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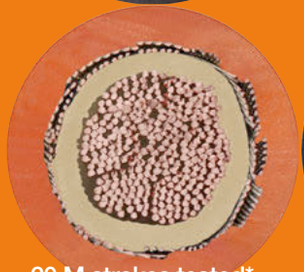
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this**issue**

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news

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features

our**opinion**

Innovation pipeline

At a time when the UK's Brexit conundrum has plumbed new depths of toxicity, there's an amusing irony to the topic of this issue's cover story: an engineering project at the forefront of efforts to connect the UK ever more closely to the European mainland.

Interconnectors, giant subsea power cables that enable the UK to share power with its nearest European neighbours, are becoming an increasingly important part of our energy infrastructure: an insurance policy against energy shortages, and a key mechanism for overcoming the intermittency challenges of wind and solar energy, and getting more green energy on the grid.

Today, there are already around 4000MW of these continental power cables linking the UK with its European partners. But there are many more in the pipeline, and in our report (page 30) we look at one of the most technically challenging and significant projects yet: North Sea Link – a 720km long, 1.4GW connection between the UK and Norway.

> "Engineers are at the forefront of efforts to connect the UK ever more closely to Europe"

Whilst the construction of interconnectors is an established art, North Sea Link is one of the most ambitious projects of its kind and our feature examines how the team has had to overcome challenges including drilling through mountains and traversing the unusual geology of the North Sea in order to bring the project to fruition.

Elsewhere in this issue we take an in-depth look at the design and manufacturing innovations behind the wing for the Airbus A220: the most recent winner of the Royal Academy of Engineering's coveted MacRobert Award. Designed and manufactured by Bombardier at a purpose built 60,000 square foot facility in Belfast the composite wing is up to 10 per cent lighter than a conventional all-aluminium product. We report on the innovations that have seen it rightly hailed as an exemplar of UK design and manufacturing expertise.

Though very different, North Sea Link and Bombardier's wing have one common component: they've both relied heavily on collaboration. In North Sea Link's case, close collaboration between the grid operators of Norway and the UK, whilst Bombardier worked closely with the wider supply chain and the research community to bring its wing to market.

So it's fitting that this issue also sees us announce the reveal the shortlist for own annual celebration of collaboration, the C2I awards (page 34). We'll reveal the winners of this year's awards, as well as an exciting new look for The Engineer, in our November issue.

Jon Excell Editor
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Cover Image: National Grid

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ENERGY

FutureCat looks to next-gen Li-ion

Team hopes for batteries with longer lifespan and more energy density

DAVID FOWLER

A multidisciplinary team of researchers is setting out to develop the next generation of lithium-ion batteries. The result is expected to be batteries with a longer lifespan and greater energy density, which could transform the performance and range of electric vehicles.

The FutureCat project was awarded £11m by the Faraday Institution on 4 September 2019 over an initial four years from October.

The team, to be led by Prof Serena Corr at Sheffield University's Department of Chemical and Biological Engineering, will include Cambridge, Oxford and Lancaster universities, UCL, Isis Neutron and Muon Source, NPL, and 11 industry partners.

The project will focus on cathode design, to produce cathodes that hold more charge, are better suited to prolonged cycling, and promote ion mobility – a factor that aids greater power density and fast charging.

The project also aims to reduce dependency of cell manufacturers on cathodes containing cobalt, because of its expense and ethical concerns surrounding its mining.

Prof Corr said that with current cathodes, degradation occurs over time, precluding long-term stable performance. In high-voltage batteries there is a risk of a dangerous reaction between the cathode and electrolytes currently used. "The project will also be looking at additives to increase stability of the electrolyte," said Prof Corr.

Unusually, the project will look at new approaches to the chemistry and architecture of cathodes.

Crucially, the team draws expertise from multiple fields, with materials scientists, inorganic chemists, solid-state chemists, physicists, chemical engineers and computational experts to provide a holistic view.

Prof Corr said one approach to designing new chemistries will be to predict new structures through computational techniques; the predictions will be fed to a synthetic chemistry group to synthesise new materials, which will be passed to electrochemists to test them in batteries.

"The other novel aspect of this project is that we're also looking at the architecture of the cathodes – the particles themselves and the morphology, and whether or not we can create novel architectures that allow those high-energy and high-power densities to be accessed," she said.

"It's a very ambitious programme, but this sort of investment enables us to assemble a very comprehensive team. We are able to take the expertise of each from these areas and apply it to these challenges."

FutureCat was one of five projects that were awarded a total of £55m from the Faraday Institution last week. Sheffield is also a partner in Nextrode, a consortium led by Oxford University with five other universities and six industry partners, to revolutionise the way electrodes for Li-ion batteries are manufactured. Prof Corr said: "Part of what we are doing at FutureCat will feed into Nextrode. Making sure new cathodes can drop right into the manufacturing supply chain is another challenge."

Nexgenna, led by St Andrews University with five other UK partner laboratories, three industrial partners and collaborations with Diamond Light Source and five leading overseas research institutes, will accelerate the development of sodium-ion battery technology. Its aim is to put on the path to commercialisation a safe sodium-ion battery with high performance, low cost and a long cycle life, suitable for static energy storage and low-cost vehicles.

Catmat, led by Bath University with six other university and 12 industry partners, will investigate the fundamental mechanisms at work in novel cathodes that currently prevent the use of nickel-rich and lithium-rich cathode materials.

In LiSTAR (Lithium-Sulfur Technology Accelerator), UCL will lead an effort to enable rapid improvements in lithium-sulphur technologies. ■

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AUTOMOTIVE

Skateboard for electric vehicles

Chassis platform incorporates full propulsion and control systems STUART NATHAN REPORTS

The S2 chassis would be built to meet customer wheelbase requirements

Delta Motorsport has developed the aluminium S2 'skateboard' chassis platform to aid electric vehicle development.

The product will help automotive OEMs to accelerate the process of developing a vehicle, Delta said, and is fully scalable in terms of the size of the vehicle and production volume.

"It can be anything from a small delivery van or a street-sweeping vehicle, up to a bus or truck," said Adriaan Gerber, director of consultancy Gerber Engineering and a contributor to the project. "The skateboard would be designed and produced with the appropriate wheelbase."

Delta chief executive Simon Dowson explained that the project sprung from the company's desire to demonstrate its platform master controller technology in an autonomous-ready system - a departure from its previous concentration on developing whole vehicles.

"Many companies are developing the artificial intelligence required for autonomous vehicles, but they do not necessarily have a vehicle capable of delivering their vision," he said. "The flexibility of the S2 chassis and the integration platform master controller allow the delivery of multiple configurations quickly and at low cost."

In general, companies developing autonomous and electric vehicle capability will start by purchasing a standard production vehicle and automating it to produce a test mule, Delta engineering director Nick Carpenter explained. Using the S2 will allow them to configure the unit to provide a much wider range of capabilities, he added.

"Using this technology, a company could develop a full prototype in about nine months," Gerber said.

The S2 chassis controls interfaces with the battery system, charger, and all other high-voltage components.

The project has been funded under the auspices of Innovate UK and involved collaborations with Titan (which provided expertise in by-wire steering), Alcon (by-wire brakes), Potenza Technology (digital safety), Tecosim (computer-aided engineering), Cranfield University and Warwick Manufacturing Group.

If the client is looking for a small production run, then Delta could manufacture the chassis for them, Dowson said. "For anything above that, we would have to find a manufacturing partner and construct a factory. ■

DEFENCE AND SECURITY

Babcock to build frigates

STUART NATHAN REPORTS

The next generation of Royal Navy warships will be built by Babcock, with the Ministry of Defence awarding preferred bidder status to a consortium led by the company.

The Type 31 frigate will be built to a design known as Arrowhead 140, with each ship costing some £250m – a quarter of the cost per ship of the larger Type 26 frigates currently being built by BAE Systems in Glasgow.

the frigates will be assembled at Rosyth using the modular construction method pioneered on the Queen Elizabeth-class aircraft carriers. Construction is expected to begin in 2021 with the first launch taking place in 2023. Babcock expects the programme to run until 2027.

The completed ships will have a maximum overall length of 138.7m, maximum beam of 19.8m, and design draft of 4.8m. Each ship will be able to accommodate an AW–10 Merlin or MH-60 Seahawk helicopter in an on-board hanger. Boat bays will be able to deploy RIBs and autonomous underwater or surface vessels.

Armaments will include 40-to-127mm deck-mounted guns, canister-launched surface-to-surface guided weapons, and various missiles.

The vessel will be powered by a combined diesel and diesel (CODAD) propulsion system incorporating four diesel engines, producing a maximum power of 32.8MW. This will give it a cruising speed of 18kt and a maximum speed of 28kt.

Paul Everitt, chief executive of ADS, said: "The long-term programme at UK shipyards, including both the Type 31 and Type 26, provides a solid foundation for the defence maritime sector to grow its exports." ■

Newsinbrief

On the charge

Over £500m of investment has been made by the government to develop technologies that will help the UK achieve its target of net zero emissions by 2050. The Treasury has launched a £400m fund to bolster Britain's electric vehicle charging infrastructure, with the first £70m allocated for 3000 charge points. Also announced is £31.5m for research into technologies to remove greenhouse gases from the atmosphere.

Record run

A pre-production Bugatti Chiron derivative has been driven into the record books with a top speed of 304.773mph (490.484km/h). The record-breaking run was certified by SGS-TÜV Saar after Bugatti test driver and Le Mans winner Andy Wallace pushed the car to the record on the test track at Ehra-Lessien in Germany. "I went at full throttle from the start for approximately 70 seconds," said Wallace.

3D organs

Researchers at Harvard University have demonstrated a new biomanufacturing process that marks a major advance in the use of 3D printing for the repair and even replacement of human organs. A number of groups have demonstrated the use of 3D printing to build living tissue constructs in the shape of human organs, but they have lacked the cellular density and organ-level functions required for organ repair and replacement.

Electric luxury

Automobili Pininfarina, Bosch Engineering and Benteler are to jointly develop a high-performance electric vehicle, which is expected to support future Automobili Pininfarina vehicles and be made available to OEMs. "This collaboration marks the first initiative among three world-class partners to develop a platform specifically tailored to the luxury and performance electric vehicle plans of Automobili Pininfarina," said Michael Perschke, CEO, Automobili Pininfarina.

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MEDICAL

Easy on the ear

Ultrasound sensor aids diagnosis of middle-ear infection

DAVID FOWLER REPORTS

A new type of ultrasound transducer developed at the Fraunhofer Institute for Photonic Microsystems (IPMS) is expected to allow faster and more reliable diagnosis of infection of the middle ear. A prototype otoscope incorporating Frauhofer's technology, developed by US company OtoNexus Medical Technologies, is undergoing clinical trials.

Antibiotics are the usual treatment for infection of the middle ear, particularly among infants and young children. However, the otoscope - the equipment used to diagnose the condition - has not developed for decades, and doctors can only deliver a diagnosis that is accurate in as low as 50 per cent of cases in distinguishing between bacterial and viral infections. This means that many children are prescribed antibiotics unnecessarily.

The new otoscope, which is undergoing clinical studies, can tell doctors in a matter of seconds whether there is air or fluid in the middle ear, and characterise any fluid. This enables the doctor to distinguish between different stages of the illness and decide on the appropriate treatment.

"The classic otoscope is an optical system and hasn't changed in decades," explained Dr Sandro Koch, a physicist at Fraunhofer IPMS in Dresden. In the new device, the transducer emits ultrasonic pulses, captures the echo reflected from the eardrum, and generates a reading that tells the doctor about the degree of infection.

It features a capacitor formed by two electrodes separated by a small air-filled gap. One of the electrodes is flexible and vibrates to transmit ultrasonic pulses. When the echo from the signal strikes a flexible membrane, the resultant vibration is converted into a detectable electrical signal.

Software developed by OtoNexus analyses the echo signal. Initial clinical studies have corroborated the accuracy of the analysis, the institute said.

The transducer is a capacitive micromachined ultrasonic transducer (CMUT), produced on a silicon wafer by means of special microelectromechanical systems (MEMS) technology developed at Fraunhofer IPMS. The transducer has a low power consumption and can be mass produced cheaply. Unlike traditional ceramic piezoelectric ultrasound transducers, it can be miniaturised, making it easier to incorporate in an otoscope.

Market launch is anticipated within a few years, providing trials are successful. Other applications for the technology could include smartphones and tablets for gesture control, or it could be used in vehicles to control on-board infotainment systems. ■

The new otoscope could replace decades-old technology

RENEWABLE ENERGY

BBOXX funding expands off-grid energy

Mitsubishi Corporation has led a US$50m investment round into a London company bringing pay-as-you-go solar energy technology to off-grid customers.

Since 2010, BBOXX has delivered solar home systems (SHS) that consist of solar panels, battery storage, and a range of home appliances on a PAYG basis.

The company, founded by alumni of Imperial College London, has installed 200,000 SHS that are remotely monitored via BBOXX Pulse, a real-time, remote monitoring system that allows BBOXX to manage operations and customer payments via mobile phone. BBOXX also plans to provide other key utilities in addition to electricity, such as gas and water, along with insurance and finance services.

Over 600 million people in Sub-Saharan Africa live in off-grid areas beyond the reach of conventional transmission and distribution networks. Kerosene lamps have typically been the main source of indoor lighting. The investment from Mitsubishi Corporation will help drive BBOXX's growth across Africa, where it currently operates in 12 countries, as well as in Asia. **JF**

AEROSPACE

BAE Systems acquires solar drone partner

Companies to launch long-endurance UAV

STUART NATHAN REPORTS

BAE Systems is to acquire Prismatic as the companies work together on a UAV that can stay airborne for a year, providing surveillance, communications and environmental monitoring functions.

The Phasa-35 project has been underway since last May, and over this period BAE and Prismatic have built two full-scale prototypes with 35m wingspans, which are now undergoing systems integration tests at BAE's facility in Wharton, Lancashire, ahead of planned flight trials early next year.

Financial details of the acquisition have not been disclosed, but Paul Brooks, founder and chief executive of the Alton, Hampshire-based company, said the transition to a subsidiary of BAE Systems gives his staff access to expertise in systems integration, production and other disciplines that will help the project reach its deployment phase much faster.

Weighing just 150kg, Phasa-35 (Phasa stands for 'persistent high-altitude solar aircraft') is powered by solar panels during the day, which charge batteries that run the engines at night. Operating in the upper regions of the Earth's atmosphere, the aircraft has the potential to deliver 5G network connectivity, as well as providing services such as persistent surveillance at much less than the cost of deploying a satellite.

Such systems, known as HALE (high-altitude long endurance) or HAPS (high-altitude pseudo-satellite), are of interest in the provision of broadband Internet coverage to otherwise unconnected regions, both in rural areas of industrialised countries and in the remote, desert or mountainous regions of less-developed nations.

The announcement was made at DSEI. where BAE Systems also noted that in 2018 it spent £1.5bn on R&D. ■

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MEDICAL

Sensor helps healing wounds

Two-year project aims to better understand healing process

JASON FORD REPORTS

Wounds are not only unpleasant for those that have them but also costly to treat, with the NHS spending £4.5-5.1bn each year to manage them.

Now, with EPSRC-funding, Dr Michael Crichton, a biomedical engineer at Heriot-Watt University and Dr Jenna Cash, a specialist in wound healing immunology from the University of Edinburgh, are working on a two-year project to better understand wounds and reverse the cost of treating them.

They will do this by developing a microsensor to detect wound healing by monitoring microscale changes that happen to the body's tissue.

"We want to understand what actually happens in a wound," said Dr Crichton. "Lots of research has looked at the biological properties of wounds, but we know very little about the mechanics of how wounds heal, especially at the microscale, which is where changes are happening at sub-hair width scales.

"We're working to create a small sensor that can be embedded in a bandage to measure changes in a wound's properties without interfering with the process.

"The sensor will make small mechanical measurements – much like how a doctor would prod a lump – and will tell us how the tissue is changing, or whether the wound needs a different dressing or treatment.

"At the moment, we judge the progress of wounds on patients' reports of pain, and how the wound looks to the naked eye of health professionals.

"Our smart sensor will alert the patient and their care team when intervention is needed to make sure the wound heals better, or when it is all progressing nicely."

Dr Crichton said the sensors will be made in house at Heriot-Watt's recently refurbished cleanroom and that a long-term aim is to include electronics into the bandage for non-contact measurement from a handheld or smart-phone-like device.

He added that at this stage of the research, power for the system is derived from a computer/digital acquisition unit, adding "this is a parallel aspect of the project that we will be thinking about at the same time as the signal transmission".

While the team is investigating how skin wounds heal, its findings could be applied to other tissues and organs. ■

Wound healing sensors could cut healthcare costs

SPACE

Telescope united

Major step in completion of NASA's James Webb Space Telescope

ANDREW WADE REPORTS

The two halves of NASA's James Webb Space Telescope (JWST) have been joined together for the first time, marking a significant step in the mammoth scientific project.

Engineers and technicians used a crane at Northrop Grumman's facilities in Redondo Beach, California, to assemble the two halves of the space telescope, which has been in development since the 1990s. Once launched, the JWST will be stationed at the L2 Lagrangian point, exploring the cosmos predominantly using infrared light. This will enable it to observe high redshift objects that are too old or distant for the Hubble telescope to see. The mission has a planned launch date of March 2021.

According to NASA, the team slowly guided the two halves of JWST into place, ensuring that all primary points of contact were perfectly aligned and seated properly. Alongside a 6.5m-diameter gold-coated primary mirror, the JWST also carries a suite of scientific instruments, including infrared cameras and spectrographs, as well as an enormous sunshield to protect them. Now that the two segments have been joined mechanically, the next stage will see all the components electrically connected.

"This milestone symbolises the efforts of thousands of dedicated individuals for over more than 20 years across NASA, the European Space Agency, the Canadian Space Agency, Northrop Grumman, and the rest of our industrial and academic partners," said Bill Ochs, JWST project manager for NASA Goddard Space Flight Centre in Greenbelt, Maryland.

Now that the halves been joined, the next phase will see engineers deploy the intricate five-layer sunshield, which is designed to keep the telescope's mirrors and scientific instruments cold by blocking infrared light from the Earth, Moon and Sun. ■

Credit: NASA Chris Gunn

SENSORS

Nanowire helps spectrometers get smart

Scientists have developed a spectrometer made from a single nanowire, an advance that could see spectroscopic devices incorporated into smartphones.

In use, the single nanowire could be used in potential applications such as assessing the freshness of foods, the quality of drugs, or to identify counterfeit objects, all from a smartphone camera. Details of the project are reported in *Science*.

Most spectroscopic devices are based around the spatial separation of light into different spectral components, which limits their size and makes it difficult to shrink them to any size much smaller than a coin.

Now, Cambridge University researchers have overcome this challenge to produce a system up to a thousand times smaller than those previously reported.

The Cambridge team, working with colleagues from the UK, China and Finland, used a nanowire whose material composition varies along its length, enabling it to be responsive to different colours of light across the visible spectrum. It then created a series of light-responsive sections on this nanowire. **JF**

START-UP TO SCALE UP

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AEROSPACE

Data is key to re-using resources

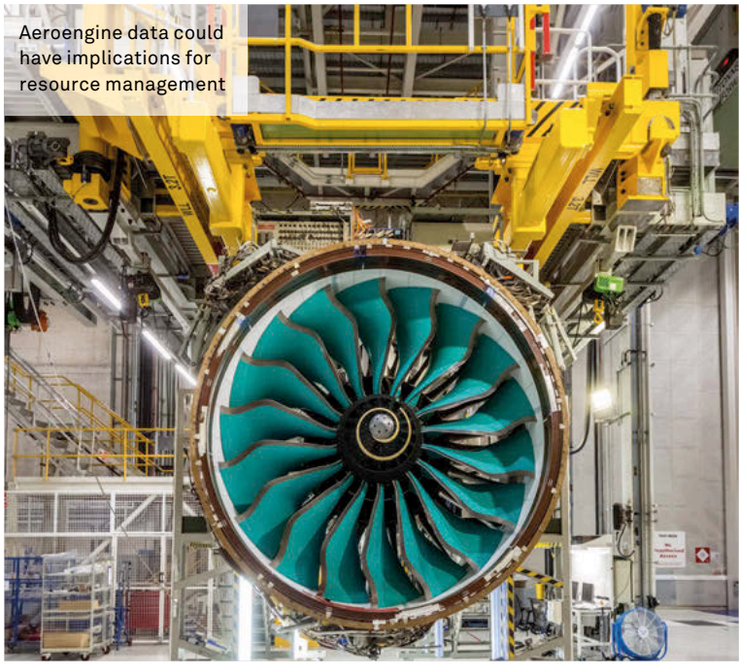
Aeroengines investigated in circular economy study

DAVID FOWLER

A research project led by Exeter University is seeking to demonstrate how data collected from products in use such as aeroengines can help companies adopt strategies for re-using resources.

