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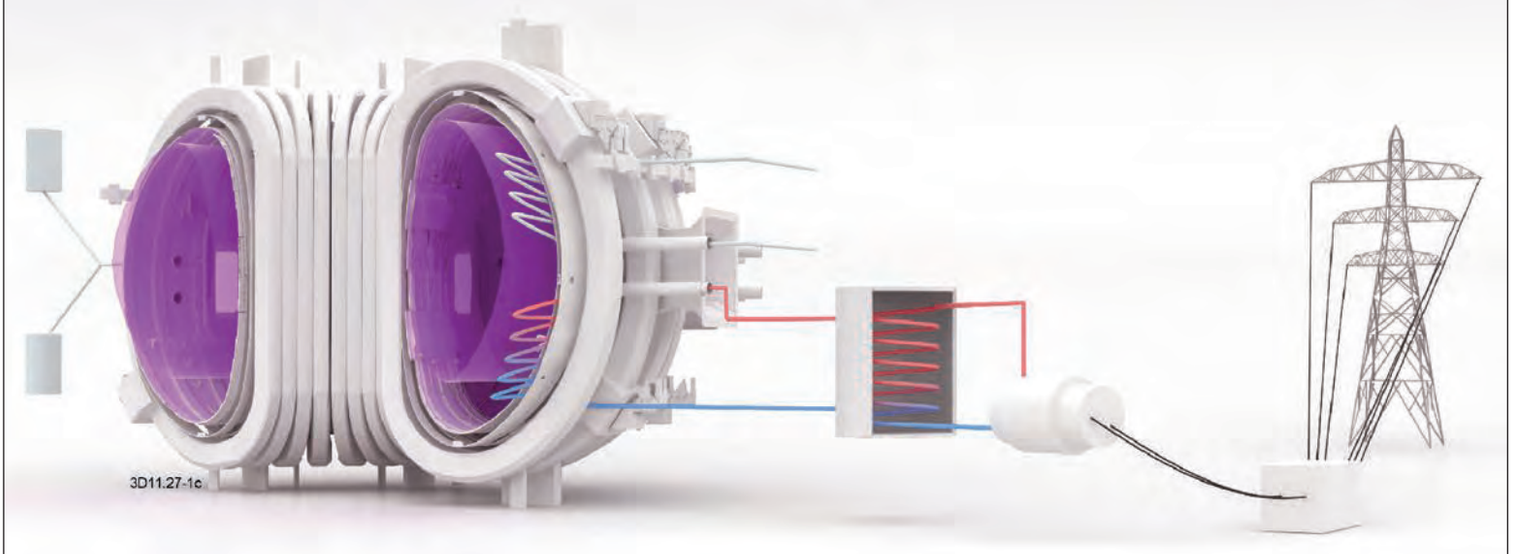
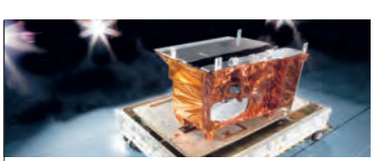


Taking nuclear fusion power from experiment to the grid

Shifting perceptions
Nusrat Ghani MP looks back at the success of the Year of Engineering
»25

Sea view
How augmented reality technologies will help reshape naval combat
»32



A new kind of space race
Raytheon's VP for space systems on the commercial forces driving launch technology
»34

Car of the issue
Chris Pickering gets behind the wheel of Aston Martin's new Vantage, a blend of aggression and sophistication
»36

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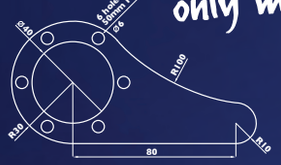

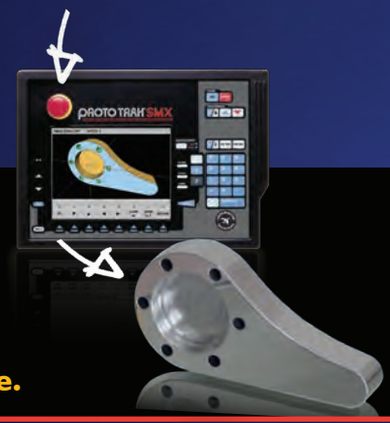

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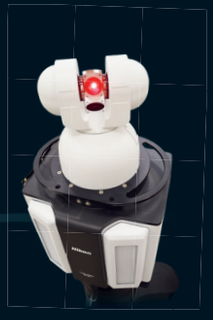

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this**issue**

Volume 298
Issue No. 7904
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news

opinion

features

our**opinion**

Fear and hope in 2019

It seems a shame to start the new year with the dreaded 'B' word. But with the UK's EU departure date now just a couple of months away, and – at the time of writing at least – the nature of our future relationship with the EU no clearer than it was two and a half years ago, it is perhaps an understatement to say that the UK's engineering and manufacturing base can rarely have faced a new year with more trepidation.

The areas of concern are well known: most firms we have spoken to agree that UK manufacturing will suffer without access to the single market, the customs union, and the pipeline of European engineering talent.

Predictably, and despite many manufacturers now backing up their words with concrete actions – see JLR's recent decision to cut 5,000 UK jobs – dismissive cries of "project fear" continue to be bandied about by people who should know better.

But despite a growing perception that ideology trumps economic reality, it is important that industry doesn't give up hope, and that – for the sake of the hundreds of thousands of UK workers whose livelihoods depend on its economic success – it continues to articulate its concerns clearly to government.

> "It is important that industry continues to articulate its concerns clearly to government"

On a more positive note, we were delighted to learn, as this issue went to press, that Bloodhound SSC – the beleaguered UK effort to build a land speed record-breaking supersonic car – could be back on again after the business behind the project was acquired by Yorkshire businessman Ian Warhurst.

The Engineer has followed the Bloodhound project from the start, reporting on both its technological milestones and celebrated educational activities. Along with many others, we lamented the news that the project had gone into administration, and we look forward to reporting on Mr Warhurst's plans for the initiative when he outlines them early in the new year.

Another project that we have covered in detail in recent years is ITER, the international effort to build an experimental fusion reactor in the South of France. Although assembly of this astonishing machine has now begun, the project is still many years away from completion. However, as we report in this issue's cover story, undeterred by the power source's famously challenging timeline (we've all heard the joke about fusion forever being 20 or 30 years away) researchers and engineers are now looking at ITER's successor – and the technologies and processes that may one day take fusion from the experimental stage to the grid. Who knows, by then we may even have solved the Brexit conundrum as well.

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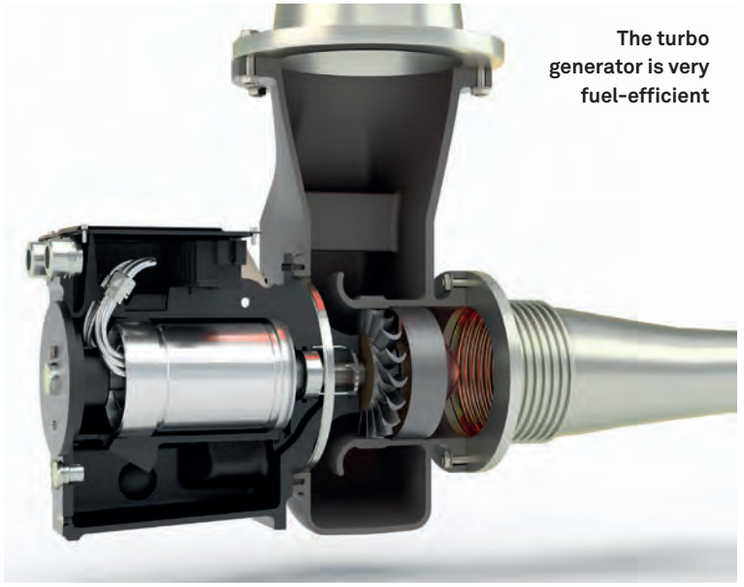
CENTAUR MEDIA

MARINE

New wave of technology fights shipping emissions

UK consortium helping maritime sector hit its carbon reduction targets

HELEN KNIGHT REPORTS



The turbo generator is very fuel-efficient

If the shipping industry were a country, it would rank as the sixth-largest carbon dioxide emitter in the world, placing it roughly level with Germany.

The shipping industry already accounts for around two per cent of the world's carbon dioxide emissions, but it is feared that this figure could rise further by the year 2050.

To prevent this, early in 2018 the International Maritime Organisation reached an agreement to cut emissions from the sector by at least half by 2050.

Now a UK consortium, led by Southampton-based Bowman Power Group, has developed a system that could help the industry to move a step closer to meeting this target, by improving the energy efficiency of a range of marine vessel types by up to 7.8 per cent per year.

The £1.5m project, which was partly funded by Innovate UK, also included Rolls-Royce Power Systems, Lloyds Register and University College London (UCL).

The system is based on Bowman's electric turbo compounding (ETC) technology, a type of turbo generator, according to Shinri Szymko, head of engineering at the company. "There is a turbine at one end [of the system], which sits in the exhaust of the engine, and effectively spins around absorbing energy from the exhaust flow, and turning it into electricity," said Szymko.

The device's power electronics system then converts the output from the generator into grid-quality electricity, he said.

"With diesel or gas engines, around 30-40 per cent of the energy simply goes out of the exhaust pipe and isn't used," said Szymko.

"The turbine is there to capture some of that wasted energy before it is lost."

Rolls-Royce Power Systems provided the project team with key information and simulation results for its MTU Series 4000 M93 engine, which is commonly used in the marine industry.

Meanwhile researchers at UCL investigated the feasibility of applying ETC technology to a range of marine fleet sectors. The researchers have developed software that enables them to model complete ship systems, said Szymko.

"The software allows them to understand how efficient a ship is during the different manoeuvres, and in the duty cycle of sitting in port, and then going out to sea," he said. In this way the team was able to investigate the benefits, performance, limits, secondary impacts and expected results of the technology.

The researchers added the ETC technology to the model, and then examined the resulting efficiency of a range of different vessels, including passenger ships, tankers and cargo vessels. They found that for all the different ship types, the system would save up to 7.8 per cent of fuel per year, based on realistic operating conditions.

The model also predicted that the technology would pay for itself in just 2.3 years.

Once the modelling work was complete, Bowman began developing prototypes and testing. It built seven different turbo generator and power electronics prototypes and tested them in different applications, including in a specialist test facility, and within a number of land-based applications. This allowed it to simulate real operating conditions.

To ensure the system complied with marine regulations and standards, the company also worked with Lloyds Register to develop mechanical and electrical marine compliance response documentation. As a result, Bowman was able to produce a road map, validated with testing, to produce a marine-capable system.

The company has since held discussions with two large marine engine OEMs, and a ferry operator, about commercialising the technology. ■

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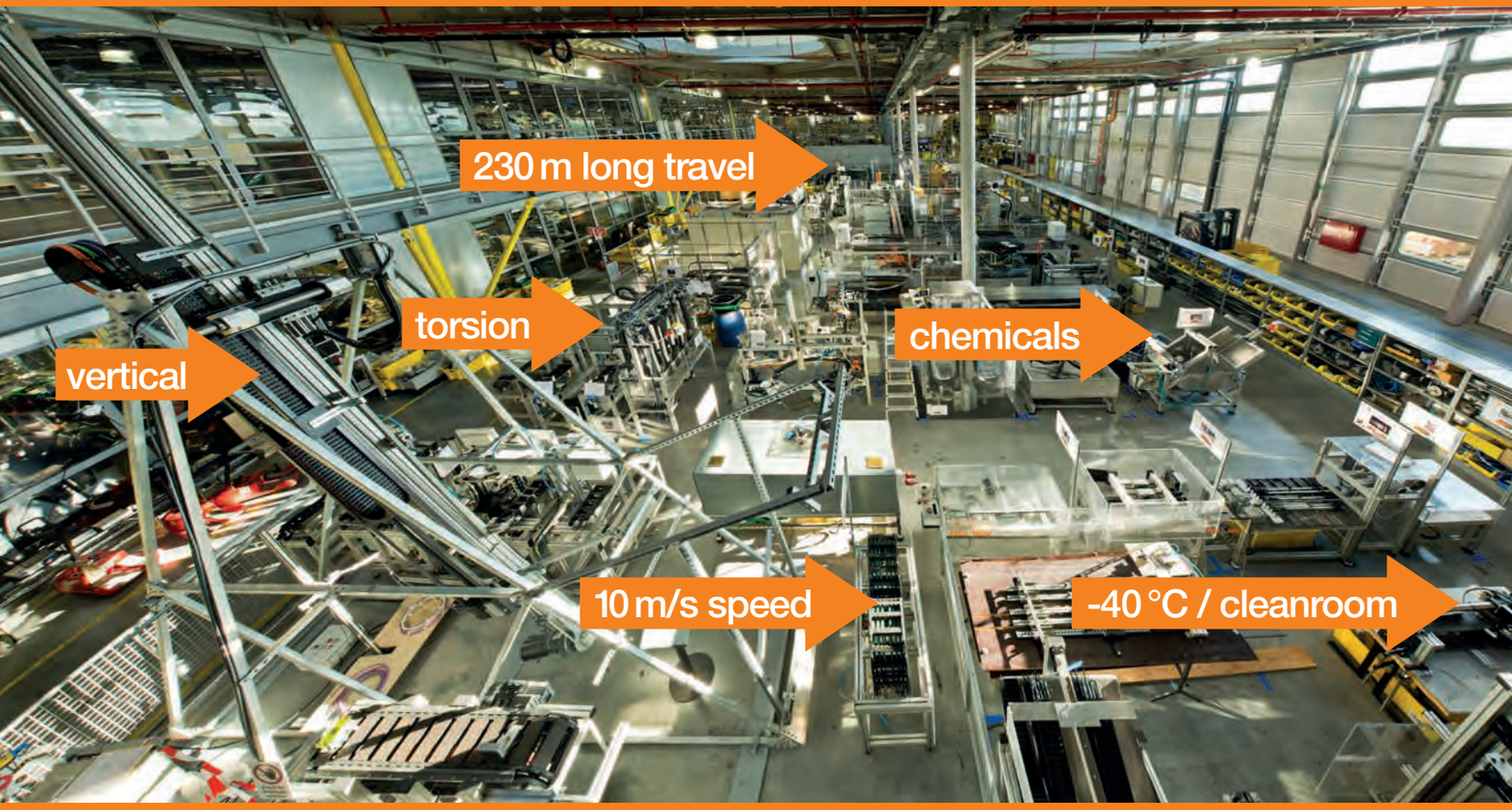

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MINING

EU eyes boost from underwater mining

Minerals worth up to €100bn targeted through inland lake exploration

HELEN KNIGHT REPORTS

The mining system will target inland lakes

Horizon 2020 is funding a project to tap mineral resources in the EU estimated to be worth as much as €100bn (£90.2bn).

The EU imports 200 million tonnes of minerals annually but might reverse this with an autonomous underwater mining system to reach and extract mineral deposits within inland lakes, such as flooded mines, at depths of 500-1,000m below the surface.

The ¡VAMOS! scheme, led by BMT Group and including 16 other partners, has tested this system at the Magcobar flooded mine pit, in Silvermines, Ireland, according to Jenny Rainbird, project lead and managing consultant for EU projects at BMT.

"Most mining in Europe is open-cast or deep mining, which means a lot of cut and blast on the surface, and then when those mines are exhausted, they are abandoned and fill up with water," said Rainbird.

Re-excavating those flooded mines is very costly, as it involves pumping out the entire lake before the area can be mined conventionally again. "While the mineral may be valuable, it's difficult and not particularly environmentally friendly to pump out all of that water for what could be quite a small seam of the mineral," she added.

Instead, the remotely operated mining vehicle is launched from a waterborne launch and recovery vessel, and then winched down to the underwater mining site.

A mechanism at the front of the vehicle is used to grind the material at the surface of the rockface. The machine then collects this material, sucking it up and pumping it to the launch and recovery vessel through a pipe. Finally, the material is sent through floating hoses as slurry to a dewatering plant on the shore to be processed, said Rainbird.

"The process is unmanned, so it is much safer, and because there is no dust, explosives, noise or vibration, and you are not demolishing large areas of rock to get to a small amount of mineral, it has a much smaller environmental footprint than conventional mining," she said.

The mining machine is remotely operated from a control cabin on the shore. Sensors on board the mining vehicle collect data on its surroundings.

A separate roving AUV, called EVA, also circles the mining vehicle, collecting positioning and navigational awareness information through various sensors, including multibeam imaging sonar.

"The sensors collect data about the underwater area, which is fused together to create a virtual reality view in the control cabin, and the pilot then pilots the mining vehicle using a joystick mechanism," Rainbird concluded. ■

MEDICAL

First steps for 'chemputer'

System aims to digitise pharmaceuticals

STUART NATHAN REPORTS

A team at Glasgow University has created a so-called 'chemputer' system that allows digitisation of chemistry and opens the door to on-demand production of pharmaceuticals.

Named by research leader Lee Cronin, Regius professor of chemistry at the university, it uses downloadable blueprints to easily and reliably synthesise drug molecules. Described in *Science*, this represents "a key step in the digitisation of chemistry and will allow the universal assembly of complex molecules on demand", Cronin claimed.

He has been working on the chemputer concept and the software system that runs the chemical recipes and directs the synthesis process, known as a 'chempiler', for some years. The *Science* paper represents a major step in perfecting the idea, he said.

