160 years of innovation
theengineer.co.uk
June 2017 | £3.70

the ENGINEER

FIRST FOR TECHNOLOGY & INNOVATION

Back on track

Is hydrogen power finally ready to deliver on its promise?

H2

Big Apple update

New York's brand-new subway – 100 years in the making »29

Growth formula

Ian Shott outlines the mission of the Royal Academy's Enterprise Hub »32

Torque of the town

Is Alfa Romeo back to its best with the new Giulia? »36

2017 Salary Survey

In-depth coverage and analysis from *The Engineer*'s latest annual survey of the engineering community

»48

Your business water bill could be cheaper. Call in...

Now the water market in England is open, every business is free to shop around for better water prices and improved service from their supplier.

Savings of up to 25% are possible as well as up to £400 cashback* with a combined utilities deal from Utilitywise.

Join the thousands of businesses who have already taken the first steps towards lower water bills.

Contact the U-team today.

Call 0330 057 8627, text WATER to 62277 or visit utilitywise.com/water

Free water mythbuster guide for every business

utilitywise

www.utilitywise.com/water

*Terms and conditions apply

this**issue**

Volume 297
Issue No.7888
Established 1856

news

opinion

features

our**opinion**

Beyond the hype

As with most areas of economic activity, the engineering sector often finds it hard to resist the temptation to describe new technologies in hyperbolic terms.

It's an understandable and sometimes helpful phenomenon, particularly for an industry mindful of its need to engage with the wider world.

But big grandiose banners can sometimes be self-defeating.

Take HS2. For its critics, the project is the ultimate white elephant, a pointless exercise in shaving minutes from an already rapid journey between London and Birmingham. But remove the headline-grabbing HS2 soubriquet; calmly recast the project as the next step in the development of a modern new railway network, and it starts to sound more credible.

The subject of this issue's cover story, hydrogen power (p22), is another example of a technology that may have been held back by its own hyperbole.

> "Now the expectation has been recalibrated, hydrogen technology may deliver on its potential"

You don't hear so much about the so-called 'hydrogen economy' these days. But a decade ago – if you believed the hype – it was the future, an irresistible force that would reshape the planet. And as some of the UK's leading engineers in the field tell us, the weight of expectation got in the way of the real incremental technology development necessary to really drive hydrogen-based power technology forward.

Now that the weight of expectation has been somewhat recalibrated, hydrogen may finally be poised to deliver on its potential. Developments in refuelling technology, the impending launch of a number of hydrogen-powered vehicles, and a growing feeling that hydrogen could play an important role in energy storage for intermittent renewables suggest that it could yet loom large in tomorrow's energy mix.

Also in this issue, we publish the findings of *The Engineer*'s 2017 Salary Survey (p48). As you'll see there are many interesting findings: not least the news that average UK engineering salaries increased by 6.6 per cent over the past 12 months. Visit our website for an even more detailed breakdown of this year's findings, and to use our salary calculator to see how your pay compares with that of your industry peers.

Jon Excell Editor
jon.excell@centaurmedia.com

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

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

the ENGINEER Centaur Media Plc, 79 Wells Street, London, W1T 3QN

Direct dial 020 7970 followed by extension listed Advertising fax 020 7970 4190 **Editor** Jon Excell (4437) jon.excell@centaurmedia.com **Features editor** Stuart Nathan (4125) stuart.nathan@centaurmedia.com **Senior reporter** Andrew Wade (4893) andrew.wade@centaurmedia.com **News editor** Jason Ford (4442) jason.ford@centaurmedia.com **Recruitment advertisement manager** Michael Whitehead (020 7970 4678) michael.whitehead@centaurmedia.com **Senior sales executive** Jason Padam (4677) **Commercial director** Sonal Dalgliesh (4487) sonal.dalgliesh@centaurmedia.com **Commercial manager** Peter York (4942) **Production** Lyndon White, Wendy Goodbun (4807) te.production@centaurmedia.com **Publisher** Simon Lodge (4849) simon.lodge@centaurmedia.com **Subscriptions & Customer Services** tecirc@centaurmedia.com

CENTAUR MEDIA

The Engineer is available for International licensing and syndication. For more information please email simon.lodge@centaurmedia.com
NEWS 020 7970 4442 DISPLAY 020 7970 4487 RECRUITMENT 020 7970 4110 SUBSCRIPTIONS/CUSTOMER SERVICES HOTLINE 020 7292 3705

SENSORS

Much better ways to clear landmines

Sensor technology is able to detect landmines more quickly and reliably

HELEN KNIGHT REPORTS

Clearing landmines from roads and fields can not only save lives and prevent life-changing injuries, it can also help communities economically, by giving them back access to agricultural land, as well as markets, food supplies, schools and hospitals.

Removing anti-vehicle mines from roads can also reconnect people in neighbouring communities, and allow aid agencies and government bodies to reach areas that were previously cut off.

But clearing landmines from roads and fields is often hampered by the slow speed of existing techniques used to detect and remove the devices. What's more, the process is further complicated by the need to prioritise the order in which different areas are cleared, to provide the greatest benefit to local people in the shortest possible time.

Now researchers led by Dr Panagiotis Kosmas at King's College London have launched an EPSRC-funded project to tackle these difficulties simultaneously. The researchers are developing a new sensor technology to detect landmines more quickly and reliably, alongside a method to consider cultural, political and socio-economic factors at national, district and community levels.

"The idea is to develop a de-mining strategy that interacts with the way that we are developing the technology," said Kosmas.

The new detector is based on a technique known as quadrupole resonance, in which a radiofrequency (RF) pulse – or series of pulses – set at a particular frequency for the explosives of interest, are directed at the ground.

A planar RF antenna is placed close to the ground, in a similar way to a metal detector, and fed with a sequence of pulses.

If the material is present, it resonates – absorbing radiofrequency pulses and retransmitting them, creating a signal that can be picked up by the same antenna that sent out the pulses. King's College London's QR research team, led by the project's co-investigator Dr Jamie Barras, has applied this technique successfully in the past in applications ranging from the detection of explosives to medicines authentication.

"We know the frequency at which the explosive material is responsive, so based on the signal we receive we can say if something is there or not," said Kosmas.

Unlike a metal detector, the sensor detects the explosive material contained within the mine, meaning there are few false alarms.

This can be particularly important with anti-vehicle mines, which contain very little metal but a lot of explosive, meaning they can be difficult to spot with conventional technologies such as metal detectors, and making them slow and expensive to clear.

The team will also be developing signal processing, to allow the detector to pick up signals in the field, even when there is interference or noise.

The researchers will initially investigate regions within Afghanistan, Somaliland and Angola, including studying economic activity within communities before and after de-mining operations.

"The economic data might suggest a specific rate at which we should carry out de-mining operations, which could be fed back into our technology development," said Kosmas. "The more time we spend [de-mining], the more accurate the technique, but if there is a need to clear certain roads in a limited amount of time, then we may have to develop technology specifications that are related to what can be done in practice," he added.

A mechanised mine-clearance project opening a road in Afghanistan. *Photo credit: Halo Trust*

Readmoreonline

Aerospace
Space experts meet to discuss asteroid deflection technologies

Automotive
Norton Motorcycles: engineering the revival of an icon

Civil & Structural
UK project aims to tackle shantytown fires

Defence & Security
Lockheed exoskeleton gives soldiers a leg up

Electronics & Communications
Embedded sensor provides real-time respiratory rate

Energy & Environment
Plastic paradise: the shocking extent of ocean waste

Manufacturing
UK coating innovation makes a splash for smartphones

Medical & Healthcare
Technology promises biometric gait recognition for battery-free wearables

Rail & Marine
Adaptable train carriage ready for UK trials

LINDE AG Engineering embraces HP PageWide XL


Thomas Riedl,
Reprographic Department Manager at Linde AG

The installation of a HP PageWide XL 8000 Printer plus online folder marks the end of a time consuming and costly printing process at Linde AG Engineering. With HP PageWide XL the overall costs for printing large format documents could be reduced by 40%.

Prior to installing the HP PageWide XL 8000 MFP plus online folder back in October 2015, the company was using three large format printers to manage their print volume which in peak times could reach up to 10.000m² per month. One black & white LED printer was used for printing pages and two additional color printers based on waxed toner pearls were needed to print an ever increasing number of coloured pages. "In the past technical drawings used to be printed only in black and white but lately we have seen a significant increase of colour pages," says Thomas Riedl, Reprographic Department Manager at the Linde Headquarter in Pullach, Germany.

The value of color

"Already five years ago we were dreaming of a large format printer who could produce black and white and colour pages in one go. However the available solutions back then didn't meet our expectations in terms of cost and quality", remembers Mr. Riedl.

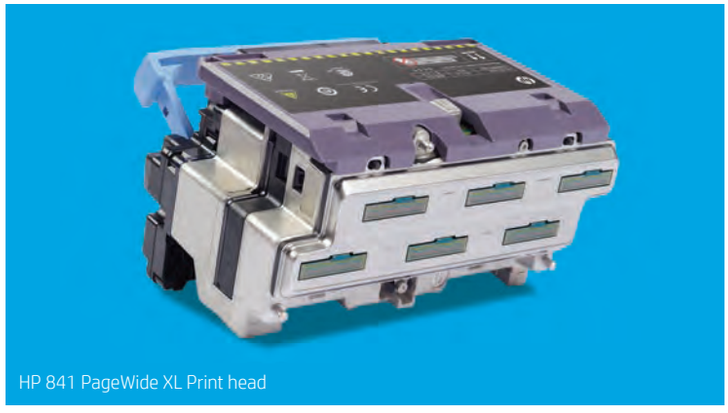
It has been proven that color documents are more easily understood and the information is retained at higher rates versus monochrome documents - it can decrease human error rates [1].

Significant cost savings from day one

The consolidation of the previous printers into one HP PageWide XL 8000 plus online folder has paid off rapidly: the internal reprographic department could cut their overall large format printing costs by 40%. In addition Linde AG is very satisfied that there is no minimum purchase commitment anymore.
"The price per square meter is very competitive and we have gained a lot of flexibility". Another positive side-effect is the low energy consumption compared to LED technology. *"We are very conscious about our environmental impact including energy consumption, resources and materials,"* confirms Mr. Riedl.

Seamless integration with existing output management system

Another argument in favor of the HP solution was the seamless integration into Linde's corporate output management system called Plossys Netdome. The System now meets Linde's requirements for enterprise-wide print and distribution of documents and information.
The HP PageWide XL 8000 printer offers the fastest large-format printing available in color and black-and-white with speeds up to 30 D/A1-size prints per minute, as well as two 775 milliliter ink cartridges per color [2].
HP PageWide Technology consists of more than 200,000 nozzles on a stationary print bar and spans the width of the page, enabling breakthrough printing speeds. Extended time between service station cycles also enables outstanding sustained productivity capacity.


HP 841 PageWide XL Print head

More information: www.linde.com • www.hp.com/go/pagewidexl

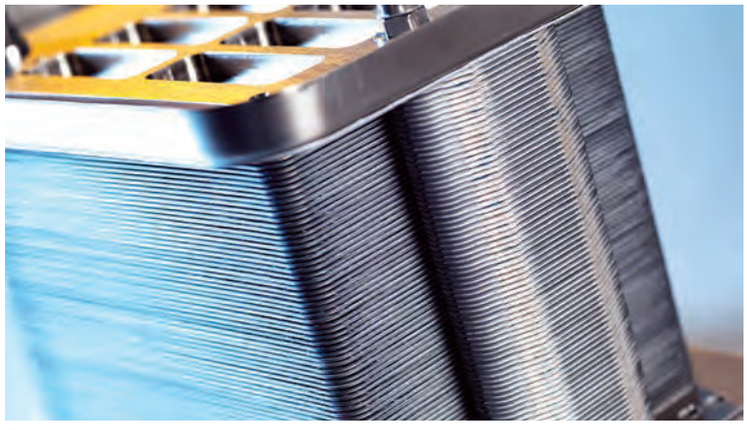
[1] According to "Why Color Matters," by Jill Morton, 2010. [2] Printing at up to 30 D/A1 pages/minute and up to 1500 D/A1 pages/hour, the HP PageWide XL 8000 Printer is faster than alternatives for large-format printing of technical documents, GIS maps, and point-of-sale (POS) posters under $200,000 USD as of March, 2015 including 36-inch wide LED printers (printing up 22 D/A1 pages/minute) and wide-format printers based on Memjet technology (printing up to 800 D/A1 pages/hour). Based on internal HP testing of the HP PageWide XL 8000 Printer in line drawing print mode on uncoated bond paper printing in D/A1 landscape.

ENERGY

Stacking up the energy savings

Fuel cell technology could significantly cut carbon dioxide emissions

HELEN KNIGHT REPORTS



The stacks can be used to provide power and heat for hot water

Fuel cell technology designed for use in homes, which could cut household carbon dioxide emissions by almost one third and significantly reduce energy bills, is being developed in the UK.

Ceres Power, which has developed solid oxide fuel cell (SOFC) technology known as SteelCell, has announced an agreement with an unnamed manufacturer to integrate the system into its products for the use of residential customers.

The two-year agreement, which is being supported with a £700,000 grant to Ceres Power by Innovate UK, will see the manufacturer carry out systems engineering work to integrate the core SteelCell technology into commercial products.

SteelCell technology consists of individual steel SOFCs, which can be piled on top of one another to form stacks. The stacks can then be used to provide power and heat for hot water.

One stack consisting of 100 cells can provide enough power and hot water for one home, while 100 stacks can be used for apartment blocks and businesses.

The cells are fuel-flexible, meaning they can be used now to generate power from natural gas supplies, but could ultimately convert biogas or hydrogen into electricity, according to Phil Caldwell, CEO of Ceres Power.

"So if in the future we decide to decarbonise the grid, and we started to use either biogas or hydrogen, the fuel cell technology we have can operate on anything from 100 per cent natural gas all the way through to any blend of hydrogen," he said.

The company is already running trials of prototype domestic power systems in the UK, where it is used as an add-on to conventional gas boilers.

"I have one powering my home: it provides me with 80 per cent of my power, free hot water, and part of my heating," said Caldwell. "I buy gas at 4p per kilowatt hour, and the fuel cell converts it at around 50 per cent [efficiency], so essentially my electricity is costing me 8p per kilowatt hour, instead of 17p per kilowatt hour if I was buying it from the grid," he said.

That would amount to energy bill savings of £300 to £400 per year for an average UK home, he said.

The improved efficiency of the technology in converting gas to power and heat also means the carbon footprint of the average home would be reduced by 25-30 per cent, even with natural gas as the fuel source, he added.

In December Ceres Power announced an agreement with another manufacturer for commercial building applications. The company is also working with Nissan to investigate the technology's use as a range extender for electric vehicles.

PAY

Survey shows salaries are on the rise

Average salary has now increased to £48,000

JON EXCELL REPORTS

Salaries for UK engineers have increased by 6.6 per cent on average over the last 12 months, according to *The Engineer*'s 2017 salary survey, which is published in this issue (p48).

While the average salary for UK engineers stood at £45,000 in 2016, our 2017 report – which is based on responses from 2,743 engineers working across a range of sectors – shows an increase in average salary to £48,000.

Despite general dissatisfaction among respondents with the levels of remuneration offered across industry (just 35 per cent are happy with their pay) engineering salaries would appear to compare favourably with most other sectors. The average salary in the financial services sector is currently £47,109, while bankers earn only slightly more on average (£50,080).

Despite painting a reasonably positive pay picture, this year's survey also reflects some key areas of concern, not least industry's continuing struggle to close the gender gap.

Female engineers accounted for just seven per cent of respondents and, according to our findings, are paid on average £10,000 less than their male colleagues. Even more alarmingly, female respondents at every level of seniority are on average paid less than their male colleagues. Women at junior level earn on average £4,000 less than their male colleagues, while at director level the gap widens to £20,000.

Find out how your salary compares to that of your peers using our online salary calculator at www.theengineer.co.uk

Newsinbrief

AI momentum

A survey has found investment in artificial intelligence gaining momentum with 42 per cent of companies planning to invest over the next five years. Nearly half of firms believe current artificial intelligence will be transformational and widespread; fundamentally transforming the industry and markets they work in.

Cambridge self-drive

RDM Group is to lead a feasibility study into the introduction of autonomous transportation to help alleviate congestion in Cambridge. The Coventry-based autonomous vehicle company will work with Cambridgeshire County Council and the Wellcome Genome Campus to deliver a £250,000 investigation into the business case for a future £3-5m self-driving shuttle service across two routes.

Electric waves

Norweigan marine technology firm Kongsberg Maritime has announced plans to build what it claims will be the world's first autonomous, electric container ship. The vessel, which is being developed in collaboration with Norweigan fertiliser manufacturer Yara International, will be used as a feeder vessel to transport products from Yara's Porsgrunn plant to nearby shipping terminals in Brevik and Larvik.

Going Dutch

A new 600MW wind farm off the Dutch coast has come online, and will eventually provide power to 1.5 million people. Situated 85km off the coast of Groningen, the Gemini wind park has 150 turbines covering 68 square kilometres, and provide an installed capacity of 600MW. According to Gemini, the location has some of the highest and most consistent wind speeds in the North Sea.

DEFENCE

Taking care of an incoming threat

Three-dimensional system protects aircraft from missiles

HELEN KNIGHT REPORTS

A three-dimensional threat detection system, designed to protect military aircraft from attack by weapons such as shoulder-launched surface-to-air missiles, has been developed by BAE Systems.

The 3-Dimensional Advanced Warning System (3DAWS) is designed to detect a potential threat and select the best available countermeasure, depending on the nature of the danger.

Existing threat detection and missile-warning systems typically use 2D information, azimuth and elevation, to assess a potential hazard. This makes identifying and confirming the threat much more difficult.

In contrast, 3DAWS incorporates a third dimension, range, allowing it to better analyse the threat, according to Cheryl Paradis, director of threat management solutions at BAE Systems.

"The typical threat that they [aircraft] see in theatre are MANPADS, or man-portable surface-to-air missiles, which detect the IR signature of the aircraft," Paradis said.

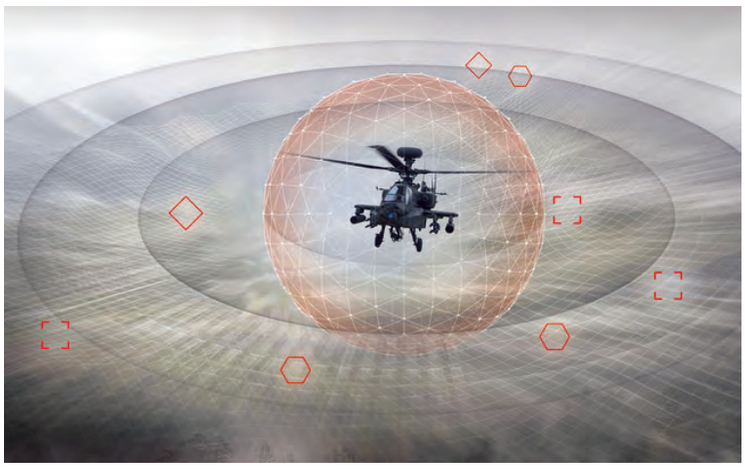
"Our customers want the ability to definitively say, there is a threat there, and that threat is coming at you, and it's not a false alarm, it's real."

The system is comprised of two components: a passive threat detection system, such as BAE Systems' Common Missile Warning System (CMWS), which is designed to detect the ultraviolet signature of missiles; and a radio frequency-based, semi-active 3D tracker.

When the passive system detects a potential threat, it cues the 3D Tracker to trigger a radar pulse to interrogate the object. This confirms if the object poses a genuine threat.

"In the world of low-altitude rotary-winged military platforms, when you are looking for signatures in the missile-warning domain, there are lots of things that look like they have a UV or an IR signature, and if you are in a hostile area, you don't want to see those and deploy countermeasures for nothing, you want to save them for when you really need them," said Paradis.

The information is passed back to the missile-warning system, which coordinates with the aircraft's onboard systems to automatically select from a range of countermeasures. These include flares and directable infrared countermeasures, which confuse an incoming missile's guidance system to ensure it misses its target; and hard-kill countermeasures, which physically counterattack the missile.



The system detects potential threats and picks an appropriate countermeasure

AUTOMOTIVE

Roborace starts to line up on the grid

Self-driving RoboCar goes on public track for the first time

Roborace, the firm hoping to kick-start the world of driverless motor racing, has demonstrated its self-driving RoboCar on a public track for the first time.

The vehicle completed a lap of the Paris ePrix circuit ahead of the city's 2017 Formula E race, which took place on 20 May.

The demonstration saw the car – which is designed to be capable of speeds of up to 200mph – negotiate its way at low speed around 14 turns of the 1.9km circuit without a human in the vehicle. It was entirely self-driven by autonomous software.

The vehicle weighs 1,000kg, is driven by four 300kW motors, and powered by a 540kW battery. It uses a number of technologies, including five lidars; two radars; 18 ultrasonic sensors; two optical speed sensors; six AI cameras; GNSS positioning; and is powered by Nvidia's Drive PX2 brain, capable of up to 24 trillion AI operations per second to be programmed by software engineers using complex algorithms. **JE**

MATERIALS

Graphene could be getting set to go nuclear

Material could reduce energy usage processes

STUART NATHAN REPORTS

Specialists working on graphene at Manchester University have found that the single-atom-thick material could have applications in reducing the energy usage of processes in the nuclear sector.

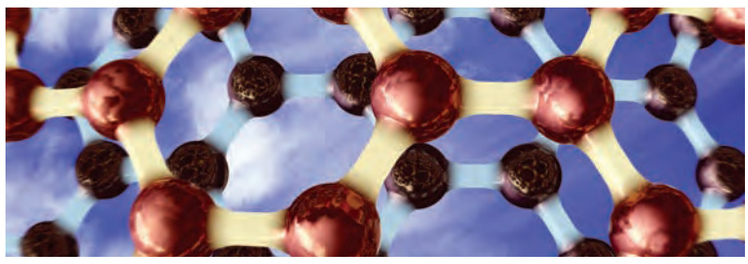
Manchester scientists discovered last year than graphene granules can separate different isotopes of hydrogen, and the team led by Marcelo Lozada-Hidalgo has now developed this discovery to demonstrate a scalable prototype of a process that uses graphene membranes to produce heavy water.

Heavy water, where the normal hydrogen of the water molecule is replaced by its neutron-containing isotope, deuterium, is used as a coolant and neutron absorber in certain types of nuclear reactor. Yet producing it is an energy-intensive process: hundreds of tonnes of isotopic mixtures are separated every year, and it takes enough energy to power an average US home for a year to produce a kilogram of heavy water.

A similar problem facing the nuclear industry is removing tritium, the heaviest isotope of hydrogen and a radioactive substance, from water used for reaction cooling. The graphene membranes can also perform this function, Lozada-Hidalgo said. In a paper in *Nature Communications*, he explained how the membrane method consumes 100 times less energy for heavy water production than conventional processes, and that energy savings for tritium decontamination are even greater. It could reduce carbon emissions associated with heavy water production by up to a million tonnes per year, the paper added.

"This is a crucial milestone in the path to taking this revolutionary technology to industrial application," said Lozada-Hidalgo. "The potential gains are high enough to justify its introduction even in the highly conservative nuclear industry."

The co-discoverer of graphene, Sir Andre Geim, said: "We believe this technology can economically transform the environmental footprint of future nuclear plants."



Graphene granules can separate different isotopes of hydrogen

Amplicon introduce new high power, small form factor embedded PC

By Gavin Chalkley - Product Specialist for Industrial Computing at Amplicon

UK electronic specialist, Amplicon, is once again first to market with the latest technology. With over 40 years of manufacturing experience based firmly in engineering delivering exceptional industrial computing solutions is second nature. Combine this with a wide range of Data Communications, Measurement & Control, and Security Automation products and Amplicon can provide the complete solution.

TODAY'S MARKET CHALLENGE

High computing power and small spaces are not generally considered a good match. The key is excellent thermal design, even more so when space limiting factors are introduced. Material used airflow and ambient air temperature play a large role in combining the most unlikely of partners. Not getting the balance exactly right will cause over heating and severely reduce any Mean-Time-Before-Failure (MTBF) and ultimately the life of the system. Traditional fan cooled systems require large amounts of lower temperature circuiting air in order to run within the limits of the components, they also require filters that will require regular servicing in order to maintain the air flow.

