working group for the Ministry of Housing.

One of the things his team has been tasked to deliver is a clear definition of off-site modular – more often referred to by government as 'modern methods of manufacture'. The result is a seven category taxonomy, from the three and two-dimensional manufacture of primary structures (volumetric and flat pack) to non-structural assemblies and sub-assemblies.

This latter category is really important, says Farmer. "From an SME point of view, there is a real understanding of what you can deliver to site as a sub-assembly, whether it is part of a house, a school or a hospital that might not be the whole structure, where there is a high intensity of effort required to deliver it on site traditionally, mostly connected with things like engineering services or high levels of fit out.

"If you can do in a factory as a discrete item of work, it could be two or three dimensional, and you deliver that bit to site, it could be a bathroom pod, a kitchen cassette, a pre-fabricated M&E riser, or a plant room. Most of the activity I see in the construction market, particularly from a tier one level, is about this category.

"Everyone thinks we are not seeing more modular schemes, not seeing offsite happening, well it is happening, but it is happening by stealth. We are seeing PMV rising on schemes because contractors have worked out that, actually they can't get the labour security they need to underpin the lump sum contracts. So, by stealth, they are taking bespoke designs and saying 'we are going to reduce site labour by doing more offsite in bits.' What we are seeing is a hybrid; you have more precast concrete happening; you see more unitised facades where they are being brought to site; bathrooms and kitchens are being preassembled and brought to site; and M&E done to reduce site labour count."

One of the things Farmer's working group with the Ministry of Housing is now looking at, is how to introduce even more manufacturing thinking into the house building process by applying tools that are routinely used in other sectors. This includes Advanced Product Quality Planning (APQP) which is standard in automotive and aerospace.

"We are currently talking to house builders and warranty providers about applying these principles in housing. And that is something that even a year ago I would have thought impossible, because the sector is so entrenched in its ways that they just won't get it. Now we have got the beginning of a conversation, and while there is more to do, the warranty providers, who are having a rough time at the moment, are recognising that APQP could prove essential to de-risking the outcomes from their projects for consumers."

Another issue explored by Farmer's working group is a so-called 'platform' based approach to manufacturing. "This is the idea of having a common set of parts; an inventory of components that can be put together in a series of different ways for mass customisation, as happens in the automotive sector. This approach will be integral to government procurement because of the presumption in favour of off-site modular for the likes of the prison service, education, health, defence and transportation.

"Currently there is a consultation for platform design for manufactured assembly (PDfMA). Every school, hospital every MoD asset will have a digital inventory of design components that designs will be using. If you don't use it you won't get through procurement. That is the only way you will drive some of this behaviour; it has to be client led/industry push relationship is key here."

This approach is already happening in the private sector in Europe where the Dutch-based construction company, Van Wijnen, operates as a vertically integrated digital design and digital manufacture business. "They have a front end optimisation tool that uses generative design to look at a site and optimise a solution," says a clearly impressed Farmer.

"You press a button and it gives you options about the form and massing of the building; press another button and it will create a price, preloaded with a supply chain sitting behind it; and press another button and it will send it to

the factory. This is the transformative stuff that is the future of our industry. You might struggle to think of how we get from where we are now to where this is going, but I think it will happen, because technology will make it happen, technology will make it the new norm and those who embrace this approach early will have such a competitive advantage over the others in the market."

The road to this kind of future in the UK is beset with pitfalls and Farmer is under no illusion about the challenges ahead. "The idea of collaborating in a common data environment relies on people, and our industry does not collaborate. So the concept of using a digital front end design in a common data environment, and then transposing that to procurement and then into construction, which is done on site in analogue, means you have got a rapidly deteriorating digital thread.

"Architects and engineers working together in Revit and Navisworks is well established now, and there is some really interesting stuff in the design space that is highly digitalised, but as you move through the construction supply chains and on to site, the digital thread just disintegrates. So the idea of a digital twin is a complete fallacy in construction; it is not possible unless you create a thread between digital design and manufacture."

As for the future, Farmer cites McKinsey's 2018 report Seizing opportunity in today's construction technology ecosystem which identifies four big technologies or 'constellations' that are dramatically changing the sector: digital twins; 3D printing, robotics and modularisation; artificial intelligence and machine learning; and digital procurement.

"Tech companies are already entering the construction space, offering bits in those constellation areas," says Farmer. 'What I think is going to happen, is that all those disparate bits are going to get joined up and you are going to get the ability to simulate vertically integrated businesses through digital tech, so the human element we have been dependent on using BIM will get superseded as the workflows get digitalised. There will still be people involved, but lots of the behavioural issues that have led to BIM failing will be overcome. Technology will join a lot of things up; it will create integrated platforms that will lead to a whole sea change in how we deliver manufactured homes"

Farmer sees what he calls 'two big picture trends' developing over the next five years and beyond that will support this integration: worker augmentation and decentralisation of manufacture. The AMRC, he said, is at the forefront of augmented reality which creates a much more resilient digital thread from design and manufacture to on-site delivery and construction.

"Augmented reality gives any worker on site the ability to see a digital twin of what they are working on at the workplace. This, coupled with the use of large volume metrology, which is another area of speciality here at the AMRC, enables the worker to recognise spatial positioning and understand what components go where in terms of dimensions and tolerances. In short, it opens up completely the way we deliver on site.

"At the moment we have got people with angle grinders and sledge hammers and trowels and saws working from analogue information. To be able to locate yourself in three dimensions, and have a digital twin of what you are supposed to be doing, with easy-to-read guidance notes coming up in your field of vision totally changes the game; augmentation for me is the on-site end of the digital thread."

So all is not gloom and doom for an industry that contributed £113 billion to the UK economy in 2017 – around 6% of the total – along with 2.4 million jobs. While the overwhelming majority of the construction sector remains wedded to traditional methods, a growing group of pioneers are taking the horizontal innovation route advocated by Farmer and are exploiting the benefits of offsite, modular (or modern methods) of construction.

Interestingly, many of these early pioneers, from industry leaders like Laing O'Rourke to new entrants such as Legal and General are being guided by senior figures with deep and wide experience in advanced manufacturing roles. Graham Herries, for instance, who is

cont...

Another brick in the wall: James Illingworth explains how aerospace technology is finding a home in construction.

“We really are at the dawn of a new age in the construction sector. We have to recognise that offsite manufacturing revolutionises everything.”

Graham Herries, Director of Digital Technologies at Laing O’Rourke

Director of Digital Technologies at Laing O’Rourke was head of a software centre of excellence at Rolls-Royce; while the CEO of Legal and General Modular Homes, Rosie Toogood, spent more than 25 years at Rolls-Royce in diverse manufacturing disciplines.

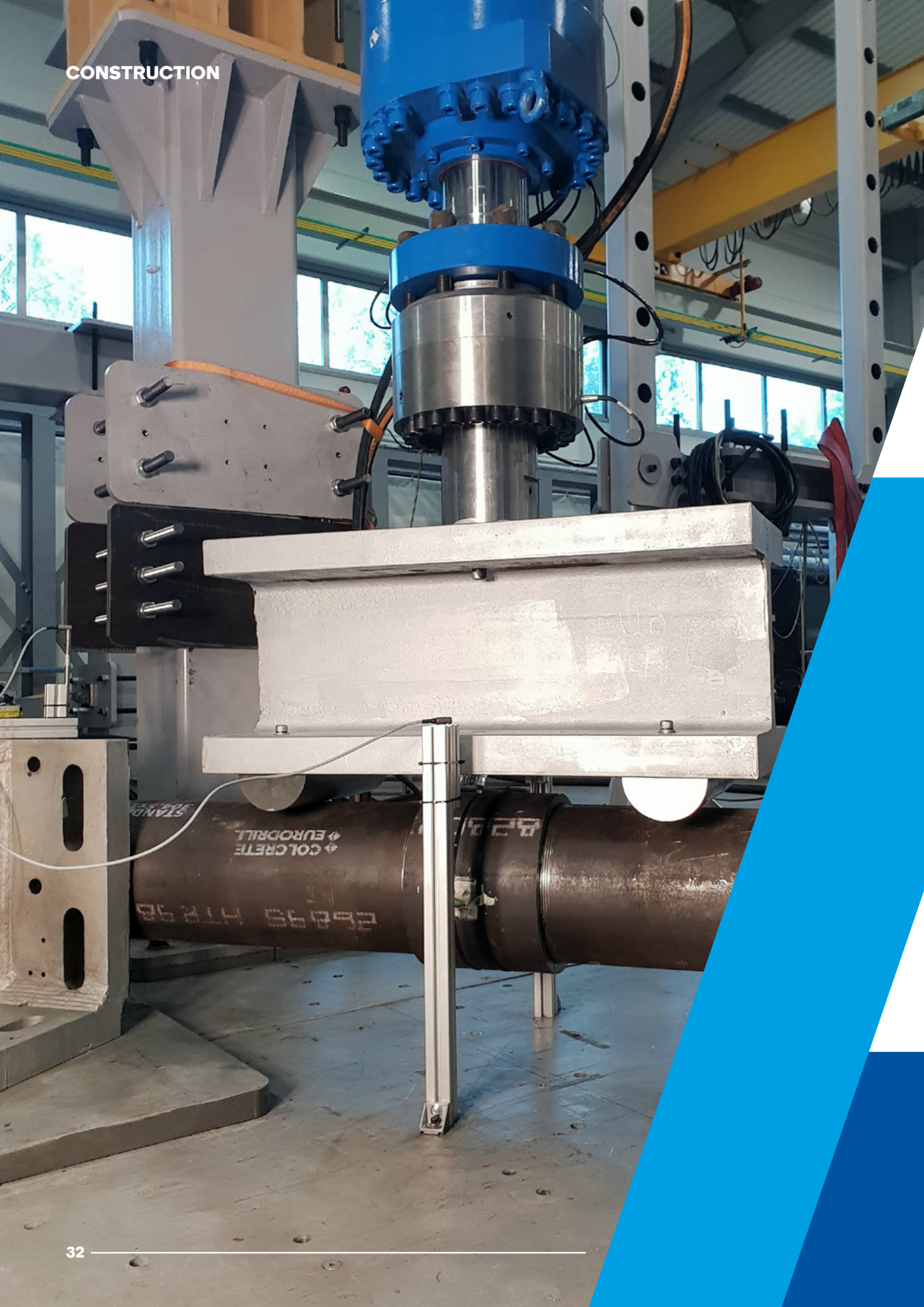
“One of the advantages of coming from the aerospace and defence sectors,” says Herries, “is that we can leverage some of that now mature technology for construction. If you look at what Airbus is doing, they are really pushing the envelope and that’s our goal to get to that level maturity. In terms of how they do design, how they do traceability, manufacturing and delivery, they are far richer than the construction sector. We really are at the dawn of a new age in the construction sector. We have to recognise that offsite manufacturing revolutionises everything.”