A key part of the project was developing new universal and interoperable standards for writing and sharing chemical recipes. The system consists of an automated series of modular reaction vessels, linked to a desktop computer that controls pumps and valves to draw liquid chemical reactants into, through and out of the vessels.

The essential modules consist of a reaction chamber, a filtration system equipped with a jacket that allows it to be cooled or heated, a liquid-liquid separation vessel and a solvent evaporator.

In tests, the researchers synthesised three very different medicine active ingredients, for Nytol (an antihistamine that causes drowsiness), the anticonvulsants medication Rufinamide and Viagra, all using the same apparatus and merely changing the software and input chemicals. ■

Newsinbrief

Fears over no-deal Brexit

Three quarters of UK automotive firms fear a 'no-deal' Brexit will threaten their future viability, according to a survey by the Society of Motor Manufacturers and Traders. Some 74.1 per cent of companies with UK operations said a no-deal scenario would damage their business.

Autonomous ferry sails

The world's first fully autonomous ferry has been demonstrated in Finland, a feat that saw Finferries' Falco – a 53.8m double-ended car vessel – navigate its way between Parainen and Nauvo. The Falco used a combination of Rolls-Royce Ship Intelligence technologies to make the outward journey. It detected objects using sensor fusion and AI, and conducted collision avoidance.

UK commits to CCUS

The Government has backed plans to have a carbon capture usage and storage (CCUS) plant running from the mid-2020s. Plans to kickstart CCUS in Britain include an investment of £20m to support the construction of technologies at industrial sites, and up to £315m to decarbonise industry, which will include the potential use of CCUS.

Floating turbine installed

The North Sea's first semi-submersible floating wind turbine has been installed at the Kincardine Project near Aberdeen. Developed by Principle Power, the WindFloat technology was installed by Bourbon Subsea, using Vryhof's mooring solutions. Its semi-submersible platform allows a mooring system to be pre-installed at sea, while the turbine is readied at a local port.

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AUTOMOTIVE

StreetDrone drives development ahead

AI systems can connect to autonomous driving technology for enhanced safety and better communication HELEN KNIGHT REPORTS

Technology to allow any vehicle to safely connect to artificial intelligence systems for autonomous driving has been developed in the UK.

The Xenos platform, developed by Oxford-based self-driving test vehicle specialist StreetDrone, allows the car and the AI system to safely communicate.

> "The opportunity is to make the vehicles ready for autonomy"
> Mike Potts, StreetDrone

A combination of software and hardware, the platform allows different vehicle controllers to communicate with autonomous applications, such as AI, self-driving software stacks and remote mission control systems.

With mobility fleets such as Uber and Lyft expected to account for a significant percentage of journeys in the future, the technology will allow any vehicle to connect to an autonomous network, according to Mike Potts, founder and CEO of StreetDrone.

"I strongly believe that people will not buy autonomous vehicles, that those cars will instead be owned and operated by fleets," said Potts. "So the real opportunity, even for the car companies, is to make their vehicles ready for autonomy, and to plug applications into those vehicles to make them smart, in a similar way that Android and Apple enabled phones to become smart by plugging applications into them."

The company has been developing the on-vehicle version of Xenos for the past 18 months, which it has built into its StreetDrone ONE, a Renault Twizy-based autonomous test vehicle, and connected to various self-driving applications.

"The Xenos platform runs on top of the Renault Twizy, and allows any hardware that is running a self-driving application to run on the car, enabling it to safely tell it to turn left, turn right, slow down, or speed up, for example," said Potts. "From an on-vehicle perspective, the most important thing is functional safety, making sure the vehicle responds in the right way to the AI, and doesn't do anything stupid."

As well as applications that are installed on the car itself, the company is also planning to extend the platform to allow it to connect to other cloud-based applications, such as fleet management systems.

"The company's ultimate aim is to make the platform the standard way in which cars are connected into an autonomous fleet," said Potts.

StreetDrone is beginning an investment drive, to secure funding to expand, and further develop Xenos. ■

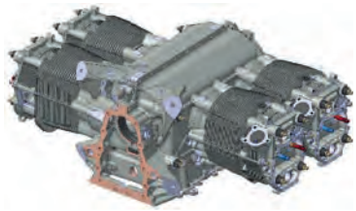
StreetDrone ONE, a Renault Twizy-based autonomous vehicle

AEROSPACE

Motorsport inspiration

Tech used to improve engine power density

HELEN KNIGHT REPORTS



Technologies developed for motorsport have been used to improve the power density of an aerospace engine.

Northampton-based Ilmor Engineering, which builds engines for Formula 1 and IndyCar racing, developed the technology for a General Aviation diesel engine as part of an EU Clean Sky 2 project, funded by the Horizon 2020 programme.

The project's aim was to improve the power density of the engine by increasing power and reducing weight, while also maintaining fuel efficiency, according to David Robertson, design engineer at Ilmor.

The company worked alongside SMA, the piston engine division of Safran Aircraft Engines, which supplied the 227hp, four-cylinder, four-stroke, horizontally-opposed engine.

By replacing the engine's iron liners with a plasma bore coating, Ilmor could reduce the overall mass by 2.6 per cent, said Robertson. "We replaced the iron with aluminium, which removed a substantial amount of weight," he said.

However, while iron is a very good material to use for surfaces that interface with a moving piston, aluminium is not, so the new liners needed careful treatment, he said.

"We used a company in Switzerland which heats up powder, in this case an iron-based mix, and blasts it at the surface, where it coats the surface in a very thin layer of iron," he said.

The team designed new components and redesigned existing ones to meet the increased demand on the engine from the greater power density. ■

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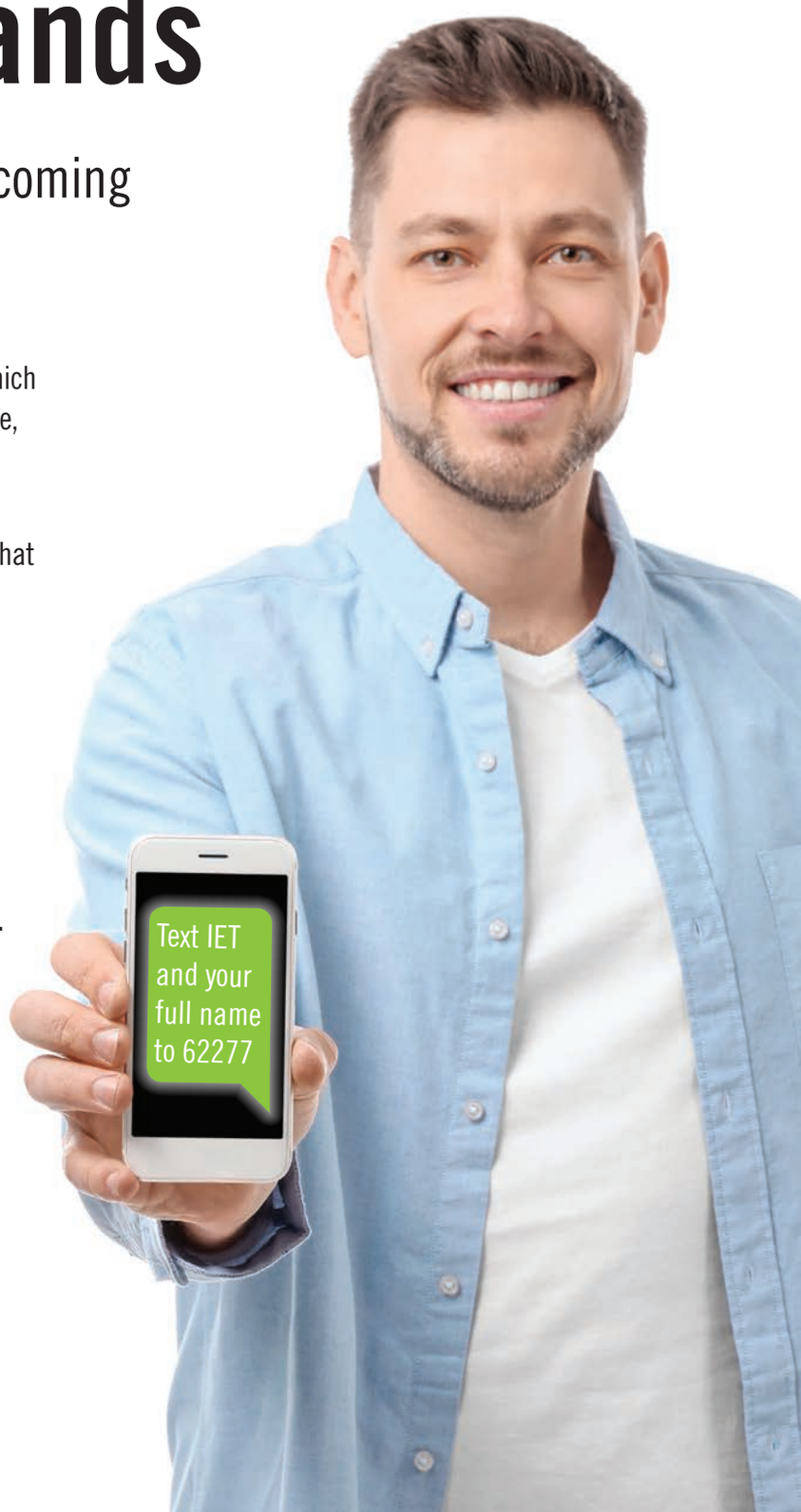


MEDICAL

Quest for oxygen dose accuracy

Camcon's fluid control system seeks to boost safety and cut costs

HELEN KNIGHT REPORTS

Patients needing respiratory care could be given more accurate oxygen dosages, improving safety and cost-efficiency, thanks to fluid control technology originally developed for the oil and gas, and automotive industries.

Cambridge-based Camcon Medical, which specialises in high-speed, low-energy liquid and gas flow control, has identified oxygen therapy as the first medical application for its binary actuation technology.

Oxygen therapy is used to treat patients with a range of conditions, including severe lung disease, carbon monoxide toxicity and cystic fibrosis. Accurate oxygen dosing is a significant challenge, as both under- or over-dosing can prove fatal, said Charles Potter, director of Camcon Medical.

"According to the British Thoracic Society, there are thousands of patients that receive too much oxygen every day, because of the way that the gas is delivered, and some patients can have severe medical problems if they are given too much oxygen," Potter added.

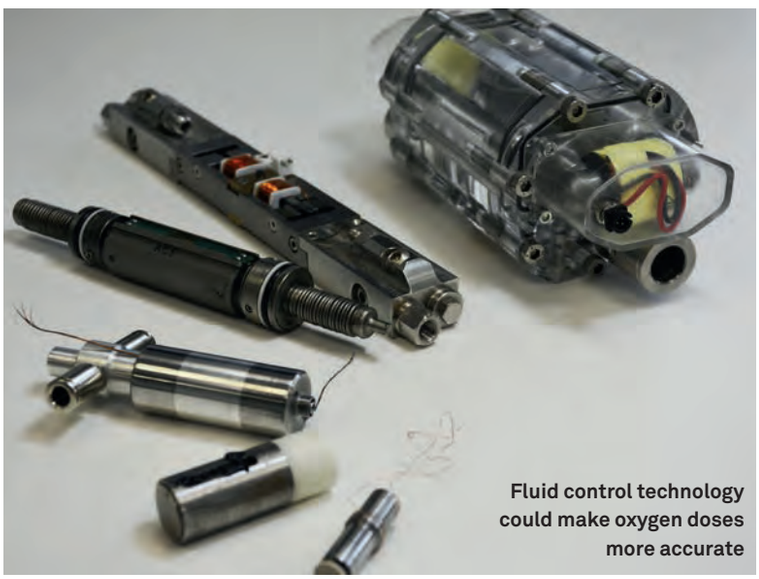
It is estimated that between 2,000 and 4,000 people die in the UK alone each year from incorrect oxygen supply. More accurate dosing within homes and hospitals could also reduce wastage, with around £34m spent in the UK each year on wasted oxygen.

The technology, which is silent, is based on capturing and recycling the kinetic energy of a moving armature, which is used to open and close the valve. Originally invented by Wladyslaw Wygnanski in 1998, the technology allows a valve to switch between its open and closed state more quickly than other mechanisms, while consuming only a tiny amount of energy.

"Because we use energy recycling, it means that when it is in position A, we already have energy stored inside the actuator, so we just need a trigger and then we have a catapult effect, which allows us to go to position B," said Wygnanski. "Then, before landing at position B, the kinetic energy is reclaimed and stored."

Reclaiming kinetic energy results in a soft close, meaning wear and tear on the valve is reduced, he said.

Camcon Medical is also investigating other applications for the technology within healthcare, including long-life implantable body fluid control devices, said Wygnanski. The company is also considering the valve technology's use in mechanical aids, such as prosthetics. ■



Fluid control technology could make oxygen doses more accurate

MEDICAL

Oximeter breakthrough

New wearable device capable of measuring oxygen levels anywhere in the human body

Engineers at the University of California, Berkeley, have created a wearable, flexible oximeter that can gauge blood-oxygen saturation in any part of the body.

Oximeters use light to detect the ratio of oxygen-rich red blood to darker, less oxygenated blood. Until now, this has only worked on areas of the body that are partially transparent, like the fingertips or earlobes.

Using flexible electronics, combined with a new way of measuring oxygenation with reflected light rather than transmitted light, the UC Berkeley team can now measure oxygen levels anywhere in the body. The research could lead to improved wound monitoring and more accurate assessments of transplant patients.

"All medical applications that use oxygen monitoring could benefit from a wearable sensor," said Ana Claudia Arias, a professor of electrical engineering and computer sciences at UC Berkeley. "Patients with diabetes, respiration diseases and even sleep apnoea could use a sensor that could be worn anywhere to monitor blood-oxygen levels 24/7." AW

MATERIALS

Rethink for nuclear suits

Iron Man-inspired gear to replace PVC design

STUART NATHAN REPORTS

Robotic technology is being combined with composite materials in an Innovate UK-funded project to improve protective gear for nuclear decommissioning.

Bristol University's South West Nuclear Hub is collaborating with Sellafield Ltd, the company that manages the large nuclear site in Cumbria and is responsible for decommissioning many of its facilities. Currently, workers in hazardous environments wear air-fed PVC suits, which get hot and can only be worn for a limited time.

The Iron Man-inspired suit will incorporate an augmented reality display and an audio system will feed the wearer information about the tasks they will have to perform. The suit will incorporate its own power source. The protective function of the suit will be performed by composite plates which will be easier to decontaminate than PVC, while also providing protection against radiation. Robotic functions provided by an exoskeleton will help reduce the mechanical load on the worker's body if they are in a confined space.

"Robotic and remotely deployed technologies are already helping the Sellafield mission, but there will always be some cases where human workers are required to do hands-on work in hazardous plant areas," said project leader Prof Tom Scott, co-director of the hub.

"Our wearable suit concept offers the prospect of major improvements in worker protection."

Other technologies being assessed for the project include eye tracking, which will help monitor worker fatigue. Project partners, including the National Nuclear Laboratory, DZP Technologies, Imitec and Lightricity, hope to construct a fully working prototype following a review of the scheme in 2019. ■

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ADDITIVE MANUFACTURING

3D printing to aid new circuit build

Use in microwave and terahertz set to improve radars and sensors HELEN KNIGHT REPORTS

Car radars, 5G communication systems and satellite-based atmospheric sensors could all be improved as a result of a UK project to develop 3D printed terahertz and microwave circuits.

Although 3D printing is widely used in many areas of manufacturing, its use in microwave and terahertz circuits has so far been limited by the level of precision required to build devices at such a small scale.

However, the accuracy of 3D printers has significantly improved in recent years, with some now able to print down to a resolution of five microns or less, according to Michael Lancaster at Birmingham University, who is leading the EPSRC-funded project.

So the research team is aiming to work with 3D printing companies to design and print novel devices at these small scales, he said. By using 3D printing techniques, the researchers hope to rapidly generate novel circuits with complex shapes and multiple functions in a lightweight form, without producing large amounts of waste material.

This should result in reliable, low-cost circuits with improved performance and faster manufacturing lead times.

The project will focus on 3D printed circuits at frequencies above 50GHz, which are typically used for free space communications, security sensing and remote monitoring of the Earth's atmosphere.

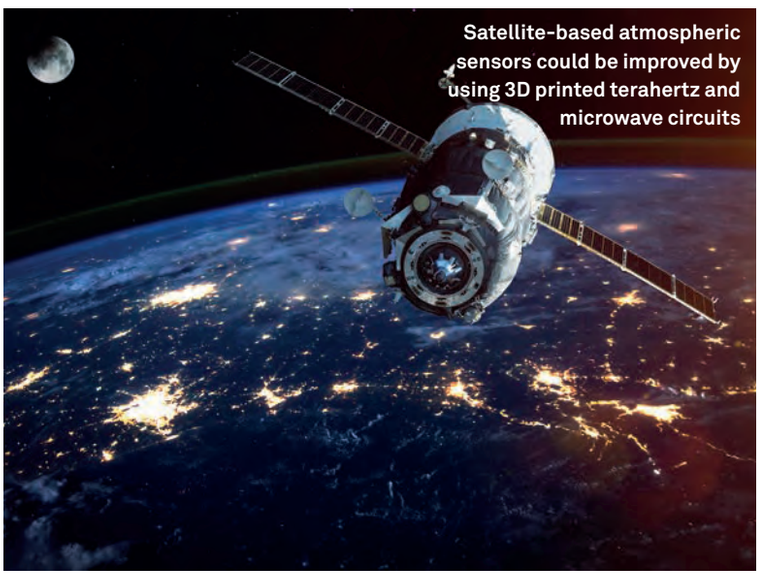
"The immediate applications are 5G communications and car radar, which have frequencies well above 100GHz, so we're working with Jaguar Land Rover," said Lancaster. "In this particular project we're also working with Rutherford Appleton Laboratory (RAL), which is interested in atmospheric sensing: putting these things on satellites to look down at the atmosphere, to study the weather and other atmospheric conditions."