The EPSRC-funded Circular 4.0 project aims to demonstrate that adopting circular economy principles can add value to businesses: economically, environmentally, and through increased brand value. Partners include Rolls-Royce, Airbus and Cranfield University.

By the end of the project in January 2022 it expects to have identified three specific use cases, applying to Rolls-Royce, Airbus and hydrogen fuel-cell-car manufacturer Riversimple. The researchers also hope to work with other partners through a series of industry engagement days.



Aeroengine data could have implications for resource management

Project leader Prof Fiona Charnley, deputy director of the Centre for Circular Economy in Exeter University's business school, said that among the project partners, Rolls-Royce's use case was currently the most advanced.

Rolls-Royce collects a wide range of data from its aeroengines, including condition monitoring information but also flying hours and historical information about which components fail most frequently. The aim is to combine this with other big-data sources on weather patterns, and whether the engine has been flown in sandy or salty conditions, for example, to develop a 'health metric' to assess the remaining life of different components. In turn this will make possible more informed decisions about whether parts can be 'harvested' for re-use in reconditioned engines, for example.

"An engine contains lots of different components and they have different life cycles. There's quite a lot of wasted value – at the end of a life cycle an engine is taken apart and it's not really understood how much life or value is left in some of those components," Prof Charnley said.

This approach could lead to a reduction in the use of valuable finite resources. "As resources get more expensive, high-value manufacturers are trying to reduce their use of virgin resources," she added. There is potentially significant business value for companies in reducing their reliance on new resources, but although they may have components that have a lot of life left in them, they lack "the specific data to demonstrate that they are as good as new effectively". ■

MEDICAL & HEALTHCARE

Artificial heart pumps move into space

Medical and space research is being combined at Leicester University in the development of a pump to help people with heart failure.

Left ventricular assist devices (LVAD) are artificial heart pumps used as an interim support for people with heart failure who are under consideration for a transplant but unlikely to survive the wait for a donor heart.

A key feature of the new LVAD is that it can be inserted into the chest wall via laparoscopic surgery; another is that it doesn't sit inside the heart, thereby reducing the risk of infection and blood clotting. Funded by the British Heart Foundation, the technology is said to have the potential to save and improve the quality of lives of patients worldwide.

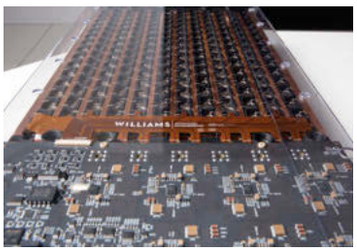
Research lead Piyal Samara-Ratna from Leicester's Space Research Centre, said: "Landing a Mars rover is a challenge and putting something into the heart is a challenge – you've got to create something that's compact and can function in harsh environments." **JF**

BATTERIES

New batteries make bid for power

Multi-Chem battery pack for electric vehicles combines power and storage

DAVID FOWLER



Wlliams Advanced Engineering has unveiled a new battery technology for electric vehicles, which it claims makes possible reduced mass and volume, and increased energy and power density for motorsport, performance car and electrified flight applications.

Adaptive Multi-Chem technology brings together the company's knowledge from a variety of projects, including four seasons as the sole battery supplier to FIA Formula E.

Usually, manufacturers are faced with a compromise between energy density and power density as they try to minimise the size and weight of battery packs for a target performance level. Cells designed for optimum storage capacity have a different physical form from high-power cells and are not suited to the sudden large current draws needed for high power. Cells are usually optimised for either energy storage or power.

Williams' solution is to integrate high-energy and high-power cells in a single power pack. A bi-directional DC/DC converter links the two and contains software to manage the transfer of current between them. The company claims the technology allows a 37 per cent increase in energy density for a target power density.

"Because high power is only needed in short bursts, the overall package can be kept small," said Williams Advanced Engineering technical director Paul McNamara. ■

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MEDICAL & HEALTHCARE

Diagnosing the RoboPatient

Robotics and AR will assist medical training procedures DAVID FOWLER REPORTS

A new research project at Imperial College London will use robotics and augmented reality to improve the training of medical students in using physical examinations to assess the condition of organs in the abdomen.

The project, RoboPatient, will also build up an archive that will suggest which techniques are more likely to be successful in a case.

GPs often use physical examinations, touching and probing the abdomen to detect conditions such as an enlarged liver, swollen intestines and, at a more advanced level, to detect possible tumours.

Doctors use a range of methods, changing the amount of pressure they apply, the shape and configuration of their fingers, and using various tapping techniques, to arrive at a diagnosis, said Dr Thrishantha Nanayakkara, reader in design engineering and robotics at the Dyson School of Design Engineering, Imperial College.

It is a difficult technique to demonstrate to students, and opportunities to practice on real patients are limited.

Dr Nanayakkara's team has developed a prototype robotic patient in which silicone rubber laid down in layers is used to realistically simulate soft tissue with various conditions such as swollen organs, or hard nodules. Sensors embedded in the 'organs' record pressure applied during an examination, and the time taken to reach a diagnosis. A finite-element tissue model allows sensor data to be displayed visually.

During the project, experts will initially examine the robot and diagnose the conditions, to provide a baseline of experience. The robot will then be presented to students to allow them to practice diagnosis.

An additional feature being developed will use augmented reality to simulate facial expressions to indicate when the patient feels pain, to encourage trainees to find techniques that minimise patient discomfort.

The robot will record details of each examination, quantifying how quickly students arrive at a diagnosis and allowing comparison with their peers and between techniques.

"We think this will make training more robust and facilitate students to quickly adapt to real patients," said Dr Nanayakkara.

Over time, accumulated data will allow creation of a probabilistic model to indicate which techniques are most likely to succeed in a situation. ■

RoboPatient will combine robotics and AR. *pressmaster via stock.adobe.com*

ROBOTICS

Optical lace gives light touch to soft robots

A stretchable optical lace material developed at Cornell University could enable soft robots to sense how they interact with their environment and adjust their actions.

The synthetic material, which is said to create a linked sensory network similar to a biological nervous system, was developed by PhD student Patricia Xu through the Organics Robotics Lab at Cornell University.

Xu used a flexible, porous lattice structure manufactured from 3D-printed polyurethane. She then threaded its core with stretchable optical fibres containing more than a dozen mechanosensors and then attached an LED light to illuminate the fibre.

While the optical lace does not have as much sensitivity as a human fingertip, which is filled with nerve receptors, the material is claimed to be more sensitive to touch than the human back. **JF**

ELECTRONICS

UK teams with Korea on space battery

Research explores radioisotope thermoelectric power

The University of Leicester and National Nuclear Laboratory have signed an agreement with the Korea Atomic Energy Research Institute on space battery design.

The organisations have agreed to cooperate on research on radioisotope thermoelectric power generators for use in space exploration. Development of these technologies will allow space missions that can reach distant, cold, dark and inhospitable environments.

The partners have also signed up to developing international standards and safety associated with the systems.

The University of Leicester and National Nuclear Laboratory (NNL) are leading the development of radioisotope thermoelectric generators and heater units as part of a European Space Agency programme, in collaboration with a host of industry and academic partners in the UK, France and Germany.

Prof Iain Gillespie, University of Leicester pro-vice-chancellor of research and engineering, said: "Missions using nuclear power offer greater versatility in challenging environments. In many cases nuclear systems can enable missions that would otherwise be impossible."

Dr Young Uk Jeong, KAERI senior vice-president for quantum science convergence, said: "This memorandum of understanding will provide our respective countries with opportunities to pursue new avenues of collaboration and to discuss ways of increasing substantive cooperation in space." **DF**

Boom or bust? Brexit's impact on innovation and R&D

Brexit will undoubtedly affect life in the UK in several ways. The nature and extent of its impact, however, is anyone's guess. Regarding research and innovation, on the surface not much should change. The R&D Tax Credit Scheme is a government initiative and while it is subject to European Union rules, ultimately the money is provided by HMRC, so the amount of funding available for creative pursuits should not be affected.

But Brexit will likely alter the entire business landscape for UK companies and these wider changes may indirectly affect the state of play for those looking to innovate.

Here innovation funding specialists MPA, who are exhibiting at Advanced Engineering 2019, look at the implications of Brexit on innovation and R&D in the UK, and whether the current political uncertainty will actually give way to a more prosperous environment for businesses.

Funding freedom

According to the latest figures from the Office for National Statistics, UK spending on R&D rose by £1.6 billion in 2017 to £34.8 billion, placing it 11th in the EU for R&D expenditure as a percentage of GDP.

While such figures are impressive, with an average of £527 spent for each person in the UK, the spending is somewhat restricted by EU regulations. R&D tax credits are classed as 'state aid' by the EU and as such there are currently limits on how much the government can hand out to companies.

Once the UK leaves the union, this cap is removed, opening the door to higher value handouts and less strict qualification criteria. Such a move would be welcomed by SMEs across the country and would signal to the world that the UK is strongly encouraging innovation. Plans to increase funding are already in place, with the government's long term industrial strategy aiming to raise R&D investment to 2.4% of GDP by 2027.

There's widespread anxiety about the impact of Brexit on British industry and the government faces significant pressure to provide a boost for the economy. Investment in innovation would be a clear statement that the country is still thriving despite the political overhaul.

With the government potentially looking to reallocate some of the money they currently send across to Brussels, there could be funds available for such action.

"Regardless of the nature of the UK's trading relationship with the EU post-Brexit, innovation is always going to be vital for businesses to stand out and thrive in competitive industry landscapes. If trade deals put UK companies at a disadvantage on the world stage, the need to be creative and forward-thinking increases tremendously."
John Lowndes, Director at MPA.

International collaboration

While international funding for UK research has fallen in recent years, from £5.6 billion in 2014 to £5 billion in 2017, it still comprises 14% of all investment in innovation. But it's not just the financial connection to Europe that UK companies will have to cope without after Brexit, but the level of continental collaboration currently in operation at universities and research centres across the country.

UK industry and innovation is revered across the globe, with our institutions producing world-leading work in every sector. Such breakthroughs are only possible by bringing together the best people from across both Europe and further afield. In fact, in the decade prior to the 2016 referendum, 50% of all UK research publications involved a co-author from overseas. Moving forward, Brexit may make it more difficult for businesses to recruit staff from overseas and make cross-country projects rather impractical, if not impossible. There is talk of plans to only allow immigrants who earn over £30,000 to stay in the country and this could make it difficult for bodies to continue hiring skilled international research assistants and graduates as salaries for these jobs are generally below the threshold.

Britain's booming tech industry has given the country potential to dominate and grow in IT and many other sectors. Mark Sewell, CIO of Microsoft recruitment partner Curo Talent, explains that for the many industries developing IT infrastructure, such as in financial services, there is concern that there may not be enough IT talent available to match increased demand. The average age of the IT workforce is increasing, and Britain's education system is not producing an adequate number of skilled workers to replace these employees once they retire. This is exacerbated by Brexit and its restriction on access to talented EU-workers. To continue this development, businesses need IT workers with the skills to deploy the latest technology, unfortunately this talent pool may become limited.

Such barriers may force businesses to seek ventures elsewhere. Even British companies might start to launch their innovative operations overseas, targeting countries which have both good R&D incentives and simpler immigration policies, allowing multi-national teams to work without obstacles. Asian nations might be among those that benefit, with China and South Korea as potential suitors. In recent years, South Korea has been one of the world's biggest investors in R&D and UK businesses could cash in on the country's commitment to progress.

Uncertain fortunes

As with most aspects of Brexit, no-one really knows how the UK leaving the EU will impact on homegrown innovation. While some relevant policies will remain unchanged, such as the general R&D claim process, there are wider-reaching implications which could affect British researchers.

The UK has an excellent reputation for innovation and this could prove significant. If our economy suffers as a result of Brexit, the value of the pound against other currencies will fall. As such, global businesses may see British companies as attractive investments, as their quality services and projects will suddenly be available for smaller sums. This could potentially fill the void left by current EU funding.

R&D tax credits and Patent Box relief will play a crucial role in establishing the UK as a creative force post-Brexit. Once EU funding for projects is removed, the importance of the domestic HMRC initiative will amplify tremendously, potentially causing a rapid increase in applications.

Continuing and improving the financial incentives for businesses to spend time on R&D will ensure that the country continues to be at the forefront of innovation. MPA's guidance on the R&D Tax Credit scheme and Patent Box relief will help you see whether your company qualifies for the initiative.

MPA is exhibiting at Advanced Engineering 2019 and can be found at stand C14 in the Automotive Engineering section.

For more information email **ellis.noble@jaywingpr.com** or **jamie.crane@jaywingpr.com** or call **0113 887 3309**.

About MPA: MPA help clients accelerate their innovation and business expansion. They help companies to capitalise on their research, innovation and development activities by maximising all the potential benefits from available HMRC tax concessions.

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Face up to freedom

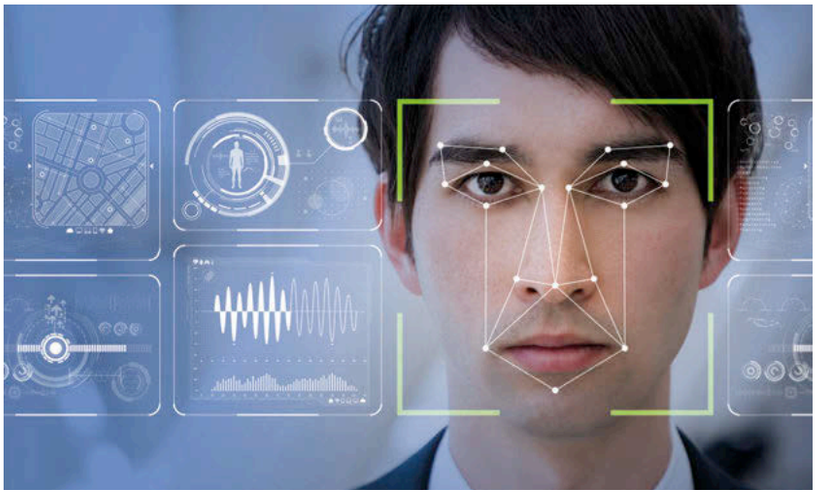
Facial recognition technology is proving controversial as police forces seek to deploy it in public areas. *Daragh Murray* explains some of the legal issues behind the arguments

The use of live facial recognition (LFR) technology in the UK has been the subject of significant public debate in recent months. High-profile trials conducted by South Wales Police and the Metropolitan Police Service have been the subject of legal challenge and investigation by the Information Commissioner's Office (ICO). Equally, the deployment of LFR by private companies has been met by public shock – due to the lack of transparency – and has also prompted an investigation by the ICO.

LFR technology involves the real-time identification of individuals passing through a camera's field of vision. This gives rise to an interference with the right to private life, as protected under Article 8 of the Human Rights Act. This is because biometric information is inherently personal, and is treated as similar to a fingerprint or DNA sample. The right to private life of every individual identified is engaged, irrespective of whether they are actively sought by the police or are an uninvolved passer-by.

The fact that LFR technology gives rise to an interference with the right to private life does not necessarily mean it violates that right. Interferences with a right can be justified, to protect public order or the rights of others. The legitimacy of an interference is determined by a human rights law test examining whether the measure (in this case the LFR deployment) is in accordance with the law, pursues a legitimate aim, and is necessary in a democratic society. Broken down to its simplest form, this test is intended to (a) protect against arbitrariness, by ensuring, for example, that the circumstances surrounding a facial recognition deployment are foreseeable, and (b) to ensure that in pursuing a legitimate aim, other rights are not inappropriately interfered with. For instance, the Surveillance Camera Commissioner concluded that police use of facial recognition technology in a Manchester shopping centre was disproportionate, in light of the limited utility of the deployment compared to the very large number of individuals whose right to private life was interfered with.

To date, attention has focused primarily on the impact of biometric processing on the right to private life. This may be a result of the relatively limited nature of current LFR deployments, which are typically limited in duration and focused on identifying individuals already known by the police. The potential inherent in this technology is, however, significantly greater. For example, when connected to other data sources – such as passport databases – LFR technology can be used not only to look for specific individuals, but also to identify anyone in an image and to match them to their government ID. The integration of LFR technology into a CCTV system also enables tracking individuals' movements across a potentially city-wide area. In turn, this information can be subject to machine-learning analysis to develop individual profiles. This can reveal incredibly detailed information regarding an individual's personal and professional life.



Facial recognition affects the right to a private life of all subjects, whether or not they are sought by the police.

Image credit: metamorworks

These more advanced uses of LFR technology give rise to more extensive human rights concerns. The right to private life remains relevant. Anonymity allows for a process of experimental learning or development, whereby individuals can engage with different ideas, political discourses, or aspects of their sexuality and so on without fear that this information will become public. As such, anonymity is recognised as essential to the development of personality and identity. LFR technology directly threatens the ability to act anonymously. Given the potential impact on individual and societal behaviour, this gives rise to a serious interference with the right to private life.

However, the human rights impacts extend far beyond the right to private life. LFR technology may affect how individuals interact with each other, receive information, and engage with different thoughts or ways of life. This is intrinsically related to individual development but brings into play rights such as freedom of expression, association, assembly, and religion. This may affect the functioning of a participatory democracy, as surveillance can dissuade individuals from seeking out new ideas or challenging the status quo; what would happen if LFR is used at protests? Also, detailed individual profiles made possible by advanced facial recognition may be used to inform diverse decisions relating, for example, to the rights to work, to health, or to social welfare.

LFR represents a step-change in surveillance and analytical capabilities. There are clear benefits associated with this technology, but the potential human rights harm is significant, particularly the possibility that participatory democracy may be (inadvertently) undermined.

Daragh Murray is a lecturer at the human rights Centre and School of Law at the University of Essex, and is co-author with Prof Peter Fussey of a report into the Metropolitan Police's trial of LFR. ■

Data Logging has Evolved

October 2019

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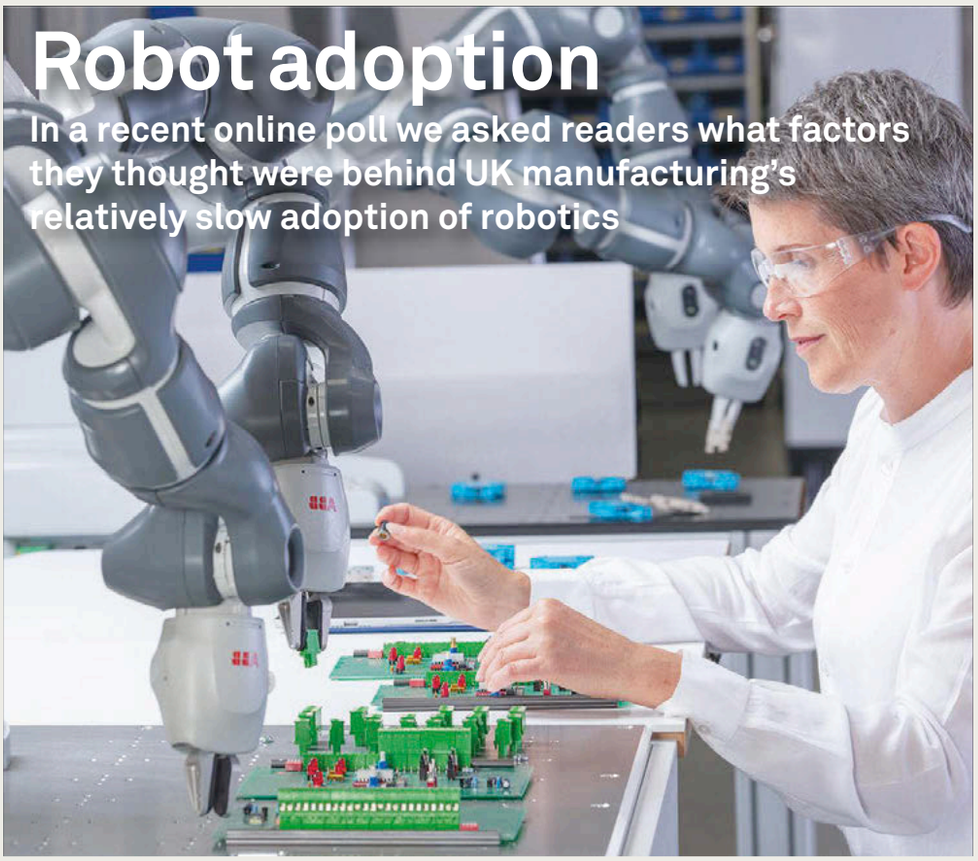


Robot adoption

In a recent online poll we asked readers what factors they thought were behind UK manufacturing's relatively slow adoption of robotics

I voted "unwillingness to invest", not because my company is failing to invest in new machinery, but rather because it is failing to "invest in people". Robots tend to require a higher level of skills in the workforce – for every operator lost you need an IE to program the robot. Our geographical location doesn't help: there's plenty of un/semi-skilled workers available, but few IE's and poor local training facilities.
Ian Wilson

Computer-controlled equipment requires a high level of thinking power to achieve any results, and more still for best results. Without that the equipment just becomes an expensive replacement for conventional machinery with no obvious gain. A further concern is that, in our case, the average age of the skilled programmers is high and rising. Where are the young, thrusting, give-me-a-problem-and-I-will-solve-it engineers? I believe that failure to invest is partly driven by the fear that a company will be unable to find the right people in the future and thus have simply wasted money and space. We really must, somehow, get across to young people the joy of engineering and the satisfaction of making a good program for a computerised machine of any sort.
Richard Jenvey

Anything less than investing in the smart application of technology as capabilities mature, is shortsighted.
Furthermore, in retirement you will depend on others, so for them, and to maintain the value of your money, you need to bring on the next generation. That means providing the schooling and encouragement for all our children and young people so they can prepare for the more varied and stimulating types of work that will come to them as machines take on all the drudgery.
Norman Canham

Many of our manufacturers are small jobbing type companies specialising in short run hand built components where it would be uneconomical to invest in robotics/automation for small run manufacturing.
Bruce Ellison

Many UK manufacturers are holding off on making an investment in robotics due to a misconceived idea that robotic automation is both costly and complex. In actual fact, the cost of robots has been declining for some time whilst technology has developed to make implementation easier. According to Management Consultancy firm McKinsey & Company, the price of robots has dropped by over half in the last thirty years whilst 'advances in computing power, software-development techniques and networking technologies have made assembling, installing and maintaining robots faster and less costly than before.' Virtual commissioning and offline programming software, which is used to design and program robotic automation offline before uploading to the live installation, also simplifies the process and significantly reduces downtime.