While there are significant differences in post-factory production between aerospace and construction, this new breed of offsite pioneers is convinced that there are aerospace and automotive technologies that can be taken off the shelf, given a slight tweak, to leverage the power of those systems and technologies within the construction sector.

The AMRC’s Chris Greaves, Operations Manager at the Integrated Manufacturing Group in Factory 2050, agrees with Herries. “Our work with the construction sector exploits the knowledge we have gained in high-value added manufacturing in aerospace and defence, and translates it to create the most efficient and appropriate factory production environment for construction,” says Greaves, who now has a team dedicated to advancing the UK’s capability in offsite modular manufacturing for homes and other buildings.

Farmer, who is a regular visitor to Factory 2050, is in no doubt about the role that Greaves and his team are playing in creating an alternative future for the construction industry. “I am convinced that the AMRC is playing a significant role in helping support the construction sector make the change to smarter, off-site production methods outlined in our report. What really impresses me about their approach to developing technology is how they make it is easy for industry to adopt,” says Farmer.

The AMRC’s head of digital, Professor Rab Scott, agrees: “Our role is to help the sector develop a roadmap to adoption. For many it will seem a daunting task. But, as Mark says in his report, unless the industry embraces change the future is truly bleak. “We are here to help the construction industry get the maximum value out of industrial digitalisation, driving improvements in productivity and quality along with improved health, safety and wellbeing, as we are doing with our aerospace and automotive partners.”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Piling on the stress

Crucial strength validation tests – the first of their kind in the UK – have been carried out on reinforcement piles being used in a major engineering project to stabilise cliffs behind the Scarborough Spa complex and protect the site for generations to come.

The University of Sheffield AMRC's Advanced Structural Testing Centre conducted the tests for piling specialists Keller UK who were appointed to do the work by the civil engineering company overseeing the £13.4m Scarborough Spa Slope Stabilisation Scheme on behalf of Scarborough council.

Andrew Heathcote, technical director at Keller UK, said: "This is the first ever test done in the UK – no-one has produced data from the UK and as far as we're aware we don't think it has been done before on this scale. We chose the ASTC because over the years it has tested piles before for a number of industry providers and has a fantastic reputation. We're very happy with the results."

Keller is manufacturing 206 concrete-filled steel piles that will be used to reinforce the cliffs behind the seafront heritage buildings to prevent further land movement. The work requires 15m length piles to be driven deep into the ground to stabilise the soil but restricted access means Keller is having to use smaller 7m sections of piles that will have to be connected together to make the longer required length.

To ensure the connected piles are strong enough to withstand soil movement, Keller approached the AMRC's Advanced Structural Testing Centre to carry out validation tests to determine the displacement on the piles - using forces of up to 150 tonnes.

Andrew said: "Our work is being carried out in the Italian Gardens and the restricted access means we have to take the piles in 7m sections so they are smaller. Because of that we have to connect them together to get the longer lengths and there isn't a lot of data available on the connectors we are using. A lot of the data available is based on drilled-thread collars from the oil industry and they are not designed for bending but more for torsion.

"We've been told we need to do tests to show the connectors we are using have the right bending moment capacity – which is what happens when an external force, or moment, is applied onto the pile causing it to bend – and the connectors are key to that. We need to know they are strong enough."

A custom rig was designed and built by the ASTC to carry out four-point bending strength tests on four concrete-filled steel piles with varying wall thicknesses and collar lengths, using forces of 1500kN (150 tonnes) to measure deflection in the middle of the tube where the two sections are connected by a threaded collar.

The tubes tested – which weigh a hefty two tonnes each – were: 17mm steel wall with a short collar; 17mm steel wall with a long collar; 22mm steel wall with a short collar; and a 22mm steel wall with a long collar.

The first tube tested was the 17mm wall thickness with a short collar as this was deemed to be the weakest of the four samples. Phil Spiers, head of the ASTC, said the result was 'very positive'.

"It withstood a load of 1500kN bearing down on it – which is 150 tonnes, the same as two A320 aircraft, 20 elephants or 30,000 house cats – and surpassed Keller's target for displacement.

"We continued to test the other tubes and they all passed well, giving Keller the validation, and confidence, they need to proceed.

"It is always a pleasure to be involved with validating engineering solutions – the capabilities, capacity, and commitment of the structural testing team at the AMRC were able to realise this test within four weeks of receiving the purchase order providing a great service to our customers is the most satisfying part of the job. Be assured that no cats were harmed in the course of the testing."

The first Keller piles arrived on site in Scarborough at the end of last year and work continues. The overall scheme by is expected to be completed by December 2019.

The first pile being inspected by Andrew Heathcote, technical director at Keller UK, following testing by the ASTC team, headed up by Phil Spiers, head of the ASTC group.

Shivan shines bright to win 'Apprentice of the Year' at AMRC Training Centre

Innovation, passion and bringing fresh thinking into the workplace are some of the qualities that won Shivan Morkar the honour of being named 'Apprentice of the Year' at the Advanced Manufacturing Research Centre (AMRC) Training Centre's annual awards ceremony.

The event, supported by Siemens and set against the stunning backdrop of the University of Sheffield's Firth Court Hall, attracted the great and good from industry, business and public office across the Sheffield City Region and beyond.

Look North presenter Harry Gration was host for the evening and among those who attended were Rt Hon Lord David Blunkett, the Lord Lieutenant of South Yorkshire Andrew Coombe, the High Sheriff of South Yorkshire Barry Eldred, Mistress Cutler Liz Cragg, Brian Holliday, managing director for Siemens Digital Factory, and Nuclear AMRC research engineer and Great British Bake Off winner, Dr Rahul Mandal.

As part of his prize for winning the Apprentice of the Year 2019 award sponsored by Siemens, Shivan, a CNC machinist for William Cook Rail in Leeds, will travel to Germany for special visit to Siemens' award-winning Industry 4.0 Smart Factory in Amberg.

Nominations for the annual awards are made by employers and trainers to recognise the achievement or contribution apprentices have made to industry, and are judged by a panel of AMRC Training Centre staff and award sponsors.

This year, the judges said they had been overwhelmed by Shivan's enthusiasm and passion for the industry, the positive impact he's had on his workplace, and that he has gone on to become an inspiration for other apprentices and work colleagues around him.

On accepting the award, Shivan, who is in the first year of his degree apprenticeship, said the win is a massive boost in confidence and 'a great feeling' knowing his hard work has earned him such recognition.

He said: "This means everything to me. I wasn't expecting it at all - thank you to everyone who has supported to me. That support has been very important, it has pushed and helped me to do to more and keep on progressing."

Shivan, of Bradford, said one of the main highlights of his year was being given the opportunity to go to a McLaren Automotive press conference announcing its partnership with the AMRC because he got to sit inside three of their impressive supercars. Another high note was being involved in a project where he had to work with a company to manufacture a team of table top football players – all while still in his early days of learning about CNC machining.

Phil Mosley, machine shop manager at William Cook Rail, was at the awards ceremony to see Shivan lift the trophy.

He said: "It is very well deserved. Shivan's hard work, effort and motivation are unbelievable and just for him to take it to the level he has to, getting his Level 3 so far ahead of schedule, shows every bit of enthusiasm and that he is keen to learn.

"Shivan has a very bright future ahead of him and will go all the way."

Other winners at this year's awards were:

- Technical Support: Katy Foster of Vector X-Cel, sponsored by the MTA;
- Fabrication and Welding: Matthew Robert Wogan of Charles Thompson, sponsored by the AMRC;
- Maintenance: Alex Bywater of Beatson Clark, sponsored by Hexagon Manufacturing Intelligence;
- Machining: Shivan Morkar of William Cook Rail, sponsored by Sandvik Coromant;
- First Year: Joel Jason Knowles of Boeing Sheffield, sponsored by Hallam FM;
- HNC Achiever: Michael Buchanan of Inductelec, sponsored by SIV;
- Degree Graduate: Joshua Thomas Parkin of Bifrangi, sponsored by Close Brothers;
- Siddall Achievement Award: Mary Stickland of Pryor Marking Technology, supported by Dr Graham Siddall;
- Siddall Achievement Award: Craig Horton of Technicut, supported by Dr Graham Siddall.

Outstanding contribution awards sponsored by the AMRC Training Centre were given to lecturer Itai Vutabwarova for the impact his teaching has had on apprentices' achievements, and to Sarah Hudson for 'going above and beyond' in her support staff duties, giving invaluable support to the centre.

Director of the AMRC Training Centre, Nikki Jones, said it was a fantastic evening and that she was proud of each and every one of the apprentices.

"This is an evening when we embrace the future; when we look with great pride on the well-rounded, articulate, passionate young people whose energy and drive will see them rise to the very top in their chosen companies," she said.

"The halls of Firth Court echoed to loud applause as the older generation handed the baton to the younger

generation, confident in the knowledge that manufacturing and engineering, the heart and soul of our region, are in safe hands and guided by smart brains."

Professor Keith Ridgway, Executive Dean of the AMRC, said: "The pride we feel in what our apprentices have achieved – and of how much further they can go with the knowledge and skills they have acquired – is what inspires and motivates us to do more.

"The success of the AMRC Training Centre is a collaborative effort involving industry partners, government and a civic university publicly committed to expanding alternative learning pathways, widening access and deepening participation among groups of people who might otherwise be left behind."

On the evening Lord Blunkett, former Education Secretary, said: "The achievements we celebrated here tonight are a testimony both to the talent and tenacity of the young apprentices and to the ambition of their employers who have made the commitment to invest in their people. But it also a time of reflection; what we saw here tonight is a region building on its historic strengths in engineering and manufacturing and using these skills and this history to chart a better future."

University of Sheffield Vice President for Education, Wyn Morgan, added: "This evening was a wonderful celebration of the hard work and effort our apprentices have made and recognises the vital role they play in driving innovation in their companies and the wider region."

TV star George Clarke finds **amazing spaces at AMRC**

Top TV architect George Clarke was blown away by the AMRC Training Centre during a visit to the Advanced Manufacturing Research Centre to learn more about the crucial role it is playing in enabling the construction industry to deploy digital manufacturing technologies for house building.