The researchers are particularly interested in the filters and other metal components found alongside the antenna and electronics on terahertz and microwave circuits, said Lancaster.

"As the devices go up in frequency these components get more difficult to make," said Lancaster.

Rather than buying in their own 3D printers, which would no longer be at the cutting edge of the technology by the end of the three-year project, the researchers will be buying in printing services from specialist companies.

"At the moment we are talking to 3D MicroPrint in Germany, and Swissto12 in Switzerland," he said. ■



Satellite-based atmospheric sensors could be improved by using 3D printed terahertz and microwave circuits

MEDICAL

Pacemaker solution for infants?

Prototype developed that could reduce time and trauma when having open-heart surgery

Researchers at Children's National Health System in Washington DC have developed a miniaturised prototype pacemaker that could lead to less invasive surgeries for infants.

Measuring about 1cm^2, the device could be delivered using a small 1cm incision, removing the need for lengthy and traumatic open-heart surgeries.

Paediatric open-heart surgery can take up to several hours, depending on the child's medical complexities. In the study, presented at the American Heart Association's Scientific Sessions 2018, the prototype was tested on piglets. It was found that the median time from incision to attaching the pacemaker was 25 minutes.

The speed of the procedure is facilitated by a patented two-channel, self-anchoring access port, previously developed by Dr Charles Berul's bioengineering lab at Children's National.

This port hosts a camera in one channel, while first a sheath and then the pacemaker's lead pass through the other channel. Once the lead is attached to the heart, the pacemaker itself is inserted into the incision, which is then closed up. AW

AEROSPACE

Partnership in air race series

Electric aircraft set to take part in new trials

STUART NATHAN REPORTS

An all-electric air racing series has taken a step forward with the formation of a partnership between Nottingham University and the race series Air Race E.

Planning to launch its inaugural race in 2020, Air Race E is envisaged as being similar to Formula One pylon air racing, a competition where eight aircraft race directly against each other around a tight circuit 1.5km end-to-end.

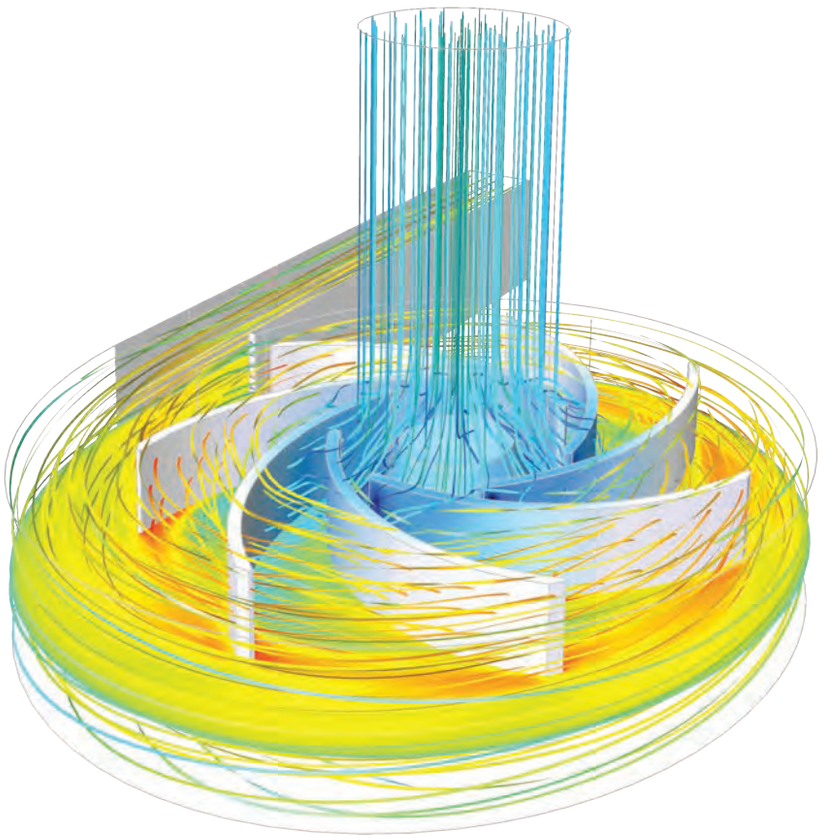
Promoter Jeff Zaltman, who runs the Air Race 1 World Cup, plans a race with electric aircraft flying some 10m above the ground around a 5km circuit. Nottingham is already involved in electric motorsport, running an electric superbike in race series including the TT Zero on the Isle of Man. The motor from this bike will form the basis for the motor of the electric race aircraft, according to project director Richard Glassock.

He plans to retrofit the motorbike motor into an existing petrol-powered Air Race 1 plane and begin air trials within the next three to six months.

"We won't have to make many adjustments to the aircraft," he said. "Basically we just remove the petrol engine, replace it with an electric motor, replace the fuel tank with battery storage and make some changes to the cockpit displays."

The project forms part of the University's £13m Beacons of Excellence programme, which addresses responses to global challenges. The partnership will take in development of new materials, components and technologies aimed at the whole field of electric aerospace propulsion.

The work at Nottingham will lead to a specification for the aircraft's motor. ■



Visualisation of the streamlines, pressure, and velocity magnitude in a centrifugal pump.

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MATERIALS

Thickness wall for synthetic material

Researchers find clothing could benefit from new stretching properties

HELEN KNIGHT REPORTS

Body armour, biomedical devices and next-generation sportswear could all benefit from the first synthetic material to be discovered that becomes thicker as it is stretched.

Conventional materials such as rubber bands become thinner as they are stretched. So for the past 30 years researchers have been attempting to mimic the so-called "auxetic" properties of naturally-occurring materials such as cat skin, human tendons, and the protective layer in mussel shells, which become thicker upon stretching.

However, until now they have only been successful by structuring conventional materials using complex engineering processes such as 3D printing, which can be time-consuming and costly. The processes can also lead to weaker, porous products.

The new non-porous material, which has been discovered by researchers at Leeds University, has inherent auxetic stretching properties, according to Dr Devesh Mistry, who led the research.

"This is not something that needed to be engineered in any particular way, you don't need to 3D-print this kind of behaviour," said Mistry.

The researchers discovered the synthetic material while investigating liquid crystal elastomers.

"Liquid crystals by themselves are probably best described as an ordered fluid, so you essentially have molecules with a rod-like shape, which are packed together in a particular alignment," said Mistry.

"But unlike a crystalline solid, the molecules are able to flow past one another, so they act very much like a liquid."

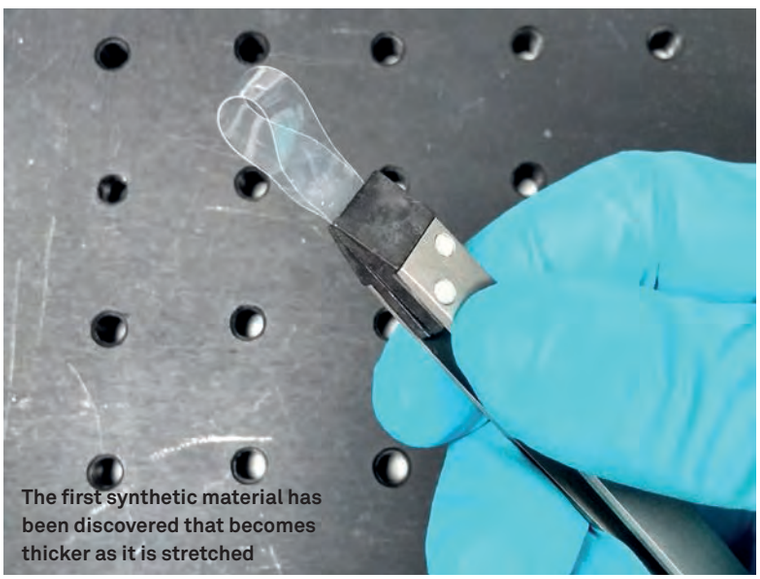
When these liquid crystals are linked with polymer chains to form rubbery networks, the material becomes auxetic at a molecular level, giving it a completely new set of mechanical properties.

For example, the materials exhibit so-called soft elasticity, in which they can be elastically stretched without energy cost, said Mistry.

More research is needed to understand what drives the auxetic behaviour, and how it can be applied commercially. But the researchers are already investigating potential applications for the material.

"[Auxetic materials] are known particularly for their shock-absorbing, tear-resisting or fracture-resisting properties," said Mistry.

"So we are looking into those type of application areas, such as biomedical devices, next-generation sportswear or sports devices, or protection." ■



The first synthetic material has been discovered that becomes thicker as it is stretched

AUTOMOTIVE

Mobility centre's Smart move

Warwickshire hub expected to aid the development of driverless vehicle technology

Europe's first multi-million-pound Smart City Mobility Centre is to be established in Warwickshire and the West Midlands, a move expected to drive the development of driverless mobility and electric vehicle technology.

The new facility will be based at Warwick University's Wellesbourne campus, with driverless capable vehicle testing on the university's campuses in Coventry and Warwickshire.

Jaguar Land Rover engineers and WMG researchers will work together at Wellesbourne to design and engineer connected, driverless capable, prototype electric modular architectures. These will be tested in real-world conditions alongside a 5G communications network on Warwick University's main campus.

WMG chairman Professor Lord Kumar Bhattacharyya said: "This is the first time in any country that such a comprehensive system is being designed and tested. This will help integrate plans for transport systems for the future that have potential to bring significant economic benefits to transform and improve the lives of a great many people." JF

ENVIRONMENT

Unearthing new sensors

Better detection for underground objects

HELEN KNIGHT REPORTS

A UK consortium of companies and universities is developing new quantum cold-atom sensors to detect and monitor subterranean objects better than existing technology.

The Gravity Pioneer project, which has been awarded £6m in funding from UK Research and Innovation, plans to develop a device that is twice as sensitive, and 10 times faster, than existing gravity sensors.

Existing techniques to search underground typically involve either the use of ground-penetrating radar or classical microgravity, or digging holes, according to George Tuckwell, project lead and divisional director for geosciences and engineering at consultancy RSK, which is leading the project.

The researchers are developing technology based on a cloud of trapped atoms that are first cooled to near absolute zero, and then manipulated to ensure they behave in a quantum manner.

Precisely timed pulses of laser light are shone at the atoms, placing them into a quantum superposition of two trajectories – or states – by causing half of the cloud to travel at a different speed to the other, before they are recombined.

"It is the interference between the two states that gives you a measure of the difference in path they have taken as they fall," said Tuckwell.

This path difference is affected by gravity, meaning the device can be used to measure gravity extremely precisely.

In turn, the pull of gravity at a given spot will depend upon the subsurface density, meaning that areas with an absence of mass underground, such as a subterranean mineshaft or cave, can be quickly identified using the sensor. ■

Engineering needs immigration

Workers from overseas, of varying skill levels, will still be needed long after Brexit – it is vital that the Government gets the numbers right

If newspaper stories are to be believed, the Government is finalising a future immigration policy for the UK. This will come into force when – or perhaps increasingly if – we disengage from the current arrangements in place with our fellow EU and EFTA countries.

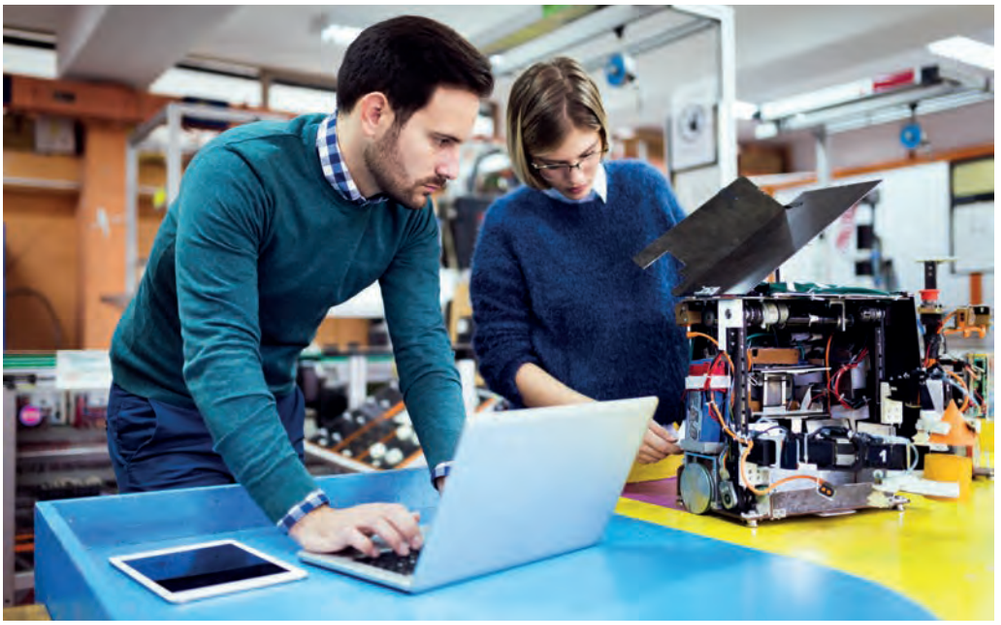
Some aspects of the Government's thinking have been reported after a draft of a White Paper was leaked. These include proposals for an 11-month visa for so-called low-skilled workers with "restricted entitlements and rights".

Eleven months is an interesting time limit. It could mean they would not show up in headline immigration statistics. There is also the prospect of a minimum salary requirement of £30,000 for skilled (or so-called 'Tier 2') visa applicants coming from the rest of Europe. This would bring EU/EEA applicants into line with individuals from the rest of the world seeking higher-value employment. Notwithstanding any loosening of quotas, these proposals would arguably represent the most significant tightening of British immigration policy since the Commonwealth Immigrants Act of 1962.

Immigration is politically fraught. On the one hand, the Government is keen to show it is responding to public concerns. Immigration shows up in polls as to why some people voted for Brexit. On the other, non-UK labour has proved invaluable in sustaining the British economy. Many sectors – from care workers to corporate finance – have a significant degree of dependence on the two million-plus EEA nationals – plus millions of other overseas individuals – who have made Britain their home. Without them, vital public services such as health and social care would suffer.

The infrastructure, construction and engineering sectors are no exceptions. According to the Royal Academy of Engineering, we need nearly 200,000 new engineers and engineering technicians a year until 2022. It would be impossible for the UK to fill all of these positions with home-grown talent alone. And, as the academy points out, engineering is a sector which often needs large numbers of skills to help deliver a particular phase of a project.

Arup, and our clients, rely on the ability to move staff between countries as a new railway, tall building or power station evolves from the drawing board to delivery. For Arup, international mobility is key to fostering the culture of our staff-owned business. We believe firmly that it helps us deliver better solutions for clients and retain the best talent. Barriers to movement risk creating delay and cost risk to projects and damaging the competitiveness of UK engineering; a sector that is not only important to the domestic economy, but also key to our export success.



If Britain is going to move away from the present immigration model, a number of objectives for policy should be centre-stage. As a recent report from business campaigning group London First highlights, these should include providing business with access to people and talent at all levels. And while for many posts we should look to further investment in training and education for UK citizens, the sheer scale of the country's requirements for lower- and higher-paid jobs mean it will be essential to allow access to overseas labour in the years ahead.

London First's report suggests a 'Tier 2' salary threshold of £20,155 (the London living wage). At present it is around £30,000. It also advocates no artificial caps on visas. The report highlights that any system will need to be based on much better data. That would help to build trust with the public and allow for a more informed debate about policy in the future.

> British engineering companies are finding it hard to recruit skilled people

Brexit – in whatever form it takes – is perhaps just months away. For the wellbeing of the UK's economy and the engineering sector, it is imperative that the Government comes forward with an immigration policy that supports long-term growth and competitiveness.

It should explicitly acknowledge that creating opportunities for all those who wish to work or contribute to such an important part of Britain's industrial base is a good thing and then back this up with sensible policy proposals.

An evidence-based, progressive immigration policy that allows all sectors of the economy to prosper and grow is urgently needed. And that includes engineering. ■

Alexander Jan is chief economist at Arup

Mailbox

Thehottopic

Ferry controversial

A demonstration of the world's first autonomous ferry sparked some lively debate among readers

Will it see moored yachts in poor visibility? If 'yes' it would make things a lot safer in the crowded waters of the Solent. The Isle of Wight ferry has crashed into yachts twice in recent months. (It strayed out of the channel into moored yachts in visibility of 100m).
Ian Downie

There are still issues relating to accidents and collisions that may be the real limitation on a larger adoption of this concept.

Ferries are one thing, large ocean-going vessels are another. I suspect the insurance premiums for a crewless vessel might have a serious commercial impact.

Surely much better to have a skeleton crew able to intervene in the event of emergencies and equipment failures. Is this a case of feasibility overcoming desirability?
Phil Mortimer

Of course it is possible to automate shipping, indeed it is in so many ways easier than autonomous road vehicles. However, I have colleagues who are ex-Merchant and Royal Navy and the life of the crew is one of constant checking and maintenance.