Robotic automation also delivers a number of benefits such as increased flexibility and greater productivity which combined lead to a significant return on investment over a number of years. Take for example, Northamptonshire-based DB Shoes, who has installed two robots to perform roughing of leather uppers. The robots can handle multiple shoe designs and can be easily adapted to handle new designs in the future so that DB Shoes can now produce around 300 pairs of shoes a day and up to 700 shoes if required.

Furthermore, during these uncertain times robotic automation allows businesses to fill the ever-growing skills gap. Recently the Institute of Engineering and Technology predicted that over the next few years there'll be an annual shortfall of 59,000 engineers and technicians.

We should avoid a culture of short-termism whereby investments are only made if a quick return is guaranteed. Not thinking ahead means UK manufacturers run the risk of losing out to foreign competitors who use robots to produce high quality products quickly and cheaply.

It's no surprise that the second most popular reason cited for UK manufacturing lagging behind is an unwillingness to change production. However, if UK manufacturers don't start to adopt robots, they run the risk of foreign competitors increasingly winning their customers in the race to automate.
Nigel Platt, Head of Robotics & Automation UK & Ireland, ABB

Thesecretengineer

From the V2 to Apollo 11: Wernher Von Braun's conflicted legacy

The man behind the Saturn V rocket was notably absent from many of the recent Apollo 11 retrospectives. Our secret engineer considers how he should be remembered.

I was born into a world teetering on the cusp of taking its first steps on the Moon. As I grew older we turned away from our neighbour and left political ideologies behind to shake hands in space via the Apollo-Soyuz mission, carried out experiments in Skylab and Mir then glimpsed the dream of everyday space travel with the Shuttle. It was an age defined by a drive to fulfil the goals set earlier, of always pushing onwards; yet the very first Moon landing remained uneclipsed as a high point. Possibly because, if only for a moment, it gave a shared pride in what we as a species could achieve. The USA might have planted the flag on the Moon but humanity as a whole claimed the prize.

You can imagine then that I avidly watched a number of the programmes centred on the 50th anniversary of this event. All looked back with pride and amazement on what was accomplished by a huge number of people, backed by an equally huge budget, with the remit to pursue a single goal. Of course the three pioneers – Armstrong, Aldrin and Collins – are always at the centre but even so various other contributors, some familiar and some not, get their time in the spotlight. Except for one person especially notable by their absence.

My memories of Wernher von Braun, formed through interviews in the media and references in books, are of the avuncular

Wernher Von Braun stands by the five F-1 engines of the Saturn V Dynamic Test Vehicle Image: NASA

figure who masterminded America's space programme. The Russians kept secret the existence of their own rocketry genius (Korolev) until only a few years ago. Von Braun by comparison was the ubiquitous face that exhorted us all to reach out from planet Earth. He was seen as the architect of our greatest achievement with the Saturn V as his masterpiece, something that is still an object of awe and which has been showered in superlatives in the recent coverage.

So what happened then? We always knew he was the brains behind Hitler's V2 and we always knew that slave labour was used in its construction and deployment. A perceived necessity during the Cold War may have helped us ignore this but it did not erase it. My understanding is that his aim from the start was to reach the Moon and he saw military funding as a way of fulfilling that dream. It's difficult to imagine he did not know of the human cost, an industrial level of disinterested and disconnected destruction of lives, for me something that is impossible to forgive.

Personally he remains a shade at least of a hero through his later achievements, but a corrupted one. Someone whose vision reached out to the stars yet whose feet remained firmly and irrevocably planted in clay and blood.

How we should view him now is undeniably tricky How much did he care about the slave labour and its consequences? Did he lose his moral compass and regret it later? It's difficult to separate fact from either opinion or the distortion caused by the US propaganda required to make the post-war use of German scientists palatable.

Even more difficult, did he at least partially redeem himself with a career that led to Apollo 11? Whatever you think, writing him out of the history of the Moon landings is shameful cowardice. We have a professional obligation regarding ethics and we , if no-one else, must lead the discussion on engineering related issues, includingthe Nazi roots of arguably mankind's greatest achievement to date. We owe at least that much to the 20,000 sacrificed on the altar of V2 mass production. ■

Inyouropinion

Babcock wins Type 31 frigate contract

Excellent news and good to see that the work will be spread around the UK.
John Swallow

The only way it can cost £250 million each, is if most sensors & weapons are missing. I wonder what the real cost of a fully equipped ship is?
JohnHartley

After years of an effective monopoly on military shipbuilding under BAE, this bodes well for increasing value for money for the UK taxpayer.

As good as high tech, high capability ships are there's no substitute for numbers when it comes to patrolling the seas.
J Eyre

Brexit & manufacturing

The continual delays are far more damaging to investment than either staying or leaving would be. Even though I am now a "leaver", I would prefer to remain rather than to continue delaying; however, our self-interested politicians dare not make either decision: hopefully their day of judgement is approaching!
jack broughton

The electorate is significantly better informed than in 2016. It is obvious that much of the positive case for Brexit is bogus (such as £350M/ week extra to NHS, "easiest trade deal in history...") It's also obvious that leaving the EU would create unresolved problems: availability of medicines, loss of access to market, loss of investment, separation of families. The Leave campaign lied extensively Boris Johnson & his cabinet repeatedly lie or fail to honour assurances such as not proroguing Parliament, the dates when decisions were made. There is no majority for any form of Brexit; MPs have been allowed multiple votes. It's time for another referendum based on facts, not lies of Leave.
Mark Harrison

Join the debate
theengineer.co.uk

The wing master

Bombardier's A220 wing requires an entirely new production philosophy, reports Stuart Nathan

Image:Airbus

Developed as the Bombardier C-class, the 130-seat airliner is now known as the Airbus A220

It's almost a cliché to say that commercial aircraft don't look much different now than they did two decades ago. But get below the skin and they have changed beyond all recognition. And little demonstrates this better than the wings of the Airbus A220, the small airliner that began its existence as the Bombardier C series. Although outwardly there is little to distinguish them from the wings of any other small airliner, they are so radically different from conventional wings they required the adoption of an entirely new design and manufacturing philosophy and the construction of a purpose-built factory at Bombardier's historic Belfast site.

It was these radical differences that led to the wing being selected as the winner of the 2019 MacRobert Award, the highest honour awarded to an engineering project by the Royal Academy of Engineering. Previous winners include the Pegasus jet engine that powered the Harrier, catalytic converters and intelligent prosthetic limbs, putting the wing into rarefied company.

Mainly composed of composites, like the wings on several of the newest-generation airliners such as the Airbus A350 and Boeing's 787 Dreamliner, what marks out the Bombardier wing is the way it is made: by resin-transfer infusion (RTI). While most composite wings are made from pre-impregnated carbon fibre (pre-preg) pieces, RTI involves placing dry carbon fibre into a mould and flooding it with liquid resin, which is then cured to hardness by heat and pressure to give a solid fibre-reinforced part. It is therefore suited to making large, single-piece structures, rather than assemblages made from many components that are fixed together with adhesives or mechanical fasteners, eliminating mass and improving mechanical qualities.

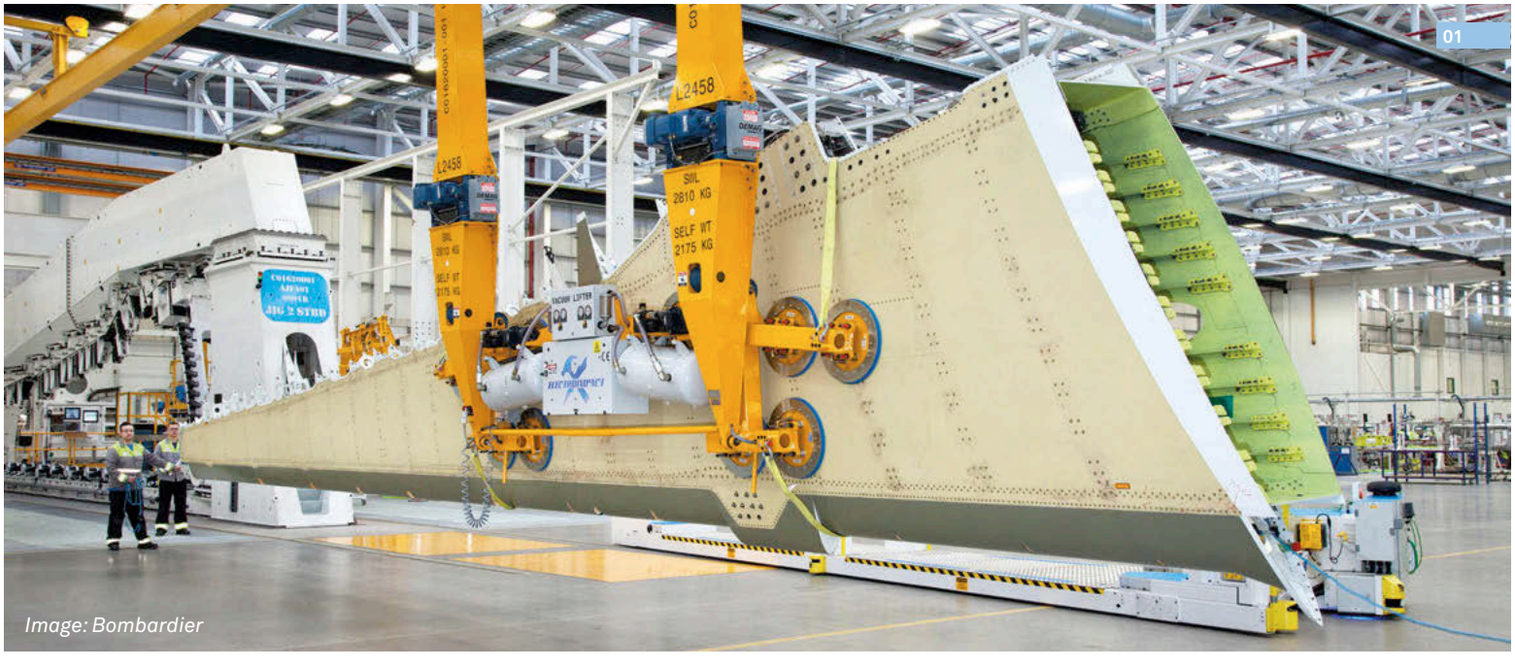
It was these advantages that drove the design of the wing, explained Gavin Campbell, director of quality, airworthiness and technology strategy at Bombardier. "RTI was very much the means to an end, rather than an end in itself. It was the best way – indeed, probably the only way – of achieving what we wanted with this design."

In terms of its performance, the wing is 10 per cent lighter than a conventional all-aluminium wing, which produces concomitant improvements in fuel economy and reductions in emissions of oxides of carbon (20 per cent less CO_2) and nitrogen (50 per cent less NO_x), reducing the aircraft's impact on climate change and air pollution. Those energy savings are also seen during manufacturing: pre-preg requires intensive refrigeration before manufacture, whereas RTI requires less energy, even with the heating and pressurisation needed for curing.

According to Campbell, the origins of the wing lie in the specification of the C series aircraft, as it then was. "Bombardier looked at the market and realised there was a gap for a small airliner to carry 100-150 passengers. As small aircraft were our area of specialisation, we decided to design an aircraft from scratch to serve that market, and this aircraft is the only one purpose-built for that sector."

Reducing weight was a major consideration on the project, because there was a trade-off involved, Campbell explained. "In the beginning, the use of the Pratt & Whitney gear turbofan engine was an important part of our plan. Although it is very efficient, it's also relatively heavy because of its large circumference – that gives it a very high bypass ratio, which is key to the efficiency. But because we knew we were taking a weight penalty there, we had to reduce weight elsewhere."

One very important method for achieving that



01
Image: Bombardier

weight gain was in reducing parts count, especially in the part of the wing known as the 'torque box'. This is the structure of the wing onto which its working components, such as engines and control surfaces, are attached. "To engineer, a wing is basically a cantilevered beam. It can twist and flex in use, and has to withstand those torque forces," said Campbell.

In conventional wings, there are many parts to the torque box, including spars (the beams that run from root to tip), ribs (the reinforcing members that run front to back, perpendicular to the spars), and skins (as the name implies, the aerodynamically curved panels that form the top and bottom outer surfaces of the wing). However, RTI allows the torque box to be made up from only four components – the front spar, rear spar, and upper and lower skins – greatly reducing complexity in manufacturing and enabling improvements in mechanical performance because there are fewer points where the structure can fail, Campbell explained.

As well as mechanical performance, RTI also allows further improvements to be made in the geometry of the wing. In an email Q&A with The Engineer, Bombardier engineers explained that the technique allows close-tolerance mould tools to be used, which improved the aerodynamic contour of the wing skins, not least by eliminating skin-panel joints. "When you're making an aluminium wing skin, you are limited by the width of aluminium sheeting that rolling mills can make, so you have no alternative but to join together many separate sheets, usually by riveting," Campbell said. "That will inevitably reduce the aerodynamics, because the air has to flow over those joins. Making the skin in one piece eliminates that problem completely; it makes a single, smooth panel." Stringers, components that run parallel to spars and connect the wing panels to the structure of spars and ribs, are co-formed and -cured with the skins, further eliminating the need for separate components and fasteners.


02
Image Bombardier

01 The wing is 10 per cent lighter than a conventional all-aluminium structure

02 Bombardier staff in the purpose-built Belfast facility

> "We knew we were taking a weight penalty with the Pratt & Whitney geared turbofan engine, so we had to reduce weight elsewhere"
>
> Gavin Campbell, Bombardier

The production technique is not the only innovation in the wing. The fuel and hydraulic systems (which are fully integrated into the wing at the Belfast factory, rather than being installed as part of a further assembly process, as is commonplace with other aircraft manufacturers) had to comply with airworthiness standards regarding protection of ignition sources. Bombardier developed a special polymer bracket that, in the event of lightning strike on the aircraft, has insulation to prevent power surges inside the fuel tank. However, it also has conductivity to dissipate the build-up of static electricity.

Much of the expertise to develop the wing and its manufacturing was in-house, Campbell said, but two collaborative projects were instrumental to the effort. Bombardier has been involved with composite design since the early 2000s and before, and this led to its involvement from 2002 to 2004 in

03 The facility handles all aspects of production from receipt of raw materials

a European research initiative known as TANGO, aimed at reducing weight and cost in wing structures, and ALCAS (advanced low-cost aircraft structures) from 2005 to 2010. TANGO involved producing a 12m-long resin-infused spar to support lateral wing-assembly techniques, which was evaluated in a static test. For ALCAS, a 14 x 4.5m upper wing skin incorporating fibre reinforcement, integral stringers, material screening and process development was assembled into a structural wing and tested to see if it could withstand in-service loads.

Subsequent to those projects, the company has been involved in UK-based research in programmes such as Integrated Wing and Next Generation Composite Wing, in partnership with the UK Aerospace Technology Institute. "So, in that sense, the development could be said to be a collaboration, but working on those projects gave us the experience to do much of the work ourselves," added Campbell.

The production system for the wing, in a fully integrated factory where carbon fibre and liquid resin come in at one end and completed wing systems ready to be assembled onto the aircraft fuselage go out the other, was devised in part in collaboration with the School of Mechanical and Aerospace Engineering at Queen's University Belfast. Queen's developed a software package called QUEST (queueing events simulation tool). This was initially used for visualisation, communicating the configuration of production lines and operator training. However, it also proved invaluable for its ability to identify bottlenecks associated with production flow. Its simulation functions allowed factory staff to introduce 'what-if' scenarios into the production line and identify their outcomes without the need to invest in expensive tooling and equipment. The factory has used QUEST to make the most of the capacity planning decisions and set its tooling/budgetary requirements.

Apart from the RTI system, manufacturing processes include complex drilling operations during final assembly of the torque box, including boring large-diameter holes through complex stacks of material carbon-fibre, titanium and aluminium. Bombardier worked with several machinery suppliers to develop a common cutting tool capable of coping with all the different requirements of these materials and adapted the large automated drilling equipment to sense the different materials as they contacted the tool and adjust feed rates and speeds accordingly.

> "We were impressed with the scale of the operation. It is unique in the aircraft world"
>
> Dame Sue Ion, chair of MacRobert Award judging panel

Structural design of the wing was performed using the software package CATIA, and associated software was used for bill-of-materials creation and management, configuration management, scheduling and quality control.

"It's a totally digital factory, with all the sensors, use of simulation and digital twins that implies," Campbell said. "However, we don't tend to use terms such as Industry 4.0 because these are all developments of systems and techniques that we were using in the aerospace industry anyway."

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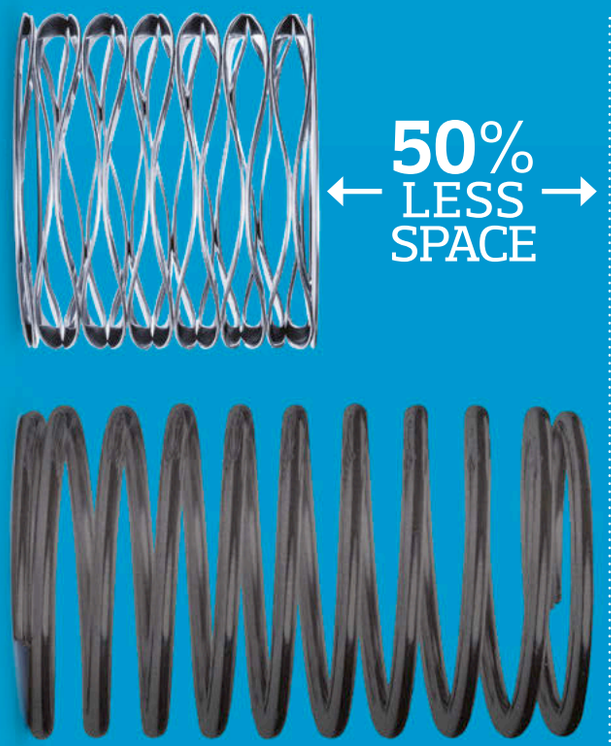

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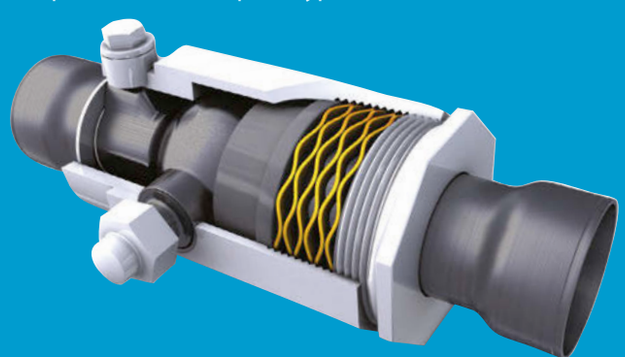

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> "The composite wing won't degrade or corrode like aluminium does, so should need longer between maintenance operations"
>
> Gavin Campbell, Bombardier

The factory, a 60,000-square-foot facility, not only allows full traceability of all the raw materials in the process but also encompasses under one roof all processes, from receipt of raw materials through fibre cutting, lay-up, the RTI system, non-destructive testing, wing assembly and testing and dispatch of the complete wings to assembly facilities in Montréal and Mobile, Alabama. It is unique in this respect and was instrumental in the MacRobert Award judges' decision. "We were impressed with the sheer scale of the operation," said Dame Sue Ion, chair of the judging panel. "It is unique in the aircraft world in going from receipt of raw materials to a fully validated wing". Carrying through the environmental credentials of the project, the facility uses low-energy solutions in its mechanical and electrical infrastructure and incorporates one of the largest rooftop solar installations in the UK, with 14,000 photovoltaic panels generating around 2,800MW hours of renewable energy.