George, host of Channel 4's Amazing Spaces and Restoration Man, visited the University of Sheffield AMRC with Mark Farmer, author of the government commissioned state-of-the-nation review of the construction sector: Modernise or Die, and members from the 'Ministry of Building, Innovation and Education' (MOBIE), a charity founded by George to inspire young people into the architecture, design and building industries.

The TV presenter was full of praise for the AMRC and, as a former apprentice, he was particularly impressed with the strong links it has nurtured with industry to foster and develop the talents of young engineers, through the AMRC Training Centre.

"This is an incredible place. The level of work that is being done here is amazing," said George, who made the trip up north on a fact-finding mission to learn about technologies and processes AMRC researcher engineers are developing for offsite modular manufacturing of homes and schools, and to make construction more efficient and sustainable.

He began his visit at the flagship Factory 2050, home to the Integrated Manufacturing Group (IMG), before heading to the training centre to meet with apprentices and director Nikki Jones to ask what the centre is doing to attract more children and women into engineering.

George heard that alongside manufacturing camps for teenagers,

there is an AMRC STEM team working with schools and a number of event are being planned throughout the year to encourage more females into the industry.

Nikki told him: "We do not just want to put a plaster on it – we are looking at the long term and want to engage with schools. That's why we have started a programme called Primary Engineers, capturing the five, six, seven and eight-year-olds, and we have a STEM team tasked to work with employers on the positivity of a diverse workforce.

"Our message is very much that it is talent not gender that matters and to help deliver on that we've set up our own Women in Engineering group to bring together females from industry to talk about their experiences and help break down some of the barriers for the next generation.

"We're also planning a series of female-focussed events. For example, later this year, we'll have some 250 school girls visiting the AMRC and the AMRC Training Centre to take part in engineering activities."

George said the AMRC Training Centre is a vote of confidence for apprenticeships and a learning model the MOBIE charity could look to replicate for the construction industry.

"I'm very impressed with the training centre and those young people doing what they are doing. What I am just as impressed about is the fact that the training they receive is so well connected with industry, which is really good," he said.

"I did an apprenticeship at 16 – a BTEC in building construction – and went through the same pathway many of these young people are going through now. I have always thought apprenticeships are the way forward and that's proven here today."

George and the MOBIE group also met with Allan Griffin, head of construction and infrastructure strategy at the AMRC, and Chris Greaves, head of operations at Factory 2050, to discuss the work being done in helping the construction industry to modernise, including how they are undertaking horizontal innovation in construction by applying proven technologies used in the aerospace and automotive sectors.

Allan said: "The AMRC is the place where construction meets manufacturing, so it was fantastic to have George and other representatives from MOBIE visit us.

"Our work with those leading the change in how housing is delivered means that productivity lessons from other high-value manufacturing sectors can be readily applied to the housing sector as it embraces modern methods of construction.

"Our proven ability to integrate technologies such as augmented, mixed and virtual reality, robotics and automation along with sensors, big data and artificial intelligence into manufacturing processes mean the future of construction is possible today."

Mark Farmer, who is at the forefront of the digital manufacturing agenda in construction – and the training of a new generation of construction workers - said in the past two years, he has been highly impressed by the work happening at the AMRC with a specific focus on new processes, skills and training together with SME engagement.

"The work the AMRC is doing with Laing O'Rourke, Legal and General, Berkeley Modular Homes and Ilke Homes is a great indicator of industry collaboration with the emerging offsite manufacturing sector," said Farmer, who is CEO of Cast Consultancy.

"The augmented worker programme is also of particular interest in terms of how digital twin visualisation tools at the work-face can transform how we deliver better accuracy and quality on site.

"As a trustee of MOBIE, George's charity is focused on transforming how we attract and train a new generation of home builders and designers, I see lots of potential synergy in how MOBIE and the AMRC can work together."

TV presenter and architect George Clarke on his tour of the AMRC campus to learn how digital manufacturing technologies for aerospace and automotive are being deployed for house building, and also met apprentices at the AMRC Training Centre.

A relentless focus on quality education

An inclusive culture of high expectations sees apprentices challenged and supported to achieve their full potential at the University of Sheffield's AMRC Training Centre, according to a new report by Ofsted.

The report said there has been a 'relentless focus' on improving the quality of education apprentices receive at the training centre and weaknesses identified at a previous inspection had all been successfully addressed.

The Training Centre, which is part of the AMRC Group in Rotherham, was judged as 'good' in all areas by Ofsted following a full inspection last month.

Inspectors praised the centre's leaders and managers for 'successfully creating an inclusive culture of high expectations throughout the apprenticeship provision' and for carefully planning the development of apprenticeship provision in a way that is 'well aligned' to the needs of employers.

"Apprentices benefit from very well-equipped training facilities, high-quality resources and knowledgeable teachers with strong industry experience," the report adds. "Apprentices demonstrate the exemplary standards of behaviour expected of successful employees. They are courteous and helpful, attend well and work to deadlines effectively."

Nikki Jones, Director of the AMRC Training Centre, is thrilled with the 'good' judgement from Ofsted and said it is testament to the hard work of apprentices, training centre staff and the wider university.

"Since the last inspection we have been working relentlessly and I'm thrilled we are now on our journey towards becoming outstanding. We're pleased inspectors recognised that we have made sustained and continuous improvement and can see how that is having real impact on the success and achievement of our apprentices.

"This result has been achieved by working hand-in-hand with the wider University of Sheffield, our Industry Board, employers and our apprentices – and we're extremely grateful for that continued support.

"We're meeting the skills needs of the economy through the careful way in which we have designed our curriculum and how we are delivering it around the regional need.

"The University of Sheffield, to the most senior level, is very positive about the quality of education for our apprentices and that's demonstrated in this report. It shows the Russell Group of Universities can make a real difference.

"What really stands out for me in this report is the recognition inspectors have given to our apprentices for their professionalism and exemplary behaviour. This means a great deal to us because we aren't just engineering the advanced manufacturing workforce of the future but creating good citizens too.

"As the report found, we have successfully addressed all the weaknesses identified in the previous inspection and there is already an action plan in place to address the actions suggested for us to improve further. We're looking forward to turning that good into outstanding."

Keith Ridgway, founder and Executive Dean of the University of Sheffield AMRC, said: "This is great news for Nikki and her team and for the growing numbers of young people across our region who see engineering apprenticeships and degree apprenticeships as a debt-free pathway to a challenging and rewarding career that makes a positive impact on the world around us.

"It's great, too, that the report recognises how Nikki and her team have successfully created an inclusive culture of high expectations for our apprentices, and how this leads to exemplary standards of behaviour in apprentices who are confident, courteous and helpful, attend well and work to deadlines effectively. We produce great engineers and good citizens.

"As the report says, there is a significant need for skilled engineers in the region, both from indigenous companies and from inward investors who increasingly see the Sheffield City Region as the place to put down roots.

"This Ofsted report gives us all the more reason to want to widen access and participation both to meet the growing demand for skills and to open up new opportunities for communities in our region who can sometimes feel left behind and ignored."

Outcomes for apprentices, according to the report, are good with a large majority of the current cohort 'making rapid progress from their starting points and meet challenging targets' with many achieving 'high grades in their examinations'.

Inspectors also said leaders and managers have taken successful action to improve the retention of female engineering apprentices through targeted 'Women in Engineering' events and placing them with supportive employers that have strong female representation at all levels of the workforce.

The quality of teaching, learning and assessment is good, along with the personal development, behaviour and welfare of apprentices.

The report says: "Teachers and trainers use their considerable academic knowledge and industrial experience well to help apprentices develop up-to-date knowledge and skills that effectively prepare them for their careers and future study at a higher level.

"A high proportion of apprentices gain valuable additional qualifications at work that develop their employability skills beyond the requirements of their apprenticeships."

Since opening in January 2014, 1,300 apprentices from more than 300 employers in the city region have been trained in engineering skills, which have helped businesses to grow and secure a sustainable future.

Apprentices with the director of the AMRC Training Centre Nikki Jones and University of Sheffield President and Vice-Chancellor, Koen Lamberts.

Innovation inside the box

Leading-edge IBM AI hardware on the shop floor of Factory 2050, at the University of Sheffield's Advanced Manufacturing Research Centre, is giving UK manufacturers access to artificial intelligence and machine learning technologies that is accelerating the pace of innovation across high-value-added manufacturing.

"This is the first industry-focused AI system of its kind in the UK," says Sean Wilson, technical lead for AI at the AMRC. "It's the result of the very close relationship with IBM we have developed over recent years, enabling the AMRC to open up another dimension of Industry 4.0 for our partners, and the wider supply chain, in the Sheffield City Region and the North with game changing technology."

The computational muscle of the IBM Power9 AC922 server and FS9150 flash storage enables AMRC research engineers to shred the time it takes to develop an algorithmic model from weeks down to a few hours.

Wilson said: "A perfect example is a recent five-day assist we did with a regional SME, in which we delivered a proof of concept to understand the structure of written documents/forms using computer vision.

"Without the power box, it would have taken a couple of weeks to generate, train, and test the deep learning model. With PowerAI Vision software, we were able to upload and train the model in just over an hour with an 86% accuracy.

"This provided the client with the proof of concept he needed to approach investors about commercialising his product. In this case, the power of AI enabled the AMRC to support an SME to do rapid innovation; testing ideas in hours to understand whether it is worth pursuing them further. Failing fast, and learning fast from those failures, is now very feasible."

Unleashing the power of artificial intelligence is also having an impact on the AMRC's bigger partners. One of the UK's leading industrial exporters, who have been collaborating with the AMRC, IBM Watson and a Sheffield- based digital company, Razor, are using AI to make a step-change in the performance and quality of their screening and inspection processes for critical aerospace components.

This not only ensures passenger safety, by providing a continuously improving inspection process built on big data analytics, but also delivers inspection rates 4,000 times faster than the original inspection. The AI solution, which brings local and global expertise together, will soon be on the factory floor of the OEM who said: "We've learned more in the last ten weeks at the AMRC than we have in ten years on our own."

Kieran Edge, AMRC Technical Lead for Machine Vision, who oversees the project said: "We used PowerAI Vision software for its classification as well as detection capabilities, and found we had a tremendous success straight off the bat."

For IBM, the deployment of the AI demonstrator at the AMRC is a way of lowering the barriers to adoption of Industry 4.0 technologies in high-value-added manufacturing sectors such as aerospace. "It's a way of demonstrating the art and science of the possible in a way that de-risks future investment in a technology which is often poorly understood by even some of the bigger players in the market place," said IBM's Ian Gardner.

