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our opinion

Salvation from above

In this issue's cover story (p22) *The Engineer* takes a look at what is surely one of the aerospace sector's most fascinating niches – the world of aerial firefighting.

As we report, thanks to a combination of climate change and increasing human intrusion into remote areas, wildfires around the world are burning for longer and with more severity. This is stretching the resources available to fight them and driving the development of a host of fascinating technologies: from the motley assortment of modified fixed-wing aircraft and helicopters used to drop water and retardant; to specially developed night-vision systems; AI tools that use weather, fire and topographical data to predict the way a fire will develop; and, increasingly, drones.

We talk to some of the leading experts in this fascinating field about the challenges they are facing and the role technology is playing in meeting these demands head on.

Remaining on the 'curious-niches-of-large-sectors' theme, this issue also takes a look at the solar railway (p28): a concept that many claim could one day transform the energy needs of one of our biggest forms of transportation. We explore Imperial College's *Riding Sunbeams* report and ask whether solar-powered trains could ever become a reality here in the UK.

“Wildfires around the world are burning for longer and with more severity, stretching the resources available to fight them”

Finally, in our regular interview slot (p30), we talk to the new CEO of UK nuclear fusion specialist Tokamak Energy – a company we've followed closely in recent years – which is developing small, modular fusion reactors.

Conventional wisdom – or cynicism – dictates that fusion is always 20 years away. But the firm's new boss Jonathan Carling hopes to knock almost a decade off this nebulous prediction, and outlines a compelling roadmap that he believes will see his company's small-scale reactors bring fusion to the UK grid by 2030. If he pulls it off, this small UK firm will be propelled to the forefront of industry that many believe will dominate power generation in the decades ahead.

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AUTOMOTIVE

The cars that put something back

£30m initiative aims to make the case for vehicle-to-grid technology HELEN KNIGHT REPORTS



Electric cars do not just reduce greenhouse gas emissions when they are on the road. When parked, they have the potential to put energy stored in their batteries back into the grid.

By recharging when the demand for power is low and returning energy to the grid when it is high, this so-called vehicle-to-grid (V2G) technology could help to stabilise electricity networks and support the increasing use of intermittent renewable energy sources.

Now, with the launch of 21 projects, a major effort is underway in the UK to develop the technology and business case for V2G charging. The initiative will benefit from £30m shared between them.

The projects, which involve 50 research organisations and industrial partners, are being funded

by the Office for Low Emission Vehicles (OLEV) and the Department for Business, Energy and Industrial Strategy, in partnership with Innovate UK. They include eight feasibility studies, five research and development projects and eight real-world V2G trials.

One such venture is PowerLoop, led by Octopus Energy, which is developing the UK's first large-scale domestic trial of V2G charging.

The £7m project, including £3m competition funding, will involve leasing about 135 electric vehicles with a V2G bundle, known as the Octopus PowerLoop, to drivers in and around London.

The PowerLoop bundle includes a two-way charger that allows drivers to charge their vehicle when needed, but also lets them use the charged battery to power their home or sell unwanted electricity back to the grid.

In this way, the project partners

– who also include Octopus Electric Vehicles, UK Power Networks, ChargePoint Services, Open Energi, the Energy Saving Trust and Navigant – hope to create a cluster of users that will help them to understand the impact of widespread electric vehicle use on the grid.

Those taking part will be able to lease the cars for a period of two, three or four years, according to Fiona Howarth, CEO of Octopus Electric Vehicles.

The project partners also plan to develop a platform that will allow users to communicate with their service providers.

“So, for example, if you were to get home at 5pm and plug in your car, you may want to ensure that 30 per cent of your battery charge is kept for emergencies,” said Howarth.

“But then you might say that the energy supplier can do what they like with the remaining 70 per cent of the battery charge until 7am, when you have to leave for a business trip.”

As well as the PowerLoop project, UK Power Networks is involved in three other trials. One of these is Bus2Grid, which intends to convert a 30-bus garage in London into the UK's first V2G bus depot.

Electricity supplier SSE is leading the multi-megawatt demonstration at the garage. The Chinese firm BYD, which manufactures electric buses, is also involved.

Another project, called HAVEN, will investigate the value V2G and vehicle-to-home (V2H) charging can offer consumers when used alongside other energy storage systems such as lithium ion batteries attached to solar panels, and hot water tanks. The project will also consider how the technology's value varies with different energy consumption and driving patterns.

The consortium, which is being led by cloud-based smart grid company Upside Energy and also includes Honda, Good Energy and Salford University, will create models of different home energy storage configurations.

Meanwhile the Scirus project, led by Nissan, will develop and deploy V2G chargers to participants who own or lease a Nissan Leaf. It will also develop a grid balancing platform to support grid operators at times of peak demand. ■

Read more online

Policy & Business

Half of UK engineers want Brexit referendum restaged, survey shows

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Why Industry 4.0 is an evolution, not a revolution

The phrase “Industry 4.0” has proliferated across trade, business and national press in recent years, and is largely hailed as the next industrial “revolution”. However, in the UK Industry 4.0 hasn’t been embraced as widely and as quickly in comparison to our European counterparts. Andrew Minturn, Business Development and Strategic Product Manager at Bosch Rexroth explores the barriers to implementation and offers practical advice on how best to approach Industry 4.0.

There is currently a general understanding that Industry 4.0 refers to the “digitalisation” of a business’s infrastructure, but there has yet to be any consistent standards or definitions applied to what remains an arguably vague concept for businesses worldwide. Yet, what is becoming clear is that Industry 4.0 will fundamentally define how a country such as the UK does business within the next five to ten years.

The difficulty lies in the UK’s understanding of what Industry 4.0 actually is. All manufacturing companies, whether large or small, are under constant pressure for their products to be better quality, lower cost and available quicker. Industry 4.0 should be seen by manufacturers as an umbrella term for a toolkit of available technology to enable them to deliver these requirements.

Barriers to Industry 4.0 implementation

Governments around the world are creating strategies and policies to encourage the adoption of digitalised manufacturing. Despite the excitement and increased media coverage, this is progressing more slowly than hoped – especially in the UK.

“The Big Bang”

The media hype around Industry 4.0 has certainly helped to disseminate the message across UK industry, but it has also had a somewhat unintended effect of an all-or-nothing mentality among businesses.

A complete digital overhaul, no matter the size of the business, is an enormous task that would prove difficult for even the most resourced businesses to undertake. It is vital that businesses understand such an approach is unnecessary, and may actually be hampering any possibility of moving forwards with an Industry 4.0 strategy.

Scalability

A concern for many will be the feasibility of scaling digital technologies to match that of their current operations. The suitability of one’s manufacturing environment to Industry 4.0 will certainly vary from business to business, but many manufacturers remain unaware that a range of technologies exist to support the digitalisation of their infrastructure, without the need to replace existing equipment.

The cost of implementation

Whether the business holds an “all-or-nothing” or “one-size-fits-all” mentality, cost will remain a primary concern. While several reports have highlighted a willingness in industry to invest, there remain some doubts over the affordability of certain Industry 4.0-based technologies, as well as the cost of training and/or hiring staff. Furthermore there is currently limited data available to demonstrate the return on investment of Industry 4.0.

Readiness

It is important to remember that Industry 4.0 does not just refer to technologies within automation, cloud or Edge computing and data sharing. It also encapsulates organisational restructuring – moving from a physical to a digital infrastructure within a more collaborative, data-reliant environment.

This, therefore, requires each employee at an individual level to change their mindset and adopt one that is, not only open to change, but open to the concepts that Industry 4.0 embodies.

Step-by-step approach

The best way to implement Industry 4.0 is through a gradual process. This means prioritising the areas in which digitalisation would offer the most benefit, such as improving productivity or levels of quality and consistency.

A step-by-step approach will enable businesses to expand Industry 4.0 capabilities by building on its initial digitalised capabilities. The advantage being that the solid foundations of technology, infrastructure and skills can be laid, facilitating the final move into the so-called “Factory of the Future”.



To download a full copy of the report, *A practical roadmap for the implementation of Industry 4.0* and to find out more about how Bosch Rexroth can assist in your Industry 4.0 journey, please visit:

<http://bit.ly/Industry40WP>

ROBOTICS

You've really got a hold on me

Inspired by octopus tentacles, a robotics team built an artificial sucker JASON FORD REPORTS



The Royal College of Art's sensorised mechanism acts as an anchoring module

Efforts are underway to replicate the way octopus suckers work – an advance that could lead to applications in industrial, medical and disaster monitoring scenarios.

The project – led by Dr Sina Sareh, academic leader in robotics at the Royal College of Art – has built a biologically inspired, soft artificial sucker that acts as a robotic anchoring module.

The aim is for the sensorised mechanism, described in *Journal of the Royal Society Interface*, to be integrated into robots and drones to enhance mobility, remain on location or manipulate objects.

Many aquatic creatures can attach themselves to objects, but the

octopus's ability is exceptional. "It can attach to something very delicate, like octopus egg capsules," said Dr Sareh. "It can grab them, it can manipulate them and change their position without damaging because it has a soft interface for gripping. It can [also] stiffen and attach to rocks, for example, to stand against a storm surge and waves... so this is completely diverse functionality in one system."

The research builds on a greater understanding of the acetabulum, the cup-like upper part of the sucker, and the infundibulum, the lower part that makes contact with surfaces in an octopus's grip. The infundibulum is covered in grooves, which spread low pressure produced by the acetabulum over the whole infundibular surface. This aids

suction and helps octopuses hold on to surfaces.

To replicate this effect, the team developed a new stiffness-gradient structure for the anchoring module based on two types of silicone materials. The hard portion is capable of containing vacuum pressure, while the soft portion is highly conformable to create a seal with varied contact surfaces.

Dr Sareh explained that a single sensory unit uses a 4-core fibre-optic cable to measure proximity and tactile information seamlessly for use in robot motion planning, as well as measuring the state of firmness of its anchor.

The resulting sensory-physical system – integrating a physical process with sensors and computation to monitor or control the process – consists of a soft artificial infundibulum and acetabulum parts integrated with the sensory unit and a vacuum supply pipe. The vacuum pressure was supplied by a vacuum pump via a vacuum regulator with an onboard pressure sensor.

In this configuration, the artificial sucker is capable of reversible attachment (switching between attachment and detachment with an electrical signal), quantifying the firmness of the anchor to attach to, and identifying suitable contact surfaces.

An approximately 25mm diameter sucker has already been produced. In the next stage of research, smaller artificial suckers will be developed in an array structure. ■

Newsinbrief

Radioactive waste dump

Two consultations have been launched into the construction of a geological disposal facility (GDF) for Britain's nuclear waste. A GDF would keep radioactive waste at least 200m underground and could add more than £8bn to the economy, along with up to 2,000 jobs. Similar facilities are under development in Finland, Sweden, France and Canada.

CBI detects optimism

Manufacturing growth accelerated in the past quarter, according to the CBI Industrial Trends Survey. The survey of 369 manufacturers found optimism about business conditions and export prospects had improved, and that output and domestic and export orders grew in the same period. Investment intentions for buildings and plant and machinery moved back above average after deteriorating in the previous quarter.

Electric car batteries

The Faraday Institution has announced up to £42m in funding to four UK-based consortia to conduct research aimed at overcoming global battery challenges for electric vehicles. Business minister Richard Harrington said that "investment in car batteries is a massive opportunity for Britain".

Circuits that self-destruct

Engineers have developed a new way of triggering electronic circuits to self-destruct. This ability is fundamental to transient electronics, in which key portions of a circuit can discreetly disintegrate, protecting sensitive data. With no harmful by-products released, engineers from Cornell University and Honeywell Aerospace foresee biomedical and environmental applications too.

RAIL

Alstom tests autonomous freight trains

Trials planned for 100km route across the Netherlands

HELEN KNIGHT REPORTS

Alstom is to test autonomous freight trains on a 100km stretch of track in the Netherlands. The trials, starting this year, will see a locomotive

equipped with Automatic Train Operation (ATO) technology run from Rotterdam harbour to CUP Valburg in the east of the country.

The locomotive will travel along the Betuweroute, a 150km double-track freight line connecting Rotterdam to Germany. It is already equipped with Automatic Train Protection (ATP), which controls its speed and carries safety information about slopes or stations on the track.

Stephen Shirlaw, operational marketing manager for Alstom Digital Mobility, said the technology will free the driver to focus on supervising the train journey.

"It frees up the driver to perform the captain's role without having to have his eyes focused on the traffic information and his hands on the accelerator and brake."

The system should also increase capacity on the railway network by allowing trains to operate at closer intervals, and reduce energy consumption by enabling trains to operate more uniformly.

Alstom is collaborating with Dutch infrastructure operator ProRail and Rotterdam Rail Feeding (RFF), which is supplying the locomotive.

The tests are due to finish by the end of this year. ■

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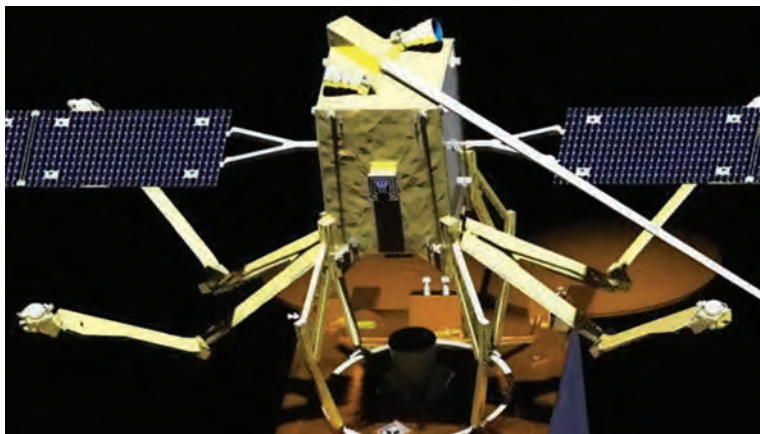
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AEROSPACE

'Space Drone' plan to keep satellites in the right orbit

Off-Earth missions will keep old equipment running HELEN KNIGHT REPORTS



Electric thrusters on the drone will adjust the satellite's position and orientation

Two UK-built spacecraft designed to latch on to ageing communications satellites and keep them in their assigned orbit, thereby extending their lives, are set to be launched in 2020.

The announcement follows the signing of a \$100m contract between UK-based Effective Space, which is developing the Space Drone spacecraft, and a major satellite operator.

According to Shahida Barick, head of satellite operations at Effective Space, the purpose of the spacecraft is to control the position and orientation of two satellites in

geosynchronous Earth orbit, potentially extending their life by several years.

Most satellites are designed for 15 years' service, said Barick. Typically, at the end of that time, their hardware systems work perfectly but their propulsion system can no longer control their position.

"These multimillion-pound satellites are decommissioned essentially because they run out of fuel," she explained.

"It doesn't make sense to decommission satellites that are otherwise healthy and providing services that are generating millions of pounds in revenue."

The Space Drones, which are capable of carrying out multiple

missions in the course of their 15-year lifespans, weigh less than 400kg and are equipped with electric thrusters. A universal docking system enables them to connect with almost all of the approximately 400 communications satellites in orbit.

"As [the Space Drone] approaches the communications satellite, it will deploy a set of four identical docking arms, which will latch on to the satellite's launch interface ring," said Barick.

This is an extremely tough part of the satellite, used to attach the spacecraft to their launch rocket.

"Once we are latched on to the ring, we essentially become part of that satellite and act as an external jet pack," Barick added.

Having docked with a satellite, the drones will use their electric thrusters – attached to another set of protruding arms – to keep the combined spacecraft in the correct position and orientation.

When the satellites are ready for decommissioning, the drones can use their thrusters to move them into a safe 'graveyard orbit'.

The agreement is one of the first commercial contracts for in-orbit satellite servicing. Space Drones could also be used for removing space debris and for in-space exploration, mining and manufacturing logistics. ■

STRUCTURAL

Bridge pier based on the backbone

Spine-like structure is designed to withstand earthquakes

HELEN KNIGHT REPORTS

UK researchers are working on a durable, low-maintenance, low-carbon bridge pier inspired by the human spine.

The structure, which could be built in a day or two and easily demounted at the end of its useful life, is being developed at Southampton University with EPSRC funding. It will be designed to withstand earthquakes and damage caused by traffic and cold weather.

In colder countries particularly, bridges suffer from corrosion caused by salt spreading in winter. This means they require expensive maintenance, according to project leader Dr Mehdi Kashani.

He added: "When these bridges are under dynamic loading – either from a high-speed train or an earthquake – because of the fixed way they are constructed, they tend to crack, and when concrete cracks it accelerates the deterioration."

By contrast, vertebrae in the human spine are stacked flexibly on top of each other and free to move. Between them are intervertebral discs, which dissipate energy from the body's movement and absorb and transmit forces without damaging the vertebrae.

The 'vertebrae' of the bridge pier will be precast composite segments with no reinforcing steel. The 'intervertebral discs', constructed from a new smart composite material being developed by the team, will prevent them from rubbing against each other, transfer shear forces through friction, absorb impacts caused by the rocking of the vertebrae and provide mechanical damping under dynamic loading.

Unlike conventional composites formed of layers, which can delaminate, the material under development will consist of entangled polymer fibres. ■

ROBOTICS

Robots handling the groceries

Ocado brings in collaborative machines

Online grocery firm Ocado has taken delivery of a prototype collaborative robot designed to help maintain systems in its highly automated warehouses.

The so-called ARMAR-6 robot prototype was developed by engineers through the EU-funded SecondHands project, an initiative that includes EPFL, Karlsruhe Institute of Technology, Sapienza Università di Roma and University College London.

The aim is to advance the development of collaborative robots that can interact with humans safely and intelligently in a factory environment.

Ocado will look at how to provide a second pair of hands that will assist technicians when they are in need of help. The robot will learn through observation and will augment the humans' capabilities by completing tasks that require a level of precision or physical strength not available to human workers.

In another initiative – the EU-funded SoMa project – Ocado is working with research groups on the development of soft robotic hands to handle goods that can be easily damaged. **JE**

Fit for the future: will the 4th industrial revolution be good or bad for our health?

At the recent XXI World Congress on Safety and Health in Singapore, Secretary General of the International Social Security Association (ISSA), Hans-Horst Konkolewsky, asked a large audience of international safety practitioners whether the 4th industrial revolution will be good or bad for worker's health and safety. Overwhelmingly the answer that came back was that yes, ultimately the changing world of work will be good for our health and wellbeing. However, there will be many challenges to navigate - and risks to understand and control - before these revolutionary changes have been completed.

What are the nature of these changes? The British Safety Council has commissioned *RobertsonCooper* to produce a literature review, *'Future changes to the world of work and the impact on employee health, safety and wellbeing'*, into the state of research about the changing world of work and their associated risks. The review tells us that people are living - and working - for longer; that many tasks are being automated; modern communication technologies are dissolving the work/home divide; new materials like nanotechnology (including tiny airborne waste products that can damage our health) and new techniques can present new risks; and an increasing use of more 'flexible' employee contracts.

With these deep and fundamental changes to work, the risks associated with work are also changing. The spectre of automation is of course at the heart of many of these discussions. Research by IPPR says that 10 million jobs are at risk from automation in the UK. When those health and safety practitioners were asked the question about the future risks of work, the health advantages of automating certain hazardous processes (for example the increasing use of automated riveting or 3D printing) - and by implication the removal of people - was uppermost in their minds. There are also health benefits to these modern, flexible ways of working where people are adding specific value to automated processes.



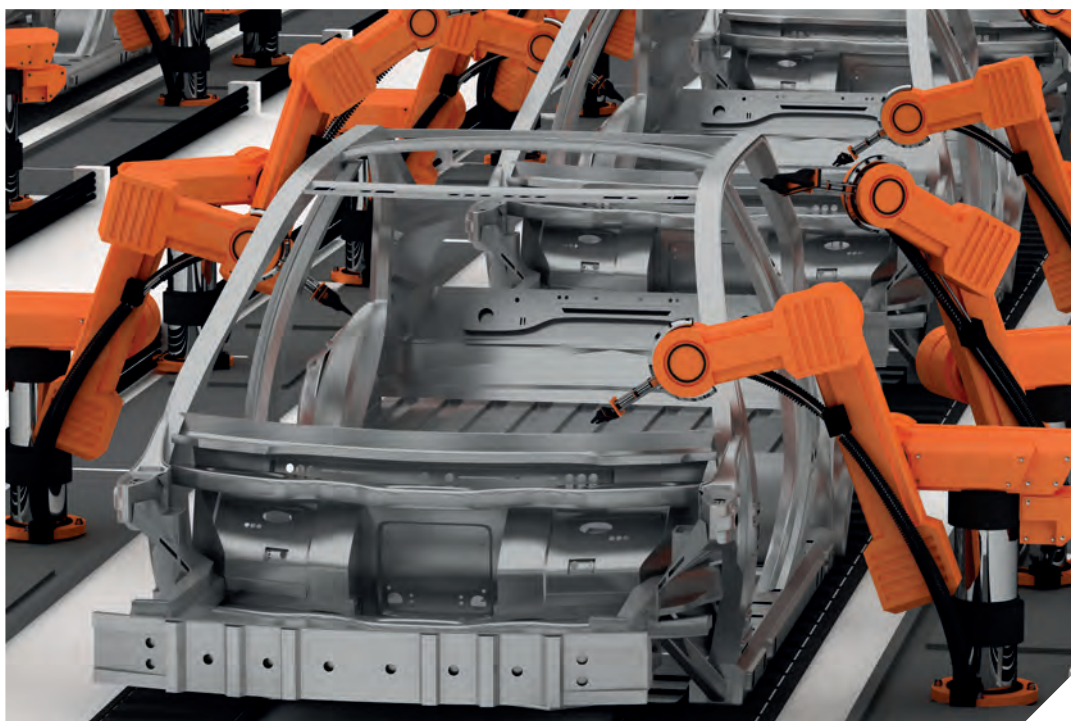
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However, automation may increase inequality - at least in the next 20 years - and there will be many less skilled workers who will not benefit from such changes. Besides, a simple calculation of increasing automation may not fully reflect what will happen as we are already seeing counter-trends of people being re-introduced into the workplace with recognition of the benefits of human labour. It is far more likely that people and intelligent machines will increasingly become 'colleagues' in the future. A colleague who can work without breaks, who is always 'on,' who isn't going to share much 'social' information, is a very different colleague; a relationship that could easily create stress and undermine wellbeing. We also know that people at work derive important health benefits from the social nature of work and this will be an issue to address in the future. Evidence also tells us that the health benefits of 'good' work, whether we define this in

terms of good employment practices, reward and recognition or fulfilling jobs, can be either enhanced or undermined by disruptive technologies.

In its 60-year history, the British Safety Council has always made sure it has the most up to date information on the risks that people experience at, or bring to, work. To argue for change, evidence must be at the heart of everything we do and this report by Professor Cary Cooper's team gives us a roadmap to plot a series of discussions, seminars, events and campaigns. Seminars hosted by the British Safety Council at The Health & Safety Event (NEC, Birmingham, 10-12 April 2018) will be one opportunity to steer us towards a fitter, healthier and happier future. ■



Research by IPPR says that 10 million jobs are at risk from automation in the UK

Free registration for The Health & Safety Event is now open, visit www.healthandsafetyevents.co.uk

RAIL

How novel materials could make rolling stock lighter

Run2Rail project aims to revolutionise train design HELEN KNIGHT REPORTS



A team in Huddersfield is looking at carbon fibre and 3D printing techniques

A European project investigating the use of carbon fibre and 3D printing techniques in bogies and sub-frames could lead to lighter, more durable trains.

A key part of the €2.7m EU-funded Run2Rail project, led by researchers at Huddersfield University's Institute for Railway Research (IRR), will consider the use of novel materials in the running gear of trains. This could reduce the weight of bogies while maintaining their strength, according to IRR director Prof Simon Iwnicki.

As part of the project – which includes Politecnico di Milano, consultants RINA and the Italian engineering and design company Blue Group – the researchers will investigate novel designs for a low-speed metro train and a high-speed intercity vehicle.

"With the low-speed vehicle, we are thinking that instead of having two bogies underneath, each with two wheel-sets and an axle, we would have either one wheel-set at each end of the vehicle or four separate wheels," said Iwnicki.

For the intercity train, the researchers will consider novel body shell construction, he added.

Once they have modelled the two vehicles, the researchers will carry out computer simulations to calculate the loads on each of the components before designing the materials to be used.

The researchers will investigate the use of additive manufacturing techniques using steel powders, in particular for producing smaller components, said Iwnicki.

They are also focusing on the use of lightweight carbon fibre composites, which have the advantage of allowing bogie frames to be constructed layer by layer using robots.

"In this way, you can ensure the robots arrange the fibres in exactly the positions you want them so the component has strength in just the right places," Iwnicki explained.

One of the biggest challenges will be to understand the failure modes of components built from these novel materials, including fatigue and de-bonding of structures.

The project is one of four research packages being undertaken under the auspices of the Run2Rail programme, which aims to develop lighter, quieter, more reliable and more comfortable rolling stock.

Run2Rail is part of a wider €1bn joint undertaking, called Shift2Rail, linking industry and the EU. ■

HEALTHCARE

Monitoring how you clean your teeth

CDP's TruthBrush uses algorithms and miniaturised sensors

HELEN KNIGHT REPORTS



A smart toothbrush that can monitor how people brush their teeth could help to improve the design of oral care products.

TruthBrush, developed by Cambridge Design Partnership (CDP), is equipped with miniaturised sensors such as accelerometers and strain gauges. Algorithms analyse information from the sensors to reveal information such as when and for how long people brush their teeth.

It could also reveal the speed with which people brush and how much force they apply, according to George Bostock, oral care leader at CDP.

"Although a toothbrush is a simple device, the physics of what is going on (inside your mouth) is extremely complicated," he said. "There is a lot of science yet to be learned about how plaque sticks to your teeth and how best to remove it, to help us understand the brush-teeth-plaque-gum interaction."

Some electric toothbrushes can already connect to smart apps that record information on brush patterns. However, the vast majority of people use a manual toothbrush. "We are putting together a sensor system that is small, neat and light, and has enough battery power that it can go inside a manual toothbrush in an unobtrusive way, so that the user doesn't know it's there," said Bostock.

The TruthBrush is aimed at developers of manual toothbrushes, and could help them to introduce design changes such as better handles for elderly people struggling with poor dexterity. ■

HEALTHCARE

Breakthrough in paediatrics

Implant treats oesophageal defect in infants

Engineers and clinicians have developed a motorised robotic implant to treat a rare birth defect that affects the oesophagus. The device – created at Sheffield University's Engineering Faculty and Boston's Children Hospital, Harvard Medical School – was designed for infants with oesophageal atresia, a condition characterised by a gap in the gullet that stops food reaching the stomach.

The defect is treated using the Foker procedure, whereby sutures are used to manually bring the upper and lower parts of the food pipe together. However, the sutures can sometimes tear.

Attached to the oesophagus by two rings, the new device has an incorporated motor that stimulates the cells by gently pulling the tissue.

Using two types of sensors – one to measure the tension in the tissue and another to measure tissue displacement – the robot monitors and applies traction depending on the tissue properties.

The implant is powered by a control unit that remains outside the body, attached to a vest. **AW**



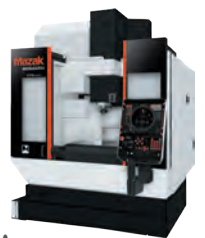
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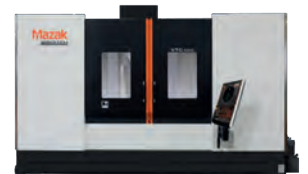
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ENERGY

Scientists aim for the 'artificial leaf'

A new effect found in graphene resembles photosynthesis in plants HELEN KNIGHT REPORTS

Graphene membranes that mimic photosynthesis to produce hydrogen could be developed following the discovery of a new effect.

Researchers at Manchester University have discovered that the rate at which graphene conducts protons increases tenfold when the

been found to be permeable to thermal protons, the nuclei of hydrogen atoms.

To discover how light affects the behaviour of these protons, researchers fabricated graphene membranes and covered them on one side with platinum nanoparticles.

When they illuminated the membrane with sunlight, they found the proton conductivity increased by

a factor of 10. Dr Marcelo Lozada-Hidalgo, who led the research alongside Prof Sir Andre Geim, said: "This is a new effect.

"It can only be found in graphene – there are no other materials that can use light to produce an enhancement in proton transport.

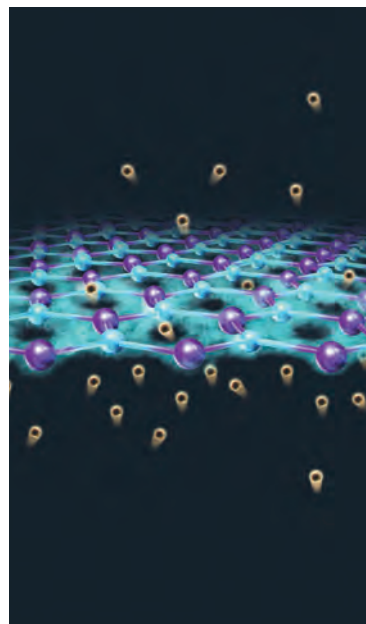
"Scientifically, this is a new physical phenomenon."

When the researchers measured the photoresponsivity of the membrane using electrical measurements and mass spectrometry, they discovered that about 5,000 hydrogen molecules were being formed in response to every light particle. Existing photovoltaic devices need thousands of photons to produce a single hydrogen molecule.

"To put this in context, people have been developing silicon photodiodes for the best part of 50 years, while we did not expect this material to be responsive to light in the first place, and found that it outperforms pretty much everything that is out there," said Lozada-Hidalgo.

The researchers have published their findings in *Nature Nanotechnology*. They now plan to investigate the addition of catalysts to the membrane, to enable it to split water molecules. This would allow it to act as a complete artificial leaf, said Lozada-Hidalgo.

The goal "is to make an artificial leaf, to split water molecules and then use the protons to generate hydrogen," he said. "What we're missing is the bit to break the water in the first place, and for that we need another catalyst." ■



"It outperforms pretty much everything that is out there."

Marcelo Lozada-Hidalgo,
Manchester University

material is illuminated with sunlight.

Dubbed the 'photo-proton' effect, the finding could lead to graphene membranes that produce hydrogen from artificial photosynthesis.

Other possible uses include light-induced water splitting, photo-catalysis and the development of new photodetectors.

Graphene can absorb light of all wavelengths and has recently

AEROSPACE

Emirates deal guarantees A380's future

\$16bn contract with Airbus paves the way for more superjumbos

JASON FORD REPORTS



Airbus will produce A380 superjumbo passenger jets for at least another ten years following a \$16bn order from Emirates. The deal for 36 A380s comprises 20 firm orders and 16 options. Deliveries will start in 2020.

Along with the airline's 101-strong A380 fleet and its current order backlog for 41 aircraft, the order brings Emirates' commitment to the A380 programme to 178 aircraft.

Emirates' chairman and chief executive, Sheikh Ahmed bin Saeed Al Maktoum, said: "We've made no secret of the fact that the A380 has been a success for Emirates. Our customers love it, and we've been able to deploy it on different missions across our network, giving us flexibility in terms of range and passenger mix.

"Some of the new A380s we've just ordered will be used as fleet replacements. This order will provide stability to the A380 production line. We will continue to work closely with Airbus to further enhance the aircraft and onboard product, so as to offer our passengers the best possible experience. The beauty of this aircraft is that the technology and real estate on board gives us plenty of room to do something different with the interiors."

The sheikh signed a memorandum of understanding with John Leahy, chief operating officer – customers, Airbus Commercial Aircraft. Leahy said: "This new order underscores Airbus's commitment to produce the A380 at least for another ten years." ■

AEROSPACE

Cold and bothered?

Facial temperatures may help diagnose stress

Changes in facial thermal patterns can be used to determine mental workload, according to a study from Nottingham University.

The research, published in *Human Factors*, details how thermal cameras can measure subtle fluctuations in temperature, particularly around the sinuses and nose. When participants carried out increasingly difficult tasks, this area of the face was observed to drop in temperature, as the autonomic nervous system

took over and breathing patterns changed. It's hoped the discovery could lead to a non-invasive method for assessing the concentration and strain levels of pilots and others in high-stress environments.

Recent advances in digital thermographic equipment mean that cameras can now be placed in a cockpit without being obtrusive. Similarly, improvements in resolution and computing power enable the technology to be programmed to recognise the operator and how he or she will react to a range of different mental demands.

With support from Airbus, the project is part of a wider EU-funded programme exploring novel technologies for aerospace. **AW**

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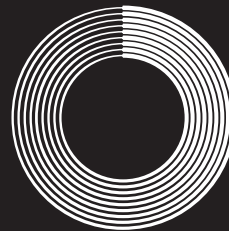


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ROBOTICS

In the swim with the microbots

Bacterial propulsion used to assess potential of micromachines HELEN KNIGHT REPORTS

Swimming micromachines inspired by bacteria could one day carry out precision tasks such as microscale assembly and targeted drug delivery.

Swimming microbots, which are capable of self-assembling to perform a specific task and then disassembling once that task has been completed, have been the subject of research worldwide.

However, it has so far proven difficult to control individual microbots effectively when they are operating within a large group, so they cannot then be used for precision tasks.

To tackle this problem, Dr Tom Montenegro-Johnson, a mathematical biologist at Birmingham University, is looking at the ways in which bacteria such as E.coli change their shape to propel themselves through their environment.

"These bacteria swim by a run-tumble method," said Montenegro-Johnson. "This means they have a ballistic trajectory for a certain amount of time called a run, where they swim in a straight line, and then they unbundle all of their flagella, and this causes a random re-orientation, and then they swim in a straight line again," he said.

To recreate this motion strategy, Montenegro-Johnson is developing swimming microbots in the form of flexible filaments made from a shape memory polymer.

Both ends of each filament are coated in platinum. When placed in hydrogen peroxide, the platinum catalyses its reduction into water and oxygen, causing a flow

"These bacteria are swimming in a run-tumble method"

Dr Tom Montenegro-Johnson
Birmingham University

at the surface of the filament.

If the filament is straight, this flow should act as a pump, if it is bent in a U-shape, the filament will translate, or move a certain distance, and if it is bent into an S-shape, it should rotate.

By targeting ultrasound at different points within the fluid, Montenegro-Johnson plans to heat individual microbots, triggering the shape memory response and causing them to switch between these pre-programmed shapes.

To control the swimmers, Montenegro-Johnson is planning to use a focused ultrasound keyboard developed by Ultrahaptics, a Bristol University spin out.

"They have created... mid-air touch sensation, which consists of lots of ultrasound emitters that can focus onto an 8mm point in space, which they can then move about 16,000 times a second," he said.

In this way the microbots should be able to navigate complex environments using a series of straight runs and on-the-spot re-orientations, just like bacteria. ■



E.coli change their shape and propel themselves through their environment

SHOW NEWS

Supply-chain insight at the cutting edge

Six-stream conference programme explores best practice

Online registration is now open for Subcon, the UK's only dedicated event for contract and subcontract manufacturing.

Taking place from the 5-7 June 2018 at the NEC in Birmingham, this year's event will feature over 400 exhibitors and is expected to attract more than 4,500 visitors from sectors including aerospace, automotive, defence, electronics, energy, materials, oil and gas and rail.

Subcon will be co-located with The Engineer Expo, a brand-new event dedicated to providing UK engineering professionals with the latest in-house manufacturing and design solutions, alongside cutting-edge developments in advanced engineering technologies. The show provides a unique platform for engineers to source the latest advanced engineering technology, products and services.

As well as a host of exhibitors from across the supply chain, this year's event will also feature a six-stream conference programme showcasing showcase cutting-edge innovation and best practice.

"Subcon, alongside The Engineer Expo, will offer unparalleled content to visitors," said Gordon Kirk, event director, Subcon. "Across three days we are delivering more quality content than any other industry event. The shows will also offer unrivalled opportunities to network with peers, industry leaders and decision makers. Visitors will have access to manufacturing and engineering leaders throughout the UK and be able to learn how to leapfrog their competition as manufacturing and engineering continue to face profound disruption." ■

To register to attend Subcon 2018 please visit www.subconshow.co.uk

AEROSPACE

Morphing up above

Shape memory alloy used on aircraft wings

NASA has used a heat-activated shape memory alloy to morph an aircraft's wings in flight tests, an advance with potential benefits for future supersonic aircraft.

The flights, which took place at NASA's Armstrong Flight Research Center in California, are part of the

SAW (Spanwise Adaptive Wing) project that aims to validate the use of a lightweight material to fold the outer portions of aircraft wings and their control surfaces to optimal angles in flight.

According to NASA, the SAW project intends to obtain a wide spectrum of aerodynamic advantages in flight by folding wings through the use of a shape memory alloy, which is built into to an actuator on the aircraft and folds the outer portion of an aircraft's wings in flight. **JF**



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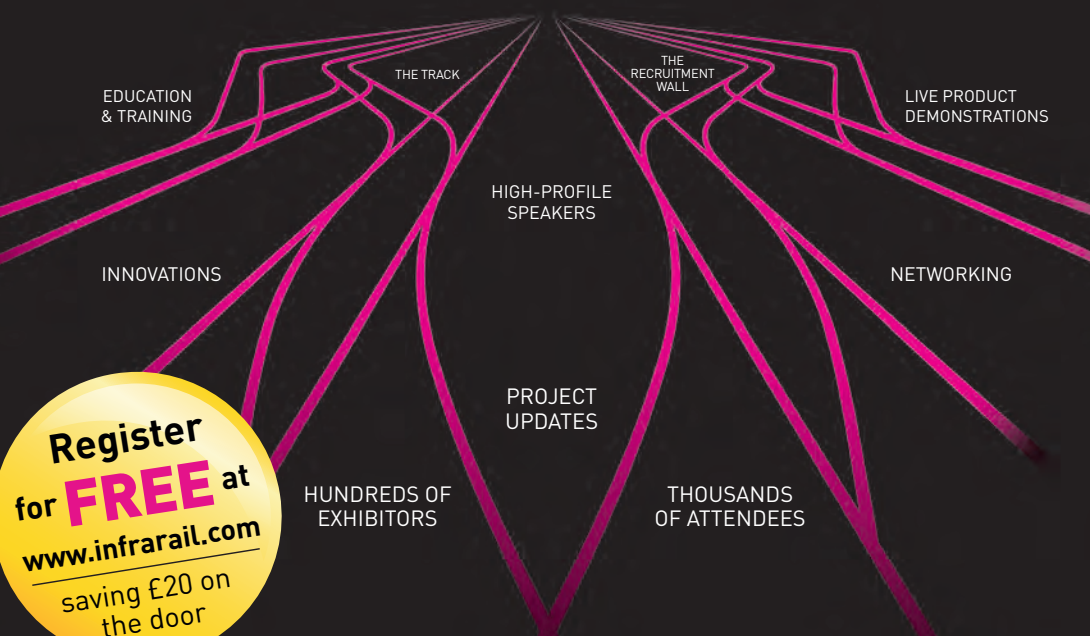
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Transforming our image for a digital age

By focusing on what teenagers love, a media blitz by the Royal Academy of Engineering aims to challenge outdated ideas and tackle the skills gap

If you search for the word 'engineer' on Google Images, you are met by a sea of hard hats and hi-vis jackets. There are plenty of clipboards, plans, blueprints and people pointing. Where the image lacks a hard hat, it will probably make up for it with a lab coat or electronics. On the plus side, the engineers are typically smiling, and often outside in the sun.

Search for 'engineering' and you don't fare much better. Technical drawings and gears predominate. On occasion a building, bridge or engine makes an appearance. It is little wonder that media outlets rarely carry inspiring images of engineering. Worse still, they report on ground-breaking achievements without mentioning the word 'engineering'.

The IET recently conducted research into what schoolchildren think a 'typical' engineer looks like. Of a sample aged 9-16, 44 per cent imagined they would don a hard hat, and 40 per cent thought they'd wear a hi-vis jacket; 67 per cent said that in their mind a typical engineer is male, and 51% thought they would be white. We know from our own research that young people are put off by images of hard hats, white coats and people working alone; images of cutting-edge technology, teamwork and creativity are more appealing.

I don't need to tell you how concerning this is, or go over the skills gap statistics that tell us why we need to change young people's opinions. A lot of good research has been undertaken to raise awareness of the challenge. At the last count, for an Academy report published in May 2016, more than 600 organisations were found to be involved in supporting engineering or STEM education.

More initiatives mean more young people are likely to engage directly with engineering, but many have argued that a lack of coordination and consistency has limited the messages' impact. To give as many young people as possible the opportunity to see that engineering could be for them, we need scale and a shared voice, so that they encounter the same messages repeatedly.

Media consumption, particularly among young people, is increasingly dominated by images and videos. Last year, more than a billion hours of video were watched on YouTube every day. Video prompts the most engagement, and that appetite is predicted to increase. Cisco estimates that 75 per

cent of the world's mobile data traffic will be video by 2020. At the same time, the increasing sophistication of social media platforms and their advertising models means that you can choose specifically who you reach with your content, making both scale and personalisation possible.

We have an incredible opportunity. Engineering is broad, varied and, for the most part, tangible. This is a great basis for films and images for social and digital media that are more representative than what currently exists. At the Academy, we have launched a multi-year digital advertising and

marketing campaign to recast the image of engineering for young people. Called This is Engineering, it will use short-form video and eye-catching images to reach teenagers.

Engineers are great problem-solvers, but with This is Engineering, we are taking a marketing approach to tackling the skills challenge. We have analysed the existing research and commissioned additional studies to answer specific questions about what will inspire teenagers. Importantly, we are starting where the teenagers are, on their favoured platforms and with the subjects they are already interested in, demonstrating to them how engineering is behind the things they love – sport, music, film, tech, fashion, gaming. And we are telling this story through role models that teens from all backgrounds can identify with. Pre-launch tests of the video adverts showed that consideration of engineering among teens rose by 69 per cent, and by 142 per cent among females.

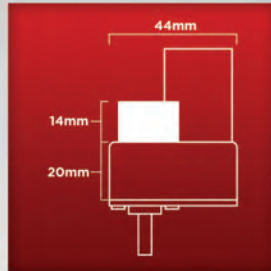
Our campaign is not designed to duplicate or replace good work already underway. We've set out to plug a gap, to give real scale to messages that resonate with young people through digital advertising. And we're doing it for the whole profession: the campaign originated as a response to a letter written to The Times by seven major engineering companies, calling on the Academy to "market the dream" of engineering to the next generation. We will make all of the This is Engineering content available to the whole profession to use.

What makes this an even more unmissable opportunity is that the government has designated 2018 the Year of Engineering, bringing together organisations across the country to encourage the public to take a closer look at engineering. This collective awareness-raising will act as a catalyst for the sustained, pan-profession energy and coordination it needs to meet its ambitions, and transform the public image of our dynamic, fulfilling, future-shaping profession. ■

Jo Trigg is associate director, communications and partnerships at the Royal Academy of Engineering. For more information, visit www.ThisIsEngineering.org.uk, @ThisIsEng or email contact@thisisengineering.org.uk

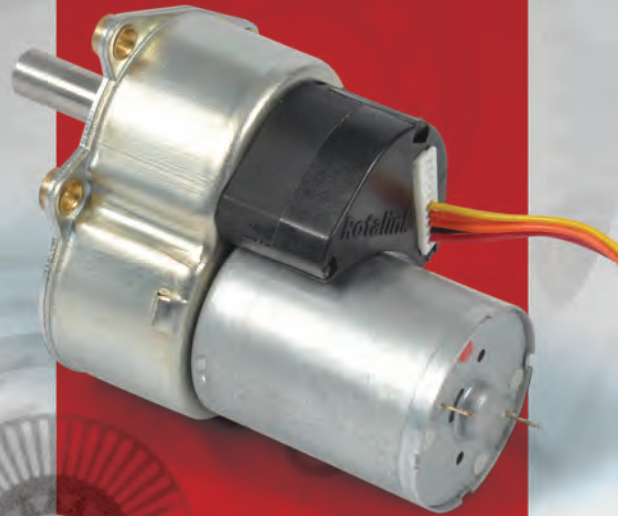


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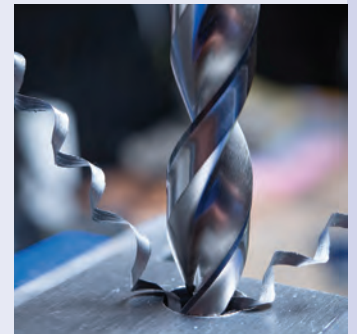


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The **hot** topic



Wasted words

Our online poll on cutting plastic packaging waste sparked a lively debate

As virtually all plastic started life as oil, why is it so difficult to return it to its starting state? Pyrolysis are not new why are they not in wider use? Also why is non-recyclable plastic allowed into widespread use if it can not be profitably recycled? Ban all non-recyclable materials from use in the packaging industry and stop the problem of waste at source.

Rod Evans

Consumers have the power to drive the change; all that's needed is to incentivise the consumer to recycle.

Geoff Iason

Remember when milk, fizzy drinks and beer were sold in returnable glass bottles. Easier to clean than plastic and if a deposit is charged then the incentive is to return and reuse. The deposit doesn't need to be high – it took only a 5p charge to dramatically reduce the use of plastic bags.

20 Cent

A letter in a major UK newspaper points out that the black plastic trays that some foods are packed in, and which are the subject of a proposed ban, are actually made from recycled plastic waste. Not being an expert, I can only trust that the writer (from a company that makes the trays) knows what he's talking about.

PR King

Plastic comes from oil feedstock and is a hydrocarbon so burn it to generate power and heat. Two-stage combustion – pyrolyse then burn. Plastic is too valuable for food hygiene, medical products and agriculture to name but three, so let's not throw the baby out with the bathwater.

Bill Church

Certainly a heck of a lot of plastic packaging in supermarkets can be eliminated: e.g. four baking potatoes in a plastic tray, and then totally wrapped in cling film. The answer is to reduce plastic packaging to a realistic level, then ensure (by law, if necessary) that the remaining plastics

are recycled or disposed of responsibly, so they don't end up in rivers and the oceans.

Alex Morris

The UK needs more recycling facilities so that it can handle 'virtually' all of its own waste. The recent reporting that a large proportion of our waste was just passed on to China was indeed news to me and probably a lot of other people. This just isn't acceptable and highlights the tricks governments get up to in order to side step pollution issues.

People are basically lazy so do need incentives to do the right thing as does industry.

Everyone should reduce, reuse and recycle more – individuals, companies and government.

Steve

The compostable plastic bags we use for the waste food bin seem very tough. Why is all packaging plastic for food not compostable? I also wonder why pyrolysis plants have not been installed nationally; it seems like a no-brainer. The supply of fuel from the plants would be very constant, and could find a use in council-run vehicles and buildings. Exporting waste should be banned. If you can't deal with it, don't produce it.

Martin Bennett

We need to work out the sources and flows of plastic into the oceans. Reducing China's (or Vietnam's) plastic waste mismanagement by 10 per cent would eclipse that of a 100 per cent of the US and EU, let alone the impact that the UK would have. The recent 'awakening' on the subject by the May government is most likely just a way to be seen to be doing something positive.

Paul Reeves

In **your** opinion

Debating diesel

Diesel is kaput, no need to save, improve, 'clean', but abandon it. The car manufacturers who cannot or don't want to move on from ICE will not make it. My bet is they will not make it by 2030. The future of mobility is electric as there will be other forms of clean, sustainable transportation.

Silvia Leahu-Aluas

Banning and penalising diesels because of NOx and particulate pollution is causing a rise in CO₂ levels. This is like treating a patient for a broken leg while they are bleeding to death.

Peter Smyth

E-power will be shown to be more polluting than

diesels if you take in the battery and electricity production not to mention the extraction of all the specialised metals that will be required to keep the electric vehicles going.

Allan Rhodes

Brexit again

The point is made in the poll analysis several times that engineers on the whole are more pro-EU than the population at large, I guess that this reflects the usual conservatism of engineers and possibly the age demographic. Older engineers, like me, who voted us in to the EU in 1975, have largely voted us out this time. The economic case either way has become so distorted, as to be little more than opinions strangling the data; so, in the end the decision is a political one.

Jack Broughton

It's crazy that we have engineers and scientists that voted for Brexit in the first place. We deserve a second referendum because this is not going to end well for research, development and manufacturing in this country.

Shaun Fowler

There is no value in arguing about the economic effects of Brexit or staying. It's all about how we see ourselves. Britain is not 'elite'. We have to live with seven billion other people on this planet. Adopting an attitude that we can go it alone is remarkably short-sighted.

Robert Palgrave

Join the debate
theengineer.co.uk



The **secret** engineer

When you're surrounded by self-appointed designers clever use of 3D CAD can help

Having written these pieces for a number of years now, it may come as little surprise to learn that a few friends know of my clandestine occupation. As it happens I had a chance to meet up with one, a Mr TM, as we crept bleary eyed into the New Year. While grabbing a coffee he explained an aspect of the way he uses CAD that I hadn't considered, and how it could help the design process. He also suggested that it might form a good basis for an article and I have to say that I agreed.

We started by discussing where the design aspect of a project is initiated. The majority of us have sat in classrooms where the product development cycle has been dissected and various theories of process considered, but the 'real world' can be very different. My current

ways. This isn't helped by those with power and influence thinking they can be design engineers and, going further, there can in fact be the accidental imposition of irrelevant limitations by such folk as they get excited by their own questionable abilities. Changing a paradigm set early on can then be quite difficult – such is the nature of things.

This is where 3D CAD can be quite a help. I have lost count of the number of times that I've shown a particular aspect of design on a CAD system, or used it to show the consequences of a modification. I have also used a terminal and projector to illustrate presentations but this is a slightly different matter. When all is said and done I have yet to actively use it fully in support of exploring design decisions at meetings. I know

that some folk think once you have a CAD model you can instantly do anything with it, but you do need to prepare it in different ways to maximise the usefulness in any given situation.

So then, TM asked: "Why not use a CAD model to enhance communication and enable the immediate exploration of the possibilities and limitations of design decisions?"

"After all, if the embryonic design meetings happen post 'clean sheet' then, despite the best efforts of those involved, almost inevitably people will come along with ideas that are inappropriate due to the project



residence, Sleepy Hollow Electronics, in particular, is very fluid regarding how projects are run and in fact just who does what. This very issue is something that may provide the raw material for future articles – possibly including one titled 'How to storm out of a job with maximum impact'. However, let's just say that my situation at the moment is possibly the most extreme I've encountered yet to back this assertion up.

One of the dangers of not following established project management convention is that certain parameters will already have a level of maturity once the active part of the design package is kicked off. Of course we are always given a number of targets and constraints but, in this most nebulous part of the whole process, exactly when particular decisions are made can affect the direction of the design in significant

having already reached that level of maturity. Experience shows that once these ideas have been tabled, time and effort then has to be expended in explaining why someone's pet idea has to be discarded or radically modified." Not everyone possesses the engineer's ability to think and analyse in 3D so this is where a prepared model, or sequence of models, becomes a very useful tool indeed. It stops being reactive and becomes proactive, saving time and keeping discussions moving along feasible paths.

I thanked my friend and promised I would present it to the world. It may be that you already do this, or that projects are run properly where you work. For me though it was an interesting new slant, as well as an encouragement to keep exploring how all tools can be used to their best advantage.

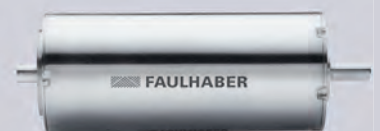


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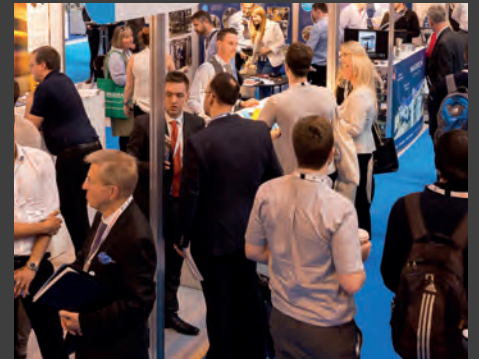
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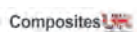


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Cyber resilience is a grand challenge

We need to ensure we understand the risks associated with increasingly complex cyber systems

The integration of physical and digital systems creates many opportunities for improved performance and innovation, offering huge potential to generate economic value, as well as social and environment benefits across a broad range of sectors. This has been recognised in the government's Industrial Strategy, with 'artificial intelligence and the data-driven economy' named as one of four 'Grand Challenges'. Digital technologies, including data analytics, artificial intelligence, autonomous systems, advanced connectivity and the Internet of Things (IoT), will also be key enablers of success for many of the other Grand Challenges and sector priorities articulated in the strategy.

However, in pursuing these opportunities, there is a need to ensure that we understand the risks associated with the increasingly complex and interdependent 'systems of systems' being created. For example, the component systems may be under the control of different organisations, with differing objectives that may not be aligned. It is vital that these risks are identified and addressed so that serious incidents are avoided, trust in such systems is maintained and the potential benefits are realised. That's why the Academy will be launching two reports addressing this topic next month.

Interdependencies between physical and digital systems can trigger an unexpected cascade of consequences. A recent incident of this kind started with a flood at an electricity substation in Lancaster in December 2015 during Storm Desmond. This caused a 24-hour blackout across the city, resulting in more than 100,000 people losing access to electricity, the internet, mobile phones, contactless payment, lifts and petrol pumps. A failure of the baggage-handling system at Heathrow last year was also initiated by a power outage, this time in a data centre. When the power was reinstated in an uncontrolled way it resulted in damage to equipment causing massive disruption to passengers and huge costs to British Airways. In addition, the Wannacry attack in May 2017 led to disruption in at least 34 per cent of hospital trusts in England (the full extent of disruption to the NHS is unknown). It also impacted on companies such as the automotive manufacturers Nissan and Renault, even though the malware was not targeted specifically at the industrial control systems in their factories.

Cyber safety refers to the ability of systems to maintain adequate levels of safety during operation, including in the event of a cyber attack or accidental event, in order to protect life and property. While safety is a desirable property of a system during normal operation, resilience describes the capacity of a system to handle operational disruptions. A key aspect of cyber resilience is the ability to prepare for, withstand, rapidly recover and learn from deliberate attacks or accidental events, which can be mediated via the internet or through other means such as radio transmitters or lasers.

It is impossible to design systems that are entirely secure or free from the risk of failure but we need to ensure that we design systems with appropriate levels of cyber resilience and safety, especially if they are part of critical national infrastructure or safety-critical systems. Many of the vulnerabilities in



current systems result from poor quality software and hardware, with vulnerabilities residing in both individual components and in the systems that are created from these components. Cyber resilience requires broader issues such as supply chain risks to be addressed, so it is crucial to embed a resilience mindset into the way we design and develop these systems.

The reality is that the depth of expertise in safety engineering required to ensure a resilience mindset is not always available in the domains where technological innovations are occurring. However, there are clear opportunities for the UK to exploit and disseminate existing expertise and best practice on safety engineering across a broader range of sectors, and to adopt a leadership position in the use of digital technologies themselves as enablers of cyber safety and resilience. The forthcoming EU directive on security of network and information systems will be an important development but only applies to essential service providers – critical infrastructure – and digital service providers. The UK

is in a strong position to lead internationally on developing regulatory and non-regulatory measures to improve the quality of software, hardware and systems, while promoting innovation and ensuring safety and resilience. The efforts of the National Cyber Security Centre, the Engineering Council and others in supporting the engineering community in embedding security thinking are very welcome in this regard.

Success in these endeavours could impact directly on the UK's future competitiveness and global influence in this exciting area of technological development. Valuable research is being done on this by the PETRAS Internet of Things Research Hub. But perhaps more importantly, it could have a significant positive effect on the level of public confidence around ethics, privacy and trust. These are likely to be key factors in determining acceptability and adoption of these systems by industry and consumers. ■

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



HIGHER BRIGADE



With wildfires apparently on the increase worldwide, can technology provide more aerial solutions for hardpressed firefighters?

Jon Excell reports

From the devastating blazes that reduced more than a million acres of California to ashes late last year to the ferocious flames that tragically killed 66 people in Portugal, 2017 was a record year for wildfires. Across southern Europe, lives were lost and homes destroyed as dry, hot weather and strong winds led to a doubling of the usual number of forest fires; meanwhile, in the US the forest service spent a record \$2bn tackling the problem.

Furthermore, while 2017 was a dramatic year, experts fear we could see more of the same in the years ahead as a combustible combination of climate-change induced extreme weather and increasing levels of human activity in fire-risk areas fuels longer and more severe fire seasons.

Against this backdrop, with wildfires burning hotter and for longer, the skills and expertise of those charged with battling the flames are being tested to the limits. And fire experts, engineers and industry are working together to identify ways in which technology, from drones to AI simulation systems, can help firefighters – particularly those attacking the blaze from above – gain the upper hand more quickly.

The aerial firefighting process typically begins with the deployment of the sector's special forces: so-called hot shots – elite wildland firefighters – and their even more exotically named colleagues, the smokejumpers, who risk their lives by parachuting in to the heart of fire-hit areas.

In an operation with obvious military parallels, these experts rapidly assess the situation, decide on a plan of action, liaise with ground crews and call in the water-bombers – aircraft that are used to either directly attack the blaze or, through carefully targeted indirect attacks, reduce its intensity and put down lines of retardant to stop it from spreading, and help crews on the ground tackle it head on.

A wide variety of fixed-wing aircraft and helicopters are used: from small, modified agricultural sprayers (so-called single-engine air tankers) able to drop around 3,000 litres (793 US gallons), through to much larger aircraft that carry retardant in huge tanks mounted on their bellies.

The undisputed monster of this curious backwater of the aerospace sector is the Global SuperTanker, a modified jumbo jet able to carry almost 73,000 litres (19,200 US gallons) of retardant. The aircraft, the only one of its kind, grabbed the headlines late last year when it was used to combat the wildfires in southern California.

Although fixed-wing aircraft are typically used for indirect attacks (Global SuperTanker is reportedly able to lay down continuous retardant lines of up to 3km), helicopters, thanks to their hovering ability, are often preferred for direct attacks.

And, if Global SuperTanker is the beast of the fixed-wing world, its rotary cousin is surely Erickson Aviation's S-64 Aircrane, a twin-engine heavy-lift helicopter able to hold almost 10,000 litres of water. Originally produced by Sikorsky as the S-64 Skycrane but heavily modified for firefighting, this unusual-looking aircraft was used alongside the Global SuperTanker to battle last year's California wildfires.

According to Erickson's chief pilot, veteran aerial firefighter Randy Erwin, a

major benefit of the Aircrane is that it does not have to return to base to reload. Instead, it can suck up water wherever it finds it using a device known as a pond snorkel – essentially a flexible hose equipped with a pump that hangs below the aircraft's landing gear.

"When immersed in a minimum of 18 inches of water, it will push water into the tank at a rate of 3,000-plus gallons per minute, and take [just] 40 seconds to get a full load," said Erwin.

The Aircrane also boasts a salt-water derivative of the pond snorkel, which dispenses with the pump and fills the tank by holding the snorkel in place and using the forward motion of the helicopter to force water up its tube.

When it comes to dropping the payload, the aircraft uses water volume data from sensors within the tank to enable its pilot to precisely regulate the amount of water dropped on the fire: the so-called coverage level.

"If the tank knows how much water is in there, it can compute what the head pressure is on the doors. And, when the pilot selects [for example] coverage level 5 [equivalent to 5 US gallons of water per 10 square feet], the doors will open just enough to give that coverage. As the quantity in the tank decreases, it tells the door to open more and more to maintain the same rate," said Erwin.

The headline-grabbing use of aircraft such as Global SuperTanker and Aircrane has certainly contributed to a perception that the wildfire battle has moved up a notch, but is the situation really getting worse?

Professor Johann Goldammer, a leading authority on wildfires and director of the Global Fire Monitoring Centre (GFMC) at Germany's Max Planck Institute of Chemistry, is in no doubt. He told *The Engineer* that changing seasonal patterns linked to climate change were producing longer, more severe, fire seasons.

"A region like the West Coast of the US is experiencing an increasingly longer fire season that now seems to be all year long," said Prof Goldammer, adding that this was being compounded by altered patterns of human behaviour.

"We are modifying the land by clear cutting, inhabiting, entering, industry, agriculture and so on. With this, the fire regimes and the vulnerabilities of ecosystems are changing."

It's a view shared by Bob Gann, acting director at the Colorado Center of Excellence for Advanced Technology Aerial Firefighting. "[Wildfires are] getting worse because people are intruding on areas and we are changing the field loads in the forest," he said.

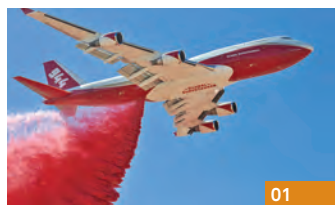
Gann's team is at the forefront of exploring how technology can help firefighters meet this evolving challenge. A key avenue of research is the development of tools that could enable firefighters to tackle blazes at night.

In many ways the conditions at night-time are ideal for firefighting: reduced temperatures, increased humidity and often lighter winds cause fires to 'stand down', providing a window of opportunity for crews on the ground. Surprisingly, though, very little night-time firefighting takes place, with the advantages of more favourable conditions often outweighed by concerns over poor visibility and, consequently, an increased risk of collision.

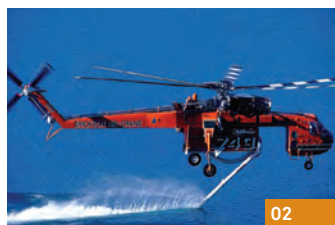
Night-vision systems similar to those used by the military seem to be a

"The problem is wildfires are in very remote terrain"

Sean Triplett,
US Forest Service



01



02

01 Global SuperTanker – a Jumbo Jet modified for firefighting

02 Erickson Aviation's Aircrane



Chad Runyan,
US Forest Service

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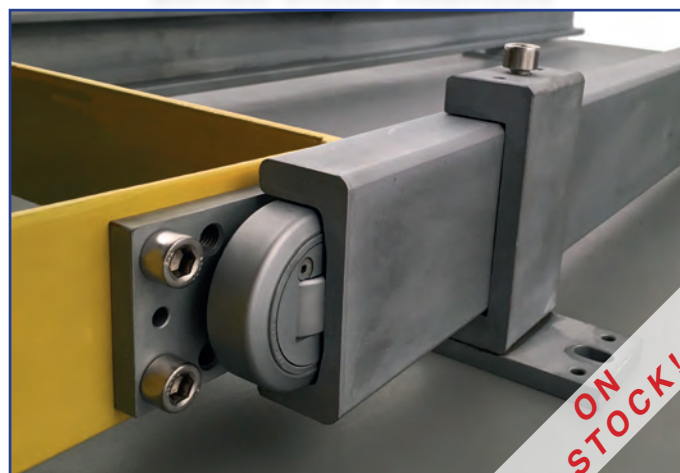
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in satellite technology are also likely to help firefighters in the years ahead.

Sean Triplett of the US Forest Service said satellites had been used for a number of years to understand the impact of wildfires, but the emergence of cubesats – smaller, lower-cost devices that are becoming increasingly widely used by the research community – holds great promise for wildfire monitoring. These diminutive spacecraft could, he said, be launched into orbit in flocks of up to 200, providing far more persistent coverage than existing orbiting satellites, which typically passed by only every four to six hours.

“If they were on 15-minute repeat intervals, you’d be able to look at the same spot of land and start doing rapid-change detection as the fires were burning and the smoke was moving around,” said Triplett.

With drones, satellites, and stratospheric platforms providing a detailed, unblinking view of the drama unfolding below, there will be no shortage of data available to the future firefighter. However, arguably the biggest challenge of all is getting this information out into the field in a useful form as quickly as possible. This is particularly difficult in the US, which, unlike Europe, has patchy cellular coverage.

“The biggest problem we have when we fight wildfires is they’re in very remote rugged terrain,” said Triplett. “There are very limited databands available and, in most cases, the cellular network doesn’t exist.

“We’re not looking to send imagery to the firefighters; they don’t need pretty pictures. They want to see vector data: what the fire is and where it’s burning. The challenges are getting a disseminated product over a network that’s not designed to handle any sort of volume at all.”

A possible solution is being explored by Gann’s team in Colorado. Its ‘Datalink’ project is trialling a prototype radio system that could send basic situational awareness data such as points, lines and polygons directly to pilots’ smartphones.

“In the western US, a lot of places don’t have that much in terms of a network,” said Gann. “We need something we can apply to hundreds of firefighters, not just one or two.”

Gann’s team is also exploring how the data acquired by today’s monitoring systems could feed in to highly accurate fire-prediction systems – tools that could have a major impact on how firefighters plan their response.

Although fire-modelling simulations are already in use, the systems are limited, said Gann, partly because the weather data used is not very reliable. In an effort to change this, the Colorado team is working with the NCAR (National Center for Atmospheric Research) to develop a system using a detailed weather model called High Resolution Rapid Refresh, which is far more predictive than existing tools. Gann said the system was currently being validated and could be out in the field in just a couple of years.

Similar work is under way in Europe through the TechForFire project, an initiative led by French information systems specialist Noveltis, which is developing tools to combine live data acquired by cameras on the front line with weather models and wind information to predict how the fire will develop. SAFE’s Dumaz says the system is being trialled by several fire departments.

Back at the GPMC, Prof Goldammer is heartened and impressed by the speed of technical innovation. The biggest challenge as he sees it is ensuring that these various technologies are not developed in isolation; that industry and agencies around the world work together to share expertise and knowledge.

And, while it may be tempting to view wildfires as a local phenomenon and therefore unlikely to galvanise a concerted international approach, there is, he said, a compelling reason for a united effort: the fires that consume up to six million square km of land around the world every year are thought to be responsible for the net emission of 0.6 billion tonnes of carbon dioxide annually.

“Unlike other disasters, the emissions from these fires are all transported to the common, global shared atmosphere,” said Goldammer, “and the atmosphere doesn’t distinguish if this greenhouse gas is coming from a fire in California or Siberia. It’s there, it’s circulating around the world and it’s part of the increasingly warming atmosphere.” ■

07 View from the cockpit of the Aircrane

08 An unmanned KMAX helicopter used in firefighting trials



Bright side of the tracks

Imperial College researchers and others are envisaging a future of trains powered by photovoltaic energy. Stuart Nathan reports

Running electric railways directly from sunlight may be a cost-effective way of expanding both photovoltaic energy generation and railway electrification in the UK and around the world, according to a report from Imperial College. Originally triggered by a movement that sprang from an anti-fracking protest, the idea led to a feasibility study and may end up in pilot projects.

The report, *Riding Sunbeams*, proposes installing photovoltaic panels directly alongside railway lines and transmitting the electricity generated directly into the railway system as traction current, without first distributing it to the grid. This would take advantage of a coincidental match between the peak generating time for solar and a peak demand for traction current, but would bypass current problems in many areas of limited grid capacity. "Many railway lines run through areas with great potential for solar power but where existing electricity networks are hard to access," explains Prof Tim Green, director of the Energy Futures Lab at Imperial College London. It would also potentially free up many sites for photovoltaic development.

The Imperial project began when the residents of Balcombe, a village in West Sussex, opposed proposals for test drilling to establish whether the area might be suitable for shale gas fracking. The protest inspired the establishment of a co-operative called Repower Balcombe, which aimed to generate the village's entire electricity demand via renewables. One stumbling block to this goal was that the local grid did not have the capacity to accept any more solar energy without costly reinforcement. Prof Green, who lives in Balcombe, decided to look into the possibility of using solar power directly on train lines. "Quite quickly you realise that the answer might be more than the solution to one village's problem and something to unlock untapped solar resource on a much wider scale," he said in the foreword to the report.

Working with 10:10 Climate Action, a charity that runs projects aimed at helping communities to achieve cuts in their carbon emissions, Green and the Energy Futures Lab started to look at the subject in engineering terms.

The report was written by Leo Murray, director of strategy at 10:10 Climate Action, and Nathaniel Botterell, a postdoctorate research associate in the control and power research group in Imperial's electrical and electronic engineering department. It begins by setting out some of the problems. The capacity constraints on the grid mean that it is not affordable to connect new renewable generating capacity across whole regions of the UK. Moreover, the withdrawal of subsidies for solar photovoltaic means the only commercially viable developments are those with an on-site final customer.

In the meantime, on the railways, demand for traction power is increasing.

Another happy coincidence comes into play here. Solar PV arrays typically output DC power at between 600 and 800V. Electric rail, meanwhile, typically operates at 750V. This, the report says, means that the cost of power electronics needed to connect solar generation to DC traction networks should be competitive with grid connection costs.

For this to be most effective, it needs to be targeted at rail systems that use DC, and, unfortunately, about two-thirds of the UK rail system does not. Most





of the network, is powered by AC running through overhead catenary cables, which is safer and better for high-speed and long distances. But in urban areas, overhead cables are much more difficult to install, because train lines run through tunnels, and under bridges and roads; in these areas, traction supply is instead conveyed through a DC third rail. "I think that focusing on the basics of integrating distributed energy generators into a railway's system with the third-rail network brings a lot of benefits," Prof Green said.

The most obvious benefit is that there's no need to convert the DC output of the solar panels into AC, which inevitably leads to losses. But there are other advantages. In areas with DC power supply, there tend to be substations or track paralleling huts around every 3km along the route. By contrast, in AC-supplied areas substations can be up to 80km apart. The closer spacing more convenient for injection of DC supply; moreover, private wire supply from solar farms is effective over distances of up to 2km, so most lineside land would be within reach of a traction network connection.

The report notes that connection to AC systems is not impossible, particularly where connections can be integrated during new electrification works that are in progress or planned on large sections of the UK network. "This opportunity should be factored into future UK electrification rail education planning," the report recommends. Each AC traction substation covers a large length of track, which could – with the required planning and infrastructure – be supplied by large solar farms or other renewable resources, such as wind farms or hydroelectricity. Another possibility might be to connect solar PV to the auto transformer sites located around every 10km along electrified routes running off AC, it suggests; these sites are used to boost the AC voltage.

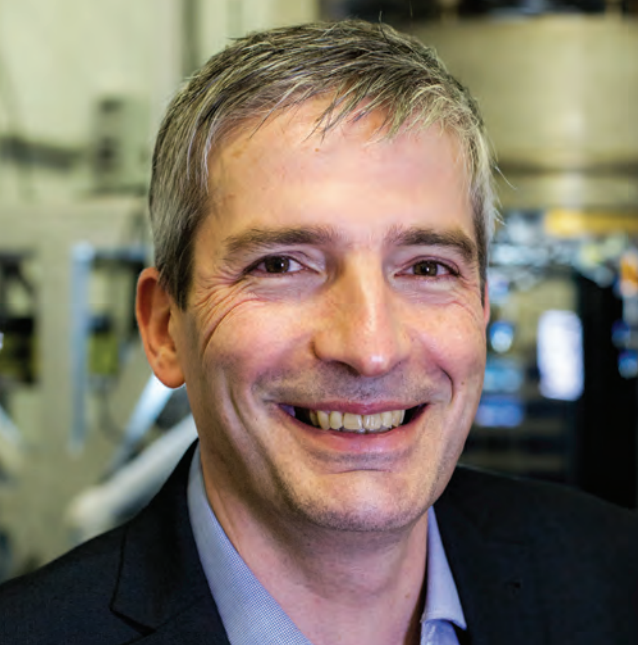
Even using the simpler option of concentrating on the third rail sections, there are still issues that need to be determined. For example, the third rail is not only used to supply power; in most rail networks, it is also used to transmit information as part of the signalling system. There are also issues around managing how and when the solar power is sent to the third rail. Such technical aspects will be investigated by a collaboration between Imperial College and Turbo Power Systems (TPS,) which specialises in the distribution and management of power in the railway sector. "We couldn't have better partners to work out how you can integrate solar power with our trains," said Leo Murray.

The report concentrates on the advantages that direct connection of solar PV to rail would have in the south of England, as statistically this is the region that receives the most sunshine. The report's authors claim that 15 per cent of commuter routes in Kent, Sussex and Wessex (sic) could be powered by solar PV. The London Underground could also benefit; much of the network in fact runs above ground, and 10:10 Climate Action has found 50 possible locations for solar installations, including derelict land, train depot rooftops, station car parks and even the possibility of floating solar on reservoirs. These sites, they claim, could provide enough electricity to power 6 per cent of the tube network.

But it's not just about southern England. Another possibility would be the commuter network in Liverpool, while smaller city metros or trams, such as Manchester Metro link or the tram systems in Sheffield or Nottingham, could also install trackside PV on brownfield sites, the report suggests.

Even more potential exists around the world. Equatorial regions receive more and stronger sunlight than northern Europe, and mega cities in Asia, Latin America and the Middle East are all good candidates for solar rail. In India, for example, the government has a very ambitious target for installing PV capacity, demanding 100GW of solar capacity by 2022. The country has 15,000 miles of electrified railway with a target of some 2,000km of new electrified track per year to be built.

Ninety per cent of the Delhi Metro is currently powered by solar via a grid connection, and 10:10 Climate Action claims there is great potential for direct power. Closer to home, Spain has 4,000 miles of electrified railway, 50 per cent more direct sunlight than London, and in Barcelona, for example, planning regulations already stipulate the large buildings must have their own solar power, so there is clearly an appetite for this form of renewably powered transport. ■



interview | **jonathan carling**

Fast tracking a new frontier

Tokamak Energy's new CEO plans on using his commercial nous to get fusion on the grid by 2030. Stuart Nathan reports

Energy generation by nuclear fusion is one of society's biggest technological challenges. Decades after fusion was first demonstrated, there has been no obvious breakthrough on this front, though it's frequently claimed that one is just around the corner. Now, following visible progress at the International Thermonuclear Experimental Reactor (ITER) in southern France, it seems that the long-anticipated milestone might finally be reached.

Yet away from this vast building site, a UK company is making the audacious claim that it will beat the international consortium to the punch. Tokamak Energy – based at Culham in Oxfordshire, next to ITER's forerunner, the Joint European Torus (JET) – aims to supply fusion-generated electricity to the National Grid by 2030, before ITER has even started fusion reactions. Chief executive Jonathan Carling, who has no background in high-energy physics, comes instead from the far more commercial aerospace and automotive industries.

Carling, who trained as a mechanical engineer at City, University of London in the mid-1980s, took on the CEO role last November, replacing co-founder David Kingham. Prior to that, he was Rolls-Royce's chief operating officer for civil large engines. "At Rolls-Royce, I looked after the manufacture of the Trent family of engines and the overhaul network, looking after the project teams that develop the engines and are responsible for building, selling and servicing them," he told *The Engineer*.

"[Before that,] I also held a number of chief engineer roles at Jaguar Land Rover; I was chief engineer for powertrain systems, and also on the Jaguar X-Type. I was chief programme engineer for the Jaguar XF."

His curiosity about nuclear fusion did not take on a professional dimension until his first encounter with Tokamak Energy, however. "I've been interested in nuclear fusion, as anyone who's an engineer or a technical person would be, but until I discovered Tokamak Energy, like many people I think I thought of it as something governments were pouring billions into, only to periodically tell us that it was a few more decades off.

"When I found that Tokamak Energy was creating a way for a small, modular fusion reactor, I was immediately attracted. Here's an agile private firm who's building on existing science – and having worked as COO in a couple of businesses, I like to see data and executability – and thought, 'This looks like a fantastic challenge,' especially as the business is currently in a phase where it's moving

from providing the scientific basic platform to doing the engineering and creating the actual machines, which is my background."

What distinguishes Tokamak Energy from the ITER project is the shape of its planned fusion reactor. Both ventures are looking at magnetic confinement fusion, whereby a plasma of hydrogen nuclei is confined within a strong magnetic field and heated up, forcing the nuclei to fuse together and release energy. But unlike ITER's reaction vessel – a huge, flat torus, called a tokamak after the original 1950s Russian technology – the kind of machine Tokamak Energy is investigating uses a plasma confinement vessel shaped more like a cored apple. Advocates of these so-called spherical tokamaks argue that they are more stable and easier to control than their wider, flatter cousins, as well as being cheaper to build.

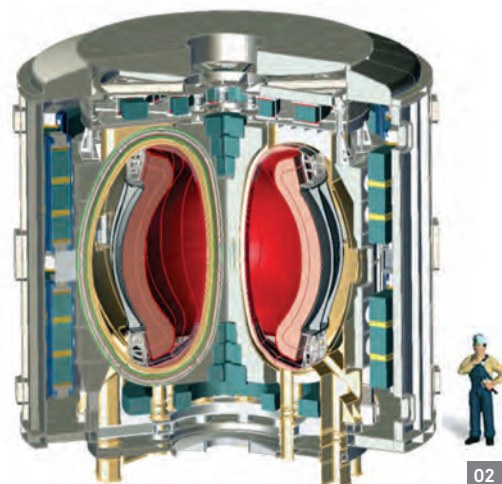
Tokamak Energy believes that a spherical tokamak much smaller than its ITER counterpart will be able to provide enough heat from the fusion reactor to generate electricity economically. The key to this, says Carling, is the strength of the magnetic fields keeping the plasma in place. "If you look at fusion power in tokamaks, the energy is proportional to the plasma volume, but it also varies according to the fourth power of the magnetic flux – so if you can run with very high magnetic flux, then that will have a much bigger effect on the fusion power than making the machine bigger."

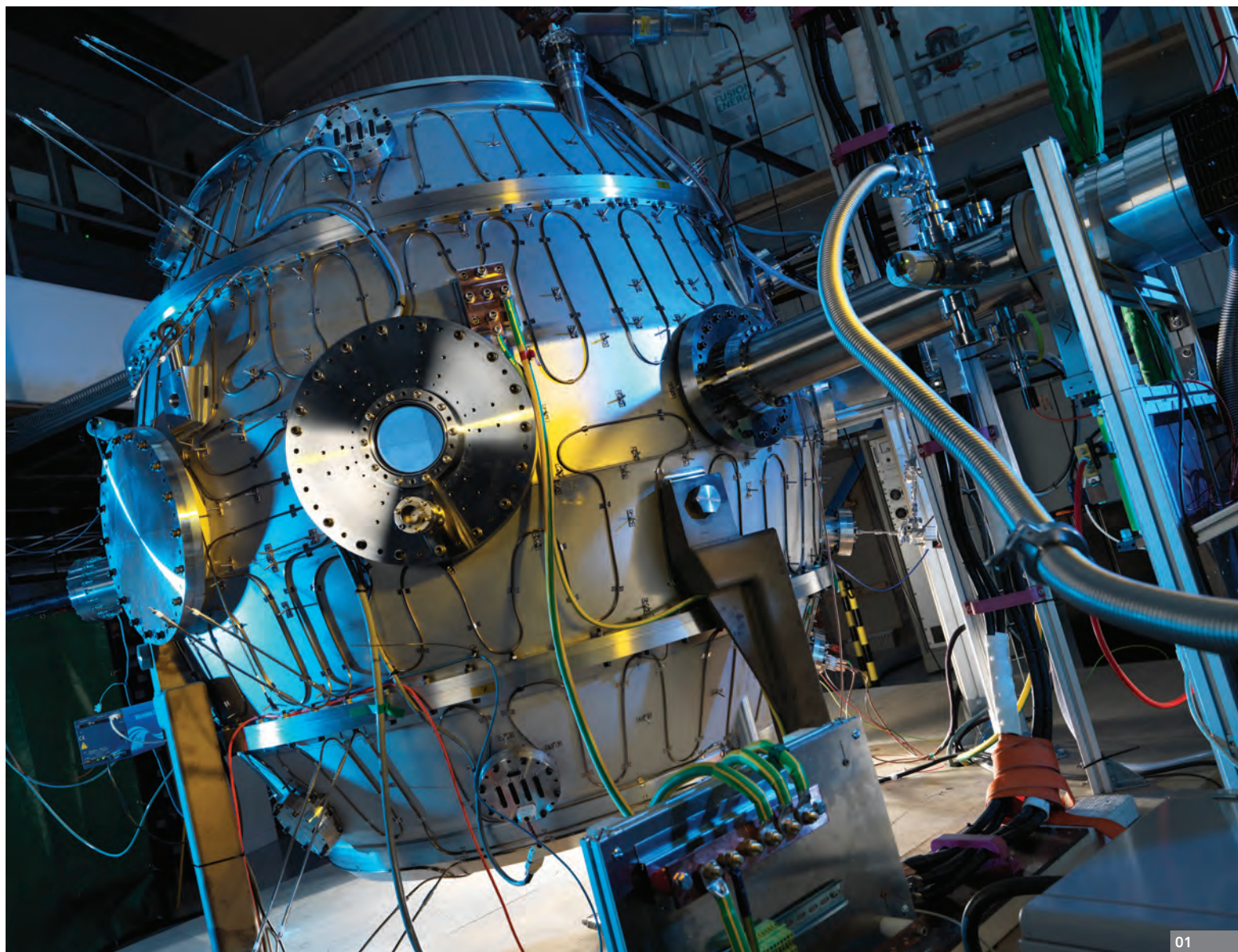
This is just one of the insights he has gained since starting his new job. "It's a very fast learning curve but luckily I've got some true experts – the best people in the world in this field – all around me and they've been incredibly welcoming. I've asked them for information about the business and the physics and they've given me lots to digest."

Meanwhile, he isn't too concerned about his status as a particle physics layman. "As a leader, it's important to remember that I don't need to reach a level of expertise equal to the chief scientist," he says. "You need to understand the overall mission and what the team needs from their leadership to succeed." Another strength, he believes,

01 The planned ST200 reactor, developed with Atkins, uses state-of-the-art superconductors

02 Spherical tokamaks are said to be cheaper and more stable than the wider, flatter type





is his expertise in running businesses and raising funding. “I’ve worked with funding businesses but not in a pre-revenue business. Pitching for investment or funding businesses isn’t new to me but in this stage, it is. I’ve been pitching the business, which involves telling people how it works, so I need to understand how the machines work well enough to do that.”

Two factors will enable Tokamak Energy to reach its goal quickly, he says. One is the smaller scale of the machines, compared to ITER’s. The other, crucially, is private sector funding. To date, the company has raised more than £22m from a variety of sources, including venture capitalists and more mainstream institutional investors such as pension funds, Carling says. It is about to embark on a new funding round, having completed its fourth fusion reactor, known as ST40, last year.

One explanation for Tokamak Energy’s ambitious schedule is that Carling believes the major roadblocks to fusion power have been removed. “We’re about to run a big test to reach 15 million degrees Celsius in ST40, and later this year we hope to reach 100 million, which is fusion temperature. That will get us very close to energy break-even in this machine by 2022, and that will prove all

“It’s a very fast learning curve but luckily I’ve got some true experts – the best people in the world in this field – all around me”

the basic science and engineering.” The company will then embark on its next construction project, the ST200, which will be three to four times larger than its predecessor (the ST40 is 4m height and 2.5m in diameter). Moreover, the ST200 will be equipped with a key technology: high-temperature superconductors based on REBCO (rare earth barium copper oxide).

REBCO magnets are more compact than other superconductors and, most importantly, work at temperatures just below 77 Kelvin (–196°C), achievable with liquid nitrogen. By contrast, ITER’s niobium-tin and niobium-titanium magnets need liquid helium at a few Kelvin above absolute zero – a much more costly demand, requiring larger equipment.

Tokamak Energy first used REBCO magnets on ST40’s predecessor, which for ease of construction uses copper in its magnets. But, Carling stresses, they are a relatively new technology and the company must develop both the magnets and the supply chain to build them. With this in mind, it has formed a partnership with Atkins.

“We hope to have ST200 running with net energy gain and industrial-level heat production in 2025,” he says. “That gets us to electricity on the grid by 2030.” ■

Excess delivery

Power, agility, comfort and a bargain price make the McLaren 720S possibly the best all-round supercar ever made, writes Chris Pickering

Even in this age of spiralling power outputs, the McLaren 720S packs a particularly formidable punch. Sure, there are a handful of multimillion-pound hypercars that can outdo its prodigious 720 PS (710 bhp) output, but this is a proper production model, aiming to shift a not-inconsequential 1,500 units this year.

Unlike the 720S's big brother, the McLaren P1, there's no hybrid assistance here. All that grunt comes from a 4-litre twin turbo V8. And unlike the Lamborghini Aventador or the Porsche 918 Spyder, there's no four-wheel drive system either: it's all channelled through the rear wheels.

That's a slightly sobering thought when you go to thumb the starter button on a cold, damp morning. By rights, it should be terrifying.

The V8 fires instantly and settles into a racy idle. It's a development of the 3.8-litre unit found in the old 650S, but McLaren claims that more than 40 per cent of the engine is new. The increased capacity comes from a 3.6 mm increase in stroke, but lighter internals and ultra-low inertia twin-scroll turbochargers mean this engine reacts even quicker than its predecessor.

There's still a hint of turbo lag, but keep the revs up and the power delivery is crisp, linear and seemingly unending. It's hard to describe the sheer ferocity of the 720S as it lunges towards the horizon, but what's more surprising is how exploitable it feels. True, the electronics will intervene if you're silly, but pick your moments and it is possible to experience the full warp-speed effect on a British B-road, albeit only for a second or two at a time. In that sense, you could say the 720S delivers just the right amount of excess; it feels otherworldly in its performance and yet – remarkably – there are still opportunities to tap into this potential on the road.

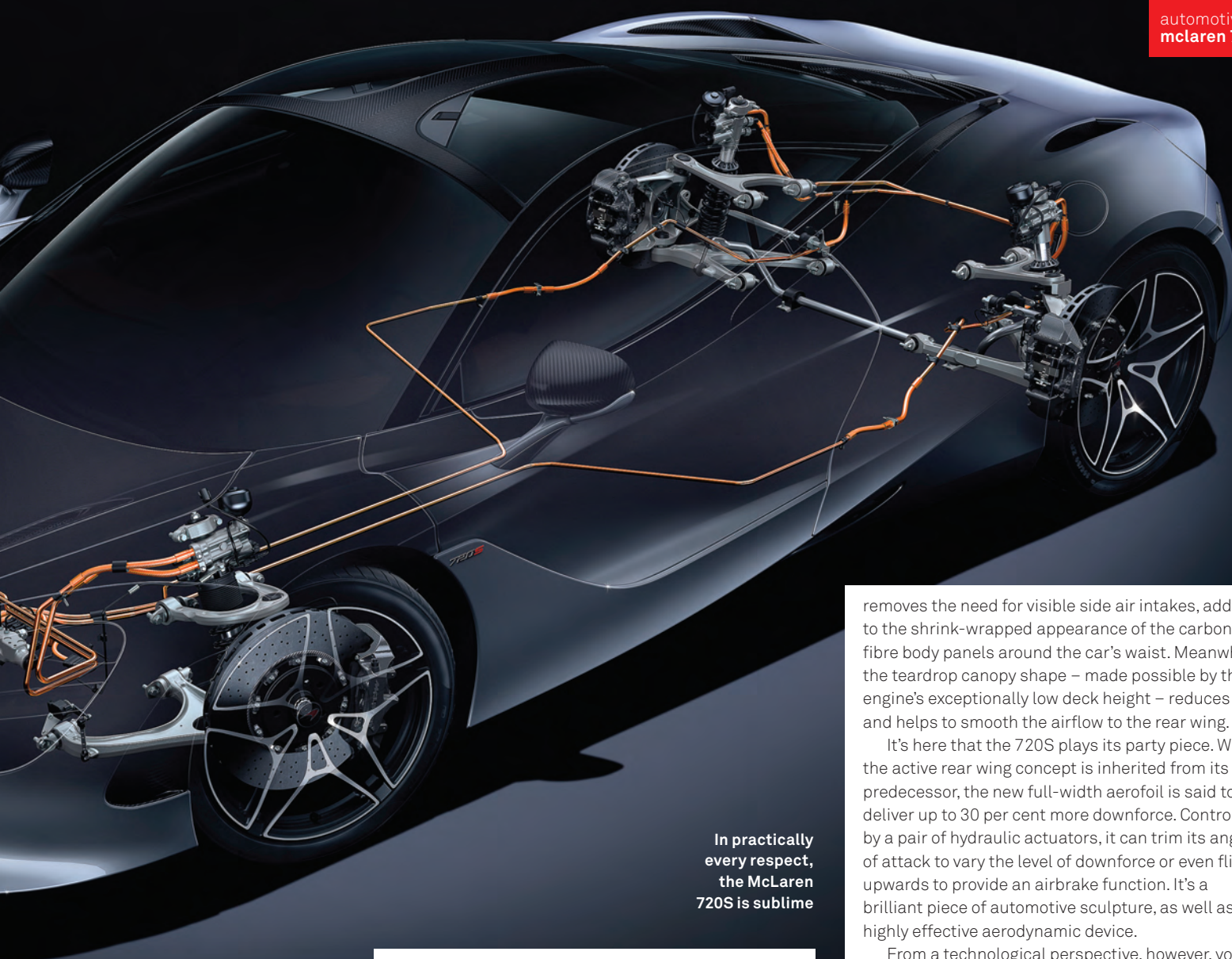
A plethora of technology helps to make this possible. For a start, the chassis is a full carbon fibre monocoque, which now includes the roof and part of the rear structure. The resulting assembly is some 18 kg lighter than the 650S tub and it contributes to a 3 per cent reduction in the centre of gravity height. In total, the 720S tips the scales at 1,283 kg (dry) – an impressive achievement for a comfortably trimmed road car with a large capacity V8.

This structure is also incredibly stiff, providing a stable platform for the suspension, which follows a conventional layout with double wishbones and coil springs on all four corners. Beyond that, however, things start to get rather more unusual.

As with its predecessors, the 720S features a sophisticated system of hydraulically interlinked active dampers. This uses a network of sensors and an algorithm based on optimal control theory to change the pressure in each of the dampers, with a response time of less than 2 milliseconds. The end result is that the roll response can be decoupled from the ride, doing away with the need for traditional anti-roll bars.

You only need to drive the superb 570S to see how adept McLaren is at setting up traditional passive suspension systems, but the active set-up takes things to a whole new level. It glides over broken tarmac with the finesse of a luxury saloon, yet even in the softest of the three chassis settings, there's remarkably little body roll.





In practically every respect, the McLaren 720S is sublime

On roads where a lot of performance cars would skip and fidget, the 720S retains a supernatural blend of agility and composure. Even in its more aggressive modes, there's enough compliance to provide phenomenal traction, yet sufficient roll stiffness to prevent any unexpected weight transfer. It's one of the factors that, when taken together, make the McLaren feel so friendly to drive.

Another is the steering. At 2.5 turns lock-to-lock, it feels very direct but never nervous or darty. And while most manufacturers are turning to electric power assistance for its efficiency benefits, McLaren has stuck with a more driver-focused hydraulic set-up. The result is a beautifully detailed stream of feedback fed straight to your palms.

One of the most impressive things about the McLaren's driving experience is that it still feels special at low speeds, and not just thanks to the sense of theatre that you get from piloting a supercar. You could drive it all day – never once using more than a quarter of the engine's potential – and still revel in the sense of connection that comes from that beautifully resolved chassis.

But delve deeper into its capabilities and the 720S feels sensational. It scythes through the air with twice the aerodynamic efficiency of the 650S, thanks to a raft of clever new features. The dihedral doors, for instance, are double-skinned, with internal channels that feed twin side-mounted radiators. This

removes the need for visible side air intakes, adding to the shrink-wrapped appearance of the carbon fibre body panels around the car's waist. Meanwhile, the teardrop canopy shape – made possible by the engine's exceptionally low deck height – reduces drag and helps to smooth the airflow to the rear wing.

It's here that the 720S plays its party piece. While the active rear wing concept is inherited from its predecessor, the new full-width aerofoil is said to deliver up to 30 per cent more downforce. Controlled by a pair of hydraulic actuators, it can trim its angle of attack to vary the level of downforce or even flick upwards to provide an airbrake function. It's a brilliant piece of automotive sculpture, as well as a highly effective aerodynamic device.

From a technological perspective, however, you could argue that the 720S's greatest triumph is not its outright performance but how effortlessly it blends that with the realities of everyday life. At a relaxed pace, it's no more taxing to drive than a family saloon. Under those circumstances, the seven-speed dual clutch gearbox will happily shuffle the gears seamlessly in the background. Similarly, wind and road noise are well suppressed; the Bowers & Wilkins stereo (complete with exposed Kevlar speaker cones) works beautifully; and unlike most mid-engined supercars, the canopy of the 720S offers almost 360-degree visibility.

That's not to say it's perfect. While the twin turbo V8 is a hugely effective power plant, it's still not the most expressive unit. In fairness, McLaren does offer a sports exhaust option that we've yet to sample, but the standard car simply can't match the orchestral qualities of the Ferrari 488 GTB's twin turbocharged V8, let alone a Lamborghini V12.

In every other respect, though, the McLaren feels sublime. It's outrageously fast and stunning to behold, but it's also genuinely engaging at lower speeds. Strange as this may sound, it's something of a bargain too. When the limited edition P1 went on sale in 2013, it would have set you back £866,000. Rumour has it that the 720S is every bit as quick in the real world, yet it starts at a comparatively affordable £208,600. Put it all together and you have quite possibly the best all-round supercar ever made. ■



Beating back the cyber threat

The engineering and manufacturing sectors are facing a growing demand for cyber-security specialists. David Fowler reports

Awareness and concern over security against cyber threats is growing. It's about much more than the risk of personal data being hacked into. A hostile cyber-attack is classed by the UK's National Security Risk Assessment as a Tier 1 risk, putting it in the most serious category alongside international terrorism, an international military crisis and a major accident or natural hazard. The National Cyber Security Centre was set up in 2016 (as a branch of GCHQ), and later the same year the government confirmed a cyberstrategy budget of £1.9bn over five years.

And although there have been high-profile examples of cybersecurity breaches, including the 'Wannacry' ransomware attack on the NHS last year, the centre's head Ciaran Martin recently said that the UK had been fortunate so far to avoid a so-called 'category 1' attack – an assault that could cripple critical infrastructure such as water or electricity supplies or financial services. He warned that it was a matter of "when, not if" such an attack occurred.

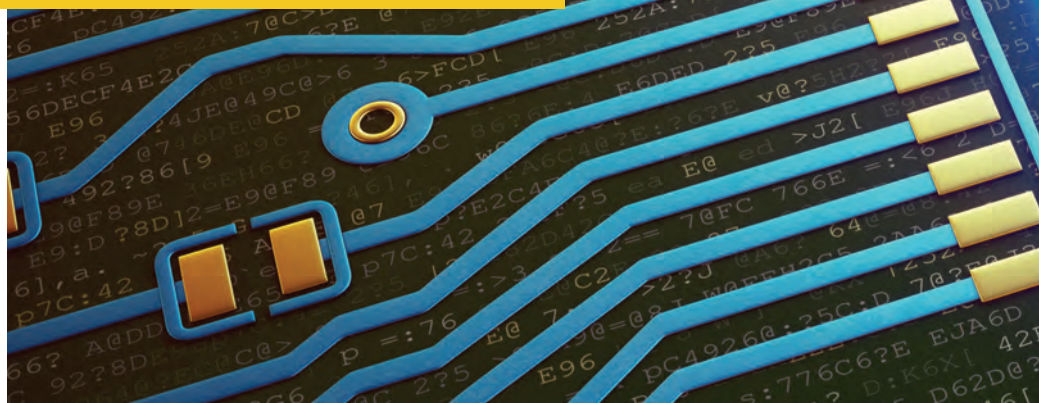
There is little wonder, then, that demand for cybersecurity specialists has grown dramatically in the last few years, as has demand for the services of companies seeking to hire their expertise.

A number of factors are underpinning this growth. Hugo Rosemont, director of security and resilience at ADS, the trade body of the aerospace, defence and security sector, said the that government's characterisation of the seriousness of the cyber-threat is reflected in the priorities of ADS member companies' clients.

In addition, the regulatory framework is about to change with the introduction of the EU General Data Protection Regulations and the Network Information Security Directive, which come into force in May, requiring companies to reassess their cyber strategies to make sure they comply.

"Whether they're critical infrastructure operators or companies in the wider economy such as retailers on the high street, the regulatory landscape is shifting so that cyber becomes more prominent, and companies are investing in technology, but crucially also in their people, in order to protect themselves," said Rosemont.

Jonathan Martin, department manager for cloud and



security at recruitment agency Networkers, added: "Cyber threats are becoming more complex, organised, and larger scale, and as the world becomes more data driven and products and services more data led, the importance of protecting that data is becoming more significant, creating a bigger market for those able to offer protection and security."

In industry, moves towards remote monitoring, the smart factory and the internet of things is adding to the complexity of networks, adding more potential weak spots or points of entry for an attack.

All this presents opportunities in particular for defence giants such as the UK's BAE Systems, Italy's Leonardo and the US's L3 Technologies, said Martin. "They are used to dealing with the complex challenges of national security. They already have the experience and legacy." They are taking a reputation for expertise, integrity and attention to detail gained on defence contracts into a more commercial world, to advise companies in finance, insurance, and healthcare, as well as in government – all typically characterised, said Martin, by large and disparate organisations with high data complexity and multiple points of entry.

Work for government organisations, Rosemont pointed out, includes support for law enforcement agencies in roles such as digital forensics and online investigation. Fraud, particularly cyber-fraud, is now the most common crime in England and Wales.

Alan Good, head of human resources for the security and information systems division of Leonardo's UK subsidiary Leonardo MW, said the company works in three areas. First, with commercial customers in banking and in industry (including its own parent company); with government departments and agencies; and its largest customer of all: NATO. "We provide protective monitoring

for all of NATO across Europe, one of the biggest secure systems in the world," he said.

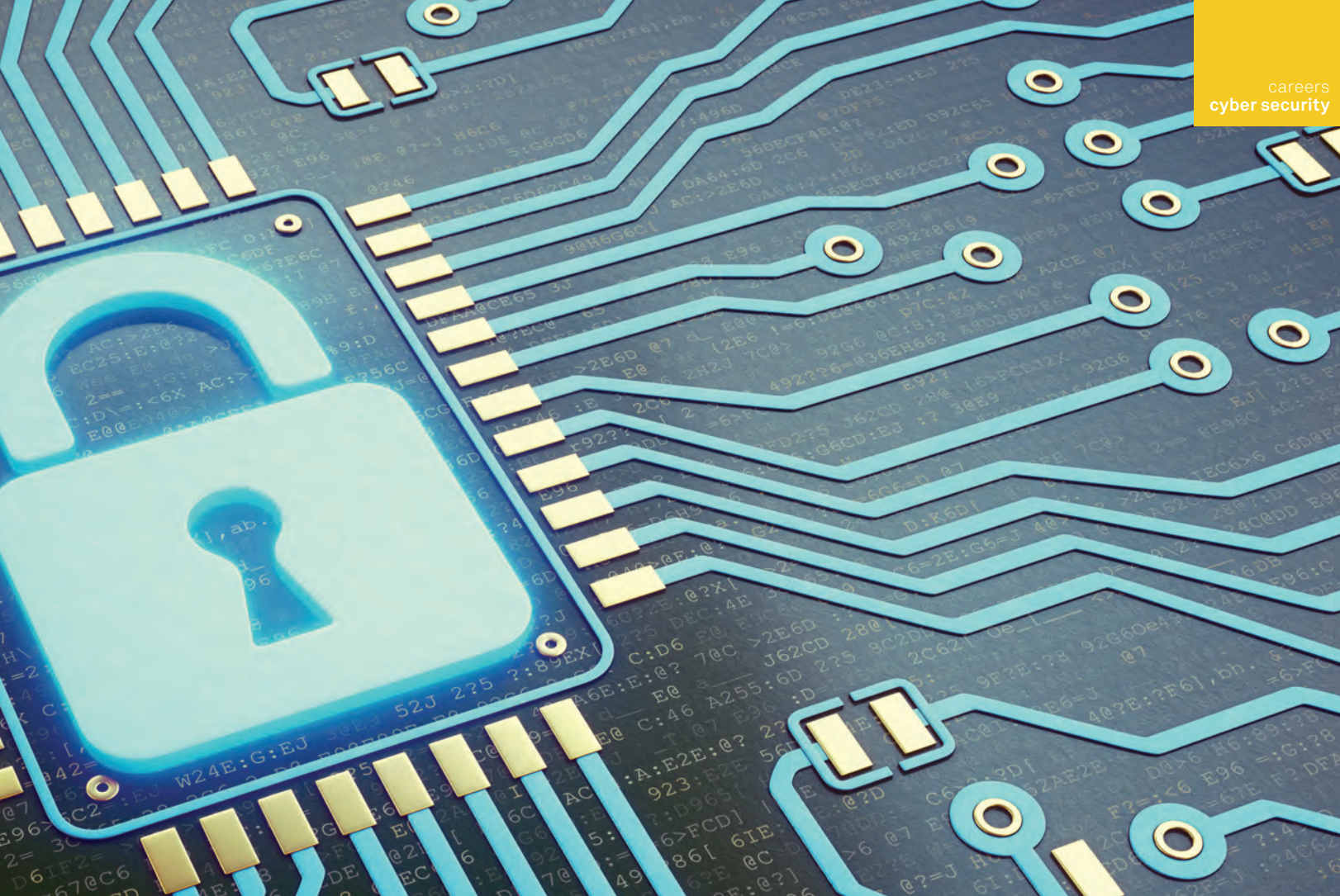
A range of skills is in demand, with broadly three groups of people being recruited.

On the technology side there is a need for people with skills in providing protective monitoring of clients' servers and systems. In Leonardo parlance, they are known as security event analysts.

A second group is network and systems engineers, specialists in the architecture, design, build and implementation of systems and secure operations centres for clients. Companies such as Leonardo both create operations centres and then provide monitoring on behalf of the client, or build centres for the client themselves to run their own protective monitoring.

Third are cybersecurity consultants, who go into organisations to provide advice and support with regard to information assurance or risk management. Martin describes this as more policy and governance based.

"They are going into organisations and looking at things from an information governance perspective," he said, in order to identify vulnerabilities on the process and



policy side – including making sure that organisations have effective staff training and consistent ways of monitoring what people are doing with the data that they have access to. This role requires governance and risk management skills rather than detailed IT knowledge.

“If you think about some of the more recent well-known hacks and data losses, a lot of those came about through human error or organisations not having the processes to ensure resilience against breaches,” said Martin.

ADS’s Rosemont cautioned against seeing cybersecurity as mainly a technology issue. “What you quickly learn is that any company’s cybersecurity approach has to be underpinned by strong governance.”

He also stressed the importance of training: “Educators have a role to play in cybersecurity. This is as much a people business as it is technology in many respects,” said Rosemont.

He added that another important role is that of people who can act as an interface between a company’s IT staff and its directors. “The board has an absolutely crucial role to play in cybersecurity, whether it’s taking decisions to invest or being at the heart of a response to an incident. Often board members won’t be

technically minded on the finer points of cybersecurity technology and an important skill is to be able to interface between the information security or IT department and senior executives.”

A range of levels of experience are required. Consultants who go into firms to advise on their cybersecurity and information assurance needs will have been steeped in cybersecurity for many years.

For a typical security event analyst job advertised by

“Some of the more recent well-known hacks came about from human error”

Ciaran Martin, NCSC

Leonardo, an “in-depth knowledge gained from both experience and qualifications in the cyber defence arena” is called for.

Conversely, a systems engineer job description focuses more on IT infrastructure skills, with “an awareness of cybersecurity capabilities”, while “experience of working within secure environments” is considered “advantageous”.

For systems analysts and the like, Martin pointed out that their IT skills should be coupled with an inquiring mind. “They should have the mentality of thinking about where threats might come from,” he said, “and be active in

identifying where systems might be vulnerable. A lot of the work is about problem-solving and asking questions, not just doing the day job.”

For those working on the information security or risk management side, up to mid-management roles, staff might be recruited who don’t necessarily have extensive information security experience but have transferable skills, for example, of compliance in other forms, such as introducing a new standard in their organisation.

A skills shortage is a cause for concern. One estimate is that there will be a shortfall of 1.8 million cybersecurity professionals worldwide by 2022; companies are experiencing difficulties in retaining staff, with some reporting the need to offer salaries above what would be considered the market rate.

Against this background there are good prospects for graduates and apprentices, provided candidates can demonstrate logical thinking and problem-solving skills. Leonardo was one of the first companies to offer a cyber apprenticeship (in partnership with South Gloucestershire and Stroud college) and took on its first intake in September last year, with another to follow this year. It looks for students “who excel at GCSE or A-level in IT-related subjects”.

ADS is promoting the sector as an attractive career for young people, while the National Cyber Security Centre’s Cyber First initiative, and the Cybersecurity Challenge UK, offers a series of competitions, courses, and other initiatives designed to inspire more people to become cyber security professionals.

According to the latest ADS Security Outlook report, cybersecurity accounted for more than a third of UK exports in the sector in 2016, with a total value of £1.5bn. There appears to be little prospect of any imminent let-up in demand for people with skills in this area. ■

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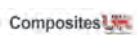
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February
1957

Baby boomer

Feeling supersonic, *The Engineer* offered fresh insights into Concorde's record-breaking forerunner, the FD2

In February 1957, Robert Lickley of the Fairey Aviation Company addressed the Royal Aeronautical Society. His subject was the Fairey Delta 2 (FD2), a supersonic research jet first displayed to the public two years earlier at Farnborough. But it was not until March 1956, when the FD2 set a flight airspeed record of 1,132mph, that the aircraft really took hold of the public's imagination.

The FD2's design was completed in 1949, but the two prototype jets ordered by the Ministry of Supply were put on ice when production of the submarine-hunting Gannet was designated a 'super-priority'.

Reporting on Lickley's lecture, *The Engineer* bemoaned the delay, finding it "surprising that, in a country with over a dozen aircraft constructors... the need to produce a deck-landing, turbo-prop submarine killer should hold back the construction of a supersonic jet research aircraft".

Boasting a distinctive tailless delta-wing design, the single-engine FD2 showed exceptional speed in testing. Several supersonic flights were conducted over southern Britain, giving rise to a number of claims for damage caused by the resulting sonic booms. Accordingly, the test programme was moved to France, where Dassault Aviation engineers took inspiration from the aircraft; its influence was later seen in the delta-winged Mirage III fighter jet. Lickley's lecture, printed in *The Engineer* a week after it was delivered, offered insights into the decisions that underpinned the FD2.

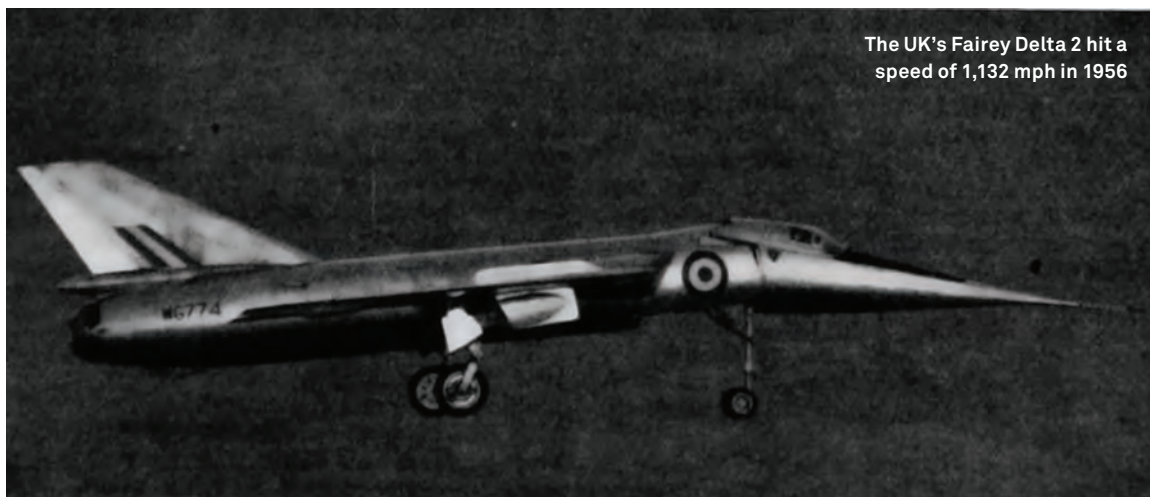
"The design which evolved was a delta-wing plan form of aspect ratio 2, having a Rolls-Royce 'RA.5' engine in the body with wing root intakes with frontal areas cut to a minimum and all possible excrescences removed," Lickley explained.

"The major target and guiding principle in the whole design period was to get an aeroplane of

minimum weight, with the smallest frontal and surface areas, while still remaining a straightforward aeroplane to handle in the air and on the ground, and yet at the same time large enough to house the 'RA.5' engine and sufficient fuel to enable worthwhile flights to be made."

From the outset, Fairey's test pilot Peter Twiss realised that the Delta 2 had the potential to hit speeds in excess of 1,000 mph. Despite having endured an engine failure and dead-stick landing early in the test programme, Twiss suggested pursuing the outright airspeed record, held at the time by the North American F-100 Super Sabre.

Support for the attempt was reportedly not forthcoming from the Ministry of Supply, however, nor indeed from Rolls-Royce. Nonetheless, Fairey pushed ahead, and on 10 March 1956, the Delta 2 set a new world airspeed record, achieving Mach 1.73 (1,132mph, or 1,811km/h). This marked a 37 per cent improvement on the previous record and made the FD2 the first aircraft to exceed 1,000mph in level flight. It also made Twiss the first man to fly faster than the Earth's rotation, so that when flying west, the sun would actually appear to move backwards in the sky. In the wake of the Delta 2's achievements, *The Engineer* was circumspect.



The UK's Fairey Delta 2 hit a speed of 1,132 mph in 1956

"Gratification at our possession of the 'Triple Crown' of speed records must not, however, blind us to the fact that, without doubt, the funds allotted to the 'FD2' were intended to contribute to the defence of this country," wrote our predecessors. "It would be a fallacy to believe that research on supersonic, as distinct from hypersonic, flight is no longer necessary for military purposes. The fact that this country could be rendered uninhabitable by long-range bombardment with fusion warheads is no reason why it should be exposed to the far cheaper and more easily mounted attack of bombers with fission missiles."

In spite of the success attained by the FD2, the concept was never developed into a production aircraft, and by 1973 both prototypes had been retired. But the legacy of its design could be seen in Concorde, in particular in the aircraft's droop-nose. One of the Delta 2s would go on to be converted into the BAC 221, which served as a testbed for Concorde. The original classic delta-wing was replaced with the ogee delta, while the drooped nose was retained. Both features would later go on to become hallmarks of the supersonic passenger jet. **AW**

Word of the issue

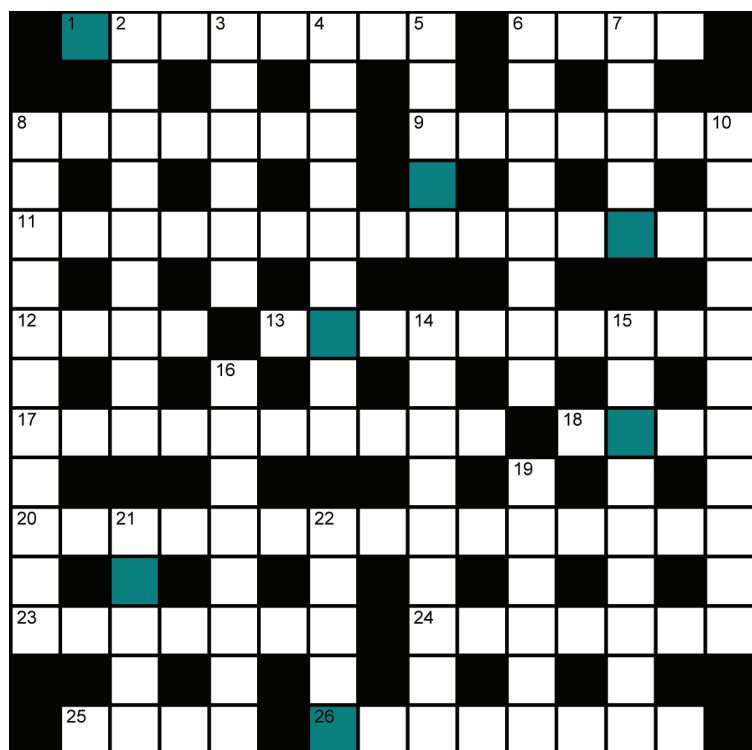
Anthony Poulton-Smith explores origins of the word 'wheel'

As a word 'wheel' does not appear to be among the simplest and this would normally suggest little longevity. Yet it is monosyllabic and this is good evidence of an early origin that proves to be true. Following this back to its Germanic roots we find the Old English or Saxon version of hweol to come from Proto-Germanic hwewlaz, also giving Old Norse hvel, Old Swedish hiughl, Old Frisian hwel and Middle Dutch weel. All these are derived from the Proto-Indo-European kwekwlo meaning not only 'wheel' but also used for 'circle', and for obvious reasons. Yet we can take this even further back to a root kwel, used to mean several things but notably 'revolve' and 'turn around'. It has also been used in the sense of 'sojourn' as in 'to stay' and 'dwell' with the same meaning. These seemingly quite opposite meanings mean we can confidently suggest there had been an earlier meaning – one which referred to a method of journeying, almost certainly for trade.

Bigpicture



Jaguar has released charging details for its much anticipated I-Pace, ahead of the all-electric SUV's premiere at the Geneva Motor Show. Using a DC 100kW charger, the I-Pace will charge from zero to 80 per cent in 45 minutes. Mains power can also be used to prepare the car's battery ahead of journeys.



Prizecrossword

When completed rearrange the highlighted squares to spell out a soft bluish-white metal. The first correct answer received will win a £20 Amazon voucher. Email your answer to jon.excell@centaur.co.uk

Across

- 1 Landlocked republic in eastern Europe (8)
- 6 A hollow cylindrical shape (4)
- 8 Thick cushion used as a seat (7)
- 9 Fast plane propelled by two engines (7)
- 11 Device that provides a path for current to flow (8,7)
- 12 Opening for money (4)
- 13 Charter granted by King John (5,5)
- 17 At a position directly lower than (10)
- 18 Highest level or degree attainable (4)
- 20 Couturier (7,8)
- 23 Formed by forcing molten metal into a mould (3-4)
- 24 Native of Rome perhaps (7)
- 25 Inflammation of the eye (4)
- 26 Unrestrained by convention (8)

Down

- 2 Acting as commercial traveller (2,3,4)
- 3 Assign to a lower position (6)
- 4 Circulate through and freshen (9)
- 5 Room in the roof (5)
- 6 Watercourse that carries water away from a mill (4,4)
- 7 Small but elegant (5)
- 8 Upholstered thickly and deeply (11)
- 10 Any polyhedron having four plane faces (11)
- 14 Chewing the fat (9)
- 15 Accept as inevitable (9)
- 16 Emptying by allowing liquid to run out (8)
- 19 The capital of Albania (6)
- 21 Heat ore to extract metal (5)
- 22 Recorded for future reference (5)

January's highlighted solution was Bauxite. Winner: **Adam Leeming**

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