Technology developed for the wing programme is also highly transferable, Bombardier believes. The torque box construction could be used in most aircraft types, particularly electrically powered aircraft where the way that energy storage and propulsion are distributed will require differences in the way that aircraft structures are designed, constructed and reinforced. RTI is well suited to manufacturing integrally stiffened panels with no need for bonding or mechanically fastened joints. The concepts can also be applied to the tailfin and horizontal tail stabilisers of aircraft, and Bombardier has already used it for the horizontal stabilisers on its Global 7500 business jet.

The engineering team also believes that the environmental benefits of the manufacturing technique will carry on beyond the service lifetime of the aircraft. Although aluminium is always easier to recycle than composites, the reduction in fuel burn and emissions enabled by the lighter weight of the composite structure means that higher embedded carbon in the production and disposal of polymers and carbon fibre relative to recyclable aluminium are repaid after only hours of flight operation.

Campbell added that the wing will have maintenance advantages over conventional aluminium constructions. "It won't degrade or corrode in the same way as aluminium does, so we should need longer between maintenance operations," he said. "What's more, composites have superior fatigue performance to aluminium." ■

04 The facility despatches fully validated wings, with all hydraulic systems integrated

05 Bombardier provides skilled employment for the Northern Ireland economy

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Moving the Moon

The Moon is often portrayed as a dead world, but it is rich with fictional potential

Fifty years on from Apollo, most of the discussions around returning to the Moon focus on mining or colonisation. Both could be useful and even profitable enterprises, but are there other, more off-the-wall reasons to visit our celestial companion? Could the Moon help us fight climate change?

Lots of people have suggested covering the Moon's surface with solar cells in order to harvest a lot of clean energy and beam it back to receiving stations on Earth. But why stop there? As a science-fiction author, my job is to take inspiration from today's headlines and add a dash of wild speculation.

So, how about we make the Moon's shadow larger?

Imagine building a 1,000km-high mast on the Moon, at the border between its visible and hidden faces. Now imagine building another 100km away, and then another. Eventually, you get the visible Moon ringed by these huge spikes, like a grapefruit with hundreds of cocktail sticks stuck in it. Now imagine we hang mirrored material between these masts. This would make the Moon appear much larger and therefore blot out the Sun's rays over a wider area of the Earth's surface, reducing the amount of sunlight reaching the Earth by a small but significant fraction.

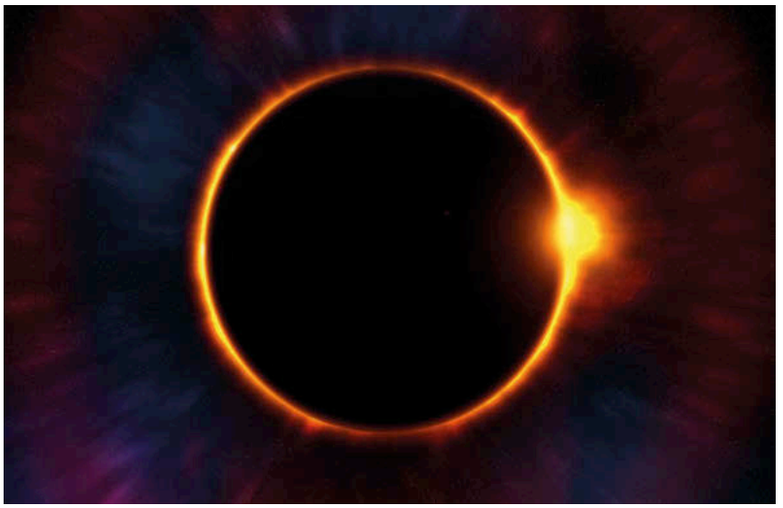
Not wild enough? Okay then, how about we draw down the Moon?

Since its formation, the Moon has been gradually pulling away from the Earth at a speed of almost 4cm per year. Although that doesn't sound like much, it is enough to subtly slow the Earth's rotation, increasing the length of our days.

One-and-a-half billion years ago, the days on Earth lasted only 18 hours. Now, they last 24 and, in the far future, they may last even longer.

However, if we could use giant motors or near misses by large asteroids to move the Moon closer to the Earth, we could maybe reset this process, using a faster-orbiting Moon to increase the Earth's rotation and shorten our days.

Why would we want to do that? Well, assuming we could withstand the resultant earthquakes and manage not to drop the entire Moon into the Pacific, the main effect of a shorter day would be that it would give the East and West hemispheres of the Earth less time to warm up in the glare of the Sun. The oceans would have less time to absorb heat, and winters would become colder. In addition, a faster-rotating Earth would give us faster-moving tides, which could have implications for tidal power generation – not to mention surfers.



The shadow of the Moon causes the effect of a solar eclipse. Making the shadow bigger might help us fight climate change but would eliminate one of the Earth's great natural wonders. Would it be a fair trade-off? *Image via Pixabay*

But if we had such god-like powers of celestial engineering, why stop with simply moving the Moon? Why not find more Moons?

Manoeuvring asteroids and comets into orbits around the Earth would put their resources at our fingertips. I don't want to start sounding like an eccentric billionaire trying to push a tech start-up, but asteroid mining would provide a cornucopia of ores and minerals, making the idea financially attractive. And if you're mining material in orbit, it makes sense to process it on-site. You could also move heavy, polluting industries into orbit, decreasing the CO_2 emitted into the Earth's atmosphere.

All those little Moons would also provide more opportunities to create Sun-blocking mirrors to shield our atmosphere from heat. Imagine looking up at the night sky and seeing a ribbon of lights stretching across from one horizon to another, each one a small town or industrial installation.

As a pragmatist, this might sound like a lot of starry-eyed foolishness; but as a writer, the idea's almost irresistible. It would make a great setting for a story. What would the people who lived on these tiny Moons be like? What kind of societies would they have? Would they be pioneers building a life in the sky, or contracted employees doing months-long shifts in orbit? Would they owe allegiance to one nation, to the whole Earth, or to themselves?

What sort of engineers would be needed in such a world? You'd need to be able to work and thrive in freefall. Perhaps you'd have physical adaptations to help you deal with the long-term health effects of living with reduced gravity. You'd certainly need to adapt your skills and techniques to working in a whole new environment; maybe you'd even need to develop some new ones.

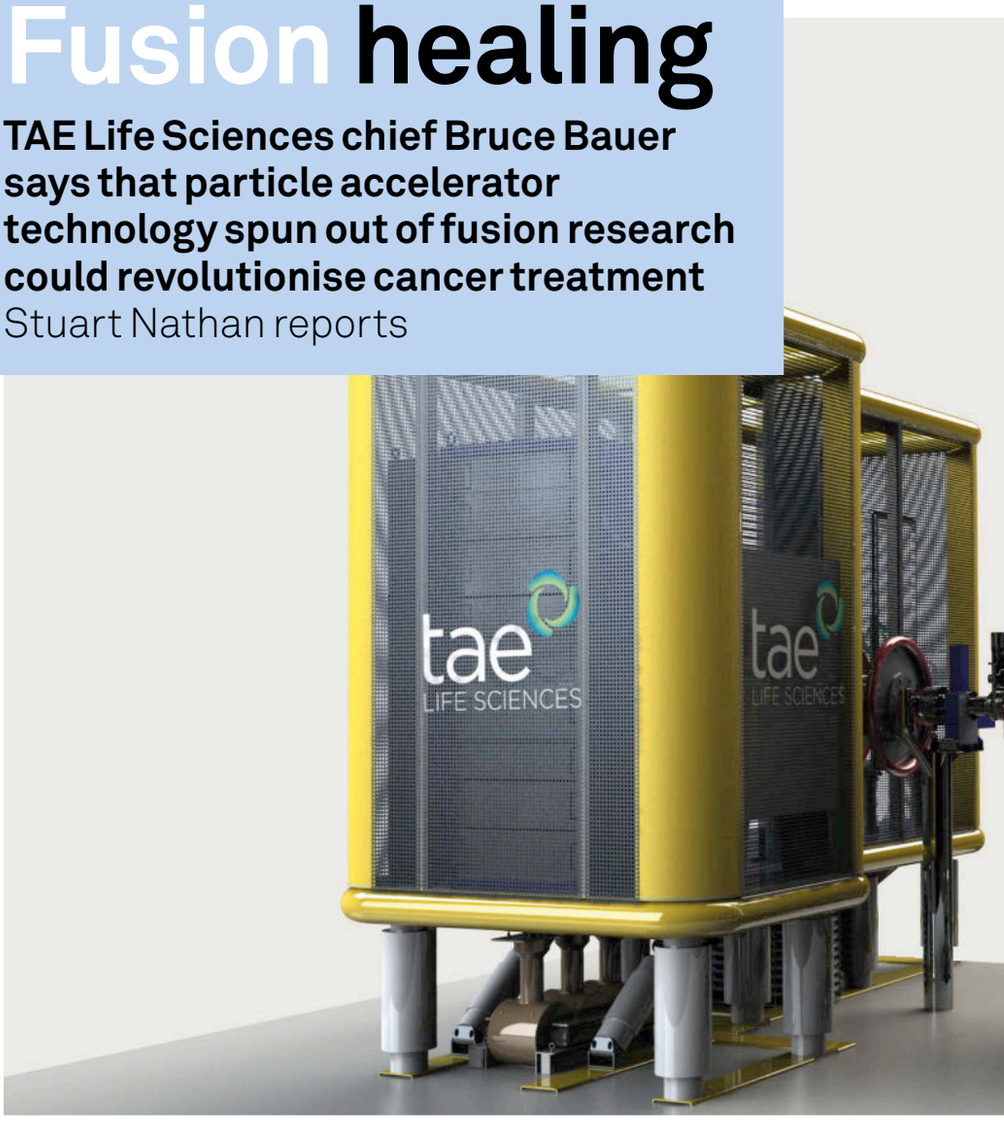
Too often, the Moon is portrayed as a dead world. But with the right kind of imagination, we can see it's alive with possibilities. The schemes I've outlined above are crazy, but as we face the reality of global climate change, the idea of finding a way to naturally cool the planet is an attractive one and moving the Moon would make a heck of a science fiction novel.

Gareth L Powell is a science-fiction novelist born in Bristol and educated in Wales. His novels include the Ack-Ack Macaque trilogy, and the Embers of War space opera trilogy.

Fusion healing

TAE Life Sciences chief Bruce Bauer says that particle accelerator technology spun out of fusion research could revolutionise cancer treatment

Stuart Nathan reports



There are never enough effective cancer therapies, it seems. The challenge of treating a disease that's essentially the body turning on itself has occupied the medical sector for much of the last half-century. No longer is a cancer diagnosis an automatic death sentence. But the problem remains: how do you kill off the invasive mutant cells of a tumour without damaging healthy surrounding tissue?

It might seem illogical that the answer could lie with nuclear fusion, but fusion depends on particle physics, and such fundamental science has often proved key to the radiotherapy side of cancer treatment. Treatments such as intense X-ray radiation of tumours, nuclear medicine and proton beam therapy all arose from studies of the fundamental composition and behaviour of matter and of electromagnetic radiation.

For California-based TAE Technologies, cancer treatments are a goal with twin advantages. The first, as Bruce Bauer, chief executive of its subsidiary TAE Life Sciences explained to *The Engineer*, is simply that it offers the opportunity to treat previously intractable forms of the disease. The second is that it allows the parent company, which has a forward-looking and unusual approach to nuclear fusion, to generate income from its technologies before they reach fruition in the energy-generation sector.

"Like most technically heavy research programmes, there's technology that gets developed along the way that has collateral applications," Bauer said. In this case, the key technology is a compact particle accelerator.

Previously known as Tri-Alpha Energy, TAE Technologies is pursuing fusion via a method known as aneutronic power. Whereas in most forms of fusion, the energy of the key reaction is transmitted by emission of fast (i.e. high-energy) neutrons, in aneutronic power the energy is carried by charged particles.

Like many types of fusion reaction, this takes place in a plasma, a cloud of gas composed of charged particles, and this plasma must be heated to encourage its constituent particles to move faster and thus promote fusion-producing collisions. To do this, neutral particles have to be injected into the plasma, and it is this process that gave rise to the key technology that Bauer's subsidiary is using: a so-called 'tandem accelerator' that generates fast neutrons.

"What we've done is take tandem accelerator design and repurposed it, downsized it to a much lower power level, and are using it to generate a neutron beam for cancer care," he said.

01 TAE's tandom accelerator technology

02 The proposed system is compact enough to be installed in a hospital.

The neutron beam is instrumental to a form of treatment that has been investigated in recent decades, but only at a very small number of locations. Boron neutron capture therapy (BNCT) involves directing a beam of high-energy neutrons at a tumour that has previously been infused with a boron 10-containing drug called Boronophenylalanine (BPA). The boron in this compound, which is not radioactive, can capture fast neutrons, and when it does, it breaks down to emit an alpha particle, a lithium nucleus and 2.31MeV of energy. This kills tumour cells but is stopped by cell walls so cannot damage adjacent healthy tissue.

Although BNCT has been studied since the 1960s, the problem with turning it into a clinically available cancer treatment has been the availability of neutron beams. These are very difficult to produce because, being uncharged, neutrons are difficult to accelerate. The only place where a neutron beam has been available is a specialised research reactor.

"At their height, there might have been 10 or 12 of these reactors worldwide that were used," Bauer said. The most prolific work was in Japan, Taipei and Helsinki, but the Finnish reactor was shut down eight years ago. The Taipei facility is due to be decommissioned next year. "And as you can imagine, a nuclear reactor was never exactly the most convenient, proper, place to treat patients," Bauer said. "Although over the years, close to 2,000 patients with recurring cancers have been treated with the technique, it's never been a clinical procedure, only ever research."

The tandem accelerator gets around the neutron acceleration problem by not accelerating neutrons: it generates fast neutrons within its mechanism by electrostatically accelerating protons so that

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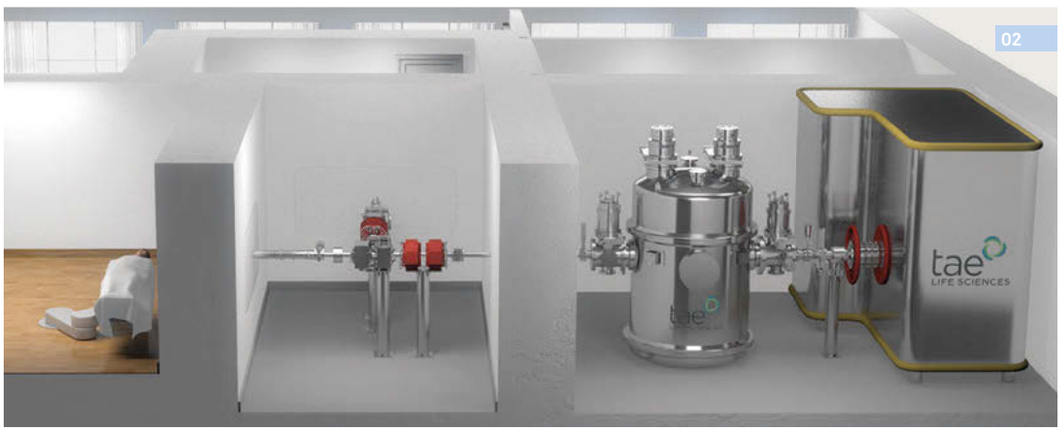


02

they collide with a lithium target. The collisions between fast protons and lithium nuclei ejects a stream of energetic neutrons that is suited to BNCT.

"When you have a tandem design, it enables a relatively compact, small footprint," Bauer explained. "It's a very reliable design because you're using a lower voltage to generate the acceleration. It's a device that has a form that's practical to install and operate in a clinical setting: you can put this in the basement hospital quite well. Our target design and beam-shaping assembly comes together into a reasonably compact set-up that can be installed in a vault or a bunker in a hospital. It's a baby version of what you would expect to see, say, for a proton-beam therapy treatment centre. The shielding is far more modest than for a proton beam."

TAE is not the only company treading this path, Bauer said. Japan is leading the field, and Finland is also looking at ways to extend its research capabilities beyond the closure of its reactor. But TAE is looking to China for its first exploitations of its version of the technology. "We are partnering with a Chinese company called New Boron, and our first system is going into China at the end of this year," he said. "We'll be hoping to treat our first patients sometime early in 2020 and start producing data to go along with Japanese and Finnish groups."

The choice of China is not just because its huge population means there are likely to be more people with the types of cancer that respond best to BNCT, Bauer explained. The technique seems to be most useful for head and neck cancers, which are difficult to treat by other means, partly because of their proximity to so many vital anatomical structures. "China has five times the incidence of head and neck cancers compared to Europe or the US. They seem to have a perfect storm of risk factors – 16 or 17 per cent of all tumours there fall into that category; elsewhere, it's more like 3 to 3.5 per cent. It is most likely that there are lifestyle risk factors: many more people smoke, and they eat a lot of food that has been processed with nitrites or smoked, which have been associated with cancer risk. Moreover, there is a high prevalence of human papillomavirus in the population and that's a known precursor to head and neck cancer. So, there tends to be many more people suffering from those difficult-to-treat cancers."

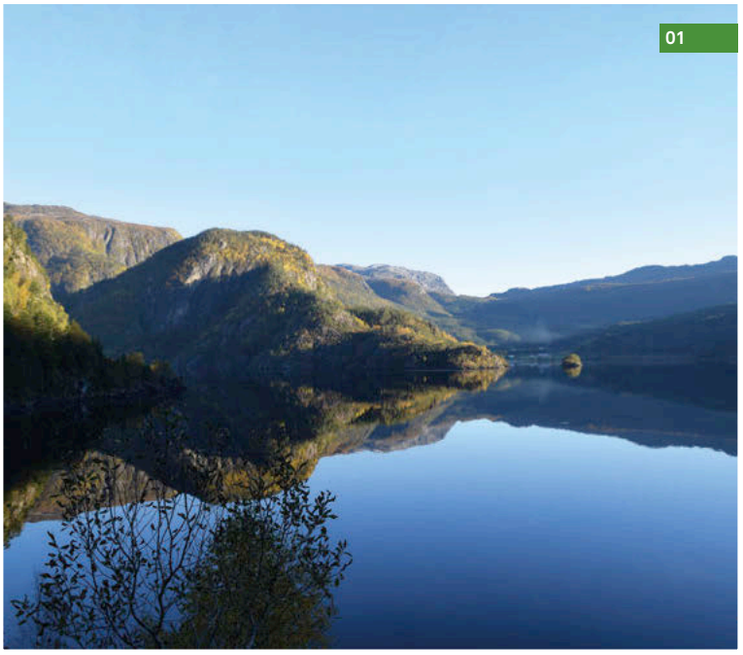
> "It's practical to install ...in a clinical setting: you can put this in a. hospital quite well."

Previously, the first-line treatment for this type of tumour is radiotherapy, but this is arduous. "The radiation has to be given in many fractions, 30 times over six weeks. You come back every day. You inevitably damage healthy tissue as well, and that gives rise to side-effects. With BNCT, the procedure is only given once or sometimes twice for half an hour or so. The tumour tissue is subjected to very high levels of destructive energy, but that only happens where you have boron and neutron together at the same time. It's a highly effective treatment, because it is very damaging to the cell. It causes a very messy double-strand break of the DNA, but it stays inside the cell and an adjacent non-cancerous cell that has no boron in it will be completely untouched. The only side-effect really is failure to treat, perhaps because the tumour is too deep for the neutron beam to reach the target, or the targeting drug hasn't been effective at getting the boron sufficiently distributed throughout the tumour cells. BPA is a modified form of an essential amino acid, and because cancer cells are perpetually growing and dividing, they have a higher propensity to take it up than healthy cells. You tend to have more than three times as much BPA in a cancer cell. Development work is concentrating on improving the take-up rate, and it would be good for it to persist for 24 to 48 hours so that you could give an infusion one day and bring the patient back the next for the neutron beam treatment. Currently, it has to be within a few hours."