PowerAI Vision software provides the AMRC and its partners with an open-source, easy-to-use framework and tools for building and managing computer vision models, including functions for installation and configuration, data labelling, model training, inference and deployment.

Located in Factory 2050, the Power Systems AC922 server offers a fully optimised platform to support the massive throughput a project's workload requires. The backbone of some of the world's largest supercomputers, the server pairs POWER9™ CPUs and NVIDIA Tesla V100 with NVLink GPUs, which delivers up to 5.6x times the

input/output (I/O) performance of x86-based servers.

The Factory 2050 team has also implemented a FlashSystem 9100 solution to boost throughput speed and storage efficiency. “FlashSystem 9100 will really increase our ability to do training and iterations on the models that we’re generating,” says Wilson. The enterprise-class storage solution combines flash performance and Non-Volatile Memory Express (NVMe) with the reliability of IBM FlashCore technology.

Designed for security, the solution features built-in encryption and FIPS 140-2 certification. It integrates well with IBM Spectrum Storage™ capabilities, enabling highly scalable, tiered storage solutions in the cloud — another plus for the AMRC and its customers who want to modernise their infrastructures using new private and hybrid cloud models.

“Cloud solutions suit many of manufacturers who come to us for R&D support with AI, eliminating the hardware investment required to adopt intelligent automation. But, for others, a hybrid cloud approach might provide a better balance. The containerised architecture implemented at the AMRC allows us to offer both to our partners,” said Edge.

Head of Digital at the AMRC, Professor Rab Scott, said the IBM solution is not only fast and powerful, it is also safe and secure. “What we are offering brings the power of cloud into the heart of the factory without dragging all the cloud and its misconceptions with it. This on-premise cloud keeps data safe, handled in the local IBM and AMRC infrastructure so that our partners can de-risk innovation with knowing that their data is secure.”

“What we have here is a massively powerful tool,” Wilson added. “Knowing how to use that tool safely while pushing it to its limits, is what the AMRC brings to the collaborative processes. Using Tensorflow, which can run on multiple CPUs and GPUs, we are able to build custom research-led neural network models with access to performance levels that would cost tens of thousands of pounds a day in cloud land.

“This means the AMRC and IBM can sweat the box without having to worry unduly about the price: achieving big innovations at cost levels that are affordable to SMEs. The future of AI manufacturing is here in Factory 2050: now.”

The University Of Sheffield.

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STEM

‘Tribe’ launches to attract young women into engineering

‘Be brave, try new things and don’t be afraid to ask questions’. That’s the advice Nuclear AMRC researcher and Great British Bake Off winner Rahul Mandal gave to a room full of girls at the launch of the #AMRCtribe campaign. Katia Harston reports.

As a Nuclear AMRC STEM (science, technology, engineering, maths) ambassador, Rahul Mandal said he was honoured to help kick start the campaign, which has been developed by the University of Sheffield AMRC to tackle one of the serious challenges facing engineering - attracting more women into the industry.

The #AMRCtribe campaign has set up an exclusive social media group to address this, providing a safe and supportive environment where young women can have the confidence to talk – outside of the school gates – about their interests in STEM subjects and pursuing STEM-related careers. This will be supported by social events to encourage the tribe to bond and foster close relationships between the members.

Jenny Cassy, Director of Learning for Futures at Fir Vale School Academy Trust, attended the launch with girls from the school. She was full of praise for the AMRC and the #AMRCtribe campaign.

“It’s been a fantastic day. What I think is really good about the tribe is the idea of being able to share information and for the girls to know what grades they need to get here and what they need to do to prepare for that,” she said.

“When our girls went on the tour of the AMRC, they all came away saying they want to come here. These are girls that live 15 minutes away from here and theyhad never thought about it before.

“From seeing and speaking to people they could relate to, and seeing facilities and showing them what’s on offer, it has really opened their eyes to the opportunities that are there.”

Current demographics of the AMRC Training Centre, and among other STEM related subjects, remains predominantly and stubbornly male. This environment can be a powerful deterrent to young women identifying and choosing engineering as a compelling and attractive career choice.

“Put simply, there are not enough female engineers in the UK,” said Rahul, who spoke to the girls about his role at the Nuclear AMRC and, of course, his passion for the science of baking. “The AMRC wants to help change that and I want to do everything I can to encourage young women to think about taking up engineering and encourage them towards STEM subjects.”

The launch fittingly took place during International Women in Engineering week and was attended by 60 girls from six schools across the Sheffield City Region who gathered at the AMRC’s Knowledge Transfer Centre to learn more about #AMRCtribe and how they can benefit from being part of the group.

The schoolgirls were given tours across the AMRC campus to see first-hand some of the advanced technologies being developed by our researchers and engineers, such as 3D printing and Virtual Reality.

A group activity saw the girls working in mixed teams to build a model wheel, similar in structure to the London Eye, using basic materials such as paper, masking tape, nuts and bolts, string and elastic bands. The task was not an easy one, requiring a high level of accuracy and precision, great teamwork and motivation to get the job done.

Emma Pennington, 14, of Silverdale School, who led her team in the activity, said: “I think the tribe is a really good idea because people can connect with other people. I liked seeing the AMRC too, it’s a really cool place. There’s a lot of technology here that you don’t get to see at school. It gives you an idea of what there is out there and about engineering.”

The campaign is being led by the AMRC Training Centre and AMRC STEM and outreach team and also involves female apprentices from the training centre who will be part of the social media group, acting as mentors to the members.

Ami Swales, from the AMRC STEM and Outreach Team, said: “Currently only 11 per cent of the workforce in engineering is female which is much lower than other countries in Europe. We realise we need to act and promote positive role models and introduce the concept of engineering as a career to young women at school age.

“From our work in going out to schools across the city region, we found that within many of the schools there were pockets of young people that had an

be
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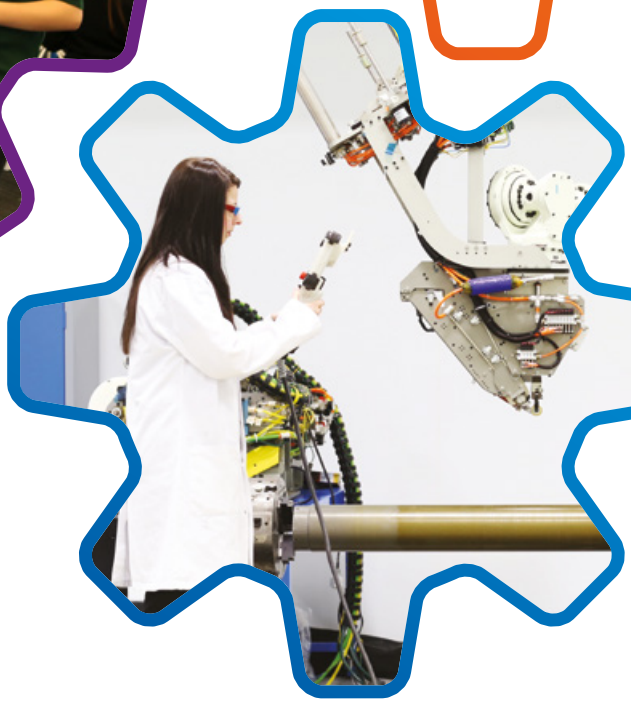


interest in STEM subjects but because that wasn't shared by their peers they didn't go on to study those subjects.

"That's why we decided to do something about it by creating the #AMRCtribe, a close knit, supportive forum for likeminded girls so they have somewhere to talk to each other and encourage each other.

"It is about raising awareness of STEM in a way that is attractive to young women and overcoming the predominantly male stereotypes that dominate the sector.

"The goal for us is to get more women into STEM careers no matter what the route they take to get there. We think this will open up a new world of opportunities for young women and provide the wider UK industrial base with the diverse and talented workforce it needs to grow and prosper in a sustainable way."

#AMRCtribe

A seismic impact on the region

'Skilled, confident and without limitations' – that's how HM Lord Lieutenant of South Yorkshire described apprentices following a visit to the AMRC Training Centre.

HM Lord Lieutenant Andrew Coombe took time away from his usual Royal duties to visit the training centre on a fact-finding mission having met centre director, Nikki Jones, at the opening of Boeing Sheffield last year.

Mr Coombe was given a tour of the impressive training facilities before meeting with apprentices from companies including AESSEAL, Arconic, Polypipe and X-Cel Superturn to learn about their personal journeys into engineering.

Duncan Cosgrove, a 35-year-old apprentice with AESSEAL, told Mr Coombe his first steps came at a job matching event run by the training centre and that he is now working with one of the most advanced engineering companies in the region exporting high-value products around the world.

Mr Coombe told the apprentices they have a world of opportunity ahead of them: "Engineering is 'wow' and not the dirty profession some people may think it is. You will have a job and be held in high regard and high demand."

He added: "I used to be a corporate lawyer and I found that the most interesting and dynamic people were those who left education with a clear vision and after training started a company and worked and worked - companies like Polypipe and AESSEAL which started on a kitchen table from nothing and are now global and in a number of countries with high turnovers and are hugely successful.

"What I'm saying is you may be engineers now but you don't know where your ceiling is and with the confidence you gain here and in work you'll probably knock through that ceiling and keep developing.