Part of this is that they know the ship intimately for that emergency situation. If an autonomous ship was without any human on board, then one could take the view if it sinks then so be it. I wonder how we reconcile that with a ferry, for example, that would have passengers of all ages and capabilities on board?

Ferry disasters such as the Herald of Free Enterprise were man-made, so what does that tell us? It tells us that in that case the systems that allowed the disaster to happen were flawed, again by design or maintenance (a human cause). Automated shipping could still suffer the same fate.

At the end of the day we can automate anything – aircraft, ships, cars and for the last 35 years logistics in industry, plus an incredible array of other things.

When we look for an area of great success of full automation, a good example is London's Docklands Light Railway. The principle of the DLR operation is actually very simple and one that has been used in industry since the late 1970s. Couple this with the fact that it is on rails with several stages of redundancy in the speed control and stopping process, it is pretty safe, and the operational record bears testament to this.

The prime reason we have not automated millions of cars is one of assured human safety, not machine capability, despite the fact that most accidents are caused by humans.
Stephen Rose

Some interesting comments here, but I think some people are confusing autonomous with unmanned. The autonomy present in the ship described seems (at least to me) to be confined to navigation, power, berthing, etc. I am certain that no ferry would ever get any passengers to board it if there was no friendly human to marshal the passengers and cargo, serve the coffee and, most importantly, be in charge of the safety equipment.

It does, however, raise some other points. So many dire warnings recently have indicated that all manual jobs will be done by robots and only skilled roles will remain for humans. In this instance it would appear that the more skilled roles are the ones under threat.

In the event, technology will evolve in accordance with what the public will accept and a balance will be achieved between automation and human tasks.
James Dunlop

Inyouropinion

UK pulls out of Galileo

The real answer is simple, forget the Brexit madness and re-join (and lead) this vital programme along with a raft of other essential initiatives that we stand to lose out on. Thank you Mr Cameron and Mrs May!
Mark Morgan

The problem is that Galileo was funded via the EU rather than directly from ESA members. The UK was actually the country that insisted on a clause to block third-party access. At the time it was still not out of the question that Russia could join as a member. Even now, should Ukraine join, there might be questions about commercial and military secrets leaking to Russia. The solution is for the other members of the project to agree to let the UK back in by exception. This is the sort of thing that a transition period might handle.
Philip Owen

We should suck it up. We voted for it, apparently. There isn't going to be money for an alternative so we can forget the military security we want.
Tim Murphy

We are 'only' talking about a global positioning capability here. We appear to have managed quite nicely to invade and destroy Iraq, Syria, Libya, Afghanistan, etc without Galileo. I'm convinced we will still have the capability to invade and destroy in the future.
Another Steve

Thesecretengineer

Technology leaps forward in wartime, but such wars deprive us of those taken before they realise their potential, writes our anonymous blogger

Last year marked the centenary of the end of the First World War, bringing an additional poignancy to 2018's acts of remembrance on 11 November.

There have been conflicts before and since, but we have to look back to 1918 to find the roots of our annual shared moment of observance and reflection.

Armistice day, the red poppy, the Cenotaph, the unknown soldier – so barbaric was the experience of those infamous mud-daubed killing fields that our shattered and shocked country, uniquely, felt a need to grieve together through these now familiar symbols.

Some 100 years on and we continue to do so, building on them through the wars and conflicts suffered in the years between. Yet we still particularly remember that initial terrible conflict. Now, due to its significance, I would like to share two stories relating to those dark, faraway days.

The first is about a young Naval officer called Francis Banks – Rod to those who knew him. He joined up at the age of 16, right at the beginning, and found himself assigned to motor torpedo boats. The main reason for this was that he had a flair for the then novel technology of the internal combustion engine. Although petrol engines had been around for a while, it was the military's need for a power plant combining convenience and low operator skill that saw it come to the fore. However, Rod could really work with them and this, coupled with his natural leadership, saw him rise through the ranks to command his own boat.

The second is about Charles Kennedy, a Scot who was 34 at the outbreak of war. His pre-war career saw him excel in the world of railway engineering. After serving his apprenticeship in Glasgow, he went to the London, Tilbury and Southend Railway, and from there out to the Great Western of Brazil. A meteoric rise through the ranks saw him appointed to the post of locomotive, carriage and wagon superintendent by the age of 30. However, when war broke out he volunteered and became an officer in the Royal Artillery.

Poppy wreaths at the London War Memorial

As engineers, we know how we can dramatically change the world with our work – even if only a few of us are privileged to do so.

After hostilities ceased, Banks further developed his skills and ended up mixing the special 'cocktail' fuels for various record-breakers, winning both recognition and awards for his work. He also helped Britain win aviation's Schneider Trophy in 1927, 1929 and 1931. During the Second World War he joined the RAF as a volunteer and again quickly rose through the ranks to Air Vice Marshal. This led to various directorships post-war and appointments at the very highest levels within the aerospace industry.

A glittering career that both helped us to win the Second World War and significantly aided our post-war economy.

Kennedy, sadly, died from the wounds he received on the Somme in 1916.

When we make our act of remembrance every year, we naturally think of the direct human cost; the untimely deaths and those left behind to mourn.

Stories of the people are told and retold but, bar a few poets and musicians, there is little consideration of what might have been. Of all the futures now forever unrealised.

Who knows what paths Lt Kennedy would have taken, or the impact he may have made within the railway industry? Similar considerations apply to all those who died, but as engineers we know how we can dramatically change the world with our work – even if only a few of us are privileged to do so.

Ultimately, this is how the books are balanced. We know that technology leaps forward in times of war due to the additional funding and the desperate need to win. Against that, though, are marked those who are taken before they have fully realised their potential.

Of course we should always predominantly mourn those who lay down their lives but perhaps, during our silent vigil, we should also consider how some of our predecessors were denied the opportunity to change the world through their work – and how we are all the poorer for it.

At the going down of the Sun... ■

Air pollution

Banning pre-2014 cars would cost governments too much money in scrappage, and a wholesale ban without compensation would bring down governments. By all means bring forward the phase-out but currently the UK and many other countries do not have a power infrastructure capable of supplying the extra power required.
Chris Oates-Miller

We should be looking at forcing long-distance goods transport on to non-[local] polluting electric transport, which in the foreseeable future means electrified railways, with fleets of much smaller electric trucks to move the goods from the railway end-points to final destinations.
Michael Morley

We used to put lead in our petrol because it made foreign petrochemical firms lots of money. To hell with the millions left brain damaged! Why do we prioritise the profits of the super-wealthy over the health and survival of the poorest?
Michael Morley

Wouldn't it be better to reduce the number of journeys people take? I'm sure a lot of people could work from home at a computer just as easily as sitting in an office at a computer. We need to reduce the number of cars on the road by reducing the need to travel.
Clive Gardner

Join the debate theengineerco.uk

Engineering events/exhibitions 2019

JANUARY

Autosport International	10-13 Jan	NEC Birmingham	www.autosportinternational.com
SteelFab	**14-17 Jan**	**ExpoCentre Sharjah, UAE**	**www.steelfabme.com**
Automotive World 2019	16-18 Jan	Tokyo Big Sight, Japan	www.automotiveworld.jp/en-gb

FEBRUARY

ACDC 2019: International Conference on AC and DC Power Transmission	5-7 Feb	DoubleTree by Hilton Hotel, Coventry	www.events.theiet.org
Southern Manufacturing & Electronics 2019	**5-7 Feb**	**Farnborough International Exhibition & Conference Centre**	**www.industrysouth.co.uk**
Cyber Security for Industrial Control Systems	7-8 Feb	IET London; Savoy Place	www.events.theiet.org
IET Annual Dinner with guest speaker, Baroness Karren Brady CBE	**20 Feb**	**Grosvenor House, London**	**www.ietannualdinner.org**
Future Powertrain Conference	27-28 Feb	National Motorcycle Museum, Birmingham	www.futurepowertrains.co.uk
Embedded World	**26-28 Feb**	**Nuremberg Exhibition Centre, Germany**	**www.embedded-world.de/en**

MARCH

Ecobuild	5-7 March	ExCel London	www.ecobuild.co.uk
JEC World	**12-14 March**	**Paris Nord Villepinte Exhibition Centre, France**	**www.jeccomposites.com**
Nuclear Engineering for Safety, Control and Security	13-14 March	Bristol Marriott Royal Hotel	www.events.theiet.org
IET Global Challenge	**Submission deadline: 14 March 2019**		**www.events.theiet.org**
StocExpo Europe	26-28 March	Rotterdam Ahoy, Netherlands	www.easyfairs.com

APRIL

THE ENGINEER COLLABORATE TO INNOVATE AWARDS		**Call for entries**	
Hannover Messe	1-5 April	Hannover Messe, Hannover, Germany	www.hannovermesse.de
Industry 4.0 Summit & Expo	**10-11 April**	**Manchester Central Convention Complex**	**www.industry40summit.com**
Plastics Recycling Show Europe	10-11 April	RAI Amsterdam, Netherlands	plasticsrecyclingexpo.wordpress.com
TotalDECOM 2019	**30 April-1 May**	**Manchester Central Exchange Hall**	**www.totaldecom.co.uk**
Commercial Vehicle Show 2019	30 April-2 May	NEC Birmingham	www.cvshow.com

MAY

Living in the IoT: Realising the Socioeconomic Benefits of an Interconnected World	1-2 May	IET London; 2 Savoy Place	www.events.theiet.org
MedTech Forum	14-16 May	Cité des Sciences et de l'Industrie, Paris, France	www.themedtechforum.eu

Railtex	14-16 May	NEC Birmingham	www.railtex.co.uk
All-Energy	15-16 May	SEC Glasgow	www.all-energy.co.uk
Med-Tech Innovation Expo	15-16 May	NEC Birmingham	www.med-techexpo.com/medtechinnovationexpo2019
Electrical Safety Management course	15-16 May	Manchester | 30-31 October, London	www.events.theiet.org
Global Automotive Components and Suppliers Expo 2019	21-23 May	Stuttgart Trade Fair, Germany	www.globalautomotivecomponentsandsuppliersexpo.com/de/
JUNE			
Automechanika Birmingham	4-6 June	NEC Birmingham	www.automechanika-birmingham.com
Subcon	**4-6 June**	**NEC Birmingham**	**www.subconshow.co.uk**
The Engineer Expo	**4-6 June**	**NEC Birmingham**	**www.theengineer-expo.co.uk**
Advanced Manufacturing	**4-6 June**	**NEC Birmingham**	**www.advancedmanufacturingshow.co.uk**
PDM Event	11-12 June	Manchester Central Convention Complex	www.pdmevent.com
Milsatcoms 2019	12-13 June	RAF Club, London	www.events.theiet.org
Women in Engineering	21 June	Birmingham Conference and Events Centre	www.events.theiet.org
JULY			
REIS 2019: Railway Electrification Infrastructure and Systems course	1-4 July	Crowne Plaza City Hotel, London	www.events.theiet.org
DPSP 2020: International Conference on Developments in Power System Protection	Call for papers deadline: 19 July 2019		www.events.theiet.org
SEPTEMBER			
Future Resource	11-12 Sept	NEC Birmingham	www.futureresourceexpo.com
PEMD 2020: International Conference on Power Electronics, Machines and Drives	Call for papers deadline: 13 Sept 2019		www.events.theiet.org
IET EngTalks: Digital Manufacturing	16 Sept	IET London: Savoy Place	www.theiet.org
Satcoms 2019: Satellite Communications Systems course	16-20 Sept	99 City Road, London	www.events.theiet.org
ECOC 2019: 45th International Conference on Optical Communications	22-26 Sept	Dublin, Ireland	www.ecoc2019.org
TCT Show	24-26 Sept	NEC Birmingham	www.tctshow.com
What's New in Electronics Live	25-26 Sept	NEC Birmingham	www.wnie.co.uk
Tank Storage Asia 2019	25-26 Sept	Marina Bay Sands Expo & Convention Centre, Singapore	www.easyfairs.com
OCTOBER			
SSCS 2019: System Safety and Cyber Security	October 2019	IET London; Savoy Place	www.events.theiet.org
2019 PPMA Total Show	1-3 Oct	NEC Birmingham	www.ppmatotalshow.co.uk
HVET 2019: High Voltage Engineering and Testing course	8-10 Oct	University of Manchester	www.events.theiet.org
Advanced Engineering UK	30-31 Oct	NEC Birmingham	www.10times.com/advanced-engineering-uk
Maintec 2019	30-31 Oct	NEC Birmingham	www.maintec.co.uk/maintec-home
NOVEMBER			
THE ENGINEER COLLABORATE TO INNOVATE AWARDS	**5 Nov**	**London**	**www.theengineer.co.uk/collaborate-to-innovate-awards-2018/**
Distributed Generation course	5-7 Nov	University of Strathclyde, Glasgow	www.events.theiet.org
LAPC 2019: Antennas and Propagation Conference	11-12 Nov	Think Tank, Millennium Point, Birmingham	www.events.theiet.org
GTI 2019: International Conference on Gas Turbine Instrumentation	20-21 Nov	Hilton Vienna Plaza, Vienna, Austria	www.events.theiet.org

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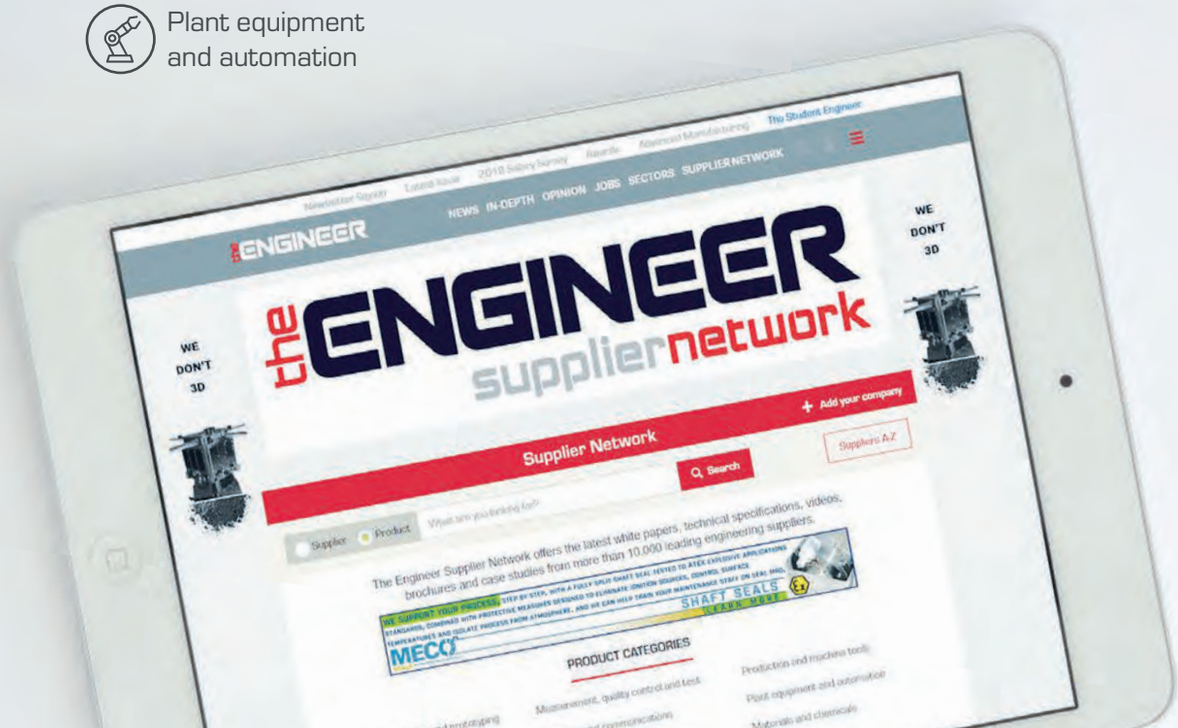

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A positive shift in perceptions

Bringing more youngsters from diverse backgrounds into engineering and smashing gender stereotypes means anyone can succeed

Last January I became the first female Muslim minister to speak at the House of Commons dispatch box. I hope this inspired other young women from minority backgrounds to aim high in careers where they might not currently feel represented.

Since then I've had the honour of leading a campaign that has strived to show young people from different backgrounds what they could achieve in engineering. The Year of Engineering has united the ambitions of the industry as a whole, making an impact that none of us could have imagined at the start of the year.

More engineering stories are being shared in schools

As the campaign began, Royal Academy of Engineering CEO Hayaatun Sillem – herself a champion of greater diversity in the sector – wrote of the Year of Engineering in this publication as "an unprecedented opportunity to bring about a step change both in perceptions of engineering and the attractiveness of engineering careers to people from all backgrounds".

Twelve months on, and following a year that has seen Government work more closely than ever with the professional institutions and the industry as a whole, we are beginning to see that change come about.

In 2018, we worked with more than 1,400 partners to deliver more than one million direct experiences of engineering – and we are seeing a tangible and positive shift in perceptions of engineering careers among young people.

Research carried out following the first six months of the campaign shows that the percentage of seven to 11-year-olds who would consider a career in engineering has risen by 36 per cent. Among girls this age we have seen a 56 per cent rise in the percentage who would consider engineering careers.

This is heartening news and testament to the commitment of an industry determined to show young people all it has to offer. Yet we all know there is a huge amount more to achieve – and for me, the true success of the campaign lies in the relationships forged, and the potential these bring for a lasting and meaningful legacy.