BNCT has also shown promising results with other types of cancer such as lung and pancreas, where recurrence is common and treatment difficult. Bauer, whose background is in the discipline of biomedical engineering and the business of venture finance, lost his business partner to glioblastoma (an aggressive form of brain cancer) at the age of 60. "It's very satisfying to me just to be part of a corporate infrastructure that is trying, whether through energy or healthcare, to make an impact on our world," he said. ■

Power sharing

North Sea Link, a subsea electricity cable linking the UK with Norway, will be the longest interconnector of its kind in the world. Jon Excell explores the engineering challenges behind this milestone energy project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It's perhaps surprising, given the increasingly divisive nature of the Brexit conundrum. But at a time when all we seem hear about is the severing of political ties to Europe, the UK is becoming ever more closely connected to the European mainland via an ambitious series of underwater power cables linking its energy network with the grids of its nearest continental neighbors.

Across Europe, these so-called interconnectors, which enable countries to trade and transfer electricity across borders, are viewed as an increasingly important way of boosting security of supply; stabilising prices; managing fluctuations in supply and demand; and driving the uptake of low-carbon technologies by helping to provide a solution to intermittency issues.

There are already almost 4,000 MW of interconnectors joining the UK to France, the Netherlands, and the Republic of Ireland, and with a pipeline of approximately 12,000MW of projects proposed or under construction by 2025, they form a major element of the UK National Grid's strategy for the future.

Earlier this year (2019) the highest capacity link yet, the 1GW NEMO interconnector – which connects the UK with Belgium – was switched on, and work is already underway on a number of other projects including the longest and most ambitious connector to date: the North Sea Link (NSL), a 720km, 1.4GW capacity electricity link between Norway and the UK.

A joint project between the UK's National Grid and Norwegian grid operator Stattnet, NSL will link Kvilldal in Norway to Blyth in Northumberland via two parallel high voltage direct current (HVDC) subsea cables. Both sites are key strategic locations for energy infrastructure. Blyth, an increasingly important hub for the UK offshore energy sector, is home to the first offshore wind farm in the UK and The National Renewable Energy Centre Catapult research facility, whilst Kvilldal is the site of Norway's largest hydroelectric power station.

When it begins operating in 2021, NSL will not only become the longest subsea interconnector in the world but also, according to Project Director, National Grid's Nigel Williams, one of the only links of its kind to exclusively carry green energy. "Norway is 100 percent hydro and on our side the only time we would trade electricity from the UK to Norway would be when the price is lower here than it is there and that only happens when there's a surplus of wind, so it's fair to say North Sea Link is always carrying green electricity." Williams added that in the early years of operation, thanks to Norway's abundance of hydro, the direction of travel along the cable is going to be dominated by flows of electricity from Norway to the UK.

> "It's fair to say that North Sea Link is always going to be carrying green electricty"
>
> Nigel Williams - Project Director

In common with other interconnectors, NSL consists of two key components: the cable system and the converter stations at each end which convert electricity from AC (which is used in each country's transmission system) to DC (which is used for sending the electricity along the subsea cable) and vice-versa.

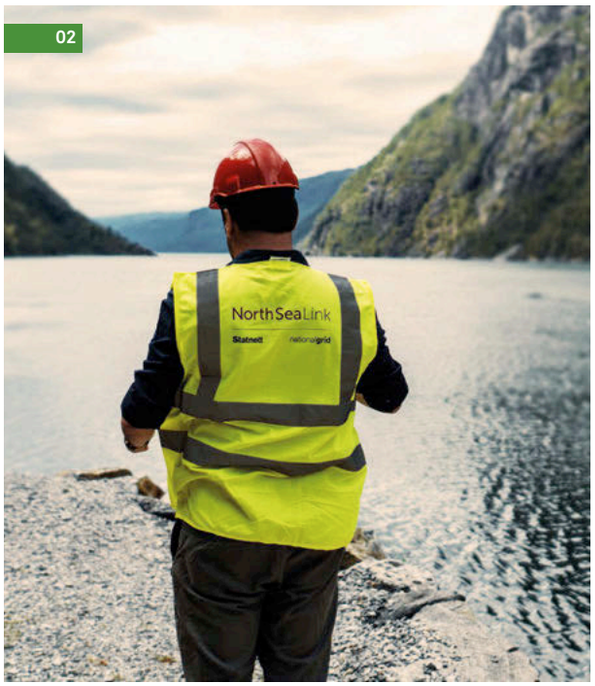
Construction of the converter stations is already well underway, explained Williams. At Kvilldal all of the civil works are complete, and the team has just begun electrical installation and fit out work whilst electrical work at the UK end is due to start around the end of this year (2019). Both stations are being built by ABB and are based its HVDC Light technology, which has been specially designed to transmit power underground and under water and over long distances.

Arguably the most logistically challenging area of any interconnector project though, is the installation of the cable system itself, and NSL is no exception.

This process began, explained Williams, with a painstaking route planning operation, aimed at ensuring that the cable avoids major seabed obstacles such as oil pipelines. Another consideration is ensuring that the cable doesn't come into contact with one of the tens of thousands of unexploded first and second world war bombs that are thought to litter the seabed around the UK.

In common with other offshore engineering projects NSL has employed specialist contractors who have used advanced magnetometer technology to scan the seabed for the tell-tale signature of buried metallic objects. So far, said Williams, they've not had any problems.

The cable itself is being manufactured and installed by two separate contractors: Prysmian and Nexans. Nexans, which is currently producing the cable at its Halden Plant in Norway, is responsible for the 500km of cabling that will run in the fjord and onshore sections in Norway, whilst Prysmian - which is manufacturing cable for the project at its plant in Milan - is supplying



01 Norway's deep, narrow Fjords present a challenge

02 The project is a true Norway / UK collaboration

03 Onshore cabling infrastructure at Blyth

04 View down the lake from the Kvilldal facility–

around 950km on the UK and Norwegian North Sea sections of the route.

The use of two contractors is, said Williams, normal for a project of this scale. "Our route is 720km end to end and we're laying 2 cables so we need 1440 km. If we want one factory to make all that cable we wouldn't be able to go live in 2021 because of the constraints in the factory."

Most of the cabling work carried out so far has been on the Prysmian side. Last year, two 130km sections of cable were laid, and three more will be down by the end of the 2019. Prysmian will complete its share of the cabling in 2020 with two further sections. Nexans will begin next year, and complete its cable laying in 2021.

The cable is installed in two phases, explained Williams, beginning with the arrival of the cable laying vessel, which uses a giant turntable and dynamic position systems to painstakingly unwind its payload and lay it on the seabed. In good weather it takes about ten days to lay a whole 130km section, he said.

The next step is to secure and protect the cable on the seabed, and ensure that it's buried deeply enough to avoid being caught up by trawler nets. Here, explained Williams, specialised ROVs (remotely operated vehicles) is used. Attached to an umbilical that provides power and a visual link to the surface, these are carefully positioned so that they straddle the cable on the seabed. They then move slowly forwards, using high pressure jets of seawater to carve a trench on the seabed, into which the cable drops as they pass by. Williams said that the aim is to bury the cable at least one metre below the seabed.

Whilst the core components and key techniques are the same as those used on other interconnector projects, NSL has, nevertheless, presented a number of unique engineering challenges, said Williams, not least the broad challenge of being the first interconnector project to cross the North Sea, a particularly crowded body of water when it comes to existing energy infrastructure. "The North Sea has never been crossed by big power cable before," he said, "so we're trailblazing a little bit. And all the crossings in the North sea and dealing with all the different oil companies is a challenge."

It also presents a significant geological challenge in the form of the Norwegian trench, a 700 metre deep ravine in the sea floor off the south coast of Norway that the cable has to cross. "We have to pick a cable route that affixes the cable to the floor, we don't want any suspended cable sections," he said.

But perhaps the biggest challenge for the project, and one which sets it apart from initiatives linking the UK with low-lying nations like the Netherlands, is the mountainous nature of Norway, and the deep, narrow environment of the fjords.

In order to reach the converter station at Kvilldal, the cable has to pass through Hylsfjorden, a 20km long Fjord in Western Norway. From here, it goes through a specially excavated 2.3 km tunnel that takes it up into the mountains to Lake Suldalsvatnet, the sixth deepest lake in Norway (376 metres deep) . It then runs across the bottom of the lake to the converter station at Kvilldal.

Rune Stoten, Nexans' project manager for NSL explained that this is one

05 A range of specialist vessels and ROVs are used to install subsea cables

of the most unusual and challenging parts of the project and, has required the construction of a purpose built barge that can be assembled in situ in the lake. "It's specially designed for this project and equipped with laying equipment so you can spool the cable from the turntable," he said. "It also has a separate ROV that can monitor the cable during laying" Stoten said that this operation will take place in the summer of 2020.

When NSL opens for business in 2021, the relationships that underpin the trading of electricity in Europe could look very different. Norway, of course, isn't a member of the EU, but as part of the European Economic Area, enjoys many of the same benefits, and there are growing concerns that should the UK leave the bloc without a deal, cross border trade in electricity could also be affected.

But whilst acknowledging that Brexit could have an impact Williams prefers to take the long view. "All I would say is that we're putting a cable system in for the next fifty years and Brexit is one point in time. Whatever happens, life will go on. The decarbonisation challenge will still be there; Norwegian hydropower will be there; our excess wind will still be there and the long term need for this is there."

In the meantime, he praises Norway for taking a more joined up view of the future of European energy. " It'd be easy for them to say "I'm all right Jack" our system is dominated by hydro, we're very clean and we'll keep it to ourselves. But....they take a view that if they can help some of their near neighbors out with some hydro and that can offset some burning of fossil fuels then it's a win win-win for everyone – they get to sell more product and the help to deliver a greener world."

More generally, whatever the broader political climate, Williams sees interconnectors, and a more joined up approach to power sharing, as key to the future of the European energy. "The power systems of the future will require us to be strongly linked to near neighbors," he said. "In continental Europe there's an infinite source of help. If we have a rapid power deficit for some reason, where else to get a fast injection from than Europe or Norway? Using our neighbors and cooperating in this way is what will make the world go round." ■

> "The power systems of the future will require us to be strongly linked to our neighbors. Cooperating in this way is what will make the world go round"
>
> Nigel Williams, Project Director

UK / Europe interconnectors

There are already 4,000 MW of operational interconnectors linking the UK to France, the Netherlands, Northern Ireland and the Republic of Ireland, and a pipeline of approximately 12,000MW of projects proposed or under construction by 2025.

- IFA1 – 70km, 2GW link with France. Opened in 1986
- Britned –1GW, 260km link with the Netherlands. Commissioned in 2011
- NEMO – 1 GW link with Belgium (2019) began operating Jan 2019
- IFA2 – 1GW link with France. Due to be commissioned in 2020
- Viking Link - 760km long, 1.4GW link with Denmark. Expected to be up and running in 2023
- East West Interconnector – 500 MW connection between Wales and Ireland. Commissioned in 2012
- Moyle Interconnector - 500MW high-voltage direct current (HVDC) link between Scotland and Northern Ireland. Went into service in 2001.

In an uncertain world, we contribute to national security in a huge number of ways. We help make sure that power is generated and distributed to everyone who needs it. We support moving people and goods around and between the big cities of an increasingly urbanised society. We work to make the world a more sustainable place. We ensure governments save time and money when public spending globally is under huge pressure. And we help our clients wrestle with the challenges and opportunities of an ever-accelerating digital revolution.

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Meet this year's C2I finalists

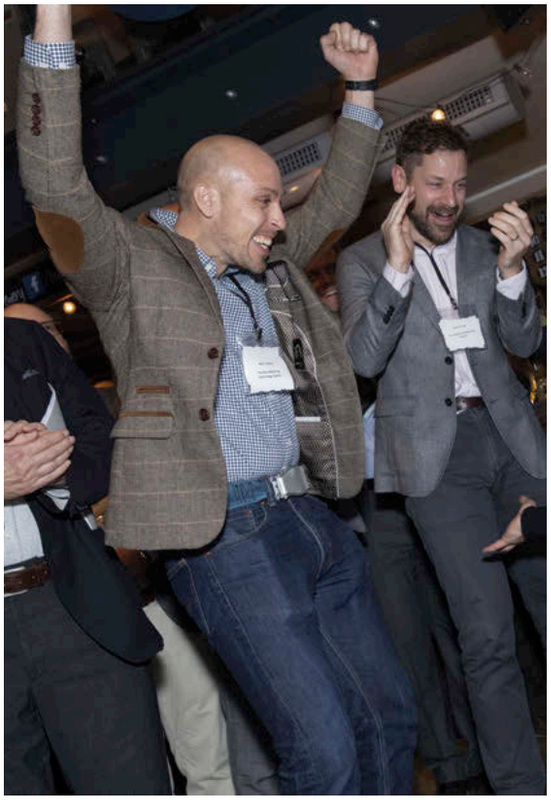
Now in its fourth year The Engineer's Collaborate To Innovate Awards celebrates the UK's most inspiring collaborative engineering projects. Shortlisted finalists this year ranged from innovations in cancer treatment to new production methods for the nuclear sector

We're delighted to reveal the shortlist for The Engineer's 2019 Collaborate To Innovate (C2I) Awards.

Now in its fourth year, C2I was established to uncover and celebrate great examples of technology-led engineering collaboration across a range of different disciplines and sectors. It's fair to say that it's more than delivered on this vision, and has regularly uncovered a fresh pipeline of innovations, showcasing the UK's strength and breadth in cross-disciplinary collaboration, and providing plenty of reasons to optimistic about the future of UK engineering.

This year's shortlist, which is detailed over the following pages, features some particularly strong examples of this crucial dynamic in action: from truly world-leading projects at the cutting edge of the automotive sector to healthcare technology breakthroughs that are going to save lives.

The ultimate winners of each category will be announced at a special event in London on 6th November and covered in detail in a special issue of The Engineer so watch this space. ■



COLLABORATING FOR A SUSTAINABLE FUTURE

This year's entries provide reassuring evidence that engineers are working together to overcome some of our biggest challenges writes Neil McDougall, Managing Director of C2I headline sponsor Frazer-Nash Consultancy.

American engineer and educator, James Kip Finch once said: "The engineer has been, and is, a maker of history." Well, it seems to me that making history looks to the past and, as engineers, I believe that while we learn from the past, our role is to create the future. But creating the future brings with it a huge responsibility: the future that we deliver to the world has to be sustainable. Eventually, the solutions we're designing and manufacturing to overcome our present challenges will become history, and we need to leave a legacy that doesn't compromise the existence of our engineering descendants.

It's a big ask. But having seen the range of inspirational projects entered into The Engineer's 2019 Collaborate to Innovate (C2I) awards, I'm confident that individuals and groups, working together, will hold the key to unlocking this sustainable future. Indeed, some of the entries focused specifically on sustainability as an outcome. There were projects exploring sustainable manufacturing; and there were environmental ideas to ensure we use the planet's limited resources wisely – whether by making magnet-free traction motors, by improving engines' efficiency, by producing 'green' ammonia that saves millions of tons of carbon dioxide, or by delivering sustainable community energy networks.

Sustainability is about respecting the need to protect the planet's resources. It's about finding new, more efficient ways of doing things; and about using the information we get from systems and equipment to improve people's lives. In this year's C2I, even where sustainability wasn't a specific goal, the teams were exploring the development or refinement of technologies and approaches to help us address the issues facing society – including ageing well, travelling safely and quickly, and meeting our power needs. I admit that I was also excited to see an innovation looking at generating electricity to power future space missions – a collaboration that could help us not just to reach for the stars, but to actually get there!

But to make sure we have future engineers to whom we can leave this sustainable legacy, we need to be encouraging science, technology, engineering and mathematics (STEM) activities. So I was particularly encouraged to see the great projects, programmes and school partnerships entered into the 'Young Innovator' category. These are our future engineers. We need these inventive, enquiring minds to 'sustain' the future of engineering – they will be helping us to solve the challenges that face us. For example, Freddie Howells' brilliant project to create a facial recognition door entry system and home monitoring system for the elderly, using Raspberry Pi, showed just how our younger engineers' ideas will help us tackle the issues of an ageing society.

As judges, we were drawn from a hugely diverse range of organisations, with a significantly broad span of expertise, experience and areas. I really enjoyed collaborating with my esteemed colleagues, and having the opportunity to give something back to such a positive activity – just as I am sure the participants in this year's C2I did. As today's and tomorrow's engineers, the future is in our hands - and I have every faith that it will be a bright one.

CATEGORY: AUTOMOTIVE

Magnet Free Traction Motors for Commercial Vehicles: HDSRM – Advanced Electric Machines Limited with Tevva Motors, Newcastle University and Motor Design Limited

Autonomous Bus: Fusion Processing Ltd with Stagecoach and Alexander Dennis Ltd

Rotary 6 Phase Electric Range Extender (R6 E-REX): Libralato Ltd with the University of Manchester, University of Eindhoven , University of Bucharest, Tevva Motors, and CRITT M2A

Venturer: University of the West of England with AXA UK, BAE Systems, Bristol City Council, South Gloucestershire Council, First Bus, Fusion Processing, Williams Advanced Engineering, Burges Salmon, and the University of Bristol

Enhancement of Inductive Power Transfer (IPT) for Wireless EV Charging: University of Cambridge with EPSRC, University of Auckland, Dynex Semiconductor, McLaren Automotive and Advanced Technology and Materials

Sponsored by Comsol: This year, COMSOL is delighted to sponsor The Engineer's Collaborate to Innovate Awards. COMSOL brings innovation to everyone involved in the product development process through multiphysics simulation and applications. Industry engineers and researchers are already accelerating product development by building numerical simulation applications in the COMSOL Multiphysics® software and distributing them throughout their organizations. Now, simulation is accessible in the field by deploying applications through COMSOL Server™ and COMSOL Compiler™ so engineers can run real-time analyses onsite. Widespread access to simulation applications and digital twins allows design engineering teams to tap into their greatest asset: each other.

CATEGORY: AEROSPACE, DEFENCE & SECURITY

Landing gear of the future: Safran, with Alvant and Innovate UK

High G centrifuge: Thales with AMST, Atkins, GallifordTry

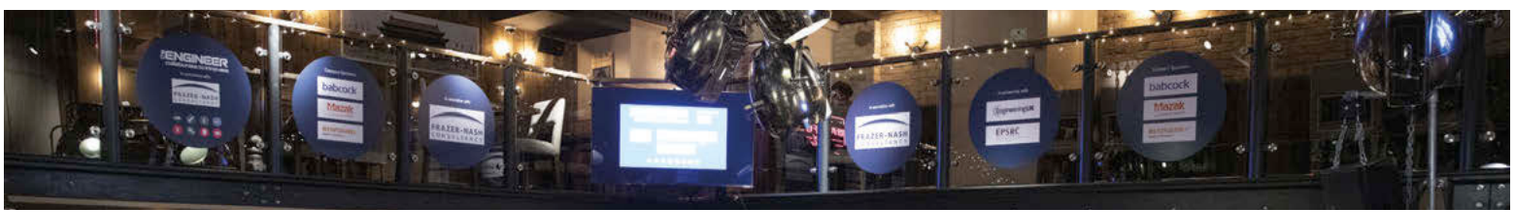
Phoenix Unmanned Air System: University of the Highlands and Islands with Banks Sails, TCS Micropumps, IQE, Stirling Dynamics, the Centre for Process Innovation, MTC and others.

Worn BioDetector: Bio-Aerosol to Droplet Converter (Bio-A/D) for Biological Threat Detection – University of Hertfordshire with Defence Science and Technology Laboratory, Porton Down, UK.

Aerospace Integration Research Centre (AIRC): Cranfield University with Airbus and Rolls Royce

UK scientists generate electricity from rare element to power future space missions: University of Leicester, National Nuclear Laboratory & European Thermodynamics Ltd

Sponsored by High Value Manufacturing Catapult: Collaboration is in the DNA of the High Value Manufacturing Catapult. Every day we bring together innovation-hungry businesses with world-leading technical experts to help boost company competitiveness and develop the products and processes that capture and secure market share. We know that when people collaborate intractable problems can be solved and great results emerge. We see that daily in the dozens of collaborative R&D projects we work on with business, academia and government. Entrants to the Collaborate to Innovate Awards demonstrate the value of collaboration very clearly. We are proud to support these awards and encourage their endeavours.