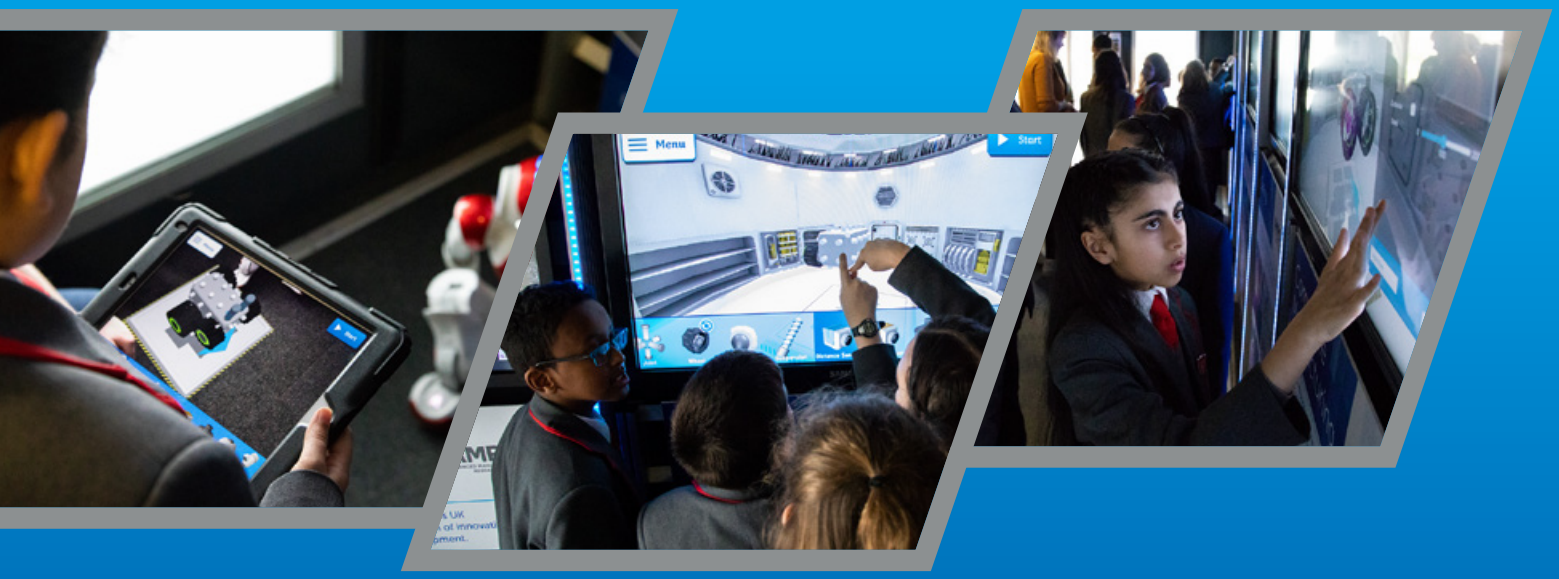
"If I could give you one piece of advice it would be this: a person that never did anything never made a mistake. If you have courage to go for something and have reasoned it through and it doesn't work - it's not a failure. Do not be frightened of failure because it's through failure you often succeed."

He sat down with Nikki to find out more about the centre's ambitions and her vision for its future. When Mr Coombe asked what her 'three wishes' would be for the AMRC Training Centre, she told him: "The first is to be able to provide more places for more learners. Second would be that the facility is big enough so that we can further develop skills for Industry 4.0. The third would be to engage more females and those from BME groups. Along with that, I would ask for employers to pledge to continue taking on a diverse workforce."

The Lord Lieutenant also spoke about the powerful, magnetic effect the AMRC has had in attracting inward investment to the area, making special mention of the new McLaren and Boeing facilities whose highly skilled workforces are made up of apprentices from the AMRC Training Centre.

"I think the impact the AMRC has had is seismic. It has been a real beacon of light again for the area and you as apprentices are in the right place at the right time," he said. "People are saying we want to come to Sheffield not just because of the AMRC but because of the AMRC's training facilities."

Impressed: HM Lord Lieutenant of South Yorkshire Andrew Coombe with AMRC Training Centre Director Nikki Jones and the centre's programme manager Dan Swift during the visit.



MANTRA brings Mars to Mercia

The AMRC's MANTRA truck was a fitting backdrop for the local launch of a national robotic design competition to help schoolchildren hone their scientific thinking and develop their talent in engineering.

The technology-packed trailer, owned by the University of Sheffield Advanced Manufacturing Research Centre, rolled up to Mercia School in Sheffield to help launch the School Robot Competition based on an augmented reality (AR) online game developed by educational publishers Twinkl and the EPSRC UK Robotics and Autonomous Systems Network (UK-RAS Network).

Pupils gained hands-on experience with some of the latest manufacturing machinery and simulators on MANTRA as part of the launch event for the competition, which invited children aged eight and 14 to design a robot that can move across Mars and complete various tasks and challenges on the planet's surface.

Debra Gisby, Training and Skills Coordinator at the AMRC, said staff were delighted to take part in the competition and praised the pupils for their boundless enthusiasm.

"Mercia School has previously hosted a MANTRA technology visit and the school pupils and teachers are so open to trying out new technologies so that's why it was our first choice," she said.

"Using the Twinkl Robotics app – a first-of-its-kind educational game that uses the latest AR technology to support science, technology, engineering and maths (STEM) learning– the students were invited to explore a variation of skills using MANTRA's on-board touch screens and Twinkl's iPads.

"The children quickly demonstrated their skills and began to build and modify their own Mars Rover explorers, and some pupils were able to achieve the higher levels of construction and durability while travelling along the virtual surface of Mars. Everyone enjoyed the whole experience and we're looking forward to hearing the announcement of this year's winners."

The competition, through building robots, helps schoolchildren learn robotic technology fundamentals and research skills, and gives them the opportunity to explore their creativity and learn the joy of engineering.

It is one of a series of activities that takes place as part of UK Robotics Week, organised annually by the EPSRC UK-RAS Network.

Winners were announced at the International Robotics Showcase – the highlight event of UK Robotics Week – held at the Royal Geographical Society in London last month.

The School Robot Competition AR platform – also available as an app – offers a range of components to build, program and test robot designs, spanning: 'build mode' connecting sensors and motors to a base block; 'program mode' inputting coding to determine how the robot moves; and 'play mode' testing the robot's ability to complete various challenges on Mars.

Chief Technology Officer for Twinkl, Pete Casson, said: "Twinkl was set the challenge by the EPSRC UK-RAS Network of inspiring children to become science and technology leaders – a challenge that we're already well-versed in. Our solution was to use our world-first AR technology to bring coding and robotics to schoolchildren in a way that puts collaboration and communication first.

"Our latest app achieves these goals on an inclusive platform that is accessible to all learners – building confidence in those looking to learn whilst challenging children with skills to showcase."

Professor Guang-Zhong Yang, Chair of the EPSRC UK-RAS Network, added: "This partnership between Twinkl and the EPSRC UK-RAS Network has delivered a fantastic AR platform that will enable schoolchildren to develop important STEM capabilities in programming, debugging, engineering and the fundamentals of robotics development.

"However, this competition aims to do more than develop STEM skills – it aims to develop confidence, communication, cooperation and leadership skills, and to inspire schoolchildren as science and technology leaders as well as innovators of the future."

AMRC helps piano designs hit right note

Schoolchildren who invented whacky extendable mechanical fingers for a record-breaking attempt to have 88 young musicians playing the same piano have been busy refining their designs with the help of AMRC engineers.

Pupils at Brockwell Junior School in Chesterfield are working with University of Sheffield Advanced Manufacturing Research Centre (AMRC) engineers to bring their imaginative designs to life, which were chosen from 2,200 entries from around the country to be part of the world record attempt taking place in August.

The youngsters pushed the boundaries of creativity to come up with the 'Metal Cog Thingie' and 'Scissor Jack' designs, which will make up the final ensemble of 88 mechanisms used to play each note and smash the current record of 21 people playing the same piano.

To make sure Brockwell's designs don't strike a duff note, the children spent the day working with AMRC engineers to figure out exactly how the mechanisms will work in practice.

Saeed Rajabi, AMRC graduate engineer, said having helped the budding engineers come up with their original designs, it was great to go back to the school and further develop their inspiring ideas.

He said: "We congratulated the school for having two wonderful winning ideas that will be used in the final 88 Pianists' world record attempt. We spent most of the day trying to further develop these two designs.

"We needed the pupils' help in overcoming some challenging problems such as working out which parts of the designs are essential to play the piano and which are decoration.

"We also needed to work out how it will stand up, stay still and fit into the space, how we can make it and ensure it is easy to play, what sort of musical effects the mechanism can create, and, importantly, what could go wrong and how can we can stop this from happening.

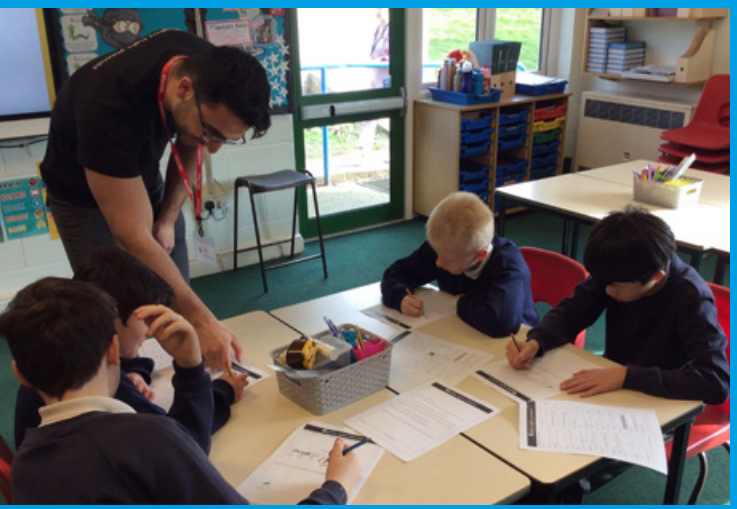
"The day was very productive and the students were very committed to helping us come up with amazing ideas that will help us build and assemble the mechanisms.

"We can definitely see some bright future engineers and musicians at Brockwell Junior School. We will be visiting them again very soon as we will be needing their help assembling and decorating the mechanisms."

The children completed a special handbook that Saeed and other engineers will use to make sure they order the right materials and machine the right parts to build the mechanisms. Once finished, Saeed and the AMRC team will go back to the school to assemble the parts and bring the designs to life.

Once built, Brockwell and other schools' finished finger extenders will be taken to Birmingham where 88 young piano students will be taught how to use them to play a newly commissioned piece composed by Martin Riley and conducted by Julian Lloyd Webber.

The '88 Pianists' project is the brainchild of University of Cambridge Professor of Engineering and the Environment, Julian Allwood, who wanted to



Left: Saeed Rajabi, AMRC graduate engineer, working with Brockwell pupils.
Right: The mechanisms being assembled at the 88 Pianist lab at the University of Cambrudge Department of Engineering.