THE SOLUTION IS SMALL AND MIGHTY

Amplicon has introduced the new Impact-D 160, a powerful Embedded PC fully packed with exceptional features. The new system offers increased computing power thanks to its Skylake processor, is I/O rich and security availability is greater than in previous models.

End users can benefit from its surprisingly small form factor, which is perfectly suited to applications in markets such as transportation, security and automation.

Designed and built in the UK, the new Impact-D 160 from Amplicon will offer two processor options: i5 and i3. Additionally, minimal design constraints enable the Impact-D 160 to be adapted and customised to suit a specific set of requirements for any application.

The unit offers both mSATA and a mechanical/solid-state drive capability for storage and OS requirements. Support of both cellular and Wi-Fi connectivity allows to "stay connected" even if you lose the Gigabit Ethernet connections ensuring maximum up time.

The Impact-D 160 comes with four DB9 serial communications ports: two supporting mixed protocol (RS232, 422, 485) and two static RS232, with options for an extra four ports of your choice. This gives the unit ease of operation in both new and legacy applications for serial control.

For more information send us an email at sales@amplicon.com

www.amplicon.com

Amplicon

"The Impact-D 160 is an exceptionally compact and powerful unit designed and built by Amplicon to meet the most demanding applications where space is limited. We are confident our customers will find in these new units the perfect match to outperform in any application"

Gavin Chalkley
Product Specialist at Amplicon

AUTOMOTIVE

Bringing engines out into the light

Team will investigate means to make engines lighter and greener

HELEN KNIGHT REPORTS

Greener and more efficient vehicles could be developed as part of a research project investigating the use of advanced boosting technology and lightweight engine design, involving Jaguar Land Rover and Ricardo.

The Latitude project, which is being part-funded through the Advanced Propulsion Centre and partly by the companies involved, is aiming to improve fuel efficiency and reduce carbon-dioxide emissions by 10 per cent.

The Jaguar Land Rover-led project, which also includes GRM Consulting, Borg Warner and Bosch, will integrate advanced boosting and fuel injection technology into an engine combustion system.

The team will investigate engine designs to reduce weight and improve thermal efficiency as part of the project, according to Marc Vigar, Ricardo programme manager for the Latitude project.

Ricardo will have overall responsibility for the structural design of two versions of the Latitude engine, which will be based on Jaguar Land Rover's Ingenium engine family.

Both a high-performance and a lower-power version of the engine will be designed, with the latter providing greater fuel efficiency.

The low-power version will be designed to have reduced peak cylinder pressure, allowing the project team to limit the mass of components and the main engine structure.

"Reducing the cylinder pressure of an engine generates lower loads on the engine components – namely the piston, conrod, crank-shaft – allowing these components to be lighter, and potentially allowing smaller, low-friction bearings," said Vigar.

Ricardo will use GRM software to allow engineers to consider weight, structural optimisation, and noise, vibration, and harshness design issues alongside thermal management.

"We are looking at ways to speed up the warm-up of the oil to reduce friction, thereby reducing fuel consumption," added Vigar.

They also aim to encapsulate the engine. "Encapsulation is the use of a thermal insulation around the engine, which reduces the heat lost from the engine when it is turned off," said Vigar. "This means the engine is warmer for a re-start, which reduces friction and fuel consumption."

Lightweight engine design is now on the agenda

AEROSPACE

Digital is all up in the air

Digital air traffic control tower set for London

London City Airport is to become the first in the UK to operate a digital air traffic control tower.

Slated to become operational in 2019, the technology will use advanced cameras and sensors to gather data from the airfield and provide a live feed via a secure and superfast fibre network to a new control room at the National Air Traffic Services (Nats) centre in Swanwick, Hampshire.

At the heart of the system will be a new 50m-high tower at the airport equipped with 14 high-definition cameras and two pan-tilt-zoom cameras. These will provide a full 360° view of the airfield and will be used to form a seamless panoramic moving image of the airfield, that will be coupled with an audio feed and radar readings from the skies above London.

Operators will be able to use viewing tools, including high-definition zoom and enhanced visuals, which provide detailed views of activity on the airfield, including close-up views of aircraft movements along the 1,500m runway. **JE**

SENSORS

Skin is in for 3D printers and sensors

Stretchy sensors could be printed directly onto skin

STUART NATHAN REPORTS

A new frontier for robotics could be crossed with the development of stretchy sensors that can be 3D printed onto a variety of surfaces.

The technology, developed by a team at the University of Minnesota, could potentially be used to print electronics directly onto human skin for remote health monitoring.

The project was led by Prof Michael McAlpine of University of Minnesota, whose team developed a customised 3D printer with four nozzles to print specialised 'inks' that make up the sensors.

The base layer of the construction is silicone, two subsequent layers are conducting inks that make up the sensor electrodes themselves, and on top of these is a coil-shaped pressure sensor.

Finally, there is a soluble layer to hold everything together that is dissolved away once the structure is complete. All of the inks set at room temperature, and can stretch up to three times their original size.

"We have a multifunctional printer that can print several layers to make these flexible sensory devices. This could take us into so many directions from health monitoring to energy harvesting to chemical sensing," McAlpine said. "This is a completely new way to approach 3D printing of electronics."

In a paper in *Advanced Materials*, McAlpine said using the sensors on surgical robots may give their operators the ability to feel while performing minimally invasive surgery, adding another layer of feedback to help in the surgery along with the visual systems using cameras that currently are the only aid to robotic surgery.

The nozzles print specialised 'inks'

Extremely accurate. Extremely fast.

Next-generation measurement technology with Beckhoff EtherCAT Terminals.

< 1 µs synchronisation
100 ppm
24 bits
10,000 samples/s

www.beckhoff.co.uk/EL3751

With the EL3751 EtherCAT Terminal, Beckhoff unveils the first product in its new generation of high-precision I/Os for measurement technology. These scalable terminals integrate high-end measurement technology directly into the standard I/O system. Superior precision and sampling rates ensure high-quality data acquisition:

- Multi-functional input: U, I, R, strain gauge, RTD (PT100/1000)
- High-precision timing: exact synchronisation < 1 µs
- High-precision values: measurement accuracy of better than 100 ppm at 23 °C
- Fast: 10,000 samples/s
- Proactive: integrated connection and functional diagnostics
- 24-bit $\Delta\sum$ ADC, integrated distributed clocks, 107 percent ExtendedRange
- Optional higher-order calibration by the user
- EtherCAT is ideal for numerous measurement applications

New Automation Technology **BECKHOFF**

FUSION

Magnet is a work of sophistication

Superconducting magnet operates at ITER fusion research complex

HELEN KNIGHT REPORTS

The world's most sophisticated superconducting magnet has been built in Europe.

The magnet, which is the first of 18 Toroidal Field (TF) coils that will operate at the ITER fusion research complex in Cadarache, France, is 14m high, 9m wide and weighs 110 tonnes.

When operational, the coils will be used to create a magnetic cage, designed to entrap the fusion fuel, which will reach temperatures of 150 million degrees Celsius.

In order to create this powerful magnetic field – with a strength of 11.8 Tesla – the coils will be powered by 68,000A, according to Alessandro Bonito-Oliva, manager for magnets at Fusion for Energy (F4E), the EU organisation managing Europe's contribution to ITER.

> "You cannot afford to break it so you have to do everything very precisely from the beginning"
>
> Alessandro Bonito-Oliva, F4E

"Essentially they are bringing the atoms as close together as possible, in order to be able to initiate fusion," said Bonito-Oliva.

Each D-shaped superconducting magnet will be built using around 1,000 copper wires, which are cabled together into a 750m-long conductor.

The conductor is heat treated and supported by grooves in seven 13 x 9m radial plates, said Bonito-Oliva. "The material, in order to become superconducting, has to be heat treated, after which it becomes fragile, and at such big dimensions this is quite difficult," he said. "You cannot afford to break it, so you have to put a lot of effort into doing everything very precisely from the beginning."

After testing, the magnet will be inserted into a huge case, where it is laser welded, wrapped in insulating material, impregnated with resin and then machined. Nine of the coils will be made in Europe, alongside one spare coil, while nine will be built in Japan.

The European coils are being built through a collaboration of F4E, ASG Superconductors, Iberdrola Ingeniería y Construcción, Elytt Energy, CNIM, SIMIC and the ICAS consortium.

The technologies and know-how being developed as part of the project are already being used in other applications. ASG Superconductors, for example, has used knowledge developed during a project in advanced magnetic resonance imaging (MRI) equipment.

"All of the satellite technologies that have been developed to make the magnets are going to be used by the different companies involved in the project," said Bonito-Oliva.

Each magnet will be built using around 1,000 copper wires

AEROSPACE

Orbital test vehicle touches down

Four extended space flights have been completed

The US Air Force's X-37B Orbital Test Vehicle (OTV) has touched down at Kennedy Space Center in Florida following a 718-day mission.

It has now completed four extended space flights, with each mission lasting longer than the previous one. Having launched on an Atlas V rocket on 20 May 2015, OTV-4 now holds the space plane orbital duration record.

Built by Boeing's Phantom Works, the X-37B resembles a miniature space shuttle. The craft also operates in a similar way, launching vertically and landing on a runway. The programme was transferred to the Defence Advanced Research Projects Agency (DARPA) in 2004, at which point it became classified.

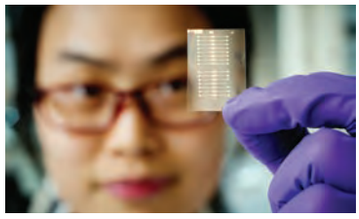
The nature of each mission is unknown, with the US military confirming only general goals of 'risk reduction, experimentation, and concept of operations development for reusable space vehicle technologies'. **AW**

SENSORS

Porous polymer is now the key to sensitivity

Film can detect traces of ammonia in breath

STUART NATHAN REPORTS



Prof Ying Diao

Based on a porous polymer film, highly sensitive sensors can detect trace compounds in breath or toxins in air, according to chemists and biomedical engineers in the US.

The result of research at the University of Illinois at Urbana-Champaign, the sensors are made from films of semiconducting plastics. They are capable of detecting molecules in breath at levels too low to smell, but that are significant for human health.

Other attempts at making sensors from these materials have not achieved the required sensitivity, but Prof Ying Diao's group discovered that the reactive sites in the material were not on the surface, but within the polymer's structure. To allow the target molecules to reach these sites, the team devised a method of making the films with a porous structure.

"We developed this method to directly print tiny pores into the device itself so we can expose these highly reactive sites," Diao said. "By doing so, we increased the reactivity by 10 times and can sense down to one part per billion."

The team made a film that can detect traces of ammonia in breath: a marker for kidney diseases. By changing the composition of the sensor, it could be made sensitive to other compounds.

"We would like to be able to detect multiple compounds at once, like a chemical fingerprint," Diao said. "It's useful because in disease conditions, multiple markers will usually change concentration at once. By mapping out the chemical fingerprints and how they change, we can more accurately point to signs of potential health issues."

DISCOUNTS ON **SOLIDWORKS**

CADTEK

SOLIDWORKS

Hurry... Offer Ends 30th June 2017

Cadtek.com/SpecialOffer

01663 741405

*Offer only valid on new license purchases with the corresponding Subscription Service according to the current SOLIDWORKS Price List. Offer expires June 30th 2017 and cannot be combined with any other discount or offer. Offer not applicable to Education Licences. Other restrictions may apply.

SENSORS

Virtual reality all in a split second

Electrodes can detect electrical signals from eye muscles

HELEN KNIGHT REPORTS

A sensor that can detect the tiny electrical signals generated by muscles as someone moves their eyes could offer split-second control over virtual or augmented reality systems.

The sensor, developed by Belgian-based innovation centre IMEC and the Holst Centre, a research and development organisation set up by IMEC and TNO in the Netherlands, can detect eye movements in real-time using a series of electrodes.

The technology could allow gamers to interact with the screen by controlling cursors with their eyes to navigate through menus and select different options, for example, or to open and close applications.

It could also provide feedback to the game on how the person is reacting to their virtual surroundings, according to Carlos Agell, senior R&D engineer at IMEC in Eindhoven.

Existing eye-movement sensors, used in gaming, research and healthcare, are based on high-resolution cameras embedded in screens or glasses. These cameras can monitor where the wearer is looking at any one time, but they are not fast enough to detect rapid eye movements, such as saccades, the jerky motion people use when reading or scanning their immediate vicinity.

Instead, researchers at IMEC and Holst have developed a system based on four electrodes, which are built into the glasses around each lens, at points where the frames touch the skin. Two of the lenses are designed to detect vertical movement of the eyeball, and two any horizontal movement.

The electrodes detect the tiny electrical impulses given off by the muscles controlling the eye, said Agell.

"The electrodes are placed around your eye, and they collect the muscle activity," he said. "So if you put a series of electrodes in perpendicular directions, you can capture the pitch and the yaw of the eyeball."

An algorithm translates the signals into a position, based on the angle the eye is making with its central point of vision.

"Camera-based systems are limited by the frame rate of the camera, usually around 30-60 frames per second on a reasonably priced device," said Agell. "By measuring the electrical activity we can go to 2,000 samples per second, versus the 30 that the camera could do."

> "Measuring electrical activity, we can go to 2,000 samples per second"
> Carlos Agell, IMEC

The sensors place the electrodes around the eye

SPACE

Private blast-off

Privately built space rocket has successful launch

Engineers from US commercial space firm Rocket Lab are celebrating after carrying out the first-ever successful launch of a privately built orbital-class space rocket from a private launch site.

The group's Electron rocket, a 17m-long launch system for delivering small payloads, such as cubesats, into space, was launched on 25 May from a purpose-built space port on New Zealand's Mahia Peninsula.

Designed to carry a payload of around 150kg, the rocket is powered by Rocket Lab's Rutherford engines. Fuelled with liquid oxygen and kerosene, the engine uses pumps powered by battery-powered electric motors rather than a gas generator, expander, or pre-burner. Many of the engine's components are fabricated using an electron-beam-melting 3D-printing process.

Although the rocket did reach space, it didn't quite reach orbit, and the team will now begin investigating why that was ahead of a further two planned test flights this year. **JE**

BIOFUELS

Energy at the bottom of a coffee cup

Method could produce biodiesel from grounds

HELEN KNIGHT REPORTS

The next time you order a latte from your favourite coffee shop, you could be helping to produce greener biofuels. Purpose-grown crops used to produce biodiesels are expensive and consume water and land that could be used to grow food.

Spent coffee grounds have a high calorific value and could be used as an environmentally friendly biofuel feedstock. In 2014, more than nine million tonnes of spent coffee grounds were sent to landfill.

Now researchers at Lancaster University, led by Dr Vesna Najdanovic-Visak, have developed a technique to significantly improve the efficiency of producing biodiesel from coffee waste.

Coffee grounds are traditionally converted into biodiesel by mixing with hexane. The mixture is then cooked at 60°C for one to two hours, after which the hexane is evaporated to leave behind the oils. Methanol and a catalyst are then added to the oils to make biodiesel and a glycerol by-product.

But by using just methanol and a catalyst, and removing the need for the hexane stage altogether, Najdanovic-Visak and her colleagues found they could produce biodiesel while reducing chemical waste.

"The role of hexane is just to extract oils from the spent coffee grounds, and then we evaporate the hexane, so that the oils that are left we can convert into biodiesel," said Najdanovic-Visak. "Instead of the hexane we use the reagent, methanol, together with a catalyst, which enter the solid matrix and extract the oils and then convert them [into biodiesel] simultaneously."

The new technique, takes 10 minutes to produce the same amount of oil as the existing process.

SOLIDWORKS

DISCOUNTS AVAILABLE ON ALL SOLIDWORKS PRODUCTS

3D CAD | VISUALIZE | SIMULATION | DATA MANAGEMENT
TECHNICAL COMMUNICATION | ELECTRICAL

SOLIDSOLUTIONS
SUPPORTING EXCELLENCE

solidsolutions.co.uk/specialoffer **01926 333777**

*Offer only valid on new license purchases with the corresponding Subscription Service according to the current SOLIDWORKS Price List. Offer expires June 30th 2017 and cannot be combined with any other discount or offer. Offer not applicable to Education Licences. Other restrictions may apply.

Brexit – towards the nuclear cliff edge

Any gap in the arrangements by which the UK nuclear industry co-operates with the world could cause considerable disruption

There's a common phrase popping up across many articles and interviews about Brexit – 'cliff edge'.

Whether that's the Institute of Directors, which said the two-year timeframe is unlikely to be enough to sever ties and form new trade deals; or EEF, the manufacturers' organisation, calling for a five-year transition period to ease the uncertainty for businesses, they've all had this word in common.

The nuclear industry has also talked of an approaching cliff edge, a scenario backed by the both the Business, Energy and Industrial Strategy Select Committee and the House of Lords Science and Technology Committee.

That cliff edge was hidden in the small print of the supporting notes to the EU Withdrawal Bill, as it detailed how the UK will also leave the European Atomic Energy Community – commonly known as Euratom – at the same time as leaving the EU.

Readers might say: 'So what?' All industries are under pressure.' But, Euratom is a fairly unique proposition for the government to contend with and the cliff edge in our scenario could bring nuclear trade to a halt.

Euratom underpins everything in the nuclear industry. It provides a framework for international nuclear safeguard compliance, undertakes inspections and reporting, and checks the right nuclear materials are in the right place to comply with the IAEA's non-proliferation requirements.

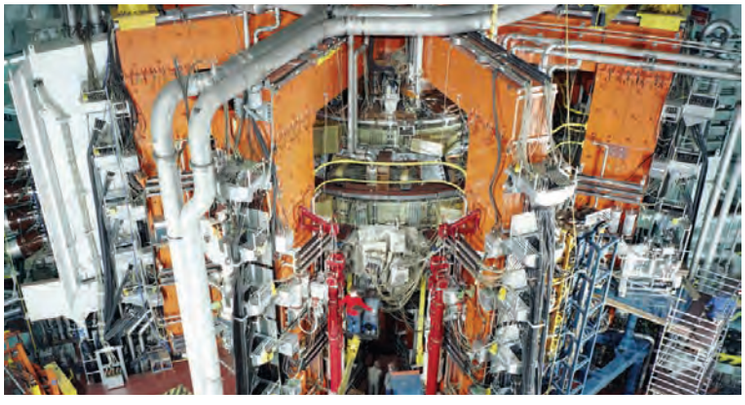
It also establishes a common market in nuclear goods, services, capital and people within the EU. Importantly, Euratom also has established Nuclear Co-operation Agreements (NCAs) that enable trade with countries outside the EU, including the US, Japan, Australia and Canada. As well as promoting long-term R&D projects, notably the ITER fusion programme in the south of France and JET based in Oxford at the Culham Centre for Fusion Energy.

So, without a replacement deal for Euratom or flexibility around the two-year time limit set out by Article 50 for the negotiations, the UK's nuclear industry faces a number of significant challenges.

In particular, normal operations such as the movement of people and equipment across borders will become more complicated, and the UK's involvement in nuclear research programmes will also be uncertain.

Reassuringly, the government appears to be well aware of this, and the white paper that triggered Article 50 states Euratom is "an important priority" and "the nuclear industry remains of key strategic importance to the UK". Furthermore the European Commission's negotiation guidelines have opened the door for a transition period.

This is positive, but we've made it clear to the government it needs to be working on these replacement arrangements now to avoid the cliff edge. It is not likely to be an easy process, but what it does have in its favour is that securing agreements is not just in the interests of the UK, but the European nuclear industries we work with too. The nuclear industry is international and any disruption would affect all of us.



The JET nuclear fusion programme is funded under Euratom

The complications will arise as there are a number of linked interdependencies, meaning one phase will need to be completed before another can begin.

The first step in the negotiation must be agreeing a replacement Voluntary Offer Agreement with the IAEA for a new UK safeguards regime.

Once this is in place, negotiations can take place to agree NCAs, and gaining third country status to help facilitate nuclear trade between the UK and the European Union.

Third country status wouldn't just benefit the UK – although for UK firms to continue to work overseas, we will need it. But for other countries to be involved in our £3bn decommissioning market or £60bn new-build sector or even to bid for contracts on existing power stations, they need us to have this agreement, so it would be foolish to make access more difficult.

The next stage of the negotiation will be agreeing a new funding arrangement for the UK's involvement in the nuclear R&D programmes, which are funded by Euratom – ITER and JET.

For JET, having these agreements in place as early as possible will be vital. Its contract with Euratom runs out in 2018, but it was expected to be extended to at least 2020 and potentially further to 2024, meaning negotiations on this extension cannot wait until 2019.

However, it is very much in our European partners' interest to resolve this issue. JET is feeding critical information to the ITER projects in the south of France, which would be lost if it closed early.

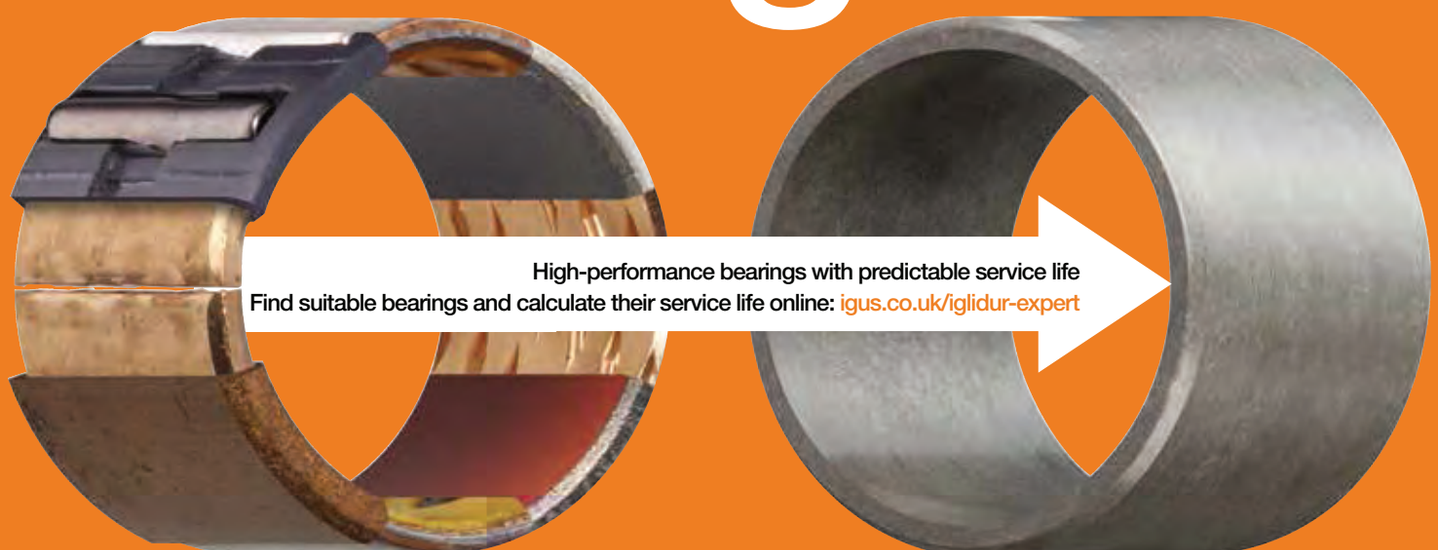
More generally, UK firms are also involved in the ITER project alongside many other international partners and have won contracts worth €500m, with this number expected to rise to at least €1bn. If the government has ambitions for the UK to remain a top-table nuclear nation, then continued participation is imperative.