CATEGORY: ENERGY & ENVIRONMENT

New engine efficiency technology makes gensets cleaner and greener: Bowman Power with Department of Energy and Climate Change, Innovate UK, Rolls-Royce Power Systems, Cummins, Lloyds Register and University College London

The Green Ammonia Demonstrator: Siemens with The Science and Technology Facilities Council (STFC), Oxford University, University of Cardiff, Innovate UK

Cryoegg: Cardiff University with University of Bristol; East Greenland Ice Core Project; RESPONDER project, Scott Polar Research Institute and Aberystwyth University

The Low Carbon Power and Energy Programme (LCPE): University of Strathclyde with ScottishPower, SSE, Wood

Safewater Innovation: Ulster University with Cantaro Azul (Mexico), Centro de Ciencia y Tecnologia de Antioquia (Colombia), University of Medellin (Colombia), University of Sao Paulo (Brazil)

SCENe (Sustainable Community Energy Networks): University of Nottingham with Loughborough University, Igloo Blueprint, Urbed, Siemens, Solar Ready and Confers.

Sponsored by Goodfellow: Currently celebrating 70 years of facilitating scientific innovation, Goodfellow is a leading global supplier of metals, alloys, ceramics, glasses, polymers, compounds, composites and other materials to meet the research, development and specialist production requirements of science and industry. The company has an extensive range of 70,000 catalogue products in multiple forms available off the shelf, most subject to free delivery within 48 hours and with no minimum order quantities. With over 6000 customers supported by a worldwide network of offices, agents and distributors Goodfellow also offers a comprehensive range of bespoke processing services, effectively operating as an extension of the production team in order to develop custom fabricated components in any quantity required.

CATEGORY: HEALTHCARE & MEDICAL

Amputee Liner Wear Comfort Improvement by Laser Drilling: ES Precision Ltd, Blatchford Group
Laparoscopic molecular probe for prostate cancer surgery: Lightpoint Medical, National Physical Laboratory
Smart soles: Infi-Tex with University of Kent
Printed Pills: Inkjet printing for pharmaceutical applications – Added Scientific Ltd with Xaar Plc and Astra Zeneca

Sponsored by Solidworks: At Dassault Systèmes SOLIDWORKS® we are delighted to support The Engineer's Collaborate to Innovate Awards and congratulate the 2019 finalists. Collaboration and innovation are in the core of our solutions as we focus on the way engineers work every day, with an intuitive, integrated 3D design environment that covers all aspects of product development and helps maximize their design and engineering productivity. Our cloud-based 3DEXPERIENCE® platform allows companies to integrate all pieces of the product development lifecycle - from design to simulation and manufacturing - into one seamless workflow to enable better-connected teams and more-agile processes. To learn more, visit: 3ds.com/solidworks.

CATEGORY: INFORMATION, DATA & CONNECTIVITY

LCR 4.0: Virtual Engineering Centre, Nursery Kitchen
SETA: The Floow Ltd with The University of Sheffield, Comune di Torino, Knowledge Now Ltd, Sheffield Hallam University and others.
Maritime Autonomy for Plymouth: Thales Group, MSubs Ltd
GeoSHM Project: University of Nottingham with UbiPOS UK Ltd, BRDI (China Railway Major Bridge Reconnaissance & Design Institute Co. Ltd.), Leica Geosystems, GVL (Geomatic Ventures Limited), Amey, and Transport Scotland.

Sponsored by Babcock : Babcock International is proud to continue our support of The Engineer's C2I Awards. We are a leading provider of complex and critical engineering services across defence, emergency services and civil nuclear, both in the UK and increasingly internationally. Our partnerships span from industry through to academia and through our deep engineering expertise we are able to identify, adapt and integrate new technologies in the critical and complex assets we manage for our customers, and ourselves. Engineering is embedded in our DNA and technology underpins everything we do, and so does the way we collaborate.

CATEGORY: MANUFACTURING TECHNOLOGY

Viable Alternative Mine Operating System (VAMOS) – BMT, Soil Machine Dynamics Limited (UK), Damen Dredging Equipment BV (The Netherlands), INESC PORTO (Portugal), Fugro EMU Limited (UK) and others.
OPTAMOT: Optimised Designs for Additively Manufactured Magneto Optical Traps – Added Scientific, University of Nottingham, University of Sussex
Nuclear Innovation Programme – SIMPLE and InFORM – Nuclear AMRC, University of Sheffield Physics Dept, University of Strathclyde, TWI, Peak NDT, Sheffield Forgemasters, Metlase, Cambridge Vacuum Engineering
SprayCoat – A step change in Lithium-ion battery manufacture – KW Special Projects, University of Warwick
Micro-photogrammetry for additive manufacturing form measurement – University of Nottingham, Taraz Metrology Ltd, University of Arkansas
SHYMAN – sustainable hydrothermal manufacturing of nanomaterials – University of Nottingham with Promethean Particles and others.

Sponsored by Mazak: Collaboration and innovation are the lifeblood of British industry. If we are to win in an ever more competitive world, then our ability to collaborate with suppliers, customers, academia and even our peers to further the cause of innovation is ever more vital. In my own industry, machine tools, the breadth of our collaboration with automation suppliers, software developers, tooling companies and universities is now on a scale few imagined only a decade ago. The results are being seen every day across industry, but we cannot be complacent. That's why Mazak is supporting Collaborate to Innovate.

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"At Babcock, our people don't just work with technology, they make it work for them."

Jon Hall, Managing Director, Technology

As a leading provider of complex and critical engineering services across defence, emergency services and civil nuclear, both in the UK and internationally, technology is at the heart of everything we do.

Our partnerships in industry and academia, coupled with our deep engineering expertise mean we are able to identify, adapt and integrate new technologies in the assets we manage for our customers, and ourselves.

Engineering is embedded in our DNA. Technology underpins everything we do.

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CATEGORY: YOUNG INNOVATOR

Design of a Fixture for Welding Conveyor Frames of Varying Dimensions – St. Patrick's Academy Dungannon with Terex Corporation and Sentinus
Engineering for People Design Challenge – Engineers Without Borders UK
Facial Recognition Door Entry System and Home Monitoring System for the Elderly – Freddie Howells with Usk Osteopathy
Richard Crosse Racing 2018 – WMG University of Warwick with TSSMAT: The Small Schools Multi-Academy Trust, APC(Advanced Propulsion Centre)
EDGE4x4 – Land Rover 4×4 in Schools Technology Challenge – The King's School, Worcester with PLUS Automation Ltd
Future Brunels – SS Great Britain Trust with Bedminster Down School
Cotham School, Merchants' Academy, Redland Green School

Sponsored by Solidworks: SOLIDWORKS

WHAT THE JUDGES SAID

"I think it's brilliant to see the breadth and the scope of engineering collaboration in this country and how we're bringing innovation to tackle the grand challenges of our time."
Abbie Hutty - STM and GTM Delivery Manager and Structure Supplier Operations Manager, ExoMars Rover Project at Airbus

"Innovation has the greatest chance of succeeding when it is the product of collaboration between the great minds of our research base, the business people who really understand how to translate ideas into something that improves the bottom line and the consumers who will use the product of the innovation. The C2I awards recognises the need to bring people together from different tranches. Reading some of the entries this year has been inspirational."
Rosa Wilkinson – Director of Communications, High Value Manufacturing Catapult

The thing that's really encouraged me is the breadth of entrants, the strength of entries into the competition and also the strength of the winners. They are the best of the best.
Neil McDougall – Managing Director, Frazer-Nash Consultancy

"The breadth and depth of entries has been really impressive. What we've seen from the awards is not only some game changing technologies that can have a real impact now but the opportunity for future innovation and those products coming through that can help the growth of the UK economy."
Philippa Oldham - Head of National Network Programmes, Advanced Propulsion Centre

In the vast majority of cases you see the real excellence of the academic endeavor in this country being both a magnet for industrial collaboration but also a multiplier for the kinds of impacts we can have out into the economy."
Dr Kedar Pandya – Associate Director, Business Engagement and Industrial Strategy EPSRC

This has been the third year I've judged this competition and again there's been a great submission of projects. The collaboration element is going to become even more important from both and academic and business perspective
John Halton – Director, Business & Industry, Engineering UK

I was impressed by the breadth and depth of the entries, in particular numerous examples of people coming together and collaborating to solve some of society's biggest challenges. Of particular note this year were a number of examples of people working together to decarbonise the whole system – not just in the energy sector, but in automotive, aerospace and others"
Alan Newby – Director Aerospace Technology and Future Programmes, Rolls-Royce Plc

It's been a pleasure to judge again. I'm always amazed at the strength of what's produced and submitted: the strength in terms of engineering and scientific prowess and the ability to be able to take ideas from incubation through to something tangible that impacts our society.
Professor Andy Wright – Director Strategic Technology, BAE Systems Programmes and Support

I'm taken aback by the strength of the entries and I think it just goes to show how important collaboration is to driving innovation – taking something from an idea , right through its fruition to something that can make a real impact and make the world a better place.
Steve Penver , Head of Data & Analytics, Babcock International

Q&A: UK infrastructure and climate change

Andrew Wade asked three leading academics if UK infrastructure is up to the task.

01 UK rail infrastucture was tested to its limits by extreme temperatures over the summer

The summer of 2019 saw temperature and rainfall extremes that pushed UK infrastructure to breaking point, including the spillway collapse at Whaley Bridge and widespread rail disruption during the hottest day on British records. In light of this, *The Engineer* asked some of the leading academics in the field about the state of the nation's infrastructure and what steps should be taken to mitigate against the changing climate.

How would you assess the overall state of the UK's built infrastructure?

Professor Roderick Smith, Imperial College London and Formerly Chief Scientific Advisor to the Department for Transport and Past President of the Institution of Mechanical Engineers: Generally speaking, the overall state of our built infrastructure is good, but less than excellent, although many issues have emerged in the last few years which give cause for longer-term concern .

The situation differs for various types of infrastructure. Much of our railway system was built in the mid-Victorian era and it has been comparatively neglected since. Although we are now engaged in a massive programme of refurbishment, the costs are enormous and disruption to traffic considerable.

On the other hand, our motorways have been built since the late 1950s and although only one per cent of the network they carry 21 per cent of the traffic. Again, improvements are taking place to increase capacity, allied to resurfacing caused by a combination of weight of traffic and weather, but the process itself is creating delays.

Our civil airports have been created since 1945 since when usage has increased and continues to increase exponentially causing the capacity crisis well illustrated by the issues surrounding the expansion of Heathrow.

Our water supply system is largely Victorian, leaks from dam to tap are large and wasteful, and vigilance on dam safety has recently been brought into sharp focus.

Dr Mohammad Heidarzadeh, Assistant Professor, Head of Coastal Engineering and Resilience LAB (CERLAB), Department of Civil & Environmental Engineering, Brunel University London: I think overall the status looks good. Obviously, a detailed assessment is not possible for an individual like me because it needs systematic data from various sectors over a long period of time. In general, my feeling is that the status is satisfactory. This is because I don't see systematic failures of infrastructure. But this is for today; the situation could be different a few days later if we do not take appropriate steps to improve them.

Are existing maintenance and inspection regimes sufficient?

Dr Helen Gavin, Knowledge Exchange Researcher and Programme Manager, Oxford Martin Programme on Integrating Renewable Energy: Existing maintenance and inspection regimes were suitable for the conditions in which they were created. But now we have unprecedented weather in the form of extreme storms and climate events putting much more stress upon built infrastructure assets. This is in addition to increased demands on assets, arising from higher levels of usage.

Therefore, it is prudent to check the frequency and extent of inspections, changing them where necessary, to pick up early signs of stress and deterioration given the conditions that are now being experienced.

MH: This depends on sector and type of infrastructure. Some need more frequent inspections like transport and water infrastructure, and some, like residential structures, do not need frequent inspections.

RS: Much of our infrastructure is being used more heavily as demand increases. The combination of ageing and increasing use means that maintenance and inspection intervals need to be shortened appropriately.

Unfortunately, these are the very activities which come under pressure as finances tighten. There is a real temptation for companies to delay in order to improve their immediate financial results. Regulation is only working up to a point.

Are parts of the infrastructure network more exposed than others to a warming climate?

MH: Yes, I think so. For example, power substations or transport infrastructures which are close to the sea could be affected by the recent increased number of storm surges and waves and associated flooding.

RS: There have been many such examples of failures due to extreme weather events that comment seems superfluous. Examples in recent months include power line failures on the railway (high temperatures), crisis at a dam (too much rainfall, too quickly), ancient bridges swept away by floods (again localised heavy rain), properties previously thought safe have been flooded, strong winds have caused problems on roads and bridges.

Furthermore, our lives are increasingly dominated by information technology which is in turn entirely dependent on a stable reliable supply of electricity. The potential for civil unrest if these systems fail should not be underestimated. It should be a threat, allied to terrorist disruption, which should be near the top of our national risk register.

HG: Those parts of the infrastructure network that are directly exposed to temperature fluctuations (such as railway lines, paved areas) and those that deal with the conduit of storm water (e.g. road drainage systems, combined sewer overflows) are particularly susceptible as they are the equivalent of 'first responders' with respect to experiencing changed climate conditions.

Existing infrastructure will have been designed and sized to cope with lower temperatures and volumes, prevalent at the time of their planning. As such, extreme changes in temperature, both high temperatures, and rapid fluctuations (such as the 'Beast from the East' event where temperature increase sharply overnight), plus storm events (e.g. a month's rainfall in one day) will have significant impacts, as the system struggles to cope.

Do we need to reassess our approach to infrastructure in anticipation of more extreme weather?

MH: Definitely, yes. We see tangible increases in the number and intensity of natural hazards such as mass fires, storms and flooding. Our infrastructure is now under much bigger pressure from the changing environment. I believe that we need a new approach to, first, update the inspection guidelines, second, re-assess the design of infrastructure and improve their load bearing capacities if needed, and third, to increase their resilience to combined multi-hazards.

I think, otherwise, we may be facing more frequent infrastructure failures. As an example, are the spillway capacities of our dams enough in the face of global warming or not? Re-assess the capacity and if it's not enough, increase it by adding another spillway. As another example, is our rail infrastructure resilient to an extreme hot day combined with a bank holiday?

HG: Yes. Further, we need to consider all aspects of the infrastructure lifecycle, and ensure existing assets are adapted to cope with existing changed weather patterns and predicted further extreme conditions. New systems must be designed to be resilient to extremes of temperature and rainfall.

It is always more cost-effective to plan to be resilient than to deal with the consequences of failing infrastructure.

RS: It is timely to review all aspects of our infrastructure and to think out-of-the box about the knock-on consequences of climate change. It is unfortunate that the time scale of climate change is longer than the short-term pressures generated by the need for immediate positive financial results and a 24-hour news media obsessed by personality.

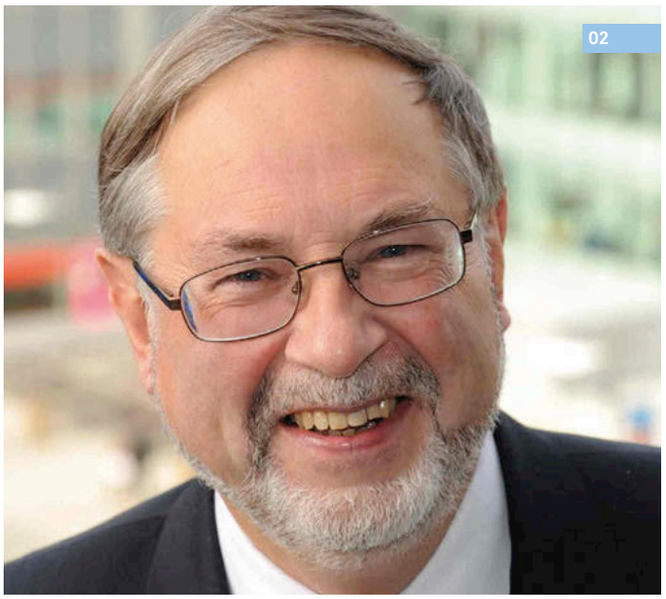
Our leaders are mainly drawn from the chattering classes devoid of any semblance of technical knowledge. It is vital that engineers lose no opportunity to educate and influence the political class about the future dangers that so far, they have failed to appreciate. ■

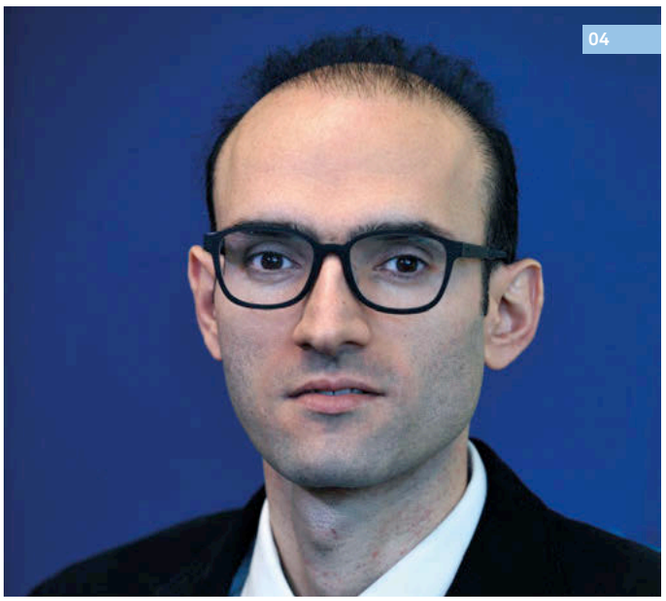
"extreme storms and climate events put much more stress upon built infrastructure"

02 Professor Roderick Smith

03 Dr Helen Gavin

04 Dr Mohammad Heidarzadeh





More thermals in the field

New thermal camera is the ideal for streamlining the inspection ofcritical assets such as substation components. Supplier: Flir Systems

The new FLIR Systems T860 camera is the first to feature onboard Inspection Route software, suitable for streamlining inspections of critical assets, including power substation components, manufacturing equipment, or facility electrical and mechanical systems. By running a pre-planned route through the camera, engineers can spend less time in the field and create survey reports more rapidly. .

The T860 has an ergonomic body, an LCD touchscreen visible from low angles, and an integrated colour viewfinder for sun-glare conditions. The 640×480-resolution thermal camera incorporates FLIR's advanced Vision Processing, including patented MSX and UltraMax image enhancement technologies to provide enhanced image clarity with half the image noise of previous models. Pairing the T860 with an optional six-degree telephoto thermal lens allows users to inspect energised targets from a safe distance or measure small targets with greater precision.

A key feature is the camera's ergonomic design

The camera includes advanced measurement tools such as one-touch level/span and laser-assisted autofocus, which helps users quickly find problems and make critical decisions. It also features an onboard routing system that works with the FLIR Thermal Studio advanced reporting software to create numbered, labelled inspection routes that users can create from the camera. This allows users to record temperature data, thermal, and visual imagery in a logical sequence .

According to FLIR, a key feature of the T-Series product line is its ergonomic design. A 180-degree rotating lens platform helps users diagnose hard-to-reach components at substations and on distribution lines. The camera also offers tools to optimise workflows, including Wi-Fi streaming to the FLIR Tools mobile app , in-camera GPS tagging, voice annotations, and customisable work folders.

The T860 camera includes the new subscription-based software, FLIR Thermal Studio Pro, a program that provides access to FLIR Thermal Studio Pro as well as free software upgrades.■

Engines benefit from measures taken

Rapid non-contact measurement system helps keep NASCAR engine supplier on track for success. Supplier: Nikon Metrology

Roush Yates engines partners with Ford as the exclusive Ford engine supplier for the NASCAR motor-racing competition in the US. Roush Yates's metrology partner for its NASCAR work since 2018 is Nikon, which provides software and measurement systems for quality control.

A combination of factors, including labour-intensive programming and potential workflow bottlenecks with coordinate measuring machine systems, prompted Roush Yates to research a better and more robust non-contact measurement system: previous methods had encountered issues that could compromise engine quality, and manual microscopes proved troublesome in many ways.

The company settled upon the iNEXIV VMA-4540 system, which was installed in March 2018 and has been used almost daily since. It is currently being used to measure about 50 components on each engine, amounting to about 50,000 parts per year. A major benefit of the system to is that it can access features of these small, fragile parts without contact or any chance of causing damage.