When government launched the Year of Engineering we always knew that we were not beginning with a blank sheet of paper – far from it. The industry has long been alive to the challenges and opportunities of transforming perceptions of engineering. Impressive and far-reaching work has been done to involve teachers and parents, and behind the scenes a wealth of research and engagement has put tackling the skills gap firmly at the top of the agenda.

Against this backdrop, the Year of Engineering was always about building on and uniting this work. It was about joining forces across industry, and bringing new partners on board who could help us reach more young people, from more diverse backgrounds.

I've been blown away by the breadth of support the campaign has received. Museums have opened pioneering new exhibitions and galleries. Apple and Facebook have invited young people behind the scenes to meet their engineers for the first time, and Siemens has trained teachers to deliver powerful lessons that smash gender stereotypes.

Campaigns like This is Engineering and Tomorrow's Engineers Week have challenged young people's perceptions of what it means to be an engineer.

We've worked with footballers, astronauts and dancers to show children the exciting places engineering could take them. YouTubers and bloggers have inspired parents to nurture their kids' creativity and curiosity at home. Through competitions, challenges and projects partners like LEGO Education, the Royal Navy and Primary Engineer have helped young people discover the enormous impact engineers have on the world around us. And we have shared myth-busting stories of engineers from all backgrounds and every corner of the UK.

Engineers design the infrastructure and technology we all use on a daily basis. They will be at the forefront of the grand challenges that the Government's Industrial Strategy is committed to tackling – from developing clean growth to helping people stay healthy and independent for longer. So it is crucial that young people with different experiences, unique viewpoints and diverse skills are part of shaping a future that works for everyone.

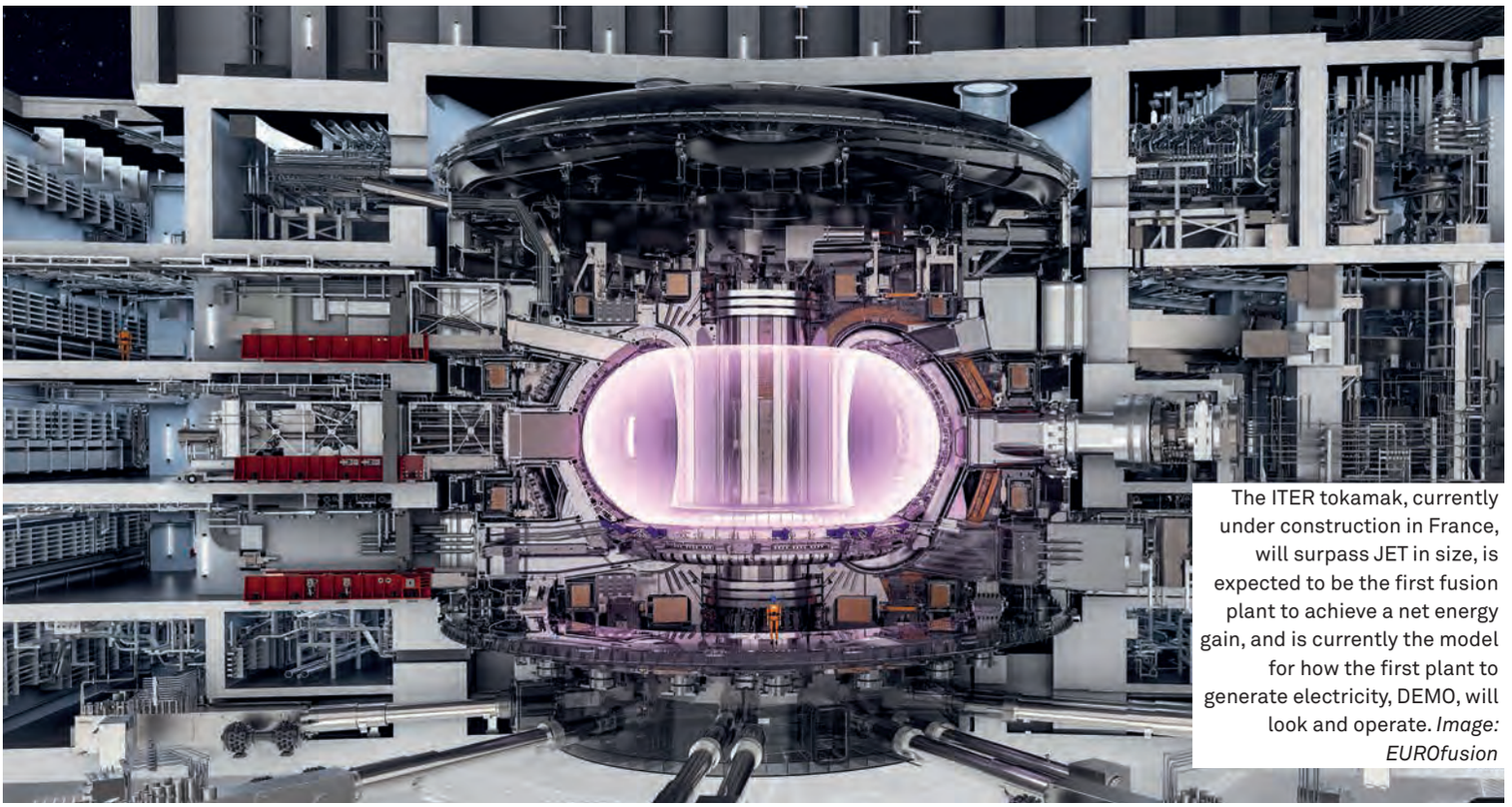
That's why the breadth of support built throughout the Year of Engineering is so fundamental, and why it brings real promise for what comes next. Connections made between schools and local employers could mean work experience and mentoring opportunities for years to come. Big names from the worlds of technology, entertainment and sport have joined forces with the STEM community for the first time on activities that could transform perceptions of engineering long into the future.

We are working across the industry and with Government to ensure these relationships can continue to grow. And as with the launch of the Year of Engineering, we won't be starting with a blank page.

The partnerships that underpin the campaign are helping us open young people's eyes to the amazing things they could achieve as engineers, and I hope that the past year is just the beginning. ■

Nusrat Ghani MP is parliamentary under-secretary of state at the Department for Transport, and minister for the Year of Engineering 2018

Beyond ITER – next



The ITER tokamak, currently under construction in France, will surpass JET in size, is expected to be the first fusion plant to achieve a net energy gain, and is currently the model for how the first plant to generate electricity, DEMO, will look and operate. *Image: EUROfusion*

As assembly of ITER begins, scientists and engineers are already looking ahead to the technologies that will take fusion a step closer to the grid. Stuart Nathan **reports**

Nuclear fusion took an important step forward last month with the beginning of the assembly phase of the experimental fusion reactor ITER at Cadarache, near Marseille. It was a humble start for a momentous event: the first completed component was transferred into the fusion machine's ultimate location. Over the next five years, increasingly complex parts will make the journey inside the concrete walls that will enclose what is planned to be the first reactor to achieve self-sustaining fusion – what's known as a "burning plasma". At this point, however, many of the components have not yet been completed.

Despite this, planning and even engineering studies have already begun on ITER's successor. This will be called DEMO, and while ITER will sustain a burning plasma, DEMO is planned to be the first real nuclear fusion power station, expected to supply electricity to a grid.

The ITER project, involving a total of 35 nations (The European Union plus Switzerland, along with the US, China, India, Japan, Russia and South Korea) is projected to take 25 years to complete once its reactor is built, and DEMO cannot start until it is finished. ITER will generate no electricity, but will investigate how to best operate a fusion reactor large enough to sustain a burning plasma – size has been one of the biggest stumbling blocks to achieving this.

So it might seem strange that engineering has begun on a project decades into the future. However, this does not look so odd if fusion is regarded as a single mega-project rather than a series of smaller projects (even though ITER is a mega-project in its own right).

It then seems only logical that potential future problems should be addressed when they become apparent, rather than when they block progress. This means that engineers today are working on projects which might be completed only after they retire or even after they die. We don't think it peculiar that mega-projects of the past – say, medieval cathedrals – spanned several lifetimes.

On the current schedule, according to the fusion roadmap published by Fusion4Europe (F4E) - the organisation which manages the European Union's contribution to nuclear fusion research and is de facto manager of ITER – the reactor is scheduled to begin its first experiments in 2025 and complete them around 2045. Construction work on DEMO could conceivably begin before 2045, and there might

steps in fusion power

be some small overlap in operation, but the roadmap envisages electricity production from DEMO by 2050 and the pace of work between 2045 and 2050 can be expected to be frenetic.

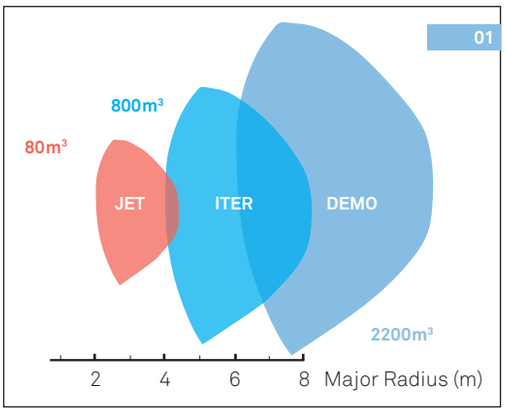
DEMO and ITER will be quite different machines, but both belong to the same general category of fusion reactor. Known as tokamaks (a Russian acronym for toroidal chamber with magnetic coils) these perform fusion in a heated plasma – a gas made up of charged particles – formed from different types of hydrogen atom.

Fusion is the process by which all stars generate energy, and they use the most abundant and simplest type of hydrogen as fuel – a single proton associated with a single electron. However, stars have enormous mass, and the colossal gravitational forces in their interior crush hydrogen to a density much greater than steel (a cubic centimetre at the centre of the sun has a mass of 160g. A cubic centimetre of steel has a mass of about 8g). Stellar fusion is a complex multistage process whereby multiple protons have to collide and fuse together, emitting other particles, to eventually form a helium nucleus of two protons and two neutrons, but the density and temperature are so great that this sequence of events is likely.

In a tokamak, gravitational crushing is replaced by magnetic fields which squeeze the plasma and different techniques are used to heat it, accelerating the particles so they overcome their electrostatic repulsion (only nuclei are fused and they all have the same positive charge) but even so, the density of the plasma is so low that the type of sequence of particle collisions that occurs in stars is hugely unlikely. To simplify the process so that only two particles need to collide in a single step, tokamaks use as fuel a mixture of deuterium (hydrogen with one proton and one neutron in the nucleus) and tritium (one proton and two neutrons).

As the Russian name implies, tokamaks are toroidal – shaped like a ring doughnut (ITER is a slightly distorted doughnut: the central hole is cylindrical, so the cross-section is D-shaped rather than circular).

The toroidal reaction chamber has three sets of magnets to provide the huge magnetic fields needed to confine hot plasma: a single large solenoid running down the middle, circular magnets surrounding the outer circumference (known as the poloidal field or PF coils), and D-shaped magnets that run up the inner wall of the central hole and down the outer wall (known as toroidal field or TF coils). These are all made from a superconducting material that needs to be cooled to a few Kelvin above absolute zero so they conduct electricity with



01 Each successive tokamak from JET to DEMO has represented a size increase

no resistance and do not reduce the overall power demand of the system. Development of such materials was another factor that has delayed successful production of more power from a fusion reactor than it took to maintain the fusion reaction – that is, to power the magnets and heat the plasma.

Both DEMO and ITER will have these essential components – toroidal vacuum chamber, central solenoid and PF and TF coils – as well as heating systems to accelerate the plasma particles, but that is the limit of their similarity. The most obvious apparent difference will be size. Although ITER is by some margin the largest tokamak ever built, DEMO will be even larger. According to Tony Donné, programme nature for EUROfusion, the European consortium for development of fusion energy and part of F4E, its linear dimensions will be some 15 per cent larger, giving its vacuum chamber a volume of 2200m³ compared with ITER's 800m³.

The research on sizing DEMO represents the first stage of engineering design on the project, and Donné has led these studies at Eindhoven University of Technology. The larger size will ensure that DEMO produces enough "excess" energy to be useful for generating electricity, Donné explained.

"ITER is intended to produce about 10 times as much energy as it takes to maintain fusion," he said. "We call the ratio of 'power out' to 'power in' the Q factor, and at the moment no fusion reactor has exceeded a Q factor of one (Q1). ITER's performance we call Q10, but because of the inefficiencies inherent in generating electricity – with heat exchange and turbines – Q10 is nowhere near enough to be useful. We need DEMO to produce about Q25, somewhere around 2 to 4GW of thermal output. Possibly full-scale commercial fusion stations will need to produce an even higher Q factor, maybe Q100."

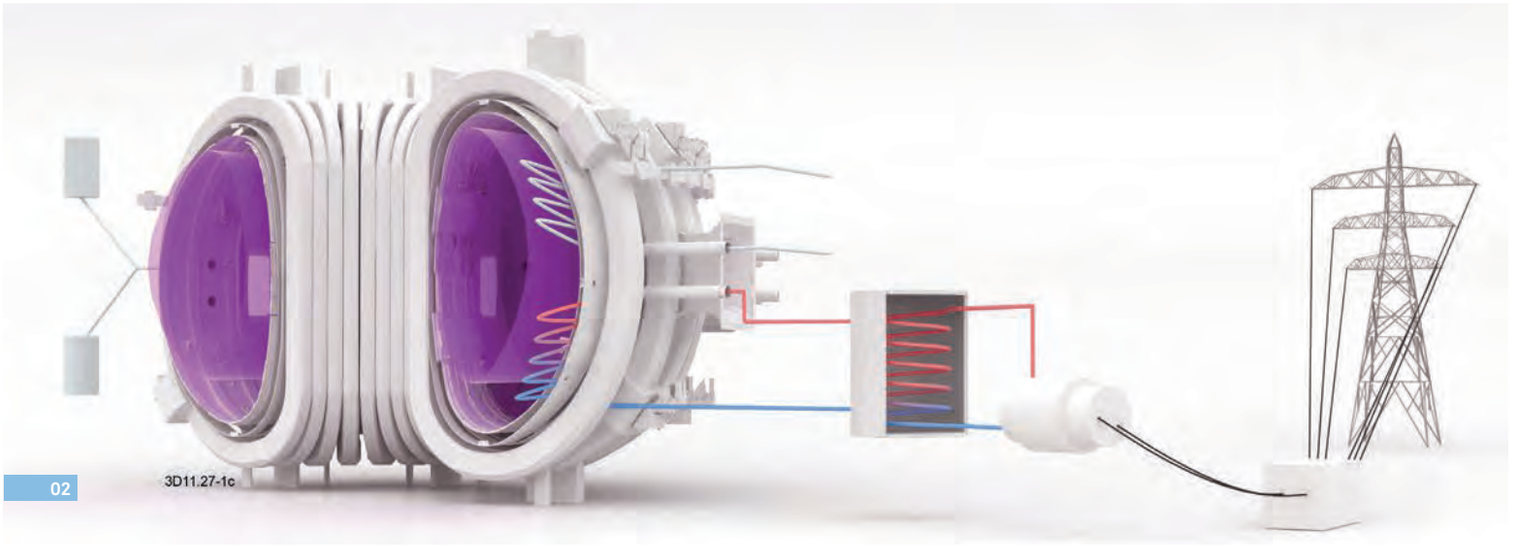
This sounds enormous when no one has achieved Q1 yet, but the potential energy content of fusion fuel is huge. The relevant equation, of course, is $E = mc^2$, where m, the mass being converted to energy, is the minute difference between the mass of a helium nucleus and the sum of the masses of a deuterium and tritium nucleus minus the single neutron emitted in the reaction, but c^2, the constant factor by which the mass is multiplied, is such an enormous number – almost 10 raised to the 17th power – that an enormous amount of energy is theoretically available for every gram of deuterium-tritium mixture.

"The extra energy output dictates the larger size, and also means that we need a plasma about 30 per cent more dense. This means there is more fuel, and therefore more fusion events, and therefore more energy produced," Donné added.

Donné's mention of heat exchange demonstrates another difference between ITER and DEMO. Unlike nuclear fission reactors, fusion reactors do not rely on cooling for safe operation. However, to generate electricity, the heat produced by fusion needs to be extracted and used to boil water to drive turbines. ITER will have only experimental small cooling systems to investigate the best ways to operate them, but DEMO will need a full-scale cooling system covering the entire inside surface of the vacuum vessel. This will form the power station's primary coolant circuit, which will be connected to steam generating systems via heat exchangers in a secondary circuit.

The vacuum vessel lining is known as a blanket, and in DEMO will have a dual purpose. As well as extracting heat, it will also have to generate tritium, and the two functions are likely to be combined. Tritium barely exists in nature; only being formed by interactions of matter with energetic cosmic rays. It currently has a few commercial uses – in making luminous markings, labelling chemicals in research to analyse reaction dynamics, tracing processes that occur in the oceans and making nuclear weapons, so it is manufactured in small quantities inside certain specialised types of nuclear fission reactor. It is toxic and radioactive. Currently, the only fusion reactor which is even capable of using tritium is the Joint European Torus (JET) at Culham in Oxfordshire, which will be the largest tokamak in the world until ITER's completion.

Nuclear fusion in ITER will require relatively large amounts of tritium, which will be imported from the current sources and handled in a dedicated plant. However, DEMO will need



commensurately larger volumes, and it will not be practical to make it using current technology. Instead, the blanket will make tritium in situ by exposing lithium to bombardment by the high-energy neutrons produced by the fusion reaction. The tritium will then be extracted from the lithium and purified.