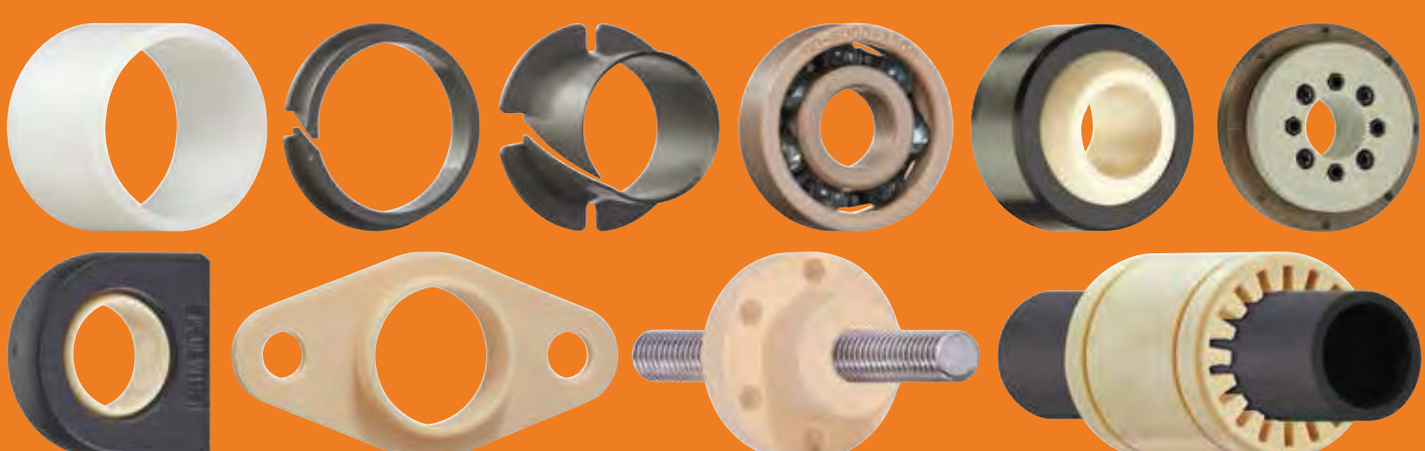
Any cliff edge to the Euratom arrangements could cause real and considerable disruption in the UK and overseas. To avoid this the government now needs to work fully with the commission and member states to ensure alternative arrangements are in place as soon as possible with transitional agreements if necessary. Any gap in arrangements would damage the nuclear industry in the UK, the EU and internationally, which isn't in anyone's interest.

Tom Greatrex is chief executive of the Nuclear Industry Association

igus® dry-tech® ... lubrication-free bearings made easy

Change your bearing now





and save 40%

Whether bronze or sintered bearings, coated metal bushings or needle roller bearings: Reduce costs and improve machine performance with iglidur® polymer bearings. Lubrication-free, lightweight and wear-resistant for your moving application. Find out all you need to know about replacement of your bearings: **igus.co.uk/change-bearing**

igus® Caswell Road Northampton NN4 7PW
Tel 01604 677240 sales@igus.co.uk
plastics for longer life®

igus®.co.uk

Mailbox

Thehottopic

Fuelling the fire

Our online article debating the relative merits of diesel and petrol engines generated plenty of discussion

The present demonising of diesels is part of the new 'fear campaign'. Cost-benefit assessment is what is needed using the old 'best available techniques not entailing excessive costs' (BATNEEC) system for continuous improvement rather than a radical unfounded change.
Jack Broughton

In the UK it's easy to tell whether you ride behind a diesel – thick black smoke. Usually buses, lorries, trains, ships. And when you tell a bus company, all they reply is 'we are aiming for the highest standards'. Why do politicians always concentrate on cars? When will we get a factual article that shows the percentages of pollution contribution from cars, buses, trains, heavy goods vehicles, light goods vehicles and industrial machinery? Perhaps when this is received we will be able to assess the impact of living without diesel. Has anyone seriously looked at ways of removing more NOx and particles from these engines before taking knee-jerk reactions? Finally, what contribution to NOx do gas turbines make? Industrial ones tend to run on diesel or gas. I believe that aircraft gas turbines also produce NOx. Will the next move be to stop air travel? Let's get all of the facts before making changes.
Ivan Taylor

Interestingly, the article only looks at engine emissions. Fine particulates are also introduced into the environment from tyre wear and brake linings and from biomass combustion. Coarser particulates predominantly come from soil/land erosion and mining. Also, if the idea is that electric cars are somehow a panacea, if we were all to convert to them we would have to bring on stream an awful lot more power generation to cope – I think the EU recently estimated that at 80 per cent adoption, this would account for 15 per cent of all electricity produced in the UK. That implies a large increase in CO_2 to go with it – or maybe the good people of Westminster would like a couple of Hinkley Points in their borough? If mass transportation of goods and people is still inevitable there will be a downside.
John Dickinson

Current developments with direct injection will bring petrol engines much closer to diesel levels of fuel consumption and CO_2 emissions. They will also have the same emissions problems. To achieve similar levels of fuel consumption they will have to be lean burn so the three-way catalyst will no longer function. They will also have to have higher maximum cylinder temperatures and pressures than current petrol engines, which increases the production of nitrogen oxides. A similar thermal efficiency will have a similar emissions profile.
Geoff Kershaw

Talking to a respected industry insider recently I understand that the CO_2 emissions from the production of a leading electric-only car battery could be equivalent to those created by 60,000 miles of emissions from a conventional internal combustion engine. Also, is any organisation producing unbiased figures that allow us to compare both tail pipe and manufacturing emissions from different classes of vehicles?
Jon

Inyouropinion

Skills test

Our readers debate the issue of an engineering skills shortage

I believe there is no skills shortage. Some employers only look at people from within their own business without understanding, or realising that a lot of the 'skills and experience' they are looking for can be obtained outside of their business sector.
Richard

The people we have got are getting older and, because of changes in lifestyle, they are able to retire earlier. We have lost several people in the last few years in their late 50s/early 60s. Although we do train our own apprentices this experience is lost.
Bryan Hyslop

It hasn't changed significantly in my 37 years in the Industry. Same moans, same catastrophe just around the corner. It is like fusion power that's been 30 years away for at least 40 years.
Mike West

In the last five years I have observed many qualified engineers who have moved to companies that pay for their talent. Unfortunately none of the companies were located in the UK. We have to decide whether we make engineering an attractive future – youngsters have the freedom of choice and are not choosing engineering.
Gerry Clarke

However the engineering professions try to dress it up by promoting environmental engineering-type activities, young people, on balance, probably see engineering as having an adverse impact on the planet. Also, too many 'zombie' low-productivity, low-margin, low-growth companies are hoarding engineers. The lack of real enthusiasm for engineering companies to actually invest in training for themselves probably backs this up. They'd rather have others do the training for them.
Paul Reeves

I think the real problem is spotting the talent. I have seen plenty of degree-qualified 'engineers' who are not up to the job. There are people with real skill and enthusiasm but they lack formal qualifications and therefore don't make it past the CV stage.
T Mair

Two main issues stand out starkly in this debate. Many employers pay peanuts and expect to get skilled engineers. Many are terrified that a hard Brexit might not only shut down a massive market to us but repatriate the many skilled engineering staff from mainland Europe. We are seriously considering moving production and/or design functions to Holland.
Michael Reid

Thesecretengineer

Our anonymous blogger is frustrated with expectations for an all-in-one engineer

One of the accusations that generally gets flung about round here is that the term 'engineer' is used far too freely. The perceived degradation that comes with its use for technicians and mechanics seems to invariably cause ire and to raise hackles. However, I would suggest that the lack of understanding by all and sundry regarding what engineers are, and engineering is, has another undesirable side effect.

Thus it is not only a problem that those who are not qualified to be called so are considered engineers. There is also the fact that if you are an engineer then you are personally expected to have a breadth of knowledge and skills that range all the way from designing a nuclear reactor to whittling a nut and bolt out of a couple of lumps of steel using nothing more than a blunt penknife. There are people I know who could do either, and possibly one or two who could do both, but these particular individuals fall into the 'genius' or possibly even 'savant' categories.

Speaking for myself, I fully admit that I'm not great at the 'practical' stuff. I know that there are some who will reel in horror at such a revelation, wondering how you can pursue a successful career in engineering when you find it difficult to even cut a piece of bar straight. I can tell you that so long as you've had a go at this sort of stuff you can develop a feel for it, even if that feel cannot be translated into worthwhile application. I can also tell you that it is a frequent source of frustration, thinking 'if I can just quickly hack this widget out I can prove the principle I am trying to introduce' – and then having to wait until someone else can do it for you. I am actually a lot better than I used to be but a natural lack of dexterity coupled to occasional problems with fine movement of the digits ensures I will never be a craftsman in this sense.

Unfortunately though, if you let slip you are an engineer then you open the flood gates to 'could you just fix this doo-hickey, the spring's missing but I'm sure it will be easy for you – after all you're an engineer'. No matter the protestations, much like a doctor at a dinner party is expected to successfully diagnose a problem from the vaguest of symptoms, you are seen as this mystical being. This blasé view of professional capability tends to manifest itself in a different way at work, or at least such are my experiences at the moment.

I know that when I talk of engineering, you and I realise that this covers a multitude of specialist areas. The knowledge required to carry out a particular role tends to overlap with others but that does not make you an expert in someone else's field. Thus, as a senior design engineer, I am aware of production techniques and theories – such that I can design sympathetically for ease of manufacture – but you wouldn't expect me to design a set of mould tools or set up a complex production line with timed routings. Unfortunately though some think that an engineer, is an engineer, is an engineer. Thus I have recently been asked, without any guidance or experience, to produce a set of assembly build instructions for an existing product that I have had no involvement with. Of course I could do it given the time and access to relevant information but, as I rather firmly pointed out, it would be much better for the production engineer to actually do it. As it happens it was passed on to the electronics engineer. After all he's an engineer so he can do it.

Join the debate theengineer.co.uk

Seeking out a social impact

The finalists in the MacRobert Award offer a valuable insight into innovation that is making a difference in the world at large

The finalists for the Royal Academy of Engineering's coveted MacRobert Award for engineering innovation have just been announced. The three companies vying for the prize – Darktrace, Raspberry Pi and Vision RT – have each produced world-beating products in the UK. I had the privilege of accompanying the MacRobert judges on some of their visits to these companies which offered a valuable insight into innovation at work. While the products and companies cover diverse technologies and sectors, the visits showed they are united by more than the quality of their innovations.

For all three companies, the teams were inspired by a clear market need with significant societal impact: for Darktrace, it was the growing threat from cyber security; for Raspberry Pi, the declining engagement of young people in computing; and for Vision RT, the need to make radiotherapy safer and less stressful for cancer patients.

In 2016, cyber-security breaches were estimated to have cost UK businesses around £30m, in addition to disrupting many vital services and eroding public confidence in online systems.

Darktrace recognised the opportunity to apply machine learning to the cyber-security challenge, in the process pioneering a novel approach that moves the cyber-security industry beyond perimeter defence models to an intelligent detect-and-neutralise capability, described by one of the MacRobert Award judges as: "neighbourhood watch for the digital world". In the four years since its launch, Darktrace has seen a meteoric take-up of its Enterprise Immune System software, with blue-chip customers in 60 countries and a global employee base of over 400 people, half of whom are in the UK.

The team behind Raspberry Pi was inspired to create their now iconic products by concern at the declining numbers of applicants for computer science degrees. Recognising the pivotal role that early home computers such as the BBC Micro, Acorn Electron and ZX Spectrum had played in shaping their own enthusiasm for computing and advancing their understanding of programming, they set about creating a new, easy-to-use, low-cost, programmable computer that would be accessible and engaging for school-age children. Their unwillingness to compromise on cost, quality or usability ultimately led to the creation of an entirely new category of computing device that not only took the educational and maker markets by storm but also proved extremely popular for industrial use due to its stability and cost-effectiveness. With 14 million devices sold to date and an innovative business model whereby the trading company feeds its profits to the parent educational charity, Raspberry Pi is achieving stellar success in meeting both its economic and social objectives.

For Vision RT, the team's motivation came from a desire to improve the experience of patients undergoing radiotherapy. Almost half the population will develop cancer at some time in their lives, and around half of all cancer patients require radiotherapy as part of their treatment. However, the radiation beam used to kill cancerous cells can also harm any healthy cells that are exposed to it, which means accuracy is vital. Vision RT began in an attic in 2001 and has gone on to pioneer surface-guided radiation therapy that helps doctors target cancerous tumours with pinpoint accuracy, reducing harmful collateral damage during treatment and eliminating the need for patients to have their skin tattooed. From the first prototype system deployed at the Royal Marsden Hospital in 2002, nearly 1,000 systems have now been sold and Vision RT has established itself as the global market leader. Its system has regulatory approval in 34 countries, and is available at the top five 'best hospitals for cancer' in the US, as well as a growing number of UK hospitals.

> Vision RT began in 2001 and has gone on to pioneer surface-guided radiation therapy

The visits also brought to light another feature shared by the finalists: they all have links to the University of Cambridge. Darktrace is a Cambridge-based company and its technology is underpinned by Bayesian algorithms developed by mathematicians from the university. Raspberry Pi is also Cambridge-based and many of the team are graduates of the Cambridge computer science course. While Vision RT is headquartered in London, one of the founders studied at Cambridge. The strength of the Cambridge entrepreneurial ecosystem is well known and the pedigree of this year's finalists reinforces the crucial role that universities play in training people who go on to create world-leading businesses – a role that is arguably more significant than the creation of 'spin-out' businesses from the universities.

The MacRobert Award is only open to companies with a strong UK presence whose innovation has been developed by a UK-based team so the provenance of the finalists is perhaps not surprising. However, it is very heartening to see that all three finalists are also choosing to manufacture their hardware in the UK. This is not for reasons of sentiment; rather, they believe that UK manufacturing offers the best value, quality and reliability. This is a trend we hope to see continue, and a useful reminder that despite the very real challenges faced by UK engineering companies, our innovation and manufacturing base can compete with the best internationally. We look forward to celebrating the achievements of our finalists – and finding out who wins – at our awards dinner on 29 June.

Dr Hayaatun Sillem is deputy chief executive of the Royal Academy of Engineering

First in Line

The world's largest range of linear systems from a single source

INA linear bearings and guidance systems from Schaeffler UK offer first quality products to meet linear guidance requirements across a comprehensive range of applications.

From simple guidance mechanisms for low to moderate accuracy to heavy duty systems offering high rigidity and load carrying capacity, the INA range is deservedly first in line. Taking the quality envelope that bit further are X-life premium products that feature enhanced characteristics including increased load carrying capacity, higher rigidity, lower operating temperatures and reduced noise levels.

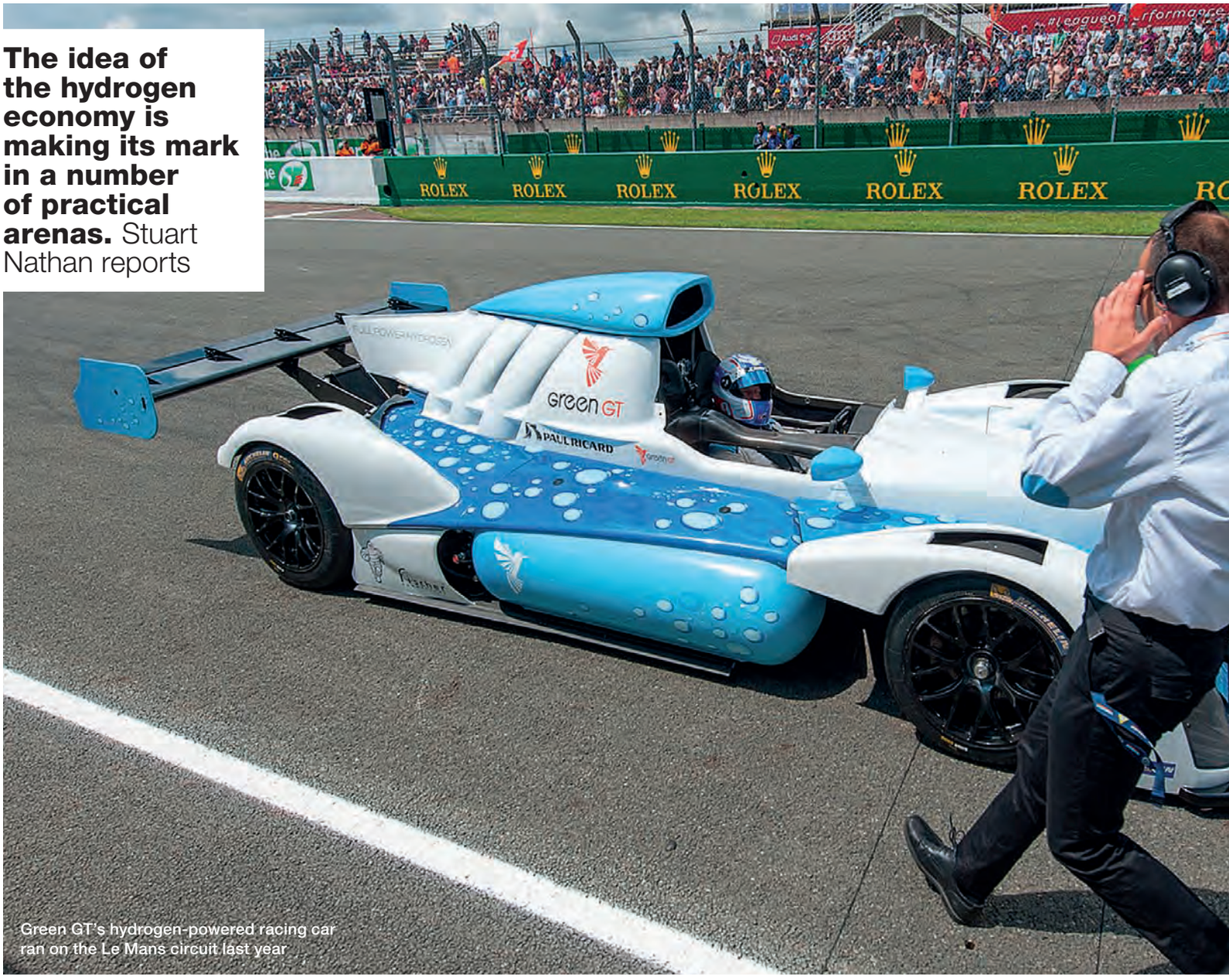
So, whether you are designing a new machine tool, packaging machine, medical device, door closing mechanism or anything else that involves linear motion, the INA linear product range can provide the perfect solution.

Schaeffler (UK) Ltd E-mail: info.uk@schaeffler.com | www.schaeffler.co.uk

SCHAEFFLER

Essential element

The idea of the hydrogen economy is making its mark in a number of practical arenas. Stuart Nathan reports



Green GT's hydrogen-powered racing car ran on the Le Mans circuit last year

The concept of a hydrogen economy has been with us for many years, and in some people's minds it is grouped with nuclear fusion as something that is always promised for the future but never seems to get any closer. But owing to advances in technology, changing circumstances in politics and concerns over health and the environment, the idea may be poised to make a comeback.

The hydrogen economy concept is an artefact of a particular time and set of circumstances. It was first proposed in 1970 at a seminar run by General Motors by a US electrochemist named John Bockris, although he was building on ideas put forward by geneticist JBS Haldane as far back as the 1920s.

Bockris suggested that hydrogen, which he envisaged as being generated using solar energy from southern latitudes and wind from northern ones, could be an alternative fuel for vehicles, with electric motors replacing internal combustion engines running on electricity generated through a fuel cell. This technology dates back to 1839, and uses a combination of hydrogen (produced by an industrial process) and oxygen from the air under controlled conditions to initiate an electric current while also producing heat. At the time, fuel cells were in the public eye because of their successful use to generate electricity for the Command and Lander Modules of the Apollo missions. There was a specific reason for Bockris's suggestion at that time: the world was on the brink of an oil crisis. The Middle East was curtailing oil production, there were predictions of oil running out in the near future and of prices climbing to $500 per barrel, and there was a widespread belief that an alternative transport fuel could be needed quickly.

Of course, the oil didn't run out and prices never climbed that high, so Bockris's vision of the future was never needed. But the hydrogen economy, in some form or another, has never completely faded away; every few years, it seems to rise to prominence again.

> "The hydrogen economy, in some form or another, has never completely faded away"

The most recent revival of interest was in the early 2000s because of hopes it could help solve another problem: emissions of carbon dioxide into the atmosphere from internal combustion engines. Once again, we were to transition from an economy based on hydrocarbons (gas to generate electricity in large power stations, petrol or diesel to power vehicles) to one based most visibly on hydrogen, but actually based on electricity to a much larger extent than we currently are. And, once again, it didn't happen; this time because of cost of fuel cells, their limited capabilities at the time and a problem that still hasn't been resolved but that we will return to: hydrogen can't flourish as an alternative vehicle fuel without a distribution network for refuelling.

It might be thought that as the hype of the last decade has declined, the idea of a hydrogen economy is once again on technology's back-burner. But not only did it never go away, it is seeing some real progress in many areas that might make some aspects of the old hydrogen economy concept come much closer to fruition.

There is a large and active 'hydrogen community' in the UK, organised as part of a network called H2FC Supergen (H2FC, meaning hydrogen fuel cell, is one of the many abbreviations and acronyms that proliferate in this sector — see panel on p24 for more — while Supergen is an acronym for SUstainable Power GENeration). Now in its sixth year of operation, the H2FC Supergen is administered from a hub organisation at Imperial College London. It funds multidisciplinary research and produces white papers on how hydrogen and fuel cell technologies can affect energy policy.

The very term hydrogen economy is not universally popular among the community. "We don't like the phrase," commented Prof Marcus Newborough, head of business development for ITM Power, a Sheffield-based company that develops and manufactures equipment to produce hydrogen by electrolysing water. "It gets in the way of feet-on-the-ground developments year by year from a zero start point, which is pretty much where the sector is today. To come up with a complete economy based on hydrogen is well beyond the day after tomorrow; it's a long time in the future." Rather than this grand vision, Newborough prefers to focus on incremental introduction of hydrogen and fuel cell technologies as demonstrators.

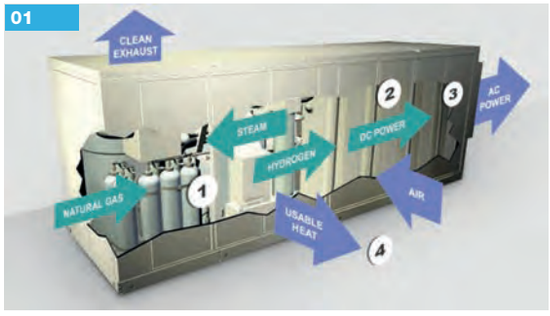
Prof Paul Dodds, who specialises in the impact of H2FC technology on policy at University College London (UCL), also pointed out the drawbacks of speaking about a hydrogen economy. "It kind of implies that everything you're going to do is powered by hydrogen, which isn't the case," he said. "Hydrogen is an energy vector such as electricity, but it isn't as good as electricity – you can't power your stereo with it." Hydrogen is, however, much easier to store than electricity, Dodds added; and this gets to the heart of why some in the community think that the energy, policy and technology landscape has changed since the early 2000s in favour of hydrogen technologies.

In the last decade, the hype around hydrogen was mostly concerned with its role in greenhouse gas emissions reduction from transport. This is still a factor, but related to this and rising in importance is the increasing deployment of renewable energy generation, its unpredictable and intermittent nature, and limited capacity of power distribution grids. Prof Dan Brett, a colleague of Dodds at UCL involved more with fuel cell research, said: "In a way hydrogen is more relevant than ever, because in the past hydrogen was very linked with transportation. But now with the huge uptake of renewables and the need for grid-scale energy storage to stabilise the energy system, hydrogen can have a real role to play, and what's interesting about that, in contrast to a pure battery play, is that there's a number of things you can do with it. You can turn it back into electricity, you can put it into vehicles or you can do a power-to-gas arrangement where you pump it into the gas grid." Dodds doubts whether turning it back into electricity is viable: the cycle efficiency is "pretty horrible", he said, "and there are so many other things you can do with the hydrogen".

Power-to-gas, however, is gaining interest in Germany, the Netherlands and the UK; for example, a project in Leeds that reported last year looked at blending hydrogen with natural gas in the gas grid as part of a gradual transition to a pure-hydrogen grid; it concluded that the polyethylene pipe-based distribution infrastructure was suitable for hydrogen-methane blends and that fairly small proportions of hydrogen in the blends has no effect on gas-burning domestic appliances such as boilers or gas hobs (Prof Newborough pointed out that all appliances on sale in the UK since 1996 have been tested and certified to be functional and safe with hydrogen content in a methane blend up to 23 per cent).