According to director of quality Jennifer LaFever, the system was easy to set up and begin programming as early as the first week with the trainer. She added that the visual interface is so intuitive and easy to learn, that even colleagues outside the quality department have been trained to use it.

One strength in the system is that it can pin-check small holes. Checking of very small holes in 100 parts can be achieved in 12 to 14 minutes, while simultaneously performing other inspection checks. With previous equipment, this would take 20 to 30 minutes before any other steps could be addressed, representing a 97per cent reduction in labour time.

The sytem is used to measure around 50,000 engine parts per year

"This system is extremely fast at measuring parts and gathering data. The greatest benefit to the speed is through CMM manager; programming new parts is extremely fast. With the touch probe, simultaneous programming vision and touch is easy and accurate," said Alexander Morothy, quality control technician and vision programmer. ■

Quality streets

The "smart cities" vision is too often focused on technologies that don't make cities better places to live, says Professor *Henrietta Moore,* director, Institute for Global Prosperity, UCL

There are 7.7 billion people on the planet today, and every year our global population grows by around 1.08% – or around 82 million people. It is estimated that by 2050, 70% of the world's population will be living in cities. The cities we know now will have changed and adapted to accommodate for this. How will we ensure they do so in a way that improves the quality of life its residents?

Smart cities are built upon a foundation of sustainable prosperity that actually improves the quality of life for all and their experience of urban living. Image: Tumisu from Pixabay

Cities are engineered to be shaped by, and respond to, different human needs. However changes to the urban landscape can be unpredictable and are not able to meet every challenge that urbanites experience in the everyday. There are many factors that dictate the issues we choose to prioritise and address, but health is one thing we all share that cannot help but be affected by our environment. As more of us live in cities, we are becoming increasingly aware of the elements beyond our immediate control that impact upon our wellbeing: be that air pollution, amount of and access to green space, or transport. The difficulties of being healthy in an urban context are now recognised the world over.

One of our greatest engineering challenges today then is: how do we create an ecological city of the future that is beneficial for us to live in? One that is supported by science and technology, rather than suffers from it? This is not just a matter of cutting emissions, but of recognising that urban sprawl is going to put more pressure on energy, on water, and on agricultural land. It is also going to create more waste and air pollution, the latter of which is already proving deadly to some populations around the world today. We need cities that will be able to cope with these strains.

At the moment, when we think about the cities of the future, we often talk about "smart cities". For some, this can conjure images of drones in the sky, or self-driving taxis. However, these already familiar scenes are more "technological" than "smart". Smart cities are cities that are genuinely better places to live. They are cities that are built upon a foundation of sustainable prosperity that actually improves the quality of life for all and their experience of urban living. Designing smart cities is a challenge for engineers, as it forces them to rethink their approach to the urban landscape, and acknowledge and address social elements to greater extent. For example, underpinning the urban situation we currently have is a huge crisis around social inequality. It follows then that any solution attempting to address this needs to take this into account – those created by engineers included. If the cities of the future have to be different, then the engineering that underpins them has to be different too.

Future cities need to be designed to cope with the growing pressures of urban sprawl

Image credit: tofumax via stock.adaobe.com

In my opinion, the challenges we face in cities today need to be brought to the forefront of the engineering endeavour. While this may already be happening, very often there is still a tendency to want to create immediate technological solutions to urban problems. Even if we have engaged imaginatively with them, we want to quickly move on once we think the challenge has been addressed. Instead, it would serve us well to take more time to consider the major challenges of the day and prioritise which, if tackled now, would be more likely to positively impact upon the broader context of contemporary city life. In order to do this, we need to consider the ethics of engineering to greater extent.

At its heart, engineering should begin with ethics – with equity, quality of life and improvement. It ought to be progressive, but not progressivist. In other words, engineering should aim to offer opportunities to build the capacities and capabilities of infrastructure that matter to people. It should give them new ways of interacting with others and aim to improve the quality of the environment that they live in, but in a way that does not dictate what they want in life. Ultimately, the big challenges we face, and the engineering solutions we are proposing for them, all in some way all revolve around ethics.

Thinking about 10 billion people on the planet and the cities that they will live in means, I think, thinking about the different ways of interacting with people. It means different ways of caring about each other, about our environments, and the quality of life we are all able to enjoy together. At its hear this is an issue of equity and sharing, and that must underpin all discussions we have about future cities, today.

Prof Moore spoke at this week's Global Grand Challenges Summit in London, hosted by the Royal Academy of Engineering, the US National Academy of Engineering and the Chinese Academy of Engineering. ■

Ferrari Portofino: Everyday supercar

Innovative chassis technology and an award-winning engine combine to deliver scintillating performance in a supercar you could use every day, writes Chris Pickering

Enzo Ferrari supposedly once said: "I don't make cars. I make engines." Whether or not he ever uttered those words is open to debate. And there's no doubt that Ferrari has been responsible for some exceptionally clever chassis technology over the years too. But when the 3.9-litre twin-turbo V8 in the Ferrari Portofino fills its lungs you can't help wondering if there's still an element of truth in that statement.

The V8s from this family – which also includes those found in the F8 Tributo and the GTC4Lusso T – have been voted International Engine of The Year no less than four times in a row. At 600PS (592bhp in old money) the variant in the Portofino is the least-powerful engine in the range. And yet the sledgehammer blow that it delivers in any gear and at almost any speed still puts the 'baby' Ferrari firmly into supercar territory.

Underneath those iconic red cam covers lurks what looks suspiciously like a race engine. It uses a flat-plane crankshaft to reduce rotational inertia and improve scavenging, its bore-to-stroke ratio of 86.5 x 82mm is notably undersquare and there's a dry sump lubrication system. Instead of the 'hot vee' layout used on a lot of modern road cars, its exhaust ports remain on the outside of the cylinder heads, with the turbochargers mounted low down to reduce the centre of gravity height. Ferrari says it tried both configurations and found this delivered lower back pressure, as well as favourable packaging.

The Portofino's engine is a development of that found in its predecessor, the California T. Cylinder pressures are up by 10 per cent, aided by a revised piston and port geometry that provides more tumble. Meanwhile, an ion-sensing ignition system is used to monitor combustion stability by analysing the current draw across the spark plugs. This information forms part of the ignition timing strategy, which can include multi-spark operation, where the same plug is fired multiple times to extend the overall duration and energy of the ignition.

The turbochargers have also been the subject of a lot of work. Each of the exhaust manifolds is cast as a single part with four equal length headers to optimise the pressure waves and reduce losses. They feed into two twin-scroll turbochargers – one for each bank – with a low-inertia turbine wheel design. But the clever bit is the control system, which uses Ferrari's Variable Boost Management philosophy to adjust the torque delivery to suit the gear that's selected.

> "An ion sensing ignition system monitors combustion stability"

You can sense all of this in action when you drive the Portofino. There's a palpable lack of inertia to the engine that makes it feel (and sound) quite different to a cross plane crank V8. If you really look for it – at very low revs in a high gear – you can detect the faintest pause while the turbochargers build up pressure, but under normal circumstances there's simply no perceptible turbo lag at all. Instead, you get razor-sharp throttle response, monumental thrust and a spine-tingling soundtrack all the way up to the 7,500rpm red line.

There's a similar feeling of agility to the chassis. At 1,664kg, the Portofino is commendably light for a 2+2 grand tourer with an electric folding roof (and

01

The Portofino's chassis technology blurs the lines between sports car and long distance tourer

01 Weighing 1,664 the Portofino is 80kg lighter than the Califonia T

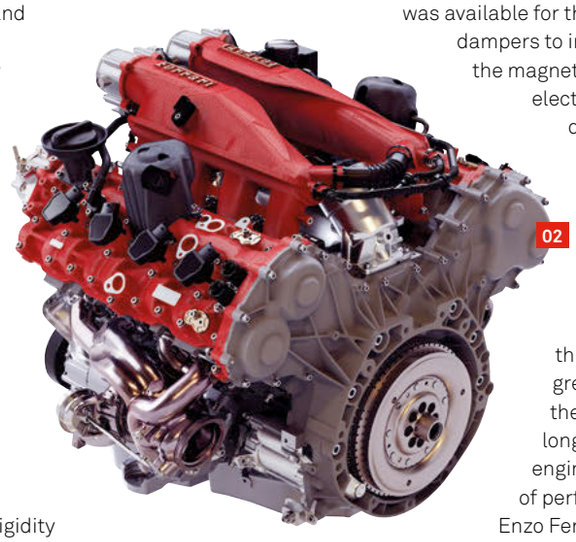
02 Beneath the cam covers the car's 3.9 litre twin-turbo V8 looks suspiciously like a race engine

some 80kg lighter than the California T it replaces). Despite its outward similarity, Ferrari says the chassis has been reworked so heavily for the Portofino that it's effectively an all-new design. No less than 12 different alloys are used for a mixture of extruded sections, castings and sheet-metal parts. Notable production techniques include superplastic forming for the doors and increased use of sandcasting for hollow components in order to reduce wall thickness (and hence decrease weight).

There's also been a concerted effort to condense different elements of the body-in-white. The A-pillars, for instance, were comprised of 21 separate sections on the California T, but they now number just two. On top of the overall weight reduction – around 40 per cent of which comes from the body-in-white – the new structure is said to be some 35 per cent stiffer, while the weld lengths have been reduced by 30 per cent.

Again, the benefits are tangible. The structure feels at least as stiff as any other front-engined convertible that I can think of and even the bumpy roads of our Scottish test route failed to provoke any scuttle shake. It's fair to assume that this structural rigidity also plays an important part in enabling the Portofino's aggressive chassis set-up – the steering is scalpel sharp and the body control is enforced with an iron fist. And yet it's also remarkably civilised, particularly when you switch to Comfort mode and the adaptive magnetorheological dampers relax.

Even in Sport mode the Portofino manages to combine its caffeinated reflexes with a good level of ride comfort. That's partly down to the damper hardware that has been introduced for the new model; the geometry is essentially the same as that of the optional Handling Speciale pack that was available for the California T, but the Portofino uses dual-coil dampers to improve the precision and speed with which the magnetic field is adjusted. It also features a new electronic control system with algorithms developed for the 488 GTB, which are said to improve response times at high input frequencies.



02

The end result is a car that's comfortable enough to function as a true grand tourer, while still delivering the characteristically sharp driving experience of a modern Ferrari. Objectively speaking, it's this chassis technology that's perhaps the greatest achievement on the Portofino – blurring the distinction between a sports car and a long-distance GT. Subjectively, though, it's that engine that steals the show with its vast reserves of performance and seemingly boundless energy. Enzo Ferrari, we suspect, would approve. ■

Alan Turing: 20th century genius

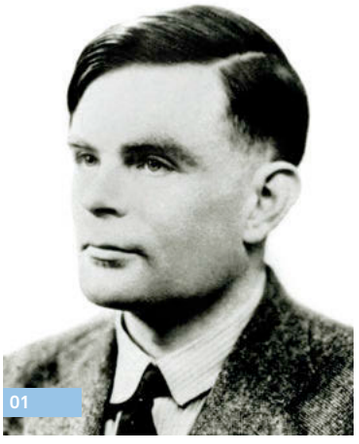
Nick Smith **looks at the life of Alan Turing, who had a huge impact on the outcome of the Second World War before tragedy brought his career to an untimely end**

When in 1999 Time Magazine named Alan Turing as one of the 100 most important people of the 20th century, the accompanying citation stated that, "everyone who taps at a keyboard, [who is] opening a spreadsheet or a word-processing program, is working on an incarnation of a Turing machine." The British Dictionary of National Biography describes Turing as "the founder of computer science, the originator of the dominant technology of the late 20th century".

Dozens of academic and technical departments worldwide are named after Turing. Winston Churchill famously said that Turing had made the single biggest contribution to Allied victory in the war against Nazi Germany. The biopic based on his life – The imitation game – was the highest-grossing independent movie of 2014. Accolades for the British mathematician, logician, cryptanalyst, philosopher, computer scientist and mathematical biologist are endless. The blue plaque at his birthplace in London's Maida Vale simply reads "founder of computer science and cryptographer". But none of these fully encapsulate the enigmatic and complex scientist that seemed to pack so much into his short life of 41 years.

Born in 23 June 1912, there was nothing specific in Alan Mathison Turing's circumstances that predicted a path into a life of science. His father was in the Indian civil service, while his uncle HD Turing was an authority on trout fishing. Perhaps a hint of what was to come lies more in his mother's side, in the form of physicist George Johnstone Stoney, a distant relative famous for introducing the word 'electron' as "the fundamental unity quantity of electricity". But, for the main part, the Turings followed the professions, notably the law. According to his biographer Andrew Hodges, Turing's childhood was largely that of being fostered in English homes with his brother while his parents were away in India. It was an existence in which "nothing encouraged expression, originality, or discovery." Science for him was an extra-curricular passion, first shown in primitive chemistry experiments. But he was given, and read, later commenting on its seminal influence, a popular book called Natural Wonders Every Child Should Know. An unpromising career at the ancient and exalted Sherborne School resulted in his headmaster reporting: "If he is to be solely a scientific specialist, he is wasting his time at a public school."

Things looked up for Turing as an undergraduate at King's College Cambridge where, aside from his academic pursuits, he threw himself into rowing, running and sailing. Armed with a first in mathematics, he was made a fellow at King's in 1935. A year later he was to deliver his paper 'On computable numbers, with an application to the Entscheidungsproblem', that introduced the idea of the 'Universal Machine' (now the 'Universal Turing Machine') that was acknowledged by the foremost mathematician of his time, John von Neumann, as establishing the central concept of the modern computer. The Turing Machine was also to become the foundation of the modern theory of computation and computability. During 1936-8, Turing was at Princeton University in the US, where he studied cryptology, worked on an electro-mechanical binary multiplier while obtaining his PhD. Although he was offered a job at Princeton by von Neumann he returned to Cambridge where, without a lectureship, he remained a fellow of King's as a logician and number theorist, during which time he attended lectures by Austrian philosopher Ludwig Wittgenstein and worked part-time at the Government Code and Cypher School (GC&CS) that was later to become GCHQ.



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Turing reported for duty at Bletchley Park, the wartime station of GC&CS, on 4 September 1939, the day after the UK declared war on Germany. It was his role in breaking German ciphers that was to form the bedrock of the Turing legend, which is neatly encapsulated in historian Asa Briggs' assertion that: "You needed exceptional talent, you needed genius at Bletchley and Turing's was that genius." Initially, Turing worked on cryptanalysis of Enigma (an encryption device used in the early- to mid-20th century to protect commercial, diplomatic and military communication) alongside senior GC&CS codebreaker Dilly Knox. It was at this time he produced the functional specification of the bombe, a development and refinement of the Polish bomba kryptologiczna electro-mechanical decryption machine. Fellow code-breaker Jack Good thought Turing's work on the bombe as his 'most important contribution.' By the end of the war, 200 such machines were in operation and had made the reading of Luftwaffe signals routine. Turing also worked on the more complex German naval communications that were considered unbreakable, a challenge he decided to take on "because no one else was doing anything about it and I could have it to myself".

Turing's section at Bletchley that deciphered U-boat messages – 'Hut 8' – became a cornerstone of the organisation's success. Turing's image was to become what Hodges calls "the genius loci at Bletchley Park, famous as 'Prof', shabby, nail-bitten, tie-less, sometimes halting in speech and

> "The idea behind digital computers may be explained by saying that these machines are intended to carry out any operations which could be done by a human computer."
>
> Alan Turing

02

01 Alan Turing (SCIENCE PHOTO LIBRARY)

02 Bletchley Park today (Bletchley Park Trust)w

03 Operating Bombe codebreaking machines at RAF Eastcote in 1944 (Bletchley Park Trust)

awkward of manner, the source of many hilarious anecdotes about bicycles, gas masks, and the Home Guard; the foe of charlatans and status-seekers, relentless in long shift work with his colleagues". In marked contrast to his somewhat eccentric exterior image, the 'Prof' (who was never actually a university professor), became an all-purpose consultant to the by now enormous Bletchley Park machine. He also wrote two papers discussing mathematical approaches to code-breaking that were of such value to the GC&CS (and later GCHQ) that they weren't released to the National Archives until 2012.

03

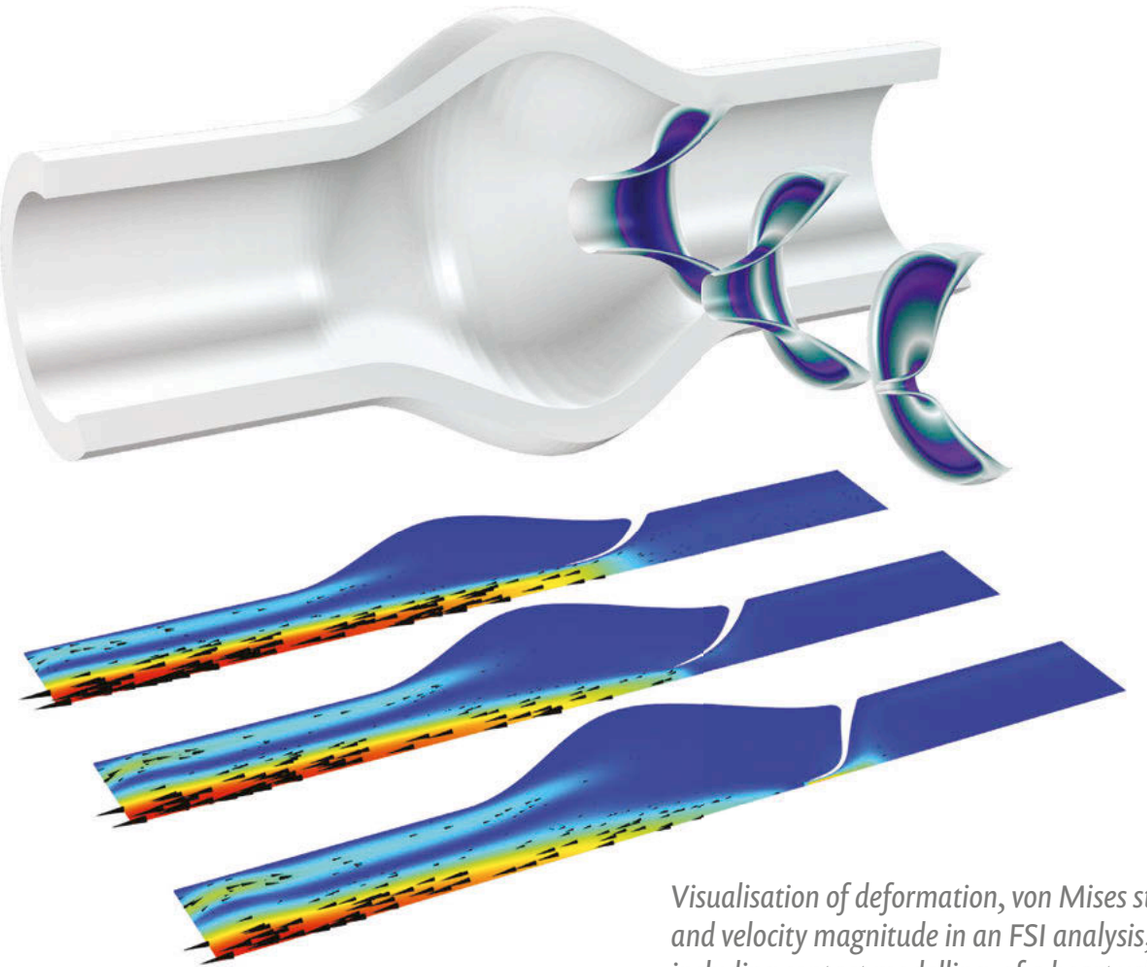
With the war coming to an end, in 1945 Turing moved to Richmond, where he concentrated on the design of the Automatic Computing Engine (ACE) at the National Physical Laboratory (NPL), presenting a paper in February 1946 outlining the first detailed design of a stored-program computer. He envisaged a machine that would be able to switch between functions such as numerical work, code-breaking, file handling and chess-playing. In 1947 his Abbreviated Code Instructions marked the beginning of programming language. But the ACE project was never built due to lack of cooperation, leaving Turing, who had expected to encounter the collaborative war-time spirit he'd experienced at Bletchley, deeply frustrated.

Heading back to the University of Cambridge once more, Turing redirected his efforts away from mathematics and technology in favour of neurology and physiology, out of which came a paper that anticipated neural nets. Meanwhile, at Manchester University, funds had been secured via a Royal Society grant to build a computer that would demonstrate Turing's principle of the stored program. In October 1948 Turing stepped into the role of deputy director of the computing laboratory at Manchester, and while this job title was deliberately vague and his status within the organisation uncertain, he at least had a clear role in electronics programming. By 1950 he was using the computer for his own research, which he described as the mathematical theory of morphogenesis: the theory of growth and form in biology. This was a change in direction that returned Turing to his childhood interest in biological structures, when he had spent time 'watching the daisies grow.' The resulting paper – 'The chemical basis of morphogenesis' – is one of the founding documents of the discipline of non-linear dynamical theory.