Once again, this technology will be trialled in ITER. The blanket in the Cadarache reactor will be essentially non-functional, serving primarily as armour to protect the steel walls of the vacuum vessel. However, modules will be emplaced in the armour blanket incorporating four prospective lithium-to-tritium breeder mechanisms. The most successful of these will be used in the blanket modules that will line the entire DEMO torus.

JET, as mentioned above, is an important testbed for technologies that will be used in both ITER and DEMO, but it is not the only one. Most of the plasma devices around the world – whether or not they are capable of actual fusion – are part of the research effort. Only a few miles from ITER, another tokamak, currently known as WEST but previously called Tore-Supra, has already carried out valuable research into the use of superconducting magnets in fusion, and has more recently been testing an important component called the diverter. In the base of the reaction vessel, this is the only part of it that comes into direct contact with the fusion plasma.

In the early years of tokamak research, the entire lining, including the diverter, was generally made from graphite panels that can withstand high temperature. However, because of the tendency for the carbon in graphite to react with hydrogen and the potential hazards posed by resulting tritium-containing hydrocarbons, the diverter at Tore-Supra was replaced by a tungsten component. JET now has a tungsten diverter to go with its beryllium-covered inner surface, and ITER will also use beryllium and tungsten. The expectation is that DEMO is likely to follow suit.

The diverter is now the focus of probably the most intense DEMO-directed engineering research. "As we start to put high-energy loads into tokamaks like JET, we are beginning to see the sort of problems that we might encounter with the diverter," explained James Harrison, a researcher at Culham working on another of the centre's experimental tokamaks, Mega-Amp Spherical Tokamak (MAST), which is currently being upgraded for a new phase of research.

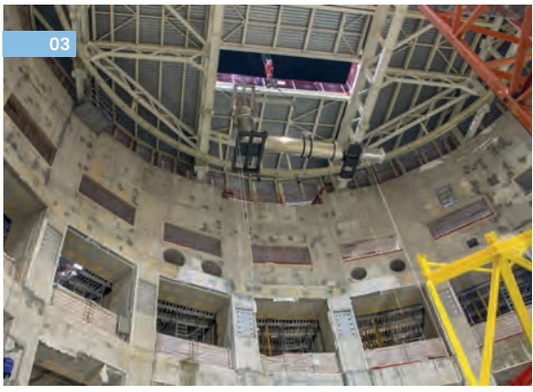
"There are two sets of issues that we know we will face: the first is the wear on the tungsten 'target panels' where the particles in the plasma impinge directly and expend their considerable energy; the second is how we extract the heat from the plasma in that region, which will provide a large proportion of the total heat that we extract from the vacuum chamber. In the first case, we want to avoid having to replace diverter panels too frequently. In the second, we want to extract the heat as efficiently as we can to transfer it to the secondary cooling circuit where it can be used to generate electricity."

For more on the various diverter research projects, see the box on page 30.

Harrison touches on one of the most important factors in the engineering planning for DEMO. ITER is proving to be a hugely costly project, although a major factor in the cost overruns has been the rise in the price of steel. The ITER tokamak is mainly composed of high-grade stainless steel, and there is even more steel in the reinforcements to the concrete buildings containing the fusion machine. But part of the rationale behind the whole fusion mega-project is to ensure that eventually, fusion energy is available to any country that wants it; and that means that methods must be found to reduce the cost. One factor works in DEMO's favour: although it may seem paradoxical, it will be less complex than ITER, which will have complex control systems to generate different plasma shapes and many sensors and diagnostic devices. DEMO, by contrast, will be designed and operated only to generate the largest possible amount of electricity. Its controls and sensors will therefore be optimised to enable that.

"It's also inevitable that we will learn a great deal from building ITER, and all that learning will help us to identify ways we can reduce costs in building the successor machine," Donné said.

Another seemingly paradoxical possible money-saving factor is that DEMO might not be such a multinational project as ITER. One of the peculiarities of the Cadarache project is that all 35 nations involved are contributing either components or expertise, and this means that manufacturing is taking place at a very large number of facilities, all of



02 All of the nuclear fusion projects to date have been leading up to a point where a tokomak reactor can be connected to heat exchangers, turbines and ultimately to the electricity generation system. *Image:EUROfusion*

03 The first component for ITER was emplaced in November

which have been specially built. The logistics of transporting these components also carries a very high cost. If, for example, only Europe was involved in DEMO, many of these costs could be eliminated, explained Donné. Moreover, he added, this could be a major factor in reducing the costs of further fusion reactors.

"We would already have the necessary production facilities and tooling and would not have to build new ones every time," he explained. "What's more, although building a fusion reactor is always going to be expensive, running it will not be. The fuel components – deuterium and lithium – are so abundant that, compared with the building cost, they are virtually free."

> "The fuel components are so abundant that, compared with the building cost, they are virtually free"
>
> Tony Donné, EUROfusion

The design of DEMO is not yet fixed. At the moment, Donné said, it is assumed that it will have similar geometry – if different proportions – to ITER, as these will have received the most study. However, other tokamak geometries are under investigation around the world, and it is not inconceivable that one of these might be chosen. Spherical tokamaks such as MAST at Culham, for example, have some advantages related to plasma stability, and have a slightly different shape.

Culinary comparisons remain useful: if ITER is a ring doughnut, spherical tokamaks are cored apples. A prospective design is expected to be chosen for DEMO around 2020. ■

Of blankets and exhausts...

Currently, the engineering research for DEMO is mainly related to two particular subsystems of importance to the electricity-generating fusion reactor: the diverter, where the fusion plasma comes into contact with the vessel, and the blanket, which generates tritium for the fusion fuel and houses the cooling circuits.

Three diverter technologies are currently under consideration. These are known as snowflake, liquid-metal and SUPER-X exhaust.

Both snowflake and SUPER-X exhaust spread the impact of the plasma over a wider area than that of the diverters used in tokamaks like JET and WEST, which formed the basis of the design that is being manufactured for ITER.

Magnets called correction coils, around the base of the reactor vessel, shape the plasma so that it contacts both edges of a trench-shaped component. The energy load is huge: more than 10MW per m^2, higher than a spacecraft re-entering Earth's atmosphere.

In the snowflake diverter, a different arrangement of correction coils shape the plasma into a snowflake-like shape, which contacts a wider diverter at several points, each of which will therefore experience less thermal load than the trench-shape diverter. This, explained EUROfusion's Tony Donné, will reduce wear on the diverter sections and increase their lifetime, while also reducing the risk of particles scraped off the diverter contaminating the plasma. As each diverter segment is made out of large, solid forgings of tungsten, this will reduce the running costs of the reactor and also make maintenance more simple.

Snowflake diverters were first investigated at the Lawrence Livermore National Laboratory in California. These experiments confirmed that heat load is reduced, the plasma is less contaminated by particles scraped off by the plasma impact and that "confinement" – the squeezing of the plasma to increase its density and increase the probability of fusion events – is unaffected. Further experiments with a snowflake diverter directed towards a DEMO-sized reactor vessel are scheduled to be carried out after an upgrade to an experimental tokamak in the Czech Republic within the next few years.

The mega-Amp spherical tokomak (MAST), also in Oxfordshire, is being upgraded to test component configurations for DEMO

The SUPER-X exhaust similarly uses magnetic fields to spread out the impact of plasma on the diverter, but rather than changing the shape of the impact zone, it increases the length of the path along which the plasma impacts the diverter. It resembles water spiralling down a conical drain. An ongoing upgrade to MAST at Culham will include the installation of correction coils which will allow different configurations of plasma exhaust to be created, and SUPER-X is one of those that will be tested. The upgrade is expected to be completed next year, and tests with the reconfigurable diverter will begin in 2020, ahead of an expected set of JET experiments using deuterium-tritium plasma, which may break the current Q-factor record.

The liquid-metal concept is slightly different. The plasma is steered into a flowing "river" of molten metal. This means that any damage caused by the plasma impact would be instantly healed.

This is a new concept, devised at the Czech Academy of Sciences and at the IAEA research establishment in Vienna, and as-yet untested. Researchers believe that lithium, tin and gallium could be possible ingredients of the liquid metal, and immersed electrodes will attract the plasma into the liquid and away from solid surfaces. A tokamak designed to test this technology is planned in Italy, but funding has not yet been confirmed (at the last review by EUROfusion, funding was delayed into the middle of the next decade).

Designs for blanket technologies are somewhat more advanced than those for diverters. Four candidate technologies are being developed for testing inside ITER: two in Europe, one in China and one in India. All the technologies take a different approach. Physics is helpfully agnostic: it doesn't matter what form lithium is in; as long as a neutron can collide with a lithium atom, it will be transmuted into a tritium atom.

All the candidates use helium as a coolant. One of the two European technologies uses a liquid eutectic alloy of lithium and lead, while the other uses 'pebbles' made of a ceramic containing both lithium and a compound containing beryllium and titanium: beryllium is useful because it has the property of multiplying neutrons.

The Chinese candidate technology is also a helium-cooled system using solid pebbles, but the modules will contain two distinct pebble beds, one containing lithium silicate and the other containing a beryllium-rich ceramic. This technology may also be tested in a planned Chinese experimental tokamak, China Fusion Engineering Test Reactor (CFETR) which is usually described by the fusion community as being "DEMO-like" in configuration and whose construction is currently scheduled for the 2020s.

The Indian technology, called a lithium-lead ceramic breeder, uses both a lithium-lead liquid eutectic and a lithium-containing ceramic: the liquid metal cools the tritium breeding zone, and helium cools the plasma-facing wall of the blanket module. Originally developed in collaboration with Russian researchers, this technology is believed to have a high tritium breeding ratio and to enable efficient heat-to-electricity conversion.

Breeder blanket concepts are currently expected to be tested fairly late in ITER's experimental schedule, possibly even late in the 2020s or early 2030s.

AR offers new sea view

BAE Systems is exploring new technologies that will change how naval personnel interact with onboard combat systems, from augmented reality to artificial intelligence.
Andrew Wade reports

Warfare at sea is a complex affair. Today's naval vessels are often home to several hundred crew, operating intricate weapons systems and sensor arrays that generate huge amounts of data. Tools such as sonar and radar provide situational awareness, which in turn feeds intelligence that command can act upon using the ship's weapons. Together, these constituent parts form the combat management system, the various operational nodes across the ship all sharing data, presenting officers with a holistic picture of complex battle scenarios.

Now, UK defence giant BAE Systems is aiming to fundamentally change how watch officers interact with combat management systems.

The watch officer on the bridge of warships is the person ultimately responsible for the safety of the vessel. While on the bridge, this officer receives audio information from personnel in the operations room, deep within the heart of the ship. An officer might ask for positional, heading or identification data relating to a specific object or vessel in his or her field of view. This will be duly provided by the ops team, the officer getting information to the ear that should match up to what the eye can actually see.

"It's a tried and trusted method that the Navy developed over the years, and it works very, very well," said Frank Cotton, BAE's head of technology for naval combat systems. "But it's not hugely efficient, and the bridge watch officer is quite often overloaded when he can see lots of things out of the window and he's trying to tie them up – via voice – with a set of operators in the bowels of the ship."

Cotton was speaking at a recent media briefing in London, where BAE provided details on a new augmented reality (AR) solution currently under development, as well as a demonstration of the technology in action. The company is developing a set of lightweight AR glasses that bypass the need for objects in the field of view to be confirmed by the ops team. According to BAE, it could be ready for use by the Royal Navy within 12 months.

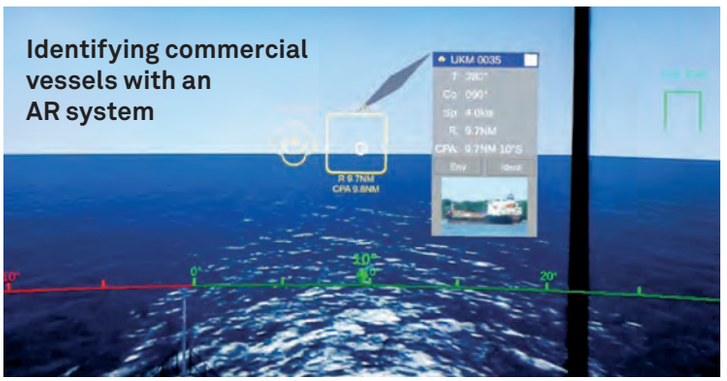
"In many ways, augmented reality – in an operational sense – has been a solution looking for a problem," said Cotton. "Finding a safe and secure way of enabling the technology to add value at a reasonable cost is the challenge we picked up. The use case we're looking at is for a bridge watch officer."

Based on the same system found in the Striker II helmet-mounted display (HMD) used by Typhoon fighter pilots, the AR glasses deliver information on ships and aircraft direct to the officer, who also has the ability to interact with this data via a simple clicker. BAE is currently

Augmented reality could improve the Navy's operational efficiency

“He can display video of what the object is”

Frank Cotton, BAE Systems



Identifying commercial vessels with an AR system

using Microsoft’s HoloLens AR headset platform to develop the system, but the plan is to scale the technology down to a more lightweight piece of hardware that can be used untethered.

“Rather than just giving (the officer) a headset with comms on it, let’s give him a set of lightweight augmented reality glasses,” said Cotton. “So that when he looks out the window at a real-world object, instead of having to ask the operators whether or not what he’s seeing is friendly or hostile, whether or not it’s an inflatable boat or a fishing vessel, he can use his glasses and a clicker to interact with the combat management system directly.

“He can display video of what the object is, he can get classification data and if what he’s seeing doesn’t match the data that the system is telling him, he’s got the ability to change that data. If he suspects that something is potentially a hazard, he can flag that in the system directly.”

According to BAE, the Navy is hoping to trial the technology in operation as early as next year, but the system will need to be refined before it is combat-ready. HoloLens is not designed to operate in bright sunlight or on a moving platform such as a ship in a swell. Incorporating elements of the Striker II electronics system into a scaled-down AR package should help address this. BAE says a prototype should be ready in the first half of 2019, with operational testing in the second half of the year. Cotton believes other areas of the ship could also benefit if the technology proves successful.

“Of course, once we’ve got the lightweight glasses in operation here (on the bridge), the potential to use them in different applications across the ship is massive,” he said.

Another area that BAE is targeting for change is the operations room itself. The hardware and software used there is functional and reliable, but much of it is decades old and ripe for a makeover. According to Cotton, the ops room will see evolution rather than revolution, with different methods of human computer interaction (HCI) trialled and introduced incrementally.

“So, virtual reality, augmented reality, touch control, gesture control, voice activation – these are the types of technology we’re exploring,” he said. “Not all of them will be appropriate for a Royal Navy operations room, but some of them will be.”

AI is another technology the company is seeking to integrate. Some of the potential use cases for AI include neural networks that can monitor ship movement and flag unusual patterns of behaviour, and target prioritisation that can maximise the ship’s chances of victory by engaging threats in a specific order.

Elsewhere, third parties, including SMEs and academic institutions, are being invited to develop software that could plug into BAE’s combat management system and harness ship data. These apps would operate in a ‘sandbox’ environment where they could add value for the operations team without interfering with the function or integrity of the overall combat system. Where previously, adding new software could take months or even years before approval, the sandbox approach would enable a much more streamlined integration of new technology.

“It needs to be cheaper and faster to introduce new capability than it is today,” said Cotton. “Typically, it can take 18 months plus to get a new capability onboard a ship. What we’re looking for is to define a baseline system that we can bring new capability in much faster, and our model is actually an iPad and the App Store. ■

A different kind of space race

Raytheon's vice president for Space Systems says competition is fierce and more complex than ever when it comes to launch development. Stuart Nathan reports

The space race is on again. But this time it's different. That, at least, is the perception of many industry observers. There is certainly competition in space. "But is it a race? That's less clear," says Wallis Laughrey, speaking to *The Engineer* during a conference on the space industry in the palatial surroundings of the Royal Aeronautical Society in Knightsbridge.

"In the classic space race, or what we might call the first space race, the situation was very clear," Laughrey explained. "The competitors were well defined: the US and Soviet Union. And so were the goals. The first finishing line was to get a spacecraft into orbit – the Soviet Union won that one. The second was to maintain life in orbit – the Soviets won again. Then to get a man into orbit – same result. The ultimate finishing line was to land humans on the moon – in this case, the US won."

But now, the race is less defined. Other countries are involved along with the US and Russia: the European Union, China and India being the most important. And there are also commercial players: Space X, Blue Origin and Virgin Galactic among them. "And they are striving towards different goals, some of which are commercial rather than linked to specific feats. Back in the 1960s, it was not apparent that there would be any commercial business around space; it was such an expensive game that only nation states could afford to play."

Despite this, in the free market economy of the 1950s and 1960s US, commercial businesses were deeply involved in the space race and Raytheon was one of the first to be involved, building launchers and other hardware for some of the first American missions. Indeed, the main site of Raytheon's space business, just outside LA, is the middle of a cluster of companies that were involved in those early flights, and remain involved today.

"As you fly into LAX, you see the Boeing satellite plant, which is the biggest satellite factory in the world. Northrop Grumman is a mile down the road, and we are six blocks south. Right in the middle is the Air Force Space and Missile System Centre where they acquire GPS signals."

But the reality is that space is now more complex than ever, Laughrey stressed. "The linearity is different now, so to speak. There are a whole lot of different races and not everybody is involved in all of them. The launcher race is a great example: you have Space X, Blue Origin, the United Launch Alliance, Ariane, the Russian Soyuz business and NASA's own Space Launch System, which it is developing – and in the case of ULA and NASA, they contract out to commercial companies to build their hardware like they used to in the old days.