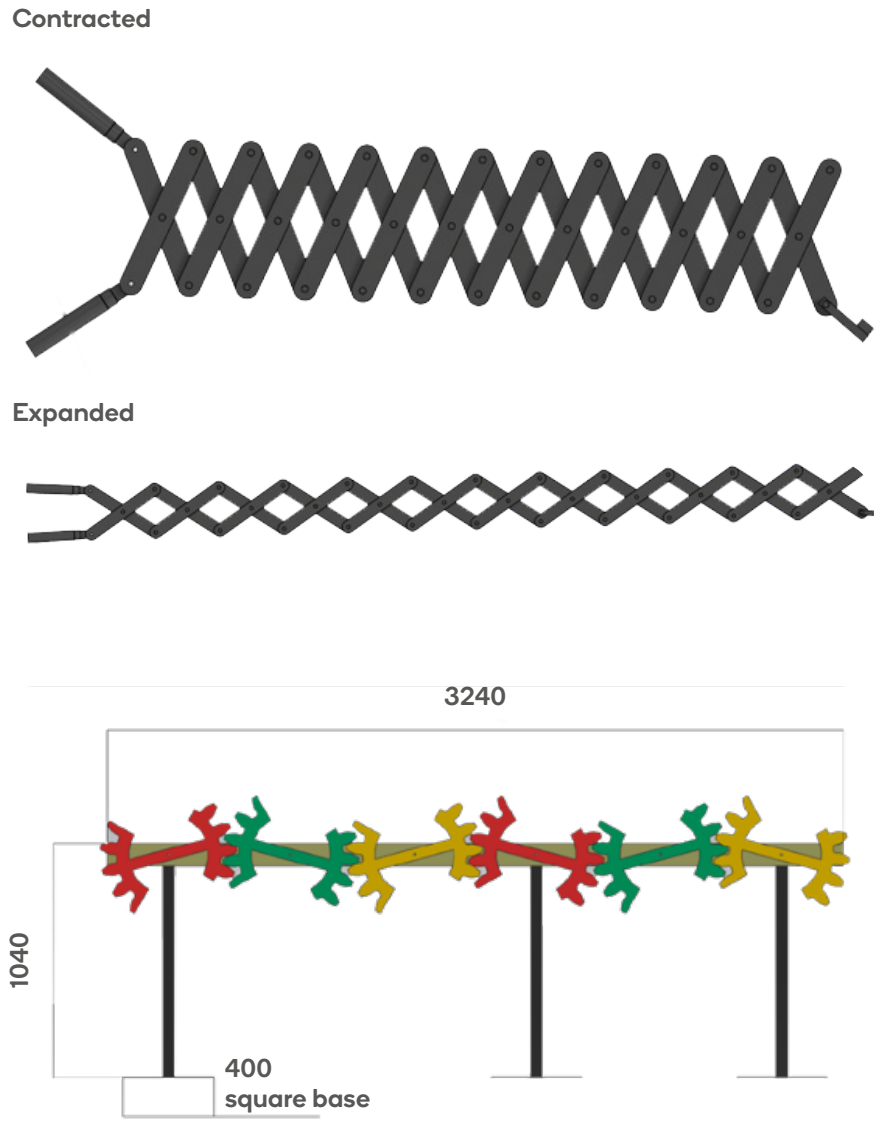
both mark the 500th anniversary of Leonardo da Vinci's death and answer a simple question: has the smart phone killed invention?

To find the answer engineering researchers at the AMRC, and seven other universities, were challenged to support Key Stage 2 children from across the country to 'fuse science and art' and beat the current world record. The attempt will be made at the opening ceremony of the 69th CIRP (The International Academy for Production Engineering) General Assembly on August 19 in Birmingham.

Senior Technical Fellow, Dr Erdem Ozturk, who is conducting the AMRC's contribution to the project, said: "There is potential in every child to be an inventor. Our role is to unlock that inventive, problem solving impulse and to challenge perceptions about engineering in the classroom: and what better way to do that than by combining science, technology, engineering and mathematics (STEM) with art and music.

"As engineers at the AMRC, we have the opportunity to be great STEM ambassadors, and we are keen to help foster the children's sense of creativity by showing that seemingly different subjects like music and engineering have something in common: creativity.

"It will be great to go back to the schools and help the children manufacture the winning designs, getting them involved in the process from start to finish will give them a real sense of achievement to see their designs come to life for the world-record attempt."



The two winning designs: Scissor Jack (top) and Metal Cog Thingie (above) created as CAD drawings.

Award recognises AMRC's commitment to gender equality

The Advanced Manufacturing Research Centre's commitment to supporting the talents and potential of women in engineering has been recognised with its first Athena SWAN Charter Bronze Award for advancing gender equality.

The flagship scheme was set up in 2005 to encourage and recognise commitment to advancing the careers of women in science, technology, engineering, maths and medicine (STEMM) employment in higher education and research institutions.

The bronze award given to the University of Sheffield AMRC recognises institutions that have a solid foundation for eliminating gender bias and developing an inclusive culture that values all staff. It recognises that the AMRC Group is working to promote gender equality and identify and address challenges particular to the AMRC and engineering.

Dr Nicola Ridgway, who leads the Athena SWAN programme at the AMRC, said: "I am very proud that the AMRC's commitment to gender equality and diversity has been recognised in this Bronze Athena SWAN award. We have made great strides, but this is just the beginning of our journey. The ethos of Athena SWAN is now part of our culture and we are determined to go further in improving equality across the AMRC and engineering in general."

AMRC Executive Dean, Prof Keith Ridgway, added: "This is fabulous news for us. Our global partners are not only leaders in their industrial sectors, they are also leaders in encouraging gender equality and diversity in their organisations. Like them, we know how important it is for advanced manufacturing to attract and grow the very best talent: and this means opening access to all.

"We are investing heavily in our STEM and outreach work in the region's schools. This is already changing the perception of engineering among teachers, parents and pupils, opening up new opportunities to communities with diverse populations in some of our more disadvantaged areas.

"The AMRC Training Centre is key to this, with high-quality apprenticeships providing clear pathways to higher education and degree qualifications, thus promoting social mobility across the region."

The award application was written by a dedicated team chaired by Nicola and co-chaired by the AMRC's Chief Executive Officer Colin Sirett.

Nicola said: "We first began this process in 2016 and have been working for two years analysing staff data and feedback from staff questionnaires, as well as discussing the best route forward.

"One of our first large actions was investing heavily in the AMRC STEM and outreach team and building on the success of MANTRA, as encouraging more people into engineering really is key for us.

"Since the STEM team was established in April last year, it has engaged with thousands of school children from right across the Sheffield City Region, inspiring our young people to explore the opportunities of a career in STEM.

"We've also given our full support and backing to important initiatives such as Primary Engineer and Get Up To Speed with STEM and have 'Women in Engineering' events in the pipeline as part of our drive to encourage more females to consider a career in engineering."

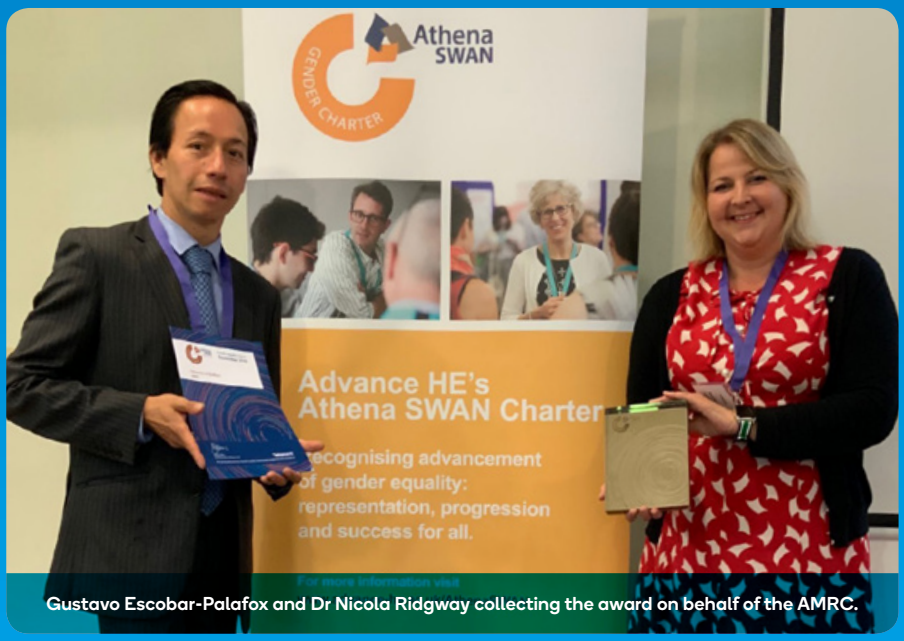
In terms of good practice, the AMRC has drawn up a targeted action plan that focuses on four key areas:

- Improving the AMRC culture and inclusivity
- Increase diversity in engineering by improving education and outreach
- Ensure improvements in under-represented groups by improving careers
- Promotion of equality and family-friendly policies.

The Bronze Award is valid until November 2022 but the AMRC is not resting on its laurels and in this time will be working towards achieving the Silver Award.

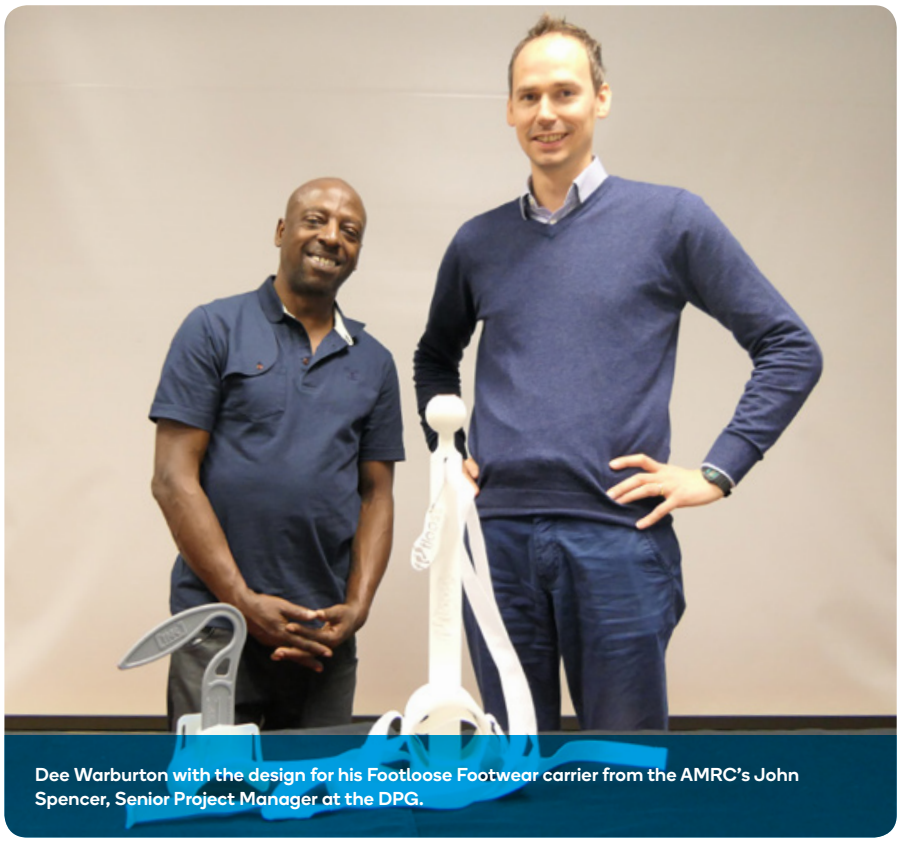
The AMRC accreditation comes at the same time as the University of Sheffield had its Silver institutional award renewed until 2022, making it one of only 18 universities to hold the accolade.