After being elected to Fellowship of the Royal Society in July 1951, Turing became involved in a sequence of events that led to him being put on trial charged with gross indecency under Section 11 of the Criminal Law Amendment Act 1885. In essence, he was being tried for committing acts of homosexuality for which – despite pleading guilty on the advice of his brother and other lawyers – he felt neither guilt nor remorse, having previously acknowledged his homosexuality during the police investigation into a burglary at his house. Convicted of the charge, Turing was offered the choice between imprisonment and probation, the latter of which carried the condition of his agreement to undergo drug therapy in the form of injections of the synthetic oestrogen stilboestrol. The year-long treatment caused serious effects to Turing's health that he took in relatively good humour. The conviction also stripped him of the security clearance required to continue working as a cryptographic consultant with the UK government and prevented him from visiting the US.

The rest is history. On 8 June 1954 Alan Turing was found dead. The cause of death was cyanide poisoning, and an inquest determined that he had committed suicide. While there have been rigorous attempts by his biographers to provide alternative explanations, and while Turing's mother certainly believed that the scientist had died by accident, the carefully orchestrated suicide by poisoned apple, that so closely resembled a scene from Walt Disney's Snow White (Turing's favourite fairy tale), seems to leave little room to doubt the inquest's finding. On 24 December 2013, Queen Elizabeth II signed a pardon for Turing's conviction. ■

Visualise and predict heart valve behaviour with multiphysics simulation.



Visualisation of deformation, von Mises stress and velocity magnitude in an FSI analysis, including contact modelling, of a heart valve.

Open fully, close tightly. The four valves in the human heart are expected to do this with each beat. When the valves do not function properly, cardiac health issues arise. In the quest for more effective treatments, medical researchers are studying heart valves to understand and predict their behaviour. To accurately visualise a heart valve, you need to account for many coupled effects. Multiphysics simulation is up for the task.

The COMSOL Multiphysics® software is used for simulating designs, devices, and processes in all fields of engineering, manufacturing, and scientific research. See how you can apply it to FSI analysis.

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COMSOL

Catching up with Polaris

July 1960

‘Skycatch’ system recovers test missiles mid-flight

The first successful submerged firing of a Polaris nuclear missile took place on the USS George Washington in July 1960 and by November the boat was on patrol with 16 A1 ballistic missiles.

The world’s first Fleet Ballistic Missile patrol marked the start of a strategy to keep nuclear weapons unseen and on the move at sea, a tactic the UK has committed to pursuing with the Dreadnought programme.

However, Polaris took five years to go from an idea to a two-stage missile with a range of 1,000nm and, in October 1959, *The Engineer*’s ‘American editor’ filed a report about Operation Skycatch, which, as the name implies, caught the missiles so that engineers could recover them for analysis.

The test programme leading to the final production of a ship-borne launcher started at the San Francisco naval shipyard as a joint effort of the Westinghouse Electric Corporation, in charge of the launching system development, and Lockheed Martin, which was in charge of the Polaris missile system with the US Navy.

Tests that preceded Skycatch saw large redwood logs and subsequently full-scale concrete-filled dummy missiles hurled from launching tubes and then recovered from San Francisco Bay.

The dummy missiles carried strain gauges and other instrumentation to show the sudden acceleration forces of launching. Similarly, dummies were launched from a submerged launching tube off the Southern California coast primarily to test the launching system itself.

As noted by Lockheed Martin, rocketry was still in its infancy and underwater launches presented a whole new set of challenges that had to be overcome. Operation Skycatch took testing to a more advanced stage and provided more complete information on how the missile would withstand the launching procedure. At this stage of the programme the dummy missiles were structurally identical metal replicas of the actual live Polaris.

“A simple recovery technique was needed to make possible the study of launching effects on the missile, without subjecting it to the damage of violent impact with the water,” our correspondent said. “The structural test vehicle was less rugged than its concrete-filled predecessors, and the test engineers wanted it to carry much delicate instrumentation. If it landed in the water, as in the past, the tests would be valueless, and the equipment destroyed. A device was needed that would permit the recovery of the missile and its instruments intact, permitting reuse and saving thousands of dollars per test.”

According to the report, the solution to this dilemma was obvious: catch the missile in the air, at the highest point of its trajectory.

“An ingenious method of giving the huge missiles a ‘lift without a let-down’ was devised by the US Navy Aeronautical Engineering Facility at Philadelphia,” *The Engineer* said. “Large overhead cranes, towering high above other shipyard installations, were fitted with a modified arresting gear engine, as normally used to shorten the runs of aircraft landing on aircraft carriers.

“Cables hanging from these cranes are attached to the test missiles before firing. As the ‘bird’ is hurled upward, reaching its highest point, the cables are reeled in to put on tension and to stop the flight. Launching data, recorded on magnetic tape, perpetuates the readings of many instruments carried in the test missile or situated at the ground-control station.”

This magnetic tape was then ‘fed into an electronic brain’ at Lockheed Martin for analysis. The results fed into development of the Polaris launching system and the production of launchers for the nuclear-powered fleet ballistic missile submarines, the first of which was the USS George Washington.

In a separate article from the same edition of *The Engineer,* our correspondent noted that Westinghouse had announced the formation of a “new atomic power organisation for the purpose of procuring a nuclear propulsion plant for Great Britain’s first atomic-powered submarine, the ‘Dreadnought’.

“The United States has authorised the transfer to the United Kingdom of a complete Skipjack-type submarine nuclear propulsion plant, spare parts, design and related classified information,” said our correspondent. **JF**

American Section THE ENGINEER 413

Recovery of “Polaris” Dummy Missiles in Mid-Flight

BY OUR AMERICAN EDITOR

IN “Operation Skycatch,” one phase of development testing of the launching system for “Polaris,” the U.S. Navy submarine-launched ballistic missile, full-scale dummy missiles are caught in mid-flight. The test programme leading to the final production of a ship-borne launcher began many months ago at the San Francisco naval shipyard as a joint effort of the Westinghouse Electric Corporation, in charge of the launching system development, and the Lockheed Missiles and Space Division, in charge of the “Polaris” missile system, in conjunction with U.S. Navy personnel. In tests preceding “Skycatch,” first large redwood logs and subsequently full-scale concrete-filled dummy missiles were hurled from launching tubes and then recovered from the San Francisco Bay. The dummy missiles carried strain gauges and other instrumentation to show the sudden acceleration forces of launching. Similarly, dummies were launched from a submerged launching tube off the Southern California coast primarily to test the launching system itself.

With “Operation Skycatch,” testing reaches a more advanced stage, which is providing more complete information on how the missile will withstand the launching procedure. The dummy missiles are now structurally identical metal replicas of the actual live “Polaris.” A simple recovery technique was needed to make possible the study of launching effects on the missile, without subjecting it to the damage of violent impact with the water. The structural test vehicle was less rugged than its concrete-filled predecessors, and the test engineers wanted it to carry much delicate instrumentation. If it landed in the water, as in the past, the tests would be valueless and the equipment destroyed. A device was needed which would permit the recovery of the missile and its instruments intact, permitting reuse and saving thousands of dollars per test. The solution to this dilemma was obvious: to catch the missile in the air, at the highest point of its trajectory. An ingenious method of giving the huge missiles a “lift without a let-down” was devised by the Navy Aeronautical Engineering Facility at Philadelphia. Large overhead cranes, towering high above other shipyard installations, were fitted with a modified arresting gear engine, as normally used to shorten the runs of aircraft landing on aircraft carriers. Cables hanging from these cranes are attached to the test missiles before firing. As the “bird” is hurled upward, reaching its highest point, the cables are reeled in to put on tension and to stop the flight. The vehicle is then lowered gently to the ground.

Launching data, recorded on magnetic tape, perpetuates the readings of many instruments carried in the test missile or situated at the ground control station. This magnetic tape is then fed into an electronic brain at the Lockheed plant for analysis. The results are evaluated both at Lockheed and at the Sunnyvale manufacturing division of Westinghouse, where development work is being conducted on the “Polaris” launching system and the production of launchers for the nuclear-powered fleet ballistic missile submarines. The first of these submarines, the U.S.S. “George Washington,” is scheduled to become operational in 1960.

Full-scale dummy “Polaris” ballistic missile being snatched by arresting gear at top of its trajectory

American Nuclear Propulsion Plant for British Submarine

THE Westinghouse Electric Corporation has announced the formation of a new atomic power organisation for the purpose of procuring a nuclear propulsion plant for Great Britain’s first atomic-powered submarine, the “Dreadnought.” The United States has authorised the transfer to the United Kingdom of a complete “Skipjack”-type submarine nuclear propulsion plant, spare parts, design and related classified information. The authority for the transfer is contained in the amended Atomic Energy Act of 1954 and in the Mutual Defence Agreement for Co-operation between the United States and the United Kingdom, which became effective on August 4, 1958. As required by the Atomic Energy Act and the Agreement, a determination has been made by the President of the United States that the transfer of the plant and the communication of related data to the United Kingdom would promote, and would not constitute an unreasonable risk to, the mutual defence and security of the United States and the U.K.

In March negotiations were concluded between Rolls-Royce and Westinghouse, with the result that a complete set of machinery similar to that being installed in the latest U.S. Navy submarines of the “Skipjack” class will be obtained from Westinghouse. Besides procuring the atomic power plant for this British submarine, Westinghouse will also train the personnel of Rolls-Royce and the Admiralty in the design and construction of this plant so that they can build their own similar plants in the future. Vickers-Armstrongs, the firm building the “Dreadnought,” has been authorised by the United States Government to obtain information and assistance from the Electric Boat Division, the U.S. shipbuilder which built the “Skipjack.”

Award of John Fritz Medal

For the first time in the fifty-eight-year history of the award, the highest honour that American engineers can bestow will go to a man with a non-engineering background, for his vision and his industrial leadership in the development of atomic power. The John Fritz Medal Board of Award announced recently that the medal will be awarded to Gwilym A. Price, chairman of the board of the Westinghouse Electric Corporation. The presentation of the gold medal, awarded annually for notable scientific or industrial achievement, will be made at the annual meeting of The American Society of Mechanical Engineers at Atlantic City in early December. Wm. F. Ryan, a past president of the A.S.M.E. and a member of the Fritz Medal Board of Award, announced that the honour had been voted to the industrialist by the representatives of the four senior engineering institutions for “his inspirational leadership, industrial pioneering and personal initiative in marshalling the creative forces of research and engineering to the cause of developing atomic power for the national defence and for the human welfare.” Mr. Price, at the end of World War II, saw the possibilities of harnessing the atom for practical uses and recognised the military significance of nuclear propulsion. He formed an atomic power organisation within his company which developed for the Atomic Energy Commission and the U.S. Navy the first nuclear steam plant for the U.S.S. “Nautilus.” From the atomic submarine pioneering, Mr. Price’s engineers and scientists gained the know-how which they applied in their work on the nation’s first full-scale atomic-electric generating station at Shippingport.

International Heat Transfer Conference in Colorado

An International Heat Transfer Conference will be held in the United States from August 28 to September 1, 1961, at the University of Colorado at Boulder. The conference will be held under the joint sponsorship of the American Society of Mechanical Engineers, the American Institute of Chemical Engineers, the Institution of Mechanical Engineers and the Institution of Chemical Engineers. Also participating in the conference are the American Chemical Society, American Nuclear Society, American Rocket Society, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Chemical Institute of Canada, the Engineering Institute of Canada, the Institute of the Aeronautical Sciences and the Society of Automotive Engineers. The conference is being held for the purpose of making known new fundamental knowledge and practical developments in the field of heat transfer and to bring together the persons engaged in research, development, and application for discussion and exchange of information. This is the second such international conference, the first having been held in London in September, 1951. Papers are desired on recent original work or new applications of theory to practice. Abstracts of papers offered for the conference should be sent to S. P. Kezios, Secretary, 1961 International Heat Transfer Conference Committee, c/o The American Society of Mechanical Engineers, 29 West 39th Street, New York 18, N.Y., prior to August 1, 1960.

Word of the issue

Anthony Poulton-Smith explores the origins of the word 'turbine'

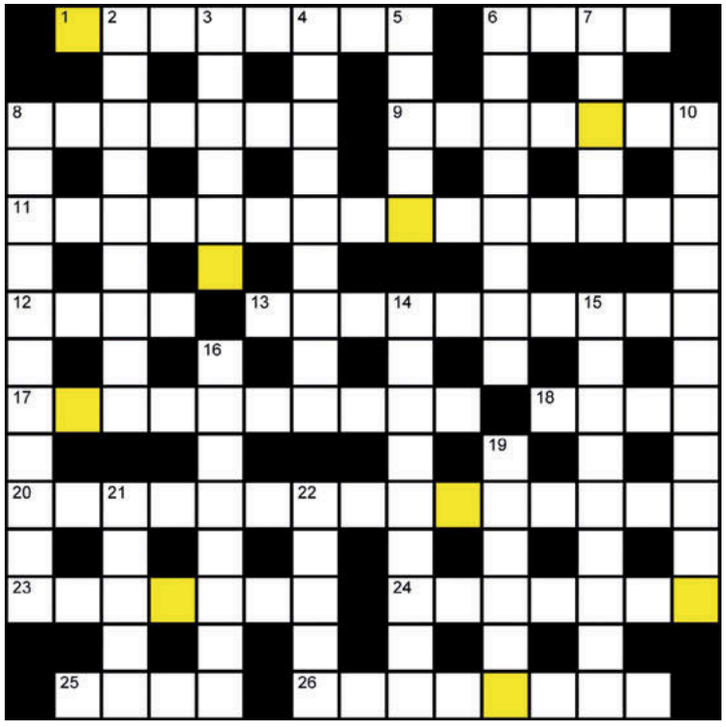
Although associated with the modern era, Turbine, like most words, has far older roots.

First coined in 1838, 'turbine' is French and taken from Latin turbine or 'spinning top, eddy, whirlwind, that which whirls'. Not used in its modern sense until as recently as 1904 when referring to a gas turbine, although the concept of water falling on a wheel to make it rotate had been used since pre-history as a watermill. Clearly related to 'turbo', we may only think of this as the abbreviation for 'turbocharged', yet it has been used centuries. Indeed this comes from the Latin where turbo referred to a child's toy, a 'spinning top'. Changing a single letter, brings us to turba meaning 'turmoil' and even 'crowd' and has also given us the adjective 'turbid'.

Ultimately all these can be traced to the Proto-Indo-European 'stwer', also the root of words including 'storm' and 'turn' and similar words describing disarray in other contexts.

Bigpicture

The Centre for Modelling & Simulation (CFMS) has created snowboard bindings for Darren Swift, a former soldier who lost his legs in an IED explosion in Northern Ireland. Engineers at CFMS developed and tested the bindings using digital engineering techniques and Airbus 3D printed the bindings with using a glass reinforced nylon material.



Prizecrossword

When completed rearrange the highlighted squares to spell out a metal bar used as a lever. The first correct answer received will win a £20 Amazon voucher. Email your answer to **jon.excell@markallengroup.com**

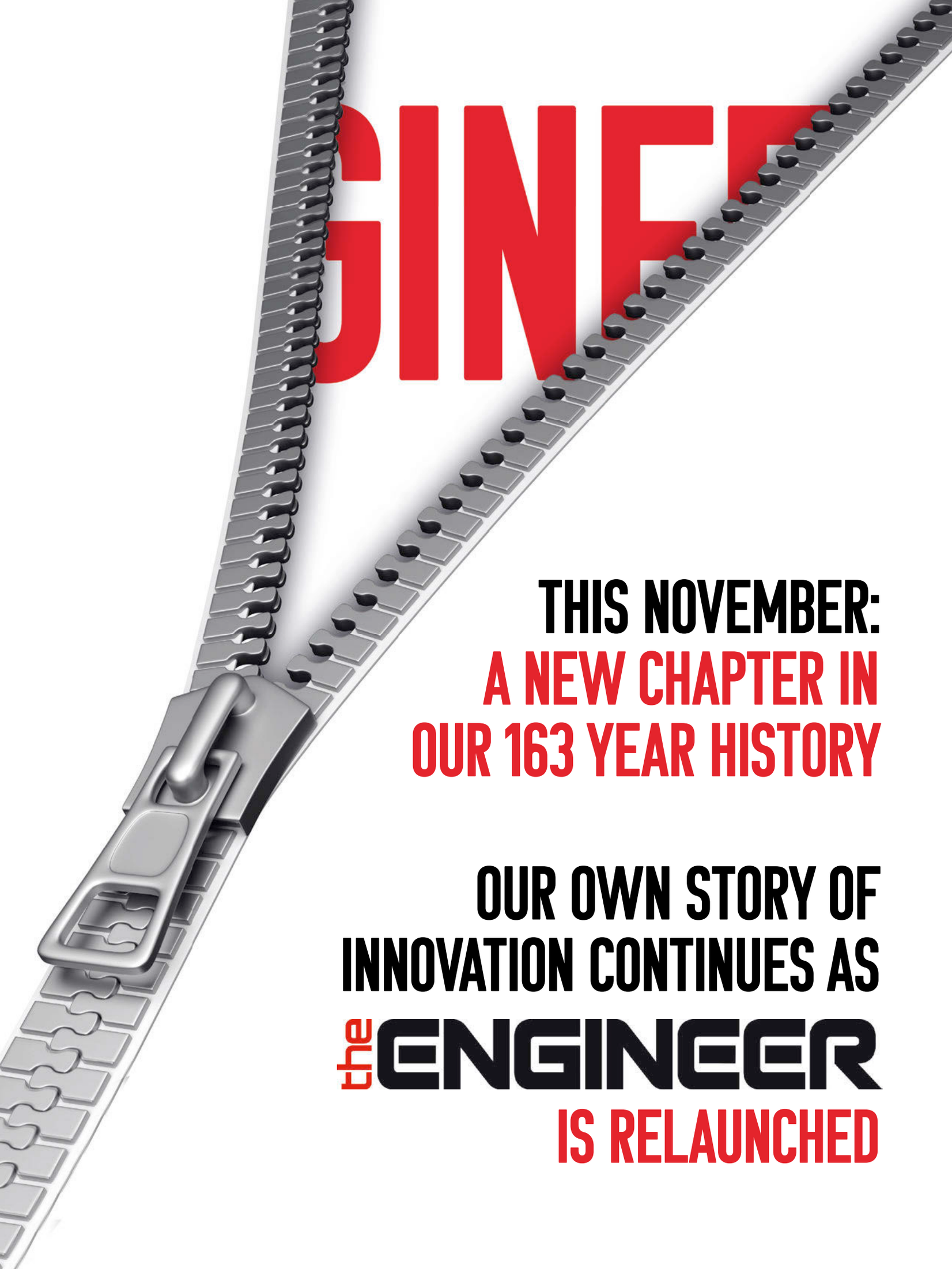
Across

1 Established as genuine (8)
6 Fill to satisfaction (4)
8 Flavoured with sour orange peel (7)
9 U -shaped bar used for attachment (7)
11 Degree achieved by many engineers (6,2,7)
12 Single undivided whole (4)
13 Device that requires skill for proper use (10)
17 Gauge for recording the speed and direction of wind (10)
18 Panel forming the lower part of an interior wall (4)
20 Written contract to protect you against accidents (9,6)
23 Flammable liquid hydrocarbon mixture (7)
24 Favourable omen (7)
25 Fastener for a door or lid (4)
26 Vague understandings (8)

Down

2 Rotating control gate (9)
3 Be superior to a standard (6)
4 Unit of apothecary weight equal to 480 grains (4,5)
5 Fine powdery materials (5)
6 Having ample room (8)
7 Insignificantly small (5)
8 Problem solving that involves numbers (11)
10 Solution that conducts charge (11)
14 Pleasure ground containing amusements (5,4)
15 Questioning closely (9)
16 Sill at an entrance (8)
19 Dwarfed ornamental tree (6)
21 Rich brown pigment used in old photography (5)
22 Navy, Army and Air Force Institutes (5)

September's highlighted solution was: **REFRACTORY**. The winner was: **Lisa Roberts.**



THIS NOVEMBER:
A NEW CHAPTER IN OUR 163 YEAR HISTORY

OUR OWN STORY OF INNOVATION CONTINUES AS the ENGINEER IS RELAUNCHED