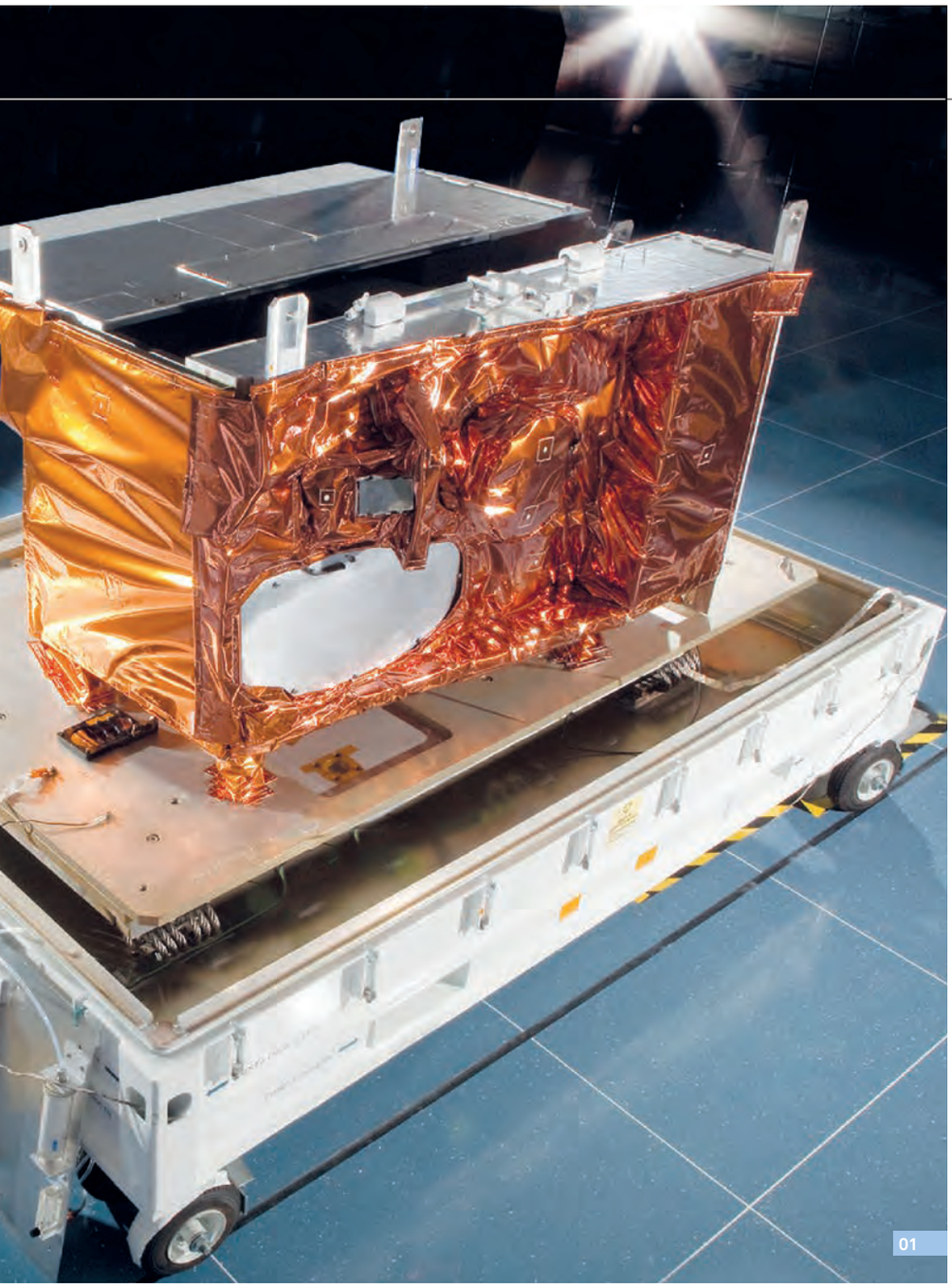
"But the launcher companies are not involved in the races to build the hardware that actually sits in orbit. So those are distinct competitions, and that's not a situation that existed in the first space race. And again, when it comes to payload there are distinct races.

"There is competition over low Earth orbit technologies. There is competition over big geosynchronous telecommunication satellites. There is competition in Earth observation for commercial purposes, like monitoring shipping. This is much more like competition in any other commercial market with various niches: you could compare it to competition in the automotive sector with small cars, people carriers and SUVs. It's a space race, but it's not like the space race that was part of the Cold War."

Raytheon's current space business is centred on its expertise in payload, Laughrey said. "We have a portfolio of technology that isn't really specific to any particular category of payload. Much of it comes out of our airborne side, and takes in things like focal plane arrays, mirror

01 Raytheon's Visible Infrared Imaging Radiometer Suite (VIIRS) brings to bear the latest space-based environmental sensing technology to provide significantly improved weather and climate forecasting models

02 Raytheon's SeaRAM Anti-Ship Missile Defence System



technologies and associated electronics. It's a toolbox of stuff that is applicable in some way to a very wide range of missions."

Laughrey himself comes out of the airborne side. His career started in the US Air Force. "But I grew up in the space business. I was on the space side in the air force, and then I worked within Northrop, and from there I moved to Raytheon."

Raytheon is most closely associated with the defence sector, and it's in defence-related applications that Laughrey is seeing the most activity for his company. "The area where we are seeing the most interest is in missile warning and missile defence, which is in response to the proliferation of advanced missiles being developed in many nations. And we're seeing a lot of interest in the international marketplace for sovereign capability as well.

"Technologies that are relevant here include things like persistent overhead infrared. But although we are seeing this interest in sovereign capability, that isn't just about missile activity. There is a real recognition that space is the front end for all sorts of advanced technology and it ends up birthing a lot of things across a huge range of sectors including, importantly, medical technology. That recognition is something we are seeing particularly in the UK, and it's just brilliant."

> "We are at a really exciting point where people are investigating so many things and it isn't possible to say where it will end up"

One area that Laughrey says is particularly interesting at the moment it space telescopes. This is partly because the long-term mission to replace the now-ageing Hubble orbital telescope is coming to an end with the completion and imminent launch of the James Webb space telescope (JWST), a much larger and more complex instrument that will sit at a distant point in space and study the colder parts of the universe for clues about its origins. The forward-looking and long-term nature of scientific space missions means that even before the launch of JWST, NASA is starting to look into the future at what the next stage in its universe-observation activities might be.

"They have already started studies into what they want to look for with future generations of space telescope. We have a technology we have been investing in for 30 years called rotating synthetic aperture, and that is of interest because it allows you to effectively collect light from whatever part of the electromagnetic spectrum you are studying as though you had a much larger collector than you actually have.

"JWST has a much larger mirror than Hubble. But it's still extra weight, and of course in the space business you want to reduce launch weight as much as you can. So although researchers want to be able to collect more light, they want to be able to do it with smaller and lighter equipment. Rotating synthetic aperture allows you to get a significantly larger light collecting area: you rotate your light-gathering equipment across the whole scene and integrate the data into a single large image, but you do that with a low mass to orbit.

"The National Academy of Sciences is doing studies into four technologies for what they think the next great space observatory might be, and rotating synthetic aperture could be relevant to three out of those four."

In the febrile nature of the space sector at the moment, it is unclear whether such technology will have applications in the private sector, but Laughrey points to companies like Planetary Resources, which is investing in space telescopes to prospect for deep-space bodies that could be investigated for mineral mining.

"We are at a really exciting point where people are investigating so many things and it isn't really possible at the moment to say where it will end up. It's almost like the aerospace sector at the beginning of the 20th century where it wasn't apparent for quite a long time whether the flight would have any commercial spin-offs, and what those spin-offs might be. People are making serendipitous discoveries because they are taking a chance.

"One good example is something that happened at NASA Ames. Some years ago they had excess launch capacity on a lunar reconnaissance orbiter mission, so they asked if anybody had any ideas what they could do with it. Northrop Grumman came up with the idea to launch a small probe from the orbiter into a crater on the moon because there was the idea that there might be water under its surface. No one was really sure what they would find, but they did locate water. We don't know yet what the value of that might be, or if it has any commercial value, but I think the next decades are going to be full of us making really amazing discoveries, and at the moment, we can only guess at their significance." ■

Aston Martin Vantage: beauty and the beast

An all-new design brings the baby Aston Martin bang up to date, writes Chris Pickering

The Aston Martin Vantage is very driver-focused

There's something unmistakably Aston Martin about the new Vantage. It has the British marque's characteristic blend of aggression and sophistication – like a cage fighter squeezed into a Savile Row suit. But in other respects it's quite different to the cars that have gone before it, and indeed the rest of the current range.

While the previous Aston Martin line-up sometimes felt a bit like a set of Russian dolls – each one an incrementally different take on the same theme – there is a concerted effort to give every model its own distinct character. For the Vantage, this remit is very clear: It is intended to be the most driver-focused car in the range; not necessarily the fastest or most powerful, but the one that delivers the purest sense of connection and involvement.

That's not to say there isn't a certain amount of commonality. Under the steel panels you'll find a bonded extruded aluminium structure that's loosely based on that of its bigger brother, the DB11. The front section of the chassis – roughly as far back as the windscreen – is structurally identical (although the tuneable components, such as suspension bushes and engine mounts, are unique to the Vantage). From that point rearwards, virtually everything is bespoke. In fact, Aston Martin says around 70 per cent of the structure is new.

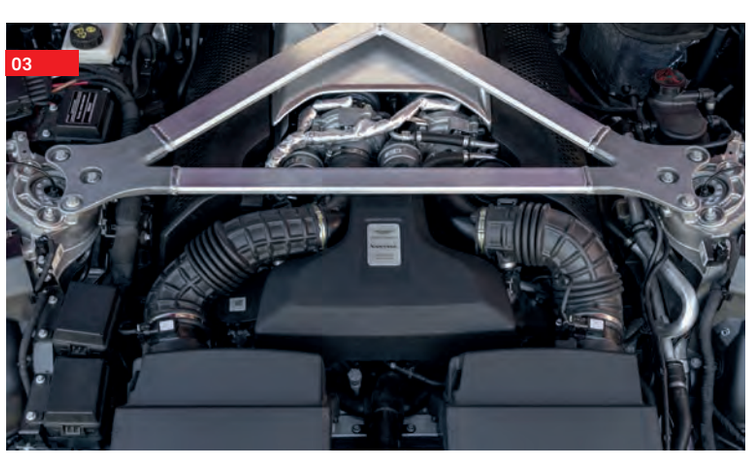
It also marks a significant departure from the old Vantage. Whereas the previous chassis used lots of straight extrusions, the new platform relies heavily on castings that can be shaped to maximise the available space. That's good news for passengers and their luggage – at 350 litres, the boot is now larger than that of a Ford Focus – but it also gives the engineers room to accommodate things like larger wheels and a bigger fuel tank.

If anything, the new Vantage should consume less super unleaded than its predecessor. Gone is the old 4.7-litre naturally aspirated V8, replaced by a 4-litre twin turbocharged unit sourced from Daimler. While the base engine is essentially the same as that found in the Mercedes-AMG GT (and indeed the go-faster versions of various Mercedes saloons), the rest is all Aston Martin.

Prod the starter button and the V8 crackles into life. It instantly sounds different to the Mercedes-AMG versions of the engine, largely thanks to the bespoke intake and exhaust systems, tuned to deliver more mid and high-frequency content. What this translates to is a sound that's more sophisticated than the brawny muscle car burble of the AMG GT, yet every bit as potent.

The performance is in a different league to the old V8 Vantage, with 503bhp at 6,000rpm and (more significantly) 685Nm of torque from just 2,000rpm. True, it's not McLaren 570S or Porsche 911 Turbo fast, but this is just the start for the new Vantage, with strong hints that there will be faster versions to come. More to the point, it's delivered in one vast sweep, right up to the 7,000rpm red line, with pin sharp responses and a total absence of turbo lag.

Along with its AMG cousins, this is perhaps the one turbocharged engine out there that could genuinely pass for a naturally aspirated unit. The 'hot vee' layout – placing the turbochargers between the cylinder banks so they're closer to the combustion chambers – certainly helps, but no other manufacturer has done it with quite the same degree of success.



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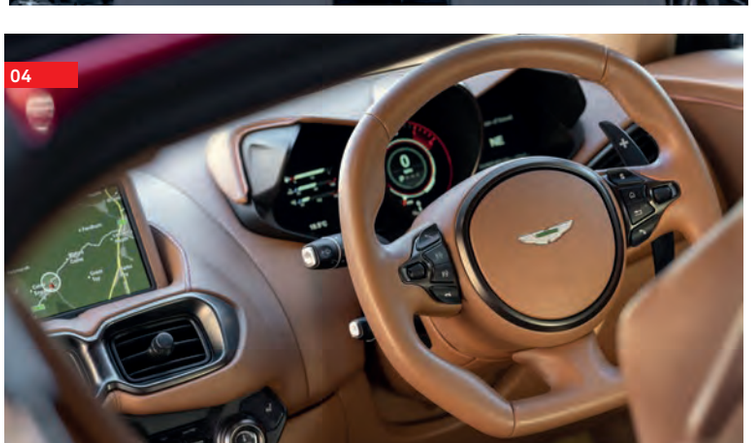

04

01 The Vantage is very agile

02 The driving position is spot-on

03 The engine gives off a sophisticated sound

04 The car has a quality infotainment system

Sharper dynamics

It only takes a matter of yards to appreciate the work that's gone into pitching the Vantage towards the more driver-focused end of the spectrum.

In the softest of its three chassis modes, the body control feels similar to the DB11 at its firmest. There's a heightened sense of connection too, with cat-like reflexes, which belie the Vantage's comparatively hefty kerbweight (quoted as 1,530kg dry).

Fuel efficiency targets mean that Aston Martin has finally caved in and adopted electric power-assisted steering (EPAS) in place of the old hydraulic system. It's pleasingly direct, with just the right rate of response to make the Vantage feel agile rather than nervous. As with most EPAS systems, however, the one area where it struggles is feel. In fairness, there is some genuine feedback to be had, but only once you're leaning on the chassis quite hard. It certainly doesn't chat away to you like the old Vantage.

When it comes to point-to-point pace, however, the new car deals a crushing blow to its predecessor. Even on cold, damp B-roads the bespoke Pirelli P Zero tyres do a remarkable job of handling the V8's mammoth torque. It helps that the new structure is around 20 per cent stiffer than the old one, while the rear subframe is now mounted direct to chassis (without the deformable bushes used in the DB11). The downside to this is that there is a touch more road noise than you might expect, but that's arguably in-line with the Vantage's remit as a sports car rather than a luxury GT.

Occasionally you can sense the electronically controlled differential making minute adjustments under power, but it's never intrusive. This works hand-in-hand with dynamic stability control (DSC) and a brake-based torque vectoring system to make the Vantage feel incredibly approachable for a 503bhp rear-wheel drive sports car. The more aggressive chassis modes slacken the safety net somewhat and for those feeling brave there is also the option of disabling the DSC completely.

Along with turbocharging and EPAS, another change that had the potential to upset the purists was the decision to use an automatic gearbox. Here, however, the news is good. Not just because there will soon be a proper manual version available, but also because the standard ZF 8-speed auto is light years ahead of the old robotised Sportshift unit. Being a torque converter design it provides smooth progress in fully automatic mode, but it also does a very passable impression of a dual clutch transmission (DCT) when you want to change gear yourself. The shifts are quick and crisp, the column-mounted paddles have a wonderfully tactile feel and the blipped downchanges certainly sound the part.

The cabin also adds to the experience. The driving position is spot-on, while the Daimler-sourced infotainment system and the virtual instrument cluster feel like they've skipped several generations on from the old Vantage. Build quality is now right up there with the Germans and the materials are generally very good too, although a couple of the plastic parts do seem a little stingy given the Aston's £120,900 starting price.

Overall, then, it's hard to find fault with the new Vantage. It's a capable and entertaining sports car. And while it's unashamedly driver-focused there is still enough comfort and refinement for longer trips. More importantly, cars like the Vantage and the DB11 show that Aston Martin is making good on its promise to strengthen the core GT and sports car models, as well as forging on with its ambitious plans to tackle new sectors. If this car is anything to go by, the future at Aston Martin looks very bright indeed. ■

Supplier: TWI

Tests to ensure integrity of vital mooring chains

Acoustic emission technology deployed to maintain chains in offshore energy industry

Mooring chains are critical to floating structures

A new project led by TWI is using acoustic emission technology to address the structural integrity of mooring chains in the offshore energy sector.

Whether it is used to secure an offshore wind turbine or an oil and gas drilling rig, the mooring chain is one of a floating structure's most critical components because it is used to anchor it to the seabed and is deployed in very deep water.

As such, maintaining and safeguarding the structural integrity of mooring chains is a high priority. The effects of incremental or immediate damage could result in catastrophic failure of the asset.

One of the ways in which industry is currently tackling how mooring chain efficacy can be improved is with designs that utilise larger links or higher-strength materials.

However, in parallel, there is a need for technologies that can predict the early stages of damage in mooring chains and shackles.

Based on many years of research and development into enhancing the lifespan and performance of mooring chains, TWI has identified that new structural health monitoring (SHM) techniques, specifically deploying acoustic emission, would be ideally suited to addressing the issue.