Using hydrogen as energy storage for renewables is

01



01 ITM Power's electrolyser technology is making hydrogen for refuelling stations around the M25

02 Fuel cells are now being made on production lines

03 Hydrogen can be blended with natural gas in municipal grids

Glossary
Navigating the terminology of hydrogen technologies

H2FC Hydrogen fuel cell
SOFC Solid-oxide fuel cell
PEM Proton-exchange membrane
FCEV Fuel cell electric vehicle
BEV Battery electric vehicle
ICEV Internal combustion engine vehicle

the subject of an EU-funded project currently underway on the Orkney Islands, which has an abundance of renewable generation sources (tidal, wind and wave) but whose electricity grid is unable to handle much of the power they produce. To get around this problem, electrolysers from ITM Power have been installed to use excess electricity to produce hydrogen from water. The hydrogen is used to generate electricity for boats docked in the islands' main harbour at Kirkwall, and also for the harbour facilities; the islands are purchasing a small fleet of vans with fuel cell range extenders and installing a filing station; and two local schools on small islands use hydrogen for heat and electricity. "The islands currently have to curtail about 30-40 per cent of [the renewable electricity] they generate, which is a frustration," said Newborough. "They could deploy even more wind; they've got the space to do it and the motivation, but they can't sell the output into the electricity grid because it doesn't have the capacity to take it away into northern Scotland. So they're demonstrating heat, transport and generation applications all with electricity that would otherwise be curtailed."

This sort of system is ideal for islands and isolated territories where excess energy from renewables would otherwise be curtailed because of grid capacity, Newborough explained. Could the whole UK itself be regarded as such an isolated territory? "Absolutely." he said. "There are hundreds and hundreds of terawatt hours of renewable energy just on the North Sea coast alone, and even more resource as you go offshore, but if you look ahead to 2050, the question becomes, how do you harness those resources? If you try to cram them all onto the electricity grid, you won't be able to do it; it'll cost a fortune to upgrade the grid sufficiently and you'll still end up curtailing a lot of it. So if you push some of the electricity into the grid and turn the rest into hydrogen, you can use that for fuelling vehicles, decarbonising the gas grid, making ammonia or other chemicals. It becomes a feedstock on which you can base a very low-carbon future." For hydrogen storage, Newborough favours geological features such as underground salt caverns, which are already used to store natural gas in the UK and Germany as a buffer for peak demand.

Newborough added that there is potential to make the gas grid much more green: rather than using fossil-fuel natural gas, he suggested making more use of methane from biogas and using hydrogen from renewables to make synthetic methane from the CO_2 content of the biogas, which approaches 50 per cent.

This sort of vision for a UK on a partly hydrogen economy and a greener gas grid is extremely radical and long term, and would require very ambitious government policy, said Newborough. But among the changes since the early 2000s are the presence today of commercial hydrogen-powered vehicles, from manufacturers such as Toyota (whose fuel-cell-powered Mirais went on sale last year), Hyundai

02

03

and Nissan, with GM and BMW reportedly planning to launch fuel cell electric vehicles (FCEVs) in the near future.

Admittedly, these are currently expensive and built in small numbers, but they are made on production lines (as are the fuel cells that power them) which, as Dodds pointed out, is a key factor in reducing production costs and final price, as has been seen with battery-electric vehicles and hybrids in the last two decades.

There seems little doubt that in terms of technology development, fuel cells for automotive application are fit for purpose. The old issue of establishing a hydrogen-fuelling network has still to be overcome, but progress is being made in the UK, starting with filling stations being opened around the M25 using ITM Power's electrolysers connected to on-site wind turbines. This is a small first step, of course; estimates of the number of filling stations that would be needed to cover the whole UK vary. Newborough pointed out that there are 8,000 petrol stations in the country, but that the H2Mobility project, a government-industry study that reported in 2014, found that 1,150 stations by 2030 would be sufficient for a first phase.

Dodds said that the number for the UK might be as small as 60 under the right circumstances. "There's nothing wrong with FCEVs," he said, "but you don't get the best advantages from cars; those come from heaver vehicles such as buses, taxis and lorries that do longer distances, and from refuse trucks." This relates to another change in circumstances since the early 2000s – rising concern about air quality in cities, often blamed on larger vehicles powered by diesel engines. With FCEVs producing only water vapour in use, this problem is avoided. "These vehicles don't need a whole refuelling network; they need depots equipped with refuelling that would be established and operated by local authorities, and if they were available to the public at certain times of day, they could form the kernel of a distribution network."

Fuel cells represent a better way of electrifying heavy vehicles than batteries, Dodds said. Batteries are heavy and as more are added to a vehicle to expand its range, eventually they add so much to the vehicle's weight that the opposite happens.

Dodds added that regulations limiting the use of diesel in cities might turn out to be the deciding factor in encouraging the spread of hydrogen-powered vehicles; in which case the change is unlikely to start in the UK or in Europe at all, but in east Asia. China has already signalled its belief in H2FC technology by curtailing subsidies for research into battery electric vehicles (BEVs) and increasing support for fuel cells, and is planning to bring 300 fuel cell buses into service this year (this might not sound a lot, but it's twice as many as were in service worldwide at the beginning of the year).

Elsewhere in east Asia, Japan currently boasts the world's largest number of fuel cells in operation by far, with numbers currently nudging a quarter of a million and rising steadily. But these aren't in vehicles; they're in buildings, providing combined heat and power (CHP). Used in this way, the efficiency of fuel cells at utilising the energy content of hydrogen can approach 90 per cent; the hydrogen and oxygen combining to produce water release energy both in the form of heat and providing electromotive force to produce electric current. With the heat transferred to the water, it exits the cell stack at about 70°C, plenty hot enough to run the central heating in a Japanese home. Domestic fuel cell stacks are made by Toshiba and Panasonic (which both make proton-exchange membranes – PEMs) and Aisin Seiki, which makes more expensive SOFCs. These are heavily subsidised by the Japanese government to make household purchase affordable (they cost around as much as a car) and are known as Ene-Farms. The roll-out plan from the ministry of economy, technology and industry, formulated in 2014, has a target of 5.3 million units in service by 2030 and is currently on schedule.

04 The Toyota Mirai FCEV has been available since last year

05 The Pininfarina H2 Speed vehicle, powered by Green GT fuel cells

"You don't get the best advantages from FCEV cars; those come from heavier vehicles such as buses, taxis and lorries"

Dr Paul Dodds, UCL

Fuel cell future

While automotive fuel cells and electrolysers are considered to be mature technology, there is still space for technology innovation in the FCEV sector, according to patent lawyer Russell Edson of Withers & Rogers. A key area of R&D for automotive companies is how the cars will be refuelled with hydrogen. "It's a high-pressure system," he said, "and it makes the refuelling more complex than just sticking a nozzle in a hole and filling your tank with petrol."

This interface between car and refuelling system is likely to require some collaboration between producers of the refuelling technology and carmakers. Edson said: "The automotive manufacturers will try to make sure that one company does not completely monopolise the connection to vehicles."

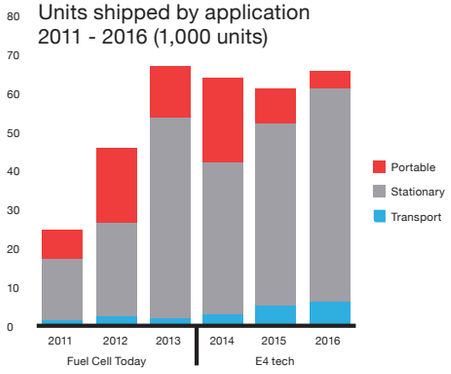
Edson agrees that large vehicles such as buses and lorries are likely to be the first major users of fuel cell technology, and that air-quality regulations will be an important driver. "If haulage and public transport operators are told you need to get rid of internal combustion engines, I think that might be what pushes the hydrogen to the fore," he said. "The quick answer for dealing with the local pollution from big vehicles is to use hydrogen. I think that regulation is likely to be the most important thing pushing that to the fore in that sector."

Such technology may not be suitable for the UK, said Newborough. “The heat demand in this country is so seasonal and peaky. There are so many gas boilers that are pretty efficient nowadays and people are happy with them. There’s also the issue of the ratio of heat to power. Imagine a cold February morning at -10°C on a whole street, with everyone’s boiler cutting in at the same time. The heat need at that point in kW is huge relative to the electricity need, but on a milder day the ratio is completely changed. The ability of CHP to match these real-time varying heat demands of people living and working in buildings is ultimately limited.”

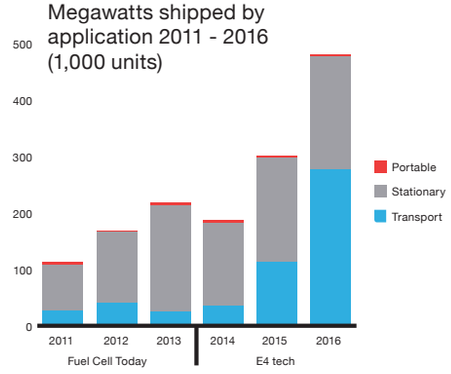
The experts contacted by *The Engineer* believe that there will be few concerns of public acceptance of hydrogen from a safety point of view. The low density of the gas means that it tends not to collect at ground level as with petrol vapours, though Dodds suggested that the high-pressure storage needed for hydrogen could possibly be a bigger concern. “You need a 700-bar tank, and that’s a lot of pressure. They’re made of carbon fibre, which is very strong. They have all been crash tested successfully; they would only be a problem if you knocked the end off and that isn’t likely. But it could still be a factor.” These tanks are now the most expensive component of a FCEV; improvements in fuel cell design have brought the cost of these down considerably in recent years, said Dodds, with a key innovation being a reduction in the amount of platinum needed in the cell to catalyse the reaction between hydrogen and oxygen.

Other applications are also growing, albeit in early stages: a FCEV ‘supercar’ concept vehicle designed by legendary Italian firm Pininfarina and powered by Swiss electric powertrain specialist Green GT won the best concept vehicle prize at last year’s Geneva Motor Show, while Green GT produced the first fuel-cell-powered racing car to run on the Le Mans circuit; meanwhile, the German national aerospace centre DLR has flown the first entirely fuel-cell-powered electric aircraft. Budget airline EasyJet is in the final stages of planning trials of a fuel-cell-powered taxiing system, with electric motors installed in the nosewheels of aircraft.

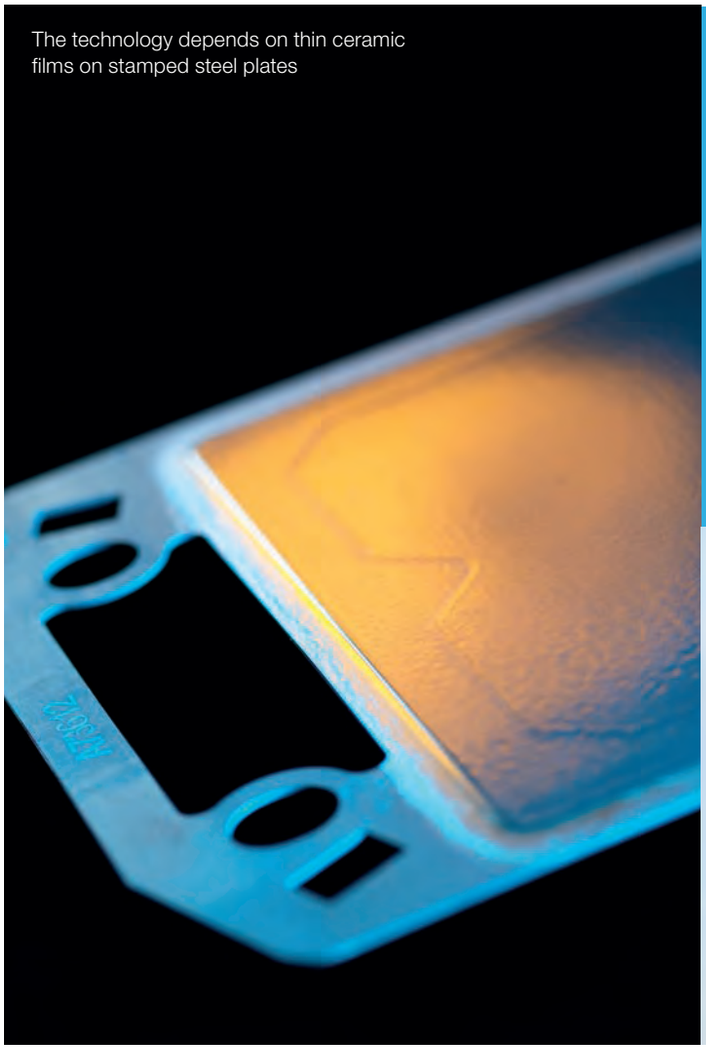
Development in fuel cell application markets



Source: E4tech



Source: E4tech



The technology depends on thin ceramic films on stamped steel plates

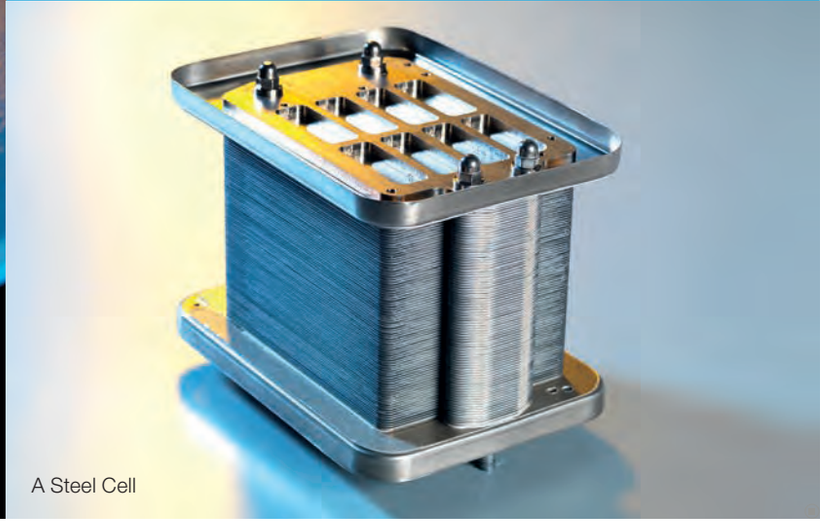
Ceres Power steels itself

UK firm offers innovative H2FC technology

Ceres Power, based near Crawley in Sussex, is one of the few UK manufacturers of commercial fuel cells, and also one of the most innovative in the sector, with a technology that centres around low-cost materials and that is well suited to mass production.

The company makes solid-oxide fuel cells, where a thin layer of a cerium-containing ceramic called ceria is printed onto stamped steel plates using technology originally developed for solar panels. These so-called Steel Cells are more robust than all-ceramic cells, and more efficient than PEM cells, according to the company.

Ceres Power has been working with Honda since last year to develop Steel Cell technology for a variety of applications, and has this month unveiled a two-year agreement with an unnamed global OEM, supported by Innovate UK, to jointly develop the solid-oxide fuel cells technology for residential applications.

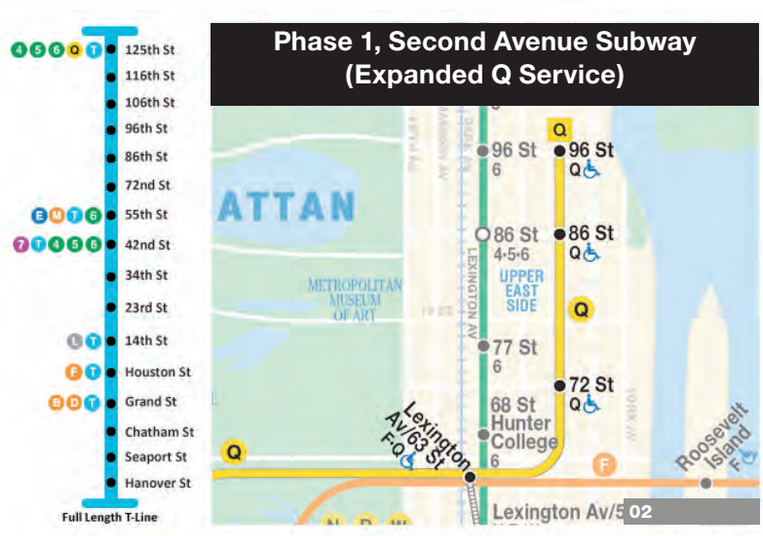


A Steel Cell

01

The line that time forgot

New York had to wait nearly 100 years for the Second Avenue Subway. Andrew Wade reports



02

03

01 Phase One is served by rerouted Q trains

02/03 The three new stations serve the Upper East Side

The first day of 2017 brought New Yorkers a belated Christmas gift, one that the city had been promising for almost a century. First proposed in 1919, the Second Avenue Subway (SAS) was part of a plan to accommodate the post-war explosion in passenger numbers using the system, which had risen to 1.3bn by 1920.

At the time, the Upper East Side was served by elevated trains on both Second and Third avenues. Initial plans called for the demolition of both, and a brand-new subway line connecting Harlem in the north to the financial district in the south, as well as spurs extending out to Brooklyn, Queens and the Bronx. But by the time both 'Els' had disappeared mid-century, there was still no sign of the SAS. Work eventually got underway in the 1970s, but New York's fiscal crisis soon saw it grind to a halt. The SAS became 'the line that time forgot', an in-joke among New Yorkers: "I'll pay you back that money when they finish the Second Avenue Subway."

Thankfully, the 1990s and 2000s saw an upturn in the city's fortunes, leading to new plans for the line's completion. Carried out over four phases, the project would be the biggest expansion of the subway system in 50 years. In 2007, a consortium of Schiavone/Shea/Skanska (S3) was awarded the tunnelling contract for phase one. The first phase would see three new stations constructed, dotting the Upper East Side at 72nd, 86th and 96th streets, and relieving pressure from the Lexington Avenue line: the busiest in the entire country, carrying around 1.3m passengers each day.

"At 92nd Street to 95th Street we built a large open-cut launch-box," explained

04

05

04 All the new stations feature mezzanine levels

05 One of the TBMs used on the subway dig

> "When people took the tour, they took ownership of the subway"
>
> Gary Almeraris, Skanska

Gary Almeraris, Skanska USA Civil vice-president of operations, using a map outside the new 72nd Street station. "That was going to be part of the future station and the interlock, but we also used that to launch our tunnel-boring machine [TBM]."

Just south of the launch box, the engineers encountered a problem. Rather than the hard rock the team had anticipated, they found a section of mixed soil and rock, which the TBM couldn't drill without risk of collapse.

"The rock profile had a big dip in it for almost 150ft, a big dip where the rock dropped off," said Almeraris. "Now, that's the tunnel on the east side. We went over to the tunnel on the west side, and found rock. So we made a decision with the MTA [Metropolitan Transport Authority] to slide the machine over and drive this [west] tunnel first."

In the meantime, they had to figure out what to do with the east tunnel. They decided to freeze a 147ft (45m) section of soil/rock mix before boring through. Vertical holes were drilled from the surface in a roughly 1 x 1m pattern, and a chill plant used pipes to circulate brine through the ground at -27°C. This essentially turned the zone into a giant block of ice, allowing the TBM to safely bore through. It was a technique Almeraris had previously used on the Big Dig in Boston, and also in Queens. But it came with a price tag.

"It's an expensive solution," he said. "But you've got to be careful… you've really got to do it and get out. You can't procrastinate."

"Behind us, because you have time before it'll melt, we installed steel rings, and we put up shutters and basically filled it with concrete, and mined our way through that zone. We mined through there working 24/7."

While still at college in the 1970s, Almeraris had worked on a Midtown tunnel that had sat unused for decades as the money ran dry. Now, he was leading a crew to help breathe new life into it. From the uptown launch-box, the team mined down to 63rd Street, where the pre-existing tunnel ran west from Lexington Avenue. Cutting across Manhattan through the southeast corner of Central Park, it then curved south down Seventh Avenue towards Times Square, New York's bustling epicentre. To get to the tunnel, the team first had to perform a delicate manoeuvre at a station in use around the clock.

"The station at 63rd Street was built with the intention of a connection to the future Second Avenue line, so they made a wide underground cavern, and split it in half with a dividing wall," said Almeraris.

Employing methods similar to Crossrail, the team drilled through to the dormant section of 63rd Street station, while F trains serving Queens passed just a few feet away behind the dividing wall. A major milestone was reached in September 2011 when the TBM broke through the station's bellmouth, marking an end to the tunnelling. Laying the track and fitting out the stations would take several more years, however, complicated by Manhattan's high-density population.

"A big thing on this programme – on Second Avenue in particular – was community," said Almeraris, who worked on construction of the 86th Street station for Skanska once the tunnelling was completed.

"The people are great, but they don't want you shaking up their houses and taking their parking spaces… you had to make sure all the businesses had access. You had to move their garbage for them. The MTA went out of its way to try and keep them well informed. We actually had tunnel tours."

Often led by Michael Horodniceanu, MTA Capital Construction president (known to all as Michael H, and usually seen sporting a bow-tie), the tours involved bringing local residents down to see the work, helping the community engage with the project.

"When the people took the tour, they took ownership of the subway. It was amazing," said Almeraris.

The new stations are bright and airy, featuring full-length mezzanines and island platforms. For now, they're served by a rerouted Q train, which comes in from Coney Island in Brooklyn, and travels up Broadway once it reaches Manhattan. The express service connects Midtown West with the Upper East Side for the first time, and the MTA recently announced that daily passenger numbers have already swelled to 176,000, a 42 per cent increase from January.

"This is the big reliever line," said Almeraris. "It's relieving a lot, but it's going to relieve more, and improve the community of Harlem with phase two."

Phase two – at least 10 years away – will see the line extended north to 125th Street, then turning west to connect with the Lexington Avenue line and Metro North at a massive new station that will swallow a sizeable chunk of the estimated $6bn budget.

"It's going to have three stations," explained Almeraris. "106th Street, 116th Street, and the mother of all stations at 125th Street. This station is going to be 1,370ft [418m] long."

Phase one came in on budget at $4.45bn, but with just 3.2km of new tunnels, this makes it substantially more expensive per kilometre than Crossrail. Manhattan's congested underground infrastructure makes building new subways difficult, and that translates to the balance sheet. This, in conjunction with potential issues around land acquisition, has led to questions being raised over the completion of phases three and four, which would involve the construction of 10 new stations, as well as about 8.5km of new track, and the introduction of a new T-line service running the length of Manhattan. For now though, Almeraris is happy to reflect on what's been achieved – the birth of a brand-new subway line for New York, carved right through the heart of the city that never sleeps.

"In the four-and-a-half million man hours, we didn't have any life-changing injuries for anybody. That's probably the thing I'm most proud of."

NEC BIRMINGHAM, UK | 26-28 SEPTEMBER 2017

interplas

Innovation Happens Here

REGISTER NOW

www.interplasuk.com

Academy ambitions

The chairman of the RAEng's Enterprise Hub is looking to change how UK technology businesses operate. Stuart Nathan reports

The basement of the Royal Academy of Engineering's headquarters, just off The Mall near Trafalgar Square, London, has a new look: a clubby one, with open spaces set out for conversation, modern artwork, and the vaulted spaces that support the building above converted into conference rooms. Smelling of fresh paint, carpeting and coffee, they are now the headquarters of the academy's Enterprise Hub, an organisation with the ambitious aim of changing how technology-based new businesses in the UK operate.

The hub's founder and first chairman, Ian Shott, has had a long career both with large corporations and in starting his own businesses. Shortly to be honoured by the academy with its President's Medal, he sat down with *The Engineer* to explain how his experience and impressions of UK industry led to him setting up the Enterprise Hub.

It began with a call from the then-president of the RAEng, John Parker, to help link up with the Royal Society to manage a £7m investment fund. "I didn't think that a professional institution should be running an investment fund and I thought the scale of the fund was trivial," Shott said. "Moreover, I thought there was a fundamental issue in Britain that was nothing to do with money; but was to do with the very poor quality of propositions; the lack of role models; the lack of an ecosystem; the lack of proper mentors; and the lack of good case studies." Part of this was just to do with the atmosphere around entrepreneurship, he added. "If you look at what has happened in the US, [computer industry pioneer, entrepreneur and investor] Hermann Hauser uses the phrase 'there's entrepreneurialism in the air'. If you go to Boston, Massachusetts, or Silicon Valley or San Francisco, I guarantee that if you go into any bar, any restaurant, any tennis club, you'll see entrepreneurs and lawyers at different ages who have been involved in deals; and bankers and funders all talking about business; but if you go into the same places in Britain you'll find people talking about the latest cynical article in the *Daily Mail* about politics or whatever. So I decided that was the problem."