Advance HE, which runs the Athena SWAN Charter, awarded official recognition of the AMRC and the university's achievements at a ceremony held in York.



Gustavo Escobar-Palafox and Dr Nicola Ridgway collecting the award on behalf of the AMRC.

AMRC gets a kick out of luxury footwear carrier project



Dee Warburton with the design for his Footloose Footwear carrier from the AMRC's John Spencer, Senior Project Manager at the DPG.

Engineers from the AMRC put their best foot forward to help develop a luxury sports shoe carrier for injection moulding manufacture by reducing the number of components by half.

Infinite Kreationz approached the Design and Prototyping Group (DPG) at the University of Sheffield Advanced Manufacturing Research Centre (AMRC) to further develop a proof-of-concept model by identifying design changes to make it manufacture ready.

DPG Design Engineer, Valdis Krumins, looked at the handle design, an alternative to using straps for securing footwear in the carrier, as well as the hook and stand design.

Dee Warburton, creative director of Infinite Kreationz, provided a Selective Laser Sintered (SLS) model to demonstrate the concept which the DPG then refined, creating a carrier made up of just three parts rather than the six in the proof-of-concept model. This meant just two injection mould tools would be needed for manufacture because two of the three parts share the same geometry.

The demonstrator was 3D printed in polymer as it allowed the team to make a functional prototype straight away in order to assess the functionality of the design without having to cut metal to create a mould tool.

John Spencer, Senior Project Manager at the DPG, said: "One of the main barriers for start-up companies launching a plastic moulded product is the initial investment in tooling. We were able to review Dee's initial design with a view to reducing the number of components and simplifying their geometry, without compromising the functionality of the product. This led to a reduction in the complexity and number of injection mould tools that would be required to manufacture the suite of components, optimising the assembly for volume manufacture.

"Dee now has a benchmark design he can take to tool-makers. Further design changes can be made with an idea of the impact of these on tooling and piece-part cost, enabling the company to make informed decisions before proceeding to manufacture."

Valdis added: "The original carrier model was made up of six components and these hadn't been designed to be injection moulded, so the whole assembly was redesigned to reduce the overall number of components by half and optimise each component for manufacture. A new method of securing the footwear was designed, removing the need for straps and allowing easy adjustment for different shoe sizes."

Dee, who is the brains behind the Footloose Footwear Carrier, said help from the AMRC to further develop his design and prototype not only resulted in the overall original design being successfully reduced but the final product remained fully functional, practical, innovative and more environmentally friendly.

"The Footloose Footwear Carrier, which was inspired during my time touring Europe in the early 1990s as a professional Street Dancer for Warp Records, is aimed at the fashion-conscious, luxury sports footwear market, alongside footballers, tennis players and other active lifestyle users wanting to carry their footwear in style," said Dee.

"The advice provided during the one-to-one meetings was invaluable and the technical CAD services were of the highest quality and second to none in professionalism and expertise.

"I would highly recommend the services of the University of Sheffield AMRC to anyone requiring advanced manufacturing research or design services – they exceeded expectations and provided the high quality services needed to develop, produce and market new products successfully.

"I'm now in the process of finalising the design to progress onto the next product development stage of tooling and production in England using recyclable and sustainable environmentally friendly materials."

Dee is aiming to fund the next stage of the Footloose Footwear Carrier's development via an online crowd funding campaign.

Sun brings cool solution to vaccine storage problem

'World-class' and a 'breath of fresh air' is how researchers at the University of Sheffield AMRC were described by a renewable energy start-up whose solar refrigeration technology could be used to store life-saving vaccines and vital food in some of the hottest and most remote places on earth.

Solar-Polar, a Peterborough-based company on a mission to take solar cooling to the developing world, approached the AMRC's Design and Prototyping Group (DPG) to request design assistance to help cut volume manufacturing costs for its innovative cooling system.

John Spencer, Senior Project Manager at the DPG said: "Solar-Polar's technology offers the flexibility and potential to be scaled up to target specific applications, such as bulk storage of vaccines. This off-grid renewable cooling system, functioning from solar energy alone and removing the reliance upon mains electricity, provides a secure, low-cost and low carbon solution to the fundamental problem of vaccine refrigeration and food storage."

Countries of high climatic temperature, particularly in remote regions with limited or no mains electricity, require an alternative means of refrigeration and air conditioning. Solar power may seem an obvious choice but solar-powered refrigeration systems rely on photovoltaic panels, control systems, batteries and moving mechanical parts prone to wear and failure, requiring regular maintenance.

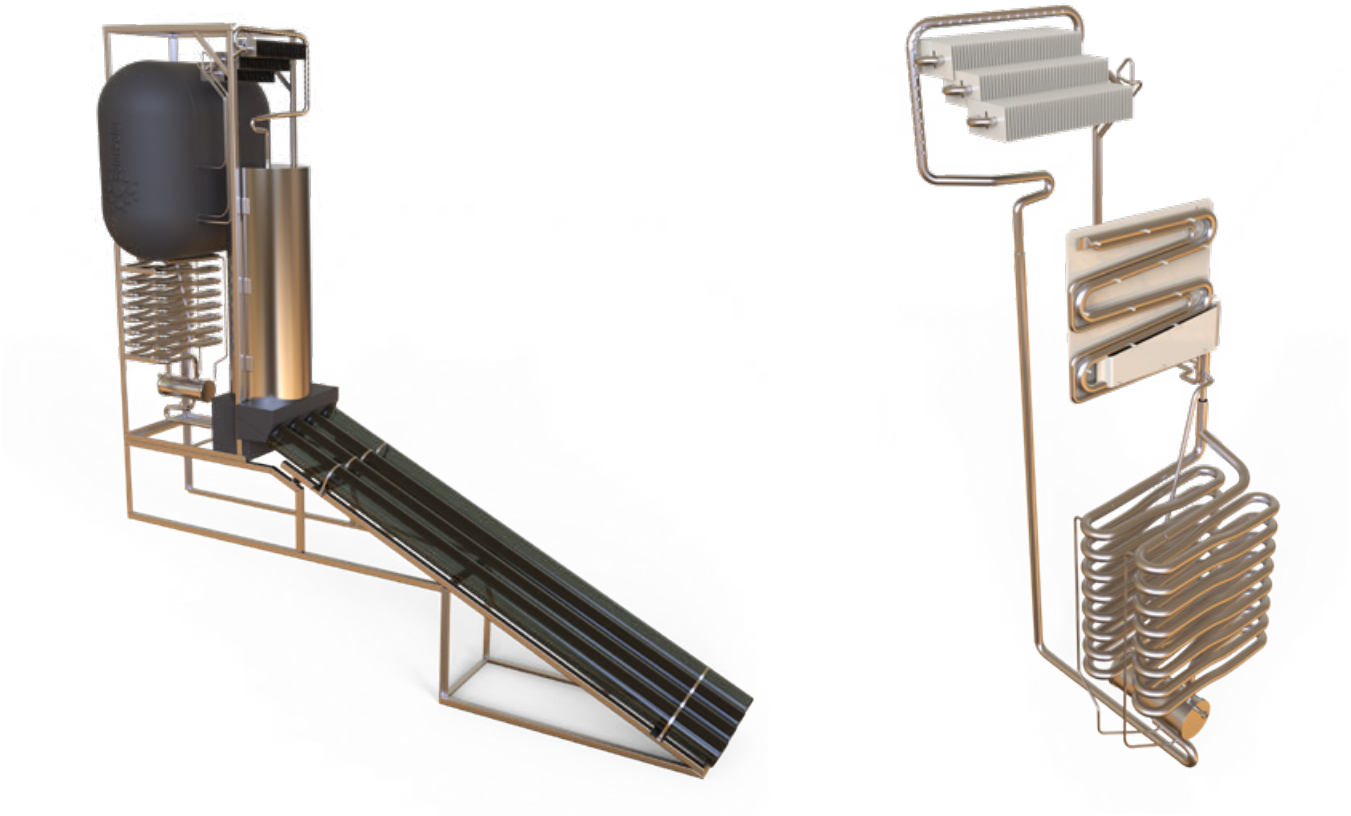
Solar-Polar has invented a technology that provides a robust electricity-free, purely thermal alternative but needed help to simplify its design to make it cheaper to mass manufacture.

The project, carried out through a Catapult-funded SME scheme run by the Advanced Manufacturing Research Centre (AMRC), involved reviewing selected components in the cooler assembly to reduce manufacturing costs. Conceptual ideas around changes to the existing design were also proposed.

Michael Reid, Engineering Director at Solar-Polar, said: "The AMRC is a breath of fresh air when it comes to assistance for small start-ups. The engineers we dealt with were extremely quick to understand what we needed and their work was world-class.

"We were recommended to the AMRC by a business contact because we needed to get an up-to-date idea of how our product might be made in volume and at a low mass-production cost.

"As a start-up on our way to a high volume product we were keen to deal with an organisation who not only knew manufacturing intimately but were able to rapidly grasp what we needed and



The Solar-Polar designs were provided to the DPG team to provide a high-level review and suggest conceptual design changes that may yield a volume manufacturing cost benefit.

deliver answers quickly and effectively.

"We weren't disappointed. The report we got not only gave us the answers but was also a document that we have been able to share with partners and investors."

A number of key system components were identified for consideration by the DPG team. The work resulted in a number of recommendations being made to reduce complexity, and in turn manufacturing costs, including concept design recommendations for future development.

AMRC research engineer Matthew Wilkinson said: "The project was about assessing Solar-Polar's initial system design from a volume manufacturing perspective, and identifying the components that would be challenging and costly to mass produce, providing suggestions for design changes based upon target production volumes.