As a result, it is launching a joint industry project, Structural Health Monitoring of Mooring Chains Using Acoustic Emission, which will have its inaugural meeting in early 2019.

The project will develop acoustic emission testing (AET) procedures that will be qualified on full-scale chain tensile and fatigue tests at a realistic loading frequency, backed by extensive material properties characterisation.

The testing will be conducted on TWI's world-class mechanical test rig facility, both in and out of seawater, and the project will establish reliable AET data for a more fundamental understanding of the factors affecting chain failure.

Furthermore, the AET procedures will be used as a tool in mechanical tests to gather information which is not currently available, regarding crack initiation and the growth in chain links.

Angela Angulo, team manager for condition and structural health monitoring at TWI, said: "TWI has expertise in developing AET procedures for a variety of SHM applications, with particular emphasis on software algorithms for extracting SHM information from noisy acoustic emission data.

"Applications have included experiments in collecting AE data during in-seawater chain tensile and fatigue tests, the methods from which will be formalised into this project as full AET procedures, qualified in accordance with guidelines set down by the European Network for Inspection Qualification." ■

Supplier: Nikon

Nikon's Laser Radar revamps measurement for automotive OEM

A large automotive OEM has deployed Nikon's Laser Radar measurement technology on its production line, improving inline and offline measurement and boosting overall efficiency on the factory floor.

The OEM was insistent upon adopting optical inspection, moving away from tactile probing. Additionally, it wanted to remove the bottleneck of the offline coordinate-measuring machine (CMM) room and effect a paradigm shift that could lead to breakthrough improvements. The ultimate goal was better metrology performance, yielding faster feedback of data during the initial phases, before a new vehicle entered full production.

For the inline measurement, robot-mounted Laser Radars are installed either side of the production line, measuring holes, slots, studs, surface points and edges as the vehicle chassis progresses. Surface points are measured in under 0.5 seconds, with other features taking less than three seconds.

The ability to provide accurate, absolute inline measurements during pre-production not only allowed the OEM to exceed its goal of bodies in tolerance by start of production, but also helped to significantly reduce the pre-production time.

The number of features measured inline has gone from 190 (relative measurements) to 1,500 (absolute measurements), achieved through a sampling measurement strategy and automatic bypass stations, resulting in precise process decisions down to 0.1mm.

For offline measurement, Laser Radars on lift and rotate cells were installed to perform component, sub-assembly and full body checks in the CMM room. Multiple turntables can be tended from a single Laser Radar, reducing measurement dead-time while loading or changing fixtures.

According to Nikon, this approach optimises productivity and reduces traditional CMM room bottlenecks. ■

The Laser Radar is used on production lines

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Modular resistor supports drive towards reliable electric braking

Increased control, energy efficiency and simplicity among benefits offered by EVT system Supplier: Cressall Resistors

Cressall Resistors has launched the EVT, a new advanced water-cooled modular resistor developed specifically for rheostatic braking in smaller hybrid and electric vehicles.

The EVT has a power rating of 10kW and a reduced pressure drop, allowing it to better tackle the automotive market. For example, in hybrid and pure electric vehicles, energy is usually discharged during braking on batteries. This is not always effective as batteries could be full, and also it may not be viable in instances where drivers need to emergency-brake.

According to Cressall, a resistor is the most size- and cost-effective brake that can be added to a vehicle, and will ensure that any dissipated energy is safely and efficiently redirected. Cooling in the EVT is achieved by pumping cold water into one end of the system. The water then absorbs the heat, which is pumped out through a radiator.

"Electric braking via an EVT system provides a number of benefits over mechanical braking, including increased control, higher reliability, mechanical simplicity and weight saving," said Simone Bruckner, managing director of Cressall Resistors.

The EVT aims to improve energy efficiency

"Additionally, any excess energy can be used to support the vehicle's cabin heating, helping to increase overall energy efficiency.

"Air cooling is not efficient in automotive applications. With electric and hybrid car sales reaching a record high in September 2018, this trend is set to continue, meaning a more efficient way to dissipate low amounts of energy is important."

According to regulations, vehicles must have three independent braking systems for safety reasons.

In a conventional car, these are dual-circuit hydraulic brakes, plus a handbrake. For electric cars, if braking systems are not regenerative, these supposedly green vehicles will waste a lot of energy.

As the number of electric cars on the roads continues to rise, using a water-cooled modular resistor can help vehicles remain as green as their intentions. ■

UK-led team hails graphene smart clothing breakthrough

Study promises more advanced wearable electronics Supplier: Exeter University

Graphene is just one atom thick

Researchers at Exeter University are leading the development of a pioneering technique that enables graphene fibres to be woven into clothing in order to create 'smart' textiles.

So-called wearable electronics are currently made by essentially gluing devices to fabrics, which can mean they are too rigid and are susceptible to malfunctioning.

The new research – carried out in collaboration with experts from the universities of Aveiro and Lisbon in Portugal, and CenTexBel in Belgium – integrates electronic devices into the fabric of the material, opening up a host of potential applications in everyday clothing and healthcare monitoring.

At just one atom thick, graphene is the thinnest substance capable of conducting electricity. It is very flexible and is one of the strongest known materials.

The race has been on for scientists and engineers to adapt graphene for use in wearable electronic devices in recent years.

The latest research, published in the scientific journal Flexible Electronics, used existing polypropylene fibres – typically used in a host of commercial applications in the textile industry – to attach the new, graphene-based electronic fibres to create touch-sensor and light-emitting devices. The technique means that the fabrics can incorporate truly wearable displays without the need for electrodes, wires or additional materials.

Professor Saverio Russo, co-author and from Exeter University's physics department, said: "The incorporation of electronic devices on fabrics is something that scientists have tried to produce for a number of years, and is a truly game-changing advancement for modern technology."

Dr Ana Neves, co-author and also from Exeter's engineering department, added: "The key to this new technique is that the textile fibres are flexible, comfortable and light, while being durable enough to cope with the demands of modern life." ■

January 1940 Warlike matters

Conflict dominated *The Engineer*'s aeronautical review

The Engineer's annual review of technological advances took a melancholic turn in January 1940 when it became clear that aeronautical innovation would be driven by conflict.

Four months had elapsed since Britain and France declared war on Germany, yet it was becoming apparent that fighters and bombers would be more pivotal to the outcome of the Second World War than the First World War.

As noted in 1940, great strides had been made to "knit the world together by rapid air transport" in the 36 years since the Wrights first flew, but military advances continued to outpace those in the civilian sector.

"It is always so with new inventions," *The Engineer* wrote with resignation. "Mankind, still in the youth of his civilisation, is quick to seize on a chance to design yet another tool for attack on his neighbours, and only gradually is the peaceful use of the device discovered and developed."

The author couldn't have predicted that by July 1940, an entirely new theatre of war would have opened up in the skies above England that would be followed by a devastating – and strategically futile – bombing campaign by the Luftwaffe. That said, our correspondent went on to exercise a degree of prescience in assessing what might be required to defend our shores.

With only a narrow window through which to observe the war, *The Engineer* noted that results were going against Germany with "certainly no less than 25, and maybe nearer 50 per cent" losses for the Luftwaffe.

"The formations concerned in the fighting so far have all been small, and the question may be asked whether the bombers would find greater security if they came in large formations," *The Engineer* wrote.

Bombers had range but they lacked the speed and manoeuvrability to outrun or out-manoeuvre fighters sent to repel attacks, but that didn't stop *The Engineer* observing that "the initiative is always with the attacker, and until one can be quite sure that every possible mode of attack has been measured up and allowed for it is not possible to say that the defence is complete".

Our correspondent said: "At present the nature of the attack depends on the speeds and manoeuvring powers attainable today, but it is necessary when planning the defence to look far ahead. The speeds are now well over 300mph and machines have even been driven at over 400mph; it must be expected that they will rise still further, though to pass Nature's steep barrier at the velocity of sound will take much more knowledge than anyone in the world now possesses.

"Fortunately, there is good reason to expect that fighting aircraft will always have a comfortable margin of speed over contemporary bombers."

Bomber designers were, said *The Engineer*, continually trying to push the performance of their aircraft in terms of speed, but realised that the omission of guns would leave their lumbering aircraft vulnerable to attack.

"As a gun platform the fighter is a much better proposition," our correspondent noted. "Better as regards accuracy, and better as regards volume of fire. No doubt it is due in part to these causes that the casualty list among German aeroplanes has been so considerable."

As if predicting a significant operational failing of the Luftwaffe during the Battle of Britain, our correspondent observed that bomber formations need the protection of accompanying fighters, but "the latter lack the range of the large bomber, and the home-based defensive fighters are vastly better circumstanced. This is to the good as it strengthens the defence".

"On the whole, therefore, it can be said that the defence in the air is now exceedingly powerful and is likely to grow still stronger," said *The Engineer*. "Defence from the ground is also becoming increasingly effective and is fully keeping pace with technical improvements in aircraft, whilst the arrival of hostile aircraft in huge formations would naturally delight the aircraft gunner's professional eye."

Our reporter said: "It is sad that our aeronautical record of 1939 should have to relate to warlike matters entirely. But the requirements of public safety make it undesirable that the scientific advances of the year, important as they are and interesting as they would be to our readers, should be disclosed at this time. We hope for better fortune when 'Aeronautics in 1940' comes to be written." **JF**

Word of the issue

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

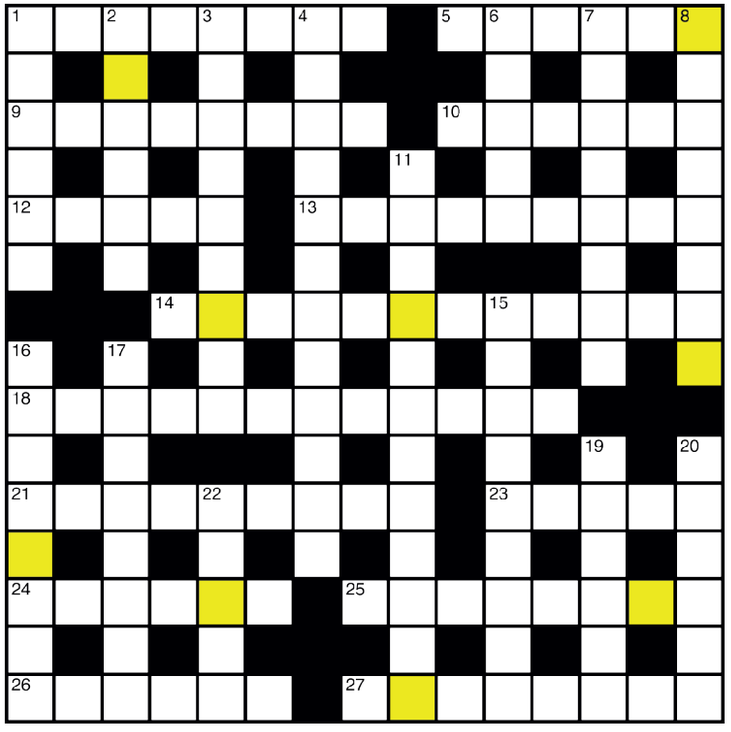
As a word, 'screw' has been used in its current engineering context since around 1400. Yet the etymology can be traced to much earlier. Famously, the idea is often associated with the Archimedes Screw, a system for raising water said to have been the idea of the Greek inventor. The term came to England from the French escroue, itself from a root which gave Gallo-Roman scroba and Germanic scruva.

The root is the Proto-Indo-European verb sker which simply means 'to cut'. Here, the modern sense of 'turn' or even 'pressure' may also be seen to refer to the screw cutting its own hole into which it fits – a woodscrew, for example, does just that.

Some slang uses of screw are quite easy to spot. To extract something by means of pressure is derived from the days when torture was employed, as in the use of thumbscrews. And to have a screw loose suggests people are coming apart – as would the majority of engineering projects without the simple screw.

Bigpicture

The Tamina Canyon Crossing in Switzerland has received the Supreme Award for Structural Engineering Excellence at the Structural Awards 2018. According to the judges, the bridge – which crosses the Tamina canyon 200m above a gorge – represents an "outstanding engineering solution". Photo: © TBA St Gallen



Prizecrossword

When completed rearrange the highlighted squares to spell out a state of deterioration in metals. The first correct answer received will win a £20 Amazon voucher. Email your answer to **jon.excell@centaur.co.uk**

Across

1 Consider in a comprehensive way (8)
5 Having a pH of less than 7 (6)
9 Cut pile fabric with vertical ribs (8)
10 Crew of workers selected for a particular task (6)
12 Minute hairlike projections (5)
13 Light that sits on a piece of furniture (5,4)
14 Digital calculator of medium size (12)
18 Thermometer consisting of two wires of different metals (12)
21 Cover with zinc (9)
23 Organisation of employees (5)
24 Clothing of a distinctive style (6)
25 Industrial plant for purifying a crude substance (8)
26 Flammable colourless gaseous alkene (6)
27 Discharging (5,3)

Down

1 Small recess opening off a larger room (6)
2 Euphemism for 'fat' (6)
3 Metallic element found primarily in bauxite (9)
4 Accidental electrical contact (5,7)
6 Soft, thin, light fabric with a crinkled surface (5)
7 Adornment of shiny material used to decorate clothing (8)
8 Instrument for measuring the distance between two points (8)
11 The lowest temperature theoretically attainable (8,4)
15 The act of contaminating (9)
16 Exist in a changeless situation (8)
17 Disengage a pedal on a machine (8)
19 Evidencing the possession of inside information (4,2)
20 Never except when (4,2)
22 Protective garment tied about the waist (5)

November's highlighted solution: **Escapement**. Winner: **Bachrun Mason**

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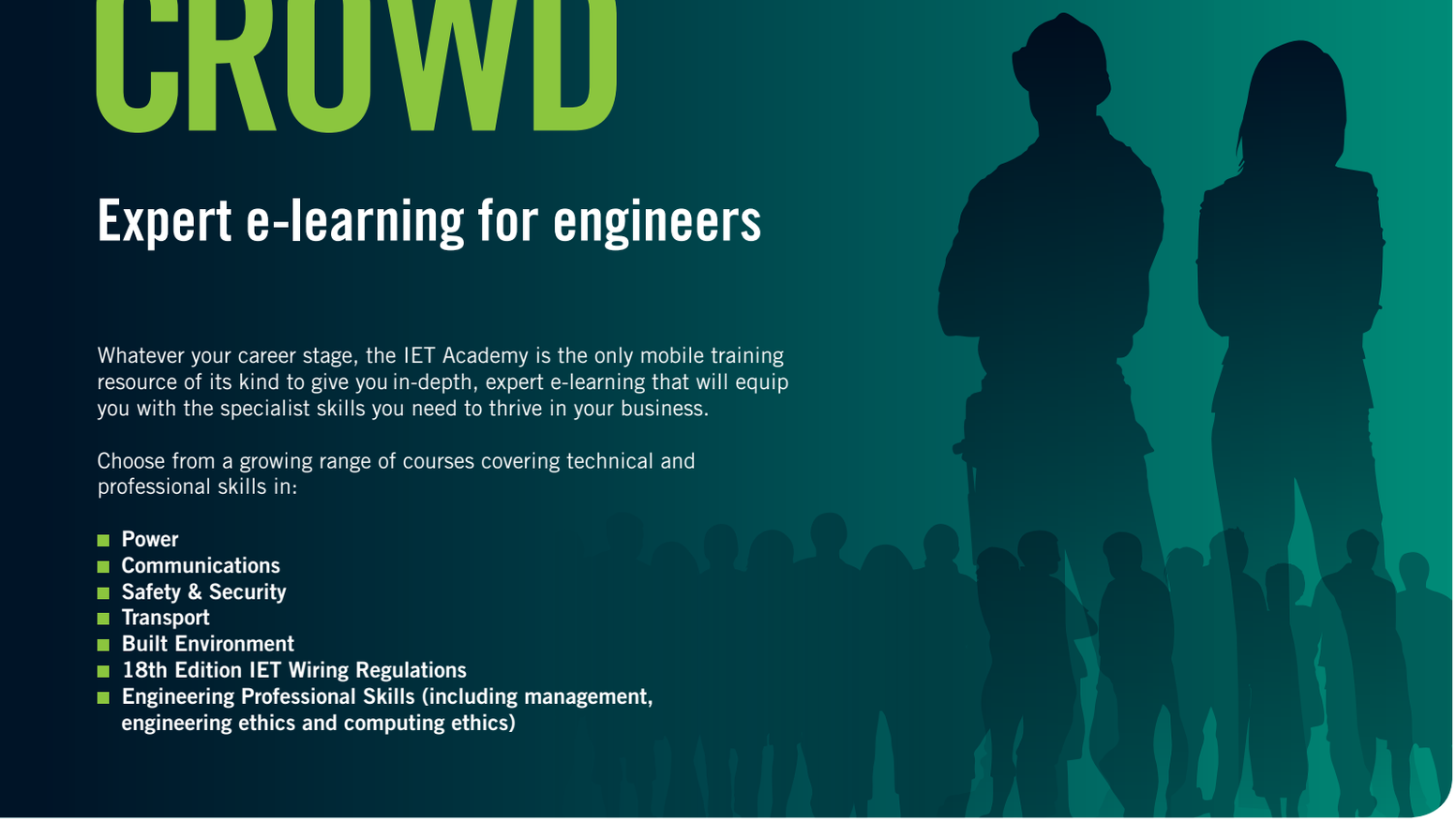

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