Young entrepreneurs discuss their ideas at the opening of the Enterprise Hub space

Shott said he knew that money was available in Britain, but when running his pharmaceuticals process research, development and scale-up company Excelsyn, he had studied the finance scene in the country closely. "The British Venture Capital Association has 450 members and I would assess that barely 100 are running a venture capital model," he said. "The majority are running a scaled-down private equity model; the difference being private equity looks for five-year track records, order books and so on, and venture capital is about start-ups where there is no track record and they are taking a punt. Another problem is that most of those companies do not employ people who are knowledgeable in the sectors, particularly in engineering and technology. And quite a lot of those companies, because you're managing people's funds, are told not to invest in manufacturing, science engineering and technology. I would assess that applies to 300 of the 450."

The RAEng was at the time setting up an Enterprise Fellowship scheme to support young entrepreneurs, which Shott had also been asked to advise on. "I thought, as a chemical engineer, this is like an experiment or a pilot study, and we can build it up into something much bigger where the key ingredient is the Fellows of the institution and not pennies in a fund," he said. "A key part of this was the funding competitions run by the academy. We would use the Fellows to judge the competitions and we would say, being shamelessly elitist, we will only

Enterprise Hub mentee George Frodsham has developed a drug-free malaria treatment

fund the very best projects or technologies with the best individuals that we really believe could be creating and driving a business even if they wouldn't be a CEO."

The winners of these competitions are taken under the wing of the Enterprise Hub, and appropriate academy Fellows act as mentors. "To run start-ups you need to have a certain risk tolerance," Shott said. "If you're going to deal with risk you have to have mechanisms to mitigate it. These are basic engineering principles – engineering is the obviation of risk – so by using some screening to get the best people; by giving them selected mentors who are the best people in the world they could have helping them; by giving them funding and training; and introducing them to funders, we're creating a landscape and ecosystem that will mitigate risk and accelerate progress."

Shott is very serious about being elitist. Only a small proportion of competition entrants are invited to interview stage, where they are expected to present their technology idea, team and business proposal to a panel of up to a dozen academy Fellows. It's daunting and it's supposed to be. "It's a rigorous and ruthless screening programme," Shott said. But the idea is to create an entrepreneurial atmosphere to rival the successful ecosystems of the US; to create companies that can demonstrate success and grow quickly. "If we litter the pavement with failure that's not going to get us there very quickly, so I'm looking to scatter success as quickly as possible."

> "The investment problem in Britain was nothing to do with money but to do with the very poor quality of the propositions"

Company growth is obviously an important issue for Shott; it's one he faced with Excelsyn and that he returns to frequently. "Britain was at the forefront of all this in 1899 but had completely lost the plot by 1999. We kind of started again in baby school and everyone was talking about the language of the 'valley of death' and start-ups, but the real problem is the lack of scale-up," he said. "We need to be helping medium-size companies become more ambitious. I was a MacRobert Award judge for four years and, each year, of the top eight companies, half were SMEs and half were big. And when we interviewed the SMEs, often they didn't know what to do to get beyond that £10-£20m size. They didn't know whether the best thing to do would be to get out and sell, and none of them thought they should be out buying other businesses and becoming a half-billion-pound company. I see this with companies I deal with at [investment company] Shott Trinova; most of them are devoid of ambition or structure to get much bigger."

Shott said he's been successful with the companies he supports at Shott Trinova: "In my portfolio, companies are growing at between 35 and 60 per cent per annum compound." And he's confident the Enterprise Hub can also have success. "In three-and-a-half years, our 52 mentees have hired 167 people and raised £33m. I've lined up all these companies of different types – not all VCs, there are crowd funders and banks or parts of banks – and there is £1bn of free available cash there to be spent. Compare that to £7m with the Royal Society, which has now been taken over by [Hermann Hauser's] Amadeus portfolio, which is much more sensible. We are funding the Enterprise Hub at £1-2m, so that can leverage £1bn or more.

"We've created, I think, a new model but we have limited capacity here because we only have 1,000 Fellows and I believe only a quarter of them are capable and competent to be mentors. A pure professor of astrophysics probably wouldn't be any good; somebody who is full-time running Rolls-Royce doesn't have the capacity; an R&D director who might never have started a business or dealt with banks wouldn't be much help. But I'm happy to share the model and if we think of the world of opportunity as an iceberg, we're the tip."

CareerCV

Ian Shott, founder, Royal Academy of Engineering Enterprise Hub

Education

1978 BSc in chemical engineering, Imperial College London

1988 Marketing diploma in advanced industrial strategy, INSEAD

Career

1987 Group marketing manager, ICI
Shott held several technical and production manager positions at ICI in the UK and Europe before taking this role

1988-92 Global general manager, ICI/Zeneca
1992-97 senior vice-president, Lonza
Shott was involved in Lonza's acquisition of Celltech Biologics, and the formation of an alliance with SmithKline Beecham

1997-2002 President and chief operating officer, Rhodia ChiRex
2004-11 Non-executive chairman, Centre for Excellence in Life Sciences
2004-11 President, technical vice-president and council chair, IChemE
2003-2010 Chief executive, Excelsyn
Shott founded pharmaceuticals process research, development and scale-up company Excelsyn and grew it to a £12m turnover concern before selling it to AMRI in 2010

2010-12 Adviser to AMRI chairman and CEO
2012-present Managing director and chairman, Arcinova and Shott Trinova
Arcinova is a contract R&D business in the new drug development sector; Shott Trinova helps SMEs in the chemical and biotech sectors

Other positions

2007-present Fellow, Royal Academy of Engineering
2008-15 Governing board member, Innovate UK
2013-present Chairman, Industrial Biotechnology Innovation Centre (Scotland)

Watch out for the asteroid!

Novelist Jon Wallace considers the science fiction implications of engineering stories that have caught his eye. This month, the enormous latent threat of the asteroid

Perhaps more than any other apocalyptic scenario, the asteroid strike holds the potential to expose humanity's hard-won evolutionary supremacy as little more than a brief spark in an unimaginably vast darkness. The more we learn about asteroids (or 'near-Earth objects') the more we realise how helpless we are before them, and how blind we are to their approach. The threat is so enormous it satisfies both deist and atheist resignation: one before the wrath of a vengeful God, the other before cruel chance played out in an indifferent universe.

Most of us feel safer by losing ourselves in numbers: we read that the near-Earth asteroid 1999 AN10 will whizz by 380,000km away in 2027 – and suppose this sounds far enough; or we say 'looks like the grandkids will have a hairy 2095 waiting on 2010 RF12' and abdicate worry to the future. Our minds seem well adapted to dismissing Damoclean threats in this way, although this grows harder the more we learn. Neither the Chelyabinsk meteor of 2013, nor 2017AG13 this year, were detected until they had already arrived. In such cases we recall animations of startled dinosaurs looking up at a ball of fire billowing across the Cretaceous sky, and our nerves jangle. Perhaps the fates won't cut it, we think. Perhaps we should look into this.

So it is that *The Engineer*'s report on May's Planetary Defence Conference gives us heart. The European Union's Project Neotwist, we learn, aims to study the alteration of asteroid paths by use of a kinetic impact. In fact, this project is the lowest of our ambitions when it comes to asteroids. The scientific community increasingly views the asteroid less as a hazard in the ocean of space and more as giant, floating goldmine. NASA is fast-tracking a mission to the 16 Psyche asteroid, a body so crammed with ore it might fetch £8,000 quadrillion in today's market. No wonder entrepreneurs of all kinds, from the Luxembourg Grand Duchy to James Cameron, are backing enterprises to harvest Earth's humble rocky neighbours, thinking of them as our solar system's 'low-hanging fruit'.

Certainly they are rich with flavour for the scifi writer. The most positive asteroid tales are near-future stories such as *Deep Impact* and *Armageddon*, where the threat of destruction brings out the best in humanity via heroic sacrifice. Here cruel fate is a benefactor, uniting mankind in the common cause of survival. Other scifi writers deploy asteroids in an opposite fashion, making them the engines of war between men – tales such as the Japanese animated series *Metal Armor Dragonar,* where the Lunar Empire uses mass driver cannons to bombard the surface of the Earth.

Of course, asteroids may be much more than engines of destruction: they make wonderful settings for story: as the squalid, slum dwellings of a harsh future frontier (TV's *The Expanse*) or mysterious islands in the sea of space, where unknowable beings lurk – the gigantic Millennium Falcon-munching space slugs of *The Empire Strikes Back* and the psirens of *Red Dwarf*.

Perhaps it was 18th century astronomer Palissa's decision to name the asteroids sharing Jupiter's orbit 'Trojans' that inspired another group of tales, where asteroids are Greek gifts: huge chariots pregnant with trouble – *Star Trek*'s 'For the World is Hollow and I Have Touched the Sky'; and Greg Bear's *Eon*.

Here there is at least one idea for story. What if the asteroids in Jupiter's two stable Lagrange points were colonised? Intended as launch pads for exploration of the Jovian planets, human solidarity is compromised by the discovery of alien life in Europa's subsurface oceans: the last survivor of an alien race, a mermaid of extraordinary beauty. She is promised in marriage to a Greek, but kidnapped by a Trojan; the Greeks launch a thousand ships to reclaim their bride, forfeiting progress in favour of impotent fury.

Perhaps the science of asteroid deflection itself could provide ideas? What of a future solar system where an unknown event causes the asteroid belt to spray the system with stray objects? A new role of gravity tractor driver emerges, people with the job of shepherding stray asteroids clear of Earth using a huge speciality space vehicle. These are considered the pests of the shipping lanes, slow-moving giants that create traffic jams. Disgruntled and vengeful, a group of drivers combines to carry out the ultimate 'near-Earth object' heist: stealing Earth's moon, dragging it into Jovian orbit until a ransom is paid.

Or, finally, we could tell an alien story: a number of cults have predicted the arrival of aliens with asteroids and comets. What of one space-faring species that really does travel in the wake of asteroids? Approaching Earth, they overhear the broadcast of a maniac cult predicting their coming. Impressed by this knowledge they beam up the broadcasters, presuming them to be the elite of their race. Realising their mistake, they nudge their asteroid Earthwards, to ensure no future passers-by are bothered by the same trick.

Jon Wallace is a science fiction author living in England. He is the author of *Barricade*, published by Gollancz

> "Asteroid strikes have the potential to expose humanity's supremacy"
>
> Jon Wallace

Asteroids are rich with flavour for the scifi writer

Renewed reverence

Could Alfa Romeo be back to its best with the new Giulia? Chris Pickering **puts the hi-tech car through its paces**

Back when Enzo Ferrari was a young man he used to work for Alfa Romeo. At the time, the brand was regarded with much the same reverence that Enzo's own creations would later attract. Alfas were among the fastest, most exotic and most exquisitely engineered cars in the world. It stayed that way well into the post-war period.

Until recently, however, the company's glory years were a fading memory. It had been pumping out re-engineered front-wheel-drive Fiats for decades with varying success. Even the 4C sports car, with its seemingly foolproof lightweight carbon-fibre tub, mid-engined layout and torquey turbocharged powerplant, managed to miss the spot.

So it was with more than a hint of trepidation that I approached the new Giulia: a mid-sized rear-wheel-drive saloon pitched into a hugely competitive market occupied by the BMW 3-Series. Simply 'good' won't cut it here. And Alfa Romeo knows it's dangerously close to exhausting the goodwill that has kept it going for the last few years.

In particular, we're looking at the Giulia Quadrifoglio. Not just because it has the most indulgently Italian name in the range but because this 503hp (510 PS) high-performance variant packs some very clever technology. Underneath the bonnet sits a 2.9-litre V6, with twin turbochargers, two ECUs and cylinder deactivation. There's also active aerodynamics and torque vectoring, plus a liberal sprinkling of carbon fibre that helps make the Quadrifoglio the lightest car in its class.

01

01/02 Ferrari has provided much of the inspiration for the Giulia Quadrifoglio

Appropriately enough, it's Ferrari – long since brought under Fiat's wing along with Alfa Romeo – that has provided much of the inspiration here. The chief engineer for the Giulia project was Philippe Krief, the man responsible for the Ferrari 458 Speciale, who now also leads the R&D department at Ferrari's Maranello headquarters. Alongside was a handpicked team of other Ferrari and Maserati personnel, along with Alfa's own engineers.

The link may go even further, however. Officially, the Quadrifoglio's V6 is a clean sheet design, but its layout and dimensions bear a striking resemblance to those of the Ferrari California T's V8 with two of the cylinders lopped off. The bore and stroke, for example, are identical at 86.5 x 82.0mm. It has been suggested by some of the more cynical commentators that the link to this comparatively affordable saloon has been downplayed to protect Ferrari's exclusivity. Either way, this is as close as you can get to a four-door Ferrari and it costs just £61,300 (slightly more than the BMW M3 but slightly less than the Mercedes C63 AMG).

It drives like a Ferrari too. In-gear acceleration perhaps isn't as brutal as the 3.9-second 0-to-62mph time would suggest, but the Quadrifoglio is still ferociously quick. Free from the speed limiters employed on its German rivals, the Alfa will hit a claimed 191mph.

There's something pleasingly analogue about the way that performance is delivered too. The torque curve has been cleverly massaged to hide the effects of turbocharging,


02


03


04

with a linear pull right up to the rev limiter and a notable absence of lag, all underscored by a deep, sonorous six-cylinder growl.

Alfa Romeo says the steering ratio is the quickest in its class at 11.8:1, and it feels sharp. Impressively, though, it also feels natural and in tune with the chassis' other responses. On a damp track at Fiat's Balocco Proving Ground that included oversteer on demand, once the Giulia's electronic brain had been placed into its most aggressive Race setting. The optional carbon ceramic brakes were mighty, with decent pedal feel and huge reserves of stopping power. And, on a subjective level, it looks and feels special. The interior, with its hooded dials and swooping surfaces, is unmistakably Italian.

From an engineering perspective, one of the greatest achievements has been combining the 2.9-litre V6's impressive specific output with best-in-class CO_2 emissions of 198g/km. That's partly due to the Quadrifoglio's relatively trim weight (1,524kg compared to 1,715 for the AMG C63) but it's also down to the engine itself.

A lot of thought went into the cylinder deactivation system, we're told. Somewhat unusually for a 90° V6 – at least in a road car application – each pair of opposing conrods shares a common crank pin. This results in an uneven firing order when the engine is operating as a full V6, but it helps greatly when the left-hand bank is run as a triple. When this happens, the hydraulically controlled lash adjusters collapse to disable to the valve motion, cutting out the pumping losses. The changeover is imperceptible.

The change in Alfa Romeo, however, is anything but. After what seems like an eternity there is once more the substance to go with all that Italian passion. Alfa Romeo, it seems, is back.

"There's something pleasingly analogue about the way the performance is delivered"

03/04/05/06 The Giulia Quadrifoglio comes packed with some very clever technology


05

06

Back to the drawing board

If we're going to unlock the full potential of 3D printing we'll need to rethink the design process, writes Sarat Babu, founder of Betatype

Established additive manufacturing (AM) sectors such as aerospace and medical have played a key role in unlocking the value of AM by advancing the technology to meet their needs.

You can now build complete, full-sized, complex aerospace or medical parts in one go using AM, reducing the timescales and materials costs over more traditional design and engineering processes. This evolution is helping to drive new designs and innovations in these sectors and, while it is a laudable achievement, we now need to look beyond these traditional, 'legacy' sectors to ensure the importance of AM technology.

In consumer-focused industries – such as sports equipment and consumer electronics – AM is still nascent. Finding applications that maximise the value of the technology can be a major challenge. While a focus on developing new AM technologies is important, understanding what novel things we can do with the technology is just as critical and often overlooked. This is precisely why AM needs to stop focusing solely on technology and start thinking more about design.

In many ways AM's history as a rapid prototyping technology has led to a bias in machines, tools and methods that focuses on trying to simplify the process of moving from design to part. While this is fine for prototyping, it robs designers of developing a deeper understanding of these technologies – which makes exploring their real capabilities a difficult task.

By applying an in-depth understanding of the technology and pushing its boundaries, we have seen that the depth of control that is possible in AM is far greater than most traditional manufacturing processes. The complexity that AM affords isn't just around the shape of the part but also the material it is constructed from. For example, laser powder bed fusion is one additive technology that has established itself as a viable for production of metal parts. It uses a very fine laser or electron beam to scan across a bed of powder that is deposited in layers, melting specific regions to form the part. In the production of a typical part, the beam can travel hundreds of kilometres, delivering millions of exposures – every single one of which could be individually addressable, allowing for far greater design complexity.

What can make AM particularly challenging is that it requires a completely different approach to the methods many companies currently employ to develop parts. In these 'non-legacy' organisations new to AM, materials are often an afterthought in the design process. AM, however, turns the material into an additional dimension that needs to be addressed right at the design concept stage. This means that industrial design, mechanical engineering and materials science need to work in concert to navigate the freedom and complexity that AM can provide.

While it is a daunting task for companies to think about re-building their design processes, we find ourselves working with more and more companies that are ready to embrace new ways of designing and to explore what AM has to offer. Interestingly, an increasing number of these companies are consumer-focused. From consumer electronics to cycling, there is a growing interest in AM from sectors that have often been ignored. The relentless pace of innovation and complexity in these industries is often a powerful driving force to engage in new manufacturing process and new ways of building parts that can give them an edge over their competitors.

Despite its history in traditional manufacturing industries, we are still in the early days of AM with respect to the impact that it can deliver both technologically and conceptually. Accepting new ways of designing parts is the first step. From there, we need technology that can help us deliver on the promise of complexity.

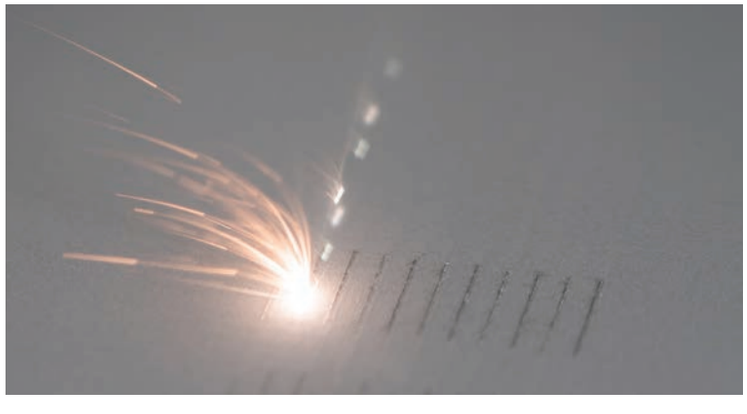
One of the big challenges here is that software really needs to be informed by the entire process from design to production. On the design side, we need tools that help us to explore the design space, unconstrained. We are still in the explorative stages of this – application engineers need to be able to wield the technology fully. On the manufacturing side, we need technology that is optimised to deliver the complexity we're trying to achieve.

When you begin to reconceive every facet of a design, you really start to unlock what AM has to offer. We've built technologies at every stage of that process and through strong partnerships with our customers and the machine manufacturers we've been able to build parts that are really pushing AM forward both in complexity and in end-part cost.

One thing we can say with certainty is that for manufacturing applications, things are only getting more complex. There are vast arrays of software tools, modular AM machines and new AM processes being developed. Where AM ends up exactly remains unclear but, for designers and engineers, AM is a chance to re-explore the narrative of what it is to design and make. So while the destination remains unclear, there has never been a more exciting time to engage with it.

Dr Sarat Babu is a materials scientist and designer, and CEO of additive manufacturing software specialist Betatype

To hear him speak in more detail about geometry, design-led thinking and laser powder bed fusion, register for this year's Additive Manufacturing and 3D Printing International Conference, 11-13 July



Laser powder-bed fusion is viable for production of metal parts

Robotic assistance in composite production

Robots help Solvay make composites at higher rate and affordability. Supplier: ABB

Four ABB robots are assisting a leading manufacturer of multi-speciality chemicals in expanding the use of lightweight composites for adoption in industrial applications.

Installed at Solvay's application centre in Heanor, Derbyshire, the robots are being used to help test, refine and demonstrate methods for reducing the cost and time associated with the creation of composite materials and composite material parts for use in high-volume production markets such as the automotive, aerospace, mass transportation, marine and renewable energy sectors.

ABB's robots – two IRB 4600s able to handle payloads up to 60kg, and two IRB 6700s, for payloads up to 250kg – are being used in various integrated cells alongside equipment from other manufacturers as part of the centre's aim to find ways to optimise composites manufacturing processes using the latest automated production technologies.

"Our main goal is to find ways to produce composites at a higher rate and affordability," said Richard Hollis, applications research and technology engineer at the centre. "Having robots in our centre enables us to develop new product formats and processing technologies, allowing us to demonstrate our ability to automate the part manufacturing for many industries where high-volume production of composite structures was not previously deployed or even possible."

One of the IRB 6700 robots is used in localised slashing and cross-plying of unidirectional prepreg material. During this process, a roll of prepreg material is first cut into squares with an ultrasonic knife. Fitted with a vacuum end effector, the robot picks up a square from one roll and lays it at a 90° angle on top of a second roll of material to create a 0/90 cross-plied prepreg. This was historically a manual, time-consuming procedure. In the same process, an IRB 4600 is integrated with a numerically controlled cutting machine, which takes the prepreg roll format created within the automated cross-ply cell. The cutting machine cuts out ply geometries associated with an automotive component and presents them to the robot, which picks up the cut pieces and deposits each in turn to create a 2D composite 'blank'. This blank is subsequently cured and trimmed using a robot.

The remaining two robots – the other IRB 4600 and IRB 6700 – are used in a cell handling trimming of dry fibre preforms. Integrated on a track motion system, they handle and trim preformed parts prior to the curing stage of manufacture.

Collaboration on the production line

Robots' flexible joints and compact size aid efficiency in China. Supplier: Universal Robots

One of the world's largest manufacturers of bathroom accessories and car parts, China's Xiamen Runner Industrial Corporation, has installed 64 robots from Universal Robots to improve its production process by creating a highly efficient, flexible and reliable production line.

The UR robots are installed in 10 applications, ranging from injection moulding machine tending to gas testing and product assembly.

Before deploying robots, most operations at Runner were manual, with operator fatigue posing risks to both safety and product yield.

"Our goal is to meet market demand by upgrading the efficiency of the production process," said William Xie, chief engineer at Runner. "Universal Robots surprised us with their efficiency and quality, which is much higher than in traditional robots."

With flexible joints and compact size, the robots can function in tandem with workers, sharing the same workspace in constrained areas. Another innovation at Runner has extended the robots' reach and efficiency by fitting them onto a slide rail, eliminating the need to move a fixed machine while supporting multiple-workstation operation.

When pre-inserting a part, one robot can operate three sets of injection moulding machines. With a six-gripper tool mounted on a flexible wrist joint, the robot quickly switches to any loading position.

"The collaborative robot is a powerful innovation in the industrial manufacturing sector, enabling automated production with unprecedented flexibility," said Xie.

The UR robot in product assembly takes a nut from the vibration disc exit, puts it into the point, picks up the part to be machined, and finally removes the assembled products.

Vision-guided pick-and-place is also handled by the UR robots.

Runner has witnessed a sharp increase in its product yield since its deployment of the robots.

People, not robots, will drive innovation

Concerns that robots will put us all out of work are unfounded, writes Olly Dmitriev, CEO of Vert Rotors

Smart manufacturing and Industry 4.0 is redefining manufacturing but it is the people behind the technology who will create innovations in the 21st century, not machines. It is the power of creating future innovative products, not robots that will write a new chapter in the history of British manufacturing. We have come a long way since the first Industrial Revolution, when mechanical looms were the height of new technology and the factory system began to emerge. As we enter what is widely acknowledged as the fourth Industrial Revolution, or Industry 4.0, the impact on our sector and the wider economy will be exponential.

Currently, there is a lot of debate about smart manufacturing. In the US, the National Institute of Standards and Technology (NIST, part of the Department of Commerce) defines smart manufacturing as systems that are "fully integrated, collaborative manufacturing systems that respond in real time to meet changing demands and conditions in the factory, in the supply network, and in customer needs."