"The reduction of complexity in a system can significantly lower manufacturing costs, such as combining parts or removing unnecessary components. The standardisation of parts can also reduce complexity because common components can be used multiple times throughout the system, reducing tooling and manufacturing cost."

The DPG has worked with Solar-Polar and other research organisations to submit a project proposal to Innovate UK to carry out the detailed design and development work packages necessary to advance the technology to a pre-production stage.

John Spencer added: "The SME assist undertaken for the company was a small package of work, focused on a select number of components. A much larger project is required to advance the suggested design changes and develop the rest of the system.

"If the final system can be manufactured at the required volumes and cost, it has the potential to radically improve the lives of rural households, communities and farmers in Africa and South Asia, as well as others in remote regions.

"By developing the system to a stage where it can be cost-effectively manufactured in volume, its potential can be realised for the benefit of communities unable to access affordable means of cooling, particularly in the growing rural populations of sub-Saharan Africa, where access to electricity is only available to a small minority.

"At a local level, the project will further promote the capabilities of the AMRC to SMEs. It will provide a clear product development route for companies working to tackle the physical challenges affecting developing countries."

Solar-Polar's Michael Reid and Robert Edwards with the innovative system following installation on a rooftop in Ahmadabad.

Medical students flying high with aid supply drone

Medical students who won UK Space Agency funding to develop a drone that delivers medical supplies to emergencies and remote areas are flying high after help from the AMRC in creating concept designs for the unmanned aircraft.

Schoolboy friends and current medical students, Thomas Franchi (University of Sheffield), Hammad Jeilani and Chris Law (both Barts and The London School of Medicine and Dentistry), set up the company MEDeus to create their drone and medical box system, MEDrone and MEDiBox respectively.

The two systems are used together to deliver medical items between GP services, hospitals and NHS Trusts in rural and congested city locations and for a range of situations – from blood samples and emergency medical equipment such as defibrillators, to life-saving organ transplant transit.

MEDeus asked the AMRC's Design and Prototyping Group (DPG) for CAD and early-stage graphical design assistance for the drone. They worked with Samuel Rees, Senior Project Engineer at the DPG, and Principal Engineer Garth Nicholson, who built on the research provided by MEDeus to produce a series of still images that could be collated in a 'storyboard' format to illustrate the drone's potential applications.

Samuel said: "Prior to us helping they had a document which explained the problems they were trying to overcome and the solutions they had developed. It had a few diagrams in it but overall the document was very wordy.

"They were concerned their idea was being 'lost' in the document and that it didn't have the visual impact or tell the story in a particularly compelling way; they were presenting lots of text that didn't necessarily engage people's enthusiasm and imagination.

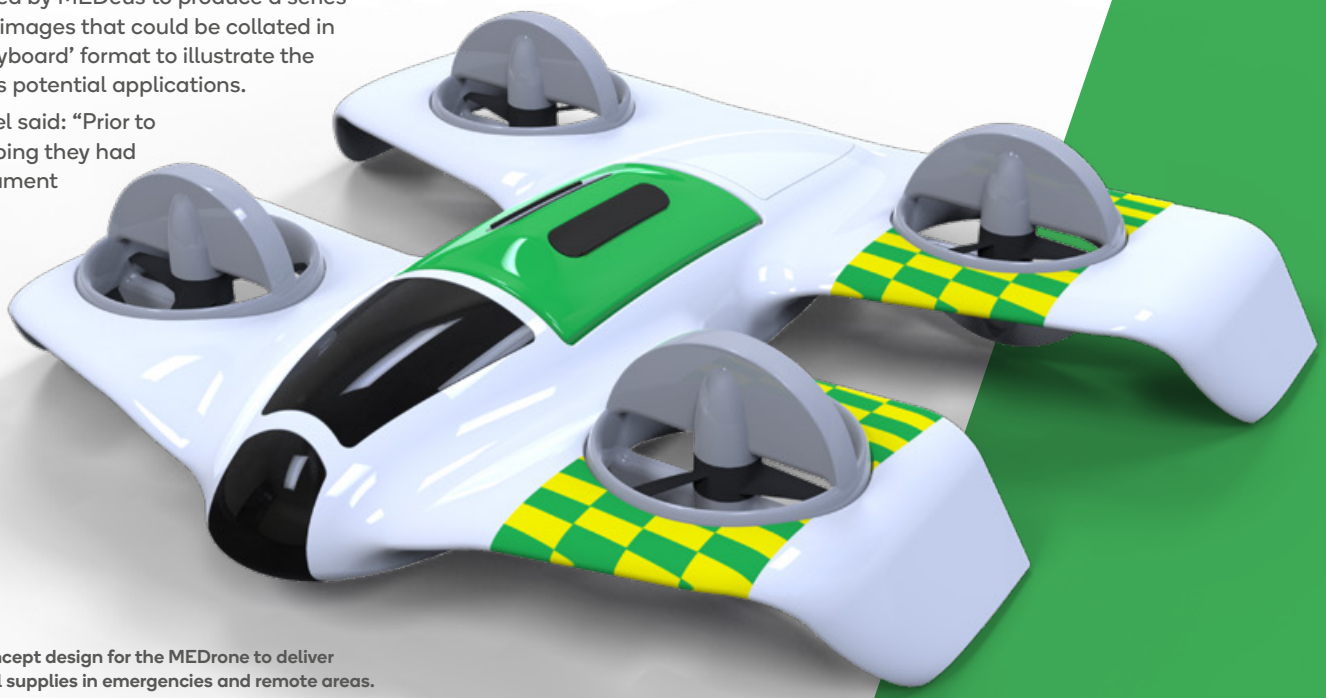
"They also had a technical problem they needed the AMRC to solve as they had envisaged a quadcopter as the type of drone they wanted to use, so we worked through some concept designs we thought would best suit the applications proposed for the MEDrone."

The main challenge was to have a drone that can travel over long distances efficiently and economically and then be able to land easily in what could be close quarters with buildings or in difficult situations.

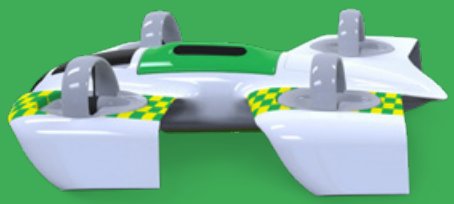
To do this Samuel and Garth came up with an innovative solution that incorporated the fans into the tandem wings.

Samuel said: "It took a few different concepts to get there and it brings together a few different ideas: a tandem wing design with the fans within the wings which allows a principle called 'blown wing' to occur so you have forced airflow over a wing and that generates its own lift.

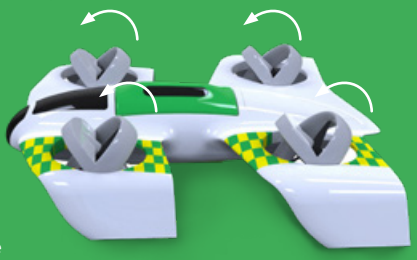
"This design also has vectoring fans; they can rotate between pointing downwards or pointing backwards so you can have vertical flight, operating like a quadcopter,



The concept design for the MEDrone to deliver medical supplies in emergencies and remote areas.



Vectoring fans rotate between pointing downwards or pointing backwards allowing vertical flight and can land in inaccessible locations.



and land in a really tight spot in what might be difficult wind conditions as they are relatively stable in that way. It can then transition from vertical flight to horizontal flight and with that you have the advantages of the wings working like a regular plane.

"MEDeus had envisaged using a quadcopter for their drone design but for travelling long distances it is a bit of a non-starter because it's really inefficient. They are quite good at lifting but not very efficient for moving sideways whereas something like this design – where you have got a streamlined body, streamlined wings and using the wing lift to give it the lift and the fans to push it forward – it can fly fast and quite efficiently, allowing it to travel those long distances required.

"We have built quadcopters and they are a known technology, but what is less certain is where the fans point straight backwards – that's new. There have been tandem wing aircraft where the fans were on the tips of the wing but they are not within the wings – we are effectively trying out something new here so we need to see if that works.

"The next stage would be to develop a prototype. The physics of this model need to be understood properly first and a prototype designed around that. Then it would be a case of test it and fly it."

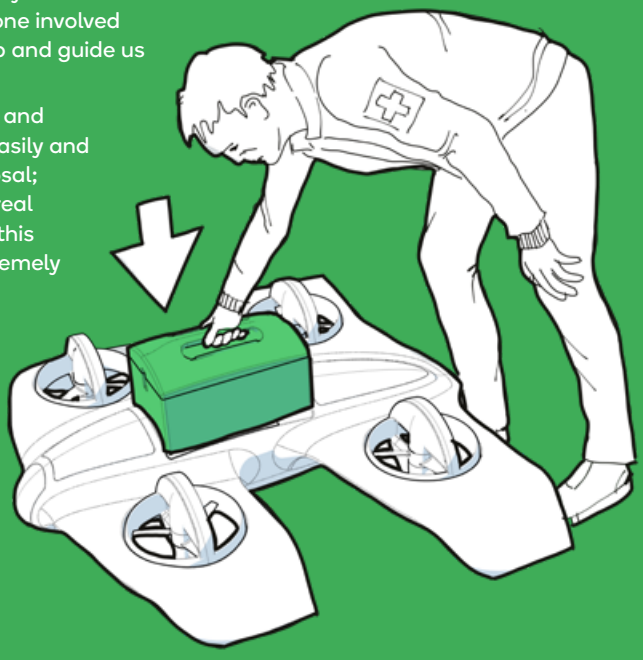
The UK space industry is a lucrative market and huge success story for the UK, supporting 38,000 jobs and generating some £14 billion in revenue across the country – and with help from the AMRC, the medical students are making good progress turning their ideas into reality.

Furthermore, they're working at the Westcott Business Incubation Centre to build their business case and are collaborating with NIHR MedTech Cooperatives.

Thomas, Hammad and Chris, who went to school together at Dulwich College and have been friends for almost a decade, said: "We have always had a strong interest in engineering and through this project we're combining our knowledge and skills in medicine and public health issues with our technical mind-sets to develop a meaningful and impactful service model.

"We approached the AMRC as it was evident they are the experts in design and prototyping. Having read about previous projects, we knew they had the capabilities we needed," said Thomas. "Our experience of working with the team went far beyond our expectations, and everyone involved put in 110 per cent to help and guide us through the process.

"We've used the designs and storyboards created to easily and quickly portray our proposal; something which was a real challenge to do without this visual display. We're extremely grateful to the AMRC for giving us this five-day SME assist, and hope to continue working alongside the AMRC as we progress."



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