the ENGINEER

collaborate to innovate

A celebration of the UK's most innovative engineering collaborations

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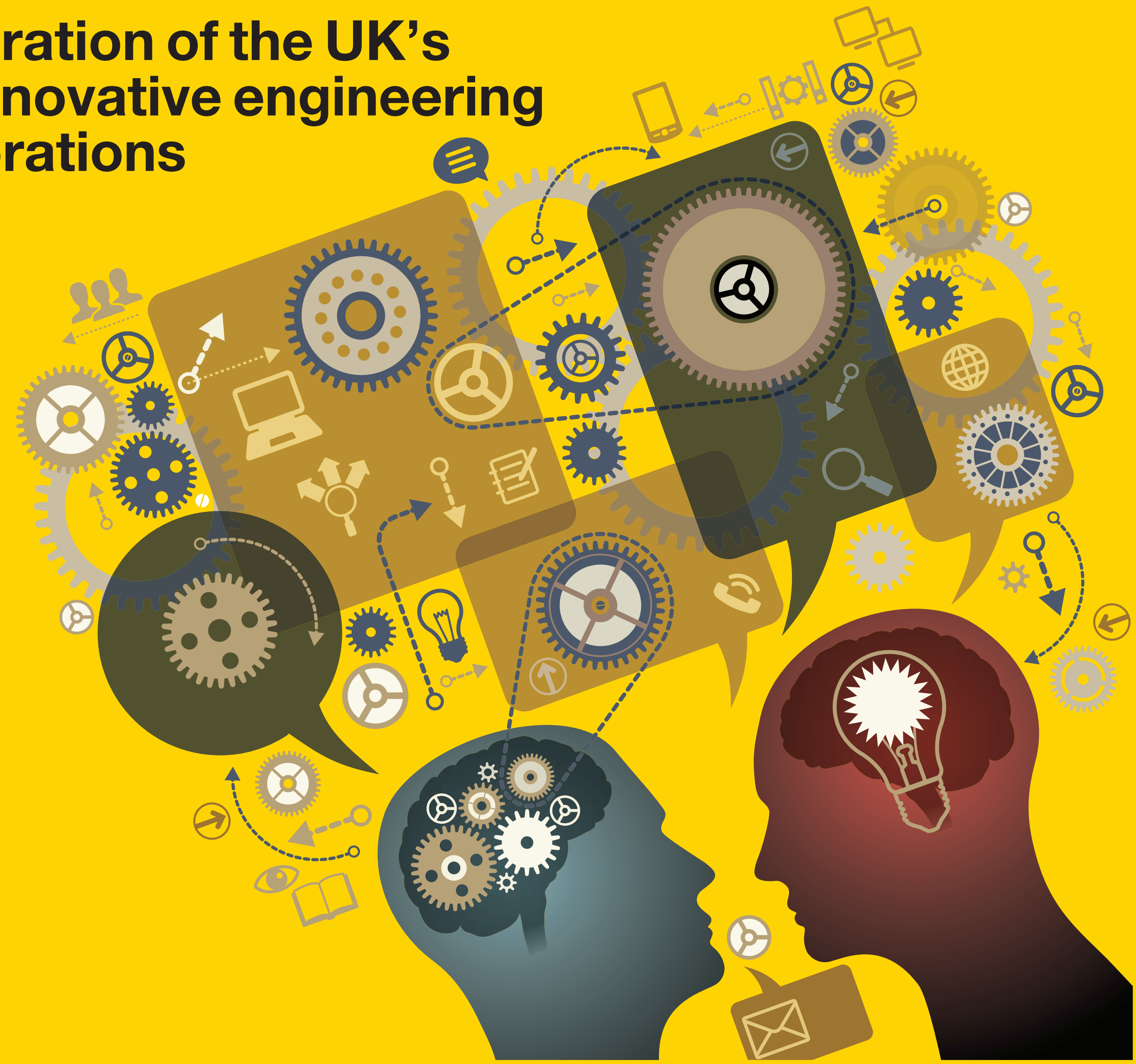

Meet the **judges**

Many thanks to our esteemed panel of judges for picking this year's winning entries

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collaborate to innovate

our opinion

A meeting of minds

This book is a celebration of something that the UK engineering community is particularly good at: collaboration — a meeting of mindsets, ideas and different types of expertise that provides the spark for great innovation.

We often hear about the challenges industry faces attracting the next generation of engineers, and some commentators have bemoaned the absence of a modern-day Brunel or Bazalgette to fly the flag for the profession.

But this desperate search for an industry superstar misses the point. In contrast to many other sectors, the world of modern engineering is, in general, refreshingly light on egos. Indeed, the amazing engineering projects and breakthroughs of the 21st century are rarely the result of one person's ambition but the product of teamwork. It's perhaps harder to spin into a bite-sized headline and doesn't play to today's x-factor narrative but it's surely a far more inspiring and appealing message.

Collaboration in all its forms, whether it's between separate businesses, or businesses and academia, is perhaps the single-most-important ingredient in addressing some of the big challenges we face in the future: from the need to develop cleaner forms of power generation and efficient transport systems to the requirement for healthcare technology that can help reduce the demands of an ageing population.

What's more, as we begin to look at how the UK can continue to maintain its edge outside of Europe the process and skill of forming relationships, and finding new ways of working together, has arguably never been more important.

> "The world of modern engineering is, in general, light on egos"

Collaborate to Innovate was launched to celebrate this critical dynamic and — through an exhaustive awards programme — uncover some of the most impressive and exciting examples of UK-led engineering collaboration.

The stories over the following pages are the fruits of this process. Between them they shed light on the richness of the UK's academic/business collaboration; the value of bringing together specialists from different disciplines; and the ways in which engineers are applying emerging technologies to solve society's most pressing problems. We hope you find these stories illuminating, inspiring and, above all, useful.

Finally, we'd like to say a huge thank you to all of the judges, sponsors, engineers and researchers who have helped make Collaborate to Innovate such a fascinating and rewarding initiative.

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UK subscriptions £75 pa UK/£117 pa overseas. Order online at www.theengineer.co.uk/subscribe or by telephone on +44 (0207) 292 3705.

ISSN 0013-7758. Printed by Headley Brothers Ltd, Ashford TN24 8HH **Visit www.theengineer.co.uk for constantly updated news, products and jobs and to sign up for our FREE weekly email newsletter and tailored job alerts**

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The forces that drive success

For firms such as Frazer-Nash, collaboration is an essential part of innovation, enabling growth and forward movement

Innovation and collaboration are the forces that drive success in the commercial world. Without the drive of innovation, forward movement stalls and other businesses speed ahead, leaving you way behind. And the engine that powers innovation is collaboration – joining skills and bringing them from one place to another delivers the momentum that takes you towards your destination.

The themes of *The Engineer*'s Collaborate to Innovate conference and awards are, for companies such as Frazer-Nash, at the heart of business. Collaboration happens every day in our projects: with academia, industry and the supply chain, internally and with our clients, within the UK and overseas. Whether we're discussing additive manufacturing solutions with Caterham Cars, corrosion sensors with the University of Southampton or advanced modelling with industry colleagues, building collaborative networks enables movement and growth – of people, ideas, goods and services.

So why do businesses and individuals collaborate? Because there are good reasons for developing new ideas, in the broadest, most creative way.

In academia, 90 per cent of cutting-edge research doesn't get exploited to its full commercial potential. An academic with a bright idea, which they want to commercialise, must go through a whole cycle to grow a business – from securing angel investors to venture capital investment and, ultimately perhaps, flotation on the stock exchange.

To combat this, the collaboration between the innovator and the commercial world – the money people – needs to be much tighter. The conversation between investor and innovator should take place right at the start. Pitching an idea, as in TV programme *Dragon's Den*, can end up being a binary transaction: "I've got a new innovation. Do you want to put some money behind it?" And a 'no' can stop even a great idea in its tracks.

But the support needed isn't always financial. On *Dragon's Den*, you frequently hear the person pitching say: "It's not the money I'm here for; it's your expertise." Imagine how much further they could get if that expertise was injected into the process from the start.

Getting in commercial expertise early enables the investor to provide advice on the best route to creating a successful market offering, and gives the innovator the power to take forward their idea with a fully formed product and business plan.

This may become even more important in a post-Brexit world if European funding for research is reduced. A greater commercial focus earlier in the process may become a necessary part of ensuring that innovative research and development continues.

If collaboration and innovation are the driving forces, a commercial focus offers a steering mechanism. Whether you're researching the nature of reality at CERN or your research has a more pragmatic application, you need to be thinking: where is this heading, what may this ultimately lead to, what will I be able to do with it? Every innovation should address the issue of: what question am I trying to answer?

This is something we apply in our business. Our Systems Approach aims to get behind the immediate requirement, to understand what's driving the client so that we can deliver the solution they need.

For Frazer-Nash and other commercial companies, collaboration is an essential part of innovation. When you've decided where you want to go as a business, part of working out how to get there is identifying what you have. Your new innovation may provide the bodywork but you need to collaborate with others to obtain the engine, tyres and fuel before you can move forward.

However, whereas within academia free movement of ideas has always been central, in the commercial world it can sometimes be perceived as a threat. In the digital age, where information can be shared at the click of a mouse, businesses need to develop agile innovation skills, enabling them to process the information before their competitors.

Protection of a business position will come, not from being the only company with the information but from being the one that exploits the information more quickly than others. In turning an idea into a commercial reality quickly, you overtake companies in the slow lane because you're so many miles ahead of them – either in scale or in the level of your knowledge, or just because you've developed the idea enough to make economies of scale work.

Using collaborative innovation, regardless of which sector you are in, enables you to both capitalise on new ideas and develop the networks needed to bring them to fruition, driving you towards a successful future.

Bill Hodson
Business director, Frazer-Nash Consultancy

Using collaborative innovation enables you to capitalise on new ideas and develop the networks needed to bring them to fruition

"Conversation between investor and innovator should take place right at the start"

Bill Hodson

Virtuous circle

A culture of innovation fostered between a firm, its customers and supply chain can lead to a virtuous circle of ideas and creative thinking

I much prefer to talk about innovation than about product development. For me, the term 'product development' has connotations of R&D working in complete isolation, before unveiling its latest creation in the hope of finding a market.

Innovation is different. By definition it is problem solving and customer focused. New products and services are developed as a direct result of the challenges being faced by the market.

My own industry, machine tools, has been highly innovative. When customers told us: "We want to mill and then turn on one machine," we developed multi-tasking. As a result, European machine tool users are among the most productive and competitive in the world. More recently, the latest generation of CNC controls has been developed to meet the future 'iPad' generation of engineers.

Furthermore, innovation leads to further innovation. In fact, at its most productive, a culture of innovation fostered between an organisation, its customers and supply chain can lead to a virtuous circle of ideas and creative thinking.

I've lost count of the times a customer has told me they have taken delivery of a new machine, worked with it for a while and then approached one of their own customers and said: "We've been thinking: we can make this part for you in a different way," – creating a supply chain of innovation.

For these reasons we are proud to be supporting Collaborate to Innovate. In particular, when I looked at the awards shortlist I was pleased to see so many examples of the close collaboration between industry and academia. This partnership is vital to the continuing robust health of British and European manufacturing, with academia providing the research capability alongside industrial partners, which offer ongoing technical support, funding and, crucially, commercialisation expertise.

At Yamazaki Mazak, for example, we have close links with a number of universities, including those of Birmingham and Cambridge, and with the MTA, supporting its Technology Design Innovation Challenge. We are currently working closely with the MTC in Coventry on an Innovate UK-funded project to develop second-generation additive manufacturing technology. All of these relationships have proved to be highly rewarding and important to us.

However, it would be wrong to suggest that all the hard work to foster collaboration and innovation has been done. The introduction of the Catapult Centre programme has significantly assisted the bridging of the Technology Readiness Level gap between pure research and delivery of commercially viable solutions. However, greater emphasis is needed on innovation at education level, along with investment, to ensure that the UK maintains and develops further its position as a cradle for innovative thinking.

There is still insufficient 'listening' on the part of manufacturers. The old sales philosophy of product development in the hope of finding a customer remains in place in too many areas. It is up to manufacturers to counteract this. At Mazak, for example, we view our customers as innovation partners and, to that end, developed the European Product Group, a team that was specifically tasked with listening to our customers, working alongside them to understand their challenges and then developing solutions to address those challenges.

The VTC 800 series of machines, which was developed and is manufactured in the UK, is testament to this approach, which followed customer feedback about the need for a vertical travelling column machining centre. Similarly, Smooth Process Support, part of our new SMOOTH Technology, was developed as a result of listening to our customers.

We need to continually invest in innovation — it can't be turned on and off like a tap

"By definition, innovation is problem solving and customer focused"

Alan Mucklow

A second barrier relates to collaboration. Intellectual property protectionism issues continue to put obstacles in the way of real collaboration between companies. Greater openness will inevitably aid collaboration and, in turn, innovation. My hope is that Industry 4.0 initiatives will aid this process.

Finally, an innovation philosophy must also be able to embrace services. The ability to remotely diagnose machine performance, deploy service teams, employ condition monitoring techniques, implement preventive maintenance programmes and instill a culture of continuous improvement will aid further productivity improvements and, ultimately, competitiveness.

The message of Collaborate to Innovate is that we need to continually invest in innovation. It is not a one-off activity that can be turned on like a tap. Most importantly, organisations need to resource, in terms of both financial and human capital, if they are to deliver real innovation.

Alan Mucklow
Director, UK and Ireland sales division
Yamazaki Mazak

Keep an unmanned eye on the climate

UAVs have a potentially important role to play in keeping tabs on methane in the atmosphere, as scientists look to tackle the issue of climate change. Stephen Harris reports

High above the equator is a growing problem. After several years with little change, the amount of methane found in the atmosphere above the tropics has started to rise again — and scientists aren't sure why. Methane is a potent greenhouse gas and a significant contributor to climate change, so working out where all this extra methane is coming from and what we can do to stop emissions is an important task for climate change scientists.

To tackle this challenge, a group of researchers from three British universities made the journey to Ascension Island in the Atlantic. They hoped the unique position of the island, which lies underneath winds from both Africa and South America, would allow them to take gas samples from the atmosphere that might help them determine the source of the increasing methane. But to do this, they had to collaborate on developing a dedicated system for gathering samples from over 1,500m above sea level, using a small fleet of unmanned aerial vehicles (UAVs) or drones.

Prof Euan Nisbet, an earth scientist from Royal Holloway, University of London, began looking at this problem in the 1990s. He and his colleagues identified Ascension Island, which lies in tropical waters just south of the equator, as an ideal spot to measure methane in the atmosphere.

While the winds that blow onto the island at sea level come from the South Atlantic, at around 1,200-2,000m above sea level are winds, depending on the season, that are blown over from the southern savannah grasslands of Africa or the equatorial wetlands of Congo and Uganda. There are also inputs of air from southern tropical South America (Brazil, Paraguay, Bolivia). This makes UK-owned Ascension one of the world's best places to track greenhouse gases in the atmosphere. The winds can be used to sniff out what is going on across a huge chunk of the southern hemisphere.

Project name
Atmospheric sampling over Ascension Island using UAVs

Partners
University of Bristol with Royal Holloway; University of London; University of Birmingham

But how to get to the winds? Aircraft or helicopters were too expensive so Nisbet considered balloons or kites to collect samples. Then he contacted Prof Jim Freer of the University of Bristol, a hydrologist who had experience using UAVs for carrying out geographical survey work. Freer was interested in the project and approached his Bristol colleague Dr Tom Richardson, an engineer specialising in autonomous flight.

"It was one of those conversations that happened in a corridor," said Richardson. "I probably should have inquired further but at the time I just said it sounded great. What I didn't know was how high they wanted us to go. I'm very used to flying UAVs at 400ft (122m) but the average height we needed for this project was 1,500m."

The final team was rounded out with several other colleagues, including Bristol's Dr Colin Greatwood, who was the safety pilot and technical lead, and the University of Birmingham's Dr Rick Thomas, an expert in sensor technology and UAV operations who designed the payload for collecting the samples.

With funding from the Natural Environment Research Council, the researchers had to select, equip and test their UAVs before taking them to Ascension Island for the fieldwork. The initial plan was to use a large, single-rotor craft powered by an internal combustion engine that could carry a payload of between 8kg and 10kg, in order to take a series of samples from the atmosphere over several hours.

But because this craft would weigh over 20kg in total, it

01/02 Using a UAV to collect repeatable scientific data isn't easy

01

02

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"Flying a UAV in a scientific way to collect repeatable data is not easy"

Dr Tom Richardson, University of Bristol

needed clearance from the Civil Aviation Authority and commissioning such a vehicle proved difficult. The air-aspirated engine would also have made it tricky to change altitude as quickly as necessary. But by discussing in more detail what samples the scientists needed, the engineering team was able to come up with an alternative plan.

"Flying a UAV in a scientific way to collect repeatable data is not easy, so getting across our message about what was difficult and easy and their message about what was needed was really important," said Richardson. "One of things about working collaboratively is the language people speak in engineering and earth sciences is very different, so we needed to learn about how to bridge between the two."

In this way, the team decided to switch to a more lightweight, multi-rotor, electrically powered UAV and collect samples over several shorter missions throughout the day. This also meant they could get to the necessary altitude much quicker and, because the craft was cheaper, take several vehicles with them as back-up. "The combination of a lightweight but powerful autonomous airframe with high stability and reliability, coupled with rapidly responding atmospheric sensors, is the reason why the campaign was so successful," said Freer.

After a long series of tests to build up flight capability, the field team of Richardson, Thomas, Greatwood and Freer, with Dave Lowry and Rebecca Brownlow from Royal Holloway, headed for Ascension Island to conduct the sampling. Once there, they would manually launch the UAV and then switch it into automatic flight mode to conduct the mission, with the craft flying beyond the line of sight of the base (something that added to the already significant amount of paperwork the team had to complete together).

They also found that they had to make real-time adjustments to the UAV's mission programme in response to the changing temperature because they couldn't obtain predictions as accurate as they needed. "The biggest element of team working is when you're out there in the field," said Richardson. "It was a very high-pressure environment. The Royal Holloway team was giving a breakdown of the temperature and winds and where we wanted to get to. Rick was managing the sensors and the science, you had myself managing the vehicle and Colin piloting it. Each mission was a very, very long 17 minutes. You've got to trust everybody in there to do their job."

The success of the mission allowed the team to redesign the payload to sample carbon dioxide, as well as methane for a second campaign.

The results have shown that the increase in methane emissions in the tropics have come from the expansion of tropical wetlands and agricultural sources such as cattle and rice paddies. The experience has also encouraged Richardson to participate in other projects with scientists — he could soon be flying UAVs over Guatemalan volcanoes and Chilean glaciers.

Deal with the electric strain

Battery research facility operates at a much higher voltage and power rating for energy storage

Project name
Willenhall Energy Storage System (WESS)

Partners
University of Sheffield; University of Aston; ABB; Toshiba; Sterling Power; Portastov; Western Power Distribution; Converter Technology; Opal-RT

The move towards much greater use of low-carbon energy sources through renewable generation and electric vehicles is set to place huge strain on the electricity grid. It's widely thought that large-scale energy storage is needed to help balance out this increased demand and intermittent supply. Yet, despite millions of pounds spent on energy storage research schemes in industry and academia over the last five years, the UK still has less than 1MW of installed and commissioned storage on the grid.

Most research has been carried out on low-scale demonstrators and, in the case of battery storage, performed at the cell level in highly controlled environments relating to characterising specific chemistries. This means many battery solutions have failed to behave as expected in the real world and the technology is still likely to take a very long time to come to market. The move from small, sub-1kW units to the megawatts of energy storage required on the grid is too large a step for a commercial timescale.

To overcome this problem, researchers from the universities of Sheffield, Southampton and Aston teamed up with power engineering firms ABB, Toshiba and several other commercial partners to build a 2MW battery research facility that operates at a much higher voltage and power rating than was previously available. The Willenhall Energy Storage System enables research to be conducted at the same power levels as used by industrial installations to give a better understanding of the technical and economic potential battery storage on the grid.

Helping out Chinese farmers

Prototype AgriRover potentially offers an affordable, robust mobile crop-sampling system

Project name
AgriRover – development of a remote handling haptic arm system for an agricultural role

Partners
University of Strathclyde; Oxford Technologies Ltd; RAL Space

China is running out of farmland to feed its 1.4 billion and still-growing population, and the constant flow of people from the countryside to the cities is creating a shortage of rural labour.

More intense farming is seen as the answer and chemical fertilisers and pesticides are being used in increasing amounts to try to get more out of the land. But because farmers don't gather enough data about their crop production, they have ended up using chemicals too much or inappropriately, which is bad for the environment and doesn't produce the desired growth in crop yields.

To help Chinese farmers collect the crop data that would allow them to optimise their use of chemicals, RAL Space, Oxford Technologies Limited (OTL) and the University of Strathclyde have collaborated with a group of Chinese research institutes on an affordable, robust mobile crop-sampling system.

This prototype AgriRover is easily operated using a remote-control haptic joystick connected via satellite, allowing data to be gathered from an office rather than manually in the fields. It gathers crop samples using a specially designed robotic arm that can grip samples while cutting them so it doesn't drop them.

This system is based on a master/slave remote operating system of the kind used in nuclear reactors to allow people to manipulate hazardous materials from a distance. The human operator controls a master robot in a way that is then replicated in multiple slave robots in the field.

Ready for Sellafield Pond life

Permanent dry rig can be used to test tools before involvement in the clean-up of nuclear waste

Project name
Pile Fuel Storage Ponds Magnetic Lifting System

Partners
Sellafield Ltd; James Fisher Nuclear

The Pile Fuel Storage Pond is one of the Sellafield nuclear decommissioning site's most hazardous facilities. It contains radioactive sludge, oxide fuel, metal fuel and other intermediate-level waste that needs to be retrieved, reprocessed and safely stored. Previously, this kind of clean-up operation involved designing, building and trialling bespoke tools in a time-consuming and costly process that often needed further expensive redesigns.

To save time and money, Sellafield has worked with James Fisher Nuclear on ways to make greater use of existing commercial technology. This was done by building a permanent dry test rig — as well as a test tank — that could be modified quickly and cheaply to test different pieces of equipment rather than constructing and removing individual rigs for each test.

The project has led to the adaptation of hand-held underwater tools used by the offshore oil industry that have then been remotely deployed and operated within the pond. But it also extended to the use of related equipment, such as buoyancy bags equipped with pneumatic magnets to move large pieces of kit within the pond, sourced at significantly cheaper cost than the previously bespoke designed floats.

This bag system was fully self-contained so it could be used without disrupting any of the other operations of Sellafield, but has proven so successful that plans for a £200,000 electric trolley system that was thought to be needed have now been shelved. It is even being considered for use elsewhere on the Sellafield site as a way of replacing plans for other expensive crane systems.

Forging ahead with additive

A three-year project set out to make state-of-the-art metal 3D-printed custom implants available to any hospital around the world with an internet connection. Andrew Wade reports

Perhaps no other sector relies on collaboration as much as healthcare, with industry, academia and government bodies all needing to align for innovation to flourish. Regulatory frameworks can make progress painstaking, and conflicting partner goals can scupper even the best ideas. ADEPT (Additive-manufacture for Design-led Efficient Patient Treatment) has overcome all these challenges, and done so in a remarkably short space of time.

The three-year project set out to make state-of-the-art metal 3D-printed custom implants available to any hospital with an internet connection, helping improve patient experience around the world. The potential benefits of the project are many and varied. Custom implants can help reduce expensive surgery time, infection risks and recovery periods, while processes such as 3D printing encourage hospitals to embrace engineering approaches such as just-in-time manufacture.

"We've always sought to explore how engineering technologies could benefit surgeons and other people in the medical sector," said Dominic Eggbeer, head of surgical and prosthetic design at Cardiff Metropolitan University's PDR (Product Design and Research) centre.

PDR had an existing relationship with lead-partner Renishaw stretching back many years, and the seeds for ADEPT were sown in the wake of the Gloucestershire firm's acquisition of MTT Technologies. MTT's domain knowledge, combined with Renishaw's existing capabilities, presented an opportunity to explore new applications for metal 3D printing.

"They had bought a new technology and were looking to develop it into new fields," said Eggbeer. "We engaged them very early on to explore that potential."

Project name
ADEPT – Additive manufacture for Design-led Efficient Patient Treatment

Partners
Renishaw PLC with PDR at Cardiff Metropolitan University; Abertawe Bro Morgannwg University Health Board (Maxillofacial Unit); LPW Technology Ltd

By employing a new software system that enables non-engineers to engage with the metal 3D-printing process, ADEPT is now hoping to transform the implant market. The software and hardware integration should facilitate fabrication of around 11 custom implants every 24 hours on a single machine.

However, achieving this ambitious goal would require a broad platform of expertise. Alongside Renishaw's engineering prowess, the ADEPT project brought PDR, the NHS, Morriston Hospital, and LPW Technology together. LPW specialises in providing raw materials for high-end metal 3D printing, while PDR led the academic elements of the project, and the NHS and Morriston helped shape the project with respect to a medical and patient viewpoint.

01 Additively produced custom implants have a range of advantages

"We've worked very closely with the NHS, and particularly Morriston Hospital, for many years, and I think this project recognised the value of involving the NHS," said Eggbeer.

"It really recognised the value of including people that could tie the whole process and system together. We needed to have the input from the healthcare side of things, to understand the fundamental requirements from the end user. We needed a precision manufacturer and engineering company to actually deliver a robust product in the right regulatory framework. We needed the supply chain sorted because that's obviously a big issue."

But collaboration isn't always easy, and drawing on such a diverse range of partners can make for difficult alchemy. Renishaw and LPW had commercial goals, while PDR was primarily focused on the academic research. The needs of end users (both surgeons and patients) were represented by the NHS and Morriston Hospital. In many cases, these differing motivations might be a cause for conflict, but ADEPT avoided this by clearly defining objectives and roles from the start.

"We addressed a lot of the challenges from the very outset," said Eggbeer. "We had a very long discussion about the collaboration agreement, which defines each partner's ambitions in this, in terms of commercial ambitions for Renishaw, ourselves looking for academic credibility throughout the project, and Morriston looking at how the healthcare system would use it effectively… it basically came down to defining things from the very outset, so we haven't really encountered many issues along the way."

The end result is a software interface that does all the heavy lifting. Surgeons can drag and drop patient data into the programme, assign basic parameters, see a preview, and send an implant for fabrication within 10 minutes. According to the ADEPT team, this is about two hours quicker than current best practice.

At the start of the project the team performed timing tests on traditional methods of implant delivery, and these will now form the benchmarks for measuring the project's success. As with all medical devices, the regulatory burden is significant, and Eggbeer and his colleagues are in the middle of clearing the final administrative hurdles before the system can undergo its initial trials.

"We're at the stage where we've got things pretty much fully functional," he said. "So [the project is going] through the regulatory checks and hurdles that the software will need to comply to, because it will be a medical device. So Renishaw is doing that in parallel with all the manufacturing process testing."

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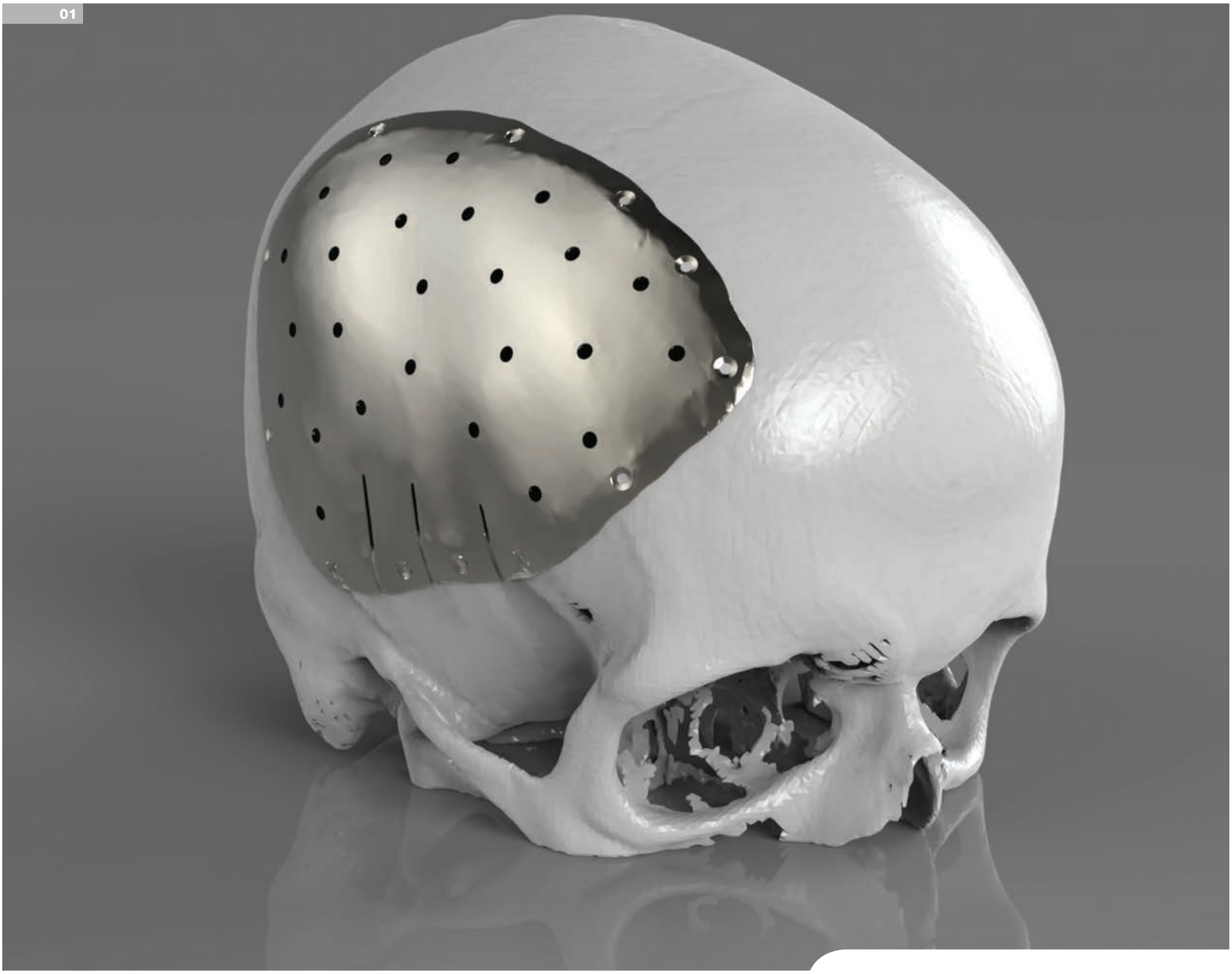

Sponsor profile: **GE Healthcare**

"We've always sought to explore how technologies could benefit surgeons"

Dominic Eggbeer, Cardiff Metropolitan University

"We'll be starting proper user trials, where people can try the software for themselves, and actually have an implant delivered from the back of it, which will then give us the benchmark against our previous studies."

Ultimately, the long-term success of ADEPT will be gauged by the number of surgeons who actually use the software to access the implant service. The initial focus will be on the craniofacial market, where figures from 2010-2011 point to over 23,000 cases in the UK where custom 3D implants would have been suitable. The same figures show over 7,000 potential orthopaedic cases.

Worldwide, there are an estimated 1.5 million craniofacial cases in other key markets that Renishaw believes it can service via its supply chain. While only 5 per cent of these may be suitable, gaining a 30 per cent market share would translate into a potential 22,500 cases per year, returning revenue of around £18 million. ADEPT expects annual growth in excess of the standard 5-6 per cent more commonly associated with the sector, as the process becomes more widely accepted and technical developments improve efficiency. It's a collaboration that has the potential to impact thousands of lives around the world, and one that will continue to drive innovation into the future.

Transforming screening

New prototype breast-screening system makes use of ultrasound computed topography

Project name
PIUCT – Phased Insensitive Ultrasound Computed Tomography

Partners
NPL – National Physical Laboratory; University Hospitals Bristol; North Bristol NHS Trust; Precision Acoustics Ltd; Designworks

Led by the National Physical Laboratory (NPL), PIUCT (Phased Insensitive Ultrasound Computed Tomography) is a collaboration aiming to transform breast-cancer screening.

Current NHS mammography methods in England involve compressing each breast between two X-ray plates, a practice that can be uncomfortable and lead to both false negatives and false positives. Traditional ultrasound is highly dependent on the operator, and inefficient at distinguishing between cancerous and healthy tissue.

PIUCT's prototype screening system uses ultrasound computed topography (UCT), which has the potential to overcome some of these issues. Developed by NPL, Precision Acoustics and Designworks, the technology employs pyroelectric sensors that convert ultrasonic energy into heat, generating electrical signals that form an ultrasound image. On the clinical side, the project was made possible with the help of University Hospitals Bristol (UHB) and North Bristol NHS Trust.

The PIUCT procedure involves placing the patient's breast in a warm water bath. Ultrasonic waves are sent through the tissue and the amount of energy emerging is measured using the prototype sensor. The transmitter array and receiver are rotated around the breast, with the measurements combined to produce a 3D image. Different tissue types, including cancerous ones, can then be identified from this image.

According to the researchers, the screening method should be safer and cheaper than current techniques, and the results should be easier for medical staff to interpret.

Radiotherapy's 'holy grail'

Project seeks to enhance the rapidly advancing arena of proton therapy

Project name
PRaVDA (Proton Radiotherapy Verification and Dosimetry Applications)

Main partner
University of Lincoln

Main collaborating partners
Birmingham, Liverpool, Surrey, Warwick and Cape Town universities; Karolinska University Hospital, Sweden; National Research Foundation (NRF) – iThemba LABS

PRaVDA (Proton Radiotherapy Verification and Dosimetry Applications) is a stunning example of the international collaborative efforts to fight cancer. Led by the University of Lincoln, the project incorporates over a dozen academic and industry partners, including organisations in Sweden, South Africa and Germany, as well as all corners of the UK.

The goal of the project is to develop a platform for proton-based computed topography (CT), which will enhance the rapidly advancing area of proton therapy. Proton therapy allows for higher doses of radiation to be focused more accurately on cancerous cells. However, conventional diagnostic X-ray imaging is not accurate enough to facilitate the full clinical benefit of the treatment.

As a result, a proton-based imaging technique has become the 'holy grail' of radiotherapy. PRaVDA aims to provide clinical quality three-dimensional images of the patient's internal anatomy to plan treatment and constantly follow anatomical changes as treatment progresses. To do so, the collaboration has brought together experts in medical physics, high-energy physics, electronic engineering and computing to develop a unique instrument that could lead to a step change in the treatment of cancer.

If successful, cancer patients can expect better outcomes, improved quality of life, shorter treatment regimes and reduced side effects. The main beneficiaries are set to be children and young adults, in whom cancer is rare, but often particularly aggressive. It is the largest-single cause of death for those aged five to 19 in the UK.

Gauging pulmonary health

A combination of advanced fibre optics alongside new detector technologies

Project name
Proteus

Partners
University of Edinburgh; Heriot-Watt University; University of Bath

Drawing on academic prowess from the University of Edinburgh, Heriot-Watt University, and the University of Bath, Proteus is developing technology to provide doctors with important information on the pulmonary health of patients in intensive care.

There is currently no method to rapidly and accurately diagnose infection, inflammation, cancer or scarring in the lungs. The ability to do so would enable doctors to make better decisions on patient treatment, such as prescribing medication, or recommending surgery where necessary.

Proteus, which is funded by the EPSRC, uses a combination of advanced fibre optics, alongside new detector technologies and molecular imaging molecules. The fibre-based system can be passed into patients allowing clinicians to 'view' inside the body, while at the same time measuring important parameters such as oxygen concentration and pH, and allowing sampling directly from the target area.

Based on the main hospital campus in Edinburgh, the collaborative hub consists of an open-plan office and four dedicated labs within the Medical School. It is populated with a team of chemists, physicists, engineers, signal processors, computer scientists and biologists, with 20 PhD students from across the three partner universities also involved.

Now at the halfway point, the project has successfully produced and tested its first device, Versicolour, which is approved for initial clinical studies. The team has also developed prototype advanced optical fibres that can sense, image and deliver micro-doses of reagents, and fabricated state-of-the-art detectors for high-resolution imaging.


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Sharing the intelligence

A team of researchers has spent the last five years working on a project to improve the way people can interact with a network of computerised agents. Stephen Harris reports

One day you might never need to call the emergency services. The growth of artificial intelligence, internet-connected devices and sophisticated sensors means that city authorities of the future might be able to automatically detect an accident, terrorist attack or natural disaster and immediately dispatch a response. Wireless sensors, flying drones and social media would relay information to the city's different teams, each of which would have its own disaster management software that would automatically coordinate a response and send necessary vehicles and maybe even robots to affected sites.

But even with all these 'agents' acting and communicating automatically, the likelihood is that humans would still be at the heart of the decision-making and the action on the ground. For that reason, a team of researchers led by the University of Southampton's Prof Nick Jennings (now at Imperial College London) has spent the last five years working on a project to improve the way people can interact with this kind of network of computerised agents.

The outcome of the ORCHID project, which involved researchers from the universities of Nottingham, Oxford and Southampton, and several firms, including BAE Systems, were a set of protocols and algorithms that enabled people to work more closely with agents. These have been applied not just to tools for planning disaster response but also to uses as disparate as creating more efficient home energy networks and gathering scientific data from members of the public.

Jennings has been studying how different computerised agents can better work with each other for over 30 years. Immediately before ORCHID, he led another five-year project known as ALADDIN, which specifically tried to develop agent collaboration software for disaster-response scenarios, and which won the aerospace and defence category of The Engineer Awards 2009. At the end of ALADDIN, Jennings reassembled the same team to take on the challenge of integrating agent networks with human operators.

"In our previous work, you got so far with the automated system and then, in many of the realistic applications, people weren't willing to let humans go out of the loop," he said. "We wanted to get humans and agents to work together in a seamless and flexible way. You see various forms of humans interacting with clever software and they feel rigid and pre-determined."

Project name
ORCHID: The Science of Human-Agent Collectives

Partners
University of Southampton with University of Oxford; University of Nottingham; University of Southampton; BAE Systems; Rescue Global; Secure Meters

01/02/03 ORCHID brought together a multi-disciplinary team of computer scientists, engineers, psychologists, sociologists and even artists

The answer was to be able to adapt the system so that humans could take more or less control depending on the situation. "I wanted some intelligence in the interplay between who was in charge and how much responsibility they can take. In terms of a disaster, if you've got lots of time or one task is really complicated then a human operator can deal with it. Whereas if there's an awful lot going on you can't possibly deal with what might be the same interaction."

To apply this idea to the practical application of coordinating disaster response, the researchers worked with BAE Systems and the charity Rescue Global to better understand what human operators would need from their artificial intelligence tools. "We watched what they did, sat alongside them and looked at how disaster responders work," said Jennings. "Then we figured out what sort of interventions would be useful and when we built the systems we presented to them and they gave feedback."

The result was a way of fusing data from lots of different


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"We wanted agents and humans working together in a seamless and flexible way"

Prof Nick Jennings, University of Southampton

sources – for example, sensors, drones and also social media posts on Twitter – into a kind of heat map that would identify where the areas of particular need or interest in a disaster situation were. This would help human planners to then decide which response teams needed to go to which areas.

"That's a complicated problem because the information comes in different types and quality," said Jennings. "Some of it might be inaccurate or even deliberately inaccurate such as exaggerated reports of damage. So to make sense of it you need very clever algorithms."

Adding human behaviour into the computer science Jennings' team had developed with ALADDIN meant adding new expertise to the project. "Southampton specialised in multi-agent systems; and Oxford in reasoning and data fusion," he said. "That was the bedrock but neither of us knew much about how to put humans in the loop so that was why we brought in Nottingham."

The previous collaboration meant many members of the team were already confident working together, but the involvement of members of Nottingham's Mixed Reality Lab brought a new challenge. This multi-disciplinary research group brings together computer scientists and engineers with psychologists, sociologists and artists to study the best ways for humans to interact with computers.

"The academic challenge for us [computer scientists] was to understand the people who study people," said Jennings. "The big way through it is by building software together. You start off by talking at one another in terms of theories and systems but that only gets you so far. So for us the key learning was building common demonstrators that are co-developed, with actual code written by all partner institutions."

As well as disaster response, the team applied its work on human-agent collectives to the development of smart home technology, where various internet-enabled devices such as thermostats and kitchen appliances can coordinate their operation to use energy more efficiently. This led to the development of some bespoke pieces of hardware and a spin-out company that makes recommendations to homeowners about their property, appliances and energy tariffs, based on data gathered from the home.

The work even had the unexpected result of feeding into a number of citizen science projects that rely on crowd-sourcing data from thousands of members of the public on things such as the presence of supernovas in astronomical images or evacuation routes from buildings. Linking these volunteers to artificial intelligence systems meant the data they created could be better organised according to how accurate it was likely to be.

Steve Roberts, professor of machine learning at the University of Oxford, said the project had opened his eyes and changed the way he thought about how humans and computers can work together. "I'd seen machine intelligence as devoid of human input and now I see it as human-machine intelligence. This was a really profound and incredibly interesting change."

Project name
Ultra-Parallel Visible Light Communications

Partners
University of Strathclyde; University of Cambridge; University of Edinburgh; University of Oxford; University of St Andrews

New ways to transmit data

'LiFi' could get around problem of transmitting data through an increasingly clogged radio spectrum

The explosion of internet-connected devices and WiFi means the world is rapidly running out of radio spectrum on which to transmit data. A promising alternative is to encode data into light waves by rapidly turning a light source on and off in a way that cannot be detected by the human eye but sends a pattern that can easily be decoded by an electronic sensor.

The problem with this concept of 'LiFi' is the conventional white LEDs used as modern light sources cannot blink on and off fast enough to transmit data at the speeds required by today's communication networks. A team of researchers led by Prof Martin Dawson of the University of Strathclyde has developed a solution by dividing LEDs into a number of micro-pixels, each around 50 micrometres to 100 micrometres in diameter (about the width of a human hair).

When modest DC currents are passed through these 'micro-LEDs' it produces a high current density that allows much faster blinking. What's more, combining many micro-pixels in a 'micro-display' allows data to be encoded through the arrangement and colour of the lights, as well as the pattern of their blinking.

Dawson had already led research on micro-displays but needed the expertise of other UK universities to develop the materials, chip design and communication system. The result was the world's fastest LEDs (data rates of over 3GHz) and the world's fastest white lights, capable of streaming high-definition video data across a room without the need for radio-frequency transmissions.

Project name
Creating a novel infrastructure for big data management

Partners
National Instruments; Jaguar Land Rover

Keeping tabs on the data

A novel data management system could make gathering and analysis more efficient

Jaguar Land Rover (JLR) has one of the largest research and development programmes in the UK, employing over 400 engineers and producing up to 500GB of time-series data a day from the numerous tests it runs on its designs and models. Until recently, the company was struggling to manage this vast amount of data. There was no standardisation, only 10 per cent of it was ever analysed and tests often had to be repeated because engineers couldn't find the correct file. When they did run an analysis it was time consuming, partly manual process using one of a multitude of different tools that all required custom programming.

To make its data gathering and analysis more efficient and so speed up the research process, JLR teamed up with National Instruments (NI) to develop a novel data management system built from NI's DIAdem and DataFinder Server Edition. This system automatically uploads any data from a test to a central dump area before it is processed and filed. It also immediately checks files have the correct metadata and pulls in any missing values so the files can be stored and categorised properly.

The system also provides a way to create and run predefined or custom analysis routines without the need for programming. It can run the analysis on a selected file or send the routine to the server for simultaneous batch processing of large sets of data. It then creates a report based on a standard template, making it easier to compare data across the company.

Project name
Simulation Tools for Rapid Innovation in Vehicle Engineering (STRIVE)

Partners
Valuechain.com; Bentley Motors; Virtual Engineering Centre; Optis Northern Europe; Optis Pristine; Northern Automotive Alliance

Spotting the problems early

Simulation tools allow problems in car designs to be flagged up before manufacturing begins

Taking a car from the drawing board to the showroom takes a luxury manufacturer such as Bentley over four years. Much of that time is spent on the design process so if potential problems with manufacturing aren't spotted until the first cars are built it can be very costly for the company.

To combat such an occurrence, Bentley launched the STRIVE project to develop a bespoke set of simulation and visualisation tools that would allow its manufacturing engineers to better influence the design of its new cars and capture any issues much earlier in the product development process.

The company teamed up with the University of Liverpool's Virtual Engineering Centre (VEC) and several small high-tech businesses local to Bentley's headquarters in Cheshire to design these tools.

They included a visualisation system that uses large high-resolution display walls and 3D glasses to create an immersive, augmented reality environment in which engineers could study the designs in great detail and assess the vehicle before the first parts were even available.

This simulated the manufacturing process, as well as the car itself, in order to optimise the way it was built and spot and resolve any problems much earlier on.

The project also produced a way to automatically generate and share standardised reports that would allow information to be easily spread across the organisation.

As a result of three years of the STRIVE project, Bentley has reduced its product development time by six months and reduced the time spent on capturing and resolving issues by 48 per cent.

Carriers fit for a queen

Designing and building the UK's largest ever warships required collaboration on an almost unprecedented scale. Jason Ford reports

The first flights of F-35Bs from HMS *Queen Elizabeth* are scheduled to take place in 2018, yet as far back as 1806 the Royal Navy was making use of airborne platforms to gain military advantages.

In the 19th century the Royal Navy's HMS *Pallas* deployed kites to spread seditious leaflets in Napoleon's France, and since that time military commanders have realised the advantages brought about by marrying two strategic assets – surface ships and aircraft – to form a formidable union.

By 1918 HMS *Argus* had become the first full-length flat-deck carrier to serve in the Royal Navy. With a squadron of 18 aircraft and a displacement of 15,775 long tons, *Argus* would be followed nearly a century later by the first of two carriers capable of accommodating 40 fast-jet aircraft (depending on configuration) and displacing 65,000 long tons, a figure that ranks the navy's new QE class of aircraft carriers as second behind the US's Nimitz nuclear-powered aircraft carriers, which are the largest of their kind in the world.

The last British aircraft carriers for fixed-wing aircraft were designed over 50 years ago and, according to BAE System's David Downs, engineering director of the Aircraft Carrier Alliance (ACA), this lapse meant the project – the largest of its kind undertaken in the UK – had little or no experience to base itself on.

While the overall utility of the new carriers would remain broadly similar to their Invincible-class predecessors, the requirement to embark the F-35 presented an entirely new set of challenges.

According to Downs, the F-35 is larger, faster, more powerful and more capable than any aircraft previously operated by the Royal Navy. Downs added that the new carriers would have to facilitate a sortie rate exceeding anything that has been achieved before while operating with a crew no larger than that on Invincible-class carriers.

To achieve these objectives alone has required an approach to the ship-aircraft interface that included a high degree of mechanisation and automation in weapon-handling arrangements, novel flight-deck coating to withstand the pressure and temperature of jet efflux, and novel approaches to visual landing aids to accommodate manoeuvres that allow the aircraft to operate at higher payloads.

Consequently, the scale of the project exceeded the capability and capacity of any one industrial entity, which necessitated collaboration between industrial partners across the UK, including a number of overseas suppliers.

As such, the Aircraft Carrier Alliance (ACA) was set up as an alternative to a traditional Prime Contract arrangement, which allowed industrial partners BAE Systems, Thales and Babcock to enter into a collaborative arrangement with the Ministry of Defence (MoD), all of which had a common goal of delivering the project on time and within budget.

The carriers were designed in two locations in the south of England, with the detailed engineering being undertaken in drawing offices across the country using multiple 3D computer-aided design (CAD) models and two separate CAD tools. According to Downs, this required industrial interaction at a very early stage, developing effective relationships that have lasted through the programme.

Furthermore, the novel build strategy required large outfitted blocks of the ships to be manufactured in six separate shipyards. The blocks were transported to the assembly yard at Rosyth by sea where the ships were assembled in a modified Victorian dry dock in a yard with no previous experience of shipbuilding.

The strategy involved transportation by sea of outfitted blocks weighing 10,000 tonnes, docking them into the build dock, and aligning and skidding them together using hydraulic jacks. The operation to move the forward end of the ship around 17m to align with the aft end is believed to be the largest such operation in the UK, said Downs.

Project name
Queen Elizabeth-class aircraft carriers

Partners
The Aircraft Carrier Alliance with BAE Systems Naval Ships; Thales; Babcock; Ministry of Defence

01 HMS *Queen Elizabeth* floats for the first time

02 The ships were assembled in blocks at Rosyth

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The novel build strategy required large outfitted blocks of the ships to be made in six separate shipyards

The upper parts of the ships were built in blocks not exceeding 1,000 tonnes and assembled onto the lower parts using the ACA's Goliath Crane at Rosyth, which is the largest lifting capacity gantry crane in Europe.

Downs said the block moves and lifts were completed safely at, or before, their scheduled delivery time, and achieving this – from engineering facilities across the UK – required a level of interaction of processes and toolsets unprecedented in British shipbuilding.

At the heart of ACA is a single leadership team, the Programme Leadership Team, which carries the executive authority to manage the programme on a day-to-day basis, with guidance through an Alliance Steering Board comprising senior management from each of the alliance partners. Downs said overall governance is through the Alliance Management Board comprising the managing directors of the participant businesses under the direction of an independent chairman.

To keep the project moving, the alliance partners worked to an Alliance Agreement through which they agreed to share in risk and reward in delivering the carriers. Each of the alliance partners had an agreed work schedule, but resourcing was done on the basis of best person for the job, with individuals being sourced from any of the alliance partners. According to Downs, the sharing of resources made it difficult to identify which partner company individuals actually worked for.

From the outset, health and safety was an area where joint working was essential, with the companies drawing on best practice from across the companies, a strategy that has led to 'lessons learned' being extended beyond the project and into industry.

Overall, the project has been a UK-wide enterprise directly employing over 10,000 people throughout Britain and involving over 300 UK suppliers. The scale of the project has required collaboration between organisations that are otherwise competitors and working with the UK MoD and the Royal Navy.

Downs said that as the project draws towards a successful conclusion this collaborative approach is seeing real benefit in growing the relationships required to manage the ongoing development of operating capability as the vessel and aircraft integration commences.

Signalling a new era of safety

Collaboration exercises complex data constituting safety-critical element of rail signal interlocking

Project name
TREsure

Partners
Hitachi; WS Atkins

Engineers from Hitachi Information Control Systems Europe (formerly TRE) have designed TREsure, a tool that automates testing of railway interlocking data.

A joint team from Atkins and Hitachi ICSE reviewed and improved the principles of the technical information and data principles behind the TREsure automated data 'test scripts' for the benefit of the rail industry.

The collaboration operated with no formal contract in place; data innovation and information sharing acted as a primary motivating factors behind it, with no applicable commercial restrictions.

TREsure fully exercises the complex data that constitutes the safety-critical element of a signalling interlocking over a number of computer-based interlocking systems.

As part of the collaboration process, the test scripts were applied to an existing solid-state interlocking and proved an effective means of testing and improving data design.

The trial found a number of minor anomalies within the existing data and the consequences of these have been passed to Network Rail. The Hitachi/Atkins TREsure trial exercised over two million automated tests of the existing data, which would be impossible to do manually.

All errors and unusual changes of state were flagged for investigation and reviewed by the joint teams who analysed these and recommended improvements to TREsure.

It is anticipated that TREsure will be employed as part of the data design phase in addition to robust processes to provide an additional layer of technical assurance.

In the time of floods

Three-dimensional scanning of embankment slopes can help protect against flood-defence failure

Project name
Assessment of flood defence embankments using geophysics

Partners
Strathclyde University; East Ayrshire Council; West Dumbartonshire Council; Environment Agency; Highlands Council; Parsons Brinckerhoff

A project involving academia, local authorities and a professional service firm has helped to reveal the extent of erosion within flood embankments. A team from Strathclyde University worked with East Ayrshire, Highlands, and West Dumbartonshire councils, plus the Environment Agency and Parsons Brinckerhoff to test a miniature electrode electrical resistivity tomography (ERT) system to detect cracks in scale models of desiccated clay.

Part of the project saw the creation of three-dimensional scans of flood embankment slopes, which normally requires time for modelling and data inversion.

The results revealed the global shape of a section of the embankment in 3D and could be presented as 'slices' on the soil section in different planes.

The project showed that improved diagnostic technologies exist and can be effectively applied by associating fundamental sciences with the right applications. Geophysics has already proved to be successful in defect detection in structures, but the real challenge in flooding is not only to predict failure points, but to use this information to tailor monitoring and remediation technologies to maintain embankment health with minimal intrusion at both the small and large scale.

Detailed diagnostics has the potential to help engineers design new 'filling' technologies and injection techniques, which are beyond the ambitions of this project. If the new methodology becomes widespread, the population will be better protected from flood-defence failures.

Policing in the digital age

Measuring, modelling and predicting the interactions between crime, policing and public reassurance

Project name
Crime, Policing and Citizenship – Space-Time Interactions of Dynamic Networks

Partners
University College London; Metropolitan Police Service

Like many public sector organisations, the UK's police forces are not immune from funding cuts. This includes the Metropolitan Police Service (MPS), which has to make 20 per cent efficiency savings by 2020 with no reduction in performance targets. These include a 20 per cent decrease in crime and a 20 per cent improvement in public confidence over the same period, meaning that MPS – which responds to over 10,000 calls every day – really does have to do more with less.

UCL, however, is helping to develop a crime-fighting weapon that takes its ammunition from the abundant sources of data that MPS officers generate.

For example, crime is recorded more comprehensively than ever before and GPS tracking offers unprecedented insight into the way that policing is undertaken. Following the launch of a £2m scheme in 2010, MPS police radios record officer locations at five-minute intervals, while vehicle locations are logged every 15 seconds.

UCL's Crime, Policing, and Citizenship (CPC) – Space-Time Interactions of Dynamic Networks in collaboration with MPS sought to develop a fully integrated approach to data-driven policing, with particular emphasis on the spatial and temporal characteristics of crime, policing and citizen reassurance. Measuring, modelling and predicting the interactions between these amounts to an intelligent and holistic approach to policing in the digital age.

The project presented a manifesto for 'intelligent policing' that goes beyond current practice, incorporating the prediction of events, how to respond to them, and how to evaluate the actions taken.


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Buildings as a power of good

The success of the SPECIFIC project's 'building as a power station' concept is mostly due to large-scale collaboration between academia and industry. Evelyn Adams reports

Every home and business in the UK may one day become 'a building as a power station' that can generate, store and release solar energy at the point of use. At least, that is the aim of the SPECIFIC project, which could help the government reach its goal of cutting emissions by 80 per cent by 2050.

There are at least 20 million buildings in the UK, of which 80 per cent are expected still to be in use in 2050. SPECIFIC plans to retrofit buildings with a range of technologies that trap and store solar energy, for the generation of both heat and electricity. As well as being used on existing buildings, glass- and steel-based coatings could be applied to building materials at the point of manufacture.

Researchers say these technologies could heat and power buildings more cheaply than conventional solar systems. By building integrated photovoltaics, they hope to generate 10GW peak electricity – equivalent to the power generated by five coal-fired power stations. They are also developing inter-seasonal heat storage technology that would store solar heat for use in the winter. Overall, the technologies have the potential to reduce carbon emissions by six million tonnes a year within the next 10 years, creating a new high-value manufacturing industry valued at £1bn.

The SPECIFIC project began in 2011. It is led by Swansea University, with strategic partners BASF, Cardiff University, NSG Pilkington and Tata Steel. The project is funded by the EPSRC and Innovate UK, with part-funding from the European Regional Development Fund through the Welsh government.

The concept was proved in 2014 with the construction of the 'Pod', the first 'building as a power station'. The Pod combines electricity- and heat-generating technologies with the storage and release of energy to develop an 'off-grid', self-sufficient building concept that uses only energy generated by the sun.

Project name
SPECIFIC Innovation and Knowledge Centre (IKC)

Partners
Swansea University with BASF; Cardiff University; NSG Pilkington; Tata Steel

The concept has since evolved with the construction of larger-scale buildings to test improved technologies. For example, last month, the UK's first energy-positive classroom was switched on in Swansea. Within the 'Active Classroom', electricity is generated by a steel roof with built-in integrated solar cells, supplied by SPECIFIC spin-out company BIPVco. The building also uses Tata Steel's perforated steel cladding for generation of solar heat energy. The plant room houses two Aquion Energy saltwater batteries, which are capable of storing enough energy to power the building for two days. Energy stored is then released back into the building through a novel electrically heated floor coating that has been developed by SPECIFIC researchers.

01 The project has already yielded a number of breakthroughs

The success of the project has largely been due to collaboration between experts in coatings, solar energy, battery storage and chemical conversion.

"Our vision to turn buildings into power stations is transformational and truly disruptive – collaboration is essential and the spirit within which we work every day," said Jan Bell, SPECIFIC's commercial engagement director. "SPECIFIC is creating an ecosystem with all parts of the supply chain for construction and energy – to scale up and commercialise through demonstration at building scale."

Currently, the SPECIFIC project has researchers working on various technologies with the ultimate aim of turning buildings into power stations. These include: using the latest photovoltaic research to capture solar energy; storage technology with researchers exploring novel storage techniques as well as more traditional battery technologies; release technology as demonstrated by the electrically heated coating; and systems integration technology so everything works together as one system.

The research ideas developed at lab scale at SPECIFIC are scaled up in its pilot line at Swansea University, and its partnership with industry accelerates the route to commercialisation. Over the past five years, more than 50 other partners have engaged with SPECIFIC, including Bath University, Imperial College London and Oxford University. Earlier this year, SPECIFIC was awarded an additional five years of funding to continue the project beyond its initial five-year lifetime.

"SPECIFIC and its partners bring together a wide range of disciplines to deliver integrated solutions," said Bell. "This is based on research excellence and great science, engineered products and integrated systems in a straightforward way to create affordable, sustainable and desirable buildings that produce more energy than they need. At SPECIFIC we have research engineers, architects, electrical specialists, business development and construction professionals. We collaborate with small and large companies, including materials suppliers, technology developers, designers and innovators throughout various supply chains."

Since its conception, SPECIFIC has grown from a small group of researchers to more than 140 staff and research engineers. Collaboration has produced 15 proof of concepts and seven demonstration projects – as well as some unexpected breakthroughs.

Through their research in functional coatings, SPECIFIC

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The technologies have the potential to reduce carbon emissions by six million tonnes a year within the next 10 years

engineers also developed a photoactive titanium dioxide-coated metal roof sheeting. When rainfall lands on the roof, organic contaminants are chemically broken down. The water is collected, passed through a filter and stored for use within the building.

Such a large-scale collaboration hasn't been without challenges. Combining people from academia and industry means integrating different mindsets, skills and work perspectives. But at SPECIFIC, an environment that promotes knowledge sharing has encouraged innovation, with communal areas where people can interact with colleagues from other groups. This synergy has enabled the project to cast its net much wider and draw on a larger collective thought process to speed up product development.

"SPECIFIC is an innovation centre creating disruptive solutions for buildings and we need to move quickly – bringing together academia and big company governance with fast-moving SMEs. This isn't easy otherwise many more would be doing it," said Bell.

"But a shared vision of buildings as power stations and a commitment to deliver value for the UK help to focus priorities."

Protection from travelling fire

Travelling fires methodology helps with the design of safer large spaces in buildings

Project name
Designing safer buildings in case of fire

Partners
Imperial College London; Arup

Our understanding of how fire spreads in buildings was based traditionally on a model that predicted uniform burning across a room. However, this model worked for small spaces, but not for larger areas such as open-plan offices.

In large spaces, fire can travel rapidly in a way that can also be modelled. The phenomenon is called 'travelling fire' and a better understanding of its behaviour could make buildings safer in the event of a disaster.

Travelling fire was not accepted by structural fire engineers as potentially important until the 9/11 attack on New York's World Trade Center in 2001.

Dr Guillermo Rein, in collaboration with Arup, pioneered the design concept of 'travelling fires methodology' (TFM) to include its modelling in structural engineering.

"The best protection of a structure from fire is twofold: engineers need to identify the critical parts that are likely to carry the largest loads and then they need to design them to be strong and resilient," said Dr Rein. "Travelling fires methodology helps structural engineers to do this."

Arup contributed to the project with both financial support and an industry viewpoint. Dr Rein and his team at the University of Edinburgh and Imperial College London provided expertise on fire dynamics and carried out essential scientific research on more realistic fire behaviour.

The design concept and methodology of TFM have already been applied by Arup and its competitors – AECOM, BuroHappold and Trenton Fire – in at least 39 iconic buildings in the UK.

Tracking the tsunami waves

Simulator used to re-enact some of the most devastating tsunami events in history

Project name
Generating a tsunami in a lab

Partners
HR Wallingford; University College London

HR Wallingford has teamed up with University College London to create the world's most realistic tsunami simulator. The Tsunami Simulator, which is installed in HR Wallingford's Fast Flow Facility in Wallingford, has been used to re-enact some of the most devastating tsunami events in history, such as the 2004 Indian Ocean tsunami and the 2011 occurrence in Japan.

The newest version of the Tsunami Simulator has been installed in a channel that is 70m long and 4m wide. It uses 70,000 litres of water to recreate a tsunami at a scale of 1:50.

Crucially, the simulator uses a pneumatic tank to 'store' the tsunami wave, rather than pushing it with a piston paddle, as with conventional systems. This makes the simulator far more accurate than other facilities of the same size.

Tests with the Tsunami Simulator could help reveal whether certain flood defences would be effective against a tsunami or might amplify its destructiveness by allowing flood waters to build up in front of them. If they then failed, areas previously thought to be safe might be suddenly inundated.

Tiziana Rossetto, professor of earthquake engineering and director of UCL EPICentre, who is leading the research, said: "Our research at this unique facility will have far-reaching implications for both building and urban design in areas at risk of tsunamis, and could help mitigate some of the most devastating risks of the phenomenon to both human lives and the land they depend on."

Making the most of the assets

Working to improve public services and amenities in Nairobi's largest slum

Project name
Productive public spaces in urban Kenya

Partners
Engineers Without Borders UK; Kounkuey Design Initiative Kenya

Kibera is the largest slum in Nairobi and infamous for its scale, history and degraded conditions. It has no formal rubbish-collection system and limited sanitation facilities. Poverty is extreme, and unemployment and crime rates are high.

Engineers Without Borders UK and the Kounkuey Design Initiative (KDI) recognised that the poverty in Kibera derives from a complex set of problems – financial, environmental, physical, political and social – but they also acknowledged Kibera's assets: community activism, informal economies and entrepreneurship. The two organisations have collaborated since 2011 to make the most of these assets, as part of the Kibera Public Space Project (KPSP).

KPSP is a network of community hubs – called productive public spaces (PPSs) – that transform the polluted waterway into community amenities. A typical PPS may start as a hazardous neighbourhood dumping site but, through a year-long, intensely collaborative process, it becomes a public space that provides basic amenities such as clean water, toilets, schools and playgrounds.

To date, seven PPSs have been completed in Kibera; the eighth and ninth are under construction. As the network has grown, so has the team's ability to work on settlement and regional issues.

As well as the PPS project, Engineers Without Borders UK and KDI have also participated on the development of a web and mobile application named watsanportal.net.

This app provides an online mapping and decision-making tool to help launch water and sanitation projects in Kibera.

Material impact on jet engines

A long-running partnership led by Rolls-Royce and EPSRC is helping deliver new materials and skilled engineers to the aerospace sector. Jon Excell reports

With global air traffic predicted to double by 2030 and environmental targets becoming ever more ambitious, the civil aerospace sector has rarely been under more pressure to innovate.

And against this backdrop, manufacturers are increasingly tapping into the expertise of the wider research base in search of the skills and technology that can help deliver a competitive edge.

One company that's been particularly adept at this over the years is Rolls-Royce, which – through its global network of 31 University Technology Centres (UTCs) – has set something of a benchmark for how industry and the academic research community can work together.

A particularly compelling example of this process in action is Rolls-Royce and EPSRC's materials Strategic Partnership, a 10-year, £50m collaboration that also involves a number of leading UK universities.

Launched in 2009, this partnership was established with two key aims: to develop understanding around the materials required for next-generation jet engines; and to help develop a pipeline of engineers and scientists that the sector will need in the future.

So far, the partnership has more than succeeded on both counts, driving a host of technical advances that are now close to commercialisation and recruiting more than 140 PhD students.

Dr Justin Burrows, Rolls-Royce project manager for university research, explained the technical drivers behind the partnership: "The issues we have with gas turbines are very complex – because we're operating materials right at their extremes and beyond we need to have a fundamental understanding of how materials behave before we can extend how they operate."

Project name
Materials Strategic Partnership

Partners
EPSRC/Rolls-Royce plc with University of Cambridge; University of Swansea; University of Birmingham

Among the many advances to arise from the project one of the most significant is the development of new high-strength steels for engine shafts.

Recent developments in gas turbine architecture have resulted in a drive for high-bypass architectures with smaller turbine cores, operating at increased temperatures to enable fuel burn and efficiency improvements. Rolls-Royce operates a three-shaft design with concentric shafts connecting low-, intermediate- and high-pressure stages.

Steels employed for shafts experience large changes in operating temperature while requiring high strength to react to torque loads.

01 The partnership is helping develop materials for Rolls-Royce's next generation of jet engines

One solution to this has been to use dissimilar shaft materials that are joined together, but within the partnership a new high-strength steel has been developed that could be used to produce a one-piece shaft, potentially having a significant impact on performance and manufacturing lead time.

In parallel, core size reduction has been realised by the development of bladed disk (blisk) technology. The mechanical attachment of blades to a turbine disc is removed as the disc and blade are integrated as a single component. This makes weight savings of up to 30 per cent possible, as the reduced rim weight means the cob at the centre of the disk can be reduced.

Another significant impact has been the development of gamma titanium aluminides – low-density materials that when inserted into the low-pressure turbines at the rear of aero engines enable reduced weight, fuel burn and emissions.

The partnership completed an integrated research programme to assess mechanical behaviour to enable manufacturing, assembly and performance. As part of this, a novel testing method was developed within the partnership at Swansea University.

As well as the development of new materials, the partnership has also developed and validated new modelling techniques for alloy design, lifing methodology and mechanical performance and corrosion effects. These tools have been inserted into the business and the partnership has been able to benefit directly from the available data generated in numerous EngD and PhD projects.

Alongside the technology breakthroughs, the partnership has also played a major role in helping build up the skills and expertise the sector will need in the future.

"Apart from the technical delivery of making new alloys, the strategic bit of developing a talent pool is really important to us," explained Burrows. "We're training the next generation of materials engineers but it's not just for our benefit, it also benefits academia and our supply chain. They get excellent post-doctoral degrees and we get fantastic technical people who have been involved in a research programme."

Indeed, Burrows estimates around half of the students that have had involvement in the partnership are recruited into Rolls-Royce or another area of the supply chain.

The success of this process owes much to the structure of the partnership. The project began with three core university technology centre partners – Cambridge, Swansea

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“We’re operating materials at their extremes – we need to understand how they behave”

Dr Justin Burrows, Rolls-Royce

and Birmingham – which were combined to create a University Technology Partnership (UTP). Since then it has grown to include an additional four ‘spoke’ universities.

Within this structure there are two integrated programmes: a post-doctoral research programme and a training programme, which comprises EngD and PhD students.

This training programme directly supports the research programme, with students being able to work closely on industrially relevant projects, while contributing sufficient, novel scientific work to allow them to publish in refereed journals and submit a thesis.

Meanwhile, Rolls-Royce provides industrial supervision to each project along with an academic supervisor. In this manner, agreement is reached on projects that allow significant opportunity for fundamental scientific research to enable a thesis while remaining industrially relevant.

This process is all underpinned by commercial agreements that provide a mechanism for Rolls-Royce and the university partners to freely share data and generate IP, thereby enabling members of the partnership to discuss all aspects of future commercial and technical strategy.

It’s a strategy and a structure that has, said Burrows, had huge benefits for both business and academia. “When it was launched in 2009, we were looking to deliver impact both in industry and academia, and also train up the next generation of engineers. I think we’ve done a very good job of doing all of those things. What we’d like to do is build on that success.”

And with three years still to run on the partnership, Burrows is confident that it will make further breakthroughs in the years ahead. “We’re already working on the next generation of alloys discovered in this programme,” he said. “We have a number of disk, blade and shaft alloys we’ve patented as a result of the work we’ve done so far, and we’re looking at the next generation of those materials.”

Burrows also believes the partnership contains some useful lessons on collaboration for the broader engineering industry, perhaps the most significant of which is the way it is set up to ensure that everyone involved understands the wider context of their research. “You need to know your road map of where you’re going and where you want your technology to go,” he said. “If you’ve got a clear vision it’s simpler to get everybody working towards that goal.”

Getting on to the runway

Novel direct-drive system could deal with problem of aircraft burning large amounts of fuel during taxiing

Project name
Smart wheel for aircraft taxiing

Partners
University of Nottingham; Safran: Messier-Bugatti-Dowty

Researchers from across the University of Nottingham's engineering faculty collaborated to solve a problem that causes considerable air and noise pollution at airports around the world.

The seemingly simple task of transferring aircraft from their departure gate to the runway is one of the least efficient parts of the entire journey; the aircraft typically use jet power for this, but jets are designed to push the aircraft through the air and not along the ground, so during taxiing they burn a great deal of fuel and produce a lot of noise.

The project involved researchers from the power electronics machines and control group at the faculty of engineering developing a novel direct-drive system for the machine with a new type of rotor concept. The extremely high torque developed by the motor means it also tends to produce a large amount of heat; the department's thermofluids group use novel materials to design a thermal management system to channel the heat away from the mechanism. Mechanical engineers analysed the structure of the machine to ensure it can cope with take-off and landing.

The university's manufacturing and testing departments produced a prototype, which achieved torque densities of 184kNm/m^3 and 43Nm/kg, well in excess of the typical 1 to 1.5Nm/kg of an industrial electric motor. This prototype was integrated into an actual aircraft wheel and tested at the landing in facilities of Safran in Paris. This resulted in the design achieving a Technology Readiness Level 5 rating, indicating that it is ready for full-scale demonstration.

A more efficient city drive

Project had the goal of developing a car capable of reducing personal transport energy use

Project name
Project M – an ultra-energy-efficient city car

Partners
Shell; Geo Technology; Gordon Murray Design

In response to projected increases in population, particularly in cities, and a subsequent increase in demand for mobility, Shell decided that the best way forward was to collaborate with automotive manufacturers to design and build a concept city car with the goal of developing a car that was affordable, accessible and capable of reducing personal transport energy use through advanced technology.

Led and funded by Shell, the project took as its starting point the T25 city car from Gordon Murray Design for which it had produced a prototype lubrication oil in 2010.

The project saw vehicle, engine and engine oil design all developed in parallel. This, says Shell, has delivered results none of the three groups could have achieved individually.

Shell's lubricating oil for the project was made using gas-to-liquid technology from natural gas, allowing its properties to be tailored for the application; in this case, a very thin, high-performance oil that extends engine life, reduces maintenance costs and keeps the engine clean.

The car's engine was designed by a team led by former Honda Formula One director Osamu Goto. The design involved lightweight pistons and low-friction diamond-like coatings on valve train components. The team from Gordon Murray Design contributed a short-bodied vehicle shape, that allows upright driver posture but has very low drag (a drag coefficient of 0.297) achieved using Prof Gordon Murray's iStream car-building technology, which uses materials with a low carbon footprint and is well suited to lightweight but strong designs.

Training under the blue light

Developing a simulator to replicate emergency services driving without associated risks

Project name
Blue-light driving simulator

Partners
Babcock; Serious Games International; Motion Simulation

Driving emergency vehicles – referred to as blue-light driving – is inherently hazardous, and training new drivers is difficult. It is currently done in a real-life environment that poses risks to trainer, trainee and the public. Babcock's project to develop a simulator to deliver blue-light training needed to create a system that would complement existing training regimes but would be safer and cost efficient.

The project entailed collaboration with developers of both software and hardware. The resulting system is fully immersive, using a 200° wraparound screen and haptic feedback to ensure that the trainees' experience is as close as possible to real-life emergency driving, but without the associated risk.

Serious Games International, which developed the simulation software, is a commercial entity of Coventry University. Particular challenges were simulating driving a fire appliance; creating software to recreate and map out 167 miles of driving terrain; and making virtual cars that behaved as real vehicles do when an emergency vehicle approaches at speed, with blaring sirens and flashing blue lights. For Motion Simulation, the hardware provider, the main focus of its R&D effort was to create a fire appliance cockpit with accurate ergonomics; a seat and steering wheel capable of incorporating haptic feedback; and features such as variable height and reach on the wheel; and realistic self-cancelling indicators.

Babcock believes that its simulator is the first in the world to include these features. When used with RoSPA-qualified instructors, it claims, it can accelerate the learning process and therefore reduce training costs.

Picking up on the hazards

Prototype system can control cranes used to move nuclear waste

Project name Nuclear Crane Zoning System

Partners
Future Tech Studio;
Sellafield Ltd

Dealing with the UK's hazardous legacy of nuclear waste is perhaps one of most complicated, expensive and long-term challenges facing its engineers.

Much of the activity centres around Sellafield's fuel reprocessing and nuclear decommissioning site in Cumbria: the site of the UK's first ever nuclear reactors, and now home to around 80 per cent of the UK's nuclear waste. And with decommissioning and waste clearance at the site likely to last for at least another 100 years, engaging with the next generation of engineers, and ensuring the UK maintains the skills to deal with this problem is absolutely vital.

With this in mind, Sellafield has a packed outreach programme aimed at enthusing young people about engineering and also educating students about some of the specific challenges the sector faces.

The organisation recently worked with a group of students from Future Tech Studio, a school for 14–19 year olds in Warrington, on the development of a prototype automated system for controlling the cranes used to move waste material in Sellafield's vitrification plant – the area of the facility where waste is converted into a stable form for transport and long-term storage.

During operation, this crane sometimes needs to be serviced. Currently, because it's too dangerous for operators to enter the plant room where the crane is used, a system of chains is used to move the crane into a 'safe zone' for maintenance. However, with this system prone to human error and mechanical failure, Sellafield challenged the Warrington students to come up with a more reliable solution.

After nine months, during which time it worked closely with graduate engineers from Sellafield, the team demonstrated a prototype automated system that could be used to control the crane movement, stop it in a safe zone, move the beam into the maintenance area and ensure that staff are safe.

With their engineering mentors, the students developed a solution and built a model, including 3D-printed parts, to demonstrate their design. The model was then refined and automated using Arduino software to program the movement of the crane, cell door and travelling beam.

Across the Thames

Developing plans for a pedestrian/cycle bridge

Project name
Nine Elms to Pimlico Bridge Design Project

Partners
Watford Grammar School For Boys;
Hyder Consulting

Encouraged by mentors from the engineering sector, a team of students from Watford Grammar School For Boys submitted an entry to a competition run by Wandsworth Council aimed at developing plans for a pedestrian/cycle bridge across the Thames linking Pimlico to Nine Elms.

A number of civil engineering firms submitted designs, including Hyder Consulting (now Arcadis), which suggested that the Watford students submitted their own mock-proposal. This included detailed CAD drawings for the bridge's superstructure, along with specifics such as the exact location and the construction process that would be needed should the designs become reality.

The project began with careful analysis of the raft of restrictions and regulations that would have to be satisfied in order for the project to be approved. Among these, the stipulation that only one 'pier' supporting the bridge must be in the water (in order to reduce the adverse effect of river traffic during and after construction) was notable as it meant that the bridge would have to be supported from above. Because of this the team chose a 'cable-stay' design with the bridge deck supported from above through tension in cables, rather than compression from below. Cables at 10m intervals suspend the deck from one of two towers.

These two towers extended from one central pier. The 'major' tower supported the longer span of the bridge, and was crescent-shaped, while the 'minor' tower was a mirror of this shape, and supported the shorter span of the bridge.

The cables were arranged in a 'modified harp' formation, and attached to just one side of the deck. However, after showing its design to consultant engineers from Hyder, the team learned that the bridge would not be stable and that the deck would be subject to 'torsional forces' — twisting caused by the cables as they support the deck from one side only. The team therefore decided to curve the deck into an 'S' shape, thereby creating a moment in the deck that would counteract the torsional forces caused by the cables, thus arriving at a striking design.

Sponsor profile: **Renishaw**

Renishaw is a world leader in engineering and science-based technologies employing over 4,300 people globally, some 2,800 of which are located within the UK. The company's products are used by manufacturers globally to produce high-quality components for industries such as aerospace, automotive, construction, agriculture and consumer electronics.

Renishaw is also the UK's only manufacturer of additive manufacturing machines (also referred to as 3D printing), which 'print' parts from metal powder. It is also applying its expertise to healthcare applications such as dentistry, neurosurgery and facial reconstructive surgery. In the UK it is working with leading hospitals, including Southmead Hospital and Bristol Children's Hospital, on pioneering neurosurgical procedures, including the treatment of Parkinson's disease and childhood brain cancers.

Renishaw is proud to sponsor the Young Innovator award and is highly committed to developing its own skilled staff. This year it recruited 65 graduates and 45 apprentices and currently has 128 young people within its four apprenticeship schemes (Technical Engineering, Manufacturing Engineering, Software and Embedded Electronic Systems Design/Development Engineering).

The company also operates a graduate intake scheme with opportunities in various disciplines including electronics engineering, physics/science, manufacturing engineering, software engineering, commercial roles and mechanical engineering.

Renishaw works very closely with schools across the South West and South Wales to encourage pupils to consider careers in engineering, or careers within an engineering company.

The opportunities to get work experience with Renishaw are numerous and include one-week work placements (15-17 year olds), summer placements (A/AS level and undergraduates), and one-year industrial placements (undergraduates).

Fundamental impacts

The shortlisted projects of Collaborate to Innovate are all world-leading examples of research and innovation

It has been a great pleasure to be involved with Collaborate to Innovate. The initiative allows us to recognise and showcase some of the UK's world-leading engineering research and innovation – and we have much to be proud of. When internationally benchmarked, the UK punches above its weight as a research nation. The UK represents just under 1 per cent of the global population and just over 3 per cent of R&D expenditure. The UK research base maximises the value of its research expenditure, with investment in the UK producing more research and at a higher quality than in the rest of the world. This is reflected in the UK producing 8 per cent of papers published and 16 per cent of the world's most highly cited articles. The UK has overtaken the US to rank first by field-weighted citation impact. The strength of the UK research base is also reflected in terms of its economic impact. When we compare the UK to other counties for which data is available we see that per unit of R&D expenditure, the UK ranks first for invention disclosures, second for start-ups and spin-offs and third for license revenue.

"The UK is a success story in terms of both research excellence and its contributions to innovation and economic impact"

Prof Tom Rodden

The UK is a success story in terms of both research excellence and its contributions to innovation and economic impact. An analysis of the impact case studies submitted to REF 2014 undertaken by EPSRC illustrates the significant economic contribution that can be linked to research. A research investment of £7.8bn from 1993 to 2013 yielded £80bn of economic activity during the five years from 2008 to 2013. This included £16bn of cost savings in the public and private sectors. It also resulted in the creation of 400 new businesses, employing 50,000 people, and contributing £4bn to the economy in revenue. The strength of research and innovation in the UK is a real cause for celebration and the Collaborate to Innovate awards showcase some of the major projects that underpin this success.

The shortlisted projects are all world-leading examples of research and innovation with each having had a major impact on the world. Some of these impacts have focused on fundamental knowledge, including work exploring the development and use of autonomous drones to collect high-altitude atmospheric samples, allowing a greater understanding of our environment. While others have delivered benefits to the health of our society, including work on novel approaches to cancer treatment and the development of sensors that revolutionise monitoring of patients with long-term critical conditions. The shortlisted projects have also varied in scale and ambition, including the design and manufacture of the largest warships ever built in the UK. Projects have showcased how foundational research work can drive innovation, accelerating the journey from discovery to impact – explorations focusing on novel materials in aerospace have resulted in significant advances in the aerospace industry and the use of smart materials in the built environment to address the growing challenge of energy and sustainability.

What is particularly striking is that research and innovation is driven by collaboration

What is particularly striking across all of the projects considered for these awards is the way in which research and innovation is driven by collaboration. The teams involved in these awards span multiple organisations and bring together a broad set of skills and experiences. They combine a range of disciplinary traditions. They link foundational discovery-led science with engineering practice. The collaborations involved in these projects allowed research users to shape and drive the key research challenges. Each team involved is very much more than the sum of its parts, often establishing new ways of working that allowed the different skills to be combined. These awards represent the best examples of the flow of ideas and the collaboration that underpins it.

Prof Tom Rodden is deputy CEO of the EPSRC

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