The advances in machinery and robotics allow us to replicate existing manufacturing methods with increasing effect. Inefficiencies are often solved with robots and mass customisation, a technique that combines the flexibility and personalisation of custom-made products with the low unit costs associated with mass production, or by changing manufacturing programs automatically.

Smart machinery is seen to outperform human capabilities on many levels. It is faster, more efficient, and can operate non-stop. With the application of Internet of Things (IoT) technology, the analysis of big data can be incorporated into the process, allowing manufacturers to quickly resolve potential issues and inefficiencies.

Naturally, there is concern about the possibility of the rise of automation technology putting people out of work. I believe this is unfounded, particularly in the UK where our strength lies in innovation, rather than mass production. Smart manufacturing will benefit our industry tremendously, but only if we engage our current workforce, encouraging our employees to adopt these new technologies. Certainly, some manufacturing jobs will change significantly but smart manufacturing must begin with people, not machines.

Robots do not create new jobs directly. Although they displace some jobs, they improve overall business competitiveness and allow businesses to expand and create new sustainable roles in post-sales support, sales and marketing etc.

Despite the automation of many of our processes and systems, manufacturing is a creative and innovative industry. Robots are able to effectively execute a known algorithm but innovative ideas and products are borne by the human intellect.

I came to Scotland in 2012 to start my own manufacturing company, Vert Rotors, and develop a line of groundbreaking new air compressors. As a small manufacturer, I knew I could level the playing field by fostering smart manufacturing skill sets within my workforce, rather than attempting to replace the workforce with smart technology.

I started to build my team drawing on the pool of highly skilled engineers coming from Scotland's oil and gas industry. Some employees have over 30 years of experience in this field, and I value the contribution they have made to the industry.

To bring my compressor design to fruition and make it as efficient as possible, our measurements had to be accurate to the level of microns. While developing our compressor, we were unable to source the parts externally, so we decided to engineer everything ourselves in-house. I worked hard to bring state-of-the-art technology to our Edinburgh workshop, installing the most precise kind of milling machinery to be brought to the UK – the DMG Mori HSC-20.

The small firm is now home to one of the most precise milling machines ever brought to the UK.

This technology was new to all of us. One of my engineers commented we were using geometry he had never even seen before but by working together with the machinery, coupled with up-to-date computer aided design (CAD) technology, we created something remarkable.

Intuitively I realised the potential of combining years of experience with new, smart manufacturing technologies. To unleash the full potential of smart manufacturing technologies, we must first develop the skills and vision needed, that only humans could provide.

Understanding the skill set of your employees will impact any decision made to implement new smart machinery onto the factory floor. It is vital we nurture the incredible potential of our workforce by allowing them to up-skill and develop a symbiotic relationship with the new smart tools we have at our disposal.

In the UK, mass manufacturing is not the only way to add value. Developing new algorithms, new ideas and new manufacturing methods will lead to more innovation. There is a long history of innovation and creativity in the UK, but it is the brains behind the machinery that drives forward innovation.

Olly Dmitriev is CEO of Vert Rotors, which designs and manufactures what it claims is the world's most compact high-pressure, low-vibration screw compressor

Measurements had to be accurate to the level of microns for the compressor design

Scanner hits right note on Ordsall Chord

Laser scanner quickly and accurately measures railway's precast concrete elements. Supplier: Faro

Engineers working on Manchester's Ordsall Chord have been using a Faro Focus3D X 330 Laser Scanner to help speed up construction.

The new section of track will create a link between the city's Victoria and Piccadilly stations for the first time.

It has involved a lot of preparatory work, such as track realignment, building of new bridges and restoring Grade I listed structures on a section of the world's first passenger railway.

A Skanska BAM Nuttall joint venture, the project required many precast concrete elements, which had the potential to cause big delays if incorrectly sized.

"Although we are able to make on-site adjustments to accommodate very minor size discrepancies, the delivery of precast structures that fall outside our specified dimensional tolerances would render them useless and cause massive time delays," said Dan Binney, Skanska BAM senior engineering surveyor.

"Even though our precast concrete subcontractors were chosen for the quality of their work, the time delays and potential financial consequences of the delivery of out-of-specification precast elements meant that we needed to find a very accurate method of guaranteeing their measurements."

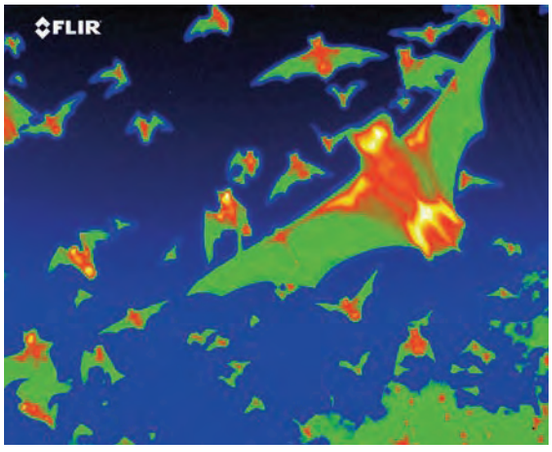
Binney and his team opted for Faro's Focus3D X 330, a high-speed 3D scanner capable of scanning objects located up to 330m away, even in direct sunlight. As a result of its integrated GPS receiver, the laser scanner is able to correlate individual scans in post-processing. According to Binney, its compact size and accuracy meant it could be easily transported to the subcontractors, saving significant amounts of time.

"Although we currently have relatively bulky and heavy equipment that could have delivered similarly precise results, it would have taken approximately eight hours to measure a single structural element," he said. "In contrast, the compact and more portable Focus3D X 330 Laser Scanner performs these high-precision tasks in less than 30 minutes."

Thermal camera sheds light through heat

Researchers in Philippines use thermal imaging to study bat behaviour. Supplier: FLIR

An international team of researchers has been using thermal imaging cameras manufactured by FLIR to study the behaviour of bats in the magnificent Puerto Princesa Underground River cave system in the Philippines.



The Puerto Princesa is the longest underground river in the world and its cave system is a designated Unesco World Heritage Site. The ecosystem is home not only to giant monitor lizards, monkeys, pythons and sea snakes but to vast numbers of bats.

Using FLIR technology, the researchers hope to gain more insight into the size and identity of the bat colony, confident that this knowledge will help them preserve the species for many years.

"The exact number of bats in a colony is very hard to determine, yet this information can be very valuable because it helps us to see population trends through the course of the years," said Dr Paolo Agnelli, an Italian zoologist and curator of the mammal collection at the Natural History Museum of Florence University.

"Should we assess that the number of bats is decreasing, we shall investigate the disturbance factors and take action in order to preserve these species," he added.

Thermal cameras enable researchers to study the bats at night, when they are most active.

Thanks to its visual nature, thermal imaging technology can also be combined with smart software that is able to count and identify bats and perform intelligent motion tracking.

Dr Agnelli and his team ultimately chose the FLIR E60bx thermal imaging camera, a 320 Å~240 resolution point-and-shoot model with a fully integrated colour camera.

"The FLIR E60bx is very easy to use. It's economical and the 60Hz frame rate allows us to present the small-sized bats in motion in very good definition," he explained.

"During our first research mission in Palawan in November and December 2016, the FLIR camera served us really well to capture large groups of bats coming out of their cave at dusk."

Tracked to the Arctic Circle

Leica Absolute Tracker aids installation of large radio telescopes. Supplier: Hexagon Manufacturing Intelligence

The advanced technology of Hexagon Manufacturing Intelligence is playing a vital role in an ambitious and innovative project in northern Norway.

Spain's Asturfeito is leading the work, which involves the installation of two large, 13.5m-diameter radio telescopes that will observe the universe from a location within the Arctic Circle.

The measurement and later assembly for this project utilised a Leica Absolute Tracker AT402.

Initially, the Leica Absolute Tracker AT402 was used to verify all the components of the complex installation for the two radio telescopes, ensuring that they exactly met the required specifications and guaranteeing a perfect adjustment during the later assembly.

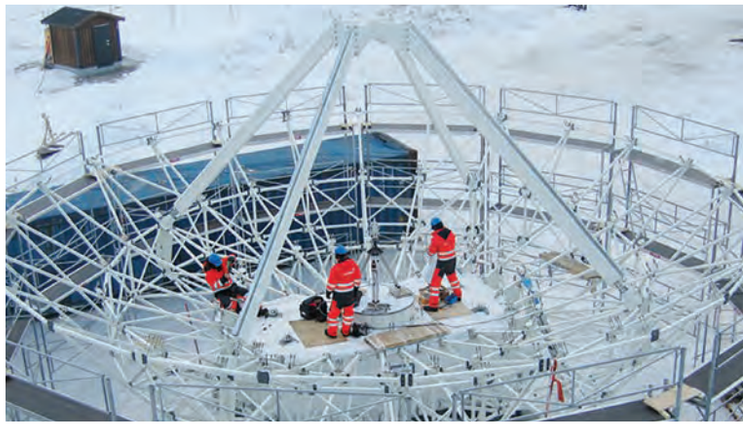
Once at the Arctic Circle, the AT402 proved essential in assembling the components, being used to control the bearing pins to ensure the correct horizontal and vertical rotation of the telescopes.

Among the requirements that the laser tracker was subject to – such as a huge measurement volume, unstable bases, difficult light conditions and changeable temperatures – were constraints specific to the high-level technology involved in the project.

"The two radio telescopes have a flatness tolerance in the azimuth and elevation axes bearing seats of less than 0.04mm in a 1.2m diameter," said Manuel Martínez Morilla, manager of the Quality Department at Asturfeito.

"The equipment worked seamlessly during intense use and in demanding conditions."

Asturfeito is active in the fields of equipment commissioning, engineering, manufacturing and assembly. The business has a team of more than 200 professionals and operates in sectors such as scientific installation and laboratory research, nuclear power, oil and gas, renewable energy and industrial plants.



Safe seat for Martin-Baker

Surface finish tester helps with design changes on ejection seat component. Supplier: Mitutoyo

For nearly seven decades, Martin-Baker has led the field in the design and manufacture of ejection seats, delivering more than 70,000 units to 93 air forces worldwide.

Recently, design changes to a vital component placed increased demands on Martin-Baker's shop-floor surface finish verification functions, so a search was made for a suitable surface finish tester.

Darren Smith, Martin-Baker inspection manager, explained: "Recent design modifications to a high-volume component's surface finish parameters prompted us to investigate the availability of cutting-edge surface finish testers. When judged against all our criteria, Mitutoyo's SV-3100, with the addition of a Y-axis table, best matched our requirements.

"The use of our new SV-3100 and Mitutoyo's Formtracepac software now provides our operators with easy access to surface roughness analysis, contour analysis and contour tolerancing. To ensure traceability, on completion of a component surface finish test a detailed inspection report is generated and archived."

The Mitutoyo Surftest SV-3100 is a multifunctional surface roughness tester that provides accurate, high-level 3D analysis of fine contours, plus conventional surface roughness measurement. The tester's X-axis uses a ceramic drive unit guideway for enhanced wear resistance, and makes use of high-accuracy glass scales to ensure reliable positioning and measurement. Advanced features include a straightness compensation function, which improves the linear accuracy of the X-axis.

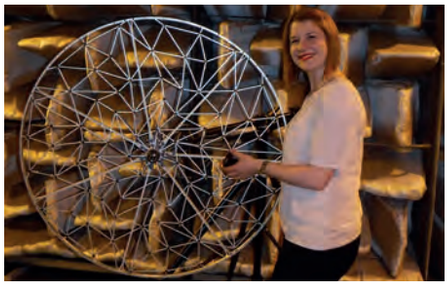
The SV-3100 also has a circular compensation function operating on the vertical movement of the stylus, plus a stylus-tip radius compensation function. The stylus and skid are easily replaced and optional styli and skids are available, enabling a wide variety of roughness measurement applications.

The SV-3100 is also supplied with a remote-control box that is independent from the main unit. The drive unit's up/down positioning and X-axis traverse can also be fine controlled manually.

Our Women in Industry

revolve.co.uk

Ford Ilka Segnini MEng



Ilka Segnini, MSc Acoustic and Vibration Engineering: Powertrain NVH Engineer, Revolve Technologies Ltd (RTL)

On contract to Ford Motor Company, Test & Development Powertrain Noise Vibration & Harshness.

Ilka has been working in the automotive industry since 2011, currently based at Ford's Dunton Technical Centre, and has been a PT NVH engineer since September 2014. Her job has recently taken her to support vehicle launches and product development for Ford in China, India, Argentina, Germany and Spain. Ilka is the only female NVH engineer employed by **Revolve**, and one of only around five female engineers within the Ford Powertrain NVH group in Europe. Understanding sound quality is a key function of the role, requiring a 'noise' to be identified as either an attribute, or as an issue to be engineered out by the powertrain team.

ULEMCo Amanda Lyne BSc

Amanda Lyne, BSc, FCIM – Managing Director, ULEMCo Ltd

Amanda has over 15 years' experience in the hydrogen and fuel cell technology industry, having previously founded fuel cell technology company ACAL Energy and working through her consultancy business Burgundy Gold Ltd where she is a specialist in the commercialisation of clean tech businesses. She is a Director of the Liverpool City Region Local Enterprise partnership, where she is the Chair of their Low Carbon Economy Board and is also the Chair of UK Hydrogen and Fuel Cell Association. ULEMCo was spun out from Revolve in the Spring of 2014, in order to commercialise the globally leading know-how in hydrogen combustion; involving the capability to convert diesel engines and vehicles to hydrogen dual fuel. Between ULEMCo and Revolve the two companies have arguably the most practical experience in options for low emission vehicles, and can provide world leading advice and expertise for R&D and the economic exploitation of a range of low carbon energy technologies.

Bearing up in the Brexit breeze

The Engineer's 2017 Salary Survey asked engineers from across the different sectors of UK industry about their role and earnings

The UK has experienced considerable political upheaval over the past 12 months, with the vote to leave the European Union triggering an immediate change in leadership and more recently a General Election.

But has uncertainty over the UK's future relationship with Europe following the Brexit vote affected salaries and job security in engineering? Have engineers in some sectors fared better than others over the past year?

The Engineer has once again surveyed professionals from across the different sectors of UK industry, to find out how much they earn, where they work, and how they feel about their chosen career.

With 2,743 engineers taking part in our 2017 survey from 11 different sectors, we have analysed the results to reveal which industries and regions offer the best salaries, what proportion of professionals are women or people from ethnic minorities, and where levels of job satisfaction are at their highest.

By comparing the results with our 2016 survey, we can also see how life has changed for engineers over the past 12 months.

"Uncertainty over Brexit has yet to have a negative impact on wages in the profession"

The average salary for UK engineers across all sectors in 2017 is £48,197, a significant increase on last year's average of £45,367, showing that uncertainty over Brexit has yet to have a negative impact on wages in the profession. Once again, this figure compares well with average salaries across other professions in the UK, sitting slightly below the average salary for qualified accountants of £52,076 and those in banking on £50,580, but above those in the financial services sector, on £47,109.

Almost 60 per cent of engineers surveyed are concerned about the potential impact of Brexit on the future of UK industry. But on a personal level, only 37.4 per cent are worried about its potential impact on their own job security.

Among the different sectors, engineers in the oil and gas industry continue to command the highest salaries, with an

£43.8k-£54.5k

Average salary by sector

DavidLeyshon chairman, CBSbutler

This year's edition of the Salary Survey has given us valuable insight into the changing trends and attitudes people in engineering are experiencing. An industry that thrives in the development of projects, ideas and innovation has become a cause for concern. It is very apparent that we are still witnessing the same disillusionment with career prospects, which has plagued the industry for many years.

We have an ageing sector; a growing skills gap; a real lack of gender and cultural diversity; and the highest-paid salaries in the most depressed sectors (oil & gas) in engineering and manufacturing still lag behind other industries.

One of the most significant issues our industry faces is a lack of gender diversity; with women engineers accounting for only 7 per cent of respondents to this survey. That's why at CBSbutler we like to promote and champion opportunities particularly in the untapped talent pools: women in STEM vocations and young people who still harbour stereotypical impressions of the sector.

With decades of experience in recruiting within engineering across a wide range of sectors, CBSbutler can attest to having specialist insight into the challenges and opportunities afforded to job seekers. Well-qualified, highly trained and experienced engineers really do have a wealth of options at their disposal. Those individuals who prefer flexibility in their work will find strong demand, lucrative earnings and continuity of employment via freelance contracting.

We really cannot ignore some of the less positive findings in this survey. We need to start investing in our young talent, offering diversity in job opportunities that will reward and stimulate them. Technology and engineering is moving at such an incredible pace that we often question the adaptability of our ageing engineers; can they really embrace new tools and inventions quickly? The survey reveals that aerospace has the highest proportion of ageing engineers where automotive has the youngest, which could explain why 54 per cent feel there is a real lack of industry knowledge and experience.

The world as we know it is evolving rapidly, innovation is hammering at our doors searching for new talent and we simply cannot keep up with the demand for skilled workers to fulfil these ambitious projects. Engineering as a profession has got to start promoting itself as a career of choice, enticing the next generation with powerful messages and thought leaders who can tap into millennial minds.

Engineering thinkers such as Sir James Dyson have tried to position engineering at the heart of our society. The UK needs niche, academic institutions with degree-awarding powers, attracting young talent, with an earn-while-you-learn work ethic.

In summary, at last there is a realisation that engineers are central to building our economy and placing the UK on the map. We need a big focus on technical schools and colleges offering incentives, placements and mentoring so young people can finally get rid of the stigma behind the industry. Any preconceptions of it being a boring and dirty job by male-dominated figures needs to be squashed, so we can drive more individuals into this industry. A diversified talent pool filled with women and men of all ages and races is what we need to enrich our industry, and it's about time their skills are valued and rewarded accordingly. Maybe then we will see that in next year's Salary Survey figures, that over half will be content in their jobs and feel valued by their employers rather than the 36 per cent this year that felt their jobs made them happy.

average of £54,461. What's more, salaries have increased in the sector since our 2016 survey, when the average was £51,370.

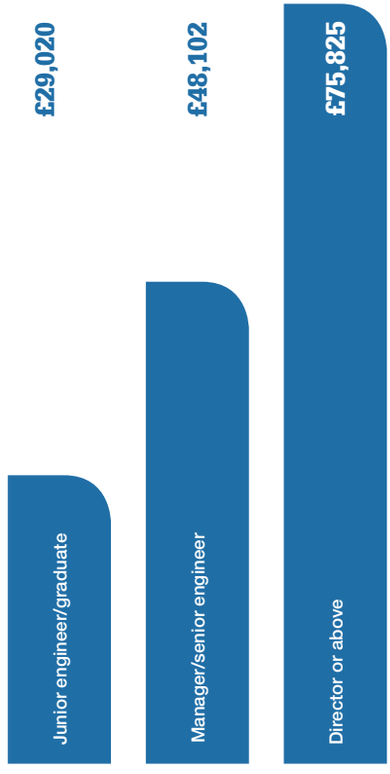
The energy, renewables and nuclear sector once again recorded the second-highest average salaries across industry, at £51,953. This figure is up from £50,132 in 2016, showing that helping to keep the nation's cars running and its lights on remains the surest path to achieving the highest earnings.

The automotive and aerospace industries employ a quarter of the engineers who took part in our survey, a similar figure to that of 12 months ago, while once again three quarters of respondents describe themselves as senior engineers or managers.

£48k

Average salary for engineers across all sectors

Average salary by seniority



The Midlands and East Anglia, the UK's traditional manufacturing base, is home to the highest percentage of engineers among the country's regions, at 27.7 per cent. This is followed by London and the South East, where 20.1 per cent of engineers surveyed said they were based.

Over 90 per cent of the engineers surveyed are male, while almost 90 per cent are white. The average age of engineer surveyed is 45.4, two years older than the 2016 average, while 60 per cent have been in the profession for over 20 years.

The vast majority of engineers remain happy in their chosen career, with 81.9 per cent expecting to stay in the profession for at least the next five years.

Over the following pages we have looked in more detail at the findings of this year's survey, and considered what they tell us about engineering in 2017.

An even more detailed report, along with an interactive tool that enables you to benchmark your salary can be found at *www.theengineer.co.uk* **>>**

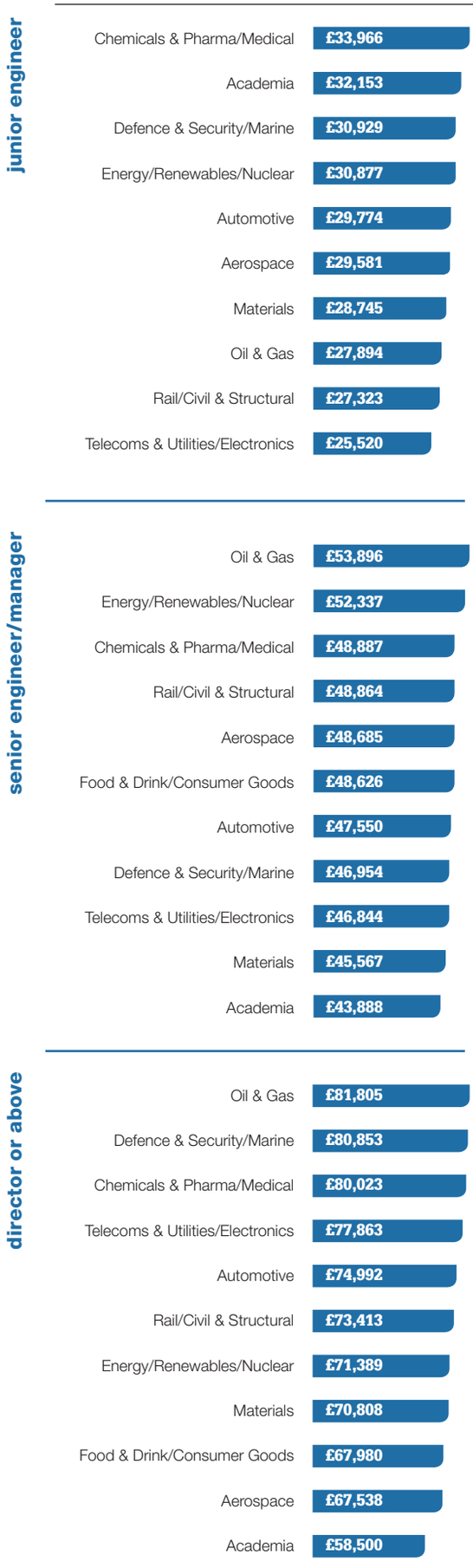
6.6%

Average year-on-year salary increase over the past 12 months

average salary by industry

The highest average salaries are found at director level in the oil & gas sector

£81.8k



1. seniority

Over 80 per cent of those engineers responding to our survey describe themselves as senior managers or above.

This is strikingly similar to the picture in 2016, and broadly reflects the seniority levels of the readership of this magazine as a whole.

Senior managers make up the largest group of respondents to our survey, at 44.3 per cent, which is up from 42.8 per cent in 2016. Of the remaining respondents, 30.9 per cent describe themselves as managers, 12 per cent as junior engineers, 7.2 per cent as directors, and 2.6 per cent as graduate trainees and apprentices.

> "Encouragingly, average salaries have increased for engineers across all levels of seniority"

Encouragingly, average salaries have increased for engineers across all levels of seniority over the past 12 months, despite the uncertainty within industry over the future of our trading relationship with Europe.

Perhaps unsurprisingly, directors have seen the biggest increase in pay over the past year, up from £71,573 in 2016 to £75,825 in 2017.

At the other end of the scale, salaries among junior engineers and graduate trainees have increased marginally, up from £28,771 to £29,020, while senior engineers' salaries have risen from £46,428 to £48,102.

As with the average salaries for engineering as a whole, there remains a considerable gap between what engineers at various levels of seniority can expect to earn in some industrial sectors when compared to others. This can be seen most strikingly among directors, where those in the oil & gas industry take home an average salary of £81,805, while those in academia earn around £58,500.

Similarly, senior engineers and managers in academia earn less than those at the same level elsewhere, with an average of £43,888. However, the gap at this level of seniority is not as wide, with senior engineers and managers in the top-earning oil and gas sector earning £10,000 more, on average.

Surprisingly, junior engineers in the oil and gas industry, however, who take home an average of £27,894, have dipped below their equivalents in a number of other sectors, including the chemical and pharmaceutical; energy, renewables and nuclear; defence, security and marine; and academic sectors, all of whom earn over £30,000.

Junior engineers in the food and drink and consumer sectors earn the lowest average salaries across industry, at £24,955.

The average age of engineers surveyed is 45.4, two years older than in 2016, with almost half of all respondents in their 50s or above. Of the remaining respondents, around a quarter are in their 40s, while 18.5 per cent are in their 30s, and 10.9 per cent in their 20s.

2. regions

Engineers from the UK work in a diverse range of locations, throughout the British Isles and beyond. Once again the largest population of engineers can be found in the manufacturing heartland of the Midlands and East Anglia, although this is down slightly compared to last year, from 29.8 per cent in 2016 to 27.9 per cent in 2017.

But there are also a sizeable number of engineers working in London and the South East (20.4 per cent) and in the North of England (18 per cent). Engineers in London and the South East have overtaken those working overseas to become the highest earners in 2017, with an average salary of £51,743. This perhaps reflects the high cost of living in the capital.

Of those working in London and the South East, engineers in the oil and gas and the chemical, pharmaceutical and medical industries command the highest salaries, at £56,575 and £56,500, respectively.

Spare a thought for engineers in the South West, who are once again the lowest earners among the different regions, earning an average of £45,022. On the plus side, however, this does represent a significant year-on-year increase from an average of £40,827 in our 2016 report. Given that the size and demographic spread of this sample group is broadly the same this year, this increase would appear to be significant.

Among the engineers working outside the UK, those in the oil and gas industry receive the highest average salary, although this has dropped to £62,716 from £67,924 in 2016.

Engineers working outside the UK are the least likely to be satisfied with their pay, with 31.3 per cent describing themselves as happy with their remuneration package.

This is surprising, since this group were the most likely to be happy with their salary in 2016. >>

where are the UK's engineers?	
27.9%	Midlands and East Anglia
20.4%	London & South East
18%	North
11.6%	South West
9%	Scotland, Wales & Northern Ireland
12.4%	Outside UK

Midlands or East Anglia

Materials	£51,071
Automotive	£50,708
Chemicals & Pharma/Medical	£50,218
Energy/Renewables/Nuclear	£49,822
Aerospace	£49,380
Academia	£48,208
Food & Drink/Consumer Goods	£47,534
Telecoms & Utilities/Electronics	£47,246
Defence & Security/Marine	£46,722
Oil & Gas	£43,305
Rail/Civil & Structural	£41,222

North (England)

Defence & Security/Marine	£57,473
Energy/Renewables/Nuclear	£56,750
Chemicals & Pharma/Medical	£51,815
Oil & Gas	£47,195
Materials	£46,565
Food & Drink/Consumer Goods	£46,411
Automotive	£45,950
Aerospace	£44,340
Rail/Civil & Structural	£43,500
Telecoms & Utilities/Electronics	£42,028
Academia	£37,647

Outside UK

Oil & Gas	£62,716
Energy/Renewables/Nuclear	£52,660
Defence & Security/Marine	£50,023
Telecoms & Utilities/Electronics	£49,899
Chemicals & Pharma/Medical	£48,391
Aerospace	£47,697
Materials	£46,817
Automotive	£40,802
Food & Drink/Consumer Goods	£40,215
Rail/Civil & Structural	£39,582
Academia	£33,950

Scotland, Wales or Northern Ireland

Oil & Gas	£72,480
Chemicals & Pharma/Medical	£51,250
Energy/Renewables/Nuclear	£50,782
Rail/Civil & Structural	£46,875
Food & Drink/Consumer Goods	£46,722
Materials	£45,571
Academia	£43,800
Automotive	£42,380
Defence & Security/Marine	£40,583
Telecoms & Utilities/Electronics	£40,384
Aerospace	£38,190

South West (England)

Materials	£53,000
Energy/Renewables/Nuclear	£50,523
Food & Drink/Consumer Goods	£48,703
Rail/Civil & Structural	£48,100
Oil & Gas	£46,909
Chemicals & Pharma/Medical	£45,411
Aerospace	£45,129
Defence & Security/Marine	£44,145
Automotive	£43,388
Telecoms & Utilities/Electronics	£40,891
Academia	£40,777

London or South East (England)

Oil & Gas	£56,575
Chemicals & Pharma/Medical	£56,500
Telecoms & Utilities/Electronics	£53,300
Automotive	£50,737
Academia	£50,588
Rail/Civil & Structural	£49,422
Materials	£49,076
Energy/Renewables/Nuclear	£49,066
Aerospace	£47,93[illegible]
Defence & Security/Marine	£47,77[illegible]
Food & Drink/Consumer Goods	£47,41[illegible]

Sector	Average salary (£)	Average age	Percentage content with salary	Percentage happy in current job	Percentage considering change of job	Percentage likely to stay in industry for five years
Academia	43,809	47	31.70	61	44.40	71.60
Aerospace	46,362	46.4	37.5	54.9	45.8	78.5
Automtoive	48,100	45	34.5	52.7	45.7	83.7
Chemicals & Pharma/Healthcare	51,750	46.6	40.8	57.4	43.8	83.4
Defence & Security/Marine	46,838	44.7	31	50.3	43.5	88.2
Energy/Renewables/Nuclear	51,953	44.6	38.8	45.7	50	83.1
Food & Drink/Consumer Goods	46,460	44.6	30.4	45.2	47	81.6
Materials	48,318	46.2	34.7	58.2	42	76.5
Oil & Gas	54,461	46.5	41.2	48.6	42.9	83.7
Rail/Civil & Structural	44,890	42	29.3	45.9	56.5	80.5
Telecoms & Utilities/Electronics	46,567	45.4	42.3	52.7	43.7	80.1

3. sectors

Despite concerns over the potential damage to the economy following the Brexit vote, and particularly over its impact on industry, salaries have risen across all sectors since 2016.

Once again, the highest salaries in engineering can be found in the oil and gas industry, with professionals earning an average of £54,461, compared to £51,370 12 months ago.

This is followed by those in the energy, renewables and nuclear industries, who earn £51,953 on average, up from £50,132 in 2016.

At the other end of the pay scale, where engineers in academia are earning over £10,000 less than their highest-paid peers in the oil industry, average earnings are £43,809. However, this is an increase on 2016, when academics were earning £38,029 on average.

But proving once again that money does not buy happiness, academics continue to be the most content in their jobs. Of those surveyed, 61 per cent of engineers in academia said they were happy in their jobs, compared to 56.1 per cent in 2016.

And despite sitting in the lower half of the earnings league table, engineers in the telecoms, utilities and electronics industries are the happiest with their salary (42.3 per cent), closely followed by those working in oil and gas (41.2 per cent).

Engineers in the materials industry, meanwhile, are the least likely to say they are considering a change of job, and the most likely to feel valued in their role (54.1 per cent).

Those in the defence, security and marine sector are the most likely to see themselves staying in the industry for the next five years.

Not everyone is happy with their lot, however. Engineers in the food and drink and consumer goods industries are the least likely to describe themselves as happy in their jobs (45.2 per cent), while despite enjoying their roles, engineers in academia are the least likely to feel valued (33.6 per cent).

Among the least content are engineers in the rail, civil and structural industries, where over half are considering a change of job (56.5 per cent). They are also the least content with salaries, with just 29.3 per cent describing themselves as happy with their pay.

Rates of holiday are highest in academia, where 41.5 per cent receive more than 30 days' paid leave, up from 35.7 per cent in 2016, and 39 per cent receive between 26 to 30 days. Outside academia though, engineers in the car industry are most likely to receive 26 to 30 days' paid leave (35.7 per cent).

Engineers in the rail, civil and structural sectors are the least likely to receive over 30 days' paid leave (4.5 per cent), while just 22.3 per cent of those working in materials receive between 26 to 30 days.

Overall, 46.8 per cent of engineers across our sample receive a bonus, but the highest-performing

45
average age of a UK engineer

81.9%
of engineers expect to remain in industry for the next five years

50%
of engineers would consider taking a position overseas

"Those in the defence, security and marine sector are the most likely to see themselves staying in the industry for the next five years"

	Percentage that feel valued in current role	Percentage that do not feel valued
	33.60	30.50
	34.9	33.8
	41.3	28.5
	47.3	24.3
	37.4	25.7
	37.4	28.8
	38.1	29.8
	54.1	22.4
	42.9	26
	34.6	32.3
	42.7	22.8

sector in this regard is chemicals, pharmaceuticals and medical, where 60.5 per cent of respondents receive a bonus.

The second-most generous industry for bonuses this year is oil and gas, where 52.2 per cent of engineers received a payment, while at the other end of the scale only 11 per cent of respondents from academia are rewarded in this way.

In terms of qualifications, once again more engineers in the energy, renewables and nuclear industries have a degree than any other sector, at 58.6 per cent, closely followed by rail, civil and structural (58.2 per cent).

The defence, security and marine industries have the fewest graduates, with 45 per cent of engineers having earned a degree.

The oil and gas sector, meanwhile, has the highest proportion of engineers who have worked their way into the industry through an apprenticeship (48 per cent), while the energy, renewables and nuclear has the lowest percentage (28.8 per cent).

4. gender and diversity

The gender imbalance within engineering continues to be a problem for its various sectors, despite numerous initiatives designed to attract more women to the profession.

Just 7 per cent of the respondents to this year's survey are women, compared to 6.5 per cent in 2016, and 5.5 per cent in 2015.

Difficulties in attracting and holding on to female professionals is not one that is limited to engineering, but affects all of the STEM sectors. However, as the latest figures from the Women into Science and Engineering (Wise) campaign's STEM workforce analysis makes clear, engineering is particularly struggling.

The proportion of women in the STEM workforce as a whole was 21 per cent in 2016, while among ICT professionals it was 18 per cent, and among science professionals it was 41 per cent. However, the figure among engineering professionals was remarkably similar to our survey, at just 8 per cent.

Among the individual sectors, the industries with the highest proportion of women are academia (10.8 per cent) and rail, civil and structural (10.3 per cent), with the figure for the latter remaining unchanged since 2016.

These are followed by the materials industry, where 10 per cent of the sample are female.

At the other end of the scale, just 2.8 per cent of engineers in the automotive industry are women, 3.4 per cent of those in chemicals, pharmaceuticals and medical, and 3.6 per cent in defence, security and marine.

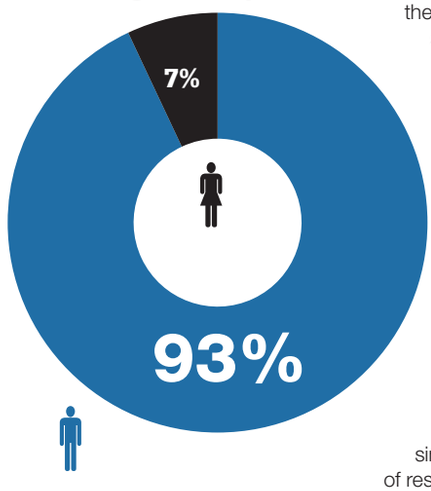
The average salary for women in engineering is £10,000 lower than their male counterparts – just as it has been in our previous surveys – at £38,109, compared to £48,866. This is a slight increase on the average salary among women in 2016, of £36,201. As with previous years, however, this may be partly a result in the difference in seniority among respondents, with 8.8 per cent of women describing themselves as graduates, for example, and 20 per cent as junior engineers, compared to 2.2 per cent and 11.5 per cent of men, respectively.

Of more concern, women at every level of seniority are, on average, paid less than their male colleagues. For example, at junior level women earn on average £4,000 less than their male colleagues.

"Women at every level of seniority are, on average, paid less than their male colleagues"

The gap widens at director level with women paid on average £20,000 less. A slightly lower percentage of women describe themselves as managers this year (25.9 per cent), compared to 2016 (29 per cent), although it must be said that the sample of female respondents is fairly small, meaning the results may not be as statistically robust.

gender split



Job satisfaction levels are only slightly higher among men than women, with 52.1 per cent of men and 49 per cent of women happy in their current role.

However, 36.5 per cent of men and just 25.8 per cent of women feel their salary level is appropriate, reflecting the pay gap between the sexes.

The diversity gap, meanwhile, has reduced slightly since last year, with 89.3 per cent of respondents describing themselves as white, compared to 92.1 per cent in 2016. Just 7.3 per cent describe themselves as BAME (black, Asian and minority ethnic), compared to only 6 per cent in 2016.

In the individual sectors, 11.5 per cent of engineers in the rail, civil and structural sectors describe themselves as BAME, of whom 7.6 per cent are Asian, and 3.1 per cent black.

In contrast, just 2.1 per cent of engineers in defence, security and marine describe themselves as BAME.

Salaries among black, Asian and ethnic minority engineers also continue to lag behind their white peers, with an average of £38,080 among BAME professionals – down from £40,979 in 2016 – compared to £49,071 among white respondents.

average salary by gender by seniority

	Junior	Senior	Director
Male	29,536	48,422	76,611
Female	25,408	42,082	56,011

Reaping the future rewards

Women engineers have a key role in helping to bridge the UK's burgeoning skills gap.

Evelyn Adams reports

01/02 According to the latest figures from the Office for National Statistics, women still make up around just 8 per cent of engineers

Over the years, the UK has been hailed as the 'workshop of the world' and a world leader in engineering and innovation. But despite this history of success, today it has the lowest percentage of female engineering professionals in Europe. According to the latest figures from the Office for National Statistics, women still only make up around just 8 per cent of engineers.

This is at a time when the industry is facing a critical skills shortage. Research by Engineering UK has found an additional 1.8 million engineers are needed by 2025. At the moment, there is a 20,000-a-year shortfall in qualified engineers. To bridge this skills gap, the UK is currently reliant on employees from abroad. However, potential restrictions on the free movement of labour in the wake of Brexit could make the skills shortage even worse.

"One way to improve the pipeline would be to persuade more women and minority groups that engineering could be a great career choice for them," said Naomi Climer, a past president of the IET. "There are so many big and global, as well as small and local, challenges for engineers to crack that we need all the talent we can get. This is not about doing the right or fair thing for women – it's a compelling economic and societal issue to train as many talented engineers as we can."

According to the McKinsey Global Institute, enabling women to meet their full potential in work could add as much as £22tn to annual GDP in 2025. Diversity is crucial to employers with companies 15 per cent more likely to perform better if they are gender diverse. It is also important to innovation. In a global survey, 85 per cent of corporate diversity and talent leaders agreed that "a diverse and inclusive workforce is crucial to encouraging different perspectives and ideas that drive innovation".

So why aren't more women being

01

02

recruited in engineering roles? Lucy Collins is a Women Into Science and Engineering (WISE) board member with a degree in civil and structural engineering. She currently works for the Ministry of Defence as a submarine designer. Collins believes the main barrier for women getting into engineering is an unconscious gender bias, in both society and the workplace.

"The effects of this unfortunately pervade the engineering and STEM environment," she said. "People may, and will, argue that sexism no longer exists and improvements such as mandatory diversity and inclusion training prove this is true. However, this simply isn't the case. Conscious gender bias may be significantly improved from where we were 30 years ago but ingrained behaviour is more difficult to overcome and certainly does still exist."

To back up her point, Collins said that Yale University carried out a study where a job application for a student wanting to become a lab manager was produced, with half the study participants receiving it with a male name attached and half with a female name. The 'female' applicants rated significantly lower than the 'male' equivalents on competence and hireability, and were also given a lower starting salary. Interestingly, both male and female scientists were equally likely to commit the gender bias.

"From a female perspective, women are missing out on jobs that they can be happy and successful in," said Collins. "Women tend towards careers that help people and contribute to society, which is why there is such a high percentage of female talent in the medical profession. There is also high competition for limited positions. In my opinion, no other profession contributes more to society than engineering does – why should women miss out?"

The WISE campaign works with companies to support them in implementing these changes that encourage women into engineering roles through the WISE Ten Steps. Some examples that have seen success include: starting a mentor and role-model programme; describing the person specification in job descriptions; offering flexible working arrangements and re-training for those returning from parental leave; and showcasing female talent through events such as the WISE awards.

Julie Holyland, learning and talent development lead at Siemens, said: "We need to reach a 'tipping point' in the number of women within engineering – especially at more senior levels. I hear much debate and some fervently held views about the relative merit of focusing specifically on developing female talent. Certainly, not everyone believes it's the way to go, and I'd be the first to say it's never the only way to go. However, all our experience and research points to the fact that getting groups of talented women together – future leaders of their organisation – can be of profound benefit both to the individuals and the business."

While other professions that are extremely male-dominated at the senior levels have a higher initial entrant population of women, the numbers of women tend to be lower right from the start in engineering. According to *The Engineer*'s latest Salary Survey, just 0.4 per cent of total respondents were women working at director level or above, while male engineers working at this level accounted for almost 10 per cent of the entire sample group.

To tackle this, Siemens has a Women Into Leadership scheme that consists of both group and one-to-one coaching, targeted and tailored events, as well as mentoring from senior individuals in the business across a six-month period. "We have such an incredible, diverse talent pool and we want to be the company where women have the same opportunities to rise to the top and become leaders as men," said Siemens chief financial officer Maria Ferraro, executive sponsor of the initiative. Other groups, such as Airbus, are also working to increase the number of applications from women. At the end of 2016, 17 per cent of Airbus's workforce was women; and women held about 11 per cent of senior manager and executive positions. This year, the company's objective is to have 30 per cent of its recruits made up of women.

"The main barriers to progression are often due to individuals' own belief in their ability," said Jacqueline Castle, head of A350 XWB and A380 landing gear at Airbus. "I have sometimes seen a lack of confidence in women, meaning they do not push themselves forward for promotion. I have not seen any barriers within my company or the aerospace industry in general for the progression of female engineers. Capable engineers who are reliable and deliver to their commitments will progress."

While there's no silver bullet to increasing the number of women in engineering, what's clear is that more needs to be done to engage female engineers. However, for those who do decide to take the leap into such a male-dominated industry, the rewards could be huge.

"We want to be the company where women have opportunities to rise to the top"

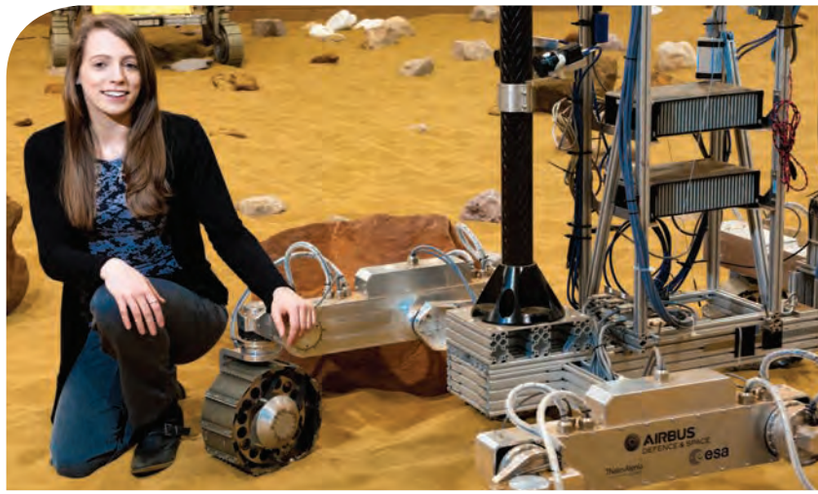
Maria Ferraro, Siemens

Move into a good space

Kat Styles reveals some of the motivations and challenges involved in her day-to-day life as a working engineer at Airbus

Kat Styles is a thermal engineer for Airbus Defence and Space. She joined Airbus as a graduate in 2013 and became a fully fledged thermal engineer in 2015. Styles studied astronomy, space science and astrophysics at the University of Kent and graduated with an MPhys in 2013.

Kat Styles is a thermal engineer for Airbus Defence and Space



What do you like most about being an engineer?
I like that every day is different and you are constantly being challenged. Each day a new problem arises and you have to work hard to come up with the right solution.

What attracted you to a career in engineering and to Airbus Defence and Space?
It wasn't until I got to university that I decided I wanted to go into engineering. Although I was mostly interested in space science at first, my degree also included physics, which allowed me to keep my options open. Being able to combine my interest of space science and engineering is what led me to Airbus Defence and Space.

What is your typical day like?
It's hard to say. A project goes through different stages and it really depends on what stage we are at. One week you will be doing design work, the next you will be focusing on the analysis. After the design and analysis work is complete, we get to test the products and hardware. A day can go from office-based design to hands on work in the test facilities. It really does vary and that keeps it interesting.

Tell us about an interesting project you've been working on recently.
I recently finished work on the ExoMars rover project. It was a unique project and was particularly interesting for me as a thermal engineer. Typically we would be designing products to work thermally in space, which is a vacuum. However, on Mars there is an atmosphere so you have to consider that as well. That was a really interesting challenge for us. And it's now been to Mars, which is extra cool.

I also work on some interesting telecoms projects. These types of projects are cutting edge and you are always working with new technology. We turn around telecommunications satellites much quicker than we would a scientific project such as the Mars rover. Scientific projects take a lot more time and are designed over the course of about 10 years.

What's your favourite thing about working for Airbus?
My favourite thing is when you successfully launch hardware into space. I had a spacecraft successfully launched earlier this year called SES-10. SES-10 was the first spacecraft I worked on and it is now operating in space. which is very exciting.

Do you think the industry has changed in terms of opportunities for female engineers?
I think there is definitely the opportunity for females to pursue a career in engineering but there is still a noticeable difference in the number of females at different stages of their careers. Among the graduates and young people there is a much higher percentage of females compared to the more senior engineers. Over the last 10 years I would say it has shifted significantly, with more female candidates applying for graduate and entry-level roles. I think pursuing careers in engineering and studying STEM subjects is becoming more attractive to females.

Do you think more needs to be done to encourage young females into careers in engineering?
There is a lot going on now to encourage more young women into engineering and other STEM careers. I'm part of Airbus's STEM ambassador network. We go to schools and career fairs to connect students with engineers to chat and arrange other events. It's great to see much younger students, especially females, who are really enthusiastic about engineering and science now. I don't think there would have been such a significant proportion of females a few years ago, before there was big push in the UK to make STEM subjects more attractive.

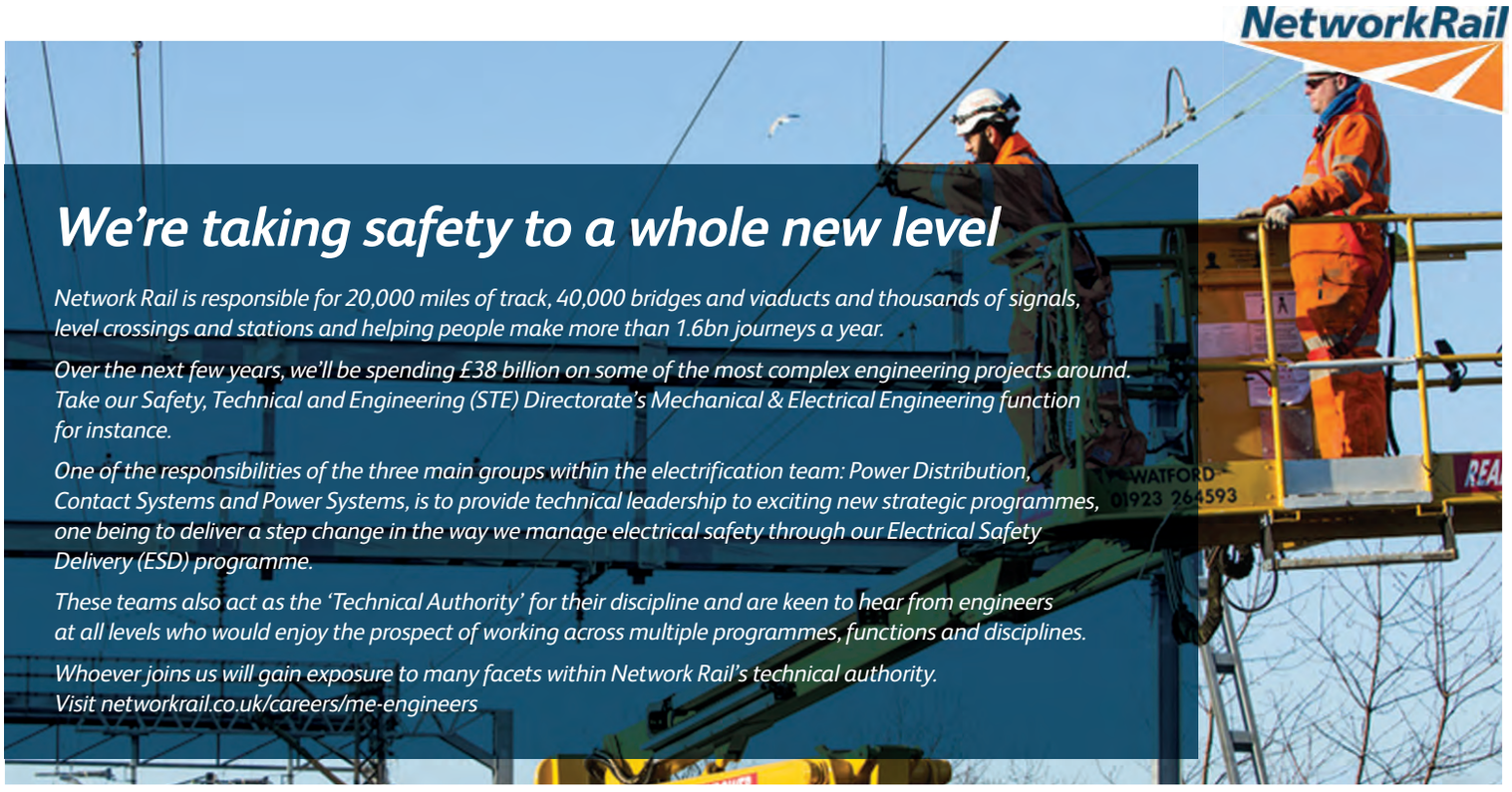
Airbus has a dedicated department for running STEM activities. We also recently attached a STEM centre and viewing gallery to our Mars Yard in Stevenage. Students can now come to Stevenage and get a real feel of what it's like to be an engineer. They can have lessons in our classroom, try out some cool experiments and view the Mars rovers.

What advice would you give to young females wanting to pursue a career in engineering?
There are three pieces of advice I would offer.

Work hard – It's not just about academic ability, you need to be hard working and determined too.

Seek opportunities for work experience – it doesn't haveto be directly related to what you want to work in but it helps you stand out. I did a placement with the Met office, working on its ground based observation team. It's not related to what I'm doing now, but it's important to have that experience.

Have confidence in your abilities – some girls might think they can't do it or won't be successful in the industry. You can be, so go for it.



We're taking safety to a whole new level

Network Rail is responsible for 20,000 miles of track, 40,000 bridges and viaducts and thousands of signals, level crossings and stations and helping people make more than 1.6bn journeys a year.

Over the next few years, we'll be spending £38 billion on some of the most complex engineering projects around. Take our Safety, Technical and Engineering (STE) Directorate's Mechanical & Electrical Engineering function for instance.

One of the responsibilities of the three main groups within the electrification team: Power Distribution, Contact Systems and Power Systems, is to provide technical leadership to exciting new strategic programmes, one being to deliver a step change in the way we manage electrical safety through our Electrical Safety Delivery (ESD) programme.

These teams also act as the 'Technical Authority' for their discipline and are keen to hear from engineers at all levels who would enjoy the prospect of working across multiple programmes, functions and disciplines.

Whoever joins us will gain exposure to many facets within Network Rail's technical authority.
Visit networkrail.co.uk/careers/me-engineers

Excellent rewards. Unrivalled exposure.

Engineers *All levels*

Milton Keynes

At Network Rail, safety is at the heart of everything we do, and one of the biggest challenges we are ready to rise to, is to deliver a step change in the way we manage electrical safety through our Electrical Safety Delivery (ESD) programme. This is just one focus for the electrification teams that form part of our Mechanical & Electrical Engineering (M&EE) function.

Within our Safety, Technical and Engineering Directorate, the M&EE function has three main electrification teams: Power Distribution, Contact Systems and Power Systems. These are the teams that act as the 'Technical Authority' for their discipline and are responsible for providing the technical leadership to exciting new strategic programmes such as ESD and National SCADA Renewal.

As new opportunities arise for engineers to join us at all levels – there will be a rare opportunity to take on a range of challenges across multiple disciplines and functions and to gain exposure to many facets within Network Rail's technical authority along the way.

So, if you're a suitably qualified engineer with a real desire to play your part in a transformational function and range of programmes, that will see you gain the breadth of experience you are unlikely to get anywhere else in the industry, maybe we should talk.

To find out more, please visit networkrail.co.uk/careers/me-engineers

Network Rail welcomes applications from a diverse range of candidates regardless of age, disability, marital status (including civil partnerships), pregnancy or maternity, race, religion or belief, sexual orientation, transgender status, sex (or gender), employment status, membership or non-membership of trade union, social class or any other irrelevant factor. We are committed to interviewing all applicants who declare a disability and meet the essential criteria advertised. We are two ticks accredited and we continue to strive to create a workforce as diverse as the communities we serve.

@NetworkRailJOBS
/NetworkRailJobs
/company/network-rail

HM Revenue & Customs

Head of Engineering

£59,532 - £68,259
Nottingham
Ref. 1541778

Setting and assuring modern technical standards, you'll enjoy significant influence on the largest estates change programme in Government. At HMRC, we're bringing all our people together in 13 large Regional Centres. Our Estates Directorate is at the very heart of our work to build a new modern, digitally enabled Estate. An inspiring, engaging and innovative Head of Engineering, you'll be a pivotal member of our senior leadership team. With considerable autonomy, you will be instrumental to keeping our people safe and delivering the best value for money possible.

A highly experienced engineering professional, you'll bring to the role a proven track record in the management of estates, together with a demonstrable ability to lead within an engineering environment. In return, you'll enjoy impressive civil service benefits and the chance to create a unique legacy within a team that aims to be the public sector's finest Estates department.

To apply, please visit the Civil Service Jobs website **https://www.civilservicejobs.service.gov.uk** and search under relevant reference number.

Closing date: 21 June 2017.

HMRC is an equal opportunity employer.

SOLIDSOLUTIONS
SUPPORTING EXCELLENCE

USE YOUR ENGINEERING KNOWLEDGE IN A HIGH-REWARD TECHNICAL SALES CAREER

Are you a self-motivated, assertive engineer who may not have considered a role in technical sales? Are you ready for a new challenge and change of direction?

Selling cutting-edge CAD technology requires individuals with the drive and determination to succeed. Our top technical sales people were engineers like you & are now seeing earnings in excess of £75,000.

We are the largest supplier of SOLIDWORKS CAD software. Due to strong growth we are expanding our team - positions are available across the UK & Ireland.

No previous sales experience is necessary as full training, support and development will be given.

SOLIDWORKS
www.solidsolutions.co.uk

Call **01926 333 777** to arrange an informal discussion with our Sales Director, Steve Oxley.

WCG

WCG is one of the largest higher and further education colleges in the country with just under 17,000 students and around 1,800 staff. Our values and culture are centred on entrepreneurialism and innovation and our aim is to create students who are ready for the professional world. We operate over two counties with seven college sites.

We are one of the leading apprenticeship providers with a 76% success rate. WCG train over 2000 apprentices every year and pride ourselves on our strong links with employers like Jaguar Land Rover to train apprentices to become the workforce of the future.

Due to our growing success with Jaguar Land Rover, we have a number of exciting opportunities in our Engineering department. If you think you have what it takes to develop the next generation of engineers and would like to work alongside a leading car manufacturer then take a look at the opportunities available with WCG below. These roles will be based at our Warwick Trident centre. Salary for the roles will be negotiable based on experience and qualifications.

Engineering Lecturer HE

Do you have a passion for helping others to learn? Do you want to share your knowledge to develop younger minds?

Working in Higher Education gives you the chance to really make an impact on the future of your students. At WCG we value the variety, ingenuity and resourcefulness that teachers bring into the classroom in order to best connect with their pupils and aid them in their understanding.

As one of the largest Further and Higher Education providers in the UK, and one of only 5 UK colleges to be granted Foundation Degree Awarding Powers, our education in the HE sector is the equivalent of many universities. With over 1000 students studying on our HE courses at any time we rely on exceptional teachers and innovative teaching methods to keep students engaged and maintain our highly personal approach to teaching.

LEARNING TO **CHANGE.**

Engineering Lecturer FE

At Further Education level WCG is an extraordinarily successful college; we have a 92% pass rate across all FE courses and a 98.6% pass rate in A-Levels, with a 100% pass rate across two of our campus'. We have the most 16-18 year old students enrolled and the highest success rates of all large general FE colleges in the county, this places us comfortably in the top 25% of all general FE colleges in the country.

We have a number of opportunities available within our Engineering department to teach on subjects such as Welding, Automotive and CAD. If you believe that you have the abilities to add to the excellent teaching that WCG requires then you shall be rewarded generously. You'll be entitled to 35 days holiday per annum (pro rata) as well as College Closure days and Bank holidays, and other benefits including addition to the Teacher's Pension, free parking and free gym membership.

Work Based Learning Manager

WCG has a strong foundation in apprenticeships, training over 2000 annually. Our Work Based Learning Manager role will involve liaising with employers, apprentices and the support team in order to facilitate the apprentice's learning journey. In order to accomplish all of this you'll need to be an enthusiastic and motivating individual, happy to work with students and help facilitate their success and that the duty of care for the apprentice is always maintained.

With students placed in many local business and companies the role is a varied one presenting many challenges and a plethora of new and exciting opportunities to undertake. If you have the necessary passion for helping others then you shall be kindly thanked by WCG, we offer 25 days holiday (pro rata) as well as Bank Holidays and College Closure days. On top of this we have perks such as free parking, free gym membership and discounted hair and beauty treatment.

How to Apply

If you are interested in applying for the above roles you can submit your CV to **jobs@warwickshire.ac.uk** quoting the role you are applying for. Alternatively if you would like more information regarding the roles please contact the **HR department on 01926 318221 or email maftab@warwickshire.ac.uk.**

Closing date: 31st July 2017

Indexing chain conveyor system expands range of pallet systems

Making cycled supply and interlinking possible Sponsor: mk Profile Systems Limited

The TKU 2040 indexing chain conveyor system expands mk's portfolio of pallet systems. It makes cycled supply and interlinking possible, for example in the machine tool and plastics industry as well as in the automotive industry.

The TKU 2040 is especially well suited for defined, position-oriented supply and removal as well as for interlinking machining centres. The system's timing can be individually configured to a fixed cycle.

The TKU 2040 is based on the mk profile system and is modularly constructed, compact, flexible and extremely robust. It is constructed from a timing chain conveyor with 2 roller chains, which permits a total load of up to 700 kg. The conveyor body consists of two profile sections with gliding assemblies for the chain and the workpiece fixtures. It is available in designs with a predefined width or with an adjustable width. The adjustable width makes it possible to use with workpieces of different sizes.

According to the specific requirements, the workpiece fixtures can be prisms made out of either polyoxymethylene (POM) or brass, which are optimal for holding round work pieces. Alternatively, profile pallets can be individually equipped with customer-supplied workpiece fixtures.

In addition to modules such as fixed and adjustable conveyor bodies, pallets, adjustment units, drives, tails and different types of frames, protective device guards, a drip pan and an automatic lubrication station are also available

New product animations for 3D modelling added to website

Videos show the products in a new and innovative light. Sponsor: TR Fastenings

Global fastener firm TR Fastenings is upgrading its online product catalogue with the introduction of exclusive new 3D models and animations to its website.

The models and animations, which allow users to move the product images around and see how they are installed and used with other materials or components, are hosted on Sketchfab.com, a VC-backed platform which acts as an online library for 3D models and virtual reality (VR) content.

TR embarked on the project in 2016, and so far has 50 models and 10 animations online. TR will be adding new models to the site over the coming months and aim to have a 3D interactive model for each one of the 800 products categories on the website by the end of 2017.

The videos not only show the products in a new and innovative light, but are also extremely useful for sales and customer service teams needing to demonstrate how the fasteners work to existing and prospective customers when they are not in the same location. The interactive models are more effective than static images, as customers can move around the model and see the product in detail from any angle. With regards to the animations, the files are much smaller than traditional videos and work on any device. No plug-ins are required and the animations have been designed with all browsers in mind.You can see an example model here and an example animation here, or visit the TR website for more. www.trfastenings.com

Rapid insert moulding and overmoulding services expanded

Proto Labs has expanded its services. Sponsor: Proto Labs

Leading digital manufacturer, Proto Labs, has officially launched insert moulding and overmoulding, supported by a fully automated quoting and manufacturing process, across its global business.

Rapid overmoulding and insert moulding processes produce custom prototypes and on-demand production parts in 15 days or less. They use aluminium moulds that offer cost-efficient tooling, and moulded parts that can be manufactured from a range of thermoplastic and liquid silicone rubber materials.

With overmoulding, the production of the substrate parts is a standard injection moulding process involving an aluminium mould with no heating or cooling lines running through it. Cycle times are a bit longer, which allows Proto Labs moulders to monitor fill pressure, cosmetic concerns, and the basic quality of the parts.

When the total run of substrate parts are moulded, overmould tooling is then assembled to the press. The substrate parts are placed by hand into mould where each part is overmoulded with either a thermoplastic or liquid silicone rubber material.

Insert moulding is a similar process but instead uses a preformed part – often metal – that is loaded into a mould where it is then overmoulded with plastic to create a final component. When the run is complete, parts (or the initial sample run) are boxed and shipped shortly thereafter.

June 1953 Higher ground

Specially designed oxygen breathing apparatus developed to help climbers on Mount Everest

When, on 29 May 1953, Sir Edmund Hillary and Tenzing Norgay became the first people to reach the summit of the world's highest mountain, their achievement was rightly hailed as a triumph of human endurance and skill.

But alongside the planning, skill and mountaineer's luck that helped them to the top of Mount Everest, their expedition also made practical use of some of the most advanced technologies available to climbers at the time.

In June 1953, just a few weeks after their historic success, *The Engineer* took an in-depth look at a key item of equipment: the specially designed oxygen breathing apparatus that was used by the climbers to overcome the effects of the rarified atmosphere at high altitudes.

As the article reports, the system was developed for the expedition by UK firm Normalair Ltd, which specialised in manufacturing high-altitude life-support equipment for the aerospace industry. The firm still exists as a division of Honeywell Aerospace in Yeovil.

Based on a design developed by Farnborough Royal Aircraft Establishment, the equipment represented a significant advance on earlier breathing devices, which were unreliable and therefore mistrusted by many climbers.

The device was a so-called 'open-circuit' system, whereby reserves of oxygen carried in canisters on the climber's back were inhaled via a system of regulators, while the climber's exhaled breath was vented out into the atmosphere.

Consisting of three oxygen cylinders carried on a light-tubular carrier frame, the apparatus weighed 18.1kg and was designed to provide a total of 2,400 litres of oxygen. The rate at which this was used up would vary depending on the flow rate selected by the climber. They had a choice of either two or four litres per minute.

> "It was extremely simple to set up and use – the user merely has to don his mask and turn the regulator valve to the 'on' position"
> *The Engineer*

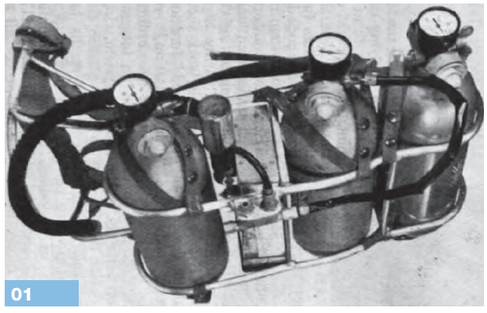
It was: wrote *The Engineer*, extremely simple to set up and use. "The user merely has to don his mask and turn the regulator valve to the 'on' position. The high-pressure oxygen is then reduced to a normal pressure and passes through flexible braided rubber tubing to a dual manifold assembly."

This assembly had two outlets – one for a low flow of oxygen and one for a higher flow. Oxygen then passed through one of these outlets to the economiser which ensured that whenever the climber began to breathe in, oxygen was automatically fed into the face mask.

When the oxygen supply ceased or the pressure dropped, the climber had to disconnect the empty bottle, discard it on the mountainside, and reconnect a fresh bottle to the system.

One particularly innovative design tweak saw the adaptors for the system altered so that the climbers would be able to make use of high-pressure oxygen bottles left on the mountain by earlier expeditions.

While Hillary and Norgay opted for an 'open-circuit' system, the 1953 attempt took place at a time when some were considering the potential benefits of closed-circuit systems that save on weight by recycling the climber's exhaled air. "Should a lighter set be necessary perhaps the best method would be to adopt the use of the closed-circuit system," wrote *The Engineer*. "But this means the 'unused' oxygen exhaled would not be wasted and only the relatively small percentage of oxygen used would need to be made good."



01

02

01 The apparatus consisted of three oxygen cylinders carried on a light-tubular carrier frame

02 Sir Edmund Hillary (left) and Tenzing Norgay reached the summit of Everest on 29 May 1953

Interestingly, just days before Hillary and Norgay reached the summit, English climber Tom Bourdillon came tantalisingly close using just such a system. Had he succeeded, it's possible that the history of breathing apparatus for high-altitude mountaineers would have taken a different path.

Today, most climbers attempting Everest use oxygen canisters. Indeed, until relatively recently an oxygen-free ascent was considered impossible. To date, of the approximately 4,000 climbers to have reached the summit, only around 200 have climbed without supplemental oxygen and a number have died trying. **JE**

Word of the issue

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

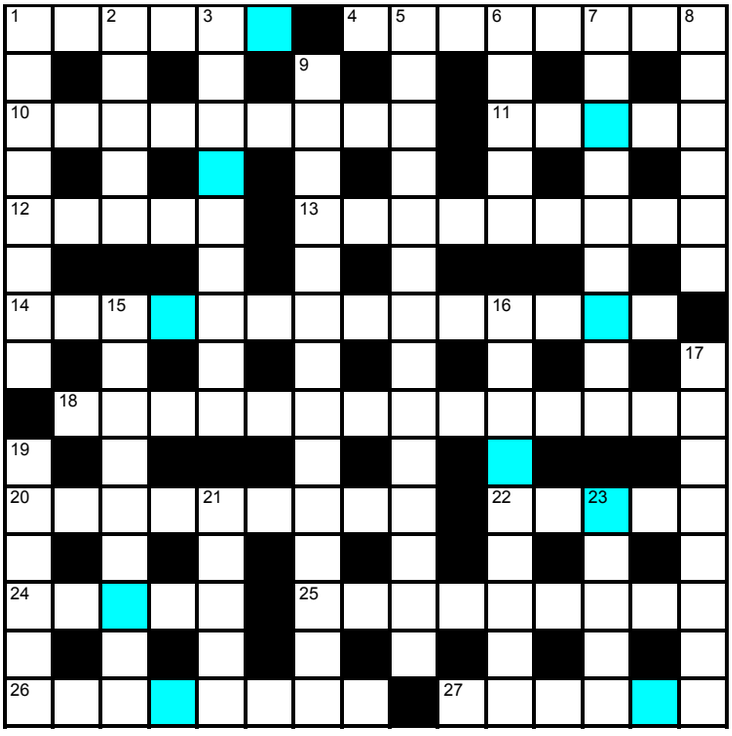
While 'battery' is seen as an electrical item, and thus very much a contemporary device, from the etymological viewpoint the origins are very different.

Strictly speaking the tale begins in the middle when starting with an examination of 'battering'. This is from 1530 and Middle French batterie and earlier Old French baterie meaning 'thrashing, assault'. This Middle French word led to 'bombardment', which is easy to see, and then to the electrical sense – this coined by Benjamin Franklin in 1748, thought to be in the sense of 'electrical discharges'.

Moving to Middle English, we find bateri used to mean 'forged metal ware', a reasonable description of items shaped by hammering. This is why we next examine the origins of the verb 'to batter', this being the origin of batter, from Old French batre and Latin battuere, both meaning 'to strike', as indeed does the Proto-Indo-European bhau.

Bigpicture

Briggs Automotive Company (BAC) has delivered a BAC Mono to the Isle of Man Police Force. The supercar, which can accelerate from 0-60mph in 2.8 seconds, will be on show at a number of local festivals to encourage safe and responsible driving.



Prize crossword

When completed rearrange the highlighted squares to spell out the total amount of raw materials processed by a refinery in a given period. The first correct answer received will win a £20 Amazon voucher. Email your answer to **jon.excell@centaur.co.uk**

Across

1 Most up to date (6)
4 Example regarded as typical of its class (8)
10 A mid-western state (9)
11 To disturb (5)
12 Dull yellowish-brown colour (5)
13 Eye for an eye (3,3,3)
14 Inventory accounting where new items sold first (4,2,5,3)
18 Literary fantasy with futuristic devices (7,7)
20 Beautiful and charismatic queen of Egypt (9)
22 More than enough (5)
24 Hang loosely (5)
25 Position oneself (9)
26 Tableware decorated with facets (3,5)
27 Instance of travelling by air (6)

Down

1 Oven used to reduce forms of calcium carbonate (8)
2 Kingdom in SW Pacific (5)
3 Make free from bacteria (9)
5 A white gypsum cement (7,2,5)
6 Goods carried by a large vehicle (5)
7 The highest peak in Japan (5,4)
8 Write down (6)
9 Defensive structures around a stronghold (14)
15 Removed with a pressure difference force (6,3)
16 Broadcast station (2,7)
17 Charge for borrowed money (8)
19 Having a pH of less than 7 (6)
21 Learner enrolled in educational institution (5)
23 Car crash (5)

May's highlighted solution was Oratory. Winner: **Peter Bourne**

CALL FOR ENTRIES DATE EXTENDED TO 23RD JUNE

the ENGINEER collaborate to innovate

In association with FRAZER-NASH CONSULTANCY and Mazak Your Partner for Innovation

Celebrating the best engineering collaborations and innovations

MEDIA | AWARDS | CONFERENCE

Meet the Judges!

DANIELLE GEORGE, PROFESSOR OF RADIO FREQUENCY ENGINEERING, UNIVERSITY OF MANCHESTER

PROFESSOR IAIN GRAY CBE, DIRECTOR OF AEROSPACE, CRANFIELD UNIVERSITY

DR CHRIS GUYOTT, ENGINEERING DIRECTOR, FRAZER-NASH CONSULTANCY LTD

JOHN HALTON, DIRECTOR - BUSINESS & INDUSTRY, ENGINEERING UK

ALAN MUCKLOW, DIRECTOR - UK AND IRELAND SALES DIVISION, YAMAZAKI MAZAK

ALAN NEWBY, DIRECTOR AEROSPACE TECHNOLOGY AND FUTURE PROGRAMMES, ROLLS-ROYCE PLC

TOM RODDEN, DEPUTY CEO, EPSRC

JENNI SIDEY, LECTURER IN INTERNAL COMBUSTION ENGINES, CAMBRIDGE UNIVERSITY

PROFESSOR ANDY WRIGHT, DIRECTOR STRATEGIC TECHNOLOGY, BAE SYSTEMS PROGRAMMES AND SUPPORT

Whether you are a small business, large corporation or academic research department share your collaborative success stories, shout about your achievements and tell us why you are the best!

Brought to you by the ENGINEER

In Association with: FRAZER-NASH CONSULTANCY, Mazak Your Partner for Innovation

Sponsor: RENISHAW apply innovation™, BAE SYSTEMS INSPIRED WORK

In Partnership with: EPSRC Engineering and Physical Sciences Research Council

Mazak

Your Partner for Innovation

The Internet of Things

Industry 4.0

JOIN US ON **STAND B56 HALL 27**
18TH - 23RD SEPTEMBER 2017

At EMO 2017, Mazak will showcase the full breadth of its **Industry 4.0** infrastructure based on latest generation Smooth CNC.

Smooth Technology is already used by Mazak and its customers to securely extract, analyse and generate action from machine and production data. Driving real-time decision-making, greater productivity and creating the connected factories of the future - iSmart Factories!

See the future of manufacturing in **Hall 27, Stand B56.**

Yamazaki Mazak U.K. Ltd.
Badgeworth Drive,
Worcester WR4 9NF

T: +44 (0)1905 755755
F: +44 (0)1905 755542
W: www.mazakeu.co.uk
E: sales@mazak.co.uk

It's all about industry